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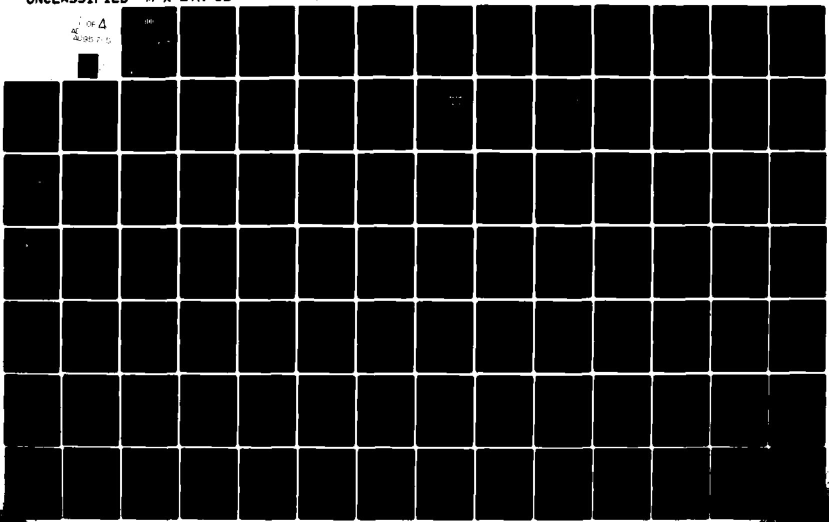

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WATER RESOURCES

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There will be two types of water demands associated with the M-X project. The construction of the protective shelters, the cluster roads, the designated transportation network (DTN) and the operating bases (OBs) will require relatively large quantities of water for a short period of time (2 to 5 years) or are short-term effects. Construction activities requiring water include earthwork, concrete and concrete plants, aggregate and aggregate plants, dust control, and irrigation of revegetation. Construction personnel will also require water. The demands for water will be at many points throughout the

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project area. Operational demands will be at the four Area Support Centers (AFSC) and the two OBs. These demands will occur for the life of the project and are considered longterm effects.

M-X ETR-12

ENVIRONMENTAL CHARACTERISTICS OF ALTERNATIVE DESIGNATED DEPLOYMENT AREAS: WATER RESOURCES

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Norton Air Force Base
California

By

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Santa Barbara, California

29 December 1980

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1.0 INTRODUCTION

M-X is a new mobile, land-based intercontinental ballistic missile (ICBM) being developed by the U.S. Air Force. The principle elements of the M-X program are:

- The missile
- Special vehicles that transport the missile and other equipment between and into the protective structures
- Multiple protective structures that protect and conceal the missiles and that are connected by special roads
- A designated transportation network (DTN) consisting of roads for movement of the missile and launcher from the designated assembly area (DAA); the place where the missile and launcher are assembled, to the designated deployment area (DDA); the place where the structures and roads are located
- Operating base (OB) or bases near the missile deployment area that will house maintenance, supply, rail/air offloading facilities, and other support functions necessary for system operation.

There will be two types of water demands associated with the M-X project. The construction of the protective shelters, the cluster roads, the DTN and the OBs will require relatively large quantities of water for a short period of time (2 to 5 years) or are short-term effects. Construction activities requiring water include earthwork, concrete and concrete plants, aggregate and aggregate plants, dust control, and irrigation of revegetation. Construction personnel will also require water. The demand for water will be at many points throughout the project area. Operational demands will be at the four Area Support Centers (ASC) and the two OBs. These demands will occur for the life of the project and are considered long-term effects.

Water used during operation of the M-X system will be predominantly for domestic purposes. All of this water will not be permanently consumed; approximately half will be returned as wastewater. Properly treated wastewater can be reused for such activities as irrigation and groundwater recharge.

During construction and operation, there will also be M-X-induced water demands as a result of indirect workers and their dependents coming into the region. These demands will mainly affect local communities.

Water, like all other needed resources, is subject to a wide variety of potential conflicts among competing uses. The types of conflicting uses are diverse, including energy production, municipal supply, agriculture, industry, recreation, and environmental protection (both habitat protection and pollution control). Rather than being easily predictable, the details of these conflicts are complex and constantly change in response to localized situations that are, in turn, shaped by local, State, and Federal policies and needs.

The possibility of these conflicts occuring is enhanced by the arid to semi-arid climate of the chosen siting areas. The water resources of the areas are direct functions of precipitation and snowmelt with losses at the surface controlled by the high summer evaporation rates and evapotranspiration from plants.

The use of water or any activities which alter the present water resource setting are important issues on local State, regional and national levels. This report will seek to define the water resource environment, establish the effects of M-X construction and operational activities and identify potential impacts.

2.0 SUMMARY AND COMPARISON ALTERNATIVES

2.1 HYDROLOGIC SETTING

The Nevada and Utah M-X siting area falls within the most arid portion of the North American continent, exclusive of the Canadian tundra. As such, surface water is scarce and, in most cases, ephemeral or intermittent.

Individual valleys within the Great Basin characteristically have either open or closed drainage. Hydrologically open surface drainage valleys topographically drain to other valleys or basins. Hydrologically closed surface drainage valleys retain all of the surface-water runoff originating within the basin.

Streamflow in the Great Basin region varies seasonally in response to both precipitation and temperature. Most of the runoff that is avaiable for development is found in the river systems in the eastern and western portions of the region.

Very few perennial streams occurr in the central and desert valleys. Most streams are ephemeral, flowing only in direct response to precipitation.

Streamflow quickly infiltrates into alluvial deposits and is present in most valley streambeds only for short distances from the source of the runoff. Based upon recharge studies performed by the Nevada Department of Water Resources, there is an average loss of 1.0 cfs per mi downstream. This loss is adquate to absorb nealy all mountain runoff produced in a normal year. Depending on local conditions, some of this water discharges down-gradient from the fans as seeps and springs, and the remainder percolates deeper to recharge the groundwater reservior.

In many valleys, irrigation and livestock watering use the runoff that flows to the playas. Water ponding on the playas rapidly evaporates.

Eakin, Price, and Harril (1976) described the M-X siting area as generally deficient in surface water, but with large volumes of water stored in valley ground-water reservoirs. In work performed by the Nevada Department of Water Resources for many of the valleys in the siting area, two distinct reservoirs were identified: valley-fill reservoirs comprised of unconsolidated alluvial deposits and bedrock reservoirs typified by fractured Paleozoic carbonates. A number of valleys within the M-X siting area have been shown to be hydraulically connected via the underlying carbonate reservoir.

Eakin (1966) noted that the valley-fill aquifers, when viewed on a regional scale, resemble isolated aquifers separated laterally by the thick sequences of Paleozoic carbonates and, in places, Tertiary volcanics. Extensive zones within the carbonates are highly permeable (in places even cavernous) and may transfer water from areas of higher elevation to areas of lower elevation. Little is known, however, about the ratee at which ground water is transmitted through the carbonate aquifer and how it is related to the "isolated" valley-fill aquifers. Although the estimated average regional transmissibility is 200,000 gallons per day per ft., the local transmissibility may vary widely.

The relationship between the basin and range faulting (north-south), the distribution of springs, and the communication between the carbonate and the alluvial aquifers is not fully understood.

The principal surface-water resources in the Texas/New Mexico project area are the Canadian and Pecos Rivers. Reservoir storage is generally needed to develop an adequate water supply. Water from the Canadian River (Lake Meredith, Texas) is used mainly for irrigation. Surface water generally is fully appropriated and is being used beneficially within the terms of international treaties, interstate compacts, court decrees, and state laws. An exception is the Ute Reservoir (Quay County, New Mexico), which has been appropriated by and is avaiable through contract from the New Mexico Interstate Stream Commission but is largely unused at present. A reliable yield of 10,000 to 15,000 acre-ft per year has been estimated fro Ute Reservoir. Other major surface-water resources in the project area would be available only by purchase of water rights or lease of water from existing users.

The principal ground water resources in the project area are the Ogallala aquifer in the High Plains of eastern New Mexico and western Texas and the carbonate and alluvial aquifers in the Roswell Basin. These aquifers are extensively developed, and water is used mainly for irrigated agriculture. In many areas underlain by the Ogallala aquifer, significant overdraft of the ground water resource is taking place. Laws relating to management and use of ground water in Texas/New Mexico differ. In the High Plains area and Roswell Basin, however, use of the prinicipla aquifers for Project M-X probably would require retiring of existing ground water uses and purchase or lease of the land and/or water rights.

A number of minor aquifers (e.g., Dakota-Purgatoire aquifer) in the study area are estimated to contain a relatively large volume of ground water in storage. These aquifers are relatively undeveloped. Published hydrologic data, therefore, probably are not sufficient to reliably estimate the quantity of recoverable ground water, potential well yields, and economics of obtaining a ground water supply.

2.2 M-X RESOURCE RELATED EFFECTS

The deployment of the M-X missile system will affect the water resources in potential siting areas in numerous ways. These effects can be categorized into two basic groups. The first group includes the placement of the roads, shelters, OBs, and ASCs. These will disrupt the physical setting of the area, thus altering the surface drainage characteristics. These effects can be termed long-term and unavoidable. This is so because all are necessary for the project and will exist throughout its useful life and probably beyond that time. Mitigation procedures may reduce potential impacts, but only a dramatic change in the proposed project can reduce the size of the M-X effects.

The second group of M-X induced effects on water resources is the demand for water for construction and operation activities. This type of effect can again be considered unavoidable. Construction demands will be short-term while the projected operational demands are long-term.

Quantities of water were determined for the total project and peak year for each system component for each alternative. Table 2.2-1 presents a breakdown of water requirements associated with DDA and OB construction, and system operation for the Proposed Action and the other alternatives.

Construction activities requiring water include earthwork, concrete and concrete plants, aggregate and aggregate plants, dust control, and irrigated for

Table 2.2-1. Comparison of total water requirements.

ALTERNATIVES	TOTAL DDA CONSTRUCTION WATER REQUIREMENTS[1] (X 10^3 ACRE-FT)		TOTAL OB CONSTRUCTION WATER REQUIREMENTS[2] (X 10^3 ACRE-FT)		30-YEAR PERMANENT OPERATIONAL WATER REQUIREMENTS (X 10^3 ACRE-FT)		TOTAL WATER REQUIREMENTS (X 10^3 ACRE-FT	
	RANGE	MPQ[4]	RANGE	MPQ	RANGE	MPQ	RANGE	MPQ
Proposed Action	82-144	120	3.6-6.7	5.2	225-420	330	310-570	455
Alternatives 1 through 6	82-144	120	3.6-6.7	5.2	225-420	330	310-570	455
Alternative 7	52-101	78	3.6-6.7	5.2	250-480	360	305-588	443
Alternative 8	67-118	96	3.9-7.3	5.6	230-375	330	301-500	432

3870-1

[1]DDA construction water requirements include no water for irrigation in Texas and New Mexico, but does include water for irrigation of protective structure sites in Nevada and Utah.

[2]OB construction water requirements include OBTS and DAA facilities.

[3]Permanent operational water requirements include water for both operating bases and the major impacted communities with 80 percent military onbase housing.

[4]MPQ - Most Probable Quantity.

Source: Air Force and HDR Sciences.

revegetation. Construction personnel would also require water. The demand for water would occur thoughout the entire project area.

Water used during operation of the M-X system would be predominantly for domestic purposes. The main demands would be located at the operating bases. A small portion of the water requirements would be distributed in the dedicated deployment area at the area support center.

During construction and operation, there would also be M-X-induced water demands as a result of indirect workers and their dependents coming into the region at a rate faster than per-M-X planning reports anticipated. These demands will mainly affect local communities.

The quantities listed for construction activities should be considered as use as the demands during construction are mostly consumptive in nature. Those quantities estimates for operational needs are simply withdrawals as much as 50 percent may be returned to the aquifer through treatment of wastewater and proper effluent disposal techniques.

2.3 IMPACT POTENTIAL

SURFACE WATER RESOURCES (2.3.1)

Surface water is not a viable source of water to meet M-X demands. The only major exception is the Ute Reservoir in New Mexico which has an unsold allocation available. With construction of a pipeline allotment could be used for DDA construction or for operational needs at Clovis or Dalhart. This use would relieve some of the additional stress that M-X place on the groundwater supply but it would also prevent the use of this water for irrigation.

Construction of M-X facilities would block existing drainage patterns possibly reducing groundwater recharge or present surface flows. Either would impact existing users of the resource.

The construction would also create large area of disturbed land that would be susceptible to increased erosion. Erosion could further alter the drainage patterns, destroy habitat and increase sediment loads in streams. Secondary impacts such as these are potentially significant.

Soil types, slopes and rainfall are extremely variable. Until a more detail layout is available and field studies one complete, it is not possible to estimate the location and size of potential impacts.

GROUNDWATER RESOURCES (2.3.2)

Determination of how much water an area can produce without creating "undesirable effects" requires analysis of both the hydrologic relationships between a pumped well and the source aquifer, and the legal constraints that define the degree to which specific effects can be tolerated. Performing such analysis in the large aquifer systems of the arid southwest is particularly difficult because both the physical and legal factors change radically over very short distances. Consequently, the specific location of pumping greatly influences the impacts of water development in any given case. Because data on aquifer performances are not readily available in most valleys or areas being considered, and because M-X wells have not yet been located, it is not possible to evaluate the impacts of M-X water development in any detailed or quantitative sense.

The most significant potential impact of M-X on groundwater resources is its possible effect on groundwater availability. The method used in assessing groundwater impacts examines gross resource characteristics in the context of factors such as current use, M-X use, legal constraints, and aquifer storage and depletion rates to identify areas where groundwater availability could be significantly impacted.

Potential impacts of M-X water development on groundwater resources and other groundwater dependent or related resources include:

- Lowering of the groundwater table in source aquifers.
- Reduced spring flows.
- Deterioration of water quality.
- Disruption or destruction of wildlife habitat.
- Land subsidence.

The potential for these impacts to occur is high when:

- M-X water demands are relatively large in comparison to available aquifer storage, current groundwater use and the perennial yield of the hydrologic system.

- The groundwater system is already under considerable "stress" as indicated either by current aquifer depletion rates, or by situations where current groundwater use is relatively large in comparison to available aquifer storage and perennial yield of the system. An additional factor used to measure "stress" or "competition" for groundwater resources was the presence of legal constraints on future groundwater development.

POTENTIAL FOR SIGNIFICANT IMPACT (2.3.3)

The potential for significance impact occur to surface water is based on the potential for erosion in each area. This was done as it is assumed the M-X will not affect surface water availability directly. Thus, erosion and all of the associated secondary impacts are the basis for the analysis. The potential for water erosion and sedimentation problems resulting from construction and operation of M-X facilities is based on there factors:

- The amount of facilities in each planning unit.

- The number of stream crossings (project defines).
- the average annual amount of surface flow.

Tables 2.3.3-1 through 2.3.3-4 present the result of that analysis. Level of impact was assigned based on the ranking received during the analysis. This assignment was arbitary and based on professional judgement.

Table 2.3.3-1. **Potential water erosion impacts in the Nevada/Utah DDA for the Proposed Action and Alternatives 1-6.**

HYDROLOGIC SUBUNIT NO.	HYDROLOGIC SUBUNIT NAME	SHORT-TERM IMPACTS[1]	LONG-TERM IMPACTS[1]
	Subunits with M-X Clusters and DTN		
4	Snake	High	High
5	Pine	High	High
6	White	High	High
7	Fish Springs	Moderate	Moderate
8	Dugway	Moderate	Moderate
9	Government Creek	Low	Low
46	Sevier Desert	Low	Low
46A	Sevier Desert & Dry Lake[2]	Low	Low
54	Wah Wah	High	High
137A	Big Smoky-Tonopah Flat	Moderate	Moderate
139	Kobeh	High	High
140A	Monitor—Northern	High	High
140B	Monitor—Southern	High	High
141	Ralston	Moderate	Moderate
142	Alkali Spring	Moderate	Moderate
148	Cactus Flat	Low	Low
149	Stone Cabin[2]	Moderate	Moderate
151	Antelope	High	High
154	Newark[2]	Moderate	Moderate
155A	Little Smoky—Northern	Moderate	Moderate
155C	Little Smoky—Southern	Moderate	Moderate
156	Hot Creek	Moderate	Moderate
170	Penoyer	Moderate	Moderate
171	Coal	Moderate	Moderate
172	Garden	High	High
173A	Railroad—Southern	Moderate	Moderate
173B	Railroad—Northern	Moderate	Moderate
174	Jakes	High	High
175	Long	Moderate	Moderate
178B	Butte—South	Moderate	Moderate
179	Steptoe	Low	Low
180	Cave	High	High
181	Dry Lake[2]	Moderate	Moderate
182	Delamar	Moderate	Moderate
183	Lake	Moderate	Moderate
184	Spring	Moderate	Moderate
196	Hamlin	Moderate	Moderate
202	Patterson	Moderate	Moderate
207	White River[2]	Moderate	Moderate
208	Pahroc	Low	Low
209	Pahranagat	Low	Low
	Overall DDA Impact	Moderate	Moderate

3839-1

[1] Legend (patterns): No impact. / Low impact. / Moderate impact. / High impact.

[2]Conceptual location of Area Support Center (ASC).

Table 2.3.3-2. Potential water erosion impacts in Texas/New Mexico DDA for Alternative 7.

COUNTY	SHORT-TERM IMPACT[1]	LONG-TERM IMPACT[1]
Bailey, TX	Low impact	Low impact
Castro, TX	Low impact	Low impact
Cochran, TX	Low impact	Low impact
Dallam, TX	Low impact	Low impact
Deaf Smith, TX[2]	Low impact	Low impact
Hartley, TX[2]	Low impact	Low impact
Hockley, TX	Low impact	Low impact
Lamb, TX	Low impact	Low impact
Oldham, TX	Low impact	Low impact
Parmer, TX	Low impact	Low impact
Randall, TX	Low impact	Low impact
Sherman, TX	Low impact	Low impact
Swisher, TX	Low impact	Low impact
Chaves, NM	Low impact	Low impact
Curry, NM[2]	Low impact	Low impact
DeBaca, NM	Low impact	Low impact
Guadalupe, NM	Low impact	Low impact
Harding, NM	Low impact	Low impact
Lea, NM	Low impact	Low impact
Quay, NM	Low impact	Low impact
Roosevelt, NM[2]	Low impact	Low impact
Union, NM	Low impact	Low impact
Overall DDA Impacts	Low impact	Low impact

3841-1

[1]
- None.
- Low impact.
- Moderate impact.
- High impact.

[2]Conceptual location of Area Support Centers (ASCs).

Table 2.3.3-3. Potential water erosion impacts in Nevada/Utah and Texas/New Mexico DDA for Alternative 8 (split basing).

HYDROLOGIC SUBUNIT OR COUNTY		SHORT-TERM IMPACT[1]	LONG-TERM IMPACTS[1]
NO.	NAME		
Subunits or Counties with M-X Clusters and DTN			
4	Snake[2]	High impact	High impact
5	Pine	High impact	High impact
6	White	High impact	High impact
7	Fish Springs	Moderate impact	Moderate impact
46	Sevier Desert	Low impact	Low impact
46A	Sevier Desert & Dry Lake[2]	Low impact	Low impact
54	Wah Wah	High impact	High impact
155C	Little Smoky—Southern	Moderate impact	Moderate impact
156	Hot Creek	Moderate impact	Moderate impact
170	Penoyer	Moderate impact	Moderate impact
171	Coal[2]	Moderate impact	Moderate impact
172	Garden	High impact	High impact
173A	Railroad—Southern	Moderate impact	Moderate impact
173B	Railroad—Northern	Moderate impact	Moderate impact
180	Cave	High impact	High impact
181	Dry Lake[2]	Moderate impact	Moderate impact
182	Delamar	Moderate impact	Moderate impact
183	Lake	Moderate impact	Moderate impact
184	Spring	Moderate impact	Moderate impact
196	Hamlin	Moderate impact	Moderate impact
202	Patterson	Moderate impact	Moderate impact
207	White River	Moderate impact	Moderate impact
	Bailey, TX	Low impact	Low impact
	Cochran, TX	Low impact	Low impact
	Dallam, TX	Low impact	Low impact
	Deaf Smith, TX	Low impact	Low impact
	Hartley, TX	Low impact	Low impact
	Hockley, TX	Low impact	Low impact
	Lamb, TX	Low impact	Low impact
	Oldham, TX	Low impact	Low impact
	Parmer, TX	Low impact	Low impact
	Chaves, NM	Low impact	Low impact
	Curry, NM	Low impact	Low impact
	DeBaca, NM	Low impact	Low impact
	Guadalupe, NM	Low impact	Low impact
	Harding, NM	Low impact	Low impact
	Lea, NM	Low impact	Low impact
	Quay, NM[2]	Low impact	Low impact
	Roosevelt, NM[2]	Low impact	Low impact
	Union, NM	Low impact	Low impact
	Overall DDA Impact	Moderate impact	Moderate impact

3842-1

[1]
- No impact.
- Low impact.
- Moderate impact.
- High impact

[2]Conceptual location of Area Support Centers (ASCs).

Table 2.3.3-4. Potential water erosion impacts which could result from construction of operating bases for the Proposed Action and Alternatives 1-8.

	HYDROLOGIC SUBUNIT OR COUNTY	SHORT-TERM IMPACTS[1]	LONG-TERM IMPACTS[1]
	Beryl, UT (Alternatives 1,3,4)		
52	Lund District	Moderate impact	Moderate impact
53	Beryl-Enterprise District	Moderate impact	Moderate impact
	Coyote Spring Valley, NV (P.A. and Alternatives 1,2,4,6,8)		
210	Coyote Springs	Moderate impact	Moderate impact
219	Muddy River Springs	Moderate impact	Moderate impact
	Delta, UT (Alternative 2)		
46	Sevier Desert	Low impact	Low impact
46A	Sevier Desert-Dry Lake[2]	Low impact	Low impact
	Ely, NV (Alternatives 3,5)		
179	Steptoe	Moderate impact	Moderate impact
	Milford, UT (P.A. and Alternatives 5,6)		
50	Milford[2]	Low impact	Low impact
52	Lund District	Low impact	Low impact
	Clovis, NM (Alternatives 7,8)		
	Curry County[3]	Low impact	Low impact
	Dalhart, TX (Alternative 7)		
	Hartley County[3]	Low impact	Low impact

3840-1

[1]
- No impact.
- Low impact.
- Moderate impact.
- High impact.

[2]Conceptual location of Area Support Centers (ASCs) for the Proposed Action and Alternatives 1-6.

[3]Conceptual location of Area Support Centers (ASCs) for Alternative 7.

The potential for impacts to groundwater is based on the analysis describe in Chapter 4. The results of the analysis are present in Tables 2.3.3-5 through 2.3.3- . Assignment of impact level is based on ranking receiver during the analysis and is based on professional judgement.

2.4 COMPARISON OF ALTERNATIVES

A comparison of the proposed alternatives is made in Table 2.4-1. If each of the rating scales is assigned a numerical value, the total can be added up and the alternative with the lowest potential for impacting water resources determined. Total scores are shown in Table 2.4-1. Based on the score, the alternatives in order of best to worst are:

Alternative 7
Alternative 5
Alternative 2
Alternative 3
Alternative 6
Alternative 8
Proposed Action
Alternative 4
Alternative 1

Table 2.3.3-5. Potential for impact to groundwater availability in Nevada/Utah DDA for the Proposed Action and Alternatives 1-6.

HYDROLOGIC SUBUNIT NO.	NAME	GROUNDWATER AVAILABILITY[1]	SHORT-TERM IMPACT[3]	LONG-TERM IMPACT[3]
	Subunits with M-X Cluster and DTN			
4	Snake	High	Low	Low
5	Pine	None	High	Moderate
6	White	None	*	*
7	Fish Springs	Moderate	Moderate	Low
8	Dugway	Low	Low	Low
9	Government Creek	Low	Low	Low
46	Sevier Desert	High	*	*
46A	Sevier Desert & Dry Lake[2]	None	None	None
54	Wah Wah	None	High	Moderate
137A	Big Smoky-Tonopah Flat	Moderate	Low	Low
139	Kobeh	None	Moderate	Low
140A	Monitor—Northern	Moderate	*	*
140B	Monitor—Southern	Moderate	*	*
141	Ralston	Moderate	High	Moderate
142	Alkali Spring	None	Low	Low
148	Cactus Flat	None	*	*
149	Stone Cabin[2]	Low	High	Moderate
151	Antelope	None	Moderate	Low
154	Newark[2]	Low	Moderate	Low
155AC	Little Smoky—N&S	None	Moderate	Low
156	Hot Creek	Moderate	Moderate	Low
170	Penoyer	Low	High	Moderate
171	Coal	None	High	Moderate
172	Garden	None	Moderate	Low
173AB	Railroad—N&S	High	High	Moderate
174	Jakes	None	Moderate	Low
175	Long	Low	Moderate	Low
178B	Butte—South	Moderate	Low	Low
179	Steptoe	High	*	*
180	Cave	None	Moderate	Low
181	Dry Lake[2]	None	Moderate	Low
182	Delamar	None	Moderate	Low
183	Lake	Low	High	Moderate
184	Spring	High	Low	Low
196	Hamlin	None	*	*
202	Patterson	*	*	*
207	White River[2]	*	*	*
208	Pahroc	*	*	*
209	Pahranagat	*	Moderate	Low
	Overall DDA		Moderate	Low

[1]Ground-Water Availability based on plate 1-I, US&S Professional Paper 813-G (Eakin, Price and Harrill, 1976.)

3926-3

*Data not available.

- None (blank pattern): No impact. (Low availability.)
- Low (open grid pattern): Low potential for impact. (Moderately low availability)
- Moderate (vertical hatch pattern): Moderate potential for impact. (Moderate availability)
- High (dark pattern): High potential for impact. (High availability)

[2]Conceptual location of Area Support Centers (ASCs).

[3] Methodology for impact assessment presented in Section 4.1.2.3.

Table 2.3.3-6. Potential for impacts to groundwater availability in Texas/New Mexico DDA for Alternative 7.

GROUNDWATER REGION	SHORT-TERM IMPACT[1]	LONG-TERM IMPACT[1]
I	No impact.	Low potential for impact.
III	No impact.	Low potential for impact.
V	Moderate potential for impact.	Low potential for impact.
VI	Moderate potential for impact.	Low potential for impact.
VII	Moderate potential for impact.	Low potential for impact.
VIII	High potential impact.	Low potential for impact.
IX	No impact.	Low potential for impact.
Overall DDA	Moderate potential for impact.	Low potential for impact.

3928-2

[1] No impact. (blank box)
Low potential for impact. (box with widely spaced vertical lines)
Moderate potential for impact. (box with closely spaced vertical lines)
High potential impact. (dark shaded box)

Table 2.3.3-7. Potential for impact to groundwater availability in Nevada/Utah and Texas/New Mexico DDAs for Alternative 8.

HYDROLOGIC UNIT OR GROUNDWATER REGION: NO.	NAME	GROUNDWATER AVAILABILITY[1]	SHORT-TERM IMPACT[1]	LONG-TERM IMPACT[1]
	Subunits or Regions with M-X Clusters and DTN			
4	Snake	High	Low	Low
5	Pine	No	High	Moderate
6	White	No	*	*
7	Fish Springs	Moderate	Moderate	Low
46	Sevier Desert	High	*	*
46A	Sevier Desert & Dry Lake[2]	No	Moderate	Low
54	Wah Wah	No	High	Moderate
155C	Little Smoky—Southern	No	Moderate	Low
156	Hot Creek	Moderate	Moderate	Low
170	Penoyer	Low	High	Moderate
171	Coal	No	High	Moderate
172	Garden	No	Moderate	Low
173AB	Railroad—N&S	High	High	Moderate
180	Cave	No	Moderate	Low
181	Dry Lake[2]	No	Moderate	Low
182	Delamar	No	Moderate	Low
183	Lake	Low	High	Moderate
184	Spring	High	Low	Low
196	Hamlin	No	*	*
202	Patterson	*	*	*
207	White River	*	*	*
	Region I		Low	Low
	Region III		Low	Low
	Region V		Moderate	Low
	Region VI		Moderate	Low
	Region VII		Moderate	Low
	Region VIII		Moderate	Low
	Region IX		Moderate	Low
	Overall DDAs		Moderate	Low

3929-4

*Data not available.

[1]
- No impact. (Low availability.)
- Low potential for impact. (Moderately low availability)
- Moderate potential for impact. (Moderate availability)
- High potential impact. (High availability)

[2]Conceptual location of Area Support Centers (ASCs).

Table 2.3.3-8. Potential for impact to groundwater availability in the operating base areas for the Proposed Action and Alternatives 1-8.

HYDROLOGIC SUBUNIT OR COUNTY	GROUNDWATER AVAILABILITY[1]	SHORT-TERM IMPACT[1]	LONG-TERM IMPACT[1]
Beryl, UT (Alternatives 1,3,4)	*	High	High
Coyote Spring Valley, NV (P.A. and Alternatives 1,2,4,6,8)	Moderate	High	High
Delta, UT (Alternative 2)	Moderate	Moderate	High
Ely, NV (Alternatives 3,5)	High	Low	Moderate
Milford, UT (P.A. and Alternatives 5,6)	High	High	High
Clovis, NM (Alternatives 7,8)	*	High	High
Dalhart, TX (Alternative 7)	*	Low	Low

3927-1

*Data not available.

[1]

- No impact. (Low availability)
- Low impact. (Moderately low availability)
- Moderate impact. (Moderate availability)
- High impact. (High availability)

Table 2.4-1. Comparison of alternatives.

ALTERNATIVE	POTENTIAL FOR SURFACE WATER IMPACTS[1]		POTENTIAL FOR GROUNDWATER IMPACTS[1]		SCORE
	SHORT-TERM	LONG-TERM	SHORT-TERM	LONG-TERM	
Proposed Action					
DDA	2	2	2	1	
Coyote Spring OB	2	2	3	3	25
Milford OB	1	1	3	3	
Alternative 1					
DDA	2	2	2	1	
Coyote Spring OB	2	2	3	3	27
Beryl OB	2	2	3	3	
Alternative 2					
DDA	2	2	2	1	
Coyote Spring OB	2	2	3	3	22
Delta	1	1	2	1	
Alternative 3					
DDA	2	2	2	1	
Beryl OB	2	2	3	3	24
Ely OB	2	2	1	2	
Alternative 4					
DDA	2	2	2	1	
Beryl OB	2	2	3	3	27
Coyote Spring OB	2	2	3	3	
Alternative 5					
DDA	2	2	2	1	
Milford OB	1	1	3	3	22
Ely OB	2	2	1	2	
Alternative 6					
DDA	2	2	2	1	
Milford OB	1	1	3	3	25
Coyote Spring OB	2	2	3	3	
Alternative 7					
DDA	1	1	2	1	
Clovis OB	1	1	3	3	17
Dalhart OB	1	1	1	1	
Alternative 8					
DDA	2	2	2	1	
Coyote Spring OB	2	2	3	3	25
Clovis OB	1	1	3	3	

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[1]0 = No impact.
1 = Low potential for impact.
2 = Moderate potential for impact.
3 = High potential for impact.

3.0 HYDROLOGIC SETTING

3.1 NEVADA/UTAH

GROUNDWATER RESOURCES (3.1.1)

The Great Basin is a physiographic province that can be characterized hydrologically as a drainage system which is internally drained. Most of the Nevada/Utah siting area lies within this basin. The only exception to this is the White River system where surficially-connected valleys drain to the south and into the Colorado River Basin.

The hydrologic cycle within the region, as illustrated in Figure 3.1.1-1, begins with precipitation in the mountainous areas. Rainfall and snowmelt provide the initial source of surface water. As runoff crosses the alluvial material in the valleys, most water percolates downward through the material and becomes part of the groundwater system. The remaining runoff flows largely through channels across the alluvial plain and discharges onto the valley floor (playa). This water becomes ponded and mostly evaporates into the atmosphere.

Maximum precipitation events occur more frequently in April and May in the north and in July and August in the south. Occurrence, amount, and type of precipitation are related to topographic orientation and elevation. Due to its higher elevation, the high plateau region receives more precipitation than other areas. Average annual precipitation ranges from 4 in. in lower valley floors to more than 16 in. in higher mountain ranges. Snowfall averages between 10 and 40 in. on valley floors and can exceed 80 in. in some mountains. A generalized estimate of average annual precipitation, with respect to elevation, is presented in Table 3.1.1-1 (Eakin, 1966).

A significant portion of precipitation in the study area is in the form of snow. In areas of significant snowfall, snowmelt accounts for most of the recharge from precipitation. The percent of average annual precipitation as it becomes recharge has been estimated (Eakin, 1966) and is presented in Table 3.1.1-1.

The two principle means by which water is lost from the Great Basin are evaporation of shallow groundwater and transpiration from plants called phreatophytes. A review of study area reconnaissance reports shows surface water evaporation estimates range from 3.5 to 5 ft per year. Transpiration is estimated at 0.1 ft for scattered vegetation up to 1.5 ft for wetlands and springs. The amount of recharge, which varies from less than one to about eight percent of the total precipitation.

The mountains and valleys comprising the Great Basin are the result of tectonic, volcanic and erosional processes (Osmond, 1960). A diagram showing the geology of a typical valley and enclosing ranges is shown in Figure 3.1.1-2. Much of the region is underlain by carbonate rocks at depth. These rocks have been altered by tectonic activity to produce the complexly folded and faulted mountain ranges. In addition, extensive areas throughout the region have been covered by extrusive volcanic rocks. Sediments resulting from the erosion of the carbonate and volcanic rocks comprise the bulk of the valley fill and consequently serve as storage areas for much of the water in the region.

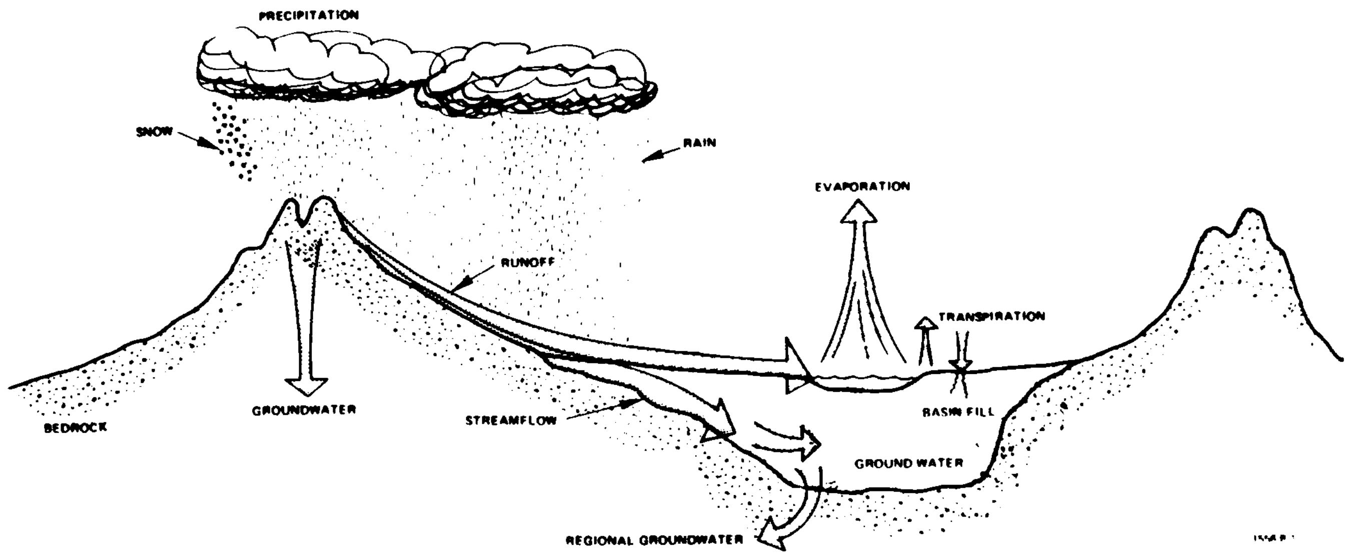
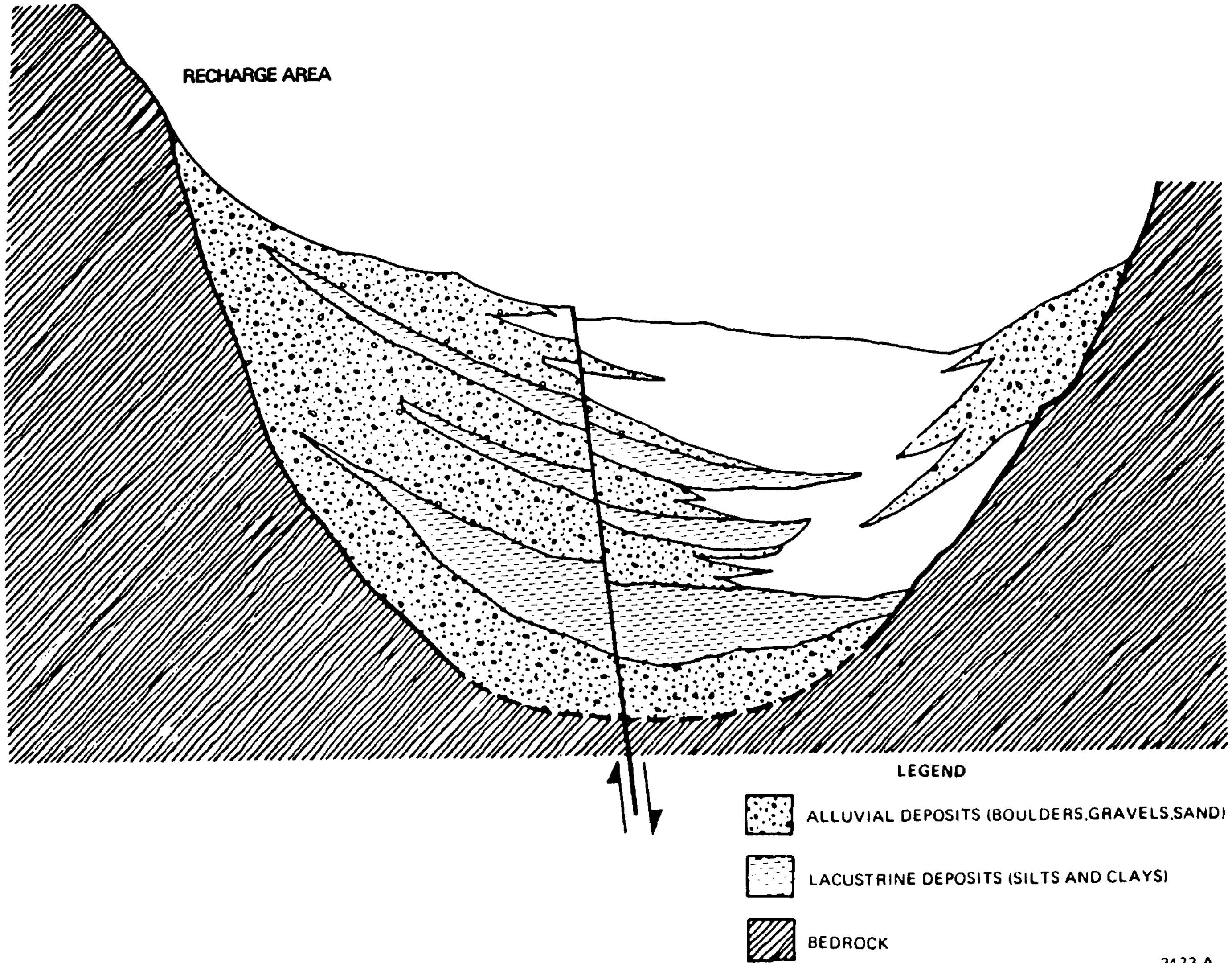


Figure 3.1.1-1. The hydrologic cycle.

Table 3.1.1-1. **Assumed values for precipitation and percent recharge for several altitude zones in area of this report.**

PRECIPITATION ZONE (in.)	ALTITUDE ZONE (ft)	ASSUMED AVERAGE ANNUAL PRECIPITATION (ft)	ASSUMED AVERAGE ANNUAL RECHARGE TO GROUNDWATER, PERCENT OF AVERAGE PRECIPITATION
Less than 8	Below 6,000	Variable	Negligible
8 to 12	6,000 to 7,000	0.83	3
20 to 15	7,000 to 8,000	1.12	7
15 to 20	8,000 to 9,000	1.46	15
More than 20	More than 9,000	1.75	25

Source: A regional Interbasin Groundwater System in the White River Area, Southeastern Nevada, State of Nevada Water Resources Bulletin No. 33, Thomas E. Eakin, 1966. 808-1



After: Young,R.A. and Carpenter, C.H.,1961,p. B-38
Malmberg,G.T., 1965,p.28

Figure 3.1.1-2. Generalized geology of a valley in the Great Basin.

Paleozoic carbonate rocks underlie much of the region to considerable depth as well as cropping out in many mountain ranges. (Kellog, 1963; Marcantel, 1975). These carbonate rocks are primarily limestone and dolomite that have been complexly folded and fractured. As a result, the carbonate rocks are capable of transmitting and storing considerable quantities of water within numerous fractures and solution channels. However, the volume of water stored in these carbonate is not be reliably estimatable because of the indeterminate nature of the passage ways.

The hydrologic significance of the carbonate rocks is primarily related to their volume beneath the surface. In some areas, the thickness of the carbonate rocks is as much as 15,000 feet (Kellog, 1963). A considerable part of the thickness have been found to be conducive to transmitting groundwater. Solution channels and cavities have been encountered in oil test wells as deep as 8,000 feet in the Snake Valley, Nevada/Utah (Hood and Rush, 1965). In the same well, fresh water was found as deep as 6,552 feet. Because of this, the carbonate rocks store and transmit considerable quantities of water on a regional basis. Eaking (1966) suggests that the regional transmissibility of the carbonate rocks is about 200,000 gallons per day per foot; a transmissivity of about 27,000 sq. ft. per day. This includes extensive areas of the carbonate rock that have no water-bearing capability as well as the highly localized fracture zones that contain the transmitted water.

Extrusive volcanic rocks (i.e., basalt, rhyolite) cover extensive areas of the surface throughout the Great Basin. These volcanic rocks are also found at depth in many of the valleys where they are interbedded with the alluvial sediments comprising the valley fill. Water-bearing characteristics of the volcanic (igneous) rocks are similar to those of the carbonate rocks. In effect, the effective porosity and permeability of the volcanic rocks is negligible. Where faulting and fracturing has occurred, however, the volcanic rocks are capable of storing and transmitting water. This water is typically limited to localized zones containing faults and fractures.

The geohydrologic characteristics of volcanic rocks have been examined in detail at the Nevada Test Site in Southern Nevada (Blankennagal and Weir, 1973). The volcanic rocks present at the Test Site are primarily rhyolite lavas and ashflow tuff of Tertiary age. Most groundwater moves through fractures with fractures being common in some flows and absent in others. The results of this study provides an approximation of the water-bearing properties of volcanic rocks in the region.

Based on analysis of drill holes, Blankennagel and Weir (1973) noted that "the combined thickness of intervals with measurable fracture permeability generally ranges from 3 to 10 percent of the total rock section penetrated in the saturated zone." During pump tests, wells produced from 56 to 423 gallons per minutre and transmissivities averaged about 10,000 gallons per day per foot. However, the saturated zone for the test wells used in this study was generally several thousand feet below the surface.

In the project area, groundwater occurs in both unconsolidated (i.e., soils, mine spoils, alluvium) and consolidated (bedrock) units. In the valleys, most recharge is provided by precipitation on mountainous areas, with the water reaching the valleyfill reservoirs by seepage lost from streams on the alluvial slopes and by underflow from the consolidated (bedrock) units. Most of the precipitation evaporates before infiltration, in the mountains and on alluvial slopes, and the remainder adds to the soil moisture, with some reaching lowland areas. In the process, only a very small percentage actually finds its way to the groundwater reservoir. In most valleys in the project area, precipitation quantities are rather small, and infiltration to the groundwater reservoir is generally minimal. Eakin, 1951, Alancy and Katzer, 1975, estimated the potential recharge in the region. The method used in the determination assumed that for any given altitude zone, a particular percentage of total precipitation potentially recharges the groundwater reservoir, with that percentage depending on the average amount of precipitation within the zone.

In the project area, movement of shallow groundwater below the ground surface exists and is generally controlled by the topography as well as the thickness and physical composition of the soil cover, while the deep groundwater flow is controlled by the geologic structure and stratigraphic sequence.

In general, groundwater, like surface water, moves from areas of topographic highs toward valleys where the head is lower. In some valleys, groundwater may be discharged to the surface as seeps and springs along valley walls, or directly into stream channels. Sandstone, and siltstone in the alternating layers, may be impermeable and confine the groundwater to isolated lenses within the permeable units. These are known as perched aquifers. In some areas, seepage may cause infiltration of surface water to the subsurface where it remains in the soils because of their low permeability. This does not necessarily reflect a high groundwater level.

Groundwater moves very slowly in most of the valleys, generally at rates ranging from less than one foot to several hundred feet per year, depending on the permeability of the deposits and the hydraulic gradient.

Groundwater movement from one valley to another occurs through both unconsolidated (alluvium soils) and consolidated (bedrock) units. The quantity of interbasin flow is small in relation to the total water supply but it may be a significant part of the hydrologic budget in some valleys. Before significant interbasin flow can occur, two conditions must be met. Consolidated rocks separating the valleys must be permeable enough to transmit appreciable amounts of water and a hydraulic gradient must exist between two valleys. Hydraulic continuity and a gradient may extend across more than two valleys and result in a regional flow system where all or part of the groundwater recharge from several valleys drains to a common sink. Figure 3.1.1-3 illustrates regional flow system now thought to exist in the Nevada/Utah siting area.

In general, recharge water at the higher elevations moves through the groundwater systems to discharge points at lower elevations. Since a gradient is required to move the water, the water table slopes upward away from the discharge areas. As a result, the water table appears to have the configuration of the subdued topographical areas. The configuration of groundwater flow systems and relationships to topography was investigated in detail by Teth (1962).

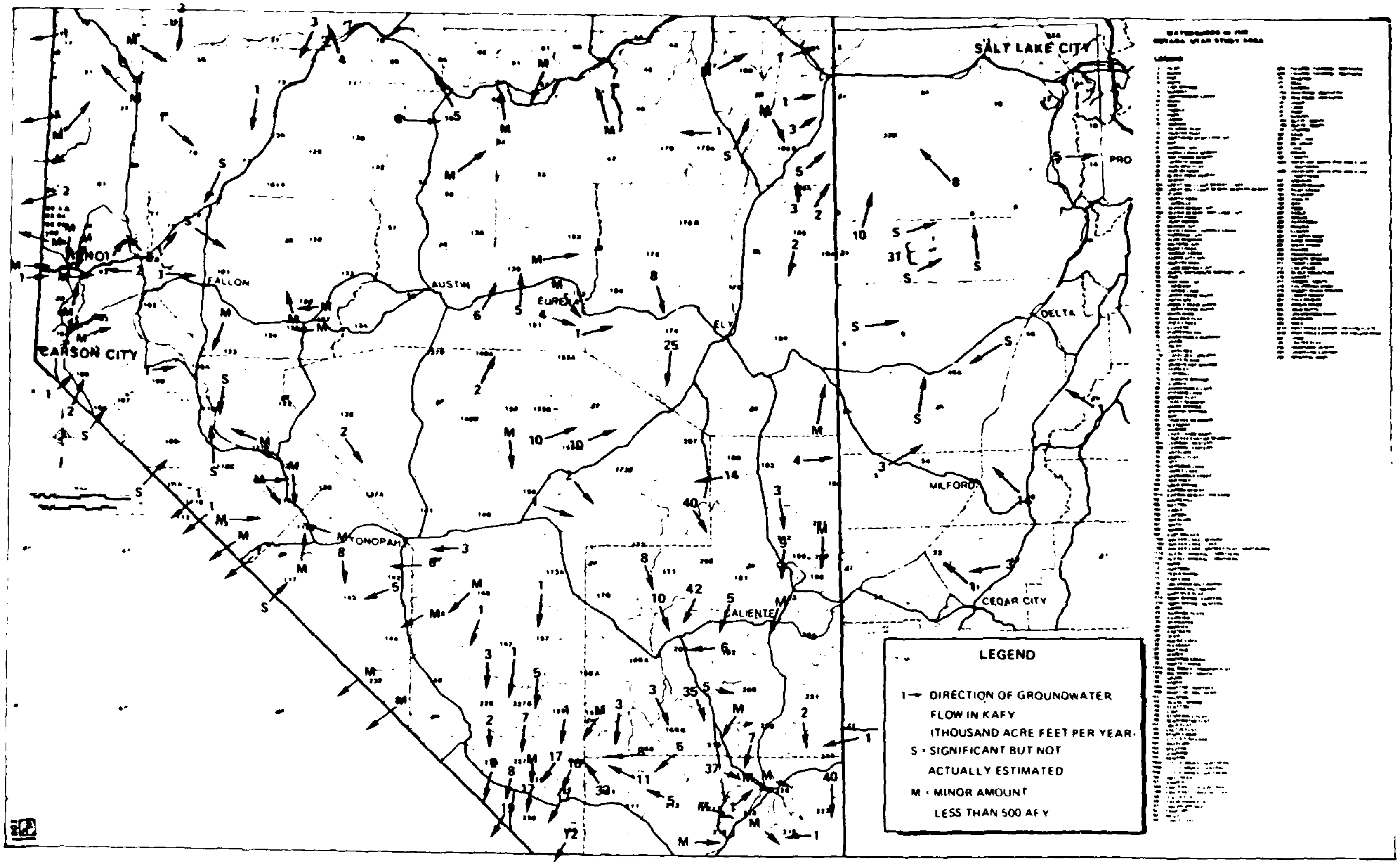


Figure 3.1.1-3. Regional flow system.

In the project area, it is assumed that the water table is never above the land surface. However, it may intersect the ground surface at the edges of bodies of water such as lakes, ponds, springs, and rivers. The presence of a sink in the water table indicates that groundwater is flowing toward that particular area. In the steady state processes, a sink would not exist unless some mechanism were available to remove water from the sink as rapidly as it flows toward the sink. Usually water is removed from the sinks in enclosed basins by discharge at the surface. Also, water may move from the existing sink to an underlying aquifer. Generally, surface discharge to maintain a reasonable size sink is common in eastern and northern Nevada.

Wells have been used extensively to produce water for domestic, stock, municipal, industrial, and irrigation purposes. Large capacity pumped wells have accounted for most of the annual withdrawals of groundwater mostly for irrigation. The average pumping rate is about 1,000 gpm according to an analysis of 2,000 large capacity wells. Reference the approximate locations of these wells can be determined by noting those valleys with large present demands in Section 3.1.4.

The chemical quality of groundwater in the Great Basin Region ranges from fresh to brine. Generally in alluvial aprons at the margins of most valleys, the groundwater is fresh. Saline water occurs locally near some thermal springs and in areas where the aquifer includes rocks containing large amounts of soluble salts, such as parts of the Sevier River area. In sink areas, such as the Great Salt Lake, Sevier Lake, and Carson Sink, the dissolved-solids concentrations may exceed that of ocean water.

Groundwater is likely to be the major source of new withdrawals. New technologies for locating water, drilling wells, pumping water, and irrigating fields has resulted in a dramatic increase in groundwater withdrawal in recent decades. Adverse impacts of withdrawal have not been readily observable probably due to the small percent of volume in storage withdrawn to date. Long-term impacts of high volume withdrawals are not yet known.

There are areas where groundwater depletions are subject to special regulation. Figure 3.1.1-4 shows those hydrologic areas which have been "designated" by the states. Designation means that permits to pump groundwater are: (1) not being issued, (2) being issued with limitations, or (3) being issued for preferred uses only.

The amount of groundwater that can be removed from a basin on an average annual long-term basis without causing depletion of the water resource or other associated problems is usually defined by the perennial yield. Estimates of the perennial yield for each basin have been made by a number of researchers. A compilation of the perennial yield for each valley within the siting area is presented in Table 3.1.1-2.

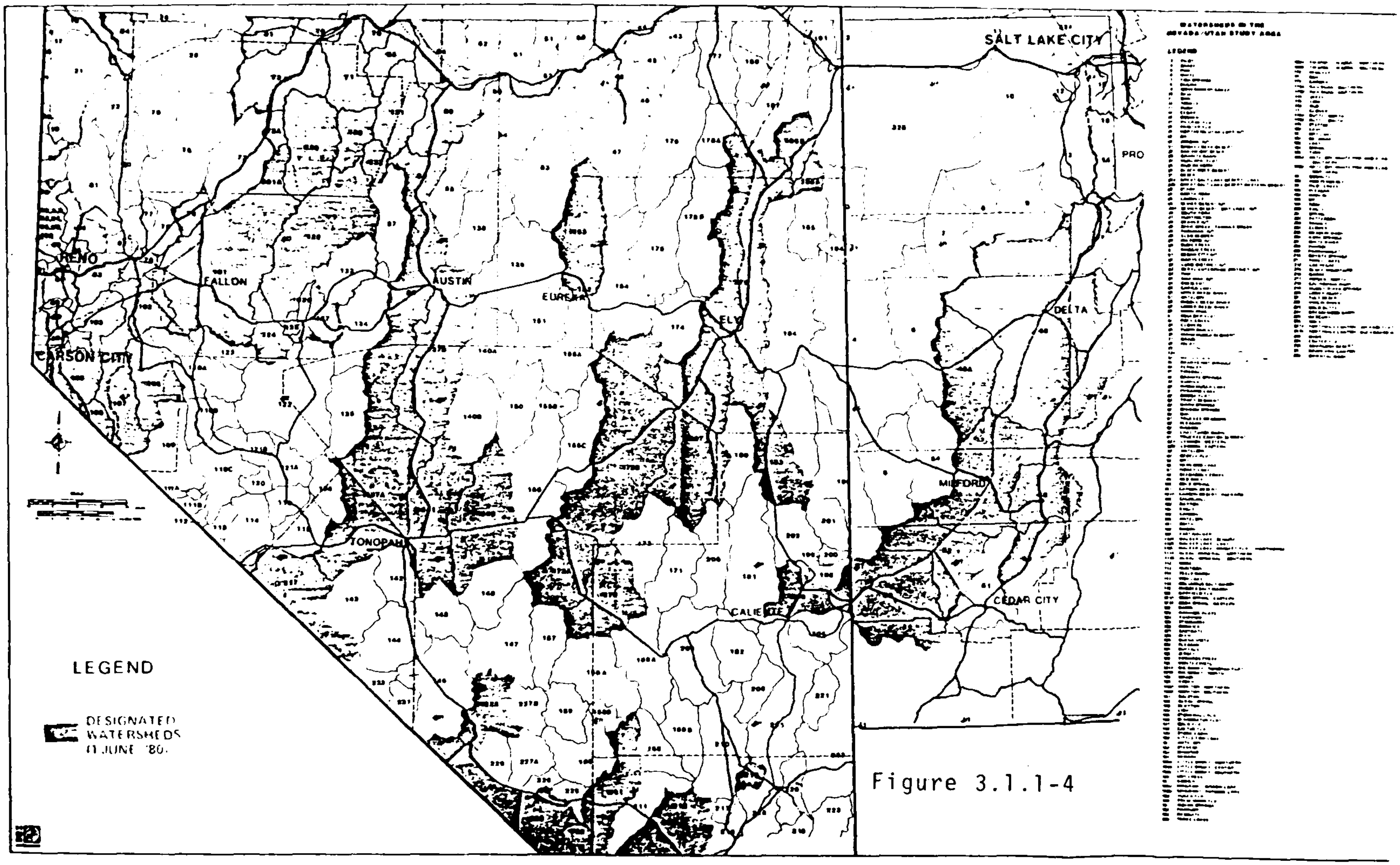


Figure 3.1.1-4. Watersheds in the Nevada/Utah study area.

Table 3.1.1-2. Water availability for M-X affected valleys.

UNIT NO.	HYDROLOGIC UNIT	PERENNIAL YIELD ACRE-FT X 10^3/YR.	STORAGE PER FT IN 1ST 100 FT ACRE FT X 10^3	CURRENT USE ACRE-FT X 10^3/YR	AVAILABILITY ACRE-FT/YR.
4	Snake	32-80	107	31	1-49
5	Pine	<5	12	M	<5
6	Tule	<5	—	M	<5
7	Fish Springs Flat	25-50	12	M	25-50
8	Dugway	5-25	13	6.2	0-19
9	Government	1	7	1.8	None
46	Sevier Desert	23	70	250	Overdraft
46A	Sevier Desert-Dry Lake				
54	Wah Wah	<5	8	M	<5
137A	Big Smoky	6	50	31	None
139	Kobeh	15	27	3.3	11.7
140A	Monitor	2	20	4.5	None
141	Ralston	6	20	0.8	5.2
142	Alkali Spring	3	13	0.3	2.7
149	Stone Cabin	2	20	1.5	0.5
151	Antelope	4	13	1.0	3.0
154	Newark	15	15	7.0	9.0
155A	Little Smoky, North	6	25	3.3	2.7
155C	Little Smoky, South				
156	Hot Creek	6	12	0.8	5.2
170	Penoyer	5	22	12.5	None
171	Coal	6	15	M	6
172	Garden	6	15	0.3	5.7
173A	Railroad, South	75	162	12.4	62.6
173B	Railroad, North				
174	Jakes	12	9	M	12
175	Long	6	16	M	6
178B	Butte, South	14	22	1	13
180	Cave	2	10	1	1
181	Dry Lake	3	28	M	<3
182	Delamar	3	12	M	<3
183	Lake	17	18	18.2	None
184	Spring	70-100	42	18	52
196	Hamlin	NA	12	1.5	NA
202	Patterson	5	—	0.5	None
207	White River	37	—	20	17
208	Pahroc	2	—	M	<2
209	Pahranagat	25	17	16	9
210	Coyote Springs	3,18	18	M	3,18
179	Steptoe	70		32	38
50	Milford	<58	29	49	None
53	Beryl-Enterprise	5-35	25	82	Overdraft

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Water Resources Program

The M-X Water Resources Program was initiated in June 1979 for the purpose of evaluating the availability of water for both the construction and operational phases of the M-X project in Nevada and Utah. Six valleys representative of typical hydrologic conditions in the Nevada-Utah siting area were studied during Fiscal Year 1979 (FY 79) ending 30 September, and a report was submitted to the Ballistic Missile Office on 21 December 1979.

Based on the FY 79 studies, it was determined that the Water Resources Field Program should be expanded to include aquifer testing and field investigations in all valleys within the Nevada-Utah siting area in order to better understand the potential effects of M-X groundwater withdrawals on the local water users and the environment and to determine the optimum water supply system for the project.

The Water Resources Program was expanded during Fiscal Year (FY 80) to include field investigations of the hydrologic conditions in 29 valleys to be used for deployment in the Nevada-Utah siting area which includes the six valleys studied during FY 79.

Field hydrologic reconnaissance of 24 of the 29 valleys has been completed to date. Data compilation and the results of the reconnaissance, however, have been completed for 16 of the valleys; the results of studies in these valleys are presented in Section 3.1.3. Drilling and testing in many of these valleys is in progress and the results of reconnaissance studies will be updated accordingly. The FY 79 and FY 80 study areas in Nevada and Utah are shown in Figure 3.1.1-5.

A preliminary literature review of the hydrologic conditions in the Texas-New Mexico siting area was initiated in FY 80. Later detailed investigations are expected.

The primary objectives of the overall Water Resources Program are to:

- Determine the effects of M-X groundwater withdrawals on the local water users, the environment, and the aquifers.
- Determine the optimum water source and supply system with possible supply alternatives for each valley.
- Provide the necessary data and documentation in support of the conclusions and recommendations of the Water Resources Program. The regulatory agencies will require thorough documentation prior to granting permits and permission for water development and use.

The scope of the Water Resources Program includes the following:

- Review of pertinent publications and data contained in agency files relating to water availability, local water use, regional groundwater flow systems, and aquifer characteristics.

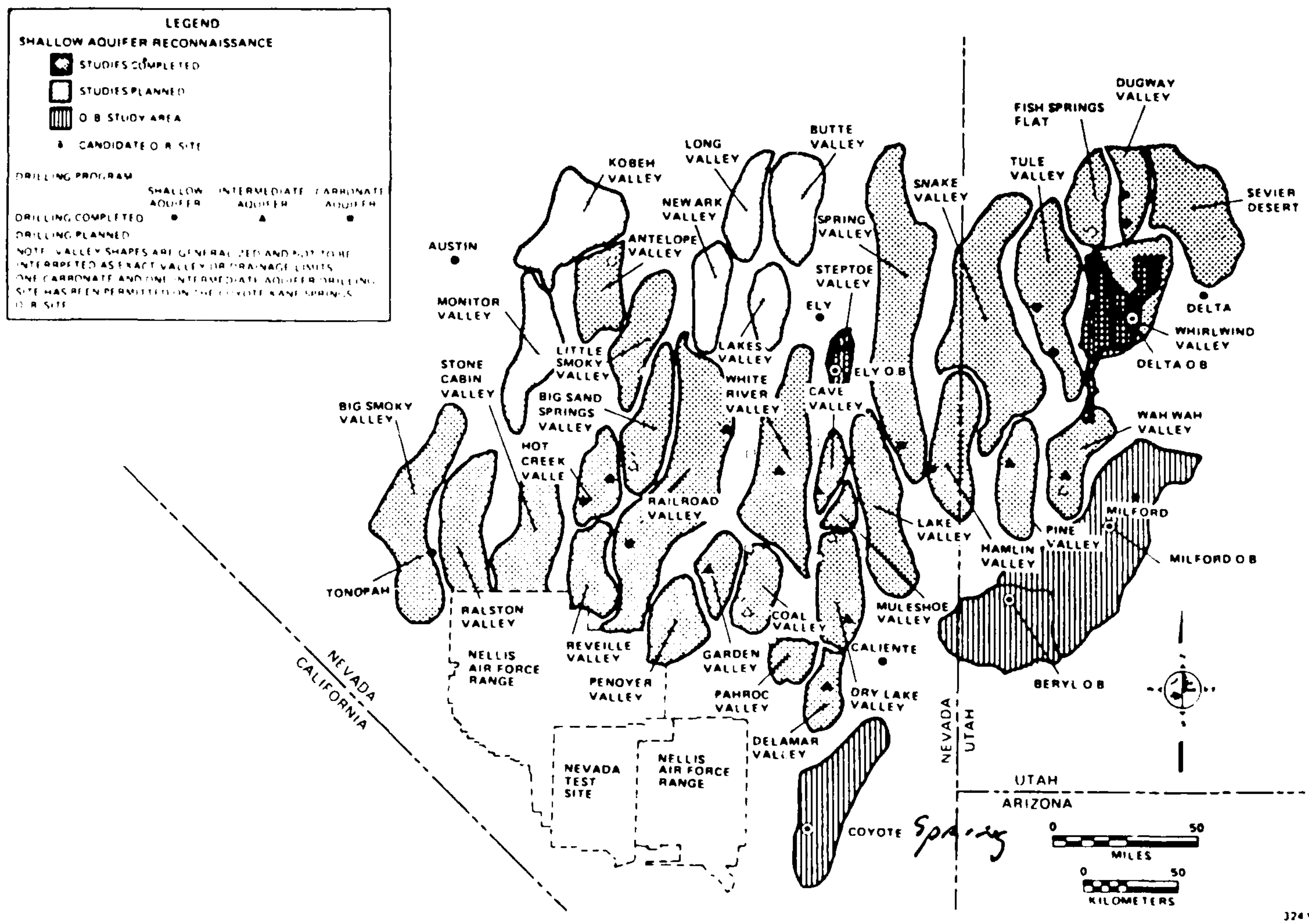

Figure 3.1.1-5. Water resource field program.

- Contact various state and federal officials knowledgeable about groundwater conditions in Nevada and Utah.

- Determination of the amount of water required for construction and operation of the M-X system.

- Hydrogeologic field studies to identify water users, measure groundwater levels, collect groundwater samples for chemical analyses, measure spring and well discharges, conduct aquifer tests, and overview general hydrogeologic conditions.

- Drilling and testing of shallow (about 500 ft) and intermediate (about 1,000 ft) valleyfill wells and deep carbonate rock (about 2,500 ft) wells. This work is in progress.

- Assess municipal water supplies and wastewater treatment facilities for their capacity to handle increases due to M-X population influx. This study included towns within and immediately adjacent to the siting area with emphasis on Tonopah, Ely, Caliente, and Pioche in Nevada, and Delta, Milford, and Cedar City in Utah.

- Evaluate basin structure to better understand regional groundwater flow systems.

- Compute numerical modeling simulations of the groundwater system in selected valleys to assess the effects of M-X groundwater withdrawals on local water users and the environment.

- Industry activity inventory to identify the water requirements of existing and proposed industries in the siting area and how these requirements may interact with M-X construction and operational activities. This study was conducted by the Desert Research Institute for Nevada and the Utah Water Research Laboratory or Utah.

- Study of Nevada and Utah water laws and permitting procedures and a water rights inventory. This study was conducted by the Desert Research Institute for both Nevada and Utah.

The 16 valleys for which field hydrologic reconnaissances and data compilation have been completed are: (1) Big Smoky, (2) Cave, (3) Delamar, (4) Dry Lake, (5) Dugway, (6) Fish Springs Flat, (7) Little Smoky, (8) Pine, (9) Railroad, (10) Sevier Desert, (11) Snake, (12) Hamlin, (13) Tule, (14) Wah Wah, (15) Whirlwind, and (16) White River. The preliminary results of investigations in these valleys are presented in Section 3.1.3. The location of the valleys studied and the activities performed in each are shown in Figure 3.1.1-5 and Table 3.1.1-2, respectively. The activity location is identified in the text and appendices according to conventional township-range terminology. An example for Nevada is: 12N/40E-13da which means Township 12 North, Range 40 East, Section 13, Subsection da (NE1/4, SE1/4). A slightly different but similar system is used for Utah.

Table 3.1.1-3. Fugro National field activities - Nevada/Utah.

AREA	ACTIVITY				
	AQUIFER TEST	WATER QUALITY ANALYSIS	WATER LEVEL MEASUREMENT	DISCHARGE MEASUREMENT	WATER TABLE MONITORING BORING
Big Smoky Valley	2	5	23	2	0
Cave Valley	0	4	8	3	0
Dry Lake/Delamar Valley	2	4	2	3	0
Dugway Valley	0	1	3	1	0
Fish Springs Flat	0	2	10	1	0
Little Smoky Valley	0	4	16	4	0
Pine Valley	0	5	1	1	0
Railroad Valley	0	7	5	11	0
Sevier Desert	1	8	21	0	0
Snake/Hamlin Valley	9	50	59	38	2
Tule Valley	1	9	17	5	1
Wah Wah Valley	9	1	0	0	0
Whirlwind Valley	0	2	13	2	0
White River Valley	4	21	55	3	1

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Methods of Investigation and Program Status

Existing Data Study. Collection of existing data has been an ongoing process through all phases of the geotechnical site selection studies conducted by Fugro National. Besides a thorough review of pertinent publications, data have been collected from federal and state agencies, private consultants, petroleum and mining firms, universities, local officials, and private citizens. All information and data collected have been evaluated and, where applicable, incorporated into this report to supplement field work and original data gathering. A survey of existing data was completed in August 1980. This survey was conducted as follows:

- Identify potential sources of new data by compiling a list of the oil, mining, drilling, and utility companies which operate in the Nevada and Utah siting area; regional libraries as well as libraries, government agencies, and academic institutions within the M-X siting area were also included.

- Collect available data from the identified sources through purchase.

- Document all contacts made, the data requested, and the response; this documentation includes both existing and secondary data.

Hydrologic Reconnaissance Study. Field hydrologic reconnaissances of 29 valleys in Nevada and Utah are scheduled for completion by the end of September 1980, and an additional six valleys in Nevada (Jakes, Long, Kobdh, Newark, Monitor, and Butte) will be studied in FY 81 beginning in October 1980. Further explanation of the evaluations and field tests being conducted by Fugro National, the methods of investigation, and the relationship of these tests to overall program objectives are as follows:

- Aquifer tests are being conducted in selected wells to determine potential well yields and the aquifer's ability to store and transmit water. This information is needed in designing well fields, in evaluating the optimum yield, and in minimizing well interference effects on local water users or springs. Aquifer tests are conducted on existing privately owned and Bureau of Land Management wells, in addition to wells drilled by Fugro National. Testing is performed on large discharge (over 500 gallons per minute) wells where available; however, smaller discharge capacity stock-water wells are also used. Right-of-entry permission is obtained from well owners prior to any aquifer testing.

- Groundwater levels are being measured in selected wells and drill holes in order to construct potentiometric maps for identifying groundwater migration patterns, identify areas of recharge or discharge, and as an aid in calculating expected pumping lifts for well design. The depth to groundwater below land surface was measured in existing wells and drill holes when accessible, and in wells and borings drilled by Fugro National. Measurements were made using electric water-level sounders or an electro/piezo recorder. Electric sounders indicate depth of water by deflection of a needle on an ammeter when a circuit is closed by contact of an electrode with the water surface. An electro/piezo recorder was used during aquifer test operations on wells developed by Fugro National.

The electro/piezo recorder monitors rapid changes in pressure from pressure transducers which are lowered a known depth below the water-level in a well. Relative pressure changes recorded during testing are adjusted for barometric changes and subsequently converted to feet of water-level change relative to the ground surface.

- Groundwater samples are being collected from wells, springs, and streams for analyses to characterize the water quality and assess its suitability for construction or drinking purposes and as an aid in identifying groundwater migration patterns and recharge areas. The water quality analyses include field measurements of the water temperature, pH and specific conductance, and laboratory determination of the concentrations of sodium, potassium, calcium, magnesium, sulfate, chloride, fluoride, nitrate, silica, carbonate, and bicarbonate.

During collection, samples for laboratory analysis are separated into bottles of various sizes and are filtered and/or acidified, depending upon the requirement for testing of the particular suite of ions. After collection, all samples are kept chilled until analysis to further inhibit bacterial production that might change the water chemistry. Water chemistry determinations are done by a qualified testing laboratory.

In addition, certain physical characteristics of the water, i.e., temperature, specific conductance, and pH, are measured in the field at the time of water sample collection and the water also is analyzed for the carbonate and bicarbonate concentrations. At the beginning of each work day in the field, the calibration of the conductivity meter is checked using the meter's internal reference system. The pH meter is calibrated by checking the meter with a buffer solution of known pH prior to each test. Analyses for carbonate and bicarbonate ions are performed using standard titration methods the same day the water samples are collected.

Discharge measurements of springs, streams and flowing wells are being conducted as an aid in determining water availability, for input into computer models to project the effects of M-X groundwater withdrawals and as a baseline data for monitoring systems during construction.

Discharge in combination with water quality can also give insight into the source of springs; regional, valleyfill or meteoric (fed by snow melt and rainfall). Various types of instruments were used to measure spring, stream, and flowing well discharge rates. Current meter and flume measurements were conducted in channel sections that were relatively smooth, straight, and had the least amount of turbulence. Calibrated containers were used to measure the discharge from small wells and from small springs which have been developed by the Bureau of Land Management. In addition to the continuation of field reconnaissance studies, a drilling and testing program was also initiated in FY 1980 to obtain information on aquifer characteristics in valleys where little or no data exists. This program is divided into three parts: a shallow program (about 500 ft), intermediate program (about 1,000 ft), and a deep (carbonate) program (about 2,500 ft). The methodology and purpose of the programs follows.

Shallow (Valley-fill Aquifer) Program

Ten shallow (approximately 500 ft deep) well sets are being drilled in the valleyfill in areas of limited data during FY 80. Each well set consists of one observation well in which piezometers will be installed to monitor the groundwater levels during aquifer testing, and one test well for aquifer testing. The wells are located about 500 ft apart. The ten well sets are scheduled for completion by the end of fiscal year 1980 (September 30). The wells are being drilled in Dugway, Tule, Spring, Hamlin, Railroad, and Hot Creek valleys. Drilling and testing is planned for other valleys in Nevada and Utah in fiscal year 1981.

The general well site locations that have been selected are based upon the following considerations: a) the monitoring of nearby springs, b) assessment of environmental impact on existing water supplies, c) determination of aquifer characteristics, and d) data gap areas.

The well sites are generally located in proximity (one to two mi) to springs or existing wells to test the effects of groundwater withdrawals in addition to the aforementioned considerations. The aquifer testing program consists of a 24-hour continuous step drawdown test, seven days of pumping, and two days of recovery.

Intermediate (Valley-fill Aquifer) Program

The intermediate program was initiated in FY 1980 (Phase I) with the drilling of three observation wells and two test wells in the following valleys:

White River Valley	(observation well) at 8N/61E-27dc
Dry Lake Valley	(observation and test well) at 3S/64E-12ca
Delamar Valley	(observation and test well) at 6S/63E-12da

The observations of the intermediate program was as follows: 1) determine the aquifer characteristics of intermediate depth aquifers in the valleys of the M-X deployment area; 2) where possible, to assess the source and direction of groundwater movement in these aquifers; 3) to evaluate possible aquifer leakage and interconnection with other aquifers, hydrologic boundaries, recharge and discharge areas, and water quality.

Phase II of the fiscal year 1980 intermediate program includes the drilling and testing of four intermediate depth well sets approximately 1,000 ft deep in the valleyfill of four selected valleys. These valleys are Pine, Wah Wah, Cave, and Garden.

The site selection process for these well sets considered the same parameters as listed previously for the Shallow Drilling Program. The four test wells, one in each valley, will be equipped with 10-inch casing and screens. The sites for these four wells (FY 80 Phase II) have been selected primarily as most suitable locations for the achievement of the objectives planned for the intermediate program.

The aquifer testing scheduled for Phase II is similar to that described for the shallow program. Additional drilling and testing in other valleys are planned for fiscal year 1981.

Deep (Carbonate Aquifer) Program

The objectives of the carbonate aquifer exploratory drilling program are to determine the source, occurrence, movement, and hydraulic characteristics of the carbonate aquifer flow system in the White River Valley area, and provide insight into the characteristics of similar regional flow systems in the Nevada-Utah siting area. A minimum of two piezometer wells are planned to be drilled in between White River drainage system by the end of fiscal year 1980. Additional carbonate wells are planned in other areas for fiscal year 1981. The four wells planned during the program will range in depth from 500 to 2,500 ft and will be drilled by rotary and air hammer methods. The borings will be 10 in. in diameter to about 50 ft into bedrock and cased with an 8-in. ID casing. The casing will keep unconsolidated material from dropping into the well during subsequent drilling and will allow a ground seal that can be secured and accrued for later water-level monitoring and water-quality sampling. The remainder of the well will be drilled with a 7 7/8-in. bit until desired aquifers are penetrated or until drilling cannot be continued due to circulation loss. If circulation is lost, a 6-in. liner will be lowered through the loss circulation zone and drilling will continue with a 5-5/8-in. bit to completion. Upon completion, the 6-in. liner will be withdrawn.

Aquifer testing will be conducted for up to 30 days in two of four wells at the highest rate of pumping withdrawal possible for the given well construction and pumping lifts.

Evaluation of data will entail reduction of aquifer test data, compilation of water quality and water level data, and incorporation of all data into the overall water resources investigation. For the carbonate aquifer investigation, water level data will be plotted on regional cross-sections and then correlated with water levels within the intervening valleys. This approach will provide further understanding of the interrelationship between the valleyfill and carbonate (regional) aquifers. Final technical graphics will include regional geologic maps, cross sections, geologic logs, and potentiometric maps of carbonate and valleyfill aquifers.

Operating Base-Site Studies

Detailed operating base field studies will be conducted for the Ely, Delta, Milford, Beryl, and Coyote Spring sites in fiscal year 1981. These studies will be "tailored" to the availability of water in each basin. For example, in the Ely area, Steptoe Valley is a designated groundwater basin. Additional appropriations may be allowed if sufficient data can be provided to demonstrate development of additional water supplies will not seriously impact current water users. There is also a potential for development of the carbonate aquifer. The Beryl, Utah area is a closed groundwater basin, no further long-term appropriations will be allowed by the State Engineer's Office, and there is no clear potential for development of carbonate aquifers. The general purpose of the operating base investigations is to:

1. Clarify the potential impacts on the nearby groundwater users and the environment resulting from groundwater extraction for M-X use; assuming that either additional water can be appropriated or existing water rights could be purchased and the points of diversion relocated near the operating base site.

2. Determine the interrelationship of various groundwater aquifers in the area.

3. Identify and confirm the viability of alternative groundwater sources of supply.

4. Make recommendations as to the water supply alternatives and the course of action to obtain water for the operational base.

To make these determinations, a program of hydrologic reconnaissance of existing water resource utilization and conditions will be conducted concurrently with drilling programs. The reconnaissance will be similar in nature to that performed in the FY 79 and FY 80 programs. Drilling will consist of constructing test/production and observation/monitoring wells in the valleyfill and/or carbonate aquifer near each basing location. One to three well sets ranging in depth from 400 to 1,000 ft below ground surface will be drilled in the valleyfill aquifer in proximity to each proposed base location. The design, construction, and testing of these wells will be similar to those in the FY 80 and 81 regional studies. One or two deep (2,500 ft) carbonate test/production wells will be constructed near OB sites that have potential for carbonate aquifer development (Ely, Coyote Spring, Milford). The wells will be similar in design, although larger in diameter, to those in the Drilling and Testing Program section of this report.

Basin Structure Study

A general geologic structure study of the Nevada/Utah siting area was conducted during FY 80 for input of general basin configuration to the computer modeling, and to determine the general occurrence, thickness and stratigraphic relationship of carbonate rock formations which have the potential to store or transport water. This study, although not complete, was utilized in locating deep drilling and testing sites and will be used in predicting the path and mechanism of intervalley flow systems. This study will continue to be updated and will be useful to the water management plan in selecting areas of potential carbonate aquifer development.

Municipal Water Supply, Water Level, and Wastewater-Treatment System Studies

Studies of the existing municipal water demand, potential supply, and impact of future growth on both water supply and sewage transmission and treatment facilities were initiated for the Nevada/Utah siting area late in calendar year 1979. The studies were conducted by the Desert Research Institute (DRI) for towns within or near the potential M-X siting area in Nevada, and by the Utah Water Research Laboratory (UWRL) for towns within or near the siting area in Utah. These studies were conducted to define the potential effects of M-X-related population growth on existing water supply and wastewater-treatment facilities and included the following:

- An assessment of the existing municipal water resources and the impacts of increased water use on Tonopah, Ely, Caliente and Pioche, Nevada, and Delta, Milford and Cedar City, Utah, including the identification of each municipality's source of water, the quantity present, and the amount of present usage.

- Determination of the ability of the water supply and sewage systems to accommodate increased usage, the maximum capacity for increase without modification of the system, and the economics of an increase if modification is required.

- Evaluation of the water quality limitations of the water supply system.

- Recommendation of the necessary water supply and wastewater treatment facility improvements required by increased usage.

- An overview of the effects of increased water usage in small towns such as Baker, Lund, Preston, Alamo, Panaca, Garrison, and others that lie within or at the margins of the Nevada-Utah siting area.

The studies, which were completed by early Summer 1980, were based upon recent water system planning reports by private consultants and state and federal agencies, supplemented by communication with community officials. Available information on the design criteria, and population projections were also utilized.

Industrial Activity Inventory Studies

An Industry Activity Inventory Study covering the area within and near the potential Nevada/Utah siting area was initiated late in calendar year 1979. The work was conducted by the Desert Research Institute DRI for the Nevada siting area and by the Utah Water Research Laborator UWRL for the Utah siting area. The inventories were conducted because large scale industrial, commercial, or mining projects in the M-X siting region could create substantial and sometimes subtle interaction with the proposed missile complex. Together, these studies provide a basis for joint consideration of how best to meet the water supply needs for the M-X missile system in the most optimal way with consideration of other future users. To accomplish this task the studies included the following:

- Inventory of existing and proposed major industrial, mining, grazing, energy extraction, energy transporting, energy producing activities.

- General assessment of present and future water requirements for enterprises in the region including estimates of location and timing of need with respect to most likely sources of supply. The inventory included but was not limited to, the following: coal mining industry, nuclear power plants, solar power projects, geothermal explorations, thermal electric generation, coal slurry transport, mining, grazing, agricultural, and recreation requirements. Water quality dimension of the problem also addressed.

- Identify the potential water transfer possibilities amongst the industries, and other water-use interactions within the region with reference to conflicts such as land use and environmental aspects.

The studies were completed in the summer of 1980, and included only pertinent projects beyond their preliminary planning stage. All available information from Fugro National, respective state and federal agencies and individual private companies was utilized. The results and conclusions of the studies are given in Section 3.1.4.

Water Management Plan

A design of a water management plan will be made for each valley for the construction and operational phases of the M-X project. The water management plan will include preliminary recommendations for:

- Source of water supplies and alternatives for each valley;
- Well field design for construction and operation;
- Spring discharge and water level monitoring systems before, during, and after construction;
- Computer models of the groundwater system for evaluation of the effects of water level or spring discharge changes detected during monitoring; and
- Wastewater treatment facilities that should be employed.

WATER LAW

Development and management of water is generally under the jurisdiction of the states, since there are no federal statutes governing water rights. The states impose regulations based on a combination of two basic doctrines: the appropriation right and the riparian right. Federal reserved rights are also discussed in this summary.

The Appropriation Right

The appropriation right was developed in the western states since 1845 in response to the unique hydrologic character of that area. An appropriation is made when a person takes water from some source and applies it to some beneficial use. The ranking of rights is according to "first in time, first in right." That is, the earliest appropriation will be the last one required to curtail use if a shortage occurs.

Under this doctrine, the right to use water is independent of the ownership of land. Appropriation is limited to the amount reasonably needed for a beneficial use. Beneficial use is broadly defined and may include mining, manufacturing, agriculture, municipal, and culinary. The water right, under appropriation, can be traded or sold. It is possible to lose the right through non-use or abandonment.

The Riparian Right

The riparian right is a water right attached to and inseparable from a parcel of land which is bounded by or traversed by a natural water course. By extension, riparian rights apply to groundwater lying beneath the land in question. A riparian proprietor has the right to the flow of the stream, undiminished in quality and quantity from a state of nature, except as affected by reasonable use by other proprietors. A riparian system typically has the following characteristics: a) rights to the use of water are created by ownership of land which is riparian to the water; b) the water right is a part of the ownership of the land and cannot be lost by non-use; and c) the riparian owner may use the water only on the riparian tract of land and may not sell it or use it himself off of that tract.

Federal Reserved Rights

Federal reserved rights are based on two clauses of the Constitution: Article I, Section 8, "Congress shall have the power to regulate commerce with foreign nations, and among the several states, and with the Indian Tribes," and Article IV, Section 3, "The Congress shall have the power to dispose of and make all needful rules and regulations respecting the territory or other property belonging to the United States." These are, respectively, the commerce clause and the property clause of the Constitution. The commerce clause is the source of federal water rights on navigable streams, and the property clause is one of the sources of the federal water rights that is applied to Indian reservations and other land which has been reserved for some federal purpose or otherwise withdrawn from public acquisition. The federal water right obtained under the property clause is inferior to the rights of state prior appropriators existing at the time that the federal reservation is made.

Overview of Nevada and Utah Water Laws

In both Nevada and Utah, the basic water law is the doctrine of prior appropriation for beneficial use.

In Nevada, the only requirement that must be satisfied for the appropriation of groundwater are: 1) unappropriated water available, 2) a recognized beneficial use, and 3) no interference with existing rights. The state engineer can be expected to take into consideration lowering of water levels at nearby wells in determining availability, while considering the average annual replenishment rate.

In Utah, the state engineer shall approve an application for appropriation if 1) there is unappropriated water available, 2) the proposed use will not impair existing rights or interfere with a more beneficial use of the water, 3) the proposed use is physically and economically feasible, 4) the applicant has the ability to complete the plan, and 5) the application is filed in good faith and not for the purpose of speculation.

Statute law in both states gives the state engineers discretion in approving applications. Decisions of the state engineers can be appealed to the courts in both states.

Process for Obtaining Permits to Appropriate Water

Permits to appropriate water in Nevada and Utah require information on the applicant and enough information on the source of water, type of construction, and use to enable the state engineer to make an informed decision on approval of the appropriation. Required information includes name and address of applicant, source and amount of water, location and cost of works, purpose, and time frame for construction and use. Hydrologic information is not required but may be needed if a protest is filed.

In both states the process for appropriating water is quite similar. The procedure is charted in Tables 3.1.1-3 and 3.1.1-4. The applicant must first file an application to appropriate, after which the state engineer publishes a notice in the local newspapers (published five consecutive weeks in Nevada and three weeks in Utah). After the date of the last publication, interested parties have 30 days, in both states, in which to file a protest. The state engineer may then approve or disapprove the application based on availability of water and the merit of the protests. This usually takes about 30 days in both states. Any decision by the state engineer is subject to appeal and review by the state court system, ultimately to the State Supreme Court.

SURFACE WATER RESOURCES (3.1.2)

Surface water sources in the siting area include lakes, reservoirs, rivers, streams, and springs. These may be fed by precipitation or discharge from the groundwater system. There also exists a largely unused quantity of sewage.

Numerous springs are located within the siting area. These springs support streamflow and the larger ones may be used for irrigation. Generally, ditches are used to divert water for application in nearby fields. A portion of the spring flow is lost to evaporation and transpiration. A relatively small quantity of the water use for irrigation seeps back into the ground and percolates to the groundwater reservoir.

Thermal mineralized springs are scattered throughout the state and are generally located near faults. To date, geothermal energy resources have been used for heating houses, domestic water supplies, swimming pools and mineral baths, and the heating systems of green houses.

The siting area in Nevada and Utah is characterized by many closed basins and numerous mountain ranges. These mountain ranges are roughly parallel in a north-south direction and are separated by alluvium-filled basins. There is an abrupt change of slope at the base of the mountains between mountain fronts and alluvial aprons. These aprons consist mainly of gently sloping fans built up by erosional debris from the mountains. Numerous small streams originate in the mountains and are usually perennial until they reach the mountain front. The streams then diverge into numerous distributory channels where they flow upon the aprons. At this point most of the stream flow is lost by infiltration into the ground, by evaporation, and by transpiration. Thus, many streams are perennial in their headwaters and intermittent in their lower reaches.

Streamflow data for the major rivers in the area are shown in Table 3.1.2-1. The gauging stations shown are the furthest downstream for each river. Losses from

Table 3.1.1-4. Sequence of actions for obtaining a water right in Nevada.

STEP	PERSON(S)	ACTION	FORM REQUIRED	TIME	FEE	COMMENTS
1	Applicant	File "Application for Permit to Appropriate Water"	N-1 Nevada Form No. 2888 (Rev.11-72)	60 days for action to correct application	$35.00	A map by a licensed State Water Rights Surveyor must be filed with the application or within 60 days of notice. Otherwise the application is cancelled. See step 11 for alternate action.
2	State Engineer	Publish notice in newspaper	—	30 days from	—	Published once a week for 5 consecutive weeks in local newspaper.
3	Public	File protest with State Engineer	—	30 days from last publication	—	Formal protests must be filed within this time.
4	State Engineer	Field investigation	—	30 days (variable)	—	Investigate the site and check protests—may reject proposal after field investigations. Applicant may appeal State Engineer's rejection in District Court.
5	State Engineer	Approve or reject application	—	1 year from final protest; may be postponed	$10.00/ cfs ($10 min.)	State Engineer gives time limit for starting and finishing construction. See step 10.
6	Applicant	Proof of commencement of work	N-2 Nevada Form No. 259	Time limit set by State Engineer	$ 1.00	The applicant starts the required work for diversion of water or drilling a well.
7	Applicant	Proof of completion of work	N-3 Nevada Form No. 260	Construction time (within 5 years; varies	$ 1.00	Filed after the work is finished and water is ready to be diverted.
8	Applicant	Proof of beneficial	N-4 Nevada Form	Not over 10 yea's; set by State Engineer	$ 1.00	Specifies the use of the water and the amount actually applied to a beneficial use. A map by a Wat‹r Rights Surveyor is required.
OTHER FORMS						
10	Applicant	Application for time extension	N-5 Nevada Form No. 901	—	$ 5.00	To get an extension of time for construction of the project.
11	Applicant	Application to change point of diversion, manner, or place of use	N-5	—	$40.00	This form is needed to change point of diversion, the manner or place of use of the water. This would be in lieu of Form 1 in step 1; steps 2 through 9 must be followed.

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Table 3.1.1-5. Sequence of actions for obtaining a water right in Utah.

STEP	PERSON(S)	ACTION	FORM REQUIRED	TIME	FEE	COMMENTS
1	Applicant	File "Application to Appropriate Water)	U-1 Utah Form 97 2M 10-70	Variable, about 60 days for action	$15.00 min. to $150.00 plus $7.50/ cfs above first cfs	For alternate actions; purchase (see step 8) or lease (see step 9) of existing water rights.
2	State	Publish notice in newspapers	—	3 weeks	—	
3	Public	File protests with State Engineer	—	30 days	—	Protests must be filed within 30 days after last publication of notice in newspapers.
4	State Engineer	Field investigation	—	30 days (variable)	—	Investigates protests and checks availability of water and feasibility of project. Applicant may appeal to district court should application be rejected (60 days time limit).
5	State Engineer	Approve application	—	—	—	State Engineer sets time limits to start and finish construction (see step 6)
6	Applicant	Proof of Appropriation form	U-2 Utah Form No. 49	After construction is completed	—	Prepared by Registered Engineer or Licensed Land Surveyor. Maps and drawings and surveys required.
7	State Engineer	Issue Certificate of Appropriation	—	About 60 days	—	
8	Applicant	Application for change in use	U-3 Utah Form No. 107 3066	Variable, about 60 days for action	See step 1	Purchase of water rights. Followed by steps 2-7 or lease for more than one year.
9	Applicant	Application for change in use	U-4 Utah Form 1118-61-2 M	Variable, about 60 days for action	$5.00 plus costs	Lease or rental change in use and/or point of diversion for one year or less.
10	Applicant	Proof of change of	U-5 Form 58	After construction is complete	—	See step 6, comments.

3297

Table 3.1.2-1. Flow characteristics of major rivers in the Nevada/Utah area.

RIVER	DRAINAGE AREA MI^2	YEARS OF RECORD	PERIOD	AVERAGE DISCHARGE FT^3/S	EXTREMES MAXIMUM FT^3/S	EXTREMES MINIMUM FT^3/S	ANNUAL DISCHARGE THOUSANDS OF ACRE FT. PER YEAR
Utah[1]							
Bear River 10127110	7,075	7	1973-1978	2,163	6,900	240	1,567.0
Weber River 10143000	2,081	74	1966-1978	480	10,100	19	347.8
Jourdan River 10171000	3,438	35+	1943-1978	141	384	89	102.2
Sevier River 10224000	5,966	36+	1942-1979	186	2,980	3.9	134.8
Nevada[2]							
Muddy River 09419000	6,780	28+	1950-1978	45.5	7,380	7.6	32.9
Walker River 10301600	2,700	2	1977-1978	32.7	490	0	—
Carson River 10312280	1,950+	11	1967-1978	37.9	1,030	0	27.4
Humboldt River 10335000	16,100	35+	1899-1978	204	4,420	0	147.8
Truckee River 10351700	1,815	21	1957-1978	439	14,400	5.1	318.4
Colorado[3]	171,700	47	1933-1980	13.270	36,000	15.2	485.0

1500-2

[1]U.S. Geological Survey, Water Resources Data for Utah, USGS Water Data Report UT-78-1, 1979.

[2]U.S. Geological Survey, Water Resources Data for Nevada, USGS Water Data Report NV-78-1, 1979.

[3]U.S. Geological Survey, Water Resources Data for Nevada, USGS Water Data Report, NV-77-1, 1977.

diversions, from evapotranspiration, and percolation to groundwater will have occurred. Thus, this data should represent the net flow for each river. Variability in stream discharge results from climate and topographic influences within the region. A comparison of the Bear River in Utah and the Muddy River in Nevada show that they have similarly sized drainage basins. Average discharge from the Bear River, however, is almost 50 times greater than the Muddy River. This occurs primarily because the headwaters of the Bear River are within the Rocky Mountains where precipitation is considerably higher than that which occurs in the mountain ranges of Nevada. Stream flow in different areas will also be affected by variations in both cultural (i.e., irrigation, municipal uses) and physical (i.e., evaporation, transpiration, subsurface flow) factors.

Streamflow in the region exhibits extreme variability with time. For the large perennial rivers, variation in flow is associated with seasonal changes in precipitation and temperature. Melted water from snow in mountainous areas is the major source of water for those rivers. This is reflected in the extreme flow category in Table 3.1.2-1. For example, the maximum recorded flow (490 cfs) for Walker River occurred during the middle of April 1978, the minimum flow (0 cfs) during July 1977 (USGS, Water Data Report NV-78-1, p. 141). Streamflow in the area is also associated with extreme variations in weather. Heavy rainfall or cloudbursts will produce high flows; conversely, extended periods of drought will result in minimum flows.

In addition to the large perennial streams, the area has thousands of streams which are ephemeral throughout their reaches. These streams usually have short periods of very high rates of runoff, resulting from high-intensity storms or cloudbursts, separated by long periods of little or no flow. Due to their erratic runoff characteristics, the surface water in the ephemeral streams can be economically impounded only in small stock and irrigation reservoirs for limited use. As a source of recharge to the groundwater system it is largely insignificant.

The estimated total annual flow of a number of small streams in selected valleys in central Nevada is shown in Table 3.1.2-2. Table 3.1.2-3 shows actual flow characteristics for several streams. Average discharges range from 0.115 cfs to 8.85 cfs, and some streams have no water during the summer months.

Numerous lakes and reservoirs provide storage within the Great Basin Region. The lake and reservoir maps presented in Figure 3.1.2-1 show locations of lakes and existing or potential reservoir sites.

Table 3.1.2-2. Estimated average annual flow of small streams in selected valleys in Central Nevada.

VALLEY	SECONDARY STREAMS[1]		MINOR STREAMS[2]	
	NUMBER OF STREAMS	ESTIMATED AVERAGE ANNUAL FLOW (acre feet/yr)	NUMBER OF STREAMS	ESTIMATED AVERAGE ANNUAL FLOW (acre feet/yr)
Big Smoky	5	19,000	14	10,000
Butte	2	3,000	2	2,000
Little Smoky	1	3,000	—	—
Newark	2	4,000	2	2,000
Railroad	1	6,000	3	1,000
Ralston	—	—	3	2,000
Spring	11	40,000	10	10,000
Steptoe	6	35,000	5	5,000
TOTAL	28	110,000	39	32,000

1501

[1]Annual flow for each stream is more than 1,000 acre feet.

[2]Annual flow for each stream is less than 1,000 acre feet.

Source: Pacific Southwest Inter-Agency Committee Water Resources Council (1971), *Great Basin Region - Comprehensive Framework Study, Appendix V, p. 30.*

Table 3.1.2-3. Flow characteristics of small streams in selected valleys in Central Nevada.

VALLEY	STREAM NAME/ STATION NO.	DRAINAGE AREA		AVERAGE DISCHARGE		EXTREMES				ANNUAL DISCHARGE
						MAXIMUM		MINIMUM		
		(mi^2	km^2)	(cfs	m^3s)	(cfs	m^3s)	(cfs	m^3s)	(acre feet)
Big Smoky	Kingston Creek/ 10249280	23.4	60.6	8.37	0.237	150	4.25	1.4	0.04	6,060
Little Smoky	Tributary Stream/ 10245300	157	407	0.115	0.0032	238	6.74	0	0	83
Railroad	Little Currant Creek/ 10246846	12.9	33.4	3.2	0.09	366	10.4	0	0	2,320
Steptoe	Steptoe Creek/ 10244950	11.1	28.7	8.85	0.25	37	1.05	2.0	0.06	4,990

1502

SOURCE: USGS Water Data Report UT-78-1, p 87-100.

The term 'wetlands' refers to those areas which are inundated by surface or groundwater with sufficient regularity to support vegetative or aquatic life that requires saturated soil conditions for growth and reproduction. Two of the major wetland areas are briefly described below:

- The bed of the pluvial White River, which is now dry for much of its course, has several wetland areas located in the Pahranagat and White River valleys. The wetlands in Pahranagat Valley are basically fed from Ash, Crystal, and Hiko springs. These thermal springs feed the Key Pittman Wildlife Management Area and upper and lower Pahranagat lakes.

- In Fish Springs Flat, Fish Springs National Wildlife Refuge contains three major and many minor springs. These springs have a combined flow of 45 cfs to 50 cfs (Bolen, 1964), and has an inundated area of 6 mi by 3 mi.

The term "floodplain" refers to any land area susceptible to being inundated from any source of flooding. Executive Order 11988 directs implementation of the "United National Program for Flood Plain Management" (U.S. Water Resources Council, 1976) which recommends federal and state action to reduce the risk of flood losses through floodplain management. The base floodplain is the area subject to inundation from a flood having a one percent chance of occurring in any given year (100-year flood).

The Nevada/Utah study area presents problems in dealing with the traditional definitions and applications for floodplains. Defining a static floodplain for a certain magnitude flood is difficult, due to the nature of desert floods. Flood waters in the study area form a sheetlike action upon contact with the alluvium where the depth is very shallow (a few inches to several feet) and is spread out, covering a relatively large surface area. Since floods carry and deposit substantial amounts of debris, a subsequent occurrence will be redirected by that debris and result in a different area of inundation. Depending on soil moisture conditions and the magnitude of the flood, at some point flood waters become subsurface flow. This subsurface flow can effectively become a subsurface flood (Doug James, Utah State WRL 1980). Therefore, depending on the conditions, a floodplain might be subsurface.

Three types of floods occur in the Great Basin area: snowmelt, rain on snow and thunderstorms. Snowmelt floods occur from April through June, rain on snow generally happens November through March, and thunderstorms occur principally during the summer and fall months. Generally, the maximum annual and most frequent type of flood in the project study area is caused by thunderstorm activity.

Although thunderstorms may occur on many days in one season and be spread over a large area, the high intensity rainfall is limited to small areas. Indications are that as much as 7 in. of rain may fall in less than one hour. It is this high intensity, usually occurring in less than 1 square mi, which produces floods and sometimes mud-rock flows. Mud-rock flows have been described as mud, rock, debris, and water mixed to a consistency of wet concrete and usually traveling at a low velocity. Flood measurements, however, have shown that flood peaks may exceed 3,000 cfs per square mi from some small drainage basins.

Principal physiographic factors affecting flood flows are: drainage area, altitude, geology, basin shape, slope, aspect and vegetal cover. Graphs showing the magnitude and frequency of floods for recurrence intervals, ranging between 1.1 and 50 years have been published by the U.S. Geological Survey (Butler, Reid and Berwick, 1966).

HYDROLOGIC CONDITIONS IN SELECTED VALLEYS (3.1.3)

Big Smoky Valley (3.1.3.1)

Physiography and Geology

The study of Big Smoky Valley in Nye and Esmeralda counties was limited to the southern portion of the valley. The valley has a northerly trend and is about 65 mi (105 km) long and up to about 25 mi (40 km) wide. The area of the valley is about 1,600 mi^2 (4,144 km^2) of which about 665 mi^2 (1,722 km^2) is suitable area for M-X deployment. The elevation of the valley floor ranges from 4,800 ft (1,463 m) in the southern playa to about 5,800 ft (1,768 m) at the north end. Elevations along the crest of the mountain ranges are from about 5,500 to 11,000 ft (1,676 to 3,353 m).

Alluvial and lacustrine deposits of Tertiary and Quaternary age fill the valley up to thicknesses believed to be from 3,000 to 5,000 ft (914 to 1,524 m) (Rush and Schroer, 1970). The generally coarse-grained alluvial deposits are probably interlayered with the fine-grained lake deposits. Playa deposits occur where there are closed topographic lows such as Alkali Spring Flat and Tonopah Flat. Rocks of the bounding mountain ranges are primarily volcanics of Tertiary age with local areas of clastic and carbonate sedimentary rocks of Paleozoic age. Minor outcrops of granitic igneous rocks occur throughout the mountain ranges.

General Hydrology

Big Smoky Valley has a closed surface and subsurface drainage (Rush and Schroer, 1970) although there is some indirect evidence for subsurface discharge based on differences in potentiometric levels and unbalanced water budgets in Clayton Valley and Tonopah Flat (Rush and Schroer, 1970).

The majority of recharge to the valleyfill aquifer is believed to occur on the fans from infiltration of streamflow from the mountain ranges in response to precipitation events. Only a minor rate of recharge is believed to take place through the finer-grained sediments on the valley floor. This is due to the low precipitation, high evaporation, and low infiltration rates of these deposits. The total recharge from precipitation is estimated to be about 12,000 acre-ft/yr (14.8 hm^3/yr) (Rush and Schroer, 1970). Additional recharge takes place by subsurface inflow from Ione Valley, Ralston Valley, and the northern part of Big Smoky Valley. The gradient down the axis of Ione Valley is about 35 ft per mi (7 m/km) and it is 5 ft/mi (0.9 m/km) down the axis from Big Smoky in the north end of the study area. Inflow from Ione and Ralston valleys is estimated to be 2,000 acre-ft/yr (2.5 hm^3/yr) (Rush and Schroer, 1970). There is no published estimate of inflow from northern Big Smoky, but based on a narrower width and lower gradient than Ione Valley, an inflow of about 1,000 acre-ft/yr (1.2 hm^3/yr) is estimated. Total recharge is therefore about 15,000 acre-ft/yr (18.5 hm^3/yr).

Discharge takes place by evapotranspiration, use by man, springs and possible subsurface outflow. Evapotranspiration is estimated at 6,000 acre-ft/yr (7.4 hm^3/yr) (Rush and Schroer, 1970) based on the area of phreatophyte growth. Total use by man is estimated at 1,000 acre-ft/yr (1.2 hm^3/yr) (Rush and Schroer, 1970). This estimate includes irrigation, but also includes domestic and municipal use. Numerous springs along the base of the mountain ranges discharge minor quantities of water, primarily from perched alluvial aquifers. The total quantity of discharge accounted for is 7,000 acre-ft/yr (8.6 hm^3/yr). The remaining 8,000 acre-ft/yr (9.9 hm^3/yr) of recharge is assumed by Rush and Schroer (1970) to leave the valley by subsurface flow to Clayton Valley, south of Tonopah Flat. There is, however, no direct evidence for subsurface outflow. If the assumption of subsurface outflow is inaccurate, the difference between recharge and discharge rates is likely due to errors in estimating evapotranspiration, infiltration, and subsurface inflow.

Rush and Schroer (1970) estimate the perennial yield to be the same as discharge by evapotranspiration or 6,000 acre-ft/yr (7.4 hm^3/yr).

The potentiometric gradient averages about 30 ft per mi (6 m/km) from north to south down the axis of the valley. Horizontal flow terminates in a closed potentiometric low southwest of the study area in southern Tonopah Flat.

There is another closed potentiometric low in Alkali Flat, in the southern end of the study area, separated from Big Smoky Valley by a groundwater divide south of Highway 6. The closed potentiometric contours indicate that discharge cannot take place by horizontal flow and that either evapotranspiration or deep interbasin flow must account for all the water entering the basin. Depth to water ranges from near the surface in the northeast part of the valley near San Antonio Ranch and in Alkali Springs Flat in the southern part, to about 150 ft (46 m) in the central part of the valley. Depth to water beneath the alluvial fans is generally over 500 ft (152 m).

Aquifer Characteristics

Aquifer (pump) tests of wells 6N/40E-13da and 3N/40E-2dcd were conducted in Big Smoky Valley. These wells are 350 and 280 ft (107 and 84 m) deep, respectively. The respective transmissivities were 124,000 and 1,400 gallons per day per foot (gpd/ft) (178 and 2.0 cm^2/sec). Aquifers with transmissivities greater than 100,000 gpd/ft are adequate for large well yields (over 2,000 gpm (63.1 l/s) capacity). The hydraulic conductivities in the screened intervals of these respective wells are 1,700 and 9 gallons per day per sq ft (gpd/ft^2) (0.08 and 4.2×10^{-4} cm/sec). These values indicate the presence of gravel or clean well-sorted sand in the vicinity of well 6N/40E-13da in the western portion of the valley and less conductive subsurface sediments around well 3N/40E-2dcd, in the southwest portion of the valley. Neither of the two wells tested had an observation well nearby. Thus, no storage coefficient values were computed.

The results of the aquifer tests suggest that wells 300 ft to 500 ft (91 to 152 m) deep tapping lake sediments of low conductivity should yield less than 100 gpm (6.3 l/s); whereas, wells tapping drainage channels and fans containing sediments of high conductivity could yield more than 1,000 (63.1 l/s). These conclusions are based on well data in Big Smoky Valley and hydrogeologic similarities with other valleys, and indicates that with proper well placement, well yields sufficient for M-X needs (up to 350 gpm (22.1 l/s)) could be attained throughout most of the valley.

Water Quality Limitations

Five groundwater samples were collected for chemical analysis during the field work in Big Smoky Valley, and tested by Controls for Environmental Pollution (CEP). In addition, two samples from the study area were tested by the U.S. Geologic Survey in 1968 (Rush and Schroer, 1970). Of the seven samples, five are from wells, and two are from springs. With the exception of the quality of water from Alkai Flat Hot Springs and well 3N/40E-2dcd, the water quality was within the minimum standards for drinking water

Groundwater from Alkali Hot Springs exceeded the criteria for sulfate (494 mg/1) and fluoride (8.2 mg/1) and that from well 3N/40E-2dcd exceeded the criteria for fluoride (1.8 mg/1). Of the five groundwater samples which were of suitable quality for drinking water, three were of good quality (from wells at 7N/40E-35cc, 7N/42E-27ce, and 9N/43E-9bbb), one from well (6N/40E-13dac) was poor due to magnesium (50 mg/1) and fluoride (0.91 mg/1) and one from Willow Spring (2N/40E10bba) was poor due to fluoride (0.88 mg/1) and calcium (94 mg/1).

In general, water quality deteriorates toward the playas where horizontal flow terminates and discharge by evapotranspiration takes place. Evapotranspiration tends to concentrate dissolved solids by removing nearly pure water. The high temperature of the water at Alkali Springs (120°F, 49°C) indicates deep circulation of groundwater. The high concentrations of flouride, sulfate, and bicarbonate at this location are probably the result of a long flow path and increased solubility due to the high temperature. Discharge from Alkali Springs is probably from a regional flow system, based on the above assumptions.

Aquifer studies indicated that in at least the western part of the valley the aquifer is capable of sustaining well yields of over 1,000 gallons per minute. Accordingly, from a hydrological point of view, with proper well placement and design well, yields sufficient for M-X water requirements could be attained in most parts of the valley with minimal impact.

Cave Valley (3.1.3.2)

Physiography and Geology

Cave Valley, located in Lincoln and White Pine counties in Nevada, is a relatively small north-south trending valley with an approximate area of 356 mi (922 km^2), of which 137 mi^2 (355 km^2) is suitable area for the deployment of M-X. Cave Valley is a southern extension of the Steptoe Valley structural basin. Cave Valley is separated from Steptoe Valley by a low topographic divide. The Egan Range separates Cave Valley from White River Valley to the west and the Schell Creek Range separates Cave Valley from Lake Valley to the east. The Schell Creek Range trends toward the southwest from latitude 38° 30 ft and closes the south end of the valley by merging with the Egan Range in a low topographic divide.

Elevations in the Egan Range are typically from 7,600 to 8,600 ft (2,315 to 2,620 m). The Schell Range has elevations ranging from 7,400 to 8,600 ft (2,225 to 2,620 m) in the northern and southern part of the range and up to 10,993 ft (3,350 m) (Mount Grafton Peak) in the middle. The low point in the valley has an elevation of 5,969 ft (1,820 m).

The Egan and Schell Creek ranges are composed of 80 percent carbonate rocks and 20 percent of shale and sandstone rocks of Paleozoic age (Kellog, 1960). The central part of the valley is composed primarily of valleyfill materials deposited partly under lacustrine (lake) conditions (Eakin, 1962). The only lacustrine deposits exposed in Cave Valley are the playa deposits occurring in the southern portion at the topographically lowest point of the valley.

In late Pleistocene time a lake occupied the lower part of Cave Valley. Several shore lines were noted at an elevation of about 6,100 ft (1,860 m). Aerial photographs and topographic maps indicate that the maximum elevation of the lake was not more than about 6,100 ft (2,860 m). It is also noted that the elevation of the drainage divide between Cave Valley and the adjacent White River Valley is about 6,400 ft (1,950 m); therefore, it is unlikely that the lake overflowed into White River Valley to the south and southwest (Eakin, 1962).

General Hydrology

The Nevada State Engineer's Office has classified Big Smoky Valley as a designated valley. This is because the current demand for and interest in developing groundwater, as shown by applications for appropriation, significantly exceeds estimated perennial yield, and not because use exceeds perennial yield. Additional groundwater appropriations for M-X needs may not be granted, and water rights would have to be purchased from current holders.

Cave Valley is a topographically closed basin, with no surface water inflow or outflow. The principal drainage in the valley lowlands is southward toward the playa. The main drainage channel contains streamflow only during the spring runoff or for short periods after high intensity storms (Eakin, 1962). Eakin estimated the average annual recharge to the groundwater reservoir from precipitation by dividing the valley into five precipitation zones based on elevation. The boundary between the zones of less than 8 in. (20.3 cm) of precipitation and 8 to 12 in. (20.3 to 30.5 cm) was delineated at the 6,000 ft (1,829 m) contour; between 8 to 12 in. (20.3 to 30.5 cm) and 12 to 15 in. (30.5 to 38.1 cm) at the 7,000 ft (2,134 m) contour; between 12 to 15 in. (30.5 to 38.1 cm) and 15 to 20 in. (38.1 to 50.8 cm) at the 8,000 ft (2,438 m) contour; between 15 to 20 in. (30.5 to 40.8 cm) and more than 20 in. (50.8 cm) at the 9,000 ft (2,743 m) contour.

The average precipitation used for the respective zones, beginning with the zone of 8 to 12 in. (20.3 to 30.5 cm) of precipitation, is 10 in. (25.4 cm), 13.5 in. (34.3 cm), 17.5 in. (44.4 cm), and 21 in. (53.3 cm).

The recharge estimates, as a percentage of the average precipitation, for each zone are: less than 8 in. (20.3 cm), 0 percent; 8 to 12 in. (20.3 to 30.5 cm), 3 percent; 12 to 15 in. (30.5 to 38.1 cm), 7 percent; 15 to 20 in. (38.1 to 50.8 cm), 15 percent; and more than 20 in. (50.8 cm), 15 percent; and more than 20 in. (50.8 cm), 25 percent. As a result the total recharge of Cave Valley was estimated at 14,000 acre ft per year (Eakin, 1962).

Groundwater discharge from Cave Valley was also estimated to be approximately 14,000 acre-ft/yr (17.3 hm^3/yr) (Eakin, 1962) (State Engineer, Nevada, 1971).

Groundwater discharging by evapotranspiration probably does not exceed a few hundred acre-ft a year, and a smaller quantity is discharged by pumping from wells: Most groundwater discharge from the valley is probably by underflow through the underlying carbonate rocks to the west, southwest or south (Eakin, 1962). Fugro National findings confirm that groundwater flow in Cave Valley has a north to south or southwest direction and that there is a drainage divide between the southern boundary of Cave Valley and White River Valley. Therefore it is likely that groundwater flow from Cave Valley to White River Valley occurs through the underlying carbonates as it has been stated by Eakin, 1962. The quantity of underflow cannot be estimated directly, without additional hydrologic and geologic data.

The potentiometric surface of the groundwater in the valleyfill aquifer slopes down from the north of the valley towards the south. The groundwater table between Township 9 and 11 is less than 50 ft (15 m) below land surface due to shallow bedrock underlying the valleyfill deposit (unpublished preliminary bedrock contour map by Fugro National). As shown on the potentiometric map, a semi-perched aquifer exists locally in Townships 8N and 9N, Range 64E. This could be caused by local shallow impervious bedrock, or a hydrologic barrier such as a fault. The geologic conditions in the area where the Egan Range protrudes into Cave Valley suggest the presence of shallow bedrock or possible local faulting.

Water-level measurements made by Fugro National, in March 1980 indicate higher water elevations in four existing wells amounting to 10 to 24 ft (3.5 to 7.3 m) than those reported by Eakin 1962 and the BLM well record 1964. However, well 8N/64E-15 bcb (Harris well) shows a 14 ft (4.3 m) decline in the groundwater level for the same period of time. Annual average precipitation from 1963 to 1977, measured at three meteorological stations (Ely, Ruth and Lund) taken from the climatological data, annual summary (Department of Commerce, NOAA), indicate no substantial departure from the overall average precipitation attributed to the Cave Valley area. Because rises or declines in groundwater levels might be attributable to incorrect early measurements, or to well casing failure; or to other unidentified causes, no explanation for the observed phenomena can be given.

<u>Aquifer Characteristics</u>

The groundwater reservoir of Cave Valley is composed of valleyfill divided into two units: older unconsolidated to partly consolidated sedimentary deposits of late Tertiary and Quaternary age, and unconsolidated clay, silt, sand, and gravel of late Quaternary age (Eakin, 1962).

The unconsolidated sand and gravel deposits of Quaternary age are capable of transmitting groundwater freely. However, the finer sand, silt, and clay have low permeability and transmit water slowly.

Because none of the existing wells in Cave Valley could be used for an aquifer test, the transmissivity for the valleyfill was estimated by way of comparison with adjacent White River Valley which has similar sedimentary depositional history. In the valleyfill of White River Valley transmissivity values of 1,420 and 10,300 gpd/ft (4.9 and 36 cm^2/sec) were obtained from wells located at 7N/61E-36cc and 10N/61E-19bc, respectively (Fugro National, Inc. 1979). The low transmissivity value can be representative of the find sand, silt, and clay sediments of the valley fill in Cave Valley. The higher transmissivity value may be representative of the partly consolidated sand and gravel deposits of the valleyfill.

Water Quality Limitations

Six groundwater samples were collected and tested for chemical quality from three springs (9N/64E-16dbd; 7N/64E-33cc; 6N/63E-19da) and three wells (10N/63E-25aca; 8N/64E-4abd; 8N/64E-15bcb). Two of these tests were conducted by the Bureau of Land Management, Ely District. Four samples were collected by Fugro National and analyzed by Controls Environmental Pollution, Inc. The results indicate good quality water for all samples taken north of Township 6 with total dissolved solids concentrations ranging from about 130 to about 280 mg/l. Two springs (7N/64E-33cc; 6N/63E-19da), analyzed by the BLM have moderately high bicarbonate concentrations (more than 250 mg/l). This condition is probably due to the solution of carbonate rocks by the groundwater.

Cave Valley Spring located at 9N/64E-16bdb also originates from the carbonates but has low bicarbonate concentration (80 mg/l) and low total dissolved solid concentrations (127 mg/l). This is probably due to a short resident time of the groundwater with the rocks which suggests that it is related to precipitation and snowmelt. Thus it is not connected to the regional carbonate aquifer. The discharge in Cave Spring ranges from a few hundred gallons per minute to less than 10 gallons per minute. All of the valley is estimated to contain groundwater of good quality.

Dry Lake/Delamar Valley (3.1.3.3)

Physiography and Geology

Dry Lake and Delamar valleys are believed to be hydrologically connected through valleyfill aquifers and are treated essentially as the same groundwater basin in the ensuing discussions. The Dry Lake/Delamar drainage basin lies within central Lincoln County in eastcentral Nevada. The basin is approximately 82 mi (132 km) long and 20 mi (32 km) wide at the widest point, and encompasses an area of 1,300 mi^2 (3,367 km^2). Of that area, 497 mi^2 (1,287 im^2) are suitable for M-X siting including 315 mi^2 (815 km^2) in Dry Lake Valley and 182 mi^2 (417 im^2) in Delamar Valley.

The valleyfill deposits are up to 10,000 ft (3 km) thick along the axis of the valleys and thin toward the margins. Based on detailed gravity maps constructed by Fugro National (FN-TR-33-DL), the volume of valleyfill in Dry Lake Valley is estimated to be 635,000,000 acre-ft (732,955 hm^3). The estimated volume of valleyfill in Delamar Valley is 200,000,000 acre-ft (246,600 hm^3). These substantial potential aquifer volumes provide tremendous storage capacity for groundwater.

Mountain crests bounding the valleys range in elevation from about 7,000 ft (2,134 m) to over 9,000 ft (2,743 m). Highland Peak, on the east side of Dry Lake Valley, has an elevation of 9,395 ft (2,864 m), and is the highest point in the basin. The playa, in the extreme south end of Delamar Valley, has an elevation of less than 4,400 ft (1,341 m) and is the lowest point in the basin. The two valleys are separated by a low, broad alluvial fan that extends across the basin just south of Dry Lake playa.

Dry Lake and Delamar valleys exhibit typical Basin and Range structure, consisting of high angle, north-south trending, normal basement faults that border the Pahroc ranges on the west and the Bristol, Highland, Chief, and Delamar ranges on the east. The area between the ranges is faulted downward. A north-south trending fault on the eastern side of the basin displaces surface alluvium and forms a prominent scarp. Additionally, Shawe (1965) shows east-west trending faults that transect the basin and displace deep valleyfill deposits. This interpretation is supported also by gravity surveys (Fugro National, FN-TR-26E).

The mountains on the western side of the valley are predominatly composed of ash flow tuffs of Tertiary age with some carbonate rocks of paleozoic age. Conversely, the eastern mountains are composed primarily of carbonate rocks of Paleozoic age with minor amounts of ash flow tuffs of Tertiary age (Stewart and Carlson, 1978).

Coarse-grained alluvial and fine-grained lacustrine deposits make up the majority of sediments in the valleys. Although playa deposits cover only a small percentage of the valley surface, they are thought to be of great thickness and interfinger with alluvial deposits in the subsurface (Fugro National, FN-TR-27). These playa deposits are located in the south-central portions of the valleys. From the central part of the valleys, the grain size and grading of alluvial deposits progressively increase towards the mountains.

General Hydrology

Dry Lake and Delamar valleys form closed surface drainage basins. There are no perennial streams in the valleys, and streamflow only occurs in the mountain ravines and alluvial fans after high-intensity rains and as snowmelt runoff.

Springs in the Dry Lake and Delamar valley area occur in volcanic rocks composed predominantly of tuffs along the basin margins. The springs are recharged by meteoric waters (precipitation and snowmelt) and are not associated with the deep regional carbonate aquifer. They generally have low yields (less than 20 gpm) and are used primarily to supply stock ponds in the area. Some water wells in the northern and western part of Dry Lake Valley tap perched aquifers with water levels significantly higher than the underlying basin aquifer. Water use in the valleys is limited to a few isolated stock ponds fed by infrequent surface runoff and nearby springs with waters of meteoric origin.

Groundwater recharge to the basin is primarily from precipitation occurring in the mountains along the northwest and east flanks of the valleys (Eakin, 1963). From these areas, groundwater moves laterally and downward toward the central part of the valleys. Generally, the groundwater moves from Dry Lake Valley toward Delamar Valley. An annual (recharge based on a percentage of average annual precipitation) of about 6,000 acre-ft (7.4 hm^3) for the valleys has been estimated by Eakin (1963). Discharge occurs primarily as deep underflow to the south through carbonate rocks. Alluvial groundwater gradients between Dry Lake Valley and Delamar Valley closely resemble the carbonate aquifer gradient between White River Valley and Pahranagat Valley. This suggests that the valleyfill aquifers of the basin and the regional carbonate aquifers are hydraulically connected (Eakin, 1963).

Aquifer Characteristics

The considerable depth to groundwater (greater than 400 ft.) has precluded much development in these valleys and, therefore, very little has been published about specific aquifer characteristics. However, all wells in the basin tap valleyfill aquifers with little indication of confinement. Existing wells produce less than 100 acre-ft of water annually for use by livestock. During Fugro National's field investigations in 1979, none of the wells were found to be suitable for aquifer testing because of pumping limitations. In 1980, two intermediate depth test wells (3S/64E-12ca and 6S/63E-12ad) were drilled in Dry Lake/Delamar valleys. At each site, observation and test wells were constructed.

Aquifer tests in Dry Lake Valley were conducted for ten days at 500 gpm (31.5 l/s) followed by an aquifer recovery test. The maximum well yield during development was approximately 750 gpm (47.3 l/s). Maximum drawdown at the pumping well during the pump test was about 50 ft (15 m). These tests indicated an aquifer transmissivity of about 45,000 gpd/ft (155 cm^2/sec) and a storage coefficient of 3×10^{-4}. Because the well only partly penetrated the aquifer, the transmissivity of the total thickness of the aquifer is probably much higher. The unusually low storage coefficient in the valleyfill aquifer is probably due to the tremendous thickness of the aquifer.

Aquifer tests in Delamar Valley were conducted for ten days at 85 gpm (5.3 l/s) followed by an aquifer recovery test. Maximum drawdown during the test was 85 ft (26 m). Transmissivity was calculated at 5,000 gpd/ft (7 cm^2/sec) with a storage coefficient of 4.0×10^{-4}.

Potential well yields in Dry Lake Valley are expected to be high in the unconsolidated valleyfill deposits around the valley periphery. However, a significant portion of the basin is probably composed of fine-grained lacustrine deposits near the central valley areas. These areas probably have relatively low hydraulic conductivities. The extent and depth of the low yield deposits are not fully known. However, there appears to be sufficient water for development of the M-X system within the basin.

Because of the great depths to water in Delamar Valley 870 ft (265 m) in test well 6S/63E-12ad, well yields are expected to be less than 100 gpm (6.3 l/s). Well yields may increase slightly away from the central valley axis, but any yield increase due to higher aquifer permeability will probably be offset by the corresponding increase in pumping lift.

Water Quality Limitations

Because there are very few wells in Dry Lake Valley, only four groundwater quality analyses are available. Four samples were collected by Fugro National in 1979 and 1980 and one sample was collected by Carpenter (1915) and reported by Eakin in 1963.

Based on the water quality criteria listed in Appendix C1-1, all of the water analyzed is of good quality and is acceptable for drinking. All groundwater samples contained moderately high bicarbonate levels ranging from 187 to 320 mg/l, which result in hardness levels of about 100 mg/l. Calcium concentrations range from about 40 to 83 mg/l and were generally in the poor range. In addition, the sample collected at 3N/65E-21dbd and analyzed by Carpenter also contained relatively high chloride (110 mg/l) and nitrate (32 mg/l) concentrations.

Groundwater in the northern part of Dry Lake Valley is of the calcium magnesium/chloride-bicarbonate type. As the goundwater migrates from the fans toward the central valley area, the concentrations of calcium and chloride increase slightly and sodium concentrations decrease, yielding water of the sodium-calcium/-bicarbonate type. The higher calcium and chloride concentrations in the central valley area may be related to the soil chemistry of the playa deposits.

The only groundwater samples for chemical quality testing from Delamar Valley was from the Fugro National test well. However, the analyses were not completed at the time of publication of this report.

Dugway Valley (3.1.3.4)

Physiography and Geology

Dugway Valley is located in Tooele and Juab counties in west-central Utah and has a total area of 890 mi^2 (2,300 km^2). Of the total area only 182 mi^2 (471 km^2) are suitable for M-X siting.

Dugway Valley trends north-south and is approximately 30 mi (48 km) long and varies in width from 1 to 8 mi (2 to 13 km). The valley is bordered on the west by the Dugway Mountains and the Thomas Range, on the south by the Drum Mountains, and on the east and northeast by Keg Mountain and Slow Elk Hills. The northern boundary of the valley is the Great Salt Lake Desert. Valley floor elevations range from 4,480 ft (1,365 m) at the north end to 5,080 ft (1,548 m) in the central-southern portion of the valley. The valley is bounded by peaks on the northwest that reach elevations of nearly 9,000 ft (1,700 m). Most of the area below about 4,600 ft (1,400 m) is nearly flat as a result of planation and deposition by ancient Lake Bonneville (*Stephens and Sumsion*, 1978).

Valleyfill deposits consist mainly of alluvial fan deposits along the margins of the valley which interfinger with lake and playa deposits in and near the center of the valley. These deposits consit mainly of clay, silt, sand, and minor amounts of gravel in the playa area and gravels and sands in the alluvial fans and stream channel deposits. Significant influence from ancient Lake Bonneville is evident with thick lake deposits and well-developed shorelines.

Although the thickest section of valleyfill deposits penetrated by drilling is 1,003 ft (306 m), the valleyfill probably reaches a thickness of up to several thousand feet. Volcanic rocks of Tertiary age locally overlie rocks of Paleozoic age in the surrounding mountains.

General Hydrology

It is believed that the groundwater in Dugway Valley flows north-westward into the Great Salt Lake Desert and that some deep underflow occurs from the Sevier Desert drainage basin from the south and east (Stephens and Sumsion). Potentiometric groundwater surface supports the theory of the northerly flow of the water. Groundwater in the valley moves principally through coarse-grained alluvium deposited by ancient streams (Stephens and Sumsion, 1978). Most of the streams within the valley area are ephemeral. Pismire Wash, the principal drainage in the northern portion of Dugway Valley, extends generally northward from the Thomas

Mountains for about 35 mi (56 km) before the channel dissipates into the desert floor southeast of Granite Peak. Flow in Pismire Wash occurs only in direct response to thunderstorms or rapid snowmelt (Stephens and Sumsion, 1978).

Most of the groundwater is under confined or partially confined conditions due to the presence of one or more layers of lacustrine silt or clay. In general, groundwater moves from recharge areas adjacent to the mountains northward to the Great Salt Lake Desert. In the southern part of the valley, due to the presence of a bedrock divide, the groundwater as well as the surface flow moves in a southeasterly direction toward Whirlwind Valley. The hydraulic gradient in the northward flow direction to the Great Salt Lake Desert is variable and is greater than 90 ft/mi (17 m/km) in some areas. According to Stephens and Sumsion (1978) the hydraulic gradient averaged about 40 ft/mi (7.6 m/km) between Sheeprock Mountains and the Great Salt Lake Desert.

Water levels in the alluvium range from very close to the land surface in the northwestern part of the valley to at least 270 ft (82 m) in the center of the valley. Yields of wells in the valley fill are generally greater where the wells penetrate coarse materials, mainly along the valley margins. According to Stephens and Sumsion (1978), reported yields of wells completed in the valley fill range from less than 10 gpm (0.6 l/s) to as much as 400 gpm (25 l/s).

Approximately 12,000 acre-ft (14.8 hm^3) of water per year is recharged to the groundwater system in Dugway Valley; of this less than 5,000 acre-ft (6.2 hm^3) is through inflow from outside the valley, the remainder is from precipitation (Stephens and Sumsion, 1978).

The volume of groundwater in storage in the area is unknown and cannot be reliably estimated because of the unknown bottom geometry of the valley. Stephens and Sumsion (1978), however, estimated the amount of water recoverable from storage in the upper 100 ft (30 m) of saturated valleyfill to be about 3.8 million acre-ft (4,700 km^3). Near-surface storage in the area is frequently short-term. Although recharge from rainfall and snowmelt fills openings in the rocks in the mountains, they are drained rapidly to intermittent springs and seeps (Stephens and Sumsion, 1978). Some groundwater enters Dugway Valley area as subsurface inflow from the Sevier Desert drainage area through the Old River Bed (T10S/R9W).

Most of the groundwater discharge from Dugway Valley is by subsurface outflow northward into the Great Salt Lake Desert (Drawing B1-5). The total annual discharge by evapotranspiration in the area is estimated to average less than 1,000 acre-ft per year (1.2 km^3) (Stephens and Sumsion, 1978). Discharge through springs which comes mainly from carbonate and igneous extrusive rocks is less than 1,350 acre-ft (1.66 km^3) per year. The majority of the springs in Dugway Valley are found at the foothills between Simpson and Sheeprock Mountains. Others are also located on the western side of Cedar Mountains in the northern part of Dugway Valley. Perennial yield is estimated to be between 5,000 and 25,000 acre-ft per year (6 to 30 km^3) by the Utah State Engineer's Office (1971).

Aquifer Characteristics

There have been no aquifer (pump) tests performed in Dugway Valley; therefore, at present, it is not possible to calculate transmissivity and storage coefficient values for the valleyfill or carbonate aquifers. According to Stephens and Sumsion, finer material composed of clay, silt, and fine sand predominate the southwestern part of Dugway Valley and the yields from wells in this portion of the valley are expected to be relatively low. However, closer to the mountains, the valleyfill material becomes coarser and well yields are expected to be larger, on the order of 400 gpm (25 l/s).

Water Quality Limitations

The majority of the groundwater within Dugway Valley exceeds the criteria for suitable drinking water. Laboratory test results for one groundwater sample collected from a well at (C-12-10)35baa tested during the FY 80 field program and for several others tested by the U.S. Geological Survey exceed criteria for domestic use based on chloride (400 mg/l), calcium (200 mg/l), and sodium (250 mg/l) concentrations. Stephens and Sumsion (1978) state that the concentrations of dissolved solids in the groundwater from the valleyfill range from about 1,000 mg/l to 2,790 mg/l and range from poor (500 to 1,500 mg/l) to exceed criteria (1,500 mg/l). Some groundwater samples were considered poor on the basis of fluoride and magnesium concentrations (1.4 and 150 mg/l, respectively). Groundwater samples taken from the western part of the valley are rich in sodium and potassium chloride as compared to those from the center and eastern parts of the valley. These samples may represent groundwater in contact with fine-grained playa deposits with high salt concentrations. In this area groundwater may have undergone an ion base-exchange where the calcium and magnesium were exchanged for sodium and potassium ions.

Fish Springs Flat (3.1.3.5)

Physiography and Geology

Fish Springs Flat is a north trending basin which is bounded on the west by the Fish Springs Range and on the east by the Thomas Range. It is separated from Whirlwind Valley to the south by a low divide in the Swasey Bottom area, and it opens to the north to the Great Salt Lake Desert. Elevations along the axis of the valley range from about 5,100 ft (1,554 m) at the drainage divide in the south to about 4,300 ft (1,310 m) at the northern end of the study area. The peaks in the Fish Springs Range are up to 8,523 ft (2,598 m) in elevation and those in the Thomas Range are up to 7,046 ft (2,148 m) in elevation. The watershed area is 590 mi^2 (1,530 km^2), of which 117 mi^2 (303 km^2) are suitable areas for M-X development.

The Fish Springs and Thomas ranges are composed primarily of carbonate rocks with minor exposures of quartzite rocks, both of Paleozoic age. About half of the area of the Thomas Range is overlain by volcanic extrusive rocks of Tertiary age. The lower slopes of the ranges are covered with alluvial fans and colluvium composed of poorly-sorted sands and gravels.

Surficial deposits in the valley are of Quaternary age and include alluvial channel, eolian, and lacustrine deposits. The valleyfill deposits are believed to be composed of mixed, reworked, and interlayed alluvial and lacustrine deposits, including Lake Bonneville sediments. It is also likely that volcanic ash and lava flows are present throughout the valleyfill stratigraphic section, based on their presence in the Thomas Range and in the valleyfill at the Brush-Wellman beryllium mine in southeast Fish Springs Flat.

General Hydrology

Recharge to the valleyfill aquifer from precipitation is believed to take place primarily on the alluvial fans along the margins of the valley. Recharge by infiltration in the central part of the valley is believed to be minor due to low rates of precipitation, high rates of evaporation, and the fine-grained nature of the surficial deposits in that area. Annual precipitation ranges from 6 to 8 in. (15 to 20 cm) on the lower part of the valley floor to 16 to 20 in. (41 to 51 cm) on the peaks of the ranges (Bolke and Sumsion, 1978). Total precipitation over the watershed is estimated to be 232,000 acre-ft/yr (286 km^3/yr), of which 4,000 acre-ft/yr (5 km^3yr) is estimated to recharge the groundwater valleyfill aquifer (Bolke and Sumsion, 1978). Recharge by interbasin flow is estimated at 31,000 acre-ft/yr (38 km^3/yr), based on the indirect evidence of an unbalanced water budget (Bolke and Sumsion, 1978). The source for this interbasin flow is probably from the valley and ranges to the west of Fish Springs Flat. This is based on differences in groundwater potentiometric surfaces in Fish Springs Flat and those to the west of it. For example, the potentiometric surface in the Fish Springs discharge area is about 4,300 ft (1,310 m); to the west in Snake Valley it is about 4,400 ft (1,341 m) at the northern end. Further to the west in Spring Valley, springs discharge at an elevation of 5,600 ft (1,707 m). Additional evidence of the regional nature of the flow to Fish Springs is the warm temperature of the water, which ranges from 63.5 degrees to 141 degrees F (17.5 degrees C to 60.5 degrees C) which indicated deep circulation. The discharge rate correlates better with regional precipitation trends than with the Fish Springs Flat precipitation record which also indicates regional groundwater flow (Bolke and Sumsion, 1978). The conduit for this interbasin low is believed to be through fracture, solution openings and faults in the deep consolidated, rock aquifers. The discharge at Fish Springs is in the valley fill alluvium near the base of the Fish Springs Range and above the inferred location of the valley bounding fault. Bicarbonate concentrations are not unusually high (246 mg/l to 321 mg/l). Therefore, no conclusions have been made about the rock type through which flow is taking place.

Discharge from groundwater in Fish Springs Flat is by springs, evapotranspiration, wells, and subsurface outflow to the Great Salt Lake Desert. There are no well-defined areas of phreatophyte growth, except for the waterfowl ponds which were built and are maintained by U.S. Department of Wildlife in the Fish Springs National Wildlife Refuge. Discharge from these ponds is accounted for in the spring discharge as explained below. Greasewood and pickleweed are the most abundant phreatophytes in the valley. They occur primarily in scattered growths on the lower margins of the fans, where the depth to water is about 40 ft (12 m) or less and where the salinity of the water does not exceed the plant tolerance (Bolke and Sumsion, 1978). It is likely that a significant amount of discharge by evapotranspiration occurs only where the groundwater level is less than about 10 ft (3 m) even though phreatophytes can survive with deeper groundwater conditions. Discharge by phreatophytes is estimated at 8,000 acre-ft/yr (9.9 km^3/yr) (Bolke and Sumsion, 1978). The majority of discharge by springs takes place from the Fish Springs group. About 26,00 acre-ft/yr (32.1 km^3/yr) discharge from this group of springs and about 600 acre-ft/yr (0.7 km^3/yr) discharge from the other smaller springs along the base of the Fish Springs Range (Bolke and Sumsion, 1978). The discharge from the Fish Springs group is used in part to maintain a series of artificial ponds for wildlife habitat. Discharge by wells is minor. There are a few stock watering wells and culinary wells at the Fish Spring Ranger Station (C-11-14)23, and the Brush-Wellman mine (C-13-12)5. The total groundwater withdrawal by these users is probably less than 100 acre-ft/yr (0.1 km^3/yr). Subsurface outflow to the Salt Lake Desert is believed by Bolke and Sumsion (1978) to be insignificant, due to the low gradient (on the order of 3 ft per mi; 0.6 m/km) and the presumed low transmissivity of the valleyfill.

There has been no estimate of the perennial yield, however the 8,000 acre-ft/yr (9.9 km^3/yr) of phreatophyte discharge could possibly be salvaged, assuming no environmental damage would occur. Any outflow to the Great Salt Lake Desert could be salvaged without undesirable results.

Water depths in the main part of the valley are from over 150 ft (46 m) in the south end of the valley and on the upper alluvaial fans to near the surface in the central and northern part of the valley. The potentiomentric surface slopes down from an elevation of 4,400 ft (1,341 m) at the southern end to 4,320 ft (1,317 m) in the northern end. The gradient is about 3 ft per mi (0.5 m/km).

Aquifer Characteristics

The valleyfill in Fish Springs Flat may be to be up to a few thousand feet thick in its central area, based on its similarity to other valleys. Bolke and Sumsion (1978), however, stated only that the average aquifer thickness is probably greater than 450 ft (137 m). No aquifer tests were conducted in this valley due to the lack of suitable wells, so neither transmissivity nor storage coefficient of the valleyfill aquifer are known. Visual inspection of materials in two excavations one at the Brush-Wellman Mine (C-13-12)5 and one north of the Fish Springs Ranger Station which contained openwork gravels, indicates that there may be at least some areas with moderate transmissivities which could support well yields of up to a few hundred gpm. However, the stock and culinary wells which are currently in use in the valley yield only 12 to 40 gpm (0.8 to 2.5 l/s). There is no evidence of the presence or absence of continuous confining beds in the valleyfill deposits. Fish Springs, however, as well as the other smaller springs along the base of the Fish Springs Range, are apparently discharging from a bedrock aquifer under artesian conditions.

Water Quality Limitations

Two groundwater samples were tested for water quality for Fugro National by the Utah Water Research Laboratory. An additional 13 groundwater samples from 11 sites were tested by the U.S. Geological Survey from 1956 through 1977. Where a source was retested by Fugro National, the U.S. Geological Survey results are not included. All of the samples exceeded one or more criteria or drinking water. The water is generally a sodium-chloride type with high total dissolved solids (1700 mg/l to 22,400 mg/l). The springs in the Fish Springs group showed a wide range of temperatures and water qualities, indicating the possibility of different source areas, flow paths, and/or depths of circulation. For example, temperatures ranged from 63.5 degrees to 141 degrees F (17.5 degrees to 60.5 degrees C) and chloride concentrations from 670 mg/l to 12,000 mg/l. Although all samples tested exceeded criteria for drinking as used in this report, these criteria are only a recommendation for potable water quality where no better quality water is readily obtained.

Little Smoky Valley (3.1.3.6)

Physiography and Geology

Little Smoky Valley encompasses about 585 mi^2 (1515 km^2) and lies in southeast Eureka and the northeast Nye counties in central Nevada. This north-trending basin is 44 mi (71 km) long and from 6 to 18 mi (9.6 to 29 km) wide. Of the total area of the valley, 296 mi^2 (767 km^2) is suitable for M-X siting.

The valley floor is nearly flat with elevations increasing from 6,000 ft (1,829 m) at the northern end, near Newark Valley, up to approximately 6,500 ft (1,981 m) elevation in the existing playa at the southern end of the basin. Fish Creek, Antelope, and Hot Creek ranges flank the west side of the valley and attain elevation of 9,000 ft (2,743 m). On the east side, the Pancake Range crests at about 7,500 ft (2,286 m). The basin is separated from Bib Sand Springs Valley to the south and east by a pediment formed of carbonate rocks of Paleozoic age. Total relief in Little Smoky valley is about 3,000 ft (about 914 m).

The mountains surrounding Little Smoky Valley are primarily composed of carbonate rocks of Mesozoic and Paleozoic ages. There are also volcanic rocks of Tertiary age which crop out at the southern end of the valley.

Valleyfill deposits consist predominantly of interfingering alluvial and lacustrine (lake) sediments of late Tertiary age. Rush and Everett (1966) suggest that two Pleistocene lakes once existed in Little Smoky Valley. One lake occurred at the south end of the valley where a small playa now exists; the second lake occurred in Fish Creek Valley, within northern Little Smoky Valley.

General Hydrology

The northern part of Little Smoky Valley is considered to have an open system in terms of surface and subsurface drainages. The southernmost part of the valley is occupied by a playa which is only about 50 ft (15 m) south of the subtle topographic divide. This part of the valley is considered to have a closed surface drainage.

There are no major perennial streams in the valley; however, Fish Creek, which is fed by Fish Creek Springs flows eastward for about 5 mi (8 km). The discharge of these springs is probably sustained by interbasin flow through the carbonate aquifer. Intermittent streamflow does occur in the valley during high intensity rains and snowmelt runoff.

Groundwater occurs at about 6 ft (2 m) below the ground surface in the northern part of the valley. The depth to water increases; however, toward the mountains and the southern portion of the valley. At the extreme southern part of the valley, the depth to water in one well (11N/53E-6cda) near the edge of the playa, is 500 ft (152 m). The playa is probably part of a local perched aquifer as evident by the presence of phreatophytes downstream from the playa. The perched aquifer overlies and is separated from the main aquifer by a thick unsaturated zone.

The groundwater flow direction in the main valleyfill aquifer is generally to the north and towards Newark Valley. This is in agreement with Eakin (1960). According to Rush and Everett (1966) the flow is mainly to the north because there are more consolidated and less permeable rocks to the south and east of the valley. The hydraulic gradient ranges from 1 ft/mi to 4 ft/mi (0.2 m/km to 0.8 m/km), depending upon location within the valley. Eakin (1960) estimated that the hydraulic gradient was 4 ft/mi (0.2 m/km).

Groundwater recharge to Little Smoky Valley is primarily from precipitation occurring in the mountains along the west flank of the valley. The average estimated volume of water that falls as precipitation in the valley is about 230,000 acre-ft/yr (284 hm^3/yr), of which about 4,000 acre-ft/yr (4.9 hm^3/yr) or 1.7 percent, recharges the valleyfill aquifer (Rush and Everett, 1966). The second source of recharge to the valleyfill aquifer is Fish Creek Springs. This complex of four springs is thought to result from interbasin flow through carbonate rocks from the east in Antelope alley. The estimated recharge to the valleyfill groundwater system from the springs is 800 acre-ft per year. The third major source of recharge to the valleyfill aquifer are two springs which occur along the western side of the valley at 16N/53E. These springs probably discharge water from the carbonate aquifer similar to Fish Creek Springs. The total contribution to the valleyfill groundwater system from these springs is estimated to be 720 acre-ft/yr (9.9 hm^3/yr) (Rush and Everett, 1966). Spring discharges are negligible on the east side of the valley.

The volume of water stored in the upper 100 ft (30.5 m) of saturated valleyfill is estimated to be 1,600,000 acre-ft (1973 hm^3). This estimate is based on the assumptions that 160,000 acre-ft (64,750 hm^3) represent the surface area of the aquifer with greater than 100 ft (30.5 m) of saturated valleyfill (75 percent of the total acreage underlain by valleyfill), and a specific yield of 10 percent (Rush and Everett, 1966).

Water use in Little Smoky Valley is mainly in the north end of the valley, where the depth to water in the valleyfill is less than 300 ft (101 m), and along the northwest part of the valley, where there are springs.

Discharge from the valleyfill aquifer occurs primarily through irrigation and stock watering, which is estimated to use 3300 acre-ft/yr (4.1 hm^3/yr) (Rush and Everett, 1966). The phreatophytes in the middle of the valley (13N/53E) are estimated to transpire about 1900 acre-ft/yr (2.3 hm^3/yr), and subsurface outflow is estimated to be 1000 acre-ft/yr (1.2 hm^3/yr). The subsurface outflow water moves northward into Newark Valley. The estimated perennial yield of Little Smoky Valley is 5000 acre-ft (6.1 hm^3) (Rush and Everett, 1966).

Aquifer Characteristics

Few wells have been developed in Little Smoky Valley and most use low-capacity piston pumps which are unsuitable for aquifer testing.

Due to the short growing season, wells that might have been tested were without power at the time of the field investigation. In northern Little Smoky Valley there are several large capacity 1000 gpm (63 l/s) irrigation wells suitable for aquifer testing. Results of well drillers' aquifer tests at these four wells in 17N/54E-21 show a range of specific capacities from 34 to 82 gpm (2.1 to 5.2 l/s) per foot of drawdown. This would indicate a range in transmissivity of about 60,000 gpd/ft to 160,000 gpd/ft. Such well yields and transmissivities indicate that the aquifer can yield sufficient quantities of groundwater for the M-X development needs.

Water Quality Limitations

Four samples were tested for water quality by Fugro National. Analyses of these samples indicated that the groundwater is generally of good quality. A water sample from Pogues Station Spring (15N/54E-11aced), which discharges near the mountains at a slow rate 0.26 gpm (.02 l/s), was found to have high calcium and sulfate concentrations of 261 mg/l and 1080 mg/l, respectively, which exceed the established drinking water criteria.

There are no water quality data for the southern end of Little Smoky Valley, where the water is at greater depths and there is little development. The groundwater quality could be poor due to former Pleistocene lake and present clay deposits at the surface, which may add salt to the infiltrating water from the surface or other recharge areas.

Pine Valley (3.1.3.7)

Physiography and Geology

Pine Valley is a relatively small valley with a total area of 730 mi^2 (1890 km^2), of which 365 mi^2 (945 km^2) are suitable area for M-X deployment. It is a southern extension of the Snake Valley structural basin, and is separated from Snake Valley by a low ridge south of the Ferguson Desert area. The Wah Wah Mountain Range is an extension of the Confusion Range, and bounds the valley on the east side. The Needle Range bounds the valley on the west. The peaks in the Wah Wah Range are up to about 9000 ft (2740 m) in elevation; in the Needle Range they are up to about 9790 ft (2980 m). The low point in the valley has an elevation of 5097 ft (1554 m).

Both of these mountain ranges are composed primarily of caronate rocks of Paleozoic age with lesser amounts of quartzites of Paleozoic age. Rocks of Paleozoic age in the Needle Range are capped by volcanic extrusive rocks of Tertiary age. There are minor intrusive rock outcrops in the Wah Wah Range. The central part of the valley is composed primarily of alluvial fans and channel deposits. Playa deposits occur at the topographically lowest point in the valley. Other than these playa deposits, there are no lacustrine deposits exposed in Pine Valley. The lowest surface elevation of the drainage divide between Pine Valley and the Ferguson Desert is 760 ft (230 m) higher than the highest mapped Lake Bonneville deposits. Therefore, there are no extensive fine-grained Lake Bonneville deposits in Pine Valley, although there may be fine-grained lacustrine deposits from localized smaller Pleistocene lakes underlying the Quarternary materials. It is possible that volcanic extrusives are also present in the valleyfill based on their presence in the Needle Range. The valleyfill is estimated to be a few thousand feet thick in the center of the valley. Geophysical work now in progress by Fugro National will enable a better estimate to be made of valley geometry.

General Hydrology

Pine Valley is a topographically closed basin, with no surface inflow or outflow. A well developed stream system leads from the mountains on both sides of the valley into the central playa. All of the surface flow is the result of precipitation within the valley (Stephens, 1976). The maximum rainfall has been estimated at over 20 in. per year (50 cm/yr) on the highest peaks in the Wah Wah Range, and the minimum has been estimated at less than 8 in. per year (20 cm/yr) in the low central part of the valley (Stephens, 1976). The average over the entire basin is estimated at 10.6 in. per year (26.9 cm/yr), (Stephens, 1976). The total precipitation over the 730 mi^2 (1890 km^2) area is therefore estimated at 410,000 acre-ft/yr (506 hm^3/yr). These estimates are not precise because they are based on average precipitation measurements at various altitudes in other parts of Utah, and not on actual measurements in Pine Valley. Total recharge from precipitation is estimated at 21,000 acre-ft/yr (26 hm^3/yr) (Stephens, 1976).

Groundwater discharge is primarily through springs and evapotranspiration, with minor amounts withdrawn from wells. Springs and seepage to stream channels have been estimated to discharge approximately 1590 acre-ft/yr (2 hm^3/yr). The spring discharge is primarily from perched alluvial aquifers in mountain canyons on the valley margins. Evapotranspiration has been estimated at 5500 acre-ft/yr (6.8 hm^3/yr), based on a phreatophyte area of 5500 acres and a consumptive use estimate of one acre-foot per acre per year (9.9993 hm^3 per hectare per year) (Stephens, 1976). According to Stephens (1976), another 3000 acre-ft/yr (3.7 hm^3yr) is estimated to flow through carbonate rocks under the divide into Wah Wah Valley. This is based on the observation that the carbonate and quartzite rocks in the Wah Wah Range dip to the east and Stephens' belief that bedding is controlling the flow of groundwater in this region. There are no direct observations to support this belief. Additional groundwater use by man is estimated to be only 5 acre-ft/yr (0.006 hm^3/yr), mainly by the Desert Range Experiment Station and the Pine Grove Associates wells. Thus, the total discharge accounted for is about 10,000 acre-ft/yr (12 hm^3/yr). The 11,000 acre-ft/yr (14 hm^3/yr) of recharge that is not accounted for in these estimates is assumed to leave the valley by deep interbasin flow through the carbonate rocks of Paleozoic age.

The potentiometric surface of the groundwater in the valleyfill aquifer slopes from the margins of the valley to the center with an average gradient of about 100 ft/mile (20 m/km) on the upper alluvial fans to about 50 ft/mile (10 m/km) on the lower slopes. This evidence combined with the lack of surface discharge tends to confirm outflow by deep percolation. Groundwater depths are 200 to 400 ft (61 to 122 m) below land surface in the central low part of the valley.

The Utah State Engineer has not made an estimate of perennial yield for Pine Valley, but the system yield has been estimated at less than 5000 acre-ft/yr (6.2 hm^3/yr) by Eakin, Price, and Harrill (1976). The rate of natural discharge through springs and seepage (1590 acre-ft/yr; 2 hm^3/yr) and through evapotranspiration (5500 acre-ft/yr; 6.7 hm^3/yr) could be considered to be the perennial yield. The diffuse nature of this discharge, however, could make it difficult to economically salvage more than a small percentage of it, because water levels would have to be lowered over a large area.

Aquifer Characteristics

No aquifer testing was done as part of the water resource program. However, Pine Grove Associates, a mining concern, has tested two of their wells. The tests are considered to be proprietary information and were given to Fugro National in confidence, and are not reproduced in this report. Public information from the Utah State Engineer on one of the Pine Grove Associates wells indicates a specific capacity of 0.33 gpm/ft (0.68 cm^2/sec). Because this well is 2006 ft (611 m) deep and has a static water level of 375 ft (144 m) it can be expected to produce a few hundred gpm. The well at the Desert Range Experiment Station has a reported specific capacity of 0.8 gpm/ft (1.6 cm^2/sec). However, only 28 ft (8.5 m) of the 649 ft (198 m) total depth is screened. The specific capacity of the total saturated thickness at this well is probably larger. These values of specific capacity indicate that well yields on the order of hundreds of gallons per minute are possible from wells 1000 ft to 2000 ft (305 to 610 m) in depth in the same type of geologic environment as the two wells described above. It is believed that there is sufficient water in Pine Valley for M-X water requirement. It is likely, however, that the wells would need to be widely distributed.

Water Quality Limitations

Eighteen groundwater samples for quality analysis were tested from 13 locations, including two ephemeral streams, eight springs, two wells, and one mine adit. Thirteen of these tests were performed by a U.S. Geological Survey laboratory for the Utah Department of Natural Resources. Five samples were collected by Fugro National, Inc., and analyzed by the Utah Water Research Laboratory. All samples tested with the exception of the sample from Mountain Home Spring were within minimum drinking water standards. Some samples, particularly those from springs along the Needle Range were poor due to high calcium (75 to 226 mg/l) and magnesium (56 to 199 mg/l); these high ionic concentrations were probably from the limestone and dolomite rocks in that range, and soils and alluvium derived from those rocks. The groundwater sample from Mountain Home Spring, (C-26-19)3acc, exceeded drinking water criteria for magnesium (199mg/l). The sample from the well at the Desert Experimental Range was poor due to a high fluoride content (0.84 mg/l). Fluorite mining is conducted in the region. It is estimated that five percent of the valley contains groundwater of good drinking quality, 94 percent contains groundwater of poor drinking quality, and one percent contains water that exceeds the water quality criteria used in this report.

Railroad Valley (3.1.3.8)

Railroad Valley is a north-trending valley and lies in Nye and White Pine Counties in east-central Nevada. The drainage basin covers 2752 mi^2 (7128 km^2) of which about 975 mi^2 (2530 km^2) are suitable for M-X siting. The valley is 110 mi (177 km) long and varies from 15 to 25 mi (24 to 40 km) in width. It is one of the largest topographically-closed basins in Nevada.

The mountains along the east and west sides of the valley range from 7000 to 10,000 ft (2134 to 3048 m) in altitude with Currant Mountain, at 11,531 ft (3515 m), the highest point in the basin. The lowest point in the basin is 4706 ft (1434 m) in elevation on the northern playa. This playa is the remnant of a large lake which existed during the Pleistocene epoch and had a maximum area of about 430 mi^2 (1114 km^2) according to Van Denburgh and Rush (1974). Additionally, there is a smaller playa in the southern part of the valley at an elevation of 4845 ft (1478 m).

Van Denburgh and Rush (1974) identified the three principal aquifers within the valley as valleyfill deposits, fractured Teriary volcanics, and fractured carbonates of Paleozoic age. The valleyfill deposits consist of interbedded gravels, sands, silts, and clays with sands and gravels predominating along the valley margins and grading to the silts and clays in the playa areas. The Tertiary volcanics crop out in the mountains to the east and west and probably underlie the valleyfill aquifer in the northern part of the valley.

General Hydrology

Railroad Valley is a topographically closed basin, but Blankennagel and Weir (1973) estimated that about 1000 acre-ft/yr (1.2 hm^3/yr) of groundwater is discharged through the valleyfill and carbonate aquifers to Kawich Valley to the south. Van Denburgh and Rush (1974) noted, however, that this estimate may be too small. Railroad Valley receives about 1200 acre-ft/yr (1.5 hm^3/yr) of surface recharge from Hot Creek Valley via Twin Springs Slough.

Van Denburgh and Rush (1974) estimated the total groundwater recharge to Railroad Valley to be 52,000 acre-ft/yr (64 hm^3/yr) from precipitation and 3000 acre-ft/yr (3.7 hm^3/yr) from subsurface inflow but noted that, due to difficulties in estimating subsurface inflow, this latter estimate could be considerably lower than the actual subsurface recharge. For water budget calculations, Van Denburgh and Rush (1974) did not include surface inflow and, reporting that the estimates of recharge through precipitation and subsurface inflow were probably low, used an assumed total inflow of 75,000 acre-ft/yr (92 hm^3/yr) to Railroad Valley.

Discharge of groundwater from Railroad Valley occurs mainly as evapotranspiration with only small discharges reported through subsurface outflow. Van Denburgh and Rush (1974) estimated the total evapotranspiration to be 80,000 acre-ft/yr (99 hm^3/yr) and estimated that subsurface outflow through the valleyfill or carbonate aquifer totals only 1000 acre-ft/yr (1.2 hm^3/yr). For water budget calculations it was assumed that the discharge from Railroad Valley is 75,000 acre-ft/yr (92 hm^3/yr).

The perennial yield of Railroad Valley was estimated to be 75,000 acre-ft/yr (92 hm^3/yr) by Van Denburgh and Rush (1974). This estimate was based on the assumption that all the losses to evapotranspiration could be recovered and put to a more economic use and that one-half of the subsurface outflow to Kawich Valley could be recovered. In addition, a transitional storage reserve of 4,000,000 acre-ft (4932 hm^3) was estimated to be available in the upper 50 ft (15 m) of saturated sediments.

The groundwater level data and interpretation is based upon published water well information and measurements made by Fugro National. As interpreted, groundwater from both ends of the valley moves toward and discharges to a wildlife management area. Numerous flowing wells indicate artesian conditions in the wildlife management area. Depths to water vary, but it is estimated that 40 to 50 percent of the valley has groundwater at depths of less than 50 ft (15 m). The shallow groundwater is in the central portions of the valley and the depth to groundwater increases to over 200 ft (61 m) along the valley margins as the land surface elevation increases.

Aquifer Characteristics

No aquifer testing could be performed in Railroad Valley because permission could not be obtained from private well owners. No records of previous aquifer tests that may have been conducted in the area are available. Reports from local well owners, however, indicate that interference between wells is very high in the Currant area. This could reflect high transmissivities in a small local perched aquifer.

The amount of groundwater stored in the upper 50 ft (15 m) of saturated sediments in Railroad Valley is vast. Lithologic logs for 76 water wells in Railroad Valley were analyzed and it was found that, in the upper 50 ft of sediments, 29 percent of the sediments were comprised of clay, 3 percent of silt, 23 percent of sand, and 32 percent of gravel. Assumming that the porositeies of clay, silt, sand, gravel, and cemented gravel are 40, 35, 30, 30, and 15 percent respectively, the total groundwater in storage in the upper 500 ft of sediments is over 7.4 million acre (9124 hm^3) or 148,000 acre-ft (183 hm^3) per foot of saturated sediments. To determine how much of that stored groundwater is actually recoverable through conventional pumping, specific yield values of 4, 10, 15, 25, and 10 percent were used for clay, silt, sand, gravel, and cemented gravel. Calculations indicate that almost 3.7 million acre-ft (4562 him^3) could be recovered from storage in the upper 50 ft or 74,000 acre-ft (91 hm^3) per foot of saturated sediments. This calculation compares well with estimates made by Van Denburgh and Rush (1974).

Water Quality Limitations

A total of 66 groundwater quality analyses were used in the compilation of the water quality analysis. Seven of these samples were collected by Fugro National and were analyzed by Controls for Environmental Pollution in Santa Fe, New Mexico. The other 59 analyses were analyzed by the U.S. Geological Survey and reported by Van Denburgh and Rush (1974). The samples were classified as good, poor, or exceeds criteria according to water quality criteria. A total of five samples were classified as poor and nine samples were classified as exceeding criteria; 52 samples were classified as good. Three samples were classified as poor due to fluoride concentrations between 0.8 and 1.4 mg/l, one sample was poor due to a calcium concentration between 75 and 200 mg/l, and one sample was classified as poor due to a chloride concentration between 250 and 400 mg/l. Five samples exceeded the fluoride criteria (1.4 mg/l), three samples exceeded the criteria for sulfate (400 mg/l), three samples exceeded the chloride criteria (600 mg/l), two samples exceeded the calcium criteria (200 mg/l), and four samples exceeded the criteria for total dissolved solids (15 mg/l).

Because of the sparsity and distribution of water quality data, only generalizations can be made about the water quality in Railroad. The high fluoride concentrations in the central and southern areas may be due to interactions between groundwater and volcanic rocks.

Sevier Desert (3.1.3.9)

Physiography and Geology

Sevier Desert is a broad, gently southwest-sloping area of approximately 970 mi^2 (1,190 km^2) in Juab and Tooele counties. About 460 mi^2 (1,190 km^2) is considered suitable area for M-X deployment. The area defined as Sevier Desert for this study is actually the north central portion of a larger Sevier Desert studied by Mower and Feltis in 1968. That study defined Sevier Desert as the 3,100 mi^2 area between the Canyon and Tintic Mountains on the east and the House Range on the west and between Clear Lake and the north end of Sevier Lake on the south and the Sheeprock Mountains on the north. For this study Sevier Desert is the area bounded by the Simpson and Sheeprock Mountains to the north, which separate the Sevier Desert from Skull and Rush Valleys. Slow Elk Hills, Keg Mountains, and the southern part of Dugway Valley form the western border. The eastern boundary is formed by a line roughly drawn from the Sheeprock Mountains to Sand Mountain. Sevier Desert is bounded to the south by the 50-ft-to-water contour line. The peaks in the Simpson and Sheeprock Mountains are the highest in the Sevier Desert study area with elevations up to 8,275 ft (2,522 m). The lowest point in the area occurs in the Old River Bed in the northwestern portion of Sevier Desert where the elevation is below 4,500 ft (1,372 m). According to Mower and Feltis, 1968, the mountains surrounding the Sevier Desert Basin are composed of igneous, sedimentary, and metamorphic rocks ranging in age from Precambrian to Tertiary. Consolidated to unconsolidated sedimentary rocks, composed of clay, silt, sand, and gravel, along with volcanic rocks of Tertiary and Quaternary age form the central part of the valley. During the Pleistocene age, Lake Bonneville altered the topography of the basin, building shoreline deposits and cutting terraces and cliffs on the bordering mountains (Mower and Feltis, 1968).

General Hydrology

The Sevier Desert as defined by Mower and Feltis, 1968, is a topographically closed basin on all sides except the south. The Sevier River enters the desert near the midpoint of the eastern boundary and flows southwest toward Sevier Lake in the southwest corner of the desert. The Beaver River enters the desert and empties into Sevier River about 5 mi (8 km) to the north near the midpoint of the southern boundary. Because of irrigation diversions, surface water from these rivers reaches Sevier Lake only during years of heavy rainfall (Mower and Feltis, 1968). These two rivers, the only signficant surface flow in the Sevier Desert, are south of the area studied for this report.

The average annual precipitation prior to 1963 ranged from less than 6 in. (15 cm) to about 12 in. (30.5 cm) in the lowlands and from 8 in. (20 cm) to more than 25 in. (63.5 cm) in the mountains (Mower and Feltis, 1968). The average annual precipitation from 1963 to 1978 in the lowlands was 7.4 in. (19 cm) (Climatological Data Annual summary 1963-1977). Most rain falls in short-term, high-intensity summer storms resulting in fast runoff and little penetration of the soil. The most important source of water within the Sevier Desert region is the mountain snowpack which sustains river flow and is the source of recharge to the groundwater reservoir (Mower and Feltis, 1968). According to Mower and Feltis (1968), the main recharge areas are along the north and east edges of the basin.

Estimated recharge of the groundwater reservoir, although quantitatively undetermined, occurs through direct infiltration through the sediments when total precipitation exceeds evapotranspiration. This happens only during years of prolonged, relatively heavy rainfall. In the fifteen-year period from 1949 to 1964 this type of rainfall occurred only twice (Mower and Feltis, 1968). Other sources of groundwater reservoir recharge include seepage from streams and canals, infiltration of irrigation water, flow through fractured consolidated rock, and underflow from Pavant Valley to the east and from Beaver River Valley to the south (Mower and Feltis, 1968).

Groundwater in the Sevier Desert is discharged primarily by subsurface outflow, by well pumpage, and by evapotranspiration. According to Mower and Feltis, 1968, the amount of subsurface outflow is probably less than 5,000 acre-ft/yr (6.2 hm^3/yr).

Mower and Feltis (1968) identified three principal aquifers within the area as valleyfill deposits, fractured volcanics of Tertiary age, and fractured carbonates of Paleozoic age. The valleyfill deposits consist of interbedded silts, clays, and evaporites in the playa area and gravel and sands in the adjacent alluvial fans. Extensive cementation has occurred in the older valleyfill deposits. The fractured volcanic aquifer is comprised of tuffs and lava flows. The carbonate rocks of Paleozoic age crop out in the mountain ranges flanking the valley and are a source of recharge through groundwater underflow toward the younger unconsolidated deposits which form the valleyfill.

The water table within the valleyfill aquifer slopes to the southwest as well as away from a hydrologic divide (12S/11W and 10 W) toward the northwest in the suitable M-X siting area and toward Dugway Valley. The groundwater gradient for Sevier Desert averages 8 ft per mile (2.4 m per km) from the recharge area in the Sheeprock, Simpson, and Tintic Mountains toward the southwest. The groundwater gradient in the northwest, as it flows through the Old River Bed toward Dugway Valley, is 20 ft per mile (3.8 m per km). A potentiometric groundwater surface analysis performed by Fugro National provides support to the general pattern of the contours and the flow directions developed by Mower and Feltis, 1968.

Records compiled by the United States Geological Survey (U.S.G.S.) (1978) and groundwater level measurements collected by Fugro National in 1979 and 1980 indicate that the depth to groundwater is less than 10 ft (3.04 m) in the Delta area with several flowing wells reported. Measured depths to water exceed 200 ft (61 m), however, along the valley margins to the northwest where elevations are higher. The Utah Division of Water Resources (UDWR) (1978) reported that a slight rise in groundwater levels occurred between 1977 and 1978, probably due to a period of high precipitation; however, an overall decrease in the groundwater level of about 6 ft (1.83 m) has occurred since 1955. The perennial yield of the Sevier Desert is not known to have been calculated by previous work. Based upon pumping rates and piezometric level declines for the period from 1960 to 1977 compiled by the UDWR (1978) and using the Hill method described by Todd (1959), it is estimated that the perennial yield of the Sevier Desert groundwater basin is 23,500 acre-ft per year.

Groundwater utilization in the Sevier Desert averaged 28,000 acreft/yr (34.5 hm^3/yr) for the 15 year period from 1963 to 1977 according to the UDWR (1978). Recent groundwater withdrawal has significantly increased, however, reaching about 50,000 acre-ft (61.2 hm^3) in 1977 (UDWR, 1978). Of that amount, about 46,500 acre-ft (57.7 hm^3) were used for irrigation, 2,000 acre-ft were extracted for industrial use, and municipal and domestic pumpage consumed an additional 1,500 acre-ft (1.8 hm^3).

Aquifer Characteristics

The groundwater reservoir in the Sevier Desert is composed mainly of unconsolidated to partly-consolidated clay, silt, sand, and gravel, deposited under subaerial and lacustrine (Lake Bonneville) conditions, forming a multi-aquifer artesian system that is more than 1,000 ft (305 m) thick (Mower and Feltis, 1968). There are two artesian aquifers in the Sevier Desert. The deep and shallow artesian aquifers are separated by 300 to 500 ft (92 to 152 m) of relatively impermeable clay, silt, and fine sand (UDWR, 1964). Geophysical work now in progress by Fugro National will enable a better estimate to be made of valley geometry.

An aquifer test was performed by Fugro National on well (C-13-7)9cbc (Desert Mountain Well), which is 210 ft (64 m) deep. This test resulted in a transmissivity value of 1,500 gpd/ft (5.2 cm^2/sec). This value is much lower than the value of transmissivity of an aquifer located in typical valleyfill deposits, and could be caused by the poor construction of the 35-year-old well tested. It is expected that had the Desert Mountain Well had a longer screened section the transmissivity value would have been greater. The storage coefficient of the aquifer could not be determined because an observation well was not present. Judging from the extensive agricultural development in the Delta area, it is likely that well yields in excess of 1,000 gpm (63.0 l/s) could be obtained through proper well placement and design.

Water Quality Limitations

Eight groundwater samples for quality analysis were collected from eight different well locations by Fugro National in March 1980 and analyzed by the Utah Water Research Laboratory. The groundwater samples from wells (C-13-6)26bac, (C-13-6)12bcb, (C-14-6)9bab, and (C-14-6)9dda show moderately high chloride (456 to 681 mg/l) and sulphate (275 to 531 mg/l) concentrations, and wells (C-13-6)26bac, (C-14-6)9bab, (C-14-6)9dda, and (C-15-7)18caa show high fluoride concentrations (greater than 1.4 mg/l). These values are categorized as "poor" according to the water quality criteria.

Water quality exceeds criteria in the sand dune area northwest of Lynndyl. Analyses of samples collected in this area exceeded permissible limits in either sulphate (greater than 600 mg/l), fluoride (greater than 1.4 mg/l), chloride (greater than (600 mg/l), total dissolved solids (greater than 1,500 mg/l), or a combination of the above. Groundwater in the Old River Bed is generally of poor quality.

In addition, more than fifty groundwater samples were previously analyzed for chemical quality under the direction of the U.S.G.S. and the Bureau of Land Management. These tests support the results of the water quality analyses conducted by Fugro National in the portion of the Sevier Desert suitable for M-X deployment.

Snake/Hamlin Valleys (3.1.3.10)

Physiography and Geology

Snake and Hamlin Valleys although separated by a narrow divide south of Garrison, Utah, and considered separate valleys by local custom, are parts of the same hydrologic system. They encompass portions of Juab, Millard, Beaver, and Iron Counties in Utah, and White Pine and Lincoln Counties in Nevada.

The valleys have a combined length of approximately 135 mi (217 km), a width ranging from 5 to 43 mi (8 to 69 km), and an area of about 3,500 mi^2. The area judged suitable for M-X missile deployment under current criteria is 887 mi^2 (2,222 km^2) in both valleys, of which 335 mi^2 (869 km^2) is in Hamlin Valley and 552 mi^2 (1,354 km^2) is in Snake Valley. The valleys are bounded on the west by peaks up to 13,063 ft (3,982 m) in elevation and on the east by peaks up to 9,785 ft (2,982 m) in elevation. The valleys extend from the Paradise Mountains in the south to the Great Salt Lake Desert in the north. The valley floor has elevations ranging from 6,600 ft (2,012 m) in the southern end at Hamlin Valley to 4,250 ft (1,295 m) at the northern end of Snake Valley.

The valleyfill deposits consist mainly of clay, silt, and sand in the lacustrine areas at the center of the valleys and predominantly of gravels and sands in the alluvial fan and stream channel deposits along the mountain fronts. There is signficant influence from ancient Lake Bonneville, with well developed shorelines and thick lake deposits occuring in portions of Snake Valley and northern Hamlin Valley. The thickest section of valleyfill sediments penetrated by exploration oil-well drilling is 4,200 ft (1,280 m) in Snake Valley at (C-20-19)19dc. Gravity surveys conducted by Fugro National in the Ferguson Desert area indicate that the valley has a maximum thickness of about 3,000 ft (914 m) and is bound by faults in this area. These faults are structurally typical for valleys in the Basin and Range. Gravity surveys conducted by Fugro National in Hamlin Valley indicates that valleyfill sediments are about 10,000 ft thick in the area east of the Limestone Hills.

The bounding mountain ranges in Snake and Hamlin valleys are composed of carbonate rocks of Paleozoic age and extrusive rocks of Cretaceous and Tertiary age; intrusive igneous rocks of Tertiary, Jurrasic, and Precambrian age underlie the valley fill deposits (Hood and Rush, 1965).

General Hydrology

Snake and Hamlin Valleys appear to form an open system in terms of both groundwater and surface water. As indicated by potentiometric maps, and according to Hood and Rush (1965), both surface and the majority of groundwater flow north into the Great Salt Lake Desert. Groundwater occurs under both confined and unconfined conditions in Snake Valley. According to Hood and Rush (1965) the artesian conditions are illustrated by some springs and flowing wells. The potentiometric maps prepared by Fugro National show that the groundwater surface slopes to the north from Hamlin Valley toward Snake Valley at a hydraulic gradient ranging from 40 ft/mi (8 m/km) to less than 14 ft/mi (3 m/km). In Snake Valley, in addition to the underflow from Hamlin Valley, there is recharge from the western side of the valley from the Wheeler Peak area and Spring Valley. The flow continues to the north; however, it also moves to the southeast through the Ferguson Desert area. The majority of the flow, nevertheless, continues northward along the valley until it reaches the Salt Lake Desert. The eastern component of the groundwater flow is significant, and it may ultimately be part of the regional groundwater underflow that moves eastward through the fractured caverneous limestones. Such flow may be part of the underflow that supplements the recharge of the tributary valleys on the eastern side of Snake Valley.

The depth to the potentiomentric surface ranges from several feet above ground level at some flowing wells along the central valley axis to about 50 ft (15 m) below ground level away from the center of the valley and several hundred feet along the margins. The zero depth to water contour follows both sides of the central part of the valley. Considerable quantity of water is lost in this part of the valley by evaporation and evapotranspiration.

The limestone bedrock beneath the valleyfill is also known to contain water and to be highly conductive due to the fractures and solution openings (Hood and Rush, 1965). Characteristics of the intermediate and deep sediments, between 500 ft (152 m) and the bedrock contact, are not well defined.

Hood and Rush (1965) estimated the total groundwater recharge of both Hamlin and Snake Valleys at 105,000 acre-ft (129 hm^3) through precipitation and runoff, and another 4,000 acre-ft/yr (4.9 hm^3/yr) is recharged through underflow from Spring Valley.

Discharge takes place as evapotranspiration from native plants, soil moisture, irrigated fields, and ponded water, as well as underflow north to the Great Salt Lake Desert and east to the Confusion Range and the Ferguson Desert. According to Hood and Rush (1965) the potential evapotranspiration rate in Snake Valley is 5 ft (1.5 m) per year per acre, where evaporation or transpirations occurs. Based on this estimate, evapotranspiration accounts for about 80,000 acre-ft/yr (98.6 hm^3/yr) and outflow accounts for about 25,000 acre-ft/yr (30.8 hm^3/yr). The phreatophytes, which mainly consist of greasewood and rabbitbrush, occupy the central part along the whole length of Snake Valley. Other groundwater users are spread along the whole valley. Active use of water in Snake Valley area for stockraising and agricultural purposes started early in 1903 (Hood and Rush, 1965). Irrigation is from wells and springs at Callao, in the southern part of Garrison, along the road from Garrison to Gandy, and at Gandy. Estimated groundwater use for agriculture is about 14,000 acre-ft/yr (17 hm^3 /yr). Springs are found in Willow Springs area (T10S/R17W) near Callao, the Old Miller Ranch (T14S/R18W), the Bishop and Knoll Spring areas (T16 and 18S/R18W) and Big Spring (T10S/R70W). According to Hood and Rush (1965), the temperature of water from these springs is 64 to 68 degrees fahrenheit (18 degrees to 20 degrees centigrade), which is 10 to 20 degrees fahrenheit (5.5 to 11 degrees centigrade) above the range of average annual air temperature. This indicates that the source of the springs is deep and it is likely to be the carbonate aquifer. Perennial yield has been estimated to range from 32,000 acre-ft/yr (39.5 hm^3/yr) (Nevada State Engineer, 1971) to 80,000 acre-ft/yr (98.6 hm^3/yr) (Hood and Rush, 1965).

Aquifer Characteristics

Five aquifer (pump) tests were performed in Snake Valley and four in Hamlin Valley. Transmissivity values in the valleys ranged from 432 gpd/ft (1.5 cm^2/sec) to 350,000 gpd/ft (1208 cm^2/sec). Transmissivities at the low end of this range are only adequate for small domestic or stock wells, while transmissivities greater than 100,000 gpd (345 cm^2/sec) are adequate for large irrigation wells of over 1000 gpm (63 l/s). The storage coefficient was computed for two aquifer tests in Snake Valley. The values for Snake and Hamlin valleys ranged between 0.08 and 9.7×10^{-5}. The high value of storage coefficients indicates water table conditions and the low value indicates an artesian condition. The range of average hydraulic conductivity of the screened sections of silt, sand, and gravel ranged from 0.02 to 0.45 ft per minute (214 to 4847 gpd/ft^2). Values greater than about 0.1 ft per minute are generally found near the mountains and indicate the presence of well sorted, coarse sand or gravel. The lower values, which are concentrated at the central part of the valley, indicate the presence of finer grained, more poorly sorted sediments.

Well yields in the area range from a few gallons per minute for some flowing wells to over 1000 gpm (63 l/s) for some irrigation wells. Yields of wells depend upon the thickness and character of materials penetrated and well construction. In general, it is anticipated that well yields up to 1000 gpm (63 l/s) are obtainable throughout much of the suitable construction area with wells of about 300 ft (98 m) in depth.

Water Quality Limitations

The majority of the water in Hamlin and Snake valleys can be considered as calcium and/or magnesium bicarbonate water. This is especially true for groundwater on the western side of the valleys. As the water moves to the north and east and passes through the playa deposits and salt lakes in the center of Snake Valley, it exchanges its calcium and magnesium ion to sodium and potassium and loses its bicarbonate nature. Ultimately, the water becomes sodium-, potassium-, cholride-, and sulphate-rich. Analysis of groundwater samples from the Ferguson Desert area indicates water quality which is classified as poor, based on high fluoride (0.8 to 1.4 mg/l) and total dissolved solid content (500 to 1500 mg/l). The Salt Marsh Lake area in Snake Valley contains water that exceeds criteria for drinking; however, it is surrounded by good quality water. Generally, most of the valley contains groundwater of good quality. Most of the samples tested have bicarbonate concentration greater than 100 mg/l and one contained a bicarbonate concentration of 335 mg/l, which is probably a result of water slowly flowing through carbonate rocks in the bounding mountains and/or through sediments derived from them. The water quality from five groundwater samples in Snake Valley and six in Hamlin Valley were considered poor based on calcium (75 to 200 mg/l), magnesium (500 to 150 mg/l), fluoride (0.8 to 1.4 mg/l), and total dissolved solids content (500 to 1500 mg/l).

Tule Valley (3.1.3.11)

Physiography and Geology

The Tule Valley drainage basin, encompassing about 940 mi^2 (2435 km^2), lies in Juab and Millard counties in west-central Utah. The north-trending basin is 65 mi (105 km) long and from 8 to 22 mi (13 to 35 km) wide. Approximately 395 mi^2 (1023 km^2) in the basin is suitable for M-X deployment.

The mountains bounding Tule Valley are primarily composed of carbonate rocks of Mesozoic and Paleozoic age. Minor amounts of younger igneous rocks occur throughout these ranges. Numerous outcrops of carbonate rocks protrude through the valleyfill deposits in the central valley area. Mountain crests generally range between 7000 and 9000 ft (2130 and 2740 m) in elevation. The highest point in he drainage basin is Swasey Peak along the eastern side of the valley which has an elevation of 9669 ft (2947 m). Total relief in the basin is about 5370 ft (about 1640 m).

Valleyfill deposits consist predominantly of interfingering alluvial and lacustrine sediments which range from clays to gravels. The lacustrine sediments were deposited during the Pleistocene epoch when the valley was inundated by Lake Bonneville. Remnant shoreline terraces from Lake Bonneville are prominent in Tule Valley.

General Hydrology

Tule Valley is a topographically closed drainage basin with mountain ranges on the east and west side and low topographic divides on the north and south. Sand Pass, which forms a narrow divide separating the Fish Springs and House ranges along the north and east side of the valley, is severed by a major fault (Stokes, 1964) which may be a significant conduit for groundwater movement through and out of Tule Valley (Stevens, 1977).

In any basin which is in hydrologic equilibrium, the rate of recharge must equal the rate of discharge. Recharge in the Tule Valley drainage basin is by two processes:

1) Infiltration of precipitation from within the drainage area, and

2) Subsurface inflow from adjoining valleys.

Stephens (1977) has estimated an average annual recharge of 7600 acre-ft (9.4 hm^3) from precipitation. Based on the areal extent of phreatophytes, Stephens (1977) estimated an annual discharge rate of 40,000 acre-ft (49.3 hm^3) by evapotranspiration. Therefore, approximately 32,000 acre-ft (39.5 hm^3) of recharge may occur annually by subsurface inflow. The direction of migration and exact quantity of inflow cannot be determined with data presently available. However, based on the groundwater gradients estimated by figure for Snake Valley, some inflow from Ferguson Desert is probably occurring in the southern Tule Valley area.

There is no interbasin surface flow and all streams in the valley are ephemeral. Numerous small springs provide the only perennial flow in the valley. A north-trending line of small springs occurs in the north-central valley floor. The water from these springs has a relatively high temperature 70° to 79°F (21° to 26°C). They are believed to indicate the presence of a fault or fault zone which provides a conduit for water moving upward under artesian head from deeper aquifers. This may indicate interbasin underflow. During the summer of 1979, all of these springs were flowing, but because they discharged into ponds, no discharge measurements could be taken. System yield in the valley has been estimated to be less than 5000 acre-ft (6.2 hm^3) (Eakin, et al., 1976).

Groundwater in the basin generally flows toward the northern playa area under a hydraulic gradient of about 3 ft per mile (0.6 m/km). Where the evapotranspiration losses occur, the potentiometric surface is at or very near the ground surface in this area and the valleyfill here is believed to be saturated below an elevation of about 4425 ft (1349 m) (Stephens, 1977).

Aquifer Characteristics

Very few wells have been developed in Tule Valley and most are equipped with low-capacity piston pumps which are not suitable for aquifer testing. An aquifer test was performed on well (C-16-16)34bcd, which is 260 ft (79 m) deep. This test provided a transmissivity value of about 2000 gpd/ft (2.9 cm^2/sec). This value is much lower than the results of aquifer tests conducted in other valleys, and is believed to be due to the well only partially penetrating the aquifer. It is expected that if the well had been deeper, the measured transmissivity value would have been greater. The storage coefficient of the aquifer could not be determined because an observation well was not present.

Tule Valley was formed under similar geological and environmental conditions as Snake Valley to the west. Because of known well yields in Snake Valley, it is expected that well yields over 100 gpm (63 l/s) can be obtained from large-capacity wells, in areas of especially coarsegrained aquifer materials, such as the alluvaial fan area. Low well yields are anticipated in playa areas because the sediments here are generally very fine-grained lacustrine deposits of low hydraulic conductivity. The valleyfill aquifer in Tule Valley is believed to be adequate to fulfill M-X water requirements with proper well designs.

Water Quality Limitations

The U.S. Geologic Survey has analyzed eight groundwater samples from six separate locations over a period from 1935 to 1976. FUGRO National analyzed an additional eight groundwater samples. A total of 12 groundwater sampling locations were used in Tule Valley. Eight of these locations are springs and four are wells. Where FUGRO National has reanalyzed a source previously tested by the U.S. Geological Survey, only the results obtained by FUGRO.

Of the groundwater samples from the 12 locations, two have good quality, seven have poor quality, and three exceed criteria. The seven samples that were considered poor had high-constituent concentrations of sulfate (314 to 330 mg/l), fluoride (1.1 to 1.3 mg/l), chloride (280 to 450 mg/l), sulfate (851 mg/l), nitrate (19 mg/l), and calcium (240 mg/l). All of the samples were moderately high in bicarbonate (132 to 320 mg/l) due to groundwater interaction with carbonate rocks in the mountain ranges, as well as the soils and alluvium derived from these rocks. Only isolated areas in the mountain ranges are likely to have good quality water. The remaining area of the valley is divided about evenly between areas of poor quality and areas which exceed criteria. The poor quality areas are in the western and southern portion of the valley. The water deteriorates in quality downgradient toward the southeast.

Wah Wah Valley (3.1.3.12)

Physiography and Geology

Wah Wah Valley trends northerly and lies within Millard and Beaver Counties, Utah. It has a total area of about 600 mi^2 (1550 km^2), of which about 300 mi^2 (777 km^2) is suitable area for M-X deployment. It is about 40 mi (64 km) long and 8 to 20 mi (13 to 32 km) wide. The valley is bounded on the west by the Wah Wah Range with peaks up to 8,980 ft (2,737 m) in elevation; on the east by the San Francisco Mountains with peaks up to 9,660 ft (2,944 m) in elevation; and on the northwest by the Confusion and House Ranges. There is a low topographic divide with an elevation of about 4,760 ft (1,423 m) separating a playa in Wah Wah Valley (Wah Wah hardpan is the local name) from Sevier Lake to the northeast. The playa is at an elevation of about 4,637 ft (1,413 m).

The Wah Wah Range is composed primarily of carbonate rocks, with minor exposures of quartzite of Paleozoic age. The southern end of the Wah Wah Range and the San Francisco Mountains are both covered with extensive extrusive igneous rocks of Tertiary age. The extrusive rocks are composed primarily of lava and ash flow tuffs. The San Francisco Range is composed of carbonate and quartzite rocks of Paleozoic age capped by an overthrust block of quartzites and argillites of Precambrian age. There is a minor intrusive body of quartz monzonite of Tertiary age in the Frisco Peak area.

The valley floor is covered primarily by alluvium and lacustrine deposits of Quaternary age, including fans and channel deposits consisting of coarse sands and gravels, and lacustrine (ancient Lake Bonneville deposits) and playa deposits consisting of gravel bars, clay, and silt (locally called hardpan). The valley is believed to be filled to a depth of 2,000 ft (610 m) by sediments of Tertiary and Quaternary age consisting of intermixed and interlayered alluvial fans, channel deposits, and lacustrine deposits ranging in size from clay to boulders. Drilling and geophysical work currently in progress or planned by FUGRO National will enable a more precise definition of the valleyfill.

General Hydrology

Wah Wah Valley is a topographically closed valley with a low divide separating it from Sevier Lake. The divide is only about 30 ft (9 m) above the Wah Wah hardpan, which is the low point in Wah Wah Valley.

Annual precipitation in Wah Wah Valley is estimated to average 9 in. (23 cm), with up to 20 in. (51 cm) on the peaks and less than 8 in. (20 cm) in the lower part of the valley (Stephens, 1974). The total annual precipitation over the 600 sq mi area is therefore about 290,000 acre-ft (360 hm^3). Recharge is believed to take place primarily on the alluvial fans where ephemeral streams flow out of the mountains. Very little recharge is believed to take place in either the playa or the fine sediments on the valley floor, or in the bedrock areas of the ranges. Stephens (1979) estimates the total annual recharge to be 2.5 percent of precipitation, or about 7,000 acre-ft (8.6 hm^3). This estimate is based on estimated infiltration rates through the various materials exposed in the valley, and not on direct measurement.

In addition to annual precipitation, about 3,000 acre-ft (3.7 hm^3) is contributed to Wah Wah Valley by subsurface inflow from Pine Valley (Stephens, 1974). Stevens based his conclusion on the belief that groundwater migrates along bedding planes in strata of the Wah Wah Range dipping from Pine Valley to Wah Wah Valley. The total recharge then is about 10,000 acre-ft/yr (12.3 hm^3/yr).

Discharge is primarily by evapotranspiration and by flow under the divide into Sevier Lake Basin to the northeast. The flow direction is based on the direction of the potentiometric gradient as estimated by FUGRO. The gradient is about 7 ft per mi (1 m/km) to the north along the valley axis. Discharge by evapotranspiration takes place predominantly in the area around Wah Wah Springs with minor amounts around some of the other springs and ephemeral stream channels. Stephens (1974) estimates total evapotranspiration to be about 640 acre-ft/yr (0.8 hm^3/yr). He estimates total spring and well discharge to be about 910 acre-ft/yr (1.1 hm^3/yr), of which the great majority, about 800 acre-ft/yr (1.0 hm^3/yr), is from the Wah Wah Springs which lies in the west central portion of the valley. Of the 910 acre-ft (1.1 hm^3) of discharge, about 300 acre-ft (0.4 hm^3) is applied to beneficial use such as irrigation, and stock and game watering. The rest of the annual discharge is lost by evapotranspiration.

The approximately 8,500 acre-ft/yr (10.5 hm^3/yr) of excess recharge which is not accounted for above is believed to leave the valley by subsurface flow north through the valleyfill sediments to the Sevier Lake area. There may also be discharge by interbasin flow through the bedrock, although there is no direct evidence to support that hypothesis.

Aquifer Characteristics

The hydrologic properties of the valleyfill aquifer are not well defined. Existing data consist of logs from one exploration oil well, four alunite exploration borings, one BLM stock well, and one privately owned stock well. Aquifer tests could not be performed at any of these wells. Earth Sciences, Inc., the owner of the alunite exploration wells, located in the southern protion of the valley, would not release any data concerning hydrologic testing; however, public information from the Utah State Engineer indicates that the wells are capable of producing 1,500 gpm (95 l/s) with drawdowns of about 100 ft (30 m). Wells for M-X water supply should be able to produce similar amounts if they are sited in a similar geologic setting.

Water Quality Limitations

The U.S. Geologic Survey has tested 20 groundwater samples from 15 locations during the period 1935 to 1973, and FUGRO National collected one groundwater sample for laboratory analyses in 1979. In general, the quality of water in Wah Wah Valley is within the criteria for drinking water. Water quality is generally good near the upstream end of the valley but deteriorates to exceeds criteria downstream. Of the 15 groundwater samples tested, three are from wells and 12 are from springs. Three of the 12 spring locations are in the Wah Wah Springs group. The water from the Wah Wah Springs group and from one well in Grover Wash on the slope of Antelope Peak in the south end of the San Francisco Mountain Range were of good quality. Results of the analyses of groundwater indicates four samples with poor quality and six samples with exceeds criteria classification. The exceeds criteria quality water was due to calcium (224 to 650 mg/l), magnesium (190 to 220 mg/l), sulfate (600 to 710 mg/l), chloride (600 to 2100 mg/l), and nitrate (10 to 73 mg/l). The poor quality water was due to concentration of calcium (100 to 190 mg/l), magnesium (64 mg/l), sulfate (288 mg/l), chloride (360 mg/l) and fluoride (1.0 mg/l).

All samples had moderately high bicarbonate concentrations in the range of about 130 mg/l to 390 mg/l, indicating the groundwater has migrated through carbonate rocks, and/or sediments derived from these rocks. Wah Wah Springs, which has the largest rate of surface discharge of groundwater in the valley, has very good water quality, with TDS of about 320 mg/l which has the largest rate of surface discharge of groundwater in the valley, has very good water quality, with TDS of about 320 mg/l to 350 mg/l, most of which is bicarbonate. The Wah Wah Springs discharge through volcanic rocks from the underlying limestone. The recharge and flow paths are believed to be local (Stephens, 1974), based on the structural geology, low TDS values of water samples (324 to 34i mg/l), and low temperatures (16.5° to 19.5°C: 61.7° to 67.1°F).

Whirlwind Valley (3.1.3.13)

Physiography and Geology

Whirlwind Valley as studied, is a large, gently-sloping extension of Sevier Desert which covers approximately 792 mi^2 (2051 km^2), of which 380 mi^2 (984 km^2) is considered suitable for M-X deployment. The House Range separates Whirlwind Valley from Tule Valley to the west. Whirlwind Valley is separated from Fish Springs Flat and Dugway Valley on the north by low topographic divides. Highway 50 and 6 is a border of the study area on the south. Longitude 112°45' West is a study area boundary between Sevier Desert and Whirlwind Valley to the east. The area defined as Whirlwind Valley for this study is actually the southwestern portion of Sevier Desert studied by Mower and Feltis (1968).

That study defined Sevier Desert as the 3,100 mi^2 (8029 km^2) area between the Canyon and Tintic Mountains on the east, the House Range on the west, between Clear Lake and the northern end of Sevier Lake on the south, and the Sheeprock Mountains on the north. The highest peaks in the region are in the House Range where the highest elevation is 9,190 ft (2,832 m). The lowest point in the area is in the eastern valley area, near Topaz Slough, where the elevation is less than 4,600 ft (1,400 m).

Mountains of sedimentary, metamorphic, and igneous rocks of Precambrian to Tertiary age bound Whirlwind Valley (Mower and Feltis, 1968). The valleyfill is composed of consolidated to unconsolidated sedimentary deposits along with volcanic rocks of Tertiary and Quaternary age. The sediments, composed of clay, silt, sand, and gravel were deposited under subaerial and lacustrine environments during the Pleistocene epoch. Lake Bonneville shoreline deposits, terraces, and cliffs of Pleistocene age are present on the lower alluvial slopes (Mower and Feltis, 1968).

General Hydrology

Whirlwind Valley, as defined for this study, forms the southwestern portion of Sevier Desert and is topographically open to the south. The Sevier River enters the desert near the midpoint of the eastern boundary and flows southwest toward Sevier Lake in the southwestern corner of the desert. The average flow of Sevier River between 1943 and 1964 was 122,700 acre-ft/yr (151 hm^3/yr) at Lynndyl and the combined flow of all other streams entering Sevier Desert was estimated at 50,000 to 65,000 acre-ft/yr (62 to 80 hm^3/yr) (Mower and Feltis, 1968). Most of this flow is believed to recharge the phreatic aquifer in Sevier Desert. No separate estimates for Whirlwind Valley recharge have been published.

The average annual precipitation ranges from less than 8 in. (20.3 cm) to more than 25 in. (63.5 cm), depending upon the elevation (Mower and Feltis, 1968). Most rainfall evaporates before it can percolate into the soil and recharge the groundwater reservoir. The most important source of water in the Sevier Desert region is snowpack in the mountains, which sustains stream flow and provides the source of recharge to the groundwater reservoirs (Mower and Feltis, 1968). Recharge in Whirlwind Valley is from intermittent stream flow where streams leave the mountains and flow over coarse-grained and relatively permeable alluvial fans, and from subsurface inflow from Sevier Desert. Underflow from the Sevier Desert appears to be the major source of recharge to the groundwater reservoir.

Groundwater discharge in Whirlwind Valley is primarily from wells and springs. Little evapotranspiration occurs within the valley study area. The only wells in the area are used for stock watering and have low discharge rates of generally less than 50 gpm (3.2 l/s).

Perennial yield has not been estimated for Whirlwind Valley because of lack of data. Any such estimate would have to take Sevier Desert into consideration, where the perennial yield has been estimated to be 23,500 acre-ft/yr (28 hm^3/yr).

Aquifer Characteristics

As in the Sevier Desert, groundwater occurs in unconsolidated deposits under unconfined and confined conditions. Most of the groundwater discharged from wells originates either in the upper or lower confined aquifers, which are separated by 300 to 500 ft (91 to 152 m) of relatively impermeable clay, silt, and fine sand (Utah Division of Water Resources, 1964). Gravity surveys conducted by FUGRO National (FN-TR-33-WW) in Whirlwind Valley on the western side of the Sevier Desert indicate that the valleyfill deposits are more than 2,000 ft (610 m) thick. Very little data are available concerning the groundwater reservoir in the western half of Whirlwind Valley. Geophysical work now in progress by FUGRO National will provide a better estimate of valley geometry in all portions of Whirlwind Valley.

Aquifer testing of existing wells was not conducted as part of the FUGRO National field investigations because of a lack of suitable wells. Therefore, neither transmissivity nor storage coefficient of the valleyfill aquifer could be computed.

However, given the similar Lake Bonneville depositional history of other valleys of known aquifer characteristics, some areas in Whirlwind Valley are expected to have moderate transmissivities and well yields on the order of a few hundred gpm. The drilling and testing of a 2,000-ft (305 m) well in this valley is planned as part of the FUGRO National Intermediate Depth Aquifer Program.

Water Quality Limitations

FUGRO National was unable to obtain ground-water samples for water quality analyses during field reconnaissances in November 1979 and March 1980. Therefore, water quality evaluations for Whirlwind Valley were based on U.S. Geological Survey groundwater quality analyses compiled by Mower and Feltis (1964).

Groundwater quality data do not exist in the western half of the valley. The eastern half of the suitable M-X siting area has poor to exceeds criteria groundwater quality as defined for this study. Two water samples were collected from springs in the House Range by FUGRO National and tested by CEP in 1979. Both were of good quality.

White River (3.1.3.14)

Physiography and Geology

White River Valley lies in northeast Nye County and portions of Lincoln and White Pine counties in east-central Nevada (Figure 4.2.13-1). The basin includes about 1,620 mi^2 (4,196 km^2), of which 509 mi^2 (13.8 km^2) are suitable for M-X deployment. The basin which trends north, is approximately 70 mi (133 km) long and ranges in width from 20 to 30 mi (32 to 48 km).

Mountain crests along the east and west sides of the valley generally range from 8,000 to 10,000 ft (2,438 to 3,048 m) in elevation. Ward South Summit, at almost 11,000 ft (3,353 m), is the highest peak in the basin. Hills and mountains of subdued relief and alluvial divides bound the valley on the north. The valley has open drainage to the south.

Mounta . ranges bounding the valley are predominately composed of carbonate rocks (limestones and dolomites) of Paleozoic age. Quartzite of Cambrian age occurs near Lund, contributing particularly coarse-grained sediments to the basin. Volcanics of Tertiary age crop out in the southeastern and southern portions of the valley.

The valleyfill deposits are composed of thick sequences of lacustrine, alluvial, and fluvial sediments that generally overlie the volcanic bedrock of Middle-Tertiary age (Eakin, 1966). Deep exploratory wells drilled along the central axis of the valley penetrated thick sequences of lacustrine clay and silt interbedded with thin discontinuous zones of fluvial sand and gravel. These deposits average about 5,000 ft in thickness in the central valley area. The lower slopes of the bounding mountain ranges are covered with broad alluvial fans of coarse-grained sediments derived from the rocks of the mountain ranges.

General Hydrology

White River drainage basin is a topographically and hydrologically open system. According to Eakin (1966), the alluvial basin lies within a regional groundwater flow system of fractured carbonate rocks of Paleozoic age. The potentiometric head within the regional flow system (represented by spring elevations around the margins of the basin) appears to maintain the high groundwater levels in the valleyfill aquifer.

The White River provides the major surface water drainage for the basin. During the winter, surface water flows to about 15 mi (24 km) south of the Adams-McGill reservoir before being totally consumed by percolation into the riverbed. During the summer, the river flows as far south as Lund in the northern end of the valley before it is depleted by irrigation diversions, evaporation, and infiltration (Maxey and Eakin, 1949). The major source of water for the river is from precipitation in the surrounding mountains.

Potentiometric surface of groundwater in the valleyfill deposits for the White River Valley. This interpretation is based on published water well information and measurements by FUGRO National, FY 79. Approximately 40 percent of the valley has water at less than 50 ft (15 m) beneath the land surface and, along the White River channel, the depth to water is commonly less than 10 ft (3 m). The potentiometric surface slopes to the south at an average gradient of about 11 ft per mi (2 m/km), indicating flow in that direction.

Recharge to the valleyfill aquifer is from infiltration of precipitation and subsurface inflow from Long and Jakes valleys on the north. Infiltration occurs where intermittent streams leave the canyons in the mountain ranges and flow over the coarse-grained and relatively permeable alluvial fans, and in the White River channel. Recharge by infiltration is estimated to be 38,000 acre-ft/yr (47 hm^3/yr) (Eakin, 1966). Recharge by underflow from Long and Jakes valleys through a regional carbonate aquifer is estimated to be 25,000 acre-ft/yr (31 hm^3/yr) (Eakin, 1966). Total recharge is therefore estimated to be 63,000 acre-ft/yr (78 hm^3/yr).

Discharge from the valleyfill aquifer is from evapotranspiration by phreatophytes, wells, springs, and subsurface outflow. Discharge by evapotranspiration is estimated to be 13,000 acre-ft/yr (16 hm^3/yr) (Eakin, 1966). Discharge from wells, primarily for irrigation, is estimated to be 26,000 acre-ft/yr (32 hm^3/yr). Discharge from the valleyfill aquifer by springs is minor. The total discharge accounted for is 45,000 acre-ft/yr (56 hm^3/yr). The 18,00 acre-ft/yr (22 hm^3/yr) of recharge not accounted for is believed to be discharged by subsurface outflow to the regional carbonate aquifer.

There are 12 springs in White River Valley which may discharge from carbonate rocks with flow rates of 200 to 4,000 gpm (13 to 252 l/s). These are not included in the water budget discussed above because the discharge is not from the valleyfill aquifer. Perennial yield is estimated to be 37,000 acre-ft/yr (46 hm^3/yr).

Aquifer Characteristics

The primary source of groundwater within the White River Basin is the alluvium and river bed deposits which underlie the lowland. These aquifers consist of moderately to highly conductive sand and gravel deposits interbedded with silt and clay (Maxey and Eakin, 1949). Well yields of over 1,000 gpm (63 l/s) are commonly obtained in these aquifers. The aquifers generally vary from 5 to 150 ft (15 to 46 m) in thickness, and wells rarely penetrate below a depth of 400 ft (122 m). The thickness of this aquifer varies significantly throughout the valley. Two wells, White Pine County Test Well 8N/62E-5D1 and FUGRO National's Observation Well No. 8N/61E-27dc in White River Valley were both drilled to a depth of 1,300 ft (396 m). The White Pine County well log indicated the presence of the sand and gravel aquifer to a depth of 800 ft (244 m). The FUGRO well, however, had only low permeability lacustrine deposits below about 430 ft and did not establish the existence of an intermediate aquifer at that location.

Aquifer (pump) tests conducted in the valleyfill aquifers in White River Basin provided transmissivity values that ranged from about 10,000 gpd/ft (34.5 cm^2/sec) along the central valley axis to about 72,000 gpd/ft (248 cm^2/sec) in the coarser-grained valleyfill deposits nearer the valley margin.

All water-level data for the pump tests in White River Valley were collected at the test wells themselves; no observation wells were available to monitor water-level declines. Therefore, values for the storage coefficient could not be calculated from aquifer test data.

Water Quality Limitations

FUGRO National personnel collected groundwater samples from 11 wells and 12 springs in White River Valley in 1979. None of the samples collected exceeded the established criteria. The spring samples were tested for total dissolved solid (TDS) concentrations which ranged from 250 to 348 mg/l, with a mean value of 294 mg/l. This range of concentration represents good quality water.

All spring waters were of the calcium/magnesium/bicarbonate type, indicating contact with and/or passage through carbonate rocks. The low TDS concentration indicates proximity to recharge areas. In general, TDS concentrations are fairly low (300 mg/l) from springs and wells along the flanks of the valley but increase towards the central portion of the valley. Water from three of the springs located in the center of the valley are classified as poor because they exceed the established limit for fluoride.

The well water samples had TDS concentrations ranging from 279 to 557 mg/l which is considered good quality water. One 800 mg/l concentration was reported, but the analyses was considered questionable because the cation-anion milliequivalent balance differed by 50 percent and the mean was only 377 mg/l. All well waters except those from wells 11 N/61Eac and 10N/61E-23 were of calcium/-magnesium/bicarbonate type, indicating some residence time in or passage through carbonate rocks.

PRESENT WATER USE (3.1.4)

General (3.1.4.1)

Available supplies of surface and ground water in the arid areas of western Utah/Nevada are already largely allocated for benefical use. In addition to the proposed M-X missile system, major developments in mining and the conversion of fossil fuels to electrical energy are proposed or currently being studied in the area.

Each of these proposed developments will require substantial quantities of water and will compete for the remaining supply that is available.

An initial task in defining the availability of water for the M-X missile system is to inventory all current water users in the area, determine their water demands, and estimate possible future industrial activities and their associated water requirements. An inventory of current water use along with an assessment of possible future demands within the Nevada/Utah siting area were initiated in the fall of 1979. The study was conducted by the Desert Research Institute (DRI) in Nevada and the Utah Water Research Laboratory (UWRL) in Utah.

Water demands were evaluated in conformances with the following four major water-use categories:

1) Irrigation of cropland;
2) Livestock watering;
3) Mining and Energy - including mining, milling power generation, and oil extraction; and Urban/Industrial - including all industrial and commercial activities in urban areas.

Water use was estimated in accordance with both present and possible future requirements for each of 64 valley areas within the Nevada/Utah siting area.

Present Water Use Inventory (3.1.4.2)

Results of the water-use inventories are summarized in Table 3.1.4.2-1 for both the present water use within the M-X siting area and potential future demands. The table shows that present water use in the siting area is estimated to be about 909,000 acre-ft per year, with the largest portion of those water demands being used for irrigated agriculture (827,000 acre-ft per year). Mining and energy-related uses represent the second largest water use, and, at present, their demands total about 65,000 acre-ft per year.

Estimating future water demands within the siting area was also included kas part of the water-use inventories. Mining- and energy-related water uses were found to represent the only industrial activity with the potential for substantial increases in demands for the near term. The potential exists for new mining activity, as well as reviving past mining sites. New and revived mining activities and the cooling needs of possible new coal-fired electric power plants represent the chief competitors with M-X for the available water. Estimated future demands for mining and energy related users are also shown in Table 3.1.4.2-1. Their combined future water demands total about 297,000 acre-ft per year which is 232,000 acre-ft per year greater than the present demands. The potential increase in water use for mining and energy represents an increase in total water demands in the study area of 25 percent.

Table 3.1.4.2-1. Summary of present and projected future industry activities and water use (sheet 1 of 2).

HYDROLOGIC SUBUNIT*	PRESENT (Acre ft. per year)					FUTURE (Acre ft. per year)
	IRRIGATION	LIVESTOCK	MINING & ENERGY	URBAN/ INDUSTRIAL	VALLEY TOTAL	POTENTIAL MINING & ENERGY
Nevada						
Alkali Spring	—	9	227	80	316	1,837
Antelope	950	48	—	—	998	
Big Smoky (North)	20,268	54	1,643	—	21,965	
Big Smoky (South)	4,140	41	26,172	270	30,623	
Cave	1,000	11	—	—	1,011	
Clayton	192	15	13,081	—	13,288	16,623
Clover	900	—	269	585	1,754	
Coal	—	15	—	—	15	
Delamar	—	44	—	—	44	
Diamond	70,300	78	845	32	71,255	885
Dry Lake	—	21	—	—	21	
Dry	3,300	14	—	—	3,314	
Eagle	1,500	1	—	—	1,501	
Garden	250	30	—	—	280	
Hamlin	1,500	15	—	—	1,515	
Hot Creek	570	62	129	—	761	
Kane Springs	—	4	—	—	4	
Kobeh	3,240	100	—	—	3,340	
Lake	18,200	30	—	—	18,230	
Lida	184	16	3	—	203	
Little Fish Lake	456	30	—	—	486	
Little Smoky (North)	3,230	40	40	—	3,310	
Little Smoky (Central)	—	1	—	—	1	
Little Smoky (South)	—	11	—	—	11	
Lower Meadow	4,500	38	—	—	4,538	
Monitor (South)	4,202	11	338	—	4,551	5,635
Newark	6,900	79	40	—	7,019	
Pahranagat	15,600	16	—	198	15,814	
Pahroc	—	20	—	—	20	
Panaca	6,900	15	968	210	8,093	
Patterson	—	56	322	94	472	
Penoyer	3,000	22	9,451	—	12,473	
Pleasant	450	1	—	—	451	
Railroad (North)	11,880	92	242	—	12,214	
Railroad (South)	—	24	161	—	185	
Ralston	760	6	—	—	766	
Rose	1,050	1	—	—	1,051	
Sarcobatus Flat	608	16	—	—	624	
Spring[1]	16,405	205	1,731	—	18,341	1,932
Spring[2]	4,200	54	—	—	4,254	
Steptoe	19,500	121	9,604	2,872	32,097	34,694
Stevens	—	2	—	—	2	
Stone Cabin	1,425	37	40	—	1,502	80
Stonewall Flat	—	6	—	—	6	
Tikaboo	—	9	—	—	9	
White River	20,000	109	—	—	20,109	
Unknown						15,000

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Table 3.1.4.2-1. Summary of present and projected future industry activities and water use (sheet 2 of 2).

HYDROLOGIC SUBUNIT*	PRESENT (Acre ft. per year)					FUTURE (Acre ft. per year)
	IRRIGATION	LIVESTOCK	MINING & ENERGY	URBAN/ INDUSTRIAL	VALLEY TOTAL	POTENTIAL MINING & ENERGY
Utah						
Beaver	26,950	53	—	5,920	32,923	
Cedar	28,490	67	18	372	28,947	5,528
Deep Creek	2,800	21	—	—	2,821	
Dugway	3,800	11	—	2,375[3]	6,186	
East	—	12	—	—	12	
Escalante (South)	82,163	21	—	—	82,184	16,530
Fish Springs Flat	—	20	4	—	24	30,850
Government Creek	1,750	7	—	1	1,758	
Hamlin	840	18	—	—	858	
Milford-Minersville	48,650	77	—	76	48,803	28,768
Pavant	102,182	96	—	265	102,543	61,700
Pine	—	47	—	—	47	8,000
Sevier Desert[4]	249,820	208	—	242	250,270	33,000
Snake[5]	30,888	74	—	—	30,962	27,550
Tintic	1,330	39	2	1	1,372	
Tule	—	33	—	—	33	
Wah Wah	—	52	—	—	52	8,212
Whirlwind	—	28	—	—	28	
Total	827,223	2,514	65,330	13,593	908,660	297,074

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[1]State hydrologic basin 184, located in White Pine County, Nevada.

[2]State hydrologic basin 201, located in Lincoln County, Nevada.

[3]Includes 2,375 acre-feet per year used by military facilities.

[4]An additional 2,047 acre-feet per year has already been appropriated for future mining and industry activities.

[5]Includes that portion of Snake Valley located in Nevada.

*The hydrologic subunit names used for compilation of water-use estimates by the Desert Research Institute were delineated by the states' engineers office in Nevada and Utah based on surface-water flow patterns. Valley names used are geographic place names which generally correspond in part or in total to the same area as the hydrographic names. However, there are several notable exceptions. Examples of these nomenclature differences for equivalent areas are listed below.

Hydrologic Subunit(s)	Geographic Valley(s)
Big Smoky (South)	Big Smoky
Dry Lake	Dry Lake and Muleshoe
Lake and Patterson	Lake
Little Smoky (North) and (Central)	Little Smoky
Little Smoky (South)	Big Sand Springs
parts of Hot Creek and Railroad (South)	Reveille

WATER RIGHTS INVENTORY (3.1.4.3)

General

A major concern expressed by many Nevada and Utah residents about the MX System has been that of water requirements and water rights. Given that both states are arid, water availability has played a significant role in how and where economic development has occurred. The scarcity and variability of occurrence of water in both states lead each to adopt the "Appropriative Doctrine" of water rights. Development and application of water law in Nevada and Utah were discussed at length in a report on the first phase of this project. (Bird and Cochran, 1979)

At the time that the proposal was made to undertake a "comprehensive" survey of water rights within the Nevada and Utah MX area, it was the investigators' perception that there was a relatively small and manageable number of rights involved. However, in Nevada, instead of finding a small handful or so of "rights" in each valley, as many as 390 in a single valley were encountered. In Utah that number approached 1500 in the Delta area. Because of the large number of "water rights" in the MX area and the limited time and financial resources with which conduct the inventory, it is less than comprehensive in nature. However, the inventory is thorough and relatively accurate and thus should be useful as a planning resource. Weaknesses and strengths of the inventory are discussed in the following sections.

DEFINITIONS AND ORGANIZATION

Definition of "Water Rights"

For lack of a better term, "water right" is being used here for discussion purposes to encompass a spectrum of distinct steps or circumstances involved with the legal acquisition of the property right in Nevada and Utah known as "a water right".

Under the Nevada law, for water rights acquired subsequent to passage of the law, the first step is to submit an Application. This establishes a priority date and if the application is approved, a Permit may be issued which allows proceeding with diversion of the water. If the water is developed in accordance with the law and provisions in the permit then a Certificate is issued. This certificate is the legal water right. For water that was in use at the time the water law was passed (vested rights) a different procedure is used. These users file a Proof of Appropriation which claims that a certain amount of water has historically been used. The actual vested water right must then be determined by adjudication.

In Utah the situation is very similar though some of the terminology is slightly different, e.g., a Nevada "Proof" and a Utah "Diligence Claim" both relate to vested rights.

In both the Nevada and Utah State Engineer Offices when a party makes application to appropriate water a permanent file is created. The contents of that file change with time as the applicant proceeds with development of the legal water right. With vested rights the file is initiated by submission of the Proof or Diligence Claim. Thus at any given instant in time the State Engineers' records are composed of files that may contain among other documents:

1. An Application: That may: Be pending further action; have been approved; have been rejected; be under protest; have been rejected and is under appeal, etc.

2. A Permit: That allows the party to proceed with an approved application under conditions prescribed with the approval.

3. A Proof: That claims historical beneficial use or vested rights (Diligence Claim in Utah).

4. A Certificate: That establishes the legal status of "a water right".

To effect a summary of the water rights inventory the above four items were grouped as 1) Applications and Permits, and 2) Proofs (of appropriation) and Certificates. Rationale for this grouping was as follows:

1. Neither an application nor a permit represents a perfected water right. However, an Application does establish a priority date and should it be approved and all conditions be met, could eventually become a valid water right. The Permit (or Approved Application) represents an intermediate stage of somewhat more substance in that the applicant has authority to proceed with those steps necessary for perfecting the water right.

2. For vested rights a "Proof" may or may not represent a more substantial "water right" than a Permit or Approved Application. However, the Proof does represent a claim to historical water use, the legal extent of which must be established through adjudication, and until such time as adjudication is competed the claimed usage stands in the records. Thus, for summary purposes, Proofs were included with fully Certificated legal water rights.

Since neither the Nevada or Utah water right records are in a computerized data storage and retrieval system, and given the number of water right files, the time constraints for this project, and financial limitations, it was impossible to develop any more refined legal status than represented by these two categories.

Summary

During the period from mid-December 1979 to late February 1980 an examination was made of the water rights records of the State Engineer of Nevada to determine water right owners of record within the MX area and to determine the extent of those rights. Inventory was accomplished according to legal status of "water rights" i.e., Application to Appropriate (not a water right), Permit to Appropriate (not a water right), Proof of Appropriation (a claimed vested water right) and Certificate (a legal water right). For purposes of this summary report these were grouped as "Permits and Applications" and "Certificates and Proofs". Table II of this report summarizes these "water rights" for 44 individual hydrographic basins together with estimated hydrologic data. The basin summaries are presented according to source of water (ground or surface), type of ownership and type of use. For some basins supplementary explanatory notes are also provided.

Water right records of the State Engineer of Utah were examined for the same purposes during January, 1980 and again in March, 1980. Comparable legal status classifications were used to summarize the Utah information which is presented in Table under the same group headings as used for Nevada, i.e., "Permits and Applications" and "Certificates and Proofs".

The data examined in Nevada represent a total of approximately 3476 water right files and in Utah approximately 1884 water right files. In Nevada approximately 1581 files fall in the "Permit and Applications" category and approximately 1895 are in the "Certificate and Proof" category. In Utah the category totals are respectively 1065 and 819.

There are two components missing from the Nevada water rights inventory. The first of these are private domestic wells, which under Nevada law are not required to have a permit. The number of domestic wells in the inventory area is unknown. While the aggregate annual water taken by domestic wells is not believed to be significant, interference with those wells by new water diversions could be a relatively serious problem — especially for the well owners. The second component consists of vested rights for which a Proof of Appropriation has never been filed, or the claim was filed at an early date in the county courthouse but never with the State Engineer. No attempt was made to inventory unfiled claims. A check was made in the Lincoln County Courthouse records and some claims were located, but a complete inventory was not made. It is believed that while many claims exist in the courthouses they primarily represent small spring flows and the aggregate quantity of water involved is relatively small. This belief is also held by personnel in the Nevada State Engineer's Office.

No attempt was made to determine whether any unfiled Diligence Claims existed in Utah. Domestic wells, however, are included.

Table 3.1.4.2-2. Comparative summary of hydrologic and water rights data for Nevada and Utah hydrographic basins in the MX area (sheet 1 of 3).

Basin Number	Hydrologic Data, AF/Y		Water Rights Data, AF/Y								
			Surface Water			Groundwater			Surface and Groundwater		
	Estimated Surface Runoff	Estimated Groundwater Perennial Yield	Permits and Applications	Certificates and Proofs	Total	Permits and Applications	Certificates and Proofs	Total	Permits and Applications	Certificates and Proofs	Total
N-137(A,B)	43,300	71,000	14,939	24,909	39,484	114,666	14,997	129,663	129,605	39,906	169,511
N-139	N/A	16,000	723	---	723	1,337	12,615	13,952	2,06C	12,615	14,675
N-140	N/A	18,000	11,274	10,458	21,732	30,071	266	30,337	41,345	10,724	52,069
N-141	10,000	6,000	8,683	162	8,845	52,519	1,276	53,795	61,202	1,438	62,640
N-142	400	3,000	362	296	658	817	17,460	18,277	1,179	17,756	18,935
N-143	3,500	22,000	---	4	4	130	---	130	130	4	134
N-144	1,600	350	1,679	3,581	5,260	2,958	35	2,993	4,637	3,616	8,253
N-145	400	100	194	---	194	---	---	---	194	---	194
N-146	N/A	3,000	9	---	9	3,207	---	3,207	3,216	---	3,216
N-148	N/A	300	1,203	76	1,279	1,600	---	1,600	2,803	76	2,879
N-149	9,700	2,000	1,050	518	1,568	29,620	3,897	35,517	30,670	4,415	35,085
N-150	38,000	10,000	---	2,980	2,980	23	---	23	23	2,980	3,003
N-151	N/A	4,000	---	1,519	1,519	1,320	993	2,313	1,320	2,512	3,832
N-152	N/A	200	52	---	52	36	---	36	88	---	88
N-153	5,900	30,000	3,146	8,687	11,833	25,142	116,898	142,040	28,288	125,585	153,873
N-154	N/A	18,000	35	106	141	24,939	---	24,939	24,974	106	25,080
N-155 (A,B,C)	5,500	6,100	831	9,871	10,702	12,802	174	12,976	13,633	10,045	23,678
N-156	8,000	5,500	18,865	1,050	19,915	25,293	3,813	29,106	44,158	4,863	49,021
N-169	N/A	4,300	4	44	48	---	---	---	4	44	48
N-170	1,000	4,000	2,212	162	2,374	36,153	15,164	51,317	38,365	15,326	53,691

Table 3.1.4.2-2. Comparative summary of hydrologic and water rights data for Nevada and Utah hydrographic basins in the MX area (sheet 2 of 3).

Basin Number	Hydrologic Data, AF/Y		Water Rights Data, AF/Y								
			Surface Water			Groundwater			Surface and Groundwater		
	Estimated Surface Runoff	Estimated Groundwater Perennial Yield	Permits and Applications	Certificates and Proofs	Total	Permits and Applications	Certificates and Proofs	Total	Permits and Applications	Certificates and Proofs	Total
N-171	N/A	6,000	5	184	189	6,515	---	6,515	6,704	---	6,704
N-172	N/A	6,000	29	2,145	2,174	5,760	795	6,555	5,789	2,940	8,729
N-173(A,B)	26,000	75,000	7,238	17,090	24,328	191,208	4,910	196,118	198,446	22,000	220,446
N-179	78,000	70,000	7,627	---	7,627	45,923	37,073	82,996	53,550	37,073	90,623
N-180	N/A	2,000	---	5,837	5,837	---	32	32	---	5,869	5,869
N-181	N/A	2,500	2,596	---	2,596	361	---	361	2,957	---	2,957
N-182	N/A	3,000	---	250	250	---	7	7	---	257	257
N-183	N/A	12,000	1,347	---	1,347	57,463	---	57,463	58,810	---	58,810
N-184	90,000	100,000	63,181	27,194	90,375	43,912	11,451	55,363	107,093	38,645	145,738
N-194		1,500	240	1,353	1,593	4,320	273	4,593	4,560	1,626	6,186
N-195	38,000	80,000	33,377	18,213	51,590	15,056	2,939	17,995	48,433	21,152	69,585
N-196		5,000	4,346	847	5,193	181	181	362	4,527	1,028	5,555
N-198	400	1,000	---	---	---	4,102	4,825	8,927	4,102	4,825	8,927
N-199	<100	100	---	---	---	---	2,440	2,440	---	2,440	2,440
N-200	4,400	30,000	---	---	---	1,642	248	1,890	1,642	248	1,890
N-201	5,700	1,000	---	825	825	4,818	198	5,016	4,818	1,023	5,841
N-202	3,300	4,500	1,481	914	2,395	7,012	965	7,977	8,493	1,879	10,372
N-203	400	9,000	1,472	2,685	4,157	25,138	13,795	38,933	26,610	16,480	43,090
N-204	40	1,000	19	---	19	5,154	28	5,182	5,173	28	5,201
N-205	300	5,000	15	515	530	168,845	12,374	181,219	168,860	12,889	181,749
N-206	150	Minor	26	83	109	23,659	---	23,659	23,685	83	23,768
N-207	26,000	37,000	8,061	42,954	51,015	140,772	31,577	172,349	148,833	74,531	223,364

Table 3.1.4.2-2. Comparative summary of hydrologic and water rights data for Nevada and Utah hydrographic basins in the MX area (sheet 3 of 3).

Basin Number	Hydrologic Data, AF/Y		Water Rights Data, AF/Y								
			Surface Water			Groundwater			Surface and Groundwater		
	Estimated Surface Runoff	Estimated Groundwater Perennial Yield	Permits and Applications	Certificates and Proofs	Total	Permits and Applications	Certificates and Proofs	Total	Permits and Applications	Certificates and Proofs	Total
N-208	1,800	21,000	16	62	78	2,028	18	2,046	2,044	80	2,124
N-209	59,800	25,000	6,876	22,114	28,990	29,722	744	30,466	36,598	22,858	59,456
Nevada Subtotal	>461,690	>721,450	203,213	207,688	410,901	1,146,206	312,461	1,458,667	1,349,621	519,965	1,869,586
U4	N/A	37,500(1)	1,336	11,964	13,300	39,945	10,121	50,066	41,281	22,085	63,366
U5	N/A	<5,000	2,416	8,995	11,411	17,266	221	17,487	19,682	9,216	28,898
U6	N/A	<5,000	13	2,186	2,199	53	50	103	66	2,236	2,302
U-7	N/A	37,500(1)	3,975	2,602	6,577	831	94	925	4,806	2,696	7,502
U-8	N/A	15,000(1)	11	---	11	384	423	807	395	423	818
U-9	N/A	15,000(1)	2	1,476	1,478	27,507	5,558	33,065	27,509	7,034	34,543
U-46	N/A	>100,000	4,239	8,458	12,697	929,134	42,374	971,508	933,373	50,832	984,205
U-46(A)	N/A	15,000(1)	3,664	11	3,675	10,859	68	10,927	14,523	79	14,602
U-50	N/A	37,500(1)	---	30,720	30,720	---	1,100	1,100	---	31,820	31,820
U-52	N/A	15,000(1)	---	186	186	---	368	368	---	554	554
U-53	N/A	15,000(1)	---	124	124	---	---	---	---	124	124
U-54	N/A	<5,000	903	251	1,154	32,576	34	32,610	33,479	285	33,764
U-194	N/A	<5,000	---	7,262	7,262	---	---	---	---	7,262	7,262
U-196	N/A	15,000(1)	2,909	278	3,187	18,553	411	18,964	21,462	689	22,151
Utah Subtotal	N/A	+322,500	19,468	74,513	93,981	1,077,108	60,822	1,137,930	1,096,576	135,335	1,231,911
Total	>461,690	±1,043,950	222,681	282,201	504,882	2,223,314	373,283	2,596,597	2,446,197	655,300	3,101,497

(1) Average of reported range.

This report does not include any data on specific individual water rights. Data on actual ownership and locations of points of diversion and use are contained in a set of working files — one file for each basin. With regard to data in working files several points must be made:

1. Ownership is listed as found in the latest record available in the State Engineer's Offices and no attempt was made to develop assignment histories. Furthermore, many addresses are incomplete or out of date, but again no attempt was made to either complete or update them.

2. No attempt was made to determine whether applications had been made or approved for changes in type of use, place or use or point of diversion.

3. In cases where records were incomplete no attempt was made to complete those records by investigating other data sources.

4. The "Basin Abstract" forms provided in each working file represent a first distillation of the raw data found in the State Engineer's Offices. For the Utah files copies of some of the raw data are included.

This entire water rights inventory project represents work done by faculty of the Desert Research Institute. All assumptions, interpretations, inferences, conclusions, and tabulations are their's alone and do not in any token represent a certification, approval or agreement by either the State Engineer of Nevada or the State Engineer of Utah or any other agency of either state.

3.2 TEXAS/NEW MEXICO

GROUNDWATER RESOURCES (3.2.1)

All surface and groundwater in the project area originates from precipitation in Texas and New Mexico. Most of the precipitation returns to the atmosphere by evapotranspiration. The remainer appears as runoff in streams or percolates into the ground to recharge underground aquifers.

Rainfall occurs unevenly in the siting area, both seasonally and annually. Additionally, most of the rainfall occurs within short periods of time. As a result, runoff is often excessive and damaging floods are frequent. Mean annual precipitation ranges from 15 to 20 in.

Like rainfall, snowfall in the area is poorly distributed from year to year. Average annual snowfall for the proposed siting area is 15 in.

The amount of lake surface evaporation is influenced by air and water temperature and wind movement over the surface of the water. During wet years when the availability of water is relatively high, net lake surface evaporation rates are low, but during years of drought, evaporation from lakes and transpiration rates of growing vegetation are high and the water supplies are increasingly depleted. Mean annual lake evaporation ranges from 60 to 70 in. per year.

Drought interrupts the flow of water supplies and increases the consumption requirements from water in storage. The water-supplying entities of the area must be prepared to store and deliver sufficient quantities of suitable-quality water to meet regular needs and to carry the water users through the drought cycle.

The principal aquifers in the project area are the Ogallala Formation on the High Plains of New Mexico and Texas and the shallow and artesian aquifers in the Roswell Basin, New Mexico. Numerous other geologic units are considered to be minor aquifers because of interior storage and production characteristics and water quality.

The Ogallala Formation (To) is the major aquifer in the project area. The boundary of the Ogallala Formation in the Texas/New Mexico area is shown in Figure 3.2.1-1 as are the counties affected by the proposed M-X project. The total volume of groundwater potentially recoverable from storage in the Ogallala Formation within the project area is approximately 142 million acre-ft. Of this total, approximately 100 million acre-ft is in storage in Texas. This is presented in Table 3.2.1-1. Average annual depletions from the Ogallala Formation are approximately 2 million acre-ft per year (see Table 3.2.1-2). The regions and subregions referred to in these Tables are illustrated in Figure 3.2.1-2.

The potential yields of wells that tap the Ogallala Formation generally exceed several hundred gallons per minute. The water quality is generally satisfactory for municipal and irrigation uses. Some groundwater contains objectionable concentrations of fluoride and hardness, and may require treatment before use. Table 3.2.1-3 a typical chemical analysis for water withdrawn from the Ogallalal Aquifer.

Recharge to the Ogallala Aquifer is mainly from precipitation and has been estimated at a fraction of an inch per year (Cronin, 1969). Use of water from the Ogallala Formation is mainly for irrigated agriculture. Relatively large users of the Ogallala aquifer for municipal supply in the project area include the cities of Clovis and Portales, and Cannon Air Force Base in New Mexico.

The artesian and shallow aquifer in the Roswell Basin make up a complex multi-aquifer system in which recharge to the groundwater almost equals removal of

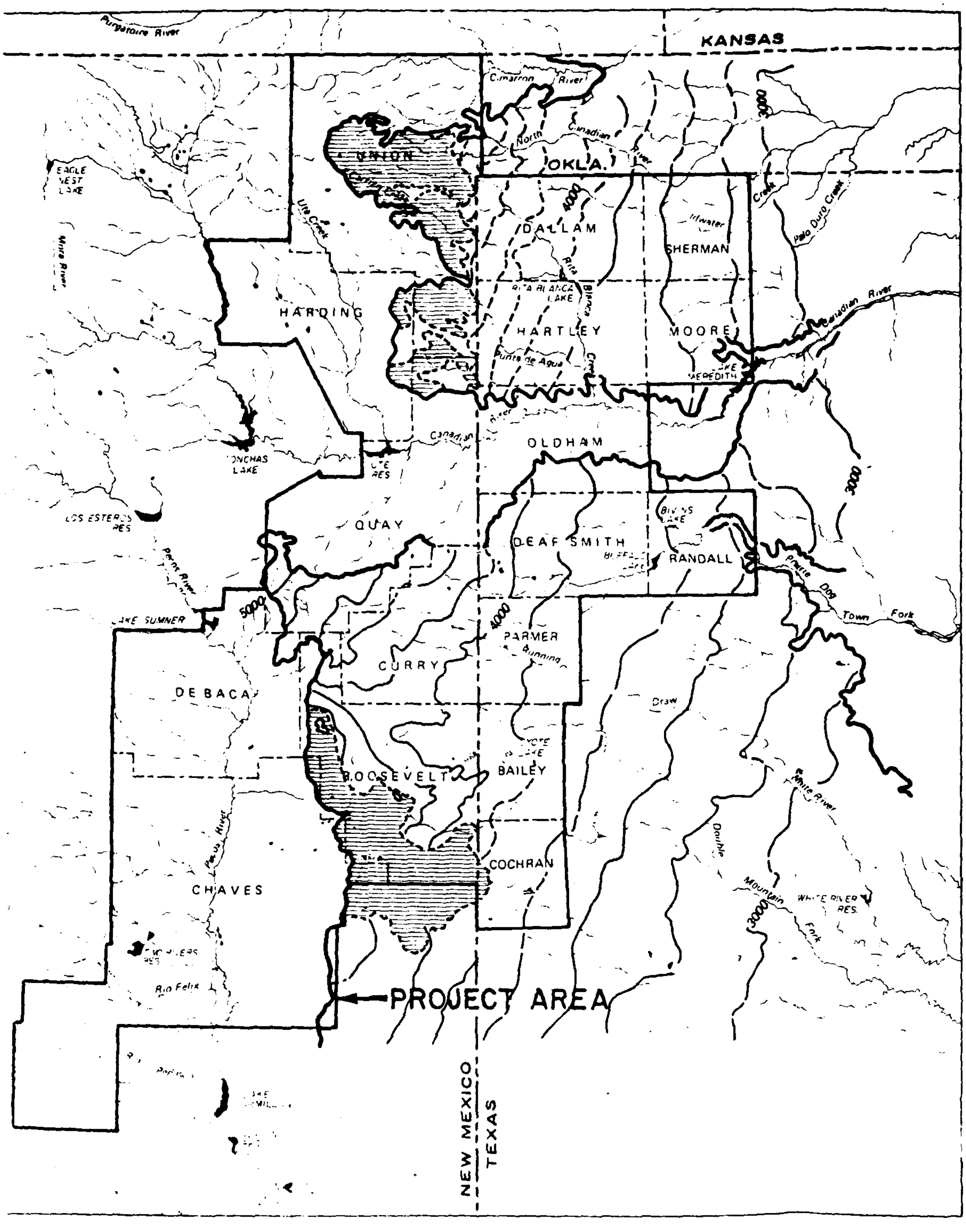

Figure 3.2.1-1. Configuration of Ogallala formation in siting area.

Table 3.2.1-1. Stored groundwater in the Texas/New Mexico study area.

REGION[1]	SUBREGION[2]	AREA (ACRES)	SATURATED THICKNESS (FEET)	SPECIFIC YIELD	AVERAGE WELL YIELD (gpm)	VOLUME OF GROUNDWATER IN STORAGE (10^3 ACRE-FEET)	RECOVERABLE GROUND WATER IN STORAGE[3] (10^3 ACRE-FEET)
I	To	—	—	0.15	500	—	28,100
	Ket	—	50	0.10			—[4]
II		—	—	—	200	—	490
III	To	—	—	0.15	700	—	72,100
	Kdp	—	—	0.10	100		—[4]
IV	shallow	—	—	—	500	—	104[5]
	artesian	—	—	—	2,000	—	184[5]
V	To-e	85,760	25	0.15	250	322	215
	To-f	568,960	75	0.15	550	6,400	4,270
	To-g	344,320	20	0.15	200	1,030	687
	To-h	243,840	25	0.15	250	914	609
	To-i	41,410	25	0.15	250	155	103
	Kdp-a	638,080	110	0.10	95	7,020	4,680
	Kdp-b	384,000	100	0.10	100	3,840	2,560
	Kdp-c	237,440	70	0.10	100	1,660	1,110
	Kdp-d	213,120	50	0.10	100	1,060	707
	Kdp-e	130,560	90	0.10	100	1,180	787
	Kdp-h	273,920	100	0.10	100	2,740	1,830
	Kdp-i	200,960	40	0.10	100	804	516
VI	Kd-a	109,070	50	0.10	100	545	363
	Je	82,980	105	0.21	125	2,000	1,330
	Trc-b	823,270	110	0.10	10	9,060	6,040
	Trc-a	996,480	90	0.10	15	8,970	5,980
VII	—	—	—	0.15	500	8,670	5,780
VIII	To	213,760	25	0.15	250	802	1,250
	K	213,760	50	0.10	500	1,070	1,870
IX	Qal-a	—	—	—	10	—	—
	Qal-b	—	—	—	1,000	—	—
	Qap	26,650	100	0.15	900	400	266
	Trc	—	—	—	<5	—	—
	Trs-a	—	—	—	<15	—	—
	Trs-b	—	—	—	500	—	—
	Pat	—	—	—	<10	—	—
	Psa (Pg)	—	—	—	<20	—	—
TOTAL	—	—	—	—			141,951

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[1] See Figure 3.2.1-2

[2] Geologic symbols for subregions are based on published reports.

[3] Regions I, II, II - published estimates
Regions V through IX - recoverable storage assumed to be 2/3 of groundwater in storage (New Mexico Statement, 1959)

[4] Values from the Ogallala Formation include contribution from this minor aquifer.

[5] Estimates of present pumpage in Region IV. Basin has substantial recharge; however, no new permits to pump groundwater have been issued since 1960.

Source: Texas Water Development Board (1977); New Mexico Interstate Stream Comm. and New Mexico State Eng. Office (1975).

Table 3.2.1-2. Summary of calculations of depletion rates in groundwater regions.

REGION	SUBREGION[1]	METHOD[2]	DEPLETION RATE (AFY)	SOURCES
I	To Ket	A	796,000 (3)	Texas Water Development Board (1977; (see Table 2)
II	--	A	15,900	--
III	To Kdp	A	936,000 (3)	Texas Water Development Board (1977); (see Table 2)
IV	--	--	--	--
V	To-e	A	11,000	Hudson (1976)
	To-f	A,C	24,300	Hudson (1976); Sorensen (1974)
	To-g	A	7,700	Hudson (1976)
	To-h	A	44,300	Hudson (1976)
	To-i	D	200	Cooper and Davis (1967)
	Kdp-a	A	0	Hudson and Borton (1974); Hudson (1976)
	Kdp-b	A	0	Hudson and Borton (1974); Hudson (1976)
	Kdp-c	A	16,000	Hudson (1976)
	Kdp-d	D	2,000	Sorensen (1974)
	Kdp-e	A	5,500	Hudson (1976)
	Kdp-h	A	35,600	Hudson (1976)
	Kdp-i	D	2,000	Cooper and Davis (1967)
VI	Kd-a	D	400	Griggs and Hendrickson (1951)
	Je	E,D	1,800	Trauger and Bushman (1964)
	Trc-b	B,C	0	Bureau of Reclamation (1971); Sorensen (1974)
	Trc-e	C	20,500	Sorensen (1974)
VII	--	A,B	154,000	Hudson and Borton (1974); Sorensen 1977)
VIII	To-K	C	26,400	Blaney and Hansen (1965); Sorensen (1974)
IX	Dab	A	0	Mourant and Shomaker (1970); Hudson (1976)
TOTAL	—	—	2,099,600	—

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[1]Geologic symbols are based on published reports.

[2]Methods of calculating depletion rate (dv/dt) (see also Section 3.2.4:

A. Rate (AFX) = (annual decline of water level) x (area) x (specific yield)

B. Rate (AFX) derived from pumpage data

C. Rate (AFX) = (amount of irrigation water minus amount of deep percolation) x (irrigated acreage)

D. Rate estimated using available data and professional judgment.

[3]Depletion rate for this minor aquifer is included in the value for the Ogallala Formation.

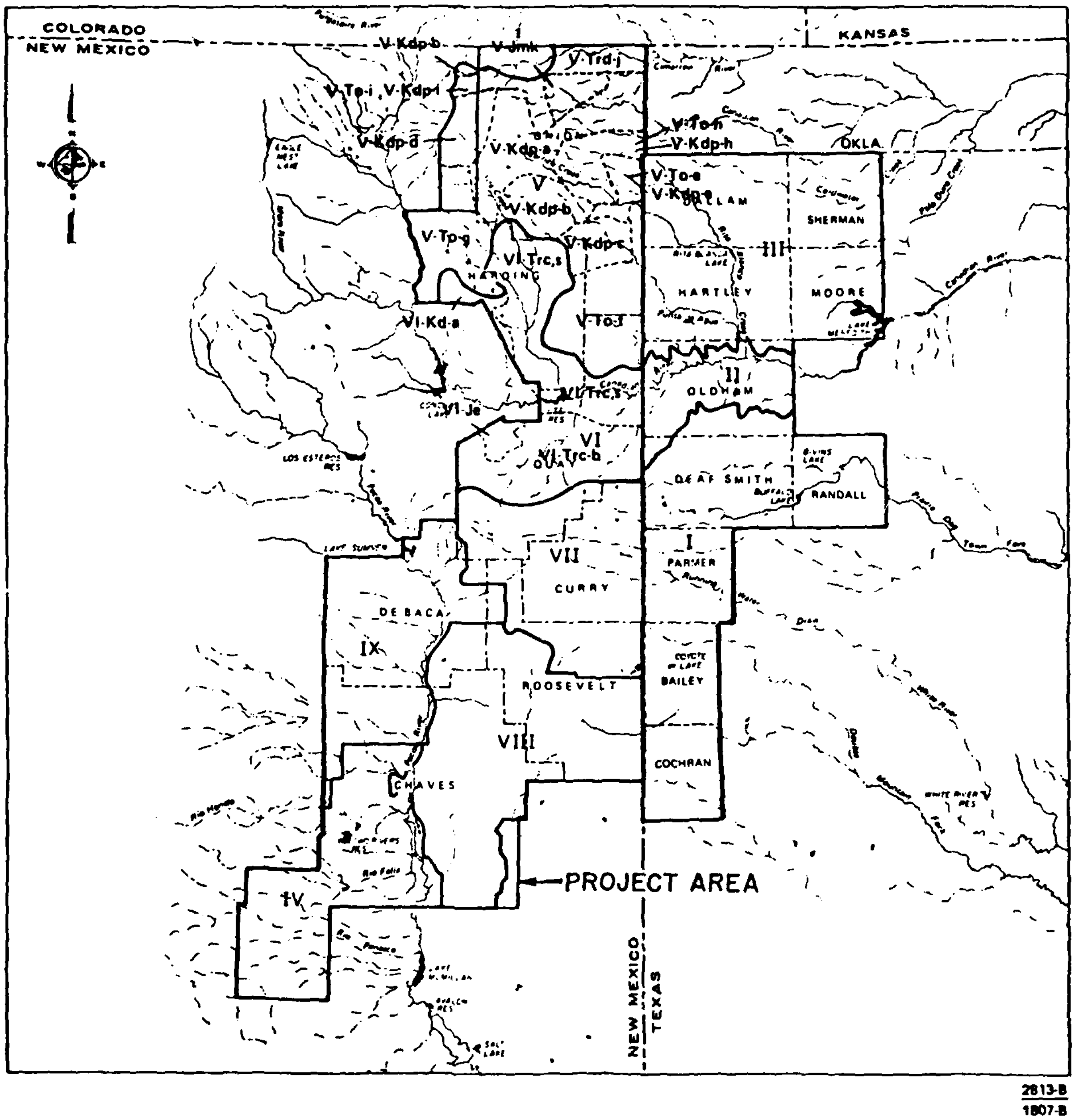

Figure 3.2.1-2. Groundwater regions and subregions.

Table 3.2.1-3. Chemical analyses of groundwater from municipal wells in Chaves Country, N.M. (sheet 1 of 3).

LOCATION NUMBER[1]	OWNER	PRINCIPAL WATER-BEARING FORMATION[2]	DATE COLLECTED	TEMPERATURE (°F)	SILICA (SiO_2)	IRON (Fe)	CALCIUM (Ca)	MAGNESIUM (Mg)
10.23.34. 432	City of Roswell	Psa	5/11/51	-	-	-	168	41
			11/30/57	68	16	-	186	60
			8/2/61	70	-	-	-	-
34.432a			11/30/57	68	16	-	183	53
			8/2/61	70	14	0.01	185	51
10.24.30. 444			9/23/58	68	-	-	191	52
			8/2/61	70	-	-	-	-
32.242			6/9/55	-	15	-	171	54
			8/2/61	-	-	-	-	-
32.314			11/30/57	-	16	-	198	56
			8/2/81	75	14	.03	194	55
33.114			11/30/57	-	18	-	185	53
			8/2/61	69	15	.02	191	57
11.24.4. 114			11/30/57	-	17	-	171	52
			8/2/61	70	15	.03	207	49
4.114a			11/30/57	68	16	-	191	53
			8/2/61	71	-	-	-	-
4.114b			11/30/57	68	19	-	198	56
			8/2/61	-	-	-	-	-
4.124			11/30/57	-	17	-	194	56
			8/2/61	-	-	-	-	-
8.124			5/12/56	69	15	-	175	62
			8/2/61	71	-	-	-	-
8.422			8/4/61	69	13	.01	195	49
16.142			11/30/57	-	16	-	189	54
			8/2/61	77	11	1.8	182	53
12.25.28. 223	Chaves County Housing Corp.	Qal	5/7/42	-	-	-	130	40
			8/4/61	67	-	-	-	-
28.224			4/28/42	-	-	-	122	42
			11/25/55	-	-	-	129	42
			8/4/61	74	-	-	-	-
13.26.17. 113	Town of Dexter		4/25/41	-	-	-	389	123
17.333		Psa	4/6/56	-	-	-	137	48
			8/3/61	73	-	-	-	-
28.114	Greenfield Water Association		4/4/56	-	-	-	142	50
			8/3/61	-	-	-	-	-
34,312	Town of Hagerman		8/3/61	-	19	.32	152	46
14.26.8. 433		Qal	6/24/55	67	30	-	197	76
			8/17/61	70	0	0	0	0
15.26.20. 321	Lake Arthur Water Coop.		8/3/61	-	28	.34	500	122

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Table 3.2.1-3. Chemical analyses of groundwater from municipal wells in Chaves Country, N.M. (sheet 2 of 3).

LOCATION NUMBER[1]	OWNER	SODIUM (Na)	POTASSIUM (K)	BICAR-BONATE (HCO_3)	CAR-BONATE (CO_3)	SULFATE (SO_4)	CHLO-RIDE (Cl)	FLUO-RIDE (F)	NI-TRATE (NO_3)	DISSOLVED SOLIDS[3]
10.23.34. 432	City of Roswell	54	3.4	237	-	421	58	0.7	7.5	943a
		59		224	-	472	111	.6	5.9	1,070a
		-		225	0	464	120	-	-	-
34,432a		62		228	-	461	96	.6	5.8	1,040a
		69		224	0	458	108	.6	5.4	1,040a
10.24.30. 444		165		219	-	461	271	.5	7.0	1,270
		-		209	0	467	285	-	-	-
32.242		67		229	-	450	93	.5	5.9	1,160a
				208	0	482	310	-	-	-
32.314		141		194	-	522	228	.6	8.2	1,260
		139		213	0	479	234	.6	9.0	1,230
33.114		196		203	-	457	325	.6	6.5	1,340
		213		198	0	472	362	.7	8.2	1,420
11.24.4. 114		219		143	-	491	342	.6	6.8	1,370
		264		199	0	511	418	.7	8.6	1,570
4.114a		194		211	0	499	295	.6	7.0	1,360
				200	0	512	435	-	-	-
4.114b		196		216	0	515	305	.7	7.2	1,400
				202	0	512	430	-	-	-
4.124		202		211	-	499	322	.6	7.1	1,430a
		-		208	0	510	405	-	-	-
4.124		51		227	-	447	103	.9	4.4	970
		95		223	0	444	157	-	5.1	-
8.422		98		220	0	462	170	.7	1.2	1,100
16.142		82		225	-	472	134	.6	6.3	1,110a
		106		207	0	459	177	.7	2.8	1,140a
12.25.28. 223	Chaves County Housing Corp.	15	2.6	235	-	291	18	.6	2.8	690a
		-		214	0	330	26	-	-	-
28.224		20		194	-	317	21	-	2.5	720a
		20		230	-	307	22	1.0	2.7	640a
		-		217	0	307	24	-	-	-
13.26.17 113	Town of Dexter	98		212	-	1,190	200	-	-	2,100
17.333		6.4		236	-	322	16	1.0	.3	715a
		-		241	0	329	14	-	-	-
28.114	Greenfield Water Association	6.0		234	-	343	15	.9	.6	754a
		-		236	0	326	16	-	-	-
34.312	Town of Hagerman	16		233	0	365	20	1.5	0.0	774a
14.26.8. 433		19		177	-	585	62	.7	2.1	1,060
		-		158	0	589	89	-	-	-
15.26.20. 321	Lake Arthur Water Coop.	51		193	0	1,530	70	.9	12	2,410

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Table 3.2.1-3. Chemical analyses of groundwater from municipal wells in Chaves Country, N.M. (sheet 3 of 3).

LOCATION NUMBER[1]	OWNER	HARDNESS AS $CaCO_3$		PERCENT SODIUM	SODIUM ADSORPTION RATIO (SAR)	SPECIFIC CONDUCTANCE (MICROMHOS AT 25° C)	pH	REMARKS
		CALCIUM MAGNESIUM	NON-CARBONATE					
10.23.34.432	City of Roswell	588	394	17	1.0	1,250	7.9	City well 10
		710	527	15	1.0	1,460	7.7	
		680	496	-	-	1,510	7.5	
34.432a		674	488	17	1.0	1,400	7.5	City well 11
		670	486	18	1.2	1,450	7.2	
10.24.30.444		690	511	34	2.7	1,940	7.3	City well 14; pumped hours before sampling
		680	508	-	-	1,990	7.5	City well 14
32.242		648	461	18	1.1	1,390	7.4	City well 6
		705	534	-	-	2,070	7.4	
32.314		724	566	30	2.3	1,850	7.7	City well 8
		710	536	30	2.3	1,860	7.2	
33.114		680	513	39	3.3	2,080	7.7	City well 7
		710	548	39	3.5	2,190	7.3	
11.24.4.114		640	524	43	3.8	2,100	8.0	City well 1
		720	557	44	4.3	2,420	7.1	
4.114a		694	522	38	3.2	2,050	7.4	City well 2
		730	566	-	-	2,510	7.4	
4.114b		724	548	37	3.2	2,100	7.6	City well 3
		725	560	-	-	2,480	7.5	
4.124		714	542	38	3.3	2,120	7.8	City well 9
		735	564	-	-	2,410	7.4	
8.124		692	506	14	.8	1,430	8.1	City well 13
		664	482	24	1.6	1,580	7.4	
8.422		690	510	24	1.6	1,630	7.5	City well 15
16.142		694	509	20	1.4	1,520	7.8	City well 12
		670	500	26	1.8	1,630	7.3	
12.25.28.223	Chaves County Housing Corp.	489	296	6	.3	907	-	Orchard Park well 1
		532	356	-	-	988	7.5	
28.224		477	318	8	.4	945	-	Well 2; standby supply for Orchard Park
		494	306	9	.4	931	7.5	
		500	322	-	-	947	7.7	
13.26.17.113	Town of Dexter	1,480	1,300	-	-	2,600	-	Standby well
17.333		540	346	3	.1	965	7.8	New well
		532	335	-	-	971	7.4	
28.114	Greenfield Water Association	560	368	2	.1	997	7.1	
		544	350	-	-	980	7.4	
34.312	Town of Hagerman	568	377	6	.3	1,030	7.4	Main well
14.26.8.433		804	659	5	.3	1,400	7.1	Standby well
		810	680	-	-	1,480	7.2	
15.26.20.321	Lake Arthur Water Coop.	1,750	1,590	6	.5	2,680	7.0	Municipal well

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[1]All locations are south of the New Mexico Base Line.

[2]Qal = Quaternary alluvium; Psa = San Andres Limestone.

[3]Calculated by sum of determined constituents or by residue after evaporation (indicated by letter "a" following number).

Source: Municipal Water Supplies and Uses, Southeastern New Mexico, Technical Report 29A.

groundwater from storage. Production characteristics of the aquifers are excellent; yields of irrigation wells that tap artesian aquifers average 2,000 gpm. The quality of groundwater generally is satisfactory for irrigation and municipal uses; however, encroachment of saline water east of Roswell has occurred as a result of pumping. The aquifers of the Roswell Basin are used mainly for irrigated agriculture and for the City of Roswell's municipal supply.

The Dakota-Purgatoire Aquifer (Kdp) is an important aquifer in Regions II and V by virtue of its relatively good water quality and large volume of recoverable groundwater in storage. Projection characteristics of this aquifer are marginal for large-scale groundwater development. However, well yields of several hundred gallons per minute generally are possible where the Dakota-Purgatoire aquifer is overlain by the Ogallala Formation and wells tap both units. The principal water use from this aquifer is irrigated agriculture. The largest depletions of groundwater storage from the Dakota-Purgatoire aquifer are occurring near Clayton in Union County, New Mexico and in Northwestern Dallam County, Texas.

Nearly 4 million AFY of water were used in the project area in recent years. Of this total, nearly 90 percent was used for irrigated agriculture. In the ten Texas counties in the project area, surface water serves relatively few uses and therefore is not tabulated. Present and projected uses of groundwater in these Texas counties are shown in Table 3.2.1-4. Surface water is used extensively in some of the seven New Mexico counties in the project area. The present and projected uses of surface and groundwater in these New Mexico counties are shown in Table 3.2.1-5. Water use is not available by region in New Mexico. Development of those quantities will take place in Tier 2 studies.

In the tabulation of water uses, a distinction is made between water use and water depletion. Water use is the quantity of water withdrawn from its source for a beneficial purpose. Water depletion is the proportion of the water withdrawn that is no longer available because it has been either evaporated, transpired, incorporated into products or crops, consumed by people or livestock, or otherwise removed from the water environment.

Since irrigation agriculture normally accounts for greater than 95 percent of withdrawals and consumption, use levels in this category are by far the most important factor in determining future demands. In some counties, irrigation is still increasing, and increased demands can be expected to cause problems of water availability during the project life unless mitigating measures or moderating influences reduce competing demands or increase supply. However, where irrigation is decreasing it is unlikely that surpluses in water availability will be generated by those declines. It is more likely that production costs associated with competition for water are already reducing the viability of marginal agricultural production thereby decreasing use levels. This problem does not preclude water use for M-X in any way, however, since M-X represents a high value use which can easily compete for water availability in a free market economy. It does suggest, however, that in many areas M-X uses will occur at the expense of irrigation agriculture or other low value uses.

Estimates of the allowable development of groundwater in the project area are presented in Table 3.2.1-6. For those subregions where value for "life of aquifer" is presented, mining (overdraft) of the groundwater reservoir (aquifer) is permitted by

Table 3.2.1-4. Use and depletion of groundwater in Texas.

YEAR	REGION	WATER USE (acre-feet)	DEPLETION (acre-feet)
1974	I	1,074,600[a]	795,980[a]
	II and III	1,934,300[b,c]	—
1980	I	975,260[a]	717,100
	II	—	15,900
	III	—	935,500
2000	I	—	545,000
	II		3,500
	II and III	1,575,500[b,c]	
	III		830,500

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[a]Value for Randall County estimated as proportion of depletion in 1980 (Texas Water Development Board, 1977).

[b]Values reflect the sum of municipal and irrigation water uses from a summary of water use in the Canadian River Basin (Texas Water Development Board, 1977). Values are considered high because, in addition to the Project Area, Hansford, Ochiltree, Lipscomb, Hutchinson, and portions of Potter, Carson, Gray, and Hemphill Counties are included in the estimate.

[c]Regions II and III are undifferentiated because they are included together in the Canadian River Basin summary.

Source: Texas Water Development Board, 1977.

Table 3.2.1-5. Use and depletion of water in New Mexico.

YEAR	COUNTY	WATER USE (acre-feet)		WATER DEPLETION (acre-feet)	
		SURFACE	GROUND	SURFACE	GROUND
1975[a]	Chaves	46,583	288,051	32,513	187,260
	Curry	1,583	314,508	1,583	172,981
	De Baca	49,727	23,371	24,067	12,892
	Harding	2,629	9,661	2,629	5,413
	Quay	81,420	37,490	42,250	20,010
	Roosevelt	11,077	243,992	11,077	134,091
	Union	10,809	90,497	7,599	50,296
		(c)		(c)	
1980[b]	Chaves	332,500		217,400	
	Curry	299,700		170,200	
	De Baca	50,800		26,300	
	Harding	18,800		12,200	
	Quay	149,900		89,900	
	Roosevelt	184,900		115,700	
	Union	132,400		70,800	
2000[b]	Chaves	332,100		219,300	
	Curry	102,600		61,700	
	De Baca	46,800		26,700	
	Harding	25,600		17,200	
	Quay	169,500		102,100	
	Roosevelt	172,900		111,500	
	Union	146,300		84,000	

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[a]Source: Sorensen (1977).

[b]Source: "BEA-BBR 1972 projection" from New Mexico Interstate Stream Commission and New Mexico State Engineer Office, 1975, County Profiles, Water Resources Assessment for Planning Purposes.

[c]Combined value for surface and ground water.

Table 3.2.1-6. Allowable development of groundwater in the Texas/New Mexico study area.

REGION[1]	SUBREGION[2]	RECOVERABLE GROUNDWATER IN STORAGE (10^3 acre-feet)	DEPLETION RATE[9] (10^3 AFY)	LIFE OF AQUIFER[3] (years)	ALLOWABLE DEVELOPMENT[4] (10^3 AFY)
I	To Ket[7]	28,100	796	35	0
II	—	490	15.9	31	0
III	To Kdp[7]	72,100	936	77	866
IV	shallow artesian	(6)	—	—	0
V	To[3]	215	11.0	19	0
	To[4]	4,270	24.3	175	82.4
	To[5]	687	7.7	89	9.5
	To[6]	609	44.3	14	0
	To[7]	103	0.2	515	2.4
	Kdp[1]	4,680	0.0	—	117
	Kdp[2]	2,560	0.0	—	64.0
	Kdp	1,110	16.0	69	11.7
	Kdp	707	2.0	353	15.7
	Jdo[3]	787	5.5	143	14.2
	Kdp[6]	1,830	35.6	51	10.2
	Kdp[7]	536	2.0	268	11.4
VI	Kd[1]	363	0.4	907	8.7
	Je	1,330	1.8	739	31.4
	Trc[2]	6,040	0.0	—	151
	Trc,s	5,980	20.5	292	129
VII		5,780	154	37	0[7]
VIII	To K[5]	1,250	26.4	47	4.8
IX	Qab	266	0.0	—	0[8]
TOTAL	—	141,951	2099.6	—	1529.4

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[1]Regions shown on Figure 3.3.1.3-2.

[2]Geologic symbols for subregions provided on Figure 3.3.1.3-2.

[3]Life of Aquifer = $\frac{\text{Recoverable Groundwater in Storage}}{\text{Depletion Rate}}$.

[4]Allowable Additional Development (Q) assumes a 40-yr life of the aquifer:

$$Q = \frac{\text{Recoverable Groundwater in Storage}}{40} - \text{Depletion Rate.}$$

[5]Values of recoverable storage and depletion rate include contributions from both aquifers.

[6]Pumpage in Roswell Basin limited by State Engineer to present amount: approximately 104,000 AFY for shallow aquifer and 184,000 AFY for artesian aquifer in Region IV

[7]Additional development in the Portales Underground Water Basin is regulated by the New Mexico State Engineer.

[8]Subregion lies within Fort Sumner Underground Water Basin. Additional development probably not allowed unless surface rights are retired.

[9]Depletion rate $\frac{\text{change IN volume of groundwater in storage}}{\text{Time}}$

state laws. The life of the aquifer, therefore, corresponds to an estimate of the additional years that the groundwater reservoir can sustain present uses.

The "allowable additional development" assumes a 40-year life of the aquifer. It is the annual use in addition to existing uses that can be developed from the groundwater reservoir such that the reservoir is depleted in 40 years. This additional groundwater development is assumed to be consumptive use, which probably would result from municipal and industrial use of the water for the proposed M-X project. Where the "life of aquifer" is less than 40 years, no additional develpment of the aquifer is assumed. The subregions with less than a 40-year "life of aquifer" are judged to have a severe problem of groundwater overdraft. Forty years is the life of the aquifer generally assigned by the New Mexico state engineer to declared underground water basins in which overdraft is permitted.

An interpretation of the estimates of physical availability of groundwater is as follows. For subregions in which "allowable additional development" is non-zero, development of groundwater, in addition to the amount presently being used, can take place. The relative size of that additional development is indicated by the values in Table 3.2.1-6. For subregions in which "allowable additional development" is zero, existing uses of groundwater would have to be retired in order to use groundwater for other purposes.

Reliance on Table 3.2.1-6 to predict the availability of groundwater must be qualified. First, in New Mexico, the state engineer may administer use of groundwater by declaration of an underground water basin. Parts of Regions IV, VII, and IX lie within such declared basins and are essentially closed to additional groundwater development. In the Portales underground water basin, use of relatively large quantities of groundwater would require the purchase of existing groundwater rights. In the Fort Sumner and Roswell underground water basins, use of groundwater probably would require the purchase of both groundwater and surface water rights. The dependability of groundwater rights in basins tributary to the Pecos River are in question because of the ongoing suit over the Pecos River Compact. In addition, the New Mexico state engineer may declare a new underground water basin in the project area if he feels management controls of groundwater use are necessary.

Secondly, in the Texas part of the project area, most of the land and, consequently, the water rights, is owned by individuals. Purchase of lease of the land and/or water rights would be required to develop the groundwater for municipal and industrial use for the proposed project M-X. In areas under the jurisdiction of underground water conservation districts, rules established by the respective districts regarding well spacing would have to be followed.

Thirdly, the values presented in Table 3.2.1-6 are for planning purposes only and should be used cautiously, especially in subregions where extensive development of groundwater has not taken place. In these relatively undeveloped subregions, published hydrologic data probably are not sufficient to reliably estimate the quantity of recoverable groundwater, potential well yields and other design factors, and the economics of obtaining a groundwater supply. In addition, the foregoing analysis has not considered uncertainties involved in the acquisition of land and/or water rights.

SURFACE WATER RESOURCES (3.2.2)

The project area lies within parts of three major surface water drainage basins: (1) Arkansas-Red White River Basins, (2) Texas Gulf Basins, and (3) Pecos River Basins (Figure 3.2.2-1). The principal surface water resources in the project area are the Canadian River in New Mexico and Texas and the Pecos River in New Mexico (Figure 3.2.2-1). The locations of major and minor water courses, surface water reservoirs, and gauging stations for both stream flow and water quality records for the project area are summarized in Table 3.2.2-1. The major surface water projects (reservoirs) that are presently operating and drainage areas that are regulated by interstate compacts are shown on Figure 3.2.2-1.

The Canadian River flows through Quay County, New Mexico, and Oldham and Moore counties, Texas. Stream flow is regulated principally by the Ute Reservoir in New Mexico and Lake Meredith in Texas. Lake Meredith supplies water for municipal and industrial uses in 11 west Texas cities, but the contracted amount of this water is only 103,000 AFY. Water from Ute Reservoir is available for municipal and industrial uses but is largely unsold at present. Ute Reservoir has been designed to comply with the provisions of the Canadian River Compact, which allow a maximum conservation storage capacity of 200,000 acre-feet between Conchas Dam and the New Mexico/Texas state line. At present, the conservation storage capacity of Ute Reservoir is about 90,000 acre-feet. The reliable yield of Ute Reservoir is estimated at approximately 10-15,000 acre-feet per year. However, the water is used only for municipal purposes at a state park and for gravel washing.

At present, Texas essentially has free and unrestricted use of waters in the Canadian River Basin in Texas, excluding the North Canadian River. Lake Meredith effectively controls all of the developable surface water resources in Texas in accordance with provisions of the Compact. Water from Lake Meredith is sold to 11 cities for municipal and industrial uses. The contracted amount of water from the reservoir, 103,000 AFY, is assumed to be the reliable yield. However, the quantity of water released to the cities in the last five years has averaged about 70,000 acre-feet per year (U. S. Water and Power Resources Service, 1980).

In recent years, water supplied from Lake Meredith for municipal uses has had to be mixed with ground water to improve the overall quality. Table 3.2.2-2 presents data on the quality at the surface flows in the Canadian River Basin.

The Pecos River flows through De Baca and Chaves Counties, New Mexico. Stream flow is regulated principally by Los Esteros Reservoir, north of the project area, and by Lake Sumner. Water uses (both ground and surface water) must comply with provisions of the Pecos River Compact, which state that upstream use of the Pecos River shall not diminish the flow entering Texas below the amount available under 1947 conditions. The Pecos River is being adjudicated at present by the U.S. Supreme Court in a suit between New Mexico and Texas.

The average annual discharge of the Pecos River in the project area is approximately 150,000 AFY. Losses of streamflow take place in the reach of the Pecos River between Sumner Dam and Acme. The river gains base flow from seepage of ground water in the reach between Acme and Lake Arthur. Water in the Pecos River in the project area is slightly saline. The water probably is adequate for irrigation but unsuitable for municipal uses. In the reach between Sumner Dam and Acme, the water quality shows a marked degradation.

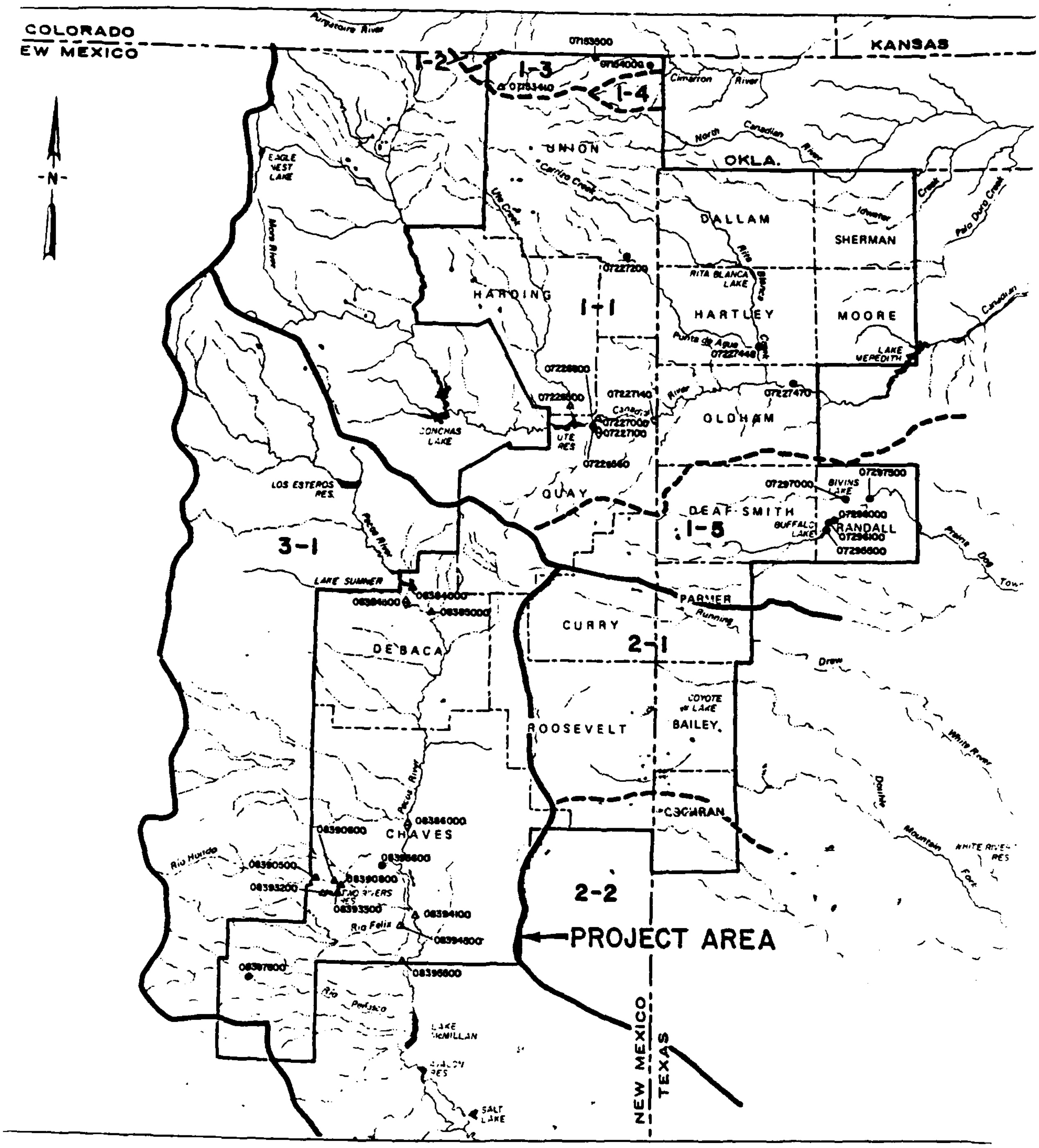

Figure 3.2.2-1. Major drainage basins and stream gauging stations.

Table 3.2.2-1. Records of gauging stations in the Texas/New Mexico study area.

STATION NUMBER	STATION NAME	DRAINAGE AREA (SQUARE MILES)	AVERAGE DISCHARGE (ACRE-FEET/YEAR)	(YEARS OF RECORD)	MEAN SPECIFIC CONDUCTANCE (MICROMHOS CM)	REMARKS
	ARKANSAS-WHITE RIVER BASIN					
07153410	Bennett Spring near Capulin, NM		200	(1978)	-	Gage at 100 ft below source
07153500	Dry Cimarron River near Guy, NM	545	8,040	(1943-1970)	-	Discontinued 1973
07154000	Cimarron River near Folsom, NM	840	7,460	(1928-1933)	-	Discontinued 1933
07226500	Ute Creek near Logan, NM	1,443	17,530	(1943-1978)	-	-
07226800 07226560	Ute Reservoir near Logan, NM	10,030	-	(1963-1978)	794	Reservoir content
07227000	Canadian River at Logan, NM	10,031	284,000	(1909, 1912-1915, 1927-1938)	-	Prior to completion of Conchas Dam
			186,200	(1939-1962)	-	Prior to completion of Ute Dam
			22,170	(1963-1978)	-	-
07227100	Revuelto Creek near Logan, NM	786	33,980	(1960-1978)	1,740	-
07227200	Tamperos Creek near Stead, NM	556	No flow most of the time	(1967-1973)	-	Discontinued 1973
07227140	Canadian River above New Mexico/ Texas state line in NM	12,616	-	-	5,826	Water quality data only
07227448	Punta De Agua Creek near Channing, TX	1,500	No flow most of the time	(1967-1973)	902	Discontinued 1973
07227470	Canadian River at Tascosa, TX	14,713	191,630	(1969-1970)	2,332	Discontinued 1977
	RED RIVER BASIN					
07295500	Tierra Blanca Creek above Buffalo Lake near Umbarger, TX	538	6,480	(1940-1954; 1967-1970)	-	Discontinued 1973
07296000	Buffalo Lake near Umbarger, TX	575	-	(1938-1954; 1968-1970)	-	Reservoir content discontinued
07296100	Tierra Blanca Creek below Buffalo Lake near Umbarger, TX	575	Very little flow most of the time	(1968-1970)	-	Discontinued 1973
07297500	Prairie Dog Town Fork Red River near Canyon, TX	711	8,110	(1925-1949)	-	Discontinued 1949
07297000	Palo Duro Creek at Amarillo City (Bivins) Lake, TX	62	2,720	(1942-1954)	-	Discontinued 1954
	PECOS RIVER BASIN					
08384000	Lake Sumner near Fort Sumner, NM	4,390	-	(1936-1978)	-	Reservoir content
08384500	Pecos River below Sumner Dam, NM	4,390	171,000	(1913-1936)	-	Prior to completion of Sumner Dam
			148,500	(1937-1978)	1,827	-
08385000	Fort Sumner Main Canal near Fort Sumner, NM	-	35,500	(1940-1943; 1954-1978)	-	-
08386000	Pecos River near Acme, NM	11,380	135,500	(1938-1978)	3,785	-
08390500	Rio Hondo at Diamond A Ranch near Roswell, NM	947	15,290	(1940-1978)	-	-
08390600	Two Rivers Reservoir near Roswell, NM	960 (Rio Hondo) 64 (Rocky Arroyo)	No content in 1978 and most of time	(1963-1978)	-	Reservoir content
08390800	Rio Hondo below Diamond A Ranch near Roswell, NM	963	5,470	(1964-1978)	-	-
08393200	Rocky Arroyo at Two Rivers Reservoir near Roswell, NM	71	630	(1964-1978)	-	-
08393300	Rocky Arroyo below Rocky Dam near Roswell, NM	64	1,090	(1964-1978)	-	-
08393600	North Spring River at Roswell, NM	19.5	30	(1959-1970)	-	Discontinued 1977
08394100	Pecos River near Hagerman, NM	13,620	Operated as a low flow station only	-	-	-
08394500	Rio Felix at Old Highway Bridge near Hagerman, NM	932	10,870	(1940-1978)	-	-
08395500	Pecos River near Lake Arthur, NM	14,760	187,600	(1939-1970)	-	-
08397600	Rio Peñasco near Dunken, NM	583	4,230	(1957-1961)	-	Discontinued 1961

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Note: Location of Gaging Stations shown on Figure 3.2.2-1.

Source: U.S. Geological Survey, 1979 (a and b); 1980.

Table 3.2.2-2. Water quality data, Canadian River Basin.

CONSTITUENT	LOCATION AND NUMBER OF GAGING STATIONS*				
	UTE RESERVOIR (NM)	REVUELTO CREEK (NM) (07227100)	NM/TX STATE LINE (07227140)	PUNTA DE AGUA CREEK (TX) (07227448)	CANADIAN RIVER (TX) (07227470)
Mean specific conductance (micromhos/cm)	794	1,740	5,826	902	2,332
Mean total hardness (mg/l)	159	0.4	312	319	286
Mean dissolved chloride (mg/l)	32	179	1,698	41	475
Mean total dissolved solids (mg/l)	517	1,333	3,537	550	1,428
Mean suspended sediment (mg/l)	—	2,009	2,042	—	—

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*Location of gaging stations shown on Figure 3.

Source: U.S. Geological Survey, 1980.

Virtually all surface water in the project area is appropriated and is being used beneficially within the terms of international treaties, interstate compacts, court decrees and state laws. A major exception is water in Ute Reservoir, which has been appropriated by the New Mexico Interstate Stream Commission but is largely unused at present. This water would be available under contract to the Interstate Stream Commission. The reliable yield of Ute Reservoir is estimated to be 10-15,000 acre-ft per year.

Other major surface water resources in the project area would be available only by purchase of water rights or lease of water from existing users. Development of these surface water resources for purposes of the proposed project M-X would require retiring existing uses of the water. Water in Lake Meredith in Moore County, Texas, must be purchased from the Canadian River Municipal Water Authority. Rights to water flowing or in storage along the Pecos River in New Mexico would have to be purchased or leased from irrigation districts. When contemplating the acquisition of water from the Pecos River, it is important to purchase or lease water rights that are of relatively senior priority, in order to assure the availability of water in times of short supply. In addition, without prior treatment, the quality of water in parts of the Pecos River may not be satisfactory for the purpose of the proposed M-X project.

ADMINISTRATION OF WATER RIGHTS (3.2.3)

New Mexico

Systems of Water Appropriations. All surface water and ground water in New Mexico belongs to the public and is subject to appropriation for beneficial use. Beneficial use is the basis, measure, and limit to the right to use water, and priority in date of appropriation gives the better right. The administration of water rights in New Mexico is under the jurisdiction of the state engineer as set forth in provisions of the constitution and statutes of the state, by adjudications of the courts, and by terms of interstate compacts.

Surface water throughout the state of New Mexico is subject to regulation by the state engineer under the 1907 water code (New Mexico Statutes, 1953, Annotated, Volume II, Part 2). Groundwater in certain areas of the state is also subject to control by the state engineer under the groundwater code enacted in 1931 (New Mexico Statutes, 1953, Annotated, Volume II, part 2). The authority of the state engineer exists only in so-called "declared undergound water basins," basins declared by the state engineer to have reasonably ascertainable boundaries and for which management controls are necessary. The state engineer may declare an undergound water basin without obtaining judicial approval. At the present time, there are 27 declared underground water basins in New Mexico, encompassing approximately 59 percent of the land area of the state.

Four concepts of New Mexico water law are important to consider in the selection of an available source of water for Project M-X. First, water rights are considered to be property rights; as such they may be transferred, sold, or leased. Second, water rights are not necessarily appurtenant to the land on which the water is diverted or extracted. One may own a water right that permits pumping of water from one groundwater basin and applying the water to beneficial use in another basin.

Third, the mining (overdrafting) of groundwater basins is permitted in New Mexico. The state engineer decides whether the groundwater in a particular basin will be mined. In a mined basin, the state engineer determines the rate at which the groundwater reservoir will be depleted. The lowering of water levels in a mined basin caused by the pumping of groundwater by relatively junior appropriators, together with the resulting increase in pumping costs and decrease in well yields, does not necessarily constitute an impairment of the rights of relatively senior appropriators. Finally, New Mexico water law does not establish a priority of uses for water, so that use of water for irrigation is as appropriate a beneficial use as is the use of water for municipal and industrial purposes.

Status of Appropriations. All or part of five declared underground water basins are present in the project area. Four of these, the Canadian River, Fort Sumner, Penasco and Roswell Underground Water Basins, are classified as stream connected, in which ground-water extraction may result in a decrease in the discharge of surface streams in the basin. No new permits to appropriate groundwater in these basins are allowed by the state engineer unless the immediate and potential effects of this appropriation are offset by the retirement of existing surface water rights.

In the Portales underground water basin, mining of groundwater is permitted at rates set by the state engineer. This basin is probably fully appropriated except for about 5,000 acre-ft per year in the sand hills in the eastern part of the basin (Jim Wright, New Mexico State Engineer Office, 1979, personal communication).

Outside of these declared basins in the project area, the drilling and pumping of water wells in unregulated. However, it is reasonable to assume that the state engineer may declare a new basin in an area where relatively large new uses of groundwater are proposed.

Surface water in the project area is fully appropriated except in the Arkansas-Red/White River Basins. About 10-15,000 acre-ft per year from the Dry Cimarron River may be available for appropriation. In the Canadian River Basin, Ute Reservoir has been designed to hold 200,000 acre-ft of conservation storage, the maximum allotted under the Canadian River Compact, when spillway gates are installed. These gates have not been built yet, although bonds for most of the construction costs have been authorized by the New Mexico Legislature. The present conservation storage capacity of Ute Reservoir is 90,000 acre-ft of unappropriated rights. It may be possible to divert streamflow in Revuelto Creek (approximately 35,000 acre-ft per year) until such time as spillway gates on Ute Dam have been installed (Slingerland, New Mexico Interstate Stream Commission, 1980, personal communication).

The Pecos River in New Mexico is generally believed to be overappropriated. The Carlsbad Irrigation District, south of the project area, has the oldest priority (1887 and 1888) for large quantities of direct flow in the river. The District also has the right to store 300,000 acre-ft per year in Los Esteros Reservoir and Lake Sumner, with a priority date of 1906. By stipulation, the Fort Sumner Irrigation District in northern De Baca County has the right to divert the first 100 cfs (35,000 acre-feet per year) in the Pecos River. This water is released from Lake Sumner.

Other uses of water from the Pecos River in the project area either are small or have relatively junior priorities. Included in this latter category are rights to pump groundwater in the Fort Sumner and Roswell underground water basins. The U.S. Supreme Court, in the suit between Texas and New Mexico regarding the Pecos River Compact, has defined the provision of the Compact regarding 1947 conditions. New Mexico, in maintaining the flow entering Texas that was occurring in 1947, must account for river losses due to development of groundwater in the Roswell Basin as of 1947. The full effect of depletion in the surface flow of the Pecos River due to pumping in 1947 may not yet have occurred. When rights in the Pecos River are adjudicated as a result of this suit, many groundwater rights in the Fort Sumner and Roswell areas may have to be retired (Slingerland, 1980, personal communication).

Texas

Systems of Water Appropriation. Surface water within a defined watercourse in Texas is public water and is subject to appropriation for beneficial use. Beneficial use is the basis, measure and limit of the right to use water, and priority in date of appropriation gives the better right. Besides priority in date of appropriation, the following priorities for types of beneficial uses are also applicable: (1) domestic and municipal; (2) industrial; (3) irrigation; (4) mining and recovery of minerals; (5) hydroelectric power; (6) navigation; (7) recreation and pleasure; and (8) other beneficial uses. Whether priority by date of priority by use takes precedence has not been decided by Texas courts. Surface water rights are adminstered by the Texas Water Commission of the Texas Department of Water Resources. An adjudication of water rights in the Canadian River Basin in the project area is underway, and a report of water-rights claims has been issued (Water Rights Adjudication Section, 1980).

Groundwater in Texas belongs to the individual landowners and is, therefore a private right. Texas courts have followed unequivocally the "English" or "common law" rule that the landowner has a right to take for use or sale all the water he can capture from beneath his land. Owners of land overlying defined groundwater reservoirs (i.e., the Ogallala aquiffer) may voluntarily adopt well regulation through mutual association in underground water conservation districts.

Three underground water conservation districts have been created in the project area. Only two of those districts, North Plains Ground Water Conservation District No. 2 and High Plains Underground Water Conservation District No. 1., are active. These districts are headquartered in Dumas and Lubbock, respectively, and have jurisdiction in part of the project area. The principal rules established by the districts that control use of ground water are the required minimal spacings for wells. The spacing between wells depends on the design discharge of the well, as measured by the inside diameter of the pump column. For example, in the North Plains Ground Water Conservation District No. 2, a proposed well with a 10-inch or larger pump must be spaced at least 500 yds from the nearest well. Other wells of the districts prohibit the waste and pollution of water.

Status of Appropriations. Surface water in the project area is considered by state authorities to be fully appropriated. Existing surface water impoundments control most of the developable surface water supplies. In the Canadian River Basin, the Canadian River Municipal Water Authority has rights to use approximately 150,000 acre-ft per year from Lake Meridith for municipal and industrial purposes. Their permit is subject to the provisions of the Canadian River Compact, which will not be enforced until Oklahoma builds more reservoirs for conservation storage. In the Red River Basin there are water-rights permits for both Bivins and Buffalo Lakes, although springflow that once supplied Buffalo Lake has dried up (Settemeyer, Permits Division, Texas Department of Water Resources, personal communication, 1980). In the Brazos and Colorado River Basins surface runoff is not sufficient to administer under a system of water rights (Haisler, Permits Division, Texas Department of Water Resources, personal communication, 1980).

East of the project area in Hansford County, Texas, the Palo Duro River Authority of Texas has rights to approximately 10,000 acre-ft of water per year in Palo Curo Creek for municipal use. A reservoir to store this water has been permitted but has not been constructed (Water Rights Adjudication Section, 1980).

HYDROLOGIC CONDITIONS IN GROUNDWATER REGIONS (3.2.4)

Region I - Southern High Plains, Texas (3.2.4.1)

Ogallala Formation

Region I, the Southern High Plains area, is located along the western edge of the Texas Panhandle and south of the Canadian River, as shown on Figure 3.2.1-2. The principal source of domestic, industrial, and agricultural water in this region is the Ogallala Formation (To) of Pliocene age. With the exceptions of the northwestern corner of Deaf Smith County and a portion of eastern Randall County, the Ogallala Formation is the only geologic unit exposed in the region (Cronin, 1964). Two minor aquifers, the Edwards-Trinity and Dockum Groups, are also capable of yielding water (discussed later in this section). Groundwater generally occurs under water table conditions in these aquifers.

According to estimates by the Texas Department of Water Resources (TDWR, 1978), the saturated thickness of the Ogallala aquifer in Region I ranges from a few feet to more than 225 feet in eastern Deaf Smith County. In general, the areas of greatest saturated thickness lie in Deaf Smith and Parmer counties; these counties have an average saturated thickness of at least 100 feet but not more than 150 feet.

The specific yield of the Ogallala Formation has been estimated to be 15 percent (Cronin, 1969). Based on the distribution of saturated thickness and specific yield, the TDWR (1977) estimated that, in 1974, approximately 28.1 million acre-feet of water were recoverable from storage in the Ogallala aquifer in Region I. This value, when compared to a 1958 Texas Board of Water Engineers estimate (TBWE, 1961), indicates that approximately 43.0 million acre-ft of water were recoverable from storage in the Ogallala Formation in Region I. These estimates of recoverable storage assume that all except the last 20 feet of saturated thickness could be developed. Any attempt to develop this residual water would probably result in hydrologic, economic, and technical difficulties (TDWR, 1979).

The potential capacity to yield water to wells is related mainly to the saturated thickness of the Ogallala Formation. The greatest well yields are found in Parmer and Deaf Smith counties. In general, for Region I, yields of wells vary from less than 100 gallons per minute (gpm) to more than 1,000 gpm (TDWR, 1979). These values also depend upon the age, condition, and size of the well.

Precipitation is the primary source of recharge to the Ogallala (Gutentag and Weeks, 1980). The effective recharge to the Ogallala aquifer has been estimated at 0.175 inch per year (TDWR, 1979). The depth to water in the Ogallala Formation (potentiometric surface) in 1958 ranged from 50 to more than 250 feet below land surface (TBWE, 1961). Groundwater in the Ogallala Formation generally moves from west to east, as shown by the configuration of the potentiometric surface. Groundwater movement in the aquifer is generally slow, although water that recharges the Ogallala aquifer in Regions VII and VIII of New Mexico has the potential to move into Region I.

Since the 1930s, the heaviest pumpage of groundwater in Region I and the rest of the Southern High Plains has been for irrigated agriculture. According to Gutentag and Weeks (1980), about 95 percent of the water for irrigation is obtained from groundwater. Other users of groundwater include municipalities, industries associated with agriculture, and oil producers. No accurate figures have been published for these users in Region I, but Cronin (1964) suggests that municipal/-industrial use may be as high as 4 percent of the total pumpage in the Southern High Plains. The estimated depletion in Region I is 796,000 AFY (Table 3.2.1-2).

Groundwater in the Ogallala Formation is generally classified as fresh. It contains between 300 and 1,000 mg/l of total dissolved solids, of which calcium, magnesium, and bicarbonate are the primary constituents (TDWR, 1979).

Edwards-Trinity Group

In Cochran County and the southern half of Bailey County, the Ogallala Formation is underlain by the Cretaceous-aged Edwards-Trinity (High Plains) minor aquifer (Ket). This aquifer is composed of sandstone and basal conglomerate of the Trinity Group and limestone of the Edwards Group. The volume of recoverable groundwater from the Edwards-Trinity Group may be as high as 1.0 million acre-feet (TDWR, 1979). The EdwardsTrinity contribution has been included in the estimated recoverable groundwater from the Ogallala aquifer in Region I (Table 3.2.1-1). Although this aquifer is hydraulically connected to the overlying Ogallala Formation, the increase in well yield for wells that tap both aquifers (compared to wells that tap only the Ogallala) is small. Where the limestone portion of the Edwards-Trinity aquifer is saturated, yields may range up to 600 gpm (Cronin, 1969; TDWR, 1979).

The average saturated thickness of the Trinity Group is 30 feet, and the specific yield of the aquifer is 0.15. The Edwards Group and associated limestones have an estimated saturated thickness of 20 feet and specific yield of 0.015. The water quality of these aquifers is usually poorer than that of the overlying Ogallala Formation and is considered to be slightly to moderately saline (TDWR, 1979).

Dockum Group

In the northern part of Region I, extensive erosion of the Pre-Ogallala surface (Cretaceous) permitted the Ogallala sediments to be deposited directly on the Triassic rocks of the Dockum Group (Trd) (TBWE, 1961). The groundwater resources of the Dockum Group were investigated by Fink (1963), who indicated that the available water in the Dockum Group, and specifically in the Santa Rosa Sandstone, was insufficient to replace the declining water supply in the overlying Ogallala aquifer. Although tested in only a few places, the wells that tap the Dockum Group generally yield low to moderate (300 gpm) quantities of water (TBWE, 1961). Groundwater produced from the Dockum Group probably would be saline and unsuitable for irrigation purposes or public supply (TBWE, 1961).

Region II - Canadian River Area, Texas (3.2.4.2)

Dockum Group

Region II, the Canadian River Breaks area, is located midway between Regions I and III along the Canadian River in Oldham County, Texas (Figure 3.2.1-2). Unlike Regions I and III, the Ogallala Formation is absent and not the principal aquifer of the region. The boundaries of Region II delineate generally where the Ogallala has been removed by erosion. The major units exposed in Region II are the Dockum Group of Triassic Age (Trd) and undifferentiated Permian rocks. The Permian rocks are not known to be tapped by wells, and their groundwater is probably saline (Cronin, 1964). Deposits of Quaternary alluvium are present in the Canadian River flood plain but supply only small amounts of water for domestic use and stock watering. Only the Dockum Group is considered to be an aquifer in Region II.

Although groundwater is available at depth in the Dockum Group (Fink, 1963), the lack of reliable data makes a fair assessment of the region difficult. In 1958, a total of 35 wells in Oldham County withdrew approximately 10,170 acre-ft from storage (TBWE, 1960). The present depletion rate in Region II is estimated to be 15,900 acre-ft per year (Table 3.2.1-2). The recoverable volume of groundwater in storage in Oldham County (as of 1974) was 0.49 million acre-ft (TWDB, 1977). No distinction was made concerning the location of the water, whether it underlies the breaks (Triassic rocks) or the plains (Ogallala Formation at surface).

Region III - Northern High Plains, Texas (3.2.4.3)

Ogallala Formation

Region III, the Northern High Plains area, is located in the northwestern corner of the Texas Panhandle and north of the Canadian River, as shown on Figure 3.2.1-2. As in the Southern High Plains of Region I, the principal source of fresh groundwater is the Ogallala Formation (To). Significant quantities of water are also currently being withdrawn from two minor aquifers: the Dakota-Purgatoire aquifer (Kdp) and the Dockum Group (Trd). Groundwater in the Ogallala Formation occurs under watertable conditions.

The Ogallala Formation is arealy extensive throughout Region III, with the exception of the southeastern corner of Moore County and isolated outcrops of Dakota-Purgatoire Formation in northwestern Dallum County. In general, the Ogallala has a saturated thickness of at least 150 feet throughout much of Region III. The Ogallala is not saturated in several areas of Dallam County, while in Sherman County, the saturated thickness exceeds 300 feet (TBWE, 1960).

No estimate of the specific yield of the Ogallala in the Northern High Plains has been made; an estimate of 0.15 (Cronin, 1969) in the Southern High Plains is probably applicable to Region III, because of the similarity of the deposits in the two areas. In 1974, approximately 72.1 million acre-feet of groundwater were recoverable from storage in the Ogallala Formation in Region III (TWDB, 1977). As shown in older compilations, approximately 82.0 million acre-feet of groundwater were potentially recoverable in 1958 from Region III (TBWE, 1960). The latter quantity included 14 million acre-ft of groundwater underlying the breaks area and not the plains area of Region III. Although the breaks area is not suitable land for irrigation, water produced in that area would be suitable for municipal use (Alexander, 1961).

The potential capacity of wells that tap the Ogallala Formation is related mainly to the saturated thickness of the aquifer. Wells located near the geographic center of Region III are capable of yields of at least 1,000 gpm.

Recharge to the Ogallala Formation in Region III is by direct precipitation in Texas and New Mexico. The sand hill areas in western Dallam and Hartley counties appear to be favorable areas for recharge. In most of Region III, the amount of precipitation that becomes recharge probably averages only a fraction of an inch per year. The depth to water (potentiometric surface) ranges from less than 50 feet in northwestern Dallum County to almost 400 feet in Hartley County (Alexander, 1961).

Groundwater in the Ogallala Formation moves from west to east, according to the slope of the potentiometric surface. Groundwater in the Ogallala Formation in Region V, New Mexico therefore has the potential to move eastward into Texas as underflow.

The primary use of water in Region III is for irrigation. In 1958 (TBWE, 1960), the groundwater withdrawals for irrigation, municipal, and industrial uses were approximately 258,000 acre-feet from an estimated 822 wells. Although estimates of groundwater use in 1980 are unavailable, the number of wells (producing more than 70 gpm) in Hartley, Sherman, and Moore counties has increased to approximately 3,300 (M. Crawford, Northern High Plains Water Conservation District No. 2, 1980, personal communication). Groundwater depletion is estimated to be 936,000 acre-feet per year at present (Table 3.2.1-2).

Groundwater in the Ogallala Formation is generally characterized as fresh and is suitable for municipal, industrial and irrigation purposes. Some water samples from the Ogallala Formation revealed relatively high concentrations of hardness, iron, silica, and fluoride (TBWE, 1960), which may make the water unsuitable for municipal use without treatment.

Dakota-Purgatoire Aquifer

In the northwestern corner of Dallum County, the Ogallala Formation is underlain by the Dakota-Purgatoire aquifer of Cretaceous age. The Dakota-Purgatoire aquifer is composed of white and yellow to brown sandstone up to 250 feet thick. Where capped by the Graneros Shale, groundwater in the underlying Dakota-Purgatoire aquifer occurs under artesian conditions and has been known to support flowing springs (Brune, 1975). A well that was completed in the Dakota Purgatoire aquifer for the City of Texline municipal supply was determined to have a total dissolved solids content of 283 mg/l and no objectionable concentrations of other mineral constituents (TDWR, 1979).

The annual effective recharge for this aquifer is 4,800 acre-feet, based on a 0.25 inch/year estimate (TDWR, 1979). The Dakota-Purgatoire aquifer has been designated as a minor aquifer by TDWR (1979) and, therefore, is identified as Subregion III-Kdp on Figure 3.2.1-2. Groundwater production characteristics are considered to be favorable in this area and most projections of groundwater use in Dallum County are based upon yields from this subregion. Estimates of recoverable groundwater and depletion rates from the Ogallala Formation in Region III also include values for the Dakota-Purgatoire aquifer (Table 3.2.1-1 and 2).

Dockum Group

Although not formally recognized by the TDWR as a minor aquifer, the Dockum Group of Triassic age (Trd) is an important source of usable groundwater in Region III. In particular, the Santa Rosa Sandstone is capable of producing large quantities of fresh to slightly saline groundwater. Unlike the Dockum Group south of the Canadian River Breaks, these rocks have a slightly steeper eastward dip (Fink, 1963). Crawford (North Plains Ground Water Conservation District No. 2, 1980, personal communication) suggests that these Triassic sandstones are experiencing a "flushing" phenomenon. Available data indicate that where fresh water occurs in the Dockum Group, it is similar in quality to the water produced in the overlying Ogallala Formation, suggesting that the source of fresh groundwater is the Ogallala Formation. Mixing of the groundwaters occur where the two formations are in contact.

Unlike in Region I, water well completion in the Dockum Group is a common practice in Region III. As much as 20 percent of groundwater production in Sherman County and 40 percent of production in Moore County are derived from the Dockum Group (M. Crawford, personal communication, 1980). Although no published information was available on volume of recoverable groundwater in storage or saturated thickness, the Dockum Group is known to range in thickness from about 100 feet in Sherman County to 1,000 feet in Dallam and Hartley counties (TBWE, 1960).

Region IV - Roswell Basin and Vicinity, New Mexico (3.2.4.4)

Region IV, Roswell Basin and vicinity, includes the northern two-thirds of the Roswell Basin in southeastern New Mexico (Figure 3.2.1-2). The Roswell Basin contains nearly all of the region's recoverable groundwater resources. The southwest quarter of Region IV also contains small corners of the Penasco and Salt Basins, for which few hydrologic data are available. The Roswell Declared Underground Water Basin extends 25 miles to the west of the Pecos River, from Chaves County south to Eddy County, New Mexico. The Basin is physiographically bounded west of Region IV by the granite basement rocks of the Capitan, Sacramento, and Guadalupe Mountains. South of Region IV, the basin is bounded by the Seven Rivers Hills in Eddy County, New Mexico. The northern boundary of the basin is vaguely defined, probably coinciding with the Arroyo del Macho at the north end of Region IV (Kinney and others, 1968).

The hydrologic system includes two main aquifers: a shallow watertable aquifer developed in Quarternary alluvium, and a deeper, east-dipping artesian aquifer composed of Permian carbonates that have high, often cavernous secondary porosity. The artesian and surficial aquifers are separated by the "leaky" shales and dolomitic limestones of the Permian Artesia Group.

Water quality in the Roswell Basin is generally good (500 ppm chloride), except in areas of saline encroachment east of Roswell (Kinney and others, 1968). Both artesian and shallow aquifers are affected by this salt water encroachment.

Within Chaves County, the annual withdrawal of groundwater from both the artesian and water table aquifers is approximately 288,000 acre-ft per year (Sorensen, 1977). No direct estimates of groundwater recharge are available for Chaves County, but basinwide recharge is estimated at 430,000 acre-ft per year (Fiedler and Nye, 1933; Kinney and others, 1968). On the basis of the area of the Roswell Basin in Chaves County, recharge to the groundwater reservoir in Chaves County is estimated to be approximately 280,000 acre-ft per year. Studies have shown, however, that recharge in the western part of the Roswell Basin is not uniform (Rabinowitz and Gross, 1972; Duffy and others, 1978). The groundwater reservoir of Region IV is thus characterized as a complex multi-aquifer system, in which recharge nearly equals withdrawals.

The Roswell Basin is one of the most studied groundwater basins in the United States. Fiedler and Nye (1933) published the first modern study of the geology and hydrology of the Roswell Basin, and although dated, it is the most comprehensive study of the basin yet published. Morgan (1938) studied the shallow alluvial aquifer of the basin. Hantush (1955, 1961), Mower (1964), and Motts and Cushman (1964) detailed the hydrology of the basin. Summers and Kottloski (1969) published the preceedings of a symposium on the reservoir properties of the San Andres Limestone, using figures from an unpublished Ph.D. thesis by Maddox (1969) to provide details of the artesian aquifer. Kinney and others (1968) published the preceedings of a review of available hydrologic data on the Roswell aquifers. Havenor (1969) provided stratigraphic cross-sections of the artesian aquifer. The U.S. Geological Survey open-file reports by Welder (1971, 1977, 1980), although unpublished at present, contain up-to-date information on the geohydrology of the Roswell Basin.

The upper boundary of the shallow aquifer is the water table. Recharge to this unit is by rainfall, irrigation return flow (from application of both groundwater and water from the Pecos River) and upward leakage (Welder, 1980). Discharge is from pumping, evaporation, and seepage into the Pecos River.

The lower boundary of the shallow aquifer is a recharge boundary, where upward leakage from the Artesia Group occurs (Welder, 1980). The eastern boundary of the shallow aquifer is the Pecos River (Welder, 1980; Kinney and others, 1968). Northern, southern, and western boundaries are the extent of valleyfill in the Roswell Basin.

The transmissivity of the shallow alluvial aquifer has been estimated to be between 31,000 and 139,000 gallons/day/foot (Hantush, 1955); a basinwide average for the transmissivity of the shallow aquifer has been estimated at 100,000 gallons/day/foot (Kinney and others, 1968).

The higher-yielding wells that tap the shallow aquifer were pumped at about 2,200 gpm in 1979. Most of the shallow-aquifer wells are cased with 8-inch casings and can be pumped at about 500 gpm (Welder, 1980). Approximately 125,000 acres are irrigated in the Roswell Basin, two-thirds using the artesian aquifer and one-third using the shallow aquifer (Slingerland, New Mexico Interstate Stream Commis sion, personal communication, 1980). Based on this proportion, the annual withdrawal of groundwater from the shallow alluvial aquifer in Region IV is estimated to be 104,000 acre-feet per year. Annual recharge to the shallow aquifer (basinwide) is estimated at 150,000 to 195,000 acrefeet per year. Water quality in the shallow aquifer generally is good (500 ppm chloride), except where highly saline waters have encroached on the aquifer from the area northeast of Roswell (Kinney and others, 1968; Welder, 1980).

Welder (1980) notes that in times of heavy pumpage of the artesian aquifer for agricultural use, the potentiometric surface of the artesian aquifer may drop below that for the watertable aquifer, in which case the alluvial aquifer may recharge the artesian aquifer on a seasonal basis.

Carbonate (Artesian) Aquifer

The artesian aquifer of the Roswell Basin consists of zones of high secondary porosity within the upper 260 to 460 feet of the Permian San Andres Limestone (Welder, 1980). South and east of Roswell, the base of the artesian aquifer rises stratigraphically above the top of the San Andres Limestone, extending 100 to 400 feet into the superjacent Grayburg and Queen Formations of the Artesia Group. The shales and limey dolomites of the Artesia Group comprise the leaky, confining bed for the San Andres Limestone in the western part of Region IV (Fiedler and Nye, 1933; Kinney and others, 1968; Havenor, 1966; Welder, 1980).

The eastern boundary of the artesian aquifer is the Pecos River fault zone. East of the river, the porosity and permeability of the San Andres Limestone and Artesia Group decrease markedly (Welder, 1980; Kinney and others, 1968).

The western boundary of the artesian aquifer is a north-south trending line where groundwater in the San Andres limestone, moving eastward under watertable conditions (from the recharge area in the western part and west of Region IV) becomes confined by the superjacent limey shales and dolomites of the Artesia Group (Kinney and others, 1968; Welder, 1980).

The southern boundary of the artesian aquifer is 12 to 18 miles south of the southern limits of Region IV and occurs where the San Andres Limestone interfingers with the less porous sandstones of the Delaware Mountain Group (Welder, 1980). The northern boundary of the artesian aquifer is unknown; north of Region IV, production of artesian groundwater from the San Andres Limestone is unknown.

The transmissivity of the San Andres Limestone has been estimated at 1.4 to 1.9 million gallons/day/foot for the oolitic and biostromal limestone facies of high secondary porosity (Hantush, 1961). Kinney and others (1968) estimate its transmissivity to be much lower in areas of low secondary porosity, decreasing to as little as 40,000 gallons/day/foot. An average basinwide transmissivity for the artesian aquifer is 300,000 gallons/day/foot (Kinney and others, 1968). The average storage coefficient for the artesian aquifer is approximately 1.5×10^{-5} (Hantush, 1955).

Based upon estimates of the amount of groundwater from the artesian aquifer used for irrigation (Slingerland, New Mexico Interstate Stream Commission, Santa Fe, 1980, personal communication), the annual withdrawal in the Chaves County part of the Roswell Basin is approximately 184,000 acre-feet per year. Estimated total basinwide recharge to the artesian aquifer is 235,000 acre-feet per year (Fiedler and Nye, 1933).

The yields of wells that tap the artesian aquifer depend on the rate of pumping and diameter of well casing. The higher yielding wells were pumped at a rate of 3,300 gpm in 1979. Wells equipped with 6-, 8-, and 10-inch casing are pumped at rates of about 450, 800 and 1,400 gpm, respectively (Welder, 1980).

Water quality of the artesian aquifer in the western part of Region IV is generally good (500 ppm chloride), but the water quality deteriorates to the east of Roswell. Salinity, caused by migration of brines from east of the Pecos River, is in response to intense pumping of fresh water from the aquifer near Roswell (Welder, 1980).

Region V - Union County and Vicinity, New Mexico (3.2.4-5)

Region V, Union County and vicinity, is located on the Great Plains of northeastern New Mexico (Figure 3.2.1-2). The principal aquifers of Region V (Griggs, 1948) are the hydrologically interconnected Cretaceous Dakota Sandstone and Purgatoire Formation, which are treated as one aquifer system (Kdp), and the Tertiary Ogallala Formation (To). Less important aquifers are the Jurassic Morrison Formation (Jm) and the Triassic Dockum Group (Trd). Groundwater generally occurs under water table conditions in these aquifers.

Recharge to the aquifers of Region V, with the exception of the Ogallala Formation, is by subsurface inflow across the western boundary of the region and by percolation of precipitation and streamflow. The Ogallala Formation is recharged only by direct precipitation and by deep percolation of excess water applied for irrigation.

Groundwater in all aquifers is discharged naturally by eastward subsurface outflow from the region. Groundwater pumpage in most of Region V is for small-scale domestic, irrigation, and stock uses, although production from the Ogallala Formation in the eastern part of Union County is for large-scale irrigation supplies. In these heavily pumped areas, water levels in the Ogallala Formation are declining at rates ranging from 0.2 to 1.2 feet per year (Hudson, 1976).

The delineation of 14 subregions in Region V is based on both the stratigraphic and geographic distribution of the major aquifer systems, as shown on Figure 3.2.1-2. The areal coverage of saturated thickness data in Region V is adequate to assess the availability of groundwater in all subregions, except V-Jm and V-Trd-j in the northeastern part of New Mexico.

Well yield data for the Ogallala (To) and Dakota-Purgatoire (Kdp) aquifer systems in Region V, although less common than saturated thickness data, were judged adequate to assess the production characteristics of the aquifers. Well yield data in subregions V-To-g, -h, and -i; and V-Kdp-b, -c, -d, and -i are rare. Average well yields of the Ogallala Formation in subregions V-To-g, V-To-h, and V-To-i (200, 250, and 250 gpm, respectively) were assumed to be similar to the average well yields in subregion V-To-e, a subregion with similar saturated thickness. Wells that tap the Dakota-Purgatoire aquifer system (Kdp) in Region V generally have the potential to yield 100 gpm (Cooper and Davis, 1967). Therefore, in subregions V-

Kdp-b, -c, -d, and -i, where subregion-specific well yield data are not available, an average well yield of 100 gpm has been assumed.

A specific yield of 0.10 has been assumed for V-Kdp subregions (Griggs, 1948), and 0.15 has been assumed for V-To subregions (Cronin, 1969).

The depth to water (potentiometric surface) ranges from several tens to several hundreds of feet.

Wells that tap the Ogallala Formation generally produce good quality water. Wells that tap the Dakota-Purgatoire aquifer and other bedrock units produce water that ranges in quality from good to poor for municipal uses; concentrations of total dissolved solids greater than 1,000 mg/l occur in these bedrock units throughout Region V.

Depletion rates were either: (1) calculated from rates of water level decline; (2) estimated from the acreage irrigated with groundwater; or (3) estimated from the distribution and uses of wells, as described in published reports. The calculated rates of groundwater depletion and methods of calculating these rates for each subregion are presented in Table 3.2.1-2.

Region VI - Northeastern Trassic and Jurassic Complex, New Mexico (3.2.4.6)

Region VI, the area referred to as the Northeastern Triassic and Jurassic Complex, is located in northeastern New Mexico, as shown on Figure 3.2.1-2. The principal aquifers of Region VI are the Cretaceous Dakota Sandstone (Kd), the Jurassic Entrada Sandstone (Je), and the Triassic Santa Rosa (Trs) and Chinle (Trc) formations. Region VI was divided into four subregions, based on the stratigraphic and geographic distribution of the principal aquifers (Figure 3.2.1-2). Groundwater generally occurs under watertable conditions in these aquifers.

Recharge to the aquifers of Region VI is primarily by percolation of precipitation and runoff in ephemeral streams. Domestic, stock, municipal, and irrigation wells withdraw relatively small amounts of groundwater, except in subregions VI-Kd-a, VI-Je, and VI-Trc,s. In these three subregions, large amounts of groundwater are pumped for irrigation. Discharge exceeds recharge in subregion VI-Je, as shown by a decline in water levels at localized rates of up to 1.8 feet per year (Trauger and Bushman, 1964). Recharge exceeds discharge, however, in the irrigated area (immediately east of Tucumcari and (encompassing part of subregion VI-Trc-b), because of irrigation with water imported via the Conchas Canal, as indicated by the rise of water levels at rates of about 1.8 feet per year (Berkstresser and Mourant, 1966).

Depths to water range from several tens to several hundred of feet. The quality of groundwater in the Chinle Formation is poor, with many wells producing water with a total dissolved solids content greater than 1,000 mg/l. The quality of groundwater produced from the Entrada Sandstone ranges from good to fair. Water quality data for other subregions of Region VI are sparse.

A specific yield value of 0.10 has been assigned to the Dakota, Santa Rosa, and Chinle formations in Region VI. This value has been assigned on the basis of equivalent specific yield values for these formations in other regions (Griggs, 1948).

Trauger and Bushman (1964) report values of specific yield for core samples of the Entrada Sandstone ranging from 0.23 to 0.29. The more conservative value of 0.23 is used in this study to estimate availability of groundwater.

The depletion rate in subregion VI-Je (1,800 acre-feet per year) is due to pumpage for municipal and irrigation uses. Part of subregion VI-Je is exhibiting a water level decline of 0.03 feet per year. The relatively large depletion rate in subregion VI-Trc,s (20,500 acre-feet per year) is caused by irrigation pumpage, principally in the Logan and Porter area.

Region VII - Clovis and Portales Area, New Mexico (3.2.4.7)

Region VII, the Clovis and Portales Area, is located in east-central New Mexico, as shown on Figure 3.2.1-2. The principal aquifers in the area are the Ogallala Formation (To) in Curry and Quay counties and the Quaternary alluvium that underlies the Portales Valley in Roosevelt County. The Quaternary alluvium and Ogallala Formation forms a single hydrologic unit (Cronin, 1969). In the western and northern part of the region, where the Ogallala Formation is relatively thin, some wells produce from the Dockum Group (Trd). Yields of wells that tap the Dockum Group are generally less than 100 gpm, and the groundwater is saline. The Dockum Group probably is unsuitable in most of Region VII for irrigation or municipal supplies (Cronin, 1969) and is therefore considered to be a minor aquifer. Groundwater generally occurs under watertable conditions in these aquifers.

As elsewhere in the High Plains of New Mexico and Texas, infiltration of precipitation is virtually the sole source of natural recharge to the Ogallala aquifer and the hydraulically connected alluvium in the Portales Valley. Precipitation on the sand hills that run along the northern part of the Portales Valley is probably an important source of recharge to the Quaternary alluvium.

The Ogallala Formation is pumped heavily for irrigation, both in Region VII and in adjoining areas in Parmer and Bailey counties, Texas, to the east. The major irrigated areas in Region VII are the Portales Valley, Clovis area in east-central Curry County, and House area in Southwestern Quay County (Figure 3.2.1-2). Although some of the irrigation water returns to the aquifer, most is lost by evapotranspiration. Pumpage of the Ogallala Formation for irrigation has resulted in a significant overdrafting of the aquifer. A depletion rate of 154,000 acre-ft per year was calculated for the Ogallala-Portales Valley aquifer in Region VII (Table 3.2.1-1).

The Ogallala Formation generally is thickest in eastern Curry County. The Quaternary alluvium in Portales Valley was deposited on an erosion surface on rocks of Triassic age and generally thickens to the east.

Yields of wells range from less than 100 to greater than 1,000 gpm. Yields are generally higher in areas where the saturated thickness of water-bearing deposits is greater. Yields of wells in the heavily irrigated areas are generally greater than 500 gpm (Cronin, 1969; Theis, 1932; Berkstresser and Mourant, 1966).

The depth to water (potentiometric surface) generally ranges from 30 to 90 feet in the Portales Valley and from 40 to 80 feet in the House area. In eastern Curry County, depths to water generally exceed 200 feet and are greater than 400 feet in some locations (Hudson and Borton, 1974). The depth to water in Region VII depends on the topography of the land surface, proximity to recharge and natural discharge, proximity to areas of withdrawal through wells, and the configuration of the bedrock surface.

Water quality from wells that tap the Ogallala Formation and Portales Valley alluvium generally is good for most irrigation and municipal supply purposes. The concentration of total dissolved solids is generally less than 500 mg/l. However, the hardness of the groundwater is high, and the relatively high fluoride concentration may make it objectionable for municipal uses (Cronin, 1969; Berkstresser and Mourant, 1966). The specific yield of the Ogallala-Portales Valley aquifer is estimated to be 0.15 (Cronin, 1969).

Region VII - East-Central Pecos Area, New Mexico (3.2.4.8)

Region VIII, the East-Central Pecos Area, is located in southeastern New Mexico, as shown on Figure 3.2.1-2. The principal aquifers of Region VIII are the Tertiary Ogallala Formation (To), the Cretaceous Dakota Sandstone locally called the Tucumcari aquifer (K), the Triassic Chinle Formation (Trc), and undiffereneti-ated Triassic units (Tr). Groundwater generally occurs under watertable conditions in these aquifers. Data available outside the region suggest that the top of the San Andres Limestone (Psa) is more than 2,000 feet deep under most of Region VIII and probably contains saline water (Mourant and Shomaker, 1970). Region VIII was divided into three subregions (Figure 3.2.1-2), based on the stratigraphic and geographic distribution of principal aquifer systems.

Information that pertains to the Triassic aquifers is insufficient to evaluate the availability of groundwater and production characteristics of these aquifers. The only available hydrogeologic data for the Triassic aquifers are in the extreme northern part of the region in De Baca County. These data are inadequate to define the amount of groundwater in storage, primarily because there are no values for saturated thickness. Also, available data on well yields from within the region and specific capacity data from adjacent areas (Berkstresser and Mourant, 1968; Griggs and Hendrickson, 1951) indicate that potential well yields are probably small. Therefore, the Triassic aquifers are considered to be a relatively minor source of groundwater supply.

Commonly, both the Tucumcari aquifer (K) and the superjacent, hydrologically interconnected Ogallala Formation (To) are penetrated by irrigation wells in the vicinity of Causey and Lingo in Roosevelt County and, therefore, were treated as one aquifer system (subregion VIII-ToK) in this study. For the region as a whole, however, the Cretaceous (K) rocks do not constitute an important source of groundwater for large scale irrigation, municipal supply, or other large uses (Cronin, 1969).

Groundwater in the Tucumcari aquifer is recharged by subsurface inflow across the northwestern boundary of the region and by infiltration of precipitation. The Ogallala Formation is recharged only by direct precipitation; the flow of groundwater in the formation is generally to the southeast. Pumpage for irrigation in subregion VIII-ToK represents the largest use of groundwater in the region, resulting in rates of water level decline of up to 2.3 ft per year in some areas (Hudson and Borton 1974).

Hydrogeologic data are few for the Ogallala and Tucumcari aquifers outside of the Causey-Lingo area (Figure 3.2.1-2). Therefore, a boundary delineating the area judged to contain adequate well data was drawn around the Causey-Lingo area. The area within this boundary has been used in Section 5.0 to calculate the volume of groundwater in storage. Undoubtedly, these aquifers extend beyond the subregion boundary, but their configuration and hydrologic characteristics cannot be reliably determined.

The specific yield of the Ogallala Formation in Region VIII is estimated to be 0.15 (Cronin, 1969). A specific yield of 0.10 was assigned to the Tucumcari aquifer, the same value reported for the Dakota Sandstone in other regions (Griggs, 1948).

The depletion rate of 26,400 acre-feet per year for Subregion VIII-ToK in the Causey-Lingo area (Table 4.2.1-3) was estimated by multiplying the 11,000 acres irrigated with groundwater (Sorensen, 1977) by the 2.4-ft-per-acre consumptive irrigation requirement (Blaney and Hansen, 1965).

The depth to water (potentiometric surface) generally ranges from 50 to 150 feet (Figure A-16). Irrigation wells that tap the Tucumcari aquifer have an average yield of about 500 gpm. Groundwater from wells that tap the Ogallala and Tucumcari aquifers ranges in quality from good to fair for irrigation and municipal uses. The total dissolved solids content generally exceeds 500 mg/l.

Region IX - Central Pecos Area, New Mexico (3.2.4.9)

Region IX, the Central Pecos Area, is located in east-central New Mexico, as shown on Figure 3.2.1-2. This region contains many aquifers: the Permian San Andres Formation (Psa), Glorieta Sandstone (Pg), and Artesia Group (Pat); the Triassic Santa Rosa Sandstone (Trs) and Chinle Formation (Trc); older alluvium and terrace deposits of the Pecos River (Qab); and younger alluvium (Qal). In most of Region IX, groundwater supplies are meager and sparse (Mourant and Shomaker, 1970). Associated with the lack of development of groundwater resources is a lack of published hydrogeologic information. The southern part of Region IX in Chaves County is not discussed in the hydrologic literature. Region IX has been divided into eight subregions (Figure 3.2.1-2), based on the stratigraphic and geographic distribution of the principal aquifer systems.

The San Andres Formation (Psa) crops out in the southwestern part of Region IX; however, the hydrogeology of most of this area is not discussed in published reports. In De Baca County, only stock wells yielding a few gallons per minute have been completed in the San Andres Formation. Water of the San Andres is of poor quality and occurs generally under watertable conditions, except where water levels rise into the overlying Artesia Group (Pat).

The Glorieta Sandstone is the oldest water-bearing formation in Region IX. Groundwater of the Glorieta occurs under watertable conditions, and yields of water wells are generally less than 20 gpm (Mourant and Shomaker, 1970).

Wells that tap the Artesia Group (Subregion IX-Pat) generally yield less than 10 gpm of poor quality water. Groundwater occurs under watertable conditions in this unit and stratigraphically younger units (Trs, Trc, Qab, Qal) in Region IX (Mourant and Shomaker, 1970).

The Santa Rosa Sandstone (subregions IX-Trs-a and -b) is the best aquifer in Region IX from the standpoint of quality and production characteristics. Wells in subregion IX-Trs-b north of Fort Sumner and east of the Pecos River yield up to 1,000 gpm and are used to irrigate a few thousand acres. At one time, some of the old municipal wells at Fort Sumner yielded 75 gpm. Generally, yields of wells that tap the Santa Rosa Sandstone are less than 15 gpm (Mourant and Shomaker, 1970). The quality of water in the Santa Rosa Sandstone is fair to poor, but generally is satisfactory for municipal use.

Wells that tap the Chinle Formation (Subregion IX-Trc) yield only a few gallons per minute of poor quality water. The poor quality of the groundwater is due to soluble material in the shale and gypsum beds that comprise the Chinle Formation (Mourant and Shomaker, 1970).

The older alluvium of the Pecos River (Qab) is used for irrigation in subregion IX-Qab. Elsewhere, both east and west of the Pecos River, the older alluvium is thin and lies above the zone of saturation. Only in this subregion are hydrogeologic data sufficient to estimate the availability of groundwater (Table 3.2.1-1). The depth to water (Potentiometric surface) is approximately 100 feet (Hudson, 1976). The quality of the groundwater in the older alluvium generally is satisfactory for irrigation, but the water may be too saline for municipal use. The specific yield of these deposits has been assumed to be 0.15.

Younger alluvium (Qal) fills the inner valley of the Pecos River. In Subregion IX-Qal-a, the younger alluvium provides domestic and stock water in the area served by the Fort Sumner Irrigation District (Mourant and Shomaker, 1970). In Subregion IX-Qal-b near Taiban, the alluvium is up to 100 feet thick and yields up to 1,500 gpm to wells. The younger alluvium is used for irrigation supplies in this area, and the quality of the groundwater is generally satisfactory for irrigation use.

Groundwater in Region IX is recharged mainly by precipitation and moves generally toward the Pecos River. Groundwater is discharged to the Pecos River and moves southward as underflow in the Pecos River alluvium or is transpired by phreatophytes.

No trend of permanent declines in water levels has been noted in the irrigated areas south of Taiban (Subregion IX-Qal-b) or north of Fort Sumner (Subregion IX-Trs-b). Springs identified on aerial photographs taken in 1939 were still active, indicating little change in groundwater conditions in these areas (Mourant and Shomaker, 1970). Groundwater levels in Subregion IX-Qab also have shown no consistent decline (Hudson, 1976), which is probably a result of recharge from surface water irrigation in the Fort Sumner Irrigation District.

3.3 BERYL OB SITE

GENERAL HYDROLOGY (3.3.1)

The Beryl, Utah area lies within the Escalanate Desert portion of the Cedar Hydrologic Unit (Utah State University, 1963). Sandberg (1966) reported that valleyfill deposits constitute the only known aquifer within the area. The valleyfill deposits consist of interbedded gravel, sand, silt, and clay. Records compiled by the U.S. Geological Survey (1979) indicate that the depth to ground water is less than 50 ft west of Beryl but exceeds 200 ft along the valley margins at higher topographic elevations. The direction of groundwater movement is from the valley margins toward the center of the valley and north-west toward Lund (Sandberg, 1966). Utah Division of Water Resources (1979) reported water-level declines of less than 20 ft for the Beryl Enterprise area during the period 1977 to 1978. Nearly all recharge to groundwater comes directly or indirectly from precipitation in the mountains. A small amount of underflow from Cedar City Valley moves through alluvial deposits in mountain range gaps.

WATER AVAILABILITY (3.3.2)

Perennial yields of 5,000 to 35,000 acre-ft have been estimated for the groundwater system in the Escalante Desert area. According to the Utah Division of Water Resources, groundwater use in the Beryl-Enterprise area averaged 79,000 acre-ft per year for the 15-year period from 1963 to 1977. Groundwater withdrawals for some years were as high as 93,000 acre-ft; however, withdrawals for 1978 totaled only 70,650 acre-ft. Of that amount, about 69,600 acre-ft were used for irrigation, 750 for domestic and stock use, and 300 for municipal purposes.

WATER QUALITY LIMITATIONS (3.3.3)

According to Sandberg (1966), groundwater in the Beryl area is either fresh or slighly saline with best quality groundwater located in the southern part of the area. The poorest quality water occurs 1 to 3 mi south of Beryl where pumpage is the highest. Of 13 groundwater analyses reported by Sandberg, six exceeded the U.S. Environmental Protection Agency (EPA, 1976) quality criterion for nitrate (10 mg/1), four samples exceeded the EPA criterion for sulfate (400 mg/1), and two samples exceeded the criterion for calcium (200 mg/1). Four of the groundwater samples were hard, that is, they contained greater than 1 150 mg/1 of calcium carbonate ($CaCO_3$).

3.4 COYOTE/SPRINGS OB SITE

GENERAL HYDROLOGY (3.4.1)

The main body of groundwater occurring in the valleyfill is probably at depths of 270 ft or more. However, around Coyote Spring, some "semi-perched" groundwater exists at shallower depths. Beneath the valleyfill groundwater system is the regional carbonate aquifer that is part of the White River system (See Figure 3.4.1-1).

WATER AVAILABILITY (3.4.2)

The combined perennial yield of groundwater in Coyote Spring and Kane Springs valleys is estimated to be on the order of 2,600 acre/ft (Eakin, 1964), which is equivalent to the estimated average annual recharge derived from precipitation within the area. The State Engineer's Office estimated (in 1971) a perennial yield of 18,000 acre/ft for Coyote Spring Valley, with less than 500 acre/ft for Kane Springs Valley. The substantial difference between the perennial yield estimates by Eakin (1964) and the State Engineer's office is due to the consideration of inter-basin underflow of groundwater in the Coyote Spring hydrological basin.

Coyote Spring and Kane Springs valleys are used principally for livestock range and use very minor amounts of water. Substantial local development of groundwater

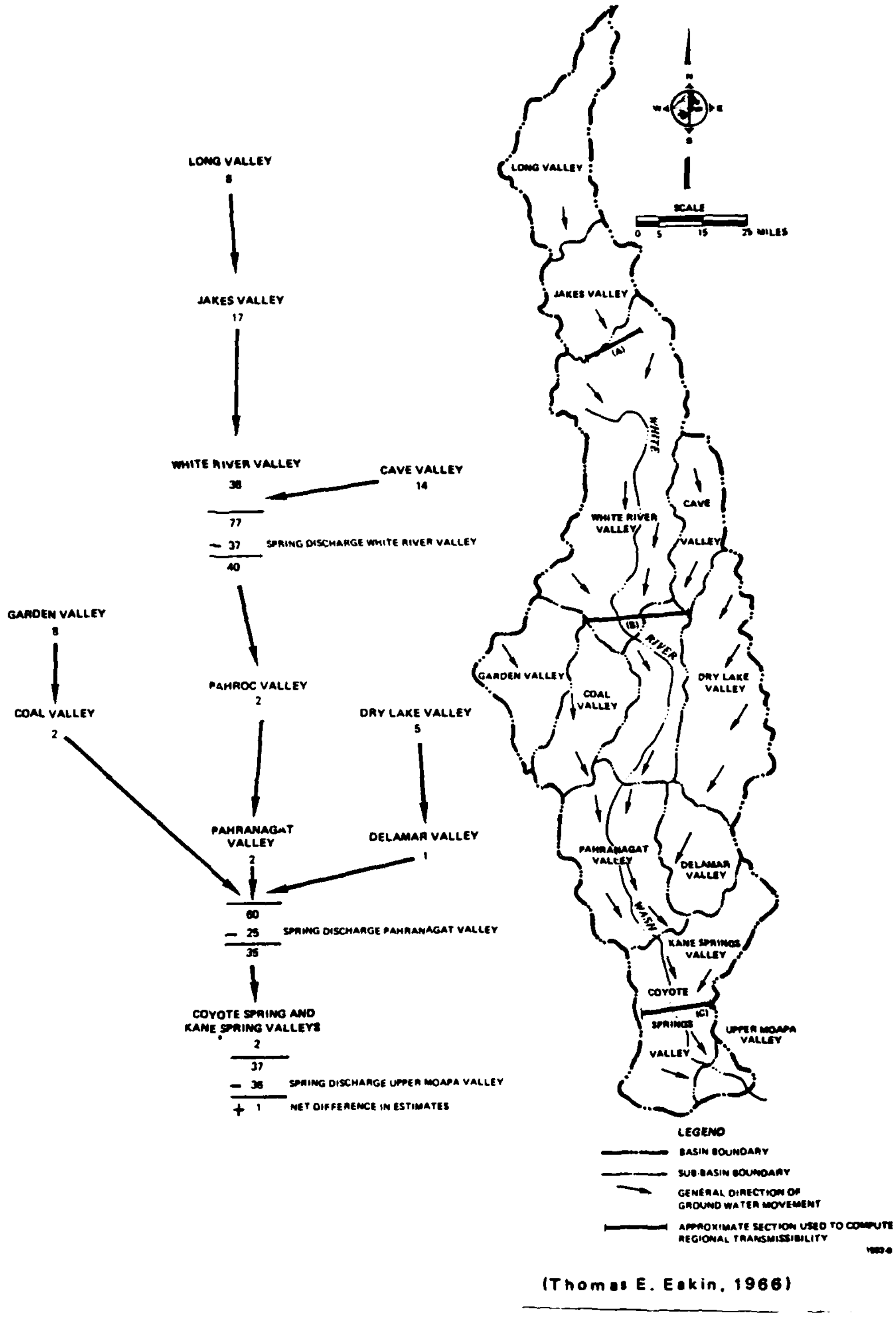

Figure 3.4.1-1. Interbasin groundwater system.

for irrigated agriculture is concentrated in the adjacent area of Muddy River Springs to the southeast of Coyote Spring Valley. In addition to groundwater use, the majority of local Spring discharge (37,000 AFY) is also used.

WATER QUALITY LIMITATIONS (3.4.3)

The chemical quality of the groundwater in parts of the valleyfill apparently is poorer than that of the water discharged from the springs. Few data are available concerning groundwater quality in the Coyote Spring and Kane Springs valleys. The chemical quality of the water in most ground-water systems in Nevada varies considerably from place to place (Eakin, 1964). Existing analyses of water from the springs in the Coyote Spring and Kane Spring valleys indicate that the water from the springs has a dissolved solids content of about 620 milligrams per liter (mg/l) and is high in sodium, calcium, bicarbonate, and sulphate.

The water from Muddy River Springs is classified as hard. In addition, the reported concentration of 2.4 mg/l fluoride in the water is relatively high and reaches the upper limits for this element concentration recommended by the U.S. Public Health Service (1962). However, in general, the water quality in Coyote Spring and Kane Springs valleys offers no constraints for construction usage, and the quality remains suitable for all ordinary purposes (Eakin, 1964).

3.5 DELTA OB SITE

GENERAL HYDROLOGY (3.5.1)

The Delta site area is located within the Sevier Desert, which covers about 3,000 square mi, and is within the Sevier Hydrologic Unit as defined by Utah State University (1963). Mowe and Feltis (1968) identified the three principal aquifers within this area as valleyfill deposits, fractured volcanic rocks of Tertiary age, and fractured carbonate rocks of Paleozoic age. The valleyfill deposits consist of interbedded gravel, sand, silt, clay, and evaporites. The evaporites are located primarily in the play area in the west-central portion of the valley. Gravel and sand exist mainly in alluvial fans along the margins of the valley. Extensive cementation has occurred in the older valleyfill materials. The fractured volcanic rock aquifer is composed of tuffs and lava flows. The Paleozoic carbonate rocks crop out in the mountain ranges flanking the valley and provide conduits for transmitting water to the younger valleyfill deposits.

The water table within the valleyfill aquifer slopes to the southwest as well as toward the valley axis (Mower and Feltis, 1968). Records compiled by the U.S. Geological Survey (1979) and groundwater level measurements taken by Fugro National in 199 and 1980 indicate that the depth to groundwater is less than 10 ft in the Delta area, with several flowing wells reported. However, depths to water exceed 200 ft along the valley margins at higher topographic elevations. The Utah Division of Water Resources (UDWR, 18) reported that a slight rise in groundwater levels occurred between 1977 and 18, but that an overall decrease of about 6 ft has occurred since 1955.

The principal sources of groundwater recharge are probably seepage losses from streams, the Sevier River, and canals and irrigation ditches. Most of the precipitation which provides recharge falls as snow during the winter on the coarse unconsolidated sediments along the north and east edge of the basin.

WATER AVAILABILITY (3.5.2)

The perennial yield estimates discussed here apply to the Sevier Desert as a whole but are principally based upon pumping records and ground-water level decline rates for the Delta area. The precise perennial yield of ground water for the Sevier Desert is unknown. Eakin, Price, and Harrill (1976) made a provisional water system yield approximation of over 100,000 acre/ft per year, however, this quantity also includes the surface water system. Surface water discharge measurements recorded by Hahl and Mundorff (1968) for the Sevier River indicate that discharge between the towns of Lynndyl and Deseret decreased by 105.5 cfs or 72,600 acre/ft during 1968 due to diversion, evaporation, and losses to the groundwater system. This would reduce the water yield of the area to about 27,400 acre/ft per year, which is principally groundwater. Using the Hill method described by Todd (1959, page 207), a perennial yield of 23,000 acre/ft is estimated for the groundwater system in the Sevier Desert area.

According to UDWR (1978), a groundwater usage in the Sevier Desrt averaged 28,000 acre/ft per year for the fifteen year period from 1963 to 1977. Recent groundwater withdrawal has significantly increased, however, reaching 50,300 acre/ft in 1977. Of that amount, 46,800 acre/ft were used for irrigation, 2,000 acre/ft were extracted for industrial use, and municipal and domestic pumpage used an additioal 1,500 acre/ft.

WATER QUALITY LIMITATIONS (3.5.3)

Mower and Feltis (1968) reported that, with the exception of the Delta area, groundwater quality within the Servier Desert is generally poor. Of 36 groundwater samples collected by Mower and Feltis, six exceeded the Environmental Protection Agency (EPA, 1976) quality criteria for sulfate (250 mg/l) and eight samples exceeded the EPA quality criteria for both chloride (250 mg/l) and total dissolved solids (500 mg/l for sulfate plus chloride). Locally, groundwater may be hard, i.e., containing greater than 150 mg/l calcium carbonate ($CaCO_3$). The aforementioned groundwater samples from wells contained $CaCO_3$ concentrations ranging from 11 to 1120 mg/l with 16 samples out of 36 exceeding 150 mg/l. The sodium concentrations of twenty samples were found to exceed the U.S. Salinity Laboratory Staff (1954) limits for irrigation water. The use of such water for irrigation would require special management and treatment.

3.6 ELY OB SITE

GENERAL HYDROLOGY (3.6.1)

An Ely site is located in the southern portion of Steptoe Valley and occupies about 1975 mi^2 within the Central Hydrologic Region as defined by the Nevada Division of Water Resources (1971). Eakin, Hughes, and Moore (1967) identified the two principal aquifers within the valley as 1) valleyfill deposits, and 2) fractured carbonate rocks of Palezoic age. The valleyfill deposits consist of interbedded gravel, sand, silt, and clay. The fractured carbonate rocks underlie the valleyfill deposits and crop out in the mountain ranges flanking the valley to the east and west.

The water table within the valleyfill aquifer slopes northward as well as away from the mountains toward the valley axis (Eakin, Hughes, and Moore, 1967).

Several areas adjacent to Steptoe and Duck creeks were reported to have depths to water of less than 20 ft. Water-level records compiled by the Soil Conservation Service (Cheney, 1980, personal communication) indicate that there are several perched aquifers with groundwater levels about 20 ft below ground level. Depth to water quickly increases, however, to 60, and even to 100, ft below the land surface basinward from these perched aquifers. Records compiled by the Geological Survey (1978) indicate that groundwater levels in Steptoe Valley declined as much as 20 ft during the period from 1954 to 1964. Since that time, however, groundwater levels have recovered to their 1954 levels.

WATER AVAILABILITY (3.6.2)

The perennial yield of Steptoe Valley was estimated to be 70,000 acre-ft by Eakin, Hughes, and Moore (1967). This figure was based on estimated acreages and water consumption of desert shrubs and was also based upon the assumption that all of the water discharged through evapotranspiration is recoverable. According to estimates by the Nevada Department of Water Resources (Cardinalli, 1976, personal communication), the present groundwater use in Steptoe Valley is approximately 53,000 acre-ft per year. Agriculture is by far the largest user, withdrawing some 33,400 acre/ft per year. Industrial requirements were estimted to be 17,600 acre/ft per year in the State Water Planning Report of 1974 (Nevada Division of Water Resources, 1974). Less than 1,000 acre/ft per year were used for domestic and stock purposes, and municipal demands accounted for only about 1,200 acre/ft per year. Additionally, applications on behalf of the White Pine Power Project have been filed to use approximately 52,000 acre/ft per year. This action has led to the "designation" of Steptoe Valley as a critical groundwater basin by the State Engineer's Office because the total allocated quantity of water would exceed the estimated perennial yield.

WATER QUALITY LIMITATIONS (3.6.3)

The water quality is variable depending on the location with respect to recharge areas and depth to the water table. In general, the water quality in Steptoe Valley is good, according to analyses reported by Eakin, Hughes, and Moore (1967). Of 20 samples analyzed, however, two samples exceeded the Environmental Protection Agency (1976) quality criterion for sulfate (250 mg/l) and, accordingly, were classified as poor for drinking purposes. Locally, ground water may be hard, i.e., containing greater than 150 mg/l calcium carbonate. The $CaCO_3$ concentration in groundwater samples from wells ranged between 136 and 281 mg/l, and groundwater samples from springs ranged from 142 to 412 mg/l $CaCO_3$. Only one groundwater sample exceeded the Environmental Protection Agency (1976) criterion of 500 mg/l total dissolved solids for good drinking suitability, although this water is still within some standards for recommended drinking water.

3.7 MILFORD OB SITE

GENERAL HYDROLOGY (3.7.1)

The main aquifer in the Milford study area is the unconsolidated valleyfill deposits. In some areas, highly fractured carbonate rocks constitute a productive aquifer.

Groundwater recharge results from seepage of intermittent streamflow from the surrounding mountains and foothills and infiltration from irrigation ditches and fields.

WATER AVAILABILITY (3.7.2)

Annual water-level data compiled by Mower and Cordova (1974) indicate that water levels declined about 30 ft between 1950 and 1970, with the area of greatest decline centered 7 mi south of Milford. Water-level measurements were made by the U.S. Geological Survey for the period 1935-1955 and 1956-1970. The water-level decline is caused by pumping for irrigation. Based upon the withdrawal and decline rates, Mower and Cordova (1974) estimated the total annual recharge to the valleyfill doposits to be 58,000 acre/ft; it is assumed that this estimate is also the available perennial yield.

Total annual groundwater consumption is 65,000 acre/ft (Gates, et. al., 1978). Municipal and domestic uses total 1,000 acre/ft, and 64,000 acre/ft are used for irrigation. Except for 1973 when only 52,000 acre/feet were pumped, annual groundwater withdrawal has exceeded the perennial yield since 1970.

WATER QUALITY LIMITATIONS (3.7.3)

The quality of the groundwater contained in the valleyfill deposits is generally good to fair (Mower and Cordova, 1974), with total dissolved solids ranging from 224 to 4,600 mg/l with a median of 569 mg/l. However, there has been a consistent increase in total dissolved solids since 1950. In areas of intensive irrigation, the total dissolved solids concentration may exceed recommended drinking water standards (2,000 mg/l) set by the U.S. Department of Health, Education, and Welfare (1962). But overall, the groundwater is suitable for human consumption and construction.

3.8 CLOVIS OB SITE

The principal groundwater source in the Clovis area is the Ogallala Formation, in which wells are often completed in gravel and coarse sand zones typically found near the base of the formation. The thickness of saturated sediments in the area average about 100 feet. Depths of the water table around Clovis are generally from 200 to 400 ft. Precipitation is the only source of recharge. Heavy pumping aquifer life is 37 years.

New Mexico law requires a permit for water appropriation in declared underground basins. If purchase of water results in a change in use, New Mexico law requires approval by the state engineer.

3.9 DALHART OB SITE

The principal aquifer is sand and gravel beds interbedded with silt, sand, and caliche and ranges in saturated thickness from 61 x 10m to 1.52×10^2 m. Precipitation is the sole contributor to groundwater recharge. Withdrawals are 15 times the annual natural recharge. Heavy pumping has resulted in large water-level declines. The groundwater is acceptable for most uses.

4.0 WATER RESOURCE RELATED IMPACTS DUE TO M-X ACTIVITIES

4.1 NEVADA/UTAH DDA

M-X EFFECTS (4.1.1)

General (4.1.1.1)

The deployment of the M-X missile system will affect the water resources in potential siting areas in numerous ways. These effects can be categorized into two basic groups. The first group includes the placement of the roads, shelters, OBs, and ASCs. These will disrupt the physical setting of the area, thus altering the surface drainage characteristics. These effects can be termed long-term and unavoidable. This is so because all are necessary for the project and will exist throughout its useful life and probably beyond that time. Mitigation procedures may reduce potential impacts, but only a dramatic change in the proposed project can reduce the size of the M-X effects.

The second group of M-X induced effects on water resources is the demands for water for construction and operation activities. This type of effect can again be considered unavoidable. Construction demands will be short-term while the projected operational demands are long-term.

The amount of facilities and the associated water demands are presented in tables in the sections which follow.

M-X Water Demands (4.1.1.2)

DDA Construction

The DDA construction would require water for the protective structures, cluster roads, DTN and ASCs. Components in the construction activities requiring water include earthwork, concrete and concrete plants, aggregate plants, domestic uses, dust control and irrigation for revegetation. The demands will necessitate diversions at specific locations (yet to be determined) throughout the project area.

Table 4.1.1.2-1 presents the estimated quantity of water that would be required in each hydrologic subunit in the siting area for the Proposed Action and Alternatives 1-6. Also presented is the number of protective shelters and amount of roads. Potential locations for construction camps are also presented in Table 4.1.1.2-1. The quantity of water that will be required for activities in these camps will be a significant portion of the total required for the subunit.

The range of values listed for water demands is basically a function of exclusion (minimum values) or inclusion (maximum values) of irrigation for revegetation of disturbed areas. A thorough description of the procedure used for calculating these demands is presented in Appendix A.

Alternative 8 locates facilities in fewer subunits than in the full basing alternatives. Table 4.1.1.2-2 presents the affected subunits, the amount of facilities in each and an estimate of the water demands for construction activities.

Table 4.1.1.2-1. MX construction water requirements by hydrologic subunit for the DDA in Nevada/Utah (sheet 1 of 3).

AREA NO.	HYDROGRAPHIC AREA	NO. OF PROTECTIVE STRUCTURES	MILES OF CLUSTER ROADS	MILES OF DTN	NO. OF CONSTRUCTION CAMPS	PEAK YEAR		TOTAL PROJECT	
						RANGE X 10^3 ACRE-FT	MPQ[1] X 10^3 ACRE-FT	RANGE X 10^3 ACRE-FT	MPQ[1] X 10^3 ACRE-FT
4	Snake	345	464	88	1	2.8-5.0	3.2	5.1-11	7.7
5	Pine	115	155	65	1	2.4-3.3	2.5	3.8-6.0	4.7
6	Tule	161	216	87	1	2.2-3.5	2.4	4.0-6.9	5.0
7	Fish Springs Flat	69	93	22	0	0.3-1.0	0.4	0.6-1.8	1.1
8	Dugway	69	93	17	0	0.3-1.0	0.4	0.6-1.8	1.1
9	Government Creek	23	31	0	0	0.1-0.3	0.2	0.8-1.2	1.0
46	Sevier Desert	276	371	98	1[2]	2.4-5.8	4.0	4.5-12	6.6
46A	Sevier Desert-Dry Lake	92	124	47	1	2.1-3.0	2.4	2.4-4.4	3.3
54	Wah Wah	184	247	48	1	2.6-4.4	3.0	4.0-7.2	5.4
137A	Big Smoky	115	155	27	0	0.6-1.8	0.9	1.0-3.0	1.9
139	Kobeh	161	216	60	1	2.7-4.1	2.8	4.0-6.9	5.2
140A	Monitor	138	185	25	0[2]	0.7-3.8	0.8	1.1-6.0	2.2
141	Ralston	207	278	60	1	3.8-6.0	4.5	5.1-8.8	6.7
142	Alkali Spring	115	155	22	0	0.6-1.8	1.0	1.0-2.9	1.8
149	Stone Cabin	138	185	59	1	2.4-4.0	2.6	3.01-5.5	4.0
151	Antelope	138	185	40	1	2.3-3.9	2.7	3.3-5.7	4.3

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[1]MPQ - Most Probable Quantity.

[2]Indicates an additional construction camp is possible if proposed construction camp location is not acceptable.

Table 4.1.1.2-1. MX construction water requirements by hydrologic subunit for the DDA in Nevada/Utah (sheet 2 of 3).

AREA NO.	HYDROGRAPHIC AREA	NO. OF PROTECTIVE STRUCTURES	MILES OF CLUSTER ROADS	MILES OF DTN	NO. OF CONSTRUCTION CAMPS	PEAK YEAR		TOTAL PROJECT	
						RANGE X 10^3 ACRE-FT	MPQ[1] X 10^3 ACRE-FT	RANGE X 10^3 ACRE-FT	MPQ[1] X 10^3 ACRE-FT
154	Newark	69	93	50	1	1.6-2.6	1.9	2.7-5.3	3.7
155A	Little Smoky,N	92	124	30	0[2]	0.5-3.1	0.8	0.8-4.5	1.5
155C	Little Smoky,S	69	93	12	1	1.4-2.2	1.8	2.1-3.3	2.7
156	Hot Creek	184	248	48	0[2]	0.8-3.4	1.3	1.4-5.8	2.6
170	Penoyer	138	185	22	0[2]	0.7-3.9	0.9	1.1-6.3	2.2
171	Coal	115	155	42	1	1.8-3.0	2.7	4.7-6.4	3.3
172	Garden	115	155	29	0[2]	0.6-3.0	1.4	1.0-6.4	1.9
173A	Railroad, S	138	186	42	1	2.5-3.6	2.7	3.9-6.0	4.8
173B	Railroad, N	207	278	116	1	2.0-3.9	2.6	2.6-6.0	3.6
174	Jakes	92	124	33	0[2]	0.5-1.5	0.7	0.8-2.5	1.5
175	Long	69	93	40	1	1.6-2.1	1.6	2.6-3.9	3.1
178B	Butte, S	92	124	30	0[2]	0.6-1.8	0.9	1.0-3.0	1.9
180	Cave	69	93	10	0	0.6-1.6	1.0	0.6-1.7	1.1
181	Dry Lake	207	278	35	2	1.9-2.7	2.2	5.3-3.9	6.8
182	Delamar	69	93	20	0[2]	0.4-2.7	0.6	0.6-3.9	1.1
183	Lake	115	155	28	1	2.1-3.5	2.7	2.5-4.4	3.3

2465

[1]MPQ - Most Probable Quantity.

[2]Indicates an additional construction camp is possible if proposed construction camp location is not acceptable.

Table 4.1.1.2-1. MX construction water requirements by hydrologic subunit for the DDA in Nevada/Utah (sheet 3 of 3).

AREA NO.	HYDROGRAPHIC AREA	NO. OF PROTECTIVE STRUCTURES	MILES OF CLUSTER ROADS	MILES OF DTN	NO. OF CONSTRUCTION CAMPS	PEAK YEAR RANGE X 10^3 ACRE-FT	PEAK YEAR MPQ[1] X 10^3 ACRE-FT	TOTAL PROJECT RANGE X 10^3 ACRE-FT	TOTAL PROJECT MPQ[1] X 10^3 ACRE-FT
184	Spring	46	62	16	0[2]	0.4-2.5	0.7	0.4-2.7	0.8
196	Hamlin	138	185	40	0[2]	0.6-3.6	0.7	1.2-6.3	2.2
202	Patterson	23	31	0	0	0.2-0.6	0.3	0.2-0.5	0.3
207	White River	161	216	34	0	0.8-2.5	2.0	1.8-4.0	2.6
208	Pahroc	0	0	20	0	0.1-0.2	0.1	0.1-0.2	0.1
209	Pahranagat	23	31	14	0	0.2-0.7	0.4	0.2-0.7	0.4

2465

[1]MPQ - Most Probable Quantity.

[2]Indicates an additional construction camp is possible if proposed construction camp location is not acceptable

Table 4.1.1.2-2. M-X water requirements by hydrologic subunit for construction of facilities in the DDA for Alternative 8, split basing.

HYDROLOGIC SUBUNIT OR COUNTY	NUMBER OF PROTECTIVE STRUCTURES	CLUSTER ROAD (MILES)	DTN (MILES)	NUMBER OF CONSTRUCTION CAMPS	PEAK YEAR RANGE X 10^3 ACRE-FT	PEAK YEAR MPQ X 10^3 ACRE-FT	TOTAL PROJECT RANGE X 10^3 ACRE-FT	TOTAL PROJECT MPQ X 10^3 ACRE-FT
Nevada-Utah								
Snake (4)	131	186	39	1	0.5-1.6	0.9	1.2-3.6	2.2
Pine [illegible]	115	[illegible]	50	1*	1.8-3.2	2.3	3.7-8.9	4.6
White [illegible]	22	31	14	0	0.1-0.3	0.2	0.2-0.7	0.6
Fish Springs (7)	1	5	0	0	M	M	M	M
Sevier Desert (46)	165	227	45	0	0.9-2.8	1.6	1.4-4.2	2.6
Sevier Desert-Dry Lake (46A)	113	155	35	1	1.0-2.9	2.2	3.2-5.2	4.0
Wah Wah (54)	181	248	53	1	2.4-4.1	3.1	4.7-7.9	6.0
Little Smoky-Southern (155C)	55	62	11	0*	0.3-2.0	0.5	0.4-2.[illegible]	0.7
Hot Creek (156)	152	217	41	1	2.6-4.6	3.2	3.2-5.9	4.4
Penoyer (170)	139	186	26	0*	0.5-2.6	1.2	1.1-6.3	2.2
Coal (171)	115	155	40	0*	0.5-3.7	0.8	1.0-6.5	3.9
Garden (172)	107	165	31	1	2.7-3.7	2.9	4.5-6.4	5.3
Railroad Southern (173A)	114	155	43	1	1.5-2.4	2.0	3.9-6.0	4.8
Railroad Northern (173B)	70	93	24	0	0.3-0.8	0.6	0.6-1.8	1.1
Cave (180)	69	93	9	0	0.2-0.6	0.3	0.6-1.7	1.1
Dry Lake (181)	216	279	73	1	1.7-2.8	1.8	4.0-7.7	5.6
Delamar (182)	66	93	22	0*	0.3-2.1	0.3	0.6-3.8	1.1
Lake (183)	86	124	27	1	1.6-2.2	1.7	3.3-4.9	4.0
Spring (184)	46	62	16	0	0.2-0.5	0.2	0.4-1.2	0.8
Hamlin (196)	145	186	42	*	0.6-3.0	1.2	1.2-6.3	2.3
Patterson (202)	23	31	0	0	0.1-0.2	0.1	0.2-0.5	0.3
White River (207)	159	217	34	0	0.6-2.0	0.9	1.4-4.0	2.6
Pahroc	10	14	2	0	0.1-0.3	0.2	0.1-0.2	0.1

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DDA Operations

DDA operational water demands are small, mostly domestic uses at the ASCs. Water demands are estimated to be less than 100 acre/ft per year per ASC. For the full basing alternatives, ASCs have been temporarily sited in the hydrologic subunits of Sevier Desert-Dry Lake, Utah, Stone Cabin, Nevada, Newark, Nevada, and Dry Lake, Nevada.

ASCs for Alternative 8 have been located in the hydrologic subunits of Pine, Utah and Garden, Nevada.

IMPACTS RELATIVE TO SURFACE WATER (4.1.2)

There will be an increase in runoff of surface water over the area covered by the DTN, cluster roads and protective structures. The increase is expected to be small when compared to total runoff in the deployment area (less than 1/100 of 1 percent). The quantities of runoff can be determined when the specific site locations are known and the slope, contouring and proximity to water courses are identified. Roads and other M-X facilities will be designed to provide road drainage and storm runoff features. Design will minimize upstream siltation and downstream erosion.

The clearing, leveling and earth moving activities associated with construction, in combination with sporadic runoff from heavy, but infrequent, rainstorms, will contribute to increased erosion rates. Short-term water erosion impacts are expected to be moderate in most valleys containing DTN and protective structures. Revegetation of the disturbed soils and proper engineering design of the roads will help mitigate the impacts after construction has been completed. Long-term impacts are expected to be low if these mitigating measures are undertaken.

Soil disturbance may create some chemical pollution of surface waters due to the enhancement of the oxidation process of some trace elements. The possible increase in dissolved minerals in runoff from the disturbed areas will be greatly diluted by the mixing runoff from the large undisturbed areas. Table 4.1.2-1 identifies potential impacts on surface waters. Impacts are difficult to assess with specificity until project siting is complete. At that time additional studies will be conducted to determine impacts.

GROUNDWATER RELATED IMPACTS (4.1.3)

Potential Impacts (4.1.3.1)

Successful implementation of the M-X project will require significant development of groundwater resources to meet both the relatively short-term (2-5 years) construction needs and the longer-term (about 30 years) support facility needs. Available groundwater resources in the large regions of the southwestern United States being considered for M-X deployment, are often not large when viewed in the context of the physical, legal and economic constraints on resource development which exist. Changes in the availability of water could affect many sectors of life in these regions.

Potential impacts of M-X water development on groundwater resources and other groundwater-dependent or related resources include:

Table 4.1.2-1. Potential impacts of construction on surface waters.

DISTURBANCES	IMPACT	AVOIDABLE	SECONDARY IMPACT
1. Earth moving	1.1 Temporary increase of sheet erosion	No	1.1 Temporary degradation of surface waters
			1.2 Sedimentation
2. Drainage channel relocation and modification	2.1 Channel instability and erosion	Yes	2.1 Temporary degradation of surface waters
			2.2 Sedimentation
3. Devegetation	3.1 Temporary increased sheet erosion	No	3.1 Temporary degradation of surface waters
	3.2 Temporary increased runoff	No	3.2 Temporary decreased recharge
			3.3 Sedimentation
4. Placement of impervious surface	4.1 Increased local local runoff	No	4.1 Degradation of surface water. Lowering of water table and ground-water supplies
	4.2 Decreased recharge	Yes	4.2 Increased erosion
5. Increased public accessibility	5.1 Loss of vegetation	No	5.1 Increased erosion
			5.2 Degradation of surface waters
6. Camp development activities	6.1 Disturbance of soils	No	6.1 Temporary increased erosion
7. Materials storage and handling	7.1 Water-borne pollutants in runoff	Yes	7.1 Surface water degradation

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- Lowering of the potentiometric surface in source aquifers. The potentiometric surface is an imaginary surface defined by levels to which water would rise in tightly cased wells, each open to a given point in the same aquifer. The water table is a particular potentiometric surface in an unconfined aquifer (an aquifer open to the atmosphere through interconnected pores in the earth materials above the water table). The potentiometric surface reflects both the elevation of the well opening to the aquifer and the pressure of the water at that point. Pumping water from an aquifer results in a lowering of water pressure within the aquifer and, consequently, a lowering of water levels in other wells within the pumped well's zone of influence. The essential factors that determine the spatial and temporal responses of aquifers to development by wells were set forth in detail by Theis, 1940 and are summarized as:

  a. Distance to, and character of, the aquifer's recharge sources,

  b. Distance to the location(s) of natural groundwater discharge,

  c. Hydraulic properties of the aquifer which control its ability to transmit and store groundwater, and

  d. The rate and duration of pumping.

  Thus, within an area the size of the Great Basin (or the High Plains Region of west Texas and eastern New Mexico) the specific aquifer responses to groundwater development will vary widely, as these four factors may be expected to vary in both time and space.

  Lowering the potentiometric surface in aquifers affects groundwater availability by increasing the pumping costs for competing water users. Thus, and economic burden is conveyed to existing and future (if significant volumes of water are removed from aquifer storage) groundwater users which, in turn, may lead to significant secondary socioeconomic impacts.

- Reduced Spring Flows. A reduction of spring flow could result from a lowering of the water table in the spring's source aquifer(s). If the spring flow is currently fully diverted for beneficial use then the user(s) will be immediately impacted. Unlike the well user who could still pump from a well with a lowered water table, the spring user would have immediate method available for retrieving the water loss. Corresponding secondary socioeconomic impacts may be felt in areas which depend on springs potentially affected by M-X-related water use. If M-X water development disrupts regional groundwater flow, then springs in adjacent valleys or regions could be affected.

The following figures and discussion and intended to schematically show hypothetical impacts on spring flows which could result from M-X groundwater development. Whether or not such hydraulic responses actually occur will depend on well placement and design, pumping schedules, and the hydraulic properties of the aquifer(s).

Figure 4.1.3.1-1 shows a generalized cross-section of a hypothetical valley with a discharging playa. The springs shown represent discharge from an idealized groundwater flow system as discussed for the Great Basin region by Maxey, 1968. Pumping from the valley fill could result in interception of all or a portion of the natural discharge as shown in Figure 4.1.3.1-2. M-X groundwater development in a valley fill aquifer could also affect springs which represent discharge of regional groundwater flow through carbonate rocks. Figure 4.1.3.1-3 is a cross-section showing a hypothetical springs discharging from a series of solution openings and cracks in carbonate rocks. The spring flows serve as a source of recharge to the valley fill aquifer. The solution openings provide pathways for transmitting groundwater flow and also impart a degree of hydraulic continuity between the carbonate rocks and the valley fill. That is, hydraulic responses (changes in water pressure and water levels) resulting from development of the valley fill may be transmitted into the carbonate rocks and result in elimination or reduction of spring flow as shown in Figure 4.1.3.1-4. The alluvial well has effectively intercepted natural groundwater discharge from the carbonate rocks and diverted it to the well. Discharge from regional flow systems may also issue from fault zones. Such springs often occur along the margins of valleys in the Great Basin region. Hydraulic responses to pumping could be similar to that shown in Figure 4.1.3.1-4.

The U.S. Geological Survey conducted a study in Ash Meadows, Nye County, Nevada to investigate the effects of groundwater pumping on spring flows and water levels in limestone dissolution/collapse features (Dudley and Larson, 1976). The springs are fed by discharge from a regional groundwater flow system which is developed largely in a deep carbonate aquifer extending over an area of several thousand square miles in southern Nevada. The investigation confirmed that pumping from the shallow aquifers effected significant hydraulic responses in the springs and collapse features. The authors conclude that the hydraulic relationships between the local and regional aquifer systems are exceedingly complex and remain poorly understood. However, it is clear that many of the shallow wells effectively draw water from the lower carbonate aquifer by lowering the water table and potentiometric surface in the local aquifers which in turn induces more discharge from the regional system to the east of Ash Meadows. (Dudley and Larson, 1976)

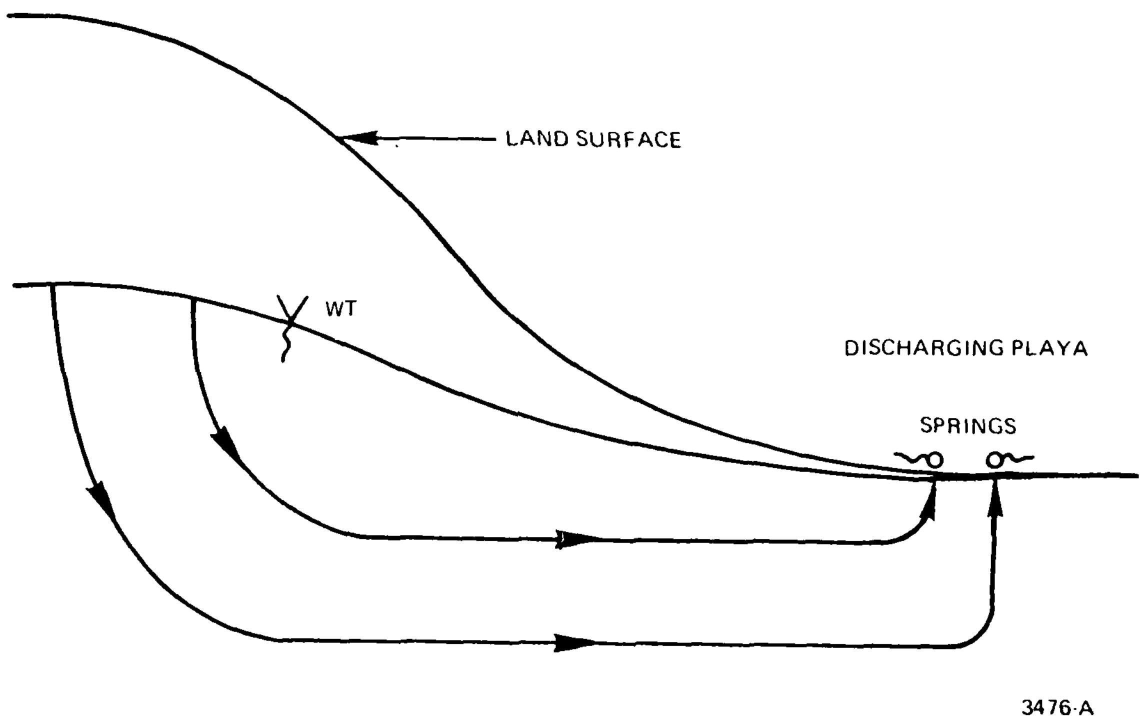

Figure 4.1.3.1-1. Idealized groundwater flow system for drainage basin in the Great Basin (from Maxey, 1968).

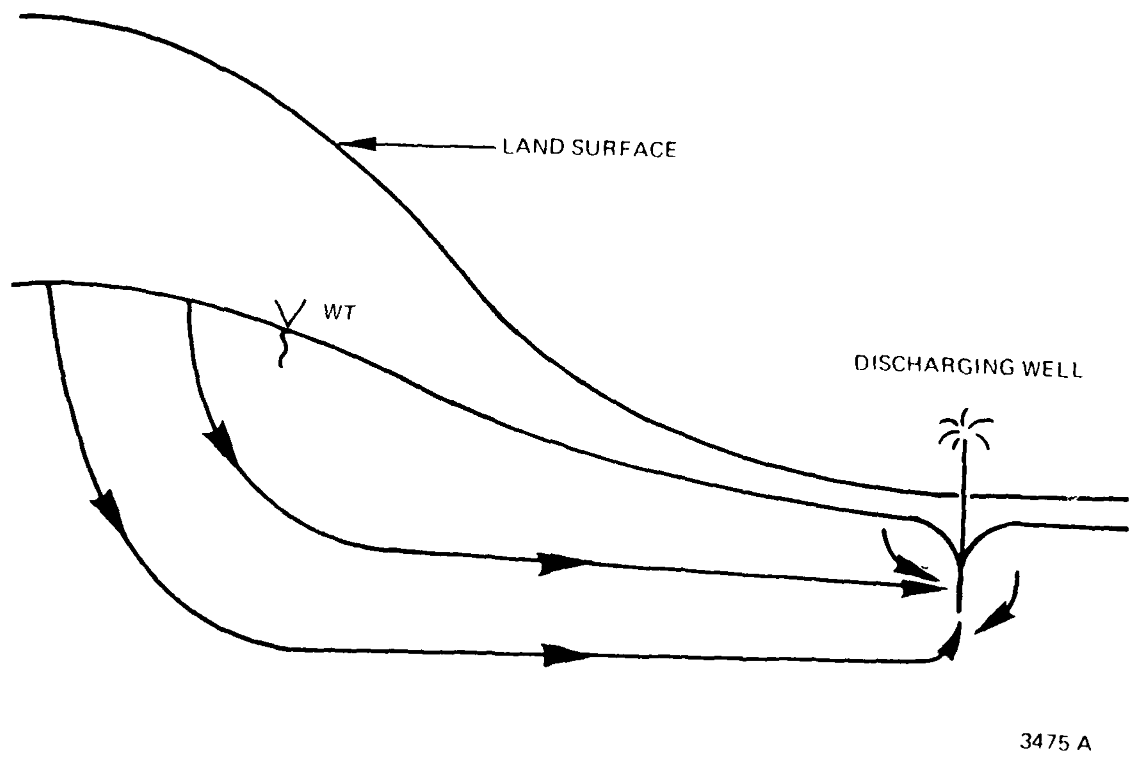

Figure 4.1.3.1-2. Idealized groundwater flow system with discharging well intercepting natural discharge.

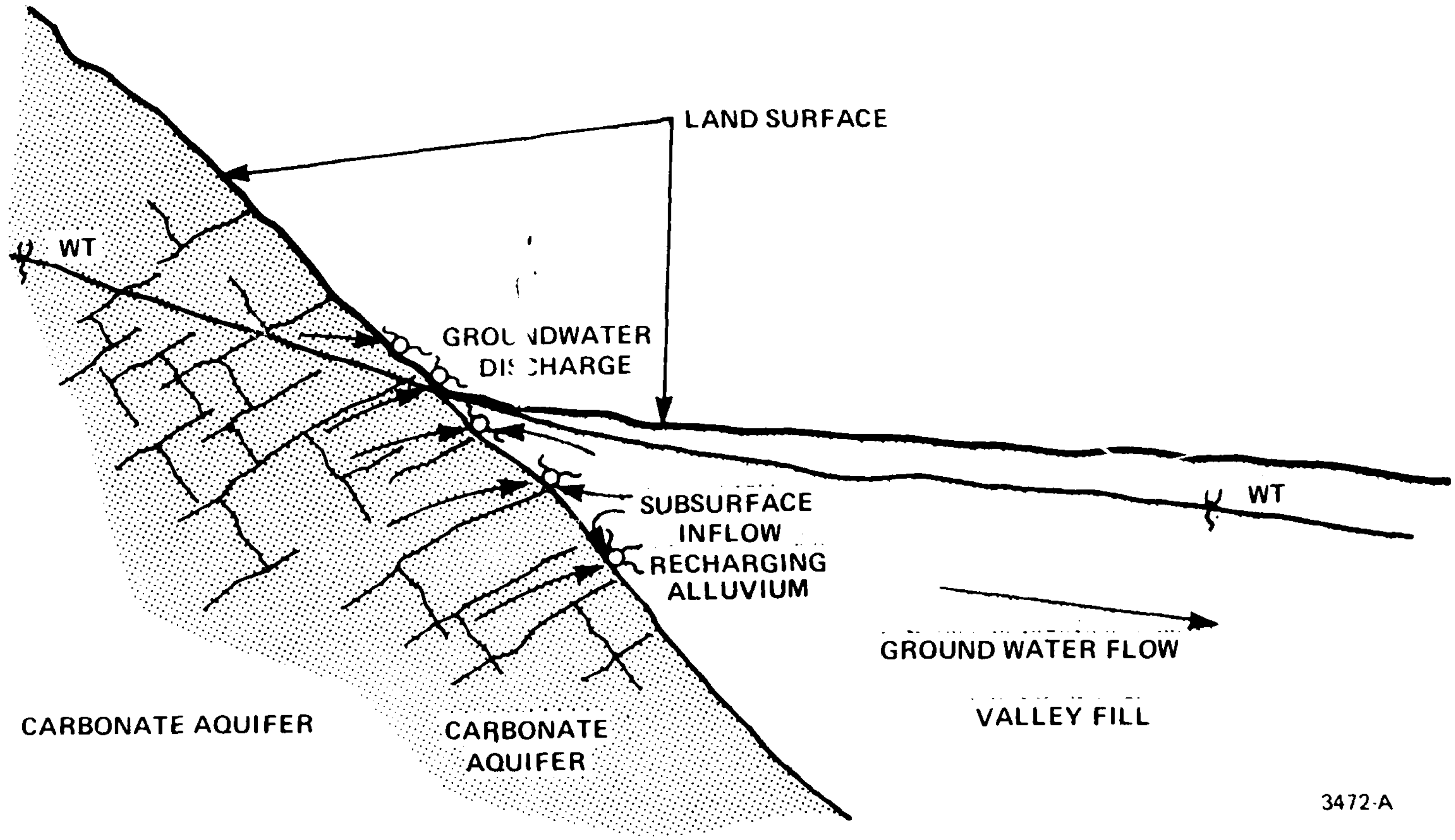

Figure 4.1.3.1-3. Idealized cross-section showing recharge of valley fill by discharge from carbonate aquifer.

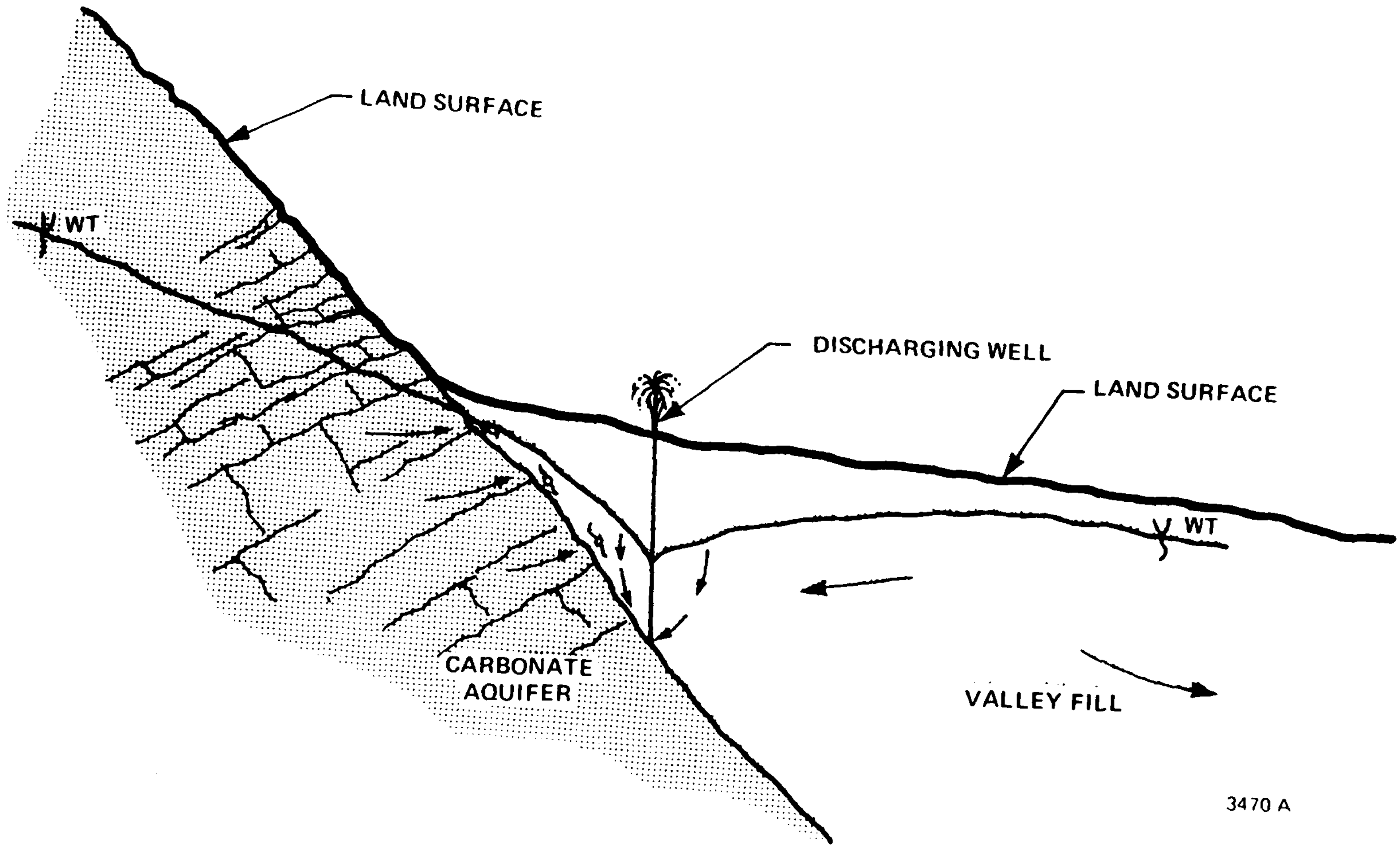

Figure 4.1.3.1-4. Idealized cross-section showing possible effect of groundwater development in valley fill on springs discharging from the carbonate aquifer.

- Deterioration of water quality. Water quality could be adversely impacted if M-X diversions result in significant volumes of water being removed form aquifer storage. As an alluvial aquifer is dewatered, water from relatively impermeable salt and clay layers drains to the well. Often this water is of relatively poor quality because of its contact with the fine-grained materials containing a much higher percentage of soluble salts than the more permeable sand and gravel sequences. Water uses most sensitive to changes in water quality include domestic, industrial, and to a lesser extent, irrigation uses. In areas where existing water quality is marginal (this may occur at specific locations within any valley), then further deterioration in water quality could render the source unfit and limit further development.

- Disruption or Destruction of Wildlife Habitat. Springs, which are natural areas of groundwater discharge, could be dried up. This may reduce in size or destroy wetlands habitats and areas of phreatophyte vegetation. From purely a water management point of view, a project which derives water largely from intercepted natural groundwater discharge is viewed with favor because water that was formerly being lost or "wasted" to evapotranspiration, is being diverted and put to beneficial use. In many areas, however, natural groundwater discharge does maintain an important habitat for native plants and wildlife. Interception of that discharge may lead to biological impacts in that community. Some of these areas support important water-based recreation such as hunting and fishing, and others may be of critical cultural significance to native Americans. If such areas of natural groundwater discharge are partially desiccated, the value of the land to support such uses would be damaged or destroyed. In confined aquifers, interception of natural discharge may occur relatively quickly as the pressure effects of pumping can be transmitted over large distances within the flow system in relatively short periods of time. In unconfined aquifers, considerable volumes of water usually must be removed from aquifer storage before a spring or natural discharge is disrupted.

- Land Subsidence. Land subsidence resulting from the withdrawal of groundwater is generally most severe in areas close to well fields and can be a serious problem, particularly if well fields are located in metropolitan areas where damage to buried pipes, building foundations, or other structures might occur. Land subsidence results primarily from the compaction of clays which occurs as hydrostatic pressure declines, and progressively more and more of the lithostatic load is supported by the column of earth materials. Land subsidence is most often a problem when wells are completed in thick sequences of poorly consolidated sediments such as the valley fill aquifers in the Great Basin Region. Subsidence also leads to vertical cracking in the alluvial materials which can threaten aquifer integrity from a water quality point of view.

As discussed above, it is clear that if groundwater resources are impacted in areas where an important "intersection" exists between groundwater and other natural or human resources, then secondary impacts are possible.

IMPACT ANALYSIS (4.1.3.2)

Determination of how much water an area can produce without creating "undesirable effects" requires analysis of both the hydrologic relationships between a pumped well and the source aquifer, and the legal constraints that define the degree to which specific effects can be tolerated. Performing such analysis in the large aquifer systems of the arid southwest is particularly difficult because both the physical and legal factors change radically over very short distances. Consequently, the specific location of pumping greatly influences the impacts of water development in any given case. Because data on aquifer performance coefficients are not readily available in most valleys or areas being considered, and because M-X wells have not yet been located, it is not possible to evaluate the impacts of M-X water development in any detailed or quantitative sense.

The most significant potential impact of M-X on groundwater resources is its possible effect on groundwater availability. The method used in assessing groundwater impacts examines gross resource characteristics in the context of factors such as current use, M-X use, legal constraints, and aquifer depletion rates to identify areas where groundwater availability could be significantly impacted. The method calls for a subjective comparison of these factors to distinguish between "low", "medium", or "high" relative potential for significant impact.

The method, by necessity, had to be one which relied on an information base which was generally available for areas considered for M-X deployment. The information used in the analysis was in part developed by hydrologists and geologists who have studied water resources in the project area on a reconnaissance level. Water resource assessments conducted at the reconnaissance level most often require subjective analysis of data using "professional judgment" to arrive at estimates of volumes of water in storage, recharge and discharge rates, perennial yield and so forth. Consequently, when these estimates are extracted from the individual reports for the purpose of a comparative analysis of water resources and impacts, the individual biases of the original authors influence the results of the analysis.

The following discussion is included to provide the reader with an understanding of the basic assumptions what were used in the analysis of potential groundwater impacts.

The method used to evaluate impacts of the M-X project on groundwater resources incorporates a fundamental assumption that M-X water needs for both short-term construction and long-term operations would be met locally by developing groundwater sources beyond the current level of development within each valley or groundwater region. It is recognized that this may not turn out to be the case, particularly in areas where legal constraints are significant, but until the water development plans are better defined, this assumption provides a consistent framework for comparing potential impacts from one area to another.

Other assumptions which form the basis of the analysis are:

- M-X impacts are potentially more significant if M-X water needs are relatively large in comparison to available aquifer storage, current groundwater use, and the perennial yield of the hydrologic system.

- M-X impacts are potentially more significant if the groundwater system is already under some "stress" as is indicated either by current aquifer depletion rates, or by situations where current groundwater use is relatively large in comparison to available aquifer storage and perennial yield of the system. An additional factor used to measure "stress" or "competition" for groundwater resources was the presence of legal constraints on future groundwater development.

The actual imput data used in the analysis were as follows:

- The volume of recoverable water in storage in the upper 100 feet of saturated valley fill (Nevada and Utah)[a]

- Estimates of economically recoverable groundwater in storage (Texas and New Mexico)[b]

- The magnitude of current groundwater use (Nevada and Utah)[c,d,e]

- Estimated perennial yield of the hydrologic system (Nevada and Utah)[a]

- Current groundwater depletion rates (Texas and New Mexico)[b]

- Legal constraints on groundwater development

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a Source: Eakin and others, 1976
b Source: Woodward-Clyde, 1980
c Source: Fugro National, 1980 (Sept.)
d Cochran and others, 1980
e Narasimahan and others, 1980

- Estimated size of the proposed M-X withdrawals
- Number of 500 gpm wells needed to supply M-X demands

The two factors related to groundwater storage both take into account the areal extent and the specific yield of the major aquifer(s) in each hydrologic area or region considered in the analysis. Storage then basically reflects the size of the groundwater reservoir. In the absence of aquifer performance coefficients, it is felt that this factor, not the perennial yield of the system, is the most sensitive and useful resource characteristic for evaluating potential impacts of relatively short-term water develoment projects (2-5 years for M-X/DDA construction). Consequently, groundwater storage was given approximately double the weight of perennial yield in the analysis.

Briefly, the reasoning behind this is as follows. All water discharged from a well is balanced by loss of water somewhere. The potential sources are intercepted natural recharge or discharge, or depletion of aquifer storage. From a water management point of view, the latter is viewed as the most serious because it leads to long-lasting impacts on water availability. Major groundwater development projects in the Great Basin Region and in the High Plains Region of West Texas and Eastern New Mexico always result in some depletion of aquifer storage, whether or not the perennial yield of the system is being exceeded. This is the case because a well cannot selectively intercept only natural groundwater recharge or natural discharge, even if well construction and placement are very carefully planned.

Therefore, while perennial yield ultimately may reflect the approximate upper level of water development that can be sustained by a groundwater system over very long time periods, it is not an expecially useful indicator of the impact potential of relatively short-term water development projects.

The volume of groundwater in storage and areal extent of the valley fill aquifer are useful indicators of potential impacts for a number of reasons. For example, if one makes the conservative or "worst case" assumption that all M-X water requirements will come from aquifer storage, (i.e., natural recharge and discharge remain unaffected) then it follows that the more water that is available in storage, the lesser will be the impact on water availability. Similarly, if the areal extent of the valley fill aquifer is large, as reflected by the groundwater storage factor used in the analysis, then more options are available for locating and spacing wells so as to minimize significant impact. This also allows for more room to avoid impermeable boundary conditions which, if encountered by the zone-of-influence of a discharging well, would lead to faster depletion of aquifer storage.

To summarize, M-X-related groundwater impacts cannot be evaluated in any detailed or quantitative sense, but the occurrence and degree of impact will depend on the location and construction details of M-X wells, the pumping rate and duration, the hydraulic characteristics of the aquifer(s) in the area of pumping, and the degree of hydraulic continuity between M-X wells and points of current water use. The analysis method used to evaluate impacts of M-X development on groundwater availability basically provides an indirect measure of the relative potential for groundwater impacts to occur on a valley-by-valley basis within Nevada/Utah or region by region basis within Texas/New Mexico.

Table 4.1.3.2-1 summarizes the basic criteria used to assign relative DDA potential impact scores to the hydrologic subunits. Distinctions between low, medium, and high potential for impact were arbitrarily drawn as shown in Table 4.1.3.2-2.

IMPACT OF M-X WATER WITHDRAWAL BY HYDROLOGIC SUBUNIT (4.1.4)

General (4.1.4.1)

The impact of groundwater development in a hydrologic subunit will in part depend on the hydraulic responses (water level responses) in the aquifer(s) and the current beneficial uses of water in that sub-unit. In turn, the hydraulic responses which occur will depend on the hydrogeologic conditions, the quantities and rates of current water demands, the quantities and rates of M-X uses and the method of development of water supplies.

Long and Short-term Effects (4.1.6.2)

Groundwater withdrawals which result in significant hydraulic responses in the aquifer(s) (i.e., changes in groundwater levels) will be both short and long term. Water requirements for DDA construction in the DDA valleys will average between 2,000 and 3,000 acre/ft per year for about three years with a continuing operational requirement of about 400 acre/ft per year for 30 years, or a total withdrawal of 15,000 acre/ft for through the operational period. On the other hand, OB facilities and local induced population growth require about 4,000 acre/ft per year for the three-year construction period and 7,000 acre/ft per year for operations, a total withdrawal of about 220,000 acre/ft over a 30 year period.

Groundwater withdrawals for the 30-year OB maintenance needs are likely to have more widespread and longer-term impacts than are groundwater withdrawals for the 2-5 year DDA construciton period.

If M-X withdrawals lead to significant removal of groundwater from aquifer storage then impacts, manifested as lower water levels in wells, could be long-term. Certain types of aquifers in the study area may yield water to a discharging well without significant depletion of aquifer storage. In such cases long-term water level declines would be less severe but would be felt over a larger area.

As a basis of comparison, to generate 1,000 MW of electrical energy, coal-fired electrical generating stations require 12,000 to 53,000 acre/ft per year to meet the water requirements for wet cooling systems. M-X water requirements per valley are small by comparison.

Water Quality (4.1.4.3)

Construction of roads and shelters is expected to slightly increase the surface water quantity by increasing runoff. Areas disturbed would be at elevations above 5,000 ft. The compaction of soil for road construction would alter the moisture-holding and runoff characteristics of the soils and would thereby increase runoff. This compaction can, then, create higher flood peaks at downstream locations, such as at road crossings.

Table 4.1.3.2-1. Relative potential for impacts to groundwater availability by construction of DDA in Nevada/Utah (sheet 1 of 2).

UNIT NO.	HYDROLOGIC UNIT	DESIGNATED AREA	LEGAL SCORES[1]	PERENNIAL YIELD[2] X10^3 AC-FT PER YR	VOLUME IN STORAGE[3] X10^3 AC-FT/FT IN 1ST 100 FT OF AQUIFER	CURRENT USE[4] X10^3 AC-FT PER YR	TOTAL/PEAK YEAR M-X DEMANDS[5]
4	Snake		1	32-80	107	31	11/5.0
5	Pine		1	< 5	12	m	6/3.3
6	Tule (White)		1	< 5	14	m	6.9/3.5
7	Fish Springs Flat		1	25-50	12	m	1.8/1.0
8	Dugway		1	5-25	13	6.2	1.8/1.0
9	Government Creek		1	1	7	1.8	1.2/0.3
46	Sevier Desert	X					
46A	Sevier Desert-Dry Lake	X					
54	Wah Wah		1	25	8	m	7.2/4.4
137A	Big Smoky (South)	X	5	6	50	31	3.0/1.8
139	Kobeh		1	15	27	3.3	6.9/4.1
140B	Monitor (North)		1				
141	Ralston	X	5	6	20	0.8	8.0/6.0
142	Alkali Spring		1	3	13	0.3	2.9/1.8
149	Stone Cabin	X	5	2	20	1.5	5.5/4.0
151	Antelope		1	4	13	1.0	5.7/3.9
154	Newark		1	15	15	7.0	5.3/2.6
155A	Little Smoky (North)		1				
155C	Little Smoky (South)		1	6	25	3.3	7.8/5.3
156	Hot Creek			6	12	0.8	5.8/3.4
170	Penoyer	X	5	5	22	12.5	6.3/3.9
171	Coal		1	6	15	m	6.4/3.0
172	Garden		1	6	15	0.3	6.4/3.0
173A	Railroad (South)	X	5				
173B	Railroad (North)	X	5	75	81	12.4	12/7.5
174	Jakes		1	12	9	m	2.5/1.5
175	Long		1	6	16	m	3.9/2.1
178B	Butte (South)		1	14	22	1.0	3.0/1.8
180	Cave		1	2	10	1.0	1.7/1.6
181	Dry Lake		1	3	28	m	8.9/2.7
182	Delamar		1	3	12	m	3.9/2.7
183	Lake	X	5	17	18	18.2	4.4/3.5
184	Spring		1	70-100	42	18	2.7/2.5
196	Hamlin		1	ND	12	1.5	6.3/3.6
202	Patterson		1	5	—	0.5	0.5/0.6
207	White River	X	5	37	—	20	4.0/2.5
208	Pahroc		1	2	—	m	0.2/0.2
209	Pahranagat		1	25	17	16	0.7/0.7

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Table 4.1.3.2-1. Relative potential for impacts to groundwater availability of construction of DDA in Nevada/Utah (sheet 2 of 2).

UNIT NO.	HYDROLOGIC UNIT	M-X DEMANDS ÷ VOLUME STORAGE CALCULATION/ RATING SCORE	CURRENT USE ÷ VOLUME STORAGE CALCULATION/ RATING SCORE	CURRENT USE ÷ PERENNIAL YIELD CALCULATION/ RATING SCORE	SUBTOTAL RATING SCORES
4	Snake	0.1/1	0.3/3	0.56/3	9
5	Pine	0.5/5	m/1	m/1	11
6	Tule (White)	0.5/5	m/1	m/1	11
7	Fish Springs Flat	0.2/1	m/1	m/1	7
8	Dugway	0.1/1	0.5/5	0.4/1	9
9	Government Flat	0.2/1	0.26/3	1.8/5	4
46	Sevier Desert				
46A	Sevier Desert-Dry Lake				
54	Wah Wah	0.9/5	m/1	m/1	13
137A	Big Smoky (South)	0.1/1	0.6/5	5.2/5	21
139	Kobeh	0.3/3	0.1/3	0.22/1	13
140B	Monitor (North)				
141	Ralston	0.4/3	0.04/1	0.13/1	15
142	Alkali Spring	0.2/1	0.02/1	0.1/1	5
149	Stone Cabin	0.3/3	0.08/1	0.75/3	17
151	Antelope	0.4/3	0.08/1	0.25/1	11
154	Newark	0.4/3	0.5/5	0.47/	15
155A 155C	Little Smoky (North) Little Smoky (South)	0.3/3	0.13/3	0.55/3	11
156	Hot Creek	0.5/5	0.07/1	0.13/1	9
170	Fenoyer	0.3/3	0.6/5	2.5/5	21
171	Coal	0.4/3	7/1	m/6	11
172	Garden	0.4/3	0.02/1	0.05/1	9
173A 173B	Railroad (South) Railroad (North)	0.1/1	0.15/3	0.17/1	15
174	Jakes	0.3/3	m/1	m/1	9
175	Long	0.2/1	m/1	m/1	7
178B	Butte (South)	0.1/1	0.05/1	0.07/1	5
180	Cave	0.1/1	0.1/3	0/1	11
181	Dry Lake	0.3/3	m/1	m/1	9
182	Delamar	0.3/3	m/1	m/1	9
183	Lake	0.2/1	1.01/5	1.1/5	21
184	Spring	0.1/1	0.4/3	0.2/1	7
196	Hamlin	0.5/5	0.1/3	-	-
202	Patterson	-	-	-	-
207	White River	-	-	-	-
208	Pahroc	-	-	-	-
209	Pahranagat	0.1/1	-0.9/5	0.64/3	13

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[1]Legal scores based on whether or not hydrologic unit is designated.

[2]As published by State of Nevada DWR and State of Utah DNR in acre-ft x 10^3.

[3]As published in USGS Professional Paper 813-G (1976); determined for upper 100 ft of saturated valley rill in acre-ft x 10^3.

[4]As published by Fugro National, Inc., 2 Sept. 1980.

[5]Represents high range of demands in acre-ft x 10^3.

Table 4.1.3.2-2. Criteria for evaluating impacts on groundwater resources in Nevada/Utah for DDA construction.

GROUNDWATER RESOURCE FACTOR	SIGNIFICANCE OF IMPACT		
	LOW	MEDIUM	HIGH
Legal	Not Designated		Designated
M-X Demands/ Volume in Storage	< 0.3	0.3 - 0.4	> 0.4
Current Use/ Volume in Storage	< 0.1	0.1 - 0.4	> 0.4
Current Use/ Perennial Yield	≤ 0.5	> 0.5 but < 1.0	≥ 1.0
Well Density	Possible Interference	Probable Interference	Likely Interference

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Disturbance of soil may expose fresh mineral surfaces to oxidation and thereby increase their solubility. The percentage of disturbed land would be small, however, and the expected increase in dissolved solids from surface runoff would be minor.

Diversion of surface runoff may, because of road and shelter construction, reduce the quantity of water that normally recharges the valley-fill aquifer. This impact is expected to be insignificant, but will depend on the final design of roadway gully crossings, and runoff diversion/control structures.

Depending upon the approach used in obtaining a water supply, the M-X defense system's consumption could either favorably or adversely affect water supply quality in siting valleys. If water is obtained through the purchase or lease of existing irrigation water rights, and the irrigated land is temporarily retired from agriculture, it is possible, in some areas, that the total dissolved solids in the groundwater would stablize since the leaching of irrigation water containing fertilizers would have been decreased. Conversely, if the amount of groundwater extracted is increased by M-X usage, and the rate of irrigation remains the same, the total dissolved solids load in the groundwater might increase at about the same or at a slightly higher rate than before the M-X withdrawals. It should be emphasized that this is only a theoretical impact. Currently, thee is nothing to indicate that irrigated agriculture is having adverse effects on groundwater quality in the project area.

Beneficial Impacts (4.1.4.4)

The principal constraints to development of the arid Great Basin valleys are the physical limits on groundwater availability and the costs associated with developing an adequate water supply. The development of water resources would have a number of beneficial impacts. The water supply system developed for M-X may become available for many types of use including irrigation, municipal supplies, ranching, and fire control.

Effect on M-X Siting Valleys in Nevada/Utah (4.1.5.5)

Following is a discussion of the impact analysis results. Key hydrologic features, M-X demands, and other factors which contributed to the evaluation of potential impacts are highlighted and the significance of potential impacts is discussed for selected valleys or hydrologic regions. Figures 4.1.4-1 through 4.1.4-5 are included to help the reader visualize the relationships between the paramters which formed the basis for the analysis. The actual numeric values of different parameters are presented in Table 4.1.3.2-1. In addition, references in the following paragraphs to the potential for individual valleys to sustain large-scale groundwater development are based on an independent analysis reported in Eakin and others, 1976. References to levels of current water use came from Cochran and others, 1980 (Nevada) and Narasimhan and others, 1980 (Utah).

Snake Valley (4)

Potential impacts of projected M-X withdrawals on groundwater availability were judged to be relatively low. An evaluation of perennial yield and available groundwater storage as general indicators of groundwater abundance indicates that

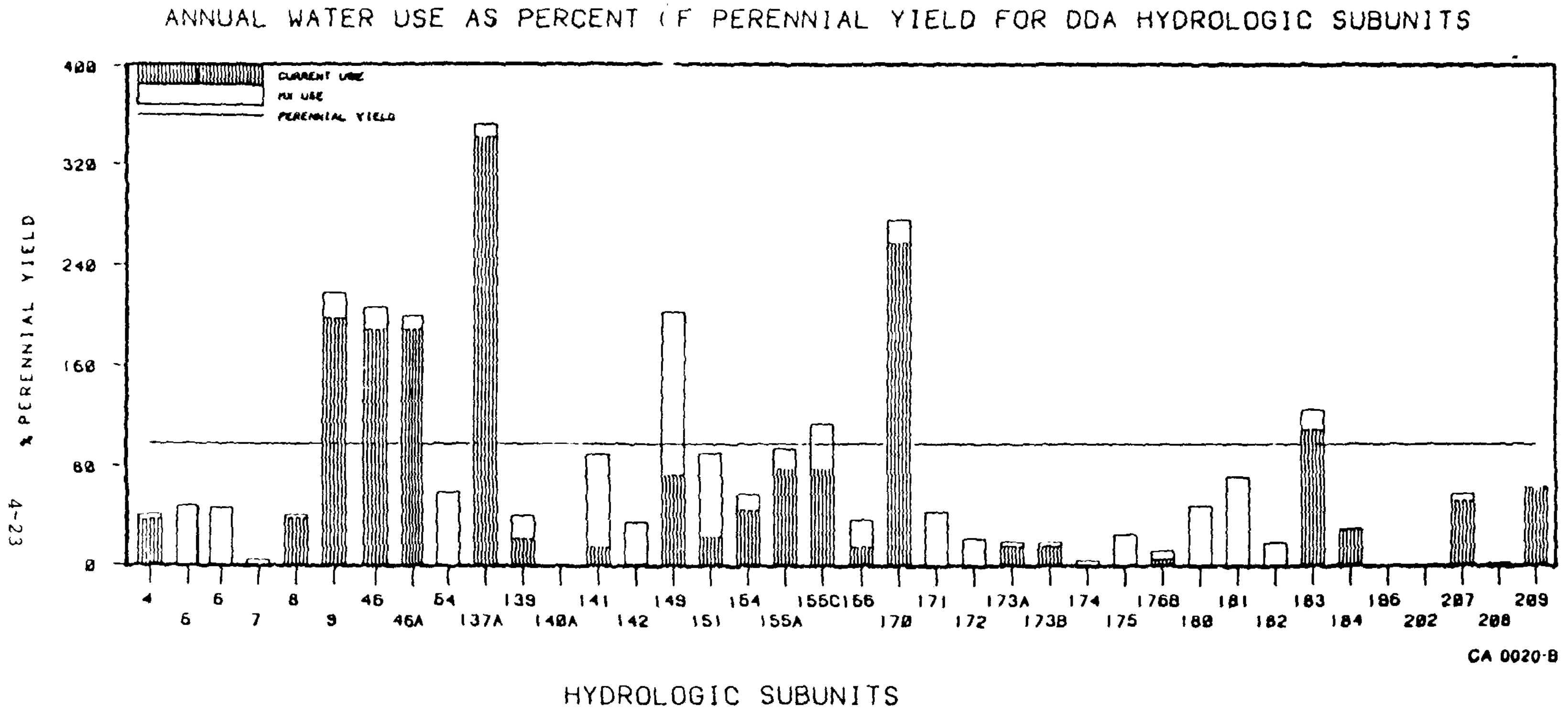

Figure 4.1.4-1. Valley-by-valley comparison of present water usage rate and projected construction peak-year usage rate with perennial yield.

AVAILABLE GROUNDWATER STORAGE, 3-YEAR CURRENT AND TOTAL M-X USE FOR DDA

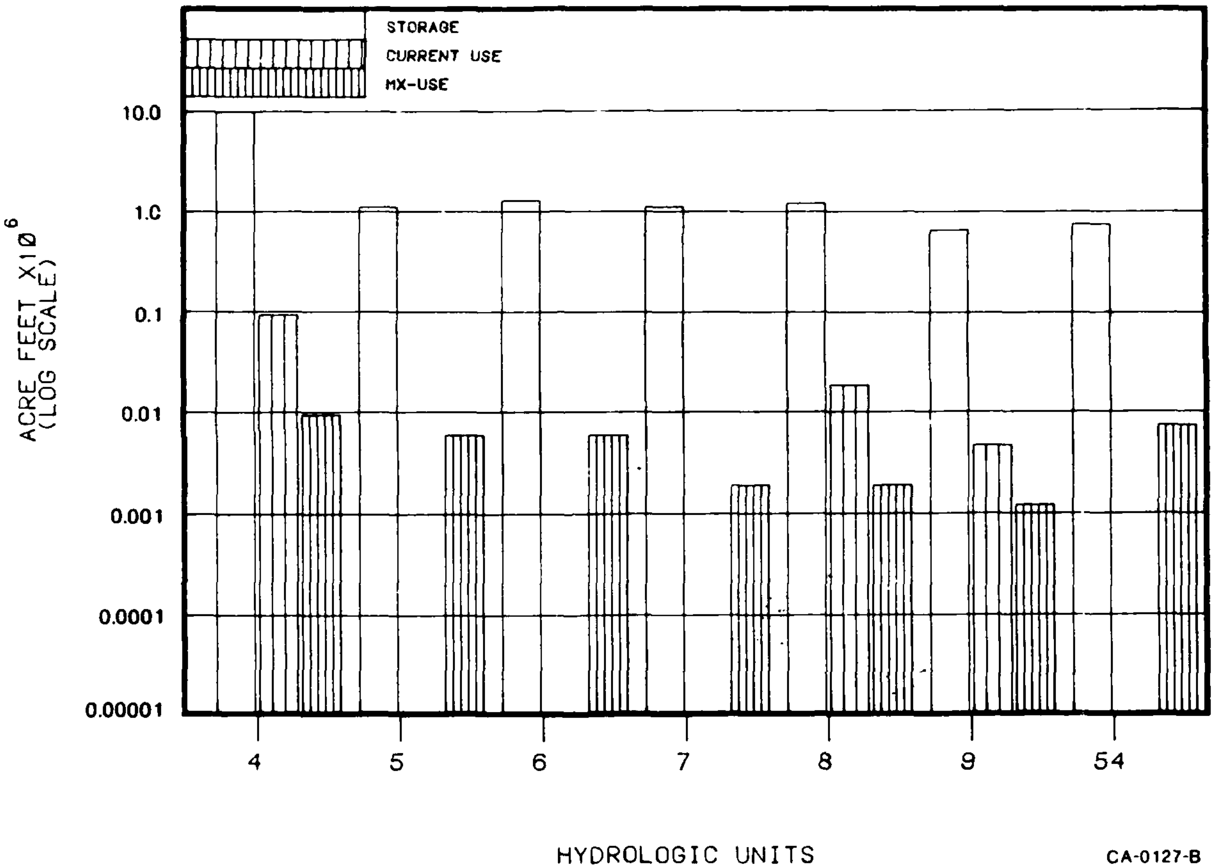

Figure 4.1.4-2. Valley-by-valley comparison of present groundwater reservoir, 3-year usage at present rate and total water demand for M-X DDA construction (sheet 1 of 4).

AVAILABLE GROUNDWATER STORAGE, 3-YEAR CURRENT AND TOTAL M-X USE FOR DDA

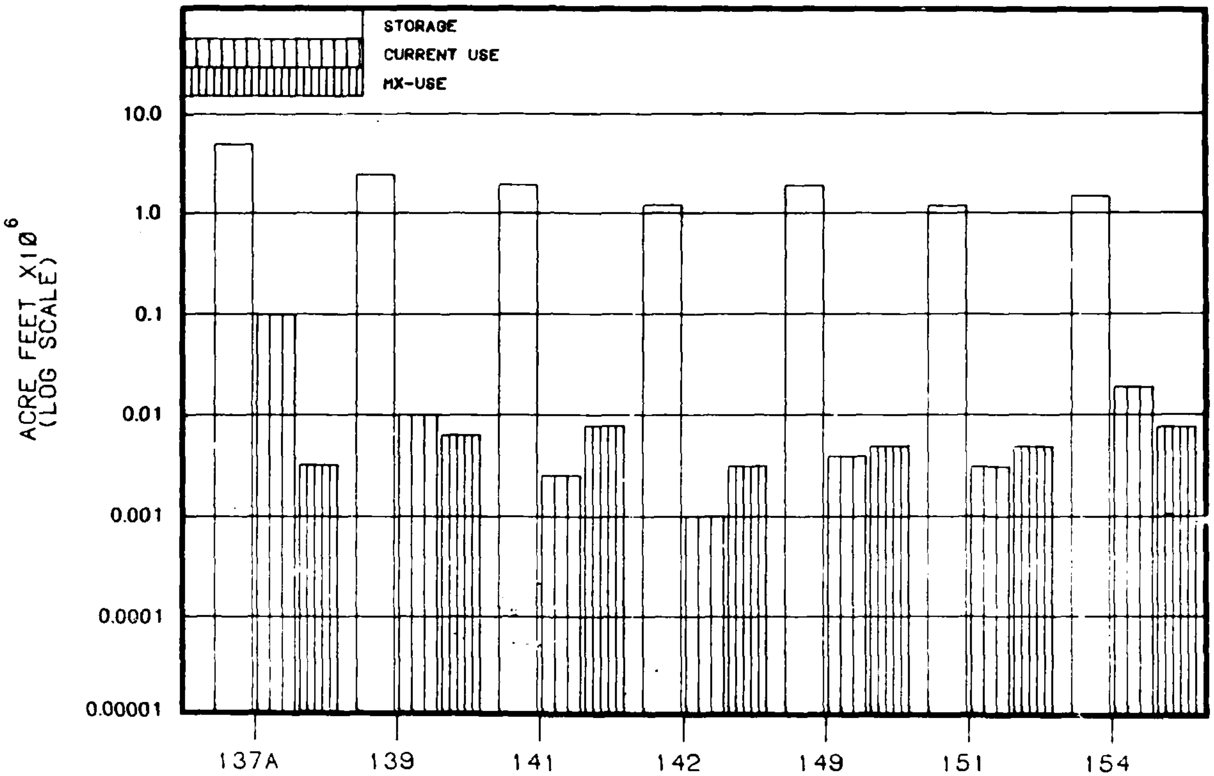

Figure 4.1.4-2. Valley-by-valley comparison of present groundwater reservoir, 3-year usage at present rate and total water demand for M-X DDA construction (sheet 2 of 4).

AVAILABLE GROUNDWATER STORAGE, 3-YEAR CURRENT AND TOTAL M-X USE FOR DDA

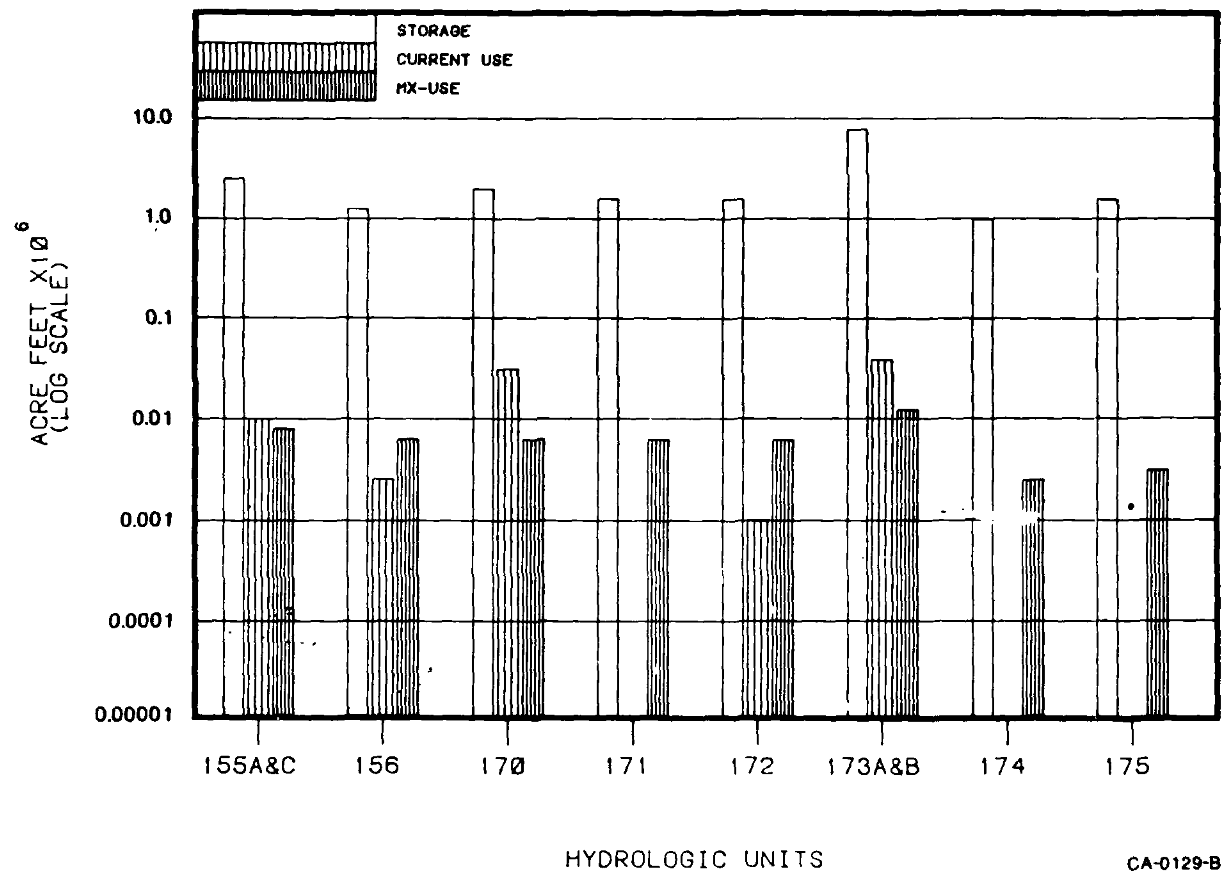

Figure 4.1.4-2. Valley-by-valley comparison of present groundwater reservoir, 3-year usage at present rate and total water demand for M-X DDA construction (sheet 3 of 4).

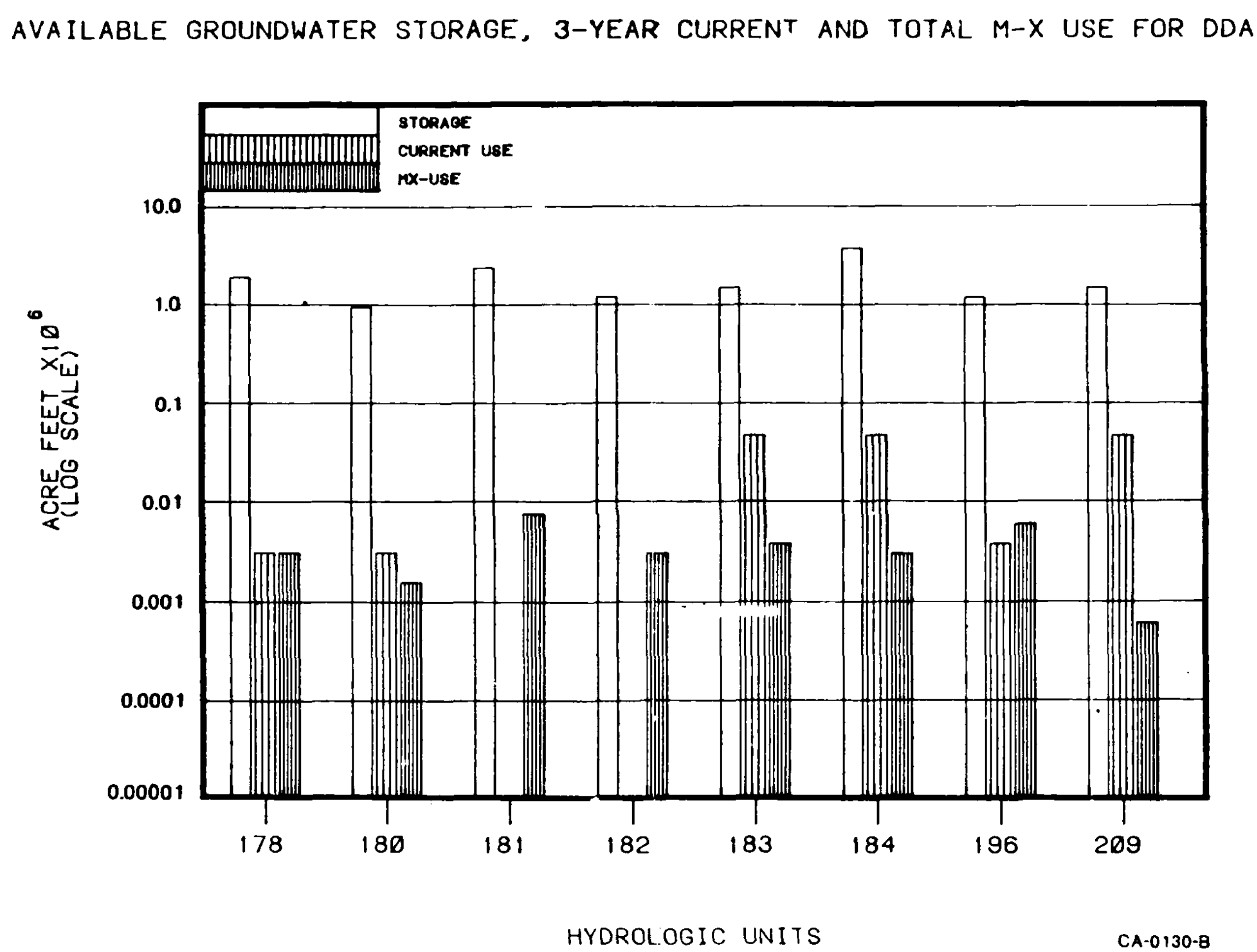

Figure 4.1.4-2. Valley-by-valley comparison of present groundwater reservoir, 3-year usage at present rate and total water demand for M-X DDA construction (sheet 4 of 4).

AVAILABLE GROUNDWATER STORAGE, 3-YEAR CURRENT AND M-X USE FOR DDA

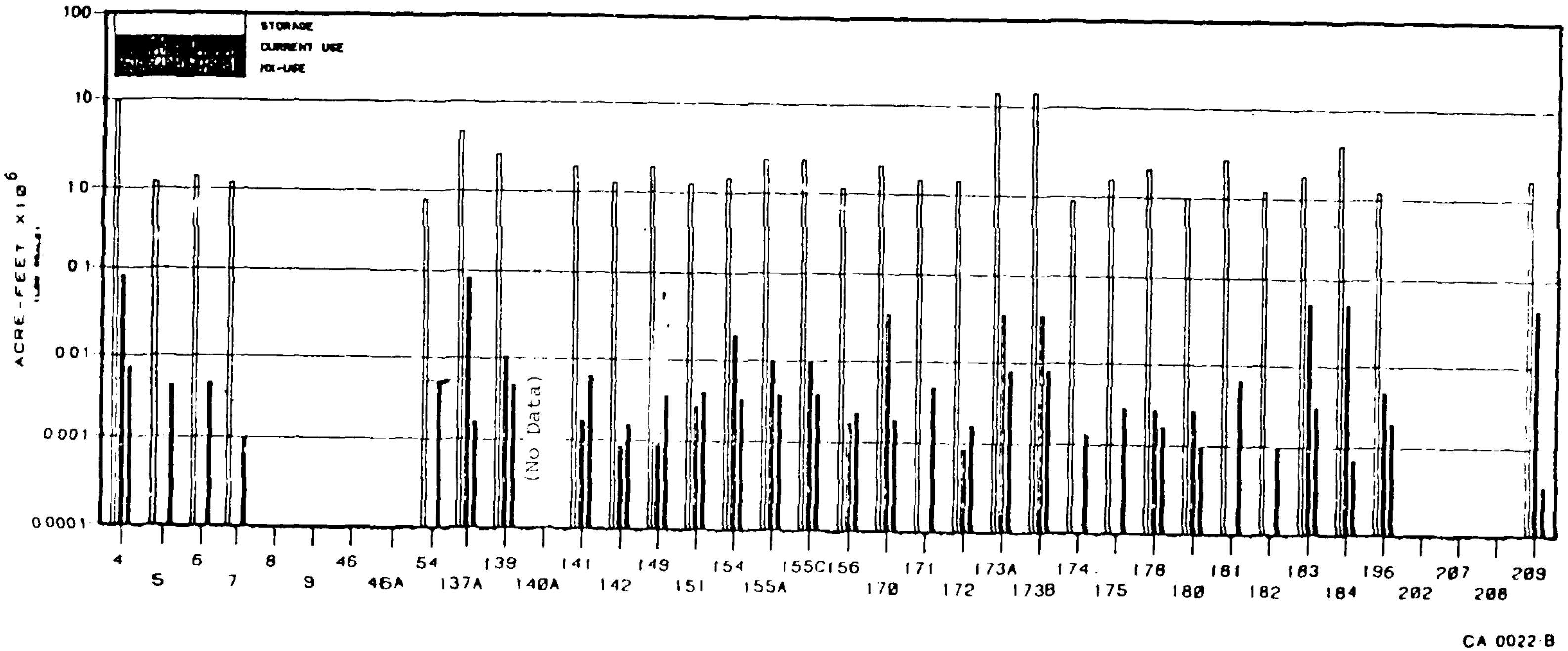

Figure 4.1.4-3. Valley-by-valley comparison of present groundwater inventory, 3-year usage at present rate and water demand for M-X DDA construction.

AVAILABLE GROUNDWATER STORAGE, 3-YEAR CURRENT AND TOTAL M-X USE FOR DDA
(SPLIT BASING)

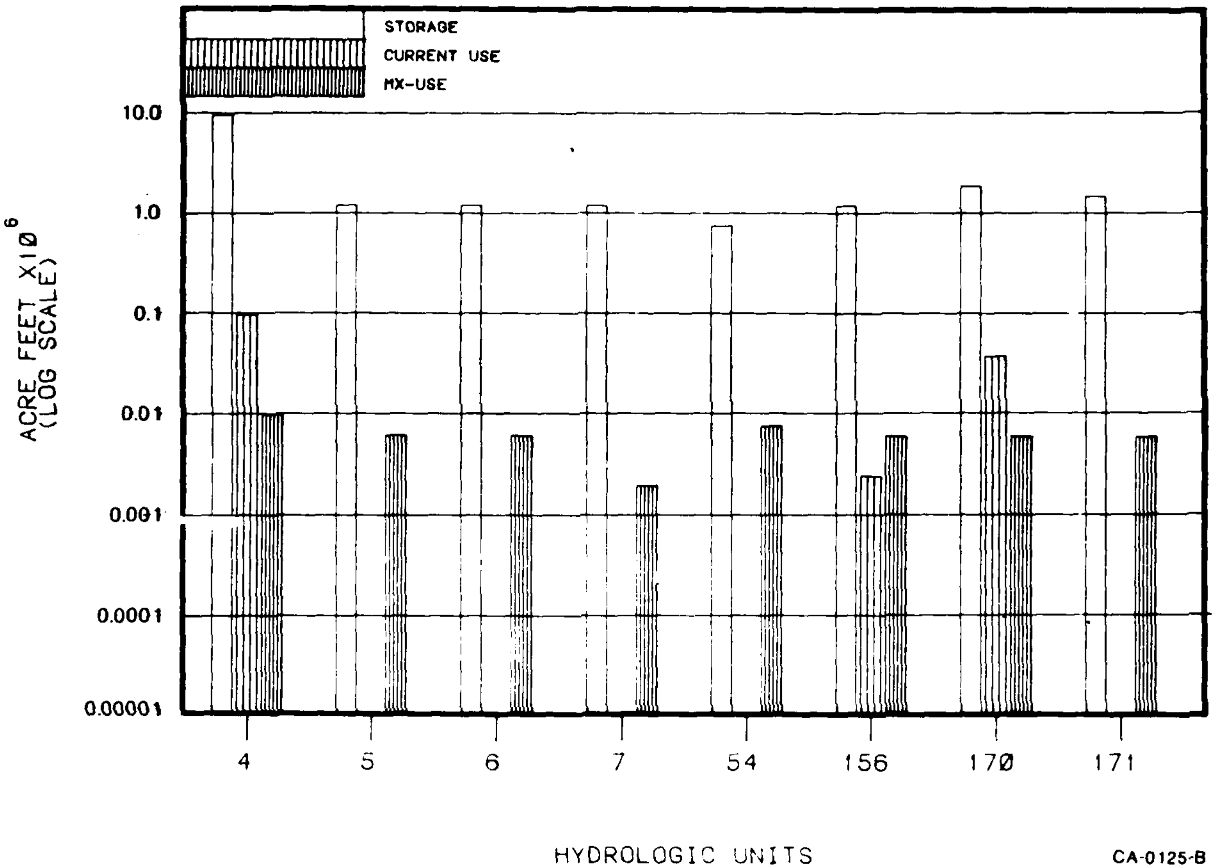

Figure 4.1.4-4. (Sheet 1 of 2)

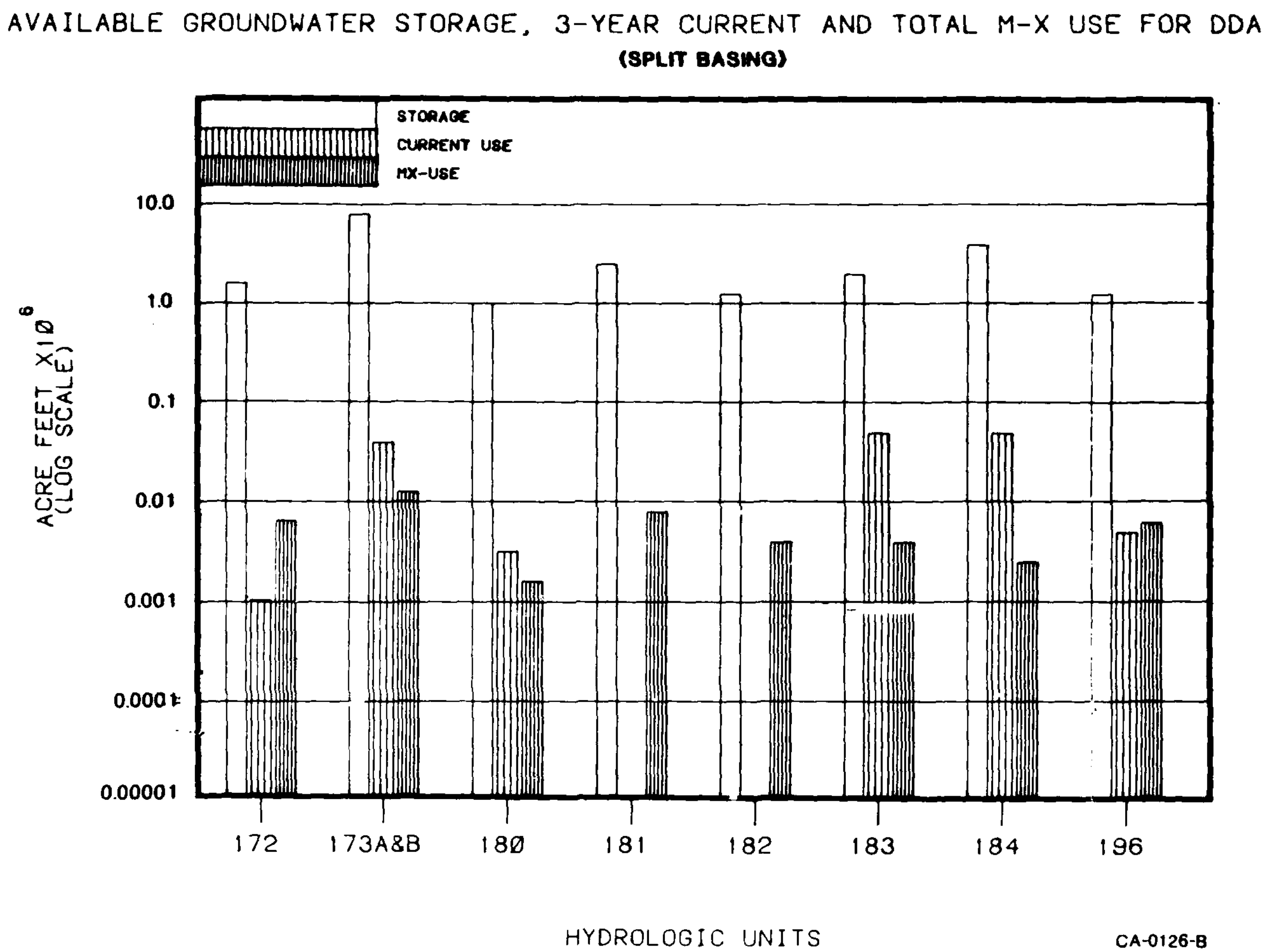

Figure 4.1.4-4. (Sheet 2 of 2)

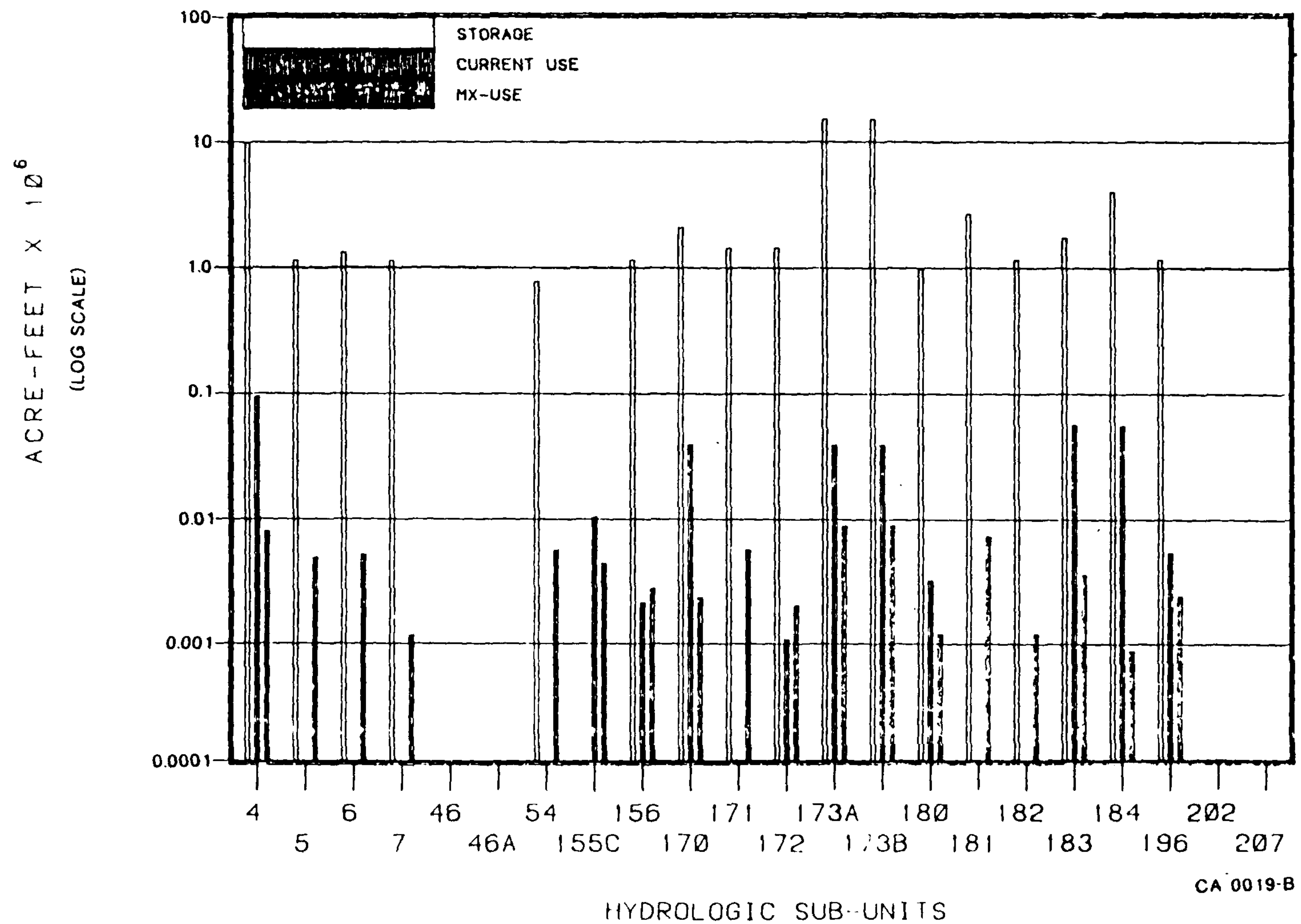

Figure 4.1.4-5. Available groundwater storage, 3-Year current and M-X use for DDA. (Split Basing)

Snake Valley has a high potential for sustaining large-scale groundwater development. The hydrologic subunit has not yet been designated by either the Nevada or Utah State Engineers. Though current water use is relatively high (about 31,000 acre-ft/year), it is quite small in comparison to available groundwater storage reserves. Any impacts on availability would be most likely to affect irrigators, who divert an estimated 30,800 acre-ft/year. Lesser amounts of water currently support grazing activities in the subunit. Additional water needs for projected future mining and energy production in the valley are estimated to be about 27,550 acre-feet/year. Several springs issue from the valley fill alluvium and are likely to represent discharge from local groundwater flow systems confined to the valley. M-X withdrawals from the valley fill could cause some decreases in flow at these springs. Other springs are thought to be largely independent of the valley fill aquifer system, having recharge sources outside the alluvium. Some may be discharge from regional groundwater flow systems extending outside the valley. However, pumping from the valley fill in these discharge zones could lead to some reduction of spring flows. Peak year M-X water requirements represent a 10 percent increase over current water use in the subunit and this would not exceed the estimated perennial yield during construction.

Pine Valley (5)

Potential impacts of projected M-X withdrawals on groundwater availability were judged to be relatively high. An evaluation of perennial yield and available groundwater storage as general indicators of groundwater abundance indicates this hydrologic subunit has a low potential for sustaining large-scale groundwater development. Pine Valley has not yet been designated by the Utah State Engineer. Compared to available supply estimates, current water use is minor totaling only 47 acre-feet/year. An additional 8000 acre-feet/year may be withdrawn in the future to support a potential molybednum mining venture. Significant impacts on groundwater availability would be most likely to affect the livestock industry which currently diverts the estimated 47 acre-feet/year. Most springs in the valley are thought to be largely independent of the valley fill aquifer system. That is, they have recharge sources which are outside the area of the alluvium. However, pumping from the valley fill in these discharge zones could lead to some reduction of spring flows. Extractions may reduce the underflow to the north through the deep carbonate aquifer. Peak year M-X water requirements represent a substantial (100 percent) increase over current water use in the valley but this would not exceed the estimated perennial yield during construction.

Fish Springs Flat Valley (7)

Potential impacts of projected M-X withdrawals on groundwater availability were judged to be moderate. An evaluation of perennial yield and available groundwater storage as general indicators of groundwater abundance indicates this hydrologic subunit has a moderate potential for sustaining large-scale groundwater development. Fish Springs Flat Valley has not yet been designated by the Utah State Engineer. Compared to available supply estimates, current water use is minor, totaling only 24 acre-ft/year. An additional 31,000 acre-feet/year may be withdrawn in the future to support potential coal-fired electric power generation. Significant impacts on groundwater availability would be most likely to affect the livestock industry which diverts an estimated 20 acre-feet/year. Lesser amounts of water are used for uranium mining activities in the valley. Most springs in the valley are thought to be largely independent of the valley fill aquifer system. That is, they have recharge sources which are outside the area of the alluvium. Some may be discharge from regional groundwater flow systems extending outside this hydrologic subunit. However, pumping from the valley fill in these discharge zones could lead to some reduction of spring flows. Extractions may reduce the underflow to the northwest through the deep carbonate aquifer. Peak year M-X water requirements represent a substantial (100 percent) increase over current water used in the valley but this would not exceed the estimated perennial yield during construction.

Dugway Valley (8)

Potential impacts of projected M-X withdrawals on groundwater availability were judged to be relatively low. An evaluation of perennial yield and available groundwater storage as general indicators of groundwater abundance indicates this hydrologic subunit has a moderate potential for sustaining large-scale groundwater development. Dugway Valley has not yet been designated by the Utah State Engineer. Current water use, though not large, is important to the local economy and totals 6200 acre-ft/year. Significant impacts on groundwater availability would be most likely to affect irrigators who divert 3800 acre-ft/year and military activities which accounts for about 2400 acre-feet/year of the current use. Lesser amounts of water currently support grazing activities in the valley. Most springs in the valley are thought to be largely independent of the valley fill aquifer system. That is, they have recharge sources which are outside the area of the alluvium. Some may be discharge from regional groundwater flow systems extending outside this hydrologic subunit. However, pumping from the valley fill in these discharge zones could lead to some reduction of spring flows. Extractions may reduce underflow to the northwest through the deep carbonate aquifer. Peak year M-X water requirements represent a 7 percent increase over current water use in the valley and this would not exceed the estimated perennial yield during construction.

Government Creek Valley (9)

Potential impacts of projected M-X withdrawals on groundwater availability were judged to be relatively low. An evaluation of perennial yield and available groundwater storage as general indicators of groundwater abundance indicates this hydrologic subunit has a moderate potential for sustaining large-scale groundwater development. Government Creek Valley has not yet been designated by the Utah State Engineer. Current water use, though not large, is important to the local economy and totals 1800 acre-ft/year. Significant impacts on groundwater availability would be most likely to affect irrigators who divert an estimated 1750 acre-feet/year. Lesser amounts of water are used for grazing activities in the valley. Several springs issue from the valley fill alluvium and are likely to represent discharge from local groundwater flow systems confined to the valley. M-X withdrawals from the valley fill could cause some decreases in flow at these springs. Other springs are thought to be largely independent of the valley fill aquifer system, having recharge sources outside the alluvium. Some springs may be discharges from regional groundwater flow systems extending outside the valley. However, pumping from the valley fill in these discharge zones could lead to some reduction of spring flows. Peak year M-X water requirements represent an 11 percent increase over current water use in the valley and the estimated perennial yield is already exceeded.

Sevier Desert Valley (46 & 46A)

Potential impacts of projected M-X DDA construction withdrawals on groundwater availability were judged to be relatively low. An evaluation of perennial yield and available groundwater storage as general indicators of groundwater abundance indicates this hydrologic subunit has high potential for sustaining large-scale groundwater development. However, severe legal constraints exist on future groundwater development. Compared to available supply estimates, current groundwater use diverted from wells is relatively high totaling about 40,000 acre-ft/year. Total water use in the valley is about 250,000 acre-feet/year. An additional 33,000 acre-feet of water may be required to support future coal-fired electric power generation. Significant impacts on groundwater availability would be most likely to affect irrigators who divert an estimated 250,000 acre-feet/year from both ground and surface water sources. Lesser amounts of water are used for livestock watering and various urban/industrial activities in the valley. Most springs in the valley are thought to be largely independent of the valley fill aquifer system. That is, they have recharge sources which are outside the area of the alluvium. Some may be discharge from regional groundwater flow systems extending outside this hydrologic subunit. However, pumping from the valley fill in these discharge zones could lead to some reduction of spring flows. Peak year M-X water requirements represent only a 1 percent increase over current water use in the valley and the estimated perennial yield is already exceeded.

Wah Wah Valley (54)

Potential impacts of projected M-X withdrawals on groundwater availability were judged to be relatively high. An evaluation of perennial yield and available groundwater storage as general indicators of groundwater abundance indicates this hydrologic subunit has a low potential for sustaining large-scale groundwater development. Wah Wah Valley has not yet been designated by the Utah State Engineer. Compared to available supply estimates, current water use is minor totaling only 50 acre-ft/year. An additional 8200 acre-feet/year may be required to support future mining and processing of alunite ore. Significant impacts on groundwater availability would be most likely to affect the livestock industry which diverts an estimated 50 acre-feet/year. Most springs in the valley are thought to be largely independent of the valley fill aquifer system. That is, they have recharge sources which are outside the area of the alluvium. Some may be discharge from regional groundwater flow systems extending outside this hydrologic subunit. However, pumping from the valley fill in these discharge zones could lead to some reduction of springflows. M-X withdrawals may reduce the underflow to the north through the deep carbonate aquifer. Peak year M-X water requirements represent a substantial (100 percent) increase over current water use in the valley but this would not exceed the estimated perennial yield during construction.

Big Smokey, South Valley (137A)

Potential impacts of projected M-X withdrawals on groundwater availability were judged to be relatively low. An evaluation of perennial yield and available groundwater storage as general indicators of groundwater abundance indicates this hydrologic subunit has a moderately high potential for sustaining large-scale groundwater development. Some legal constraints exist on future goundwater development. Compared to available supply estimates, current water use is relatively high totaling 31,000 acre-feet/year. Any singificant impacts on groundwater availability would be most likely to affect mining and energy industries which divert about 26,000 acre-feet/year and irrigators who account for about 4140 acre-feet/year of the current use. Lesser amounts of water are used for urban, industrial and grazing activities in the valley. Most springs in the valley are thought to be largely independent of the valley fill aquifer system. That is, they have recharge sources which are outside the area of the alluvium. Some may be discharge from regional groundwater flow systems extending outsdide this hydrologic subunit. However, pumping from the valley fill in these discharge zones could lead to some reduction of spring flows. M-X extractions could cause some reduction of the underflow to the south through the deep carbonate aquifer. Peak year M-X water requirements represent only a 3 percent increase over current water use in the valley and the estimated perennial yield is already exceeded.

Kobeh Valley (139)

Potential impacts of projected M-X withdrawals on groundwater availability were judged to be moderate. An evaluation of perennial yield and available groundwater storage as general indicators of groundwater abundance indicates this hydrologic subunit has a low potential for sustaining large-scale groundwater development. Kobeh Valley has not yet been designated by the Nevada State Engineer. Current water use, though not large, is important to the local economy and totals 3500 acre-ft/year. Any significant impacts on groundwater availability would be most likely to affect irrigators who divert about 3300 acre-feet/year and the livestock industry which accounts for about 100 acre-feet/year of the current use. M-X withdrawals could result in some reductions of spring flows in the valley. Peak year M-X water requirements represent an 80 percent increase over current water use in the valley but, this would not exceed the estimated perennial yield during construction.

Ralston Valley (141)

Potential impacts of projected M-X withdrawals on groundwater availability were judged to be relatively high. An evaluation of perennial yield and available groundwater storage as general indicators of groundwater abundance indicates this hydrologic subunit has a moderate potential for sustaining large-scale groundwater development. Severe legal constraints exist on future groundwater development. Current water use, though not large, is important to the local economy and totals 766 acre-ft/year. Significant impacts on groundwater availability would be most likely to affect irrigators who divert an estimated 760 acre-feet/year. Lesser amounts of water currently support grazing activities in the valley. About 270 acre-feet/year is pumped from wells in this subunit for use in Tonopha, Big Smokey Valley. Most springs in the valley are thought to be largely independent of the valley fill aquifer system. That is, they have recharge sources which are outside the area of the alluvium. Some may be discharge from regional groundwater flow systems extending outside the hydrologic subunit. However, pumping from the valley fill in these discharge zones could lead to some reduction of spring flows. M-X withdrawals could also reduce the underflow to the south through the deep carbonate aquifer. Peak year M-X water requirements represent a substantial (100 percent) increase over current water use in the valley and this would come very close to exceeding the estimated perennial yield during construction.

Alkali Spring Valley (142)

Potential impacts of projected M-X withdrawals on groundwater availability were judged to be relatively low. An evaluation of perennial yield and available groundwater storage as general indicators of groundwater abundance indicates this hydrologic subunit has a low potential for sustaining large-scale groundwater development. Alkali Spring Valley has not yet been designated by the Nevada State Engineer. Compared to available supply estimates, current water use is minor totaling 320 acre-ft/year. Additional water needs for projected future mining and energy production in the valley are estimated to be 1840 acre-feet/year. Any significant impacts on groundwater availability would be most likely to affect the mining industry which diverts an estimated 230 acre-feet/year. Lesser amounts of water are used for urban/industrial, and livestock uses in the valley. M-X withdrawals could result in some reduction of spring flow in the valley. Peak year M-X water requirements represent a substantial (100 percent) increase over current water use in the valley but, this would not exceed the estimated perennial yield during construction.

Stone Cabin Valley (149)

Potential impacts of projected M-X withdrawals on groundwater availability were judged to be relatively high. An evaluation of perennial yield and available groundwater storage as general indicators of groundwater abundance indicates this hydrologic subunit has a moderate potential for sustaining large-scale groundwater development. Severe legal constraints exist on fuuture groundwater development. Current water use, though not large, is important to the local economy and totals 1500 acre-ft/year. Significant impacts on groundwater availability would be most likely to affect irrigators who divert an estimated 1425 acre-feet/year. Lesser amounts of water are used by the livestock and mining industries in the valley. Most springs in the valley are thought to be largely independent of the valley aquifer system. That is, they have recharge sources which are outside the area of the alluvium. Some may be discharge from regional groundwater flow systems extending outside this hydrologic subunit. However, pumping from the valley fill in these discharge zones could lead to some reduction of springs flow. M-X withdrawals may also reduce the underflow to the south through the deep carbonate aquifer. Peak year M-X water requirements represent a 170 percent increase over current water use in the valley and this would exceed the estimated perennial yield during construction.

Antelope Valley (151)

Potential impacts of projected M-X withdrawals on groundwater availability were judged to be moderate. An evaluation of perennial yield and available groundwater storage as general indicators of groundwater abundance indicates this hydrologic subunit has a low potential for sustaining large-scale groundwater development. Some legal constraints exist on future groundwater development. Antelope Valley has not yet been designated by the Nevada State Engineer. Current water use, though not large, is important to the local economy and totals 1,000 acre-ft/year. Significant impacts on groundwater availability would be most likely to affect irrigators who divert an estimated 950 acre-ft/year. Lesser amounts of water are used for livestock watering in the valley. Most springs in the valley are thought to be largely independent of the valley fill aquifer system. That is, they have recharge sources which are outside the area of the alluvium. However, pumping from the valley fill in these discharge zones could lead to some reduction of spring flows. Pumping may also reduce the underflow to the north through the deep carbonate aquifer. Peak year M-X water requirements represent a substantial (100 percent) increase over current water use in the valley and this would nearly exceed the estimated perennial yield during construction.

Newark Valley (154)

Potential impacts of projected M-X withdrawals on groundwater availability were judged to be moderately high. An evaluation of perennial yield and available groundwater storage as general indicators of groundwater abundance indicates this hydrologic subunit has a moderate potential for sustaining large-scale groundwater development. Newark Valley has not yet been designated by the Nevada State Enginner. Compared to available supply estimates, current water use is relatively high, totaling 7,000 acre-ft/year. Significant impacts on groundwater availability would be most likely to affect irrigators who divert about 6,900 acre-ft/year and the livestock industry which accounts for about 80 acre-ft/year of the current use. Lesser amounts of water are used for mining activities in the valley. Numerous springs issue from the valley fill alluvium and are likely to represent discharge from local groundwater flow systems confined to the valley. M-X withdrawals from the valley fill could cause some decreases in the flow at these springs. Some springs may be largely independent of the valley fill aquifer system, having recharge sources outside the alluvium. Some springs may be discharges from regional groundwater flow systems extending outside the valley. However, pumping from the valley fill in these discharge zones could lead to some reduction of spring flows. Peak year M-X water requirements represent a 27 percent increase over current water use in the valley, but this would not exceed the estimated perennial yield during construction.

Little Smoky, North and South Valleys (155, A,C)

Potential impacts of projected M-X withdrawals on groundwater availability were judged to be moderate. An evaluation of perennial yield and available groundwater storage as general indicators of groundwater abundance indicates this hydrologic subunit has a low potential for sustaining large-scale groundwater development. These valleys have not yet been designated by the Nevada State Engineer. Current water use, though not large, is important to the local economy and totals 3,300 acre-ft/year. Significant impacts on groundwater availability would be most likely to affect irrigators who divert an estimated 3,230 acre-ft/year. Lesser amounts of water currently support grazing and mining activities in the valley. Most springs in the valley are thought to be largely independent of the valley fill aquifer system. That is, they have recharge sources which are outside the area of the alluvium. Some may be discharge from regional groundwater flow systems extending outside this hydrologic subunit. However, pumping from the valley fill in these discharge zones could lead to some reduction of spring flows. M-X pumping may reduce the underflow to the south through volcanic and carbonate rocks. Peak year M-X water requirements represent a 78 percent increase over current water use in the valley, and this would exceed the estimated perennial yield during construction.

Hot Creek Valley (156)

Potential impacts of projected M-X withdrawals on groundwater availability were judged to be moderate. An evaluation of perennial yield and available groundwater storage as general indicators of groundwater abundance indicates this hydrologic subunit has a moderately high potential for sustaining large-scale groundwater development. Hot Creek Valley has not yet been designated by the Nevada State Engineer. Compared to available supply estimates, current water use is minor, totaling 760 acre-ft/year. Foreseeable future water requirements to support expanded mining activities are estimated to be 250 acre-ft/year. Significant impacts on groundwater availability might affect irrigators and the mining industry, who divert an estimated 630 acre-ft/year. Lesser amounts of water currently support livestock watering. Several springs issue from the valley fill alluvium and are likely to represent discharge from local groundwater flow systems confined to the valley. M-X withdrawals from the valley fill could cause some decreases in flow at these springs. Other springs are thought to be largely independent of the valley fill aquifer system. Some of these springs may be discharge from a larger regional deep groundwater flow system. However, pumping from the valley fill in these discharge zones could lead to some reduction in these spring flows. Pumping may also reduce the underflow to the east through the deep carbonate aquifer. Peak year M-X water requirements represent a 170 percent increase over current water use in the valley, but this would not exceed the estimated perennial yield during construction.

Penoyer Valley (170)

Potential impacts of projected M-X withdrawals on groundwater availability were judged to be relatively high. An evaluation of perennial yield and available groundwater storage as general indicators of groundwater abundance, indicates that Penoyer Valley has a moderately low potential for sustaining large-scale groundwater development. Severe legal constraints exist on future groundwater development. Compared to available supply estimates, current water use is relatively high, totaling 12,473 acre-ft/year. Significant impacts on groundwater availability would be most likely to affect the mining industry, which diverts an estimated 9,400 acre-ft/year, and irrigated agriculture which accounts for about 3,000 acre-ft/year. Lesser amounts of water are used for grazing. Most springs in the valley are thought to be largely independent of the valley fill aquifer system. That is, they have recharge sources which are outside the area of the alluvium. However, pumping from the valley fill in these discharge areas may lead to some reduction of spring flows. Peak year M-X requirements represent a 7 percent increase over current use in the valley and the estimated perennial yield is already exceeded.

Coal Valley (171)

Potential impacts of projected M-X withdrawals on groundwater availability were judged to be relatively high. An evaluation of perennial yield and available groundwater storage as general indicators of groundwater abundance indicates this hydrologic subunit has a low potential for sustaining large-scale groundwater development. Coal Valley has not yet been designated by the Nevada State Engineer. Compared to available supply estimates, current water use is relatively minor, totaling 15 acre-ft/year. This water is used for livestock. M-X withdrawals could result in some reductions of spring flows throughout the valley, as well as reduce the underflow to the south through the deep carbonate aquifer. Peak year

M-X water requirements represent a very substantial increase over current water use in the valley, but this would not exceed the estimated perennial yield during construction.

Garden Valley (172)

Potential impacts of projected M-X withdrawals on groundwater availability were judged to be moderate. An evaluation of perennial yield and available groundwater storage as general indicators of groundwater abundance indicates this hydrologic subunit has a low potential for sustaining large-scale groundwater development. Garden Valley has not yet been designated by the Nevada State Engineer. Compared to available supply estimates, current water use is minor, totaling 280 acre-ft/year. Significant impacts on groundwater availability would be most likely to affect irrigators who divert an estimated 250 acre-ft/year. Lesser amounts of water currently support livestock activities in the valley. M-X withdrawals could result in some reductions of spring flows throughout the valley, as well as reduce the underflow to the southeast through the deep carbonate aquifer. Peak year M-X water requirements represent a 50 percent increase over current water use in the valley, but this would not exceed the estimated perennial yield during construction.

Railroad N & S Valley (173, A,B)

Potential impacts of projected M-X withdrawals on groundwater availability were judged to be relatively high. An evaluation of perennial yield and available groundwater storage as general indicators of groundwater abundance indicates this hydrologic subunit has a high potential for sustaining large-scale groundwater development. Some legal constraints exist on future groundwater development. Current water use is relatively high, totaling 12,500 acre-ft/year and is important to the local economy. Any significant impacts on groundwater availability would be most likely to affect irrigators who divert an estimated 11,880 acre/ft per year. Lesser amounts of water (approximately 116 acre-ft/year) are used for livestock watering. Several springs issue from the valley fill alluvium and are likely to represent discharge from local groundwater flow systems confined to the valley. M-X withdrawals from the valley fill could cause some decreases in flow at these springs. (Other springs are thought to be largely independent of the valley fill aquifer system, having recharge sources outside the alluvium.) Some springs may be discharges from regional groundwater flow systems extending outside the valley. However, pumping from the valley fill in these discharge zones could lead to some reduction of spring flows. Pumping may also reduce underlow leaving the valley via the alluvium and possibly carbonate rocks. Peak year M-X water requirements represent a 40 percent increase over current water use in the valley but this would not exceed the estimated perennial yield during construction.

Cave Valley (180)

Potential impacts of projected M-X withdrawals on groundwater availability were judged to be moderate. An evaluation of perennial yield and available groundwater storage as general indicators of groundwater abundance indicates this hydrologic subunit has a low potential for sustaining large-scale groundwater development. Cave Valley has not yet been designated by the Nevada State Engineer. Compared to available supply estimates, current water use is moderate, totaling 1,000 acre-ft/year. Any significant impacts on groundwater availability would be most likely to affect irrigators who divert an estimated 1,000 acre-ft/year. Lesser amounts of water are used for livestock activity in the valley. M-X withdrawals may cause some reduction of spring flows in the valley. Pumping may also reduce the underflow to the west, southwest, or south through bedrock aquifers. Peak year M-X water requirements represent a 100 percent increase over current water use in the valley, but this would not exceed the estimated perennial yield during construction.

Dry Lake Valley (181)

Potential impacts of projected M-X withdrawals on groundwater availability were judged to be moderate. An evaluation of perennial yield and available groundwater storage as general indicators of groundwater abundance indicates this hydrologic subunit has a low potential for sustaining large-scale groundwater development. Dry Lake Valley has not yet been designated by the Nevada State Engineer. Compared to available supply estimates, current water use is relatively minor, totaling 21 acre-ft/year. It is used mainly by livestock. Springs are very scarce in Dry Lake Valley as most of the estimated groundwater recharge is balanced by underflow to the south through the deep carbonate aquifer. Pumping may lead to some reduction of this underflow. Peak year M-X water requirements represent a very substantial increase over current water use in the valley but this would not exceed the estimated perennial yield during construction.

Delamar Valley (182)

Potential impacts of projected M-X withdrawals on groundwater availability were judged to be moderate. An evaluation of perennial yield and available groundwater storage as general indicators of groundwater abundance indicates this hydrologic subunit has a low potential for sustaining large-scale groundwater development. Delamar Valley has not yet been designated by the Nevada State Engineer. Compared to available supply estimates, current water use is minor, totaling 44 acre-ft/year. Livestock are the main consumers. Springs are very scarce in Delamar Valley as most of the estimated groundwater recharge is balanced by the underflow to the south through deep carbonate rocks. Pumping could lead to some reduction of this underflow. Peak year M-X water requirements represent a substantial increase over current water use in the valley, but this would not exceed the estimated perennial yield during construction.

Lake Valley (183)

Potential impacts of projected M-X withdrawals on groundwater availability were judged to be relatively high. An evaluation of perennial yield and available groundwater storage as general indicators of groundwater abundance indicates this hydrologic subunit has a moderately low potential for sustaining large-scale groundwater development. Severe legal constraints exist on future groundwater development. Compared to available supply estimates, current water use is relatively high, totaling 18,230 acre-ft/year. Significant impacts on groundwater availability would be most likely to affect irrigators who divert an estimated 18,200 acre-ft/year. Lesser amounts of water currently support the livestock industry in the valley. Several springs issue from the valley fill alluvium and are likely to represent discharge from local groundwater flow systems confined to the valley. M-X withdrawals from the valley fill could cause some decreases in flow at these springs. Other springs are thought to be largely independent of the valley fill aquifer system, having recharge sources outside the alluvium. Peak year M-X water requirements represent a 15 percent increase over current water use in the valley and the estimated perennial yield is already exceeded.

Spring Valley (184)

Potential impacts of projected M-X withdrawals on groundwater availability were judged to be relatively low. An evaluation of perennial yield and available groundwater storage as general indicators of groundwater abundance indicates this hydrologic subunit has a high potential for sustaining large-scale groundwater development. Spring Valley has not yet been designated by the Nevada State Engineer. Current water use is relatively high, totaling 18,340 acre-ft/year, but this does not exceed the estimated perennial yield. Any significant impacts on groundwater availability would be most likely to affect irrigators who use 11,880 acre-ft/year and mining which accounts for about 240 acre-ft/year of the current use. Lesser amounts of water (about 90 acre-ft/year) are used by livestock. Several springs issue from the valley fill alluvium and are likely to represent discharge from local groundwater flow systems confined to the valley. M-X withdrawals from the valley fill could cause some decreases in flow at these springs. Other springs are thought to be largely independent of the valley fill aquifer system, having recharge sources outside the alluvium. Some springs may be discharges from regional groundwater flow systems extending outside the valley. However, pumping from the valley fill in these discharge zones could lead to some reduction of spring flows. Peak year M-X water requirements represent a 4 percent increase over current water use in the valley and this would not exceed the estimated perennial yield during construction.

Pahranagat Valley (209)

Potential impacts of projected M-X withdrawals on groundwater availability were judged to be relatively low. An evaluation of perennial yield and available groundwater storage as general indicators of groundwater abundance indicates this hydrologic subunit has a moderate potential for sustaining large-scale groundwater development. Pahranagat Valley has not yet been designated by the Nevada State Engineer. Compared to available supply estimates, current water use is relatively high, totaling 15,800 acre-ft/year. Any significant impacts on groundwater availability would be most likely to affect irrigators who divert about 15,600 acre-ft/year. Lesser amounts of water are used in urban/industrial activities in the valley (about 200 acre-ft/year). Livestock use minor amounts. Several major springs issue from the valley fill alluvium. These springs probably represent discharges from a regional groundwater flow system which extends along the length of the White River Wash in east-central Nevada. M-X withdrawals from the valley fill could cause some decreases in flow at these springs. Similarly, pumping may reduce the underflow to the south entering Coyote Spring Valley. Peak year M-X water requirements represent only a 2.5 percent increase over current water use in the valley and this would not exceed the estimated perennial yield during construction.

SPLIT BASING (4.1.5)

Split basing seeks to lesson the impacts by dividing the required 200 clusters into several deployment regions. This is accomplished by eliminating some sections of suitable area. In Nevada/Utah this reduces the number of affected hydrologic units from 38 to 23. In Texas/New Mexico the number of counties affected is reduced from 21 to 18 but the number of shelters in many of the counties, especially in Texas, is greatly reduced.

The reduction of the number of hydrologic subunits may lesson the total number of potential impacts but it does not reduce the potential for impact in each candidate site. Still included for siting are 71 percent of the designated subunit, 50 percent of those with a high potential for impact and 60 percent of those with a moderate potential for impact. It would appear that the choice of subunits for split basing was not based upon water availability.

In Texas/New Mexico the regions chosen for split basing include those experiencing some of the most severe groundwater depletions. Those areas where aquifer life is still long were not utilized. Again although the total impact to siting region the impacts at the specific well locations has not been lessoned.

The OBs chosen for split basing also are not the best available. Clovis is a much more impacted area in Dalhart. Coyote Spring is rated as one of the more sensitive basing sites due to its proximity to several critical springs.

4.2 TEXAS/NEW MEXICO DDA

M-X EFFECTS (4.2.1)

General (4.2.1.1)

The deployment of the M-X missile system will affect the water resources in the potential siting area in numerous ways. These effects can be categorized into two basic groups. The first group includes the placement of the roads, shelters, OBs, and ASCs. These will disrupt the physical setting of the area, thus altering the surface drainage characteristics. These effects are long-term and unavoidable. This is so because all of these are necessary for the project and will exist throughout its useful life and probably beyond that time. Mitigation procedures may reduce potential impacts but only a dramatic change in the proposed project could reduce the size of the M-X effects.

The second group of M-X induced effects on water resources is the demand for water for construction and operation activities. This type of effect can again be considered unavoidable. However, construction demands would be short term effects, while the projected operational demands are long-term.

The amount of facilities and the associated water demands are presented in tables in the sections which follow.

M-X Water Demands (4.2.1.2)

DDA Construction

The DDA construction would require water for the protective structures, cluster roads, DTN and ASCs. Components in the construction activities requiring water include earthwork, concrete and concrete plants, aggregate plants, domestic uses, dust control and irrigation for revegetation. The demands will necessitate diversions at specific locations (yet to be determined) throughout the project area.

Tables 4.2.1.2-1 and 4.2.1.2-2 present the estimated quantity of water that would be required in each county in the siting area for Alternative 7. Also presented is the number of protective shelters and amount of roads by county. Potential locations for construction camps are also presented in Tables 4.2.1.2-1 and 4.2.1.2-2. The quantity of water that will be required for activities in these camps will be a significant portion of that total required for the county.

In Alternative 8, fewer clusters and less miles of roads are located in each county. Table 4.2.1.2-3 presents the affected counties, the amount of facilities in each and an estimate of the water demands for construction activities.

The range of values listed for water demands is basically a function of exclusion (minimum values) or inclusion (maximum values) of irrigation for revegetation of disturbed areas. Even though system requirements are very similar, there is a significant difference between the "Most Probable Quantity" water requirements in Nevada/Utah and Texas/New Mexico, because it is anticipated that some irrigation for revegetation would be required in Nevada/Utah, whereas very little would be required in Texas/New Mexico.

DDA Operations

DDA operational water demands are small, mostly domestic uses at the ASCs. Water demands are estimated to be less than 100 acre/ft per year per ASC. For the full basing alternatives, ASCs have been sited in the counties of Hartley and Deaf Smith (Texas) and Roosevelt (New Mexico).

ASCs for Alternative 8 have been located in the counties of Quay and Roosevelt (New Mexico).

IMPACTS RELATIVE TO SURFACE WATER (4.2.2)

There will be an increase in runoff of surface water over the area covered by the DTN, cluster roads and protective structures. The increase is expected to be small when compared to total runoff in the deployment area. The quantities of runoff can be determined when the specific site locations are known and the slope, contouring and proximity to water courses is identified. Roads and other M-X facilities will be designed to provide road drainage and storm runoff features. Design will minimize upstream siltation and downstream erosion.

The clearing, leveling and earth moving activities associated with construction, in combination with sporadic runoff from heavy, but infrequent, rainstorms, will contribute to increased erosion rates. Short-term water erosion impacts are

Table 4.2.1.2-1. M-X water requirements for construction of dedicated deployment area in Texas.

COUNTY	NO. OF PROTECTIVE STRUCTURES	MILES OF CLUSTER ROADS	MILES OF DTN	NO. OF CONSTRUCTION CAMPS	PEAK YEAR		TOTAL PROJECT	
					RANGE X10³ ACRE-FT	MPQ[1] X10³ ACRE-FT	RANGE X10³ ACRE-FT	MPQ[1] X10³ ACRE-FT
Bailey	92	119	31	1	1.2-2.1	1.6	2.6-4.8	3.7
Castro	161	208	50	1/2	1.1-2.2	1.6	1.9-3.5	2.7
Cochran	92	119	2	0	0.2-0.4	0.3	0.5-0.8	0.7
Dallam	667	861	165	3	4.7-8.7	6.7	9.1-17	13
Deaf Smith	598	772	90	2-1/2	2.5-4.7	3.6	6.9-13	9.8
Hartley	345	416	80	1	2.0-3.6	2.8	4.6-8.5	6.5
Hockley	23	30	0	0	0.05-0.09	0.07	0.1-0.2	0.2
Lamb	46	59	15	0	0.1-0.2	0.2	0.3-0.5	0.4
Oldham	46	59	3	0	0.08-0.1	0.1	0.3-0.4	0.4
Parmer	138	178	90	1-1/2	1.4-2.6	2.0	2.7-5.1	3.9
Randall	69	89	12	1/2	0.7-1.7	1.0	1.0-2.3	1.4
Sherman	46	59	5	0	0.1-0.2	0.2	0.3-0.4	0.4
Swisher	23	30	0	0	0.07-0.1	0.1	0.1-0.2	0.2

2463

[1]MPQ - Most Probable Quantity.

Table 4.2.1.2-2. M-X water requirements for construction of dedicated deployment area in New Mexico.

COUNTY	NO. OF PROTECTIVE STRUCTURES	MILES OF CLUSTER ROADS	MILES OF DTN	NO. OF CONSTRUCTION CAMPS	PEAK YEAR		TOTAL PROJECT	
					RANGE X10³ ACRE-FT	MPQ[1] X10³ ACRE-FT	RANGE X10³ ACRE-FT	MPQ[1] X10³ ACRE-FT
Chaves	483	621	104	1	2.1-3.9	3.0	4.7-8.7	6.7
Curry	184	238	130	0[2]	1.0-3.3	1.3	1.4-5.7	1.9
DeBaca	115	149	8	1	1.4-2.6	2.0	2.7-4.9	3.8
Harding	207	267	62	1	1.8-3.4	2.6	3.6-6.6	5.1
Lea	23	30	0	0	0.07-0.1	0.1	0.1-0.2	0.2
Quay	460	594	145	1[2]	2.2-4.0	3.1	5.0-11	7.2
Roosevelt	552	713	210	2	2.0-3.4	2.8	7.1-13	10
Union	230	297	50	0[2]	0.6-2.2	0.8	1.4-5.1	1.9

2463

[1]MPQ - Most Probable Quantity.

[2]Indicates an additional construction camp is possible if proposed construction camp location is not acceptable.

Table 4.2.1.2-3. M-X water requirements for construction of dedicated deployment area in Texas and New Mexico, split basing.

HYDROLOGIC SUBUNIT OR COUNTY	NUMBER OF PROTECTIVE STRUCTURES	CLUSTER ROAD (miles)	DTN (miles)	NUMBER OF CONSTRUCTION CAMPS	PEAK YEAR RANGE X10³ AC-FT	PEAK YEAR MPQ[1] X10³ AC-FT	TOTAL PROJECT RANGE X10³ AC-FT	TOTAL PROJECT MPQ[1] X10³ AC-FT
Bailey	14	18	26	0	0.1 - 0.3	0.2	.2 - .4	0.3
Cochran	51	66	0	0	0.3 - 0.8	0.5	.7 - 1.3	1.0
Dallam	190	245	50	1	1.7 - 3.1	2.4	2.3 - 4.3	3.3
Deaf Smith	242	313	40	1	1.8 - 3.3	2.5	2.8 - 5.2	4.0
Hartley	250	323	51	1	1.8 - 3.4	2.6	3.0 - 5.6	4.3
Hockley	14	18	0	0	m - 0.1	0.1	0.1 - 0.4	0.3
Lamb	9	12	1	0	m - 0.1	0.1	0.1 - 0.3	0.2
Oldham	41	53	0	0	0.3 - 0.5	0.4	0.5 - 0.9	0.7
Parmer	1	2	0	0	m	m	m	m
Chaves	474	611	71	1	3.4 - 6.2	4.3	5.5 - 10.3	7.9
Curry	43	56	80	0	0.3 - 0.5	0.7	0.6 - 0.9	0.8
DeBaca	115	149	18	0	0.8 - 1.6	1.2	1.4 - 2.6	2.0
Harding	202	261	51	1	1.5 - 2.7	2.1	2.7 - 4.9	3.8
Lea	17	22	0	0	0.1 - 0.3	0.2	0.2 - 0.4	0.3
Quay	312	401	95	1	2.2 - 4.2	3.2	3.7 - 6.9	5.3
Roosevelt	164	212	125	1	1.2 - 2.2	1.7	2.1 - 3.9	3.0
Union	155	200	40	0	0.4 - 0.8	0.6	0.6 - 1.0	0.8
Guadalupe	6	8	0	0	m - 0.1	0.1	m - 0.1	0.1

4177

[1]MPQ = Most Probable Quantity.

m = Minor Demand < 0.1 acre-ft.

expected to be moderate in most valleys containing DTN and protective structures. Revegetation of the disturbed soils and proper engineering design of the roads will help mitigate the impacts after construction has been completed. Long-term impacts are expected to be low if these mitigating measures are undertaken.

Soil disturbance may create some chemical pollution of surface waters due to the enhancement of the oxidation process of some trace elements. The possible increase in dissolved minerals in runoff from the disturbed areas will be greatly diluted by the mixing runoff from the large undisturbed areas. Table 4.2.2-1 identifies potential impacts on surface waters. Impacts are difficult to assess with specificity until project siting is complete. At that time additional studies will be conducted to determine impacts.

IMPACT ANALYSIS FOR GROUNDWATER (4.2.3)

Potential Impacts (4.2.3.1)

Impacts on groundwater availability which could result from M-X deployment in the Texas/New Mexico deployment area are of similar nature to those discussed for the various alternatives involving Nevada and Utah. Also, much of the description of the impact analysis methodology, including assumptions used and limitations of the results, is relevant to the analysis performed for Texas and New Mexico.

Impact Analysis (4.2.3.2)

The analysis method used to evaluate potential impacts of M-X water development on groundwater resources in Texas and New Mexico is different from that used for the Nevada/Utah deployment alternatives, largely because of the different systems of water appropriation. In both Texas and New Mexico, large volumes of water may be legally removed from aquifer storage and put to beneficial use.

In New Mexico this is allowed in certain groundwater basins where the State Engineer decides that the only way to derive significant economic benefit from the groundwater resource is to mine it, or pump it at a rate which greatly exceeds the natural rate of groundwater recharge. In such groundwater basins, water rights are issued on the basis of an assigned "economic life of the aquifer" (generally 40 years) which controls the rate at which the groundwater reservoir will be depleted. In other areas, like major parts of Curry County for example, overdrafting is permitted by default, because the State Engineer has not declared an Underground Water Basin for the purpose of administering water rights.

In Texas, overdrafting is permitted without legal control. Water is a property right that is conveyed with the land and in accordance with the "English" or "common law" rule, landowners have the right to capture, for use or sale, all the water they can from beneath their land. In some areas, landowners have adopted voluntary regulations which control well spacing, not withdrawal volumes.

The result of the above is that, in large areas of both western Texas and eastern New Mexico, aquifer storage in the Ogallala Formation (the area's principal aquifer) is being depleted.

Table 4.2.2-1. Potential impacts of construction on surface waters.

DISTURBANCES	IMPACT	AVOIDABLE	SECONDARY IMPACT
1. Earth moving	1.1 Temporary increase of sheet erosion	No	1.1 Temporary degradation of surface waters
			1.2 Sedimentation
2. Drainage channel relocation and modification	2.1 Channel instability and erosion	Yes	2.1 Temporary degradation of surface waters
			2.2 Sedimentation
3. Devegetation	3.1 Temporary increased sheet erosion	No	3.1 Temporary degradation of surface waters
	3.2 Temporary increased runoff	No	3.2 Temporary decreased recharge
			3.3 Sedimentation
4. Placement of impervious surface	4.1 Increased local runoff	No	4.1 Degradation of surface water. Lowering of water table and ground-water supplies
	4.2 Decreased recharge	Yes	4.2 Increased erosion
5. Increased public accessibility	5.1 Loss of vegetation	No	5.1 Increased erosion
			5.2 Degradation of surface waters
6. Camp development activities	6.1 Disturbance of soils	No	6.1 Temporary increased erosion
7. Materials storage and handling	7.1 Waterborne pollutants in runoff	Yes	7.1 Surface water degradation

2390-2

The Texas/New Mexico siting area was divided into nine groundwater regions on the basis of similar hydrologic characteristics and the Texas/New Mexico state line (see Figure 4.2.4-2). The analysis method used to evaluate potential impacts of M-X water development for OB and DDA-related needs basically focused on answering the following question:

> Could M-X water requirements lead to a significant increase in the rate of aquifer depletion that already exists within a given groundwater region, and thus shorten "the economic life of the aquifer"?

Specifically, the analysis involved comparing M-X water needs to resource availability (aquifer storage) and competition for the resource (current aquifer depletion rates). For purposes of the analysis, any increases in aquifer depletion assume greater significance if the projected economic life of the aquifer is already relatively short (less than 50 years). Table 4.2.3-1 summarizes the basic criteria used to assign impact scores to the individual groundwater regions. Distinctions between low, medium and high potential for impact were arbitrarily drawn as shown in the table.

It should be emphasized that, by necessity, M-X withdrawals were essentially distributed evenly throughout each groundwater region to determine their possible influence on the "average" depletion rate in each region as a whole. It is recognized, of course, that M-X withdrawals will not be distributed uniformly over the entire groundwater region, but rather will be concentrated near construction camps and operating bases. Consequently, the analysis does not provide information useful in determining specific impacts on water levels, nor does it quantify or identify areas where groundwater will actually be removed from storage.

IMPACT OF M-X WATER WITHDRAWALS RELATIVE TO GROUNDWATER IN TEXAS/NEW MEXICO (4.2.4)

General (4.2.4.1)

The impacts of groundwater development in an M-X siting hydrologic subunit will, in part, depend on the hydraulic responses (water level respones) in the aquifer(s) and the uses of water in that subunit. In turn, the hydraulic responses which occur will depend on on the hydrogeologic conditions, the quantities rate of water diverted to M-X uses, and the method of development of the water supplies.

Long- and Short-Term Effects (4.2.4.2)

Groundwater withdrawals which result in significant hydraulic responses in the aquifers (i.e., changes in groundwater levels and pressure distribution) will be both short- and long-term. Groundwater withdrawals for the 30-year OB maintenance needs are likely to have more widespread and longer term impacts than groundwater withdrawals for the 2-5 year DDA construction period.

Through extraction of groundwater, lowering of the water table, [illegible] heads, and pumping levels in existing neighboring wells may occur. The [illegible] of this impact is dependent primarily upon the design characteristics [illegible] schedule of the well and the hydraulic properties of the [illegible] impact can be minimized by proper spacing of the wells.

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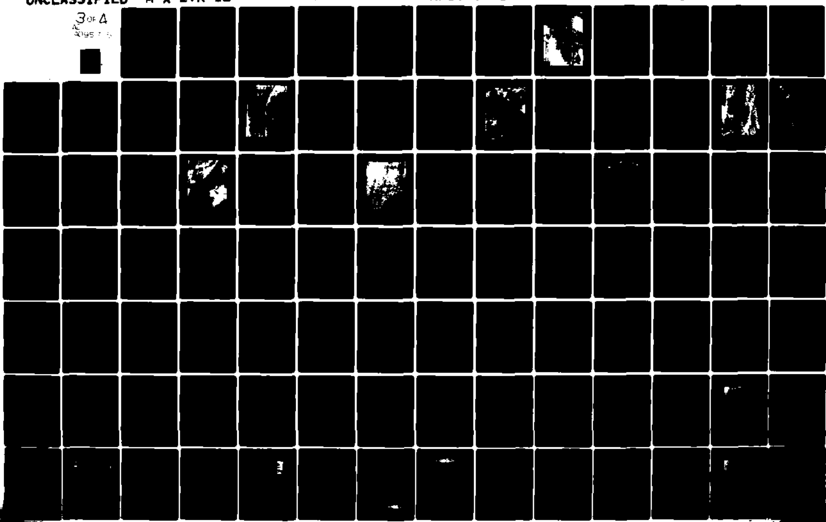

Table 4.2.3-1. Criteria for evaluating potential impacts on groundwater availability in Texas and New Mexico.

Impact Score	Criteria
2	M-X demand represents <1% of current aquifer depletion rate and aquifer life >50 years.
2	M-X demand represents <1% of current aquifer depletion rate but aquifer life <50 years
3	M-X demand represents 1 - 5% of current aquifer depletion rate and aquifer life >50 years.
3	M-X demand represents 1 - 5% of current aquifer depletion rate and aquifer life <50 years.
3	M-X demand represents >5% of current aquifer depletion rate and aquifer life >50 years.
4	M-X demand represents >5% of current aquifer depletion rate and aquifer life <50 years

1 - No impact

2 - Low potential impact

3 - Moderate potential impact

4 - High potential impact

Local and Regional Effects (4.2.4.3)

Changes in hydrologic environment can be local, i.e., immediate vicinity of wells, valley-wide, or regional where a number of hydrologic subunits are connected by underlying aquifers.

In the North Plains Groundwater Conservation District No. 2 for example, the required spacing between wells is regulated according to the design discharge, as measured by the inside diameter of the pump column. A proposed well with an inside diameter of 10 inches or larger must be spaced at least 500 yards away from the nearest well. Spacings in other regions will be selected to minimize the drawdown impact on nearby wells.

A reduction of spring discharge rates may occur. Running Water Draw in the Brazoa River Basin was once perennially supplied by springs; however, due to groundwater pumpage and depletion, it is now intermittent. Any spring discharge decrease could also adversely impact wildlife whose habitats depend upon the springs.

Possible regional impacts have been identified which may affect areas that are not actually considered for M-X siting purposes, but are within the same regional flow system as M-X sites. The Pecos River at the south project area boundary represents a good example of such potential impact. The river immediately above this location receives water from its tributaries and from springs in the Roswell artesian basin. During the period from 1964 to 1978, the average annual gain in base flow in a 12-mile reach was 18,250 acre/ft per year. From 1957 to 1963, the gain was a much larger 30,850 acre/ft per year. The decline in base flow gain is probably due to development of the aquifers in the Roswell Basin. It should be noted that the annual water demands of the M-X project are small compared with existing pumping rates. The potential impact of M-X extractions on flow in the Pecos River has not been determined; however, the relatively minor extractions associated with the project are not expected to have a significant impact on flow in the river.

Water Quality (4.2.4.4)

Construction of roads and shelters would be expected to slightly increase the surface water quantity by increasing runoff. The compaction of soil for road construction would alter the moisture-holding and runoff characteristics of the soils and would thereby increase runoff. This compaction can, then, create higher flood peaks at downstream locations, such as at road crossings.

Disturbance of soil may expose fresh mineral surfaces to oxidation and thereby increase their solubility. The percentage of disturbed land would be small, however, and the expected increase in dissolved solids from surface runoff would be minor.

Diversion of surface runoff may, because of road and shelter construction, reduce the quantity of water that normally recharges the aquifers. This impact is expected to be insignificant.

Depending upon the approach used in obtaining a water supply, the M-X system's consumption could either favorably or adversely affect water supply quality. If water is obtained through the purchase or lease of existing irrigation water rights, and the irrigated land is temporarily retired from agriculture, it is possible, in some areas, that the total dissolved solids load in the groundwater would stabilize since the leaching by irrigation water containing fertilizers would have been decreased. Conversely, if the amount of groundwater extracted is increased by M-X usage, and the rate of irrigation remains the same, the total dissolved solids load in the groundwater might increase at about the same or at a slightly higher rate than before the M-X withdrawals. It should be emphasized that this is only a theoretical impact. Currently there is nothing to indicate that irrigated agriculture is having adverse effects on groundwater quality in the project area.

Beneficial Impacts (4.2.4.5)

As in the Nevada/Utah siting region, the local Texas/New Mexico communities may benefit from the newly developed water supplies and the associated infrastructure when these supplies are no longer needed for M-X.

Effects on M-X Siting Regions in Texas/New Mexico (4.2.4.6)

Following is a brief discussion on the impact analysis results. Key factors which contributed to the evaluation of impacts are highlighted for each hydrologic region. Figures 4.2.4-1 and 4.2.4-2 are included to help the reader visualize the relationships between the parameters which formed the basis for the analysis. The actual numeric values of aquifer storage and depletion which were used are found in Tables 3.2.1-1 and 3.2.1-2.

Region I

Potential impacts of M-X withdrawal on groundwater availability were judged to be relatively low. M-X water requirements for construction are estimated at 21,000 acre/ft over 3 years. This represents only a minor increase of .8 percent in the region's current aquifer depletion rate. M-X withdrawals are also only .07 percent of the recoverable groundwater in storage. The projected economic life of the aquifer in Region I is only about 35 years, but because M-X withdrawals are so small relative to current pumping volumes, the long- and short-term viability of the resource should not be significantly affected. The current depletion rate of springflows along Running Water Draw could increase slightly.

Region III

Potential impacts of projected M-X withdrawals on groundwater availability were judged to be relatively low. Total M-X water requirements for construction are estimated to be 18,000 acre/ft over a three-year period. This, however, represents a very minor .6 percent increase in the region's current aquifer depletion rate. Similarly, M-X withdrawals represent only .02 percent of the estimated recoverable groundwater in storage in Region III. The projected economic life of the aquifer is 77 years, but because M-X withdrawals are so small compared to current pumping volumes, the long- and short-term viability of the resource should not be significantly affected. No springs are reported in the region.

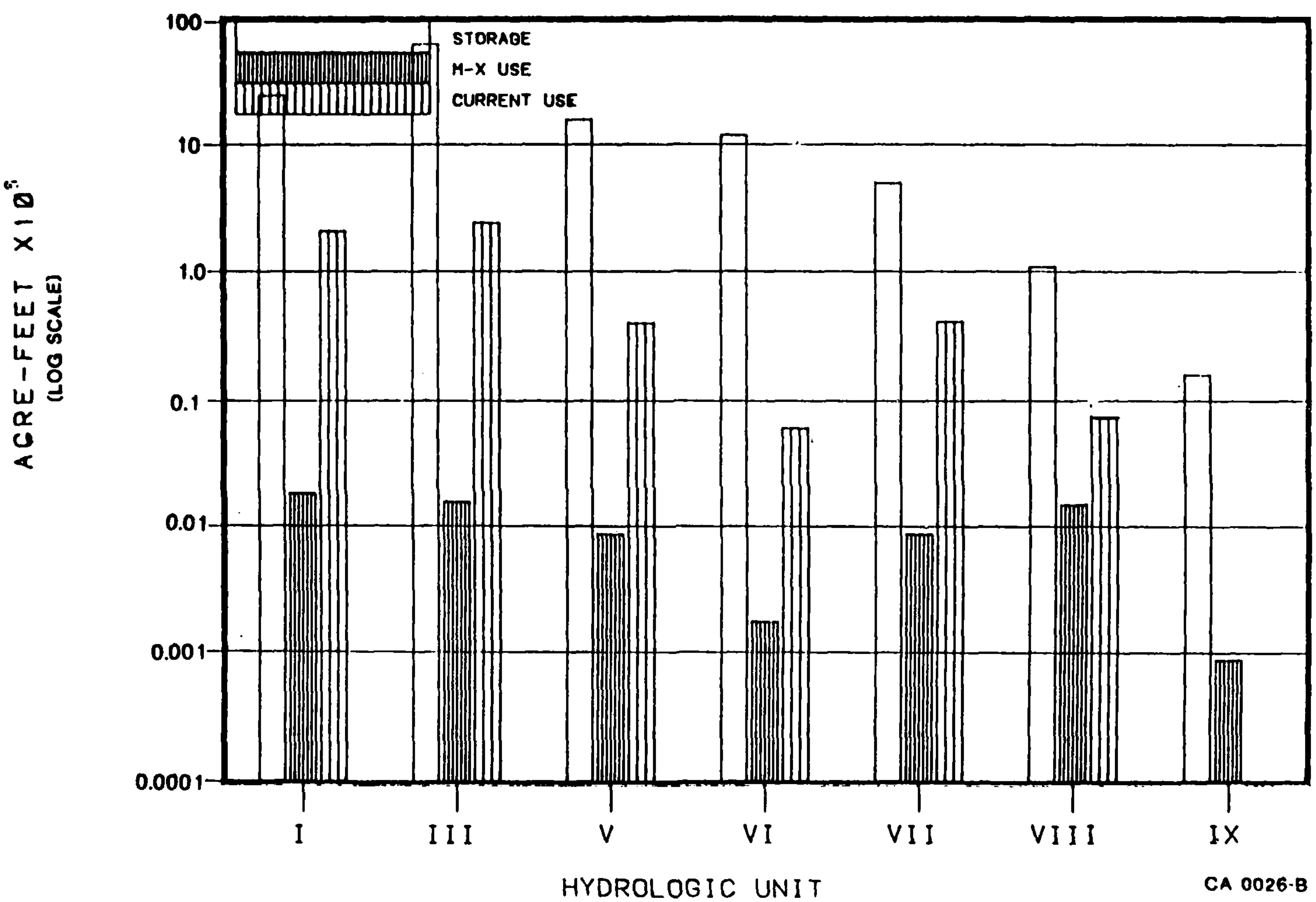

Figure 4.2.4-1. Available groundwater storage, 3-year aquifer depletion, and M-X use.

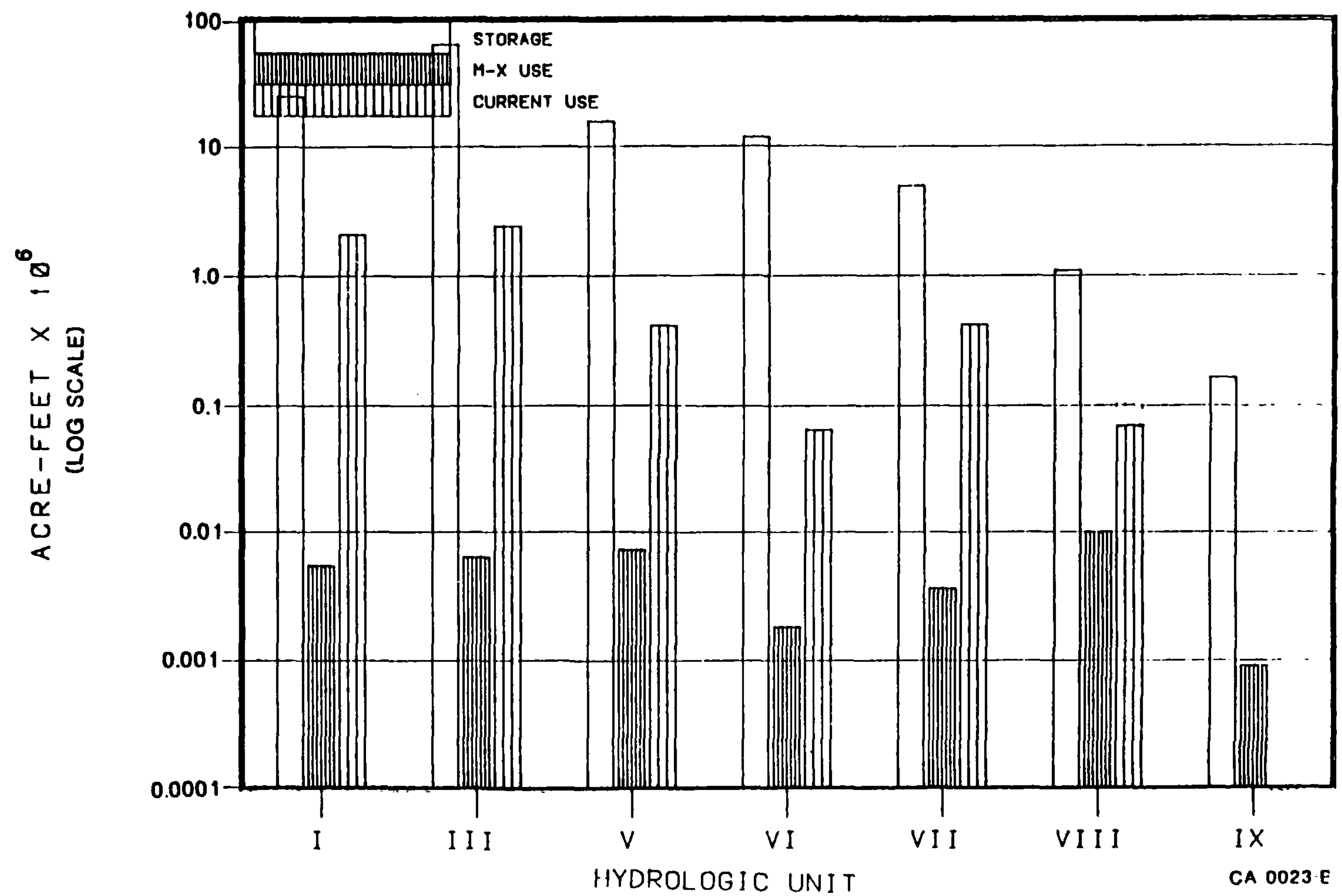

Figure 4.2.4-2. Available groundwater storage, 3-year aquifer depletion, M-X use.

Region V

Potential impacts of projected M-X groundwater withdrawals on resource availability were judged to be moderate. Total M-X water requirements for construction are estimated at 10,000 acre/ft over a three-year period. This represents a 2.2 percent increase in the region's current aquifer depletion rate, which has some significance. However, M-X withdrawals represent only .05 percent of the estimated recoverable groundwater in storage, and the projected economic life of the aquifer is greater than 100 years, with or without M-X. No springs are reported in the region.

Region VI

Potential impacts of projected M-X withdrawals on groundwater availability were judged to be moderate. Total estimated M-X water requirements for construction are 2,000 acre/ft over a three-year period. This represents a 2.9 percent increase in the current aquifer depletion rate, which has some significance. However, M-X withdrawals represent only .01 percent of the estimated recoverable groundwater in storage, and the projected economic life of the aquifer is greater than 100 years, with or without M-X. No springs are reported in the region.

Region VII

Potential impacts of M-X groundwater withdrawals on resource availability were judged to be moderate. Total M-X water requirements for construction are estimated to be 10,000 acre/ft during a three-year period. This represents a 2.2 percent increase in the region's current aquifer depletion rate, which has some significance. M-X withdrawals are .2 percent of estimated recoverable groundwater in storage. The projected economic life of the aquifer is only 37 years, so the additional withdrawal of 10,000 acre/ft must be viewed as significant. The current depletion rate of springs along Running Water Draw could increase slightly.

Region VIII

Potential impacts of M-X withdrawals on groundwater availability were judged to be relatively high. Total water requirements for DDA construction over a three-year period are estimated to be 17,000 acre/ft. This represents a very substantial increase of 21.4 percent in the region's current aquifer depletion rate. This also represents a significant 1.4 percent of the total estimated volume of recoverable groundwater in storage. In addition, the projected economic life of the aquifer in Region VIII is only 47 years, and M-X pumping could shorten that projection by ten years. No springs are reported in the region.

Region IX

Potential impacts of M-X withdrawals on groundwater availability were judged to be relatively low. M-X water requirements for construction are estimated to be 1,000 acre/ft during a three-year period. Current water use in Region IX is not resulting in significant depletion of groundwater supplies, and M-X withdrawals should not alter that situation. Depending on pumping locations, there could be some reduction of current groundwater discharge to the Pecos River.

4.3 BERYL OB SITE

GENERAL (4.3.1)

The Beryl site is proposed as a first operating base in Alternatives 3 and 4 and as a second operating base in Alternative 1. As a first operating base, it would occupy approximately 6,000 acres and include an airfield, support facilities, clear zones, a designated assembled area (DDA), an operational base test site (OBTS), a designated transportation network and a railroad spur. A second operating base is smaller as it has no DDA or OBTS and houses fewer personnel. The proposed location for the base is shown in Figure 4.3.1-1.

IMPACTS RELATIVE TO SURFACE WATER (4.3.2)

Construction and maintenance of the operating base will effect the local surface waters. Storm runoff will be increased by the introduction of additional impermeable surfaces. The increase is expected to be small when compared to total runoff in the siting area. The quantities of runoff can be determined when the specific site locations are known and the slope, contouring and proximity to water courses is identified. Roads, runways, and M-X facilities will be disigned to provide drainage and storm runoff features. Design will minimize upstream siltation and downstream erosion.

The clearing, leveling and earth moving activities associated with construction, combination with sporatic runoff from heavy, but infrequent, rainstorms, will contribute to increased erosion rates. Short-term water erosion impacts are expected to be moderate. Revegetation of the disturbed soils and proper engineering design of the facilities will help mitigated the impacts after construction has been completed. Long-term impacts are expected to be low if these mitigating measures are undertaken.

Soil disturbance may create some chemical pollution of surface waters due to the enhancement of the oxidation process of some trace elements. The possible increase in dissolved minerals in runoff from the disturbed areas will be greatly diluted by the mixing runoff from the large undisturbed areas. Table 4.2.2-1 identifies potential impacts on surface waters. Impacts are difficult to assess with specificity until project siting is complete. At that time additional studies will be conducted to determine impacts.

M-X WATER DEMANDS (4.3.3)

Construction (4.3.3.1)

Construction activities, similar to those in the DDA, will require water. This will most likely be obtained from the groundwater supply. The quantities required depend upon the facilities constructed. The Beryl site could be a first or a second OB depending upon the final alternative chosen. Estimated water demands for construction of a OB at Beryl are presented in Table 4.3.3.1-1.

Operation (4.3.3.2)

The operational water requirements are presented in Table 4.3.3.2-1. The OB and community water requirements assume 80 percent of military personnel and dependents live on base and 20 percent off base.

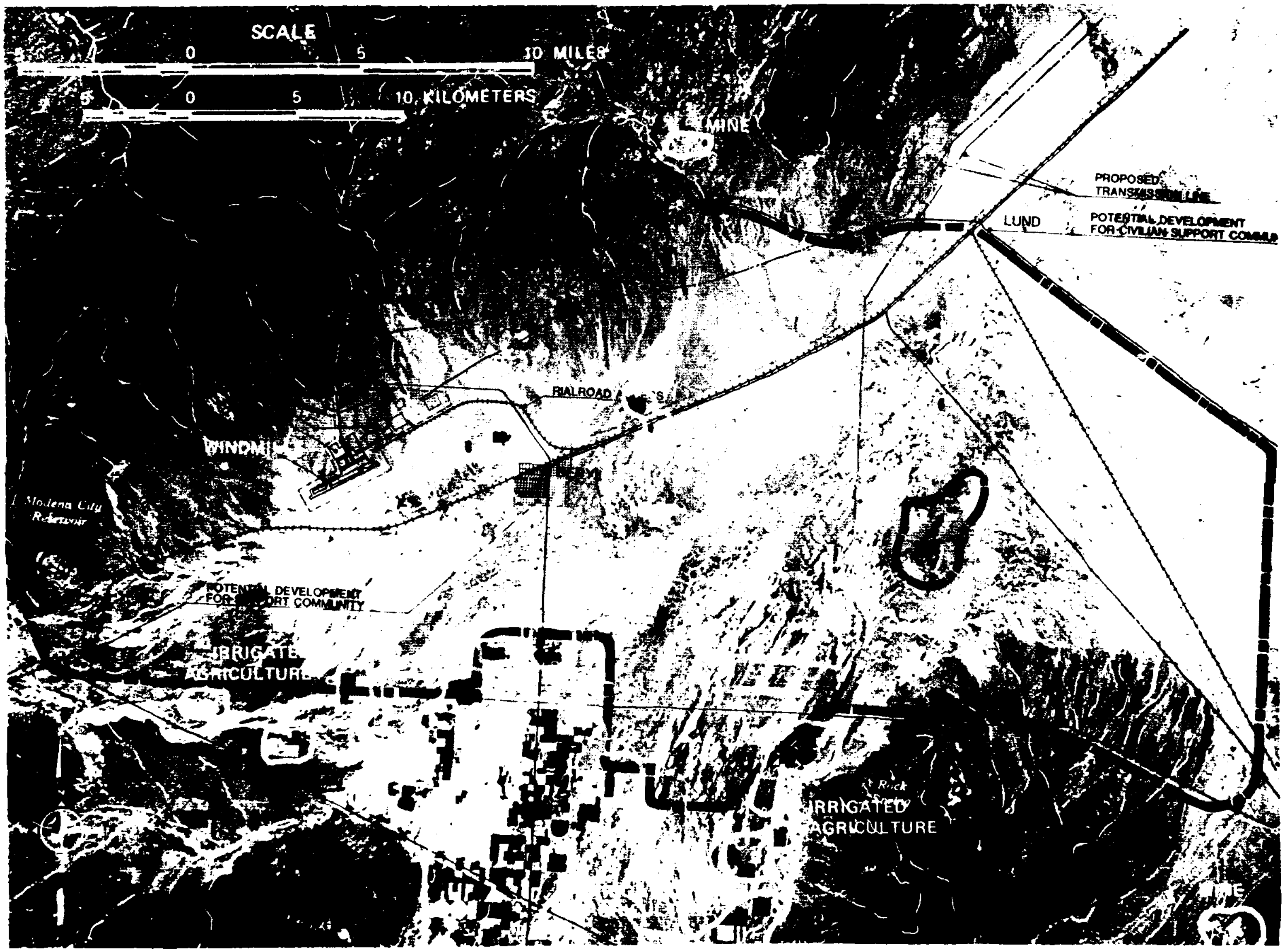

Figure 4.3.1-1. Water resources and use in vicinity of proposed Beryl OB (for color print which includes more detail see Figure 4.3.1.1-10) in DEIS.

Table 4.3.3.1-1. OB construction demands.

OB TYPE	OB CONSTRUCTION DEMANDS x10^3 ACRE-FT	
	RANGE	MPQ
First OB	2.0 - 3.6	2.8
Second OB	1.7 - 3.1	2.4

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Table 4.3.3.2-1. OB operational requirements.

OB TYPE	PEAK YEAR			PERMANENT YEARLY		
	NUMBER	RANGE	MPQ[1]	NUMBER	RANGE	MPQ[1]
First OB						
Military-Living Offbase	1,700	0.10	0.10	1,700	0.10	0.10
Military and Dependents	17,100	2.9-3.8	3.8	17,100	2.9-3.8	3.8
Civilians	1,000	0.06	0.06	1,000	0.06	0.06
A & CO	4,500	0.4	0.4	0	-	-
Base and Construction Workers	0	-	-	0	-	-
Total		3.5-4.4	4.4		3.0-4.0	4.0
Second OB						
Military-Living Offbase	1,220	0.07	0.07	1,220	0.07	0.07
Military and Dependents	12,300	2.0-2.8	2.8	12,300	2.0-2.8	2.8
Civilians	900	0.06	0.06	900	0.06	0.06
A & CO	0	-	-	0	-	-
Base Construction Workers	0	-	-	0	-	-
Total		2.2-2.9	2.9		2.2-2.9	2.9

4051

[1]Most probable quantity.

The operating base requirements are essentially independent of the region. A first OB requires more water because additional people are required for the DAA an OBTS.

The operation of the OB's will cause an in-migration of people to work at the base and provide services to those working at the base. The people will settle in present communities near the Ob site or new communities may be developed. Table 4.3.3.2-2 presents potential additional water demands in affected communities near the Beryl site. Demands are presented in acre-ft for convenience in determining the size of additional water rights needed. Since water use for the proposed OB is mainly domestic, additional water could be available as reuse of treated waste-water. This would reduce the effective consumptive use of the demands presented by about 50 percent.

GROUNDWATER RELATED IMPACTS (4.3.4)

The area in the vicinity of the proposed OB near Beryl has been closed to further development of water resources by the Utah State Engineer. The reason for this is illustrated in Figures 4.3.4-1 and 4.3.4-2. Figure 4.3.4-1 shows current usage and OB operational demands relative to the estimated perennial yield for all Nevada/Utah OB sites. When the use bars exceed the perennial yield, a groundwater "mining" situation is assumed. Continued use at this rate will result in a lowering of the groundwater table which could result in the impacts previously discussed. This figure also illustrates the relative size of the current use and the projected M-X operational demands (includes the base needs and those of the suport communities). As seen, current use greatly exceeds the perennial yield at the Beryl site. This is the cause of the declining groundwater table in the area which is why the area has been closed by the State Engineer.

The estimated M-X usage, 4,600 to 6,300 acre-ft per year, would increase the current aquifer depletion rate (current usages above perennial yield) by as much as 13 percent. This is shown in Figure 4.3.4-2 which presents the relative volume of groundwater storage in Nevada/Utah at each of the potential basing sites. Also shown is the relative magnitude of 30 years of use at the present rate and 30 years of M-X use at estimated rates. It would appear that for Beryl as for Delta and Milford, the groundwater in storage could be depleted or nearly so in thirty years. This will probably not be the case as the figure does not illustrate the effect of recharge on the aquifer and only the estimated storage in the top 100 feet of the aquifer in shown. The depth of the aquifer could be greater.

An analysis similar to that performed for the DDA was done for each of the potential basing sites. However in evaluating the potential for long term impacts in groundwater related resources in Nevada and Utah, perennial yield and aquifer storage were given equal weight. This was done because OB withdrawals are of relatively long duration (30 years or greater) and the importance of perennial yield increases due to its relationship in time.

Table 4.3.4-1 summarizes the basic criteria used to assign the potential for impact ranking for the OB sites in Nevada/Utah. Distinctions between low, moderate and high potential for impacts were arbitrarily drawn. For graphic representation of the relationships of the analysis factors, see Figure 4.3.4-1 and 4.3.4-2.

Table 4.3.3.2-2. Increase in water demands at support communities.

BASE TYPE	COMMUNITY OR AREA	ADDITIONAL DEMANDS IN NEARBY COMMUNITIES			
		PEAK YEAR DEMANDS ($X\ 10^3$ AC-FT)		PERMANENT YEARLY DEMANDS ($X\ 10^3$ AC-FT)	
		RANGE	MPQ[1]	RANGE	MPQ[1]
First OB	Milford	0.4-1.0	0.6	0.1-0.4	0.3
	Minersville	0.2-0.5	0.3	0.1-0.2	0.1
	Cedar City	0.8-2.3	1.4	0.4-1.0	0.6
	New Castle	0.2-0.6	0.4	0.1-0.2	0.2
	Near Base	1.6-2.9	1.8	0.5-1.2	0.7
	Enterprise	0.2-0.4	0.3	0.1-0.3	0.2
	St. George	0.2-0.4	0.3	0.1-0.3	0.2
Second OB	Milford	0.4-0.8	0.6	0.1-0.3	0.2
	Minersville	0.2-0.4	0.2	M-0.3	0.1
	Cedar City	0.7-2.8	1.1	0.3-0.7	0.4
	New Castle	0.2-0.7	0.3	0.1-0.2	0.1
	Near Base	0.9-3.3	1.4	0.4-0.9	0.6
	Enterprise	0.1-0.3	0.2	M-0.2	0.1
	St. George	0.1-0.3	0.2	M-0.2	0.1

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[1]MPQ = most probable quantity.

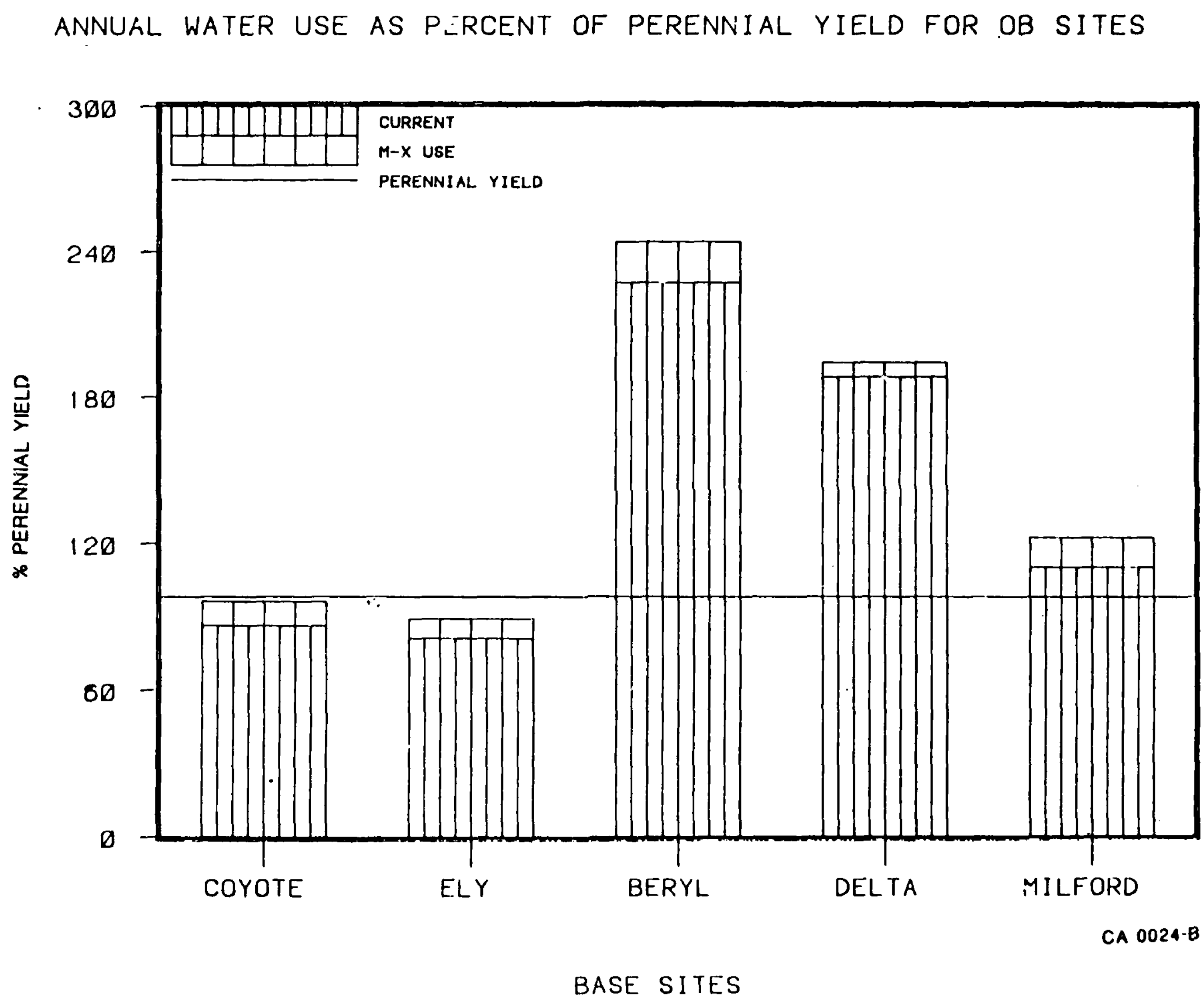

ANNUAL WATER USE AS PERCENT OF PERENNIAL YIELD FOR OB SITES
300
240
180
120
60
0
% PERENNIAL YIELD
CURRENT
M-X USE
PERENNIAL YIELD
COYOTE
ELY
BERYL
DELTA
MILFORD
CA 0024-B
BASE SITES

Figure 4.3.4-1.

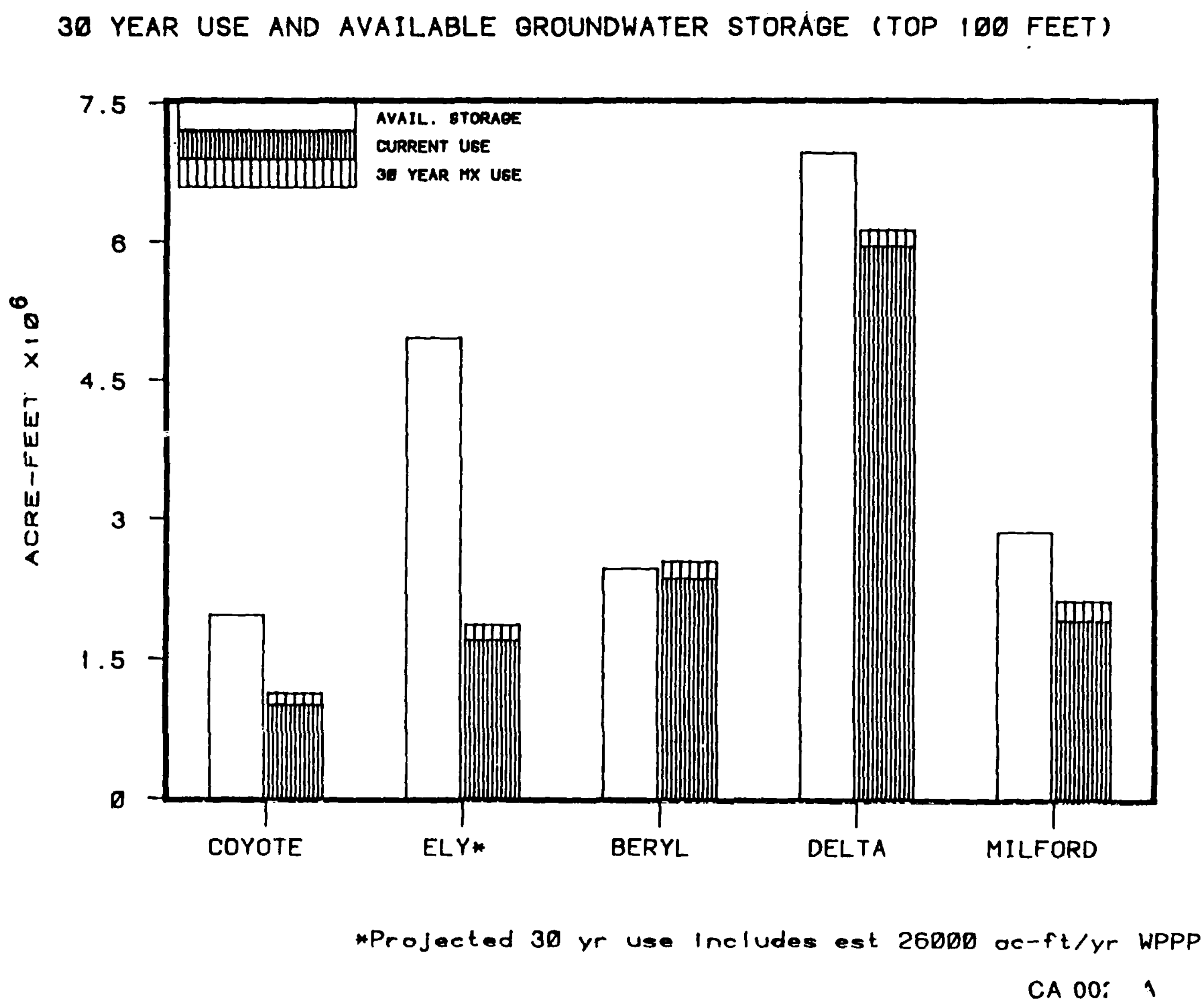

30 YEAR USE AND AVAILABLE GROUNDWATER STORAGE (TOP 100 FEET)
AVAIL. STORAGE
CURRENT USE
30 YEAR MX USE
ACRE-FEET X10^6
7.5
6
4.5
3
1.5
0
COYOTE
ELY*
BERYL
DELTA
MILFORD
*Projected 30 yr use includes est 26000 ac-ft/yr WPPP
CA 00:

Figure 4.3.4-2.

Table 4.3.4-1. Relative potential for impact to groundwater availability in Nevada/Utah for OB sites (sheet 1 of 2).

SITE	HYDROLOGIC SUBUNIT NO.	HYDROLOGIC SUBUNIT NAME	VOLUME IN STORAGE[1]	CURRENT USE[2]	PERENNIAL YIELD[3]	M-X DEMANDS[4] TOTAL/ANNUAL	CURRENT USE (30) ÷ VOLUME IN STORAGE CALCULATION/RATING
Coyote Spring	210	Coyote Spring	20	35	40	120/4.0	53/5
Milford	50	Milford	29	65	< 58	210/7.0	67/5
Beryl	53	Beryl Enterprise	25	80	35	180/6.0	96/5
Delta	46	Sevier Desert	70	200+	105	170/5.7	86/5
Ely	179	Steptoe	50	32	70	160/5.3	19/3

4178

Table 4.3.4-1. Relative potential for impact to groundwater availability in Nevada/Utah for OB sites (sheet 2 of 2).

SITE	M-X DEMANDS ÷ VOLUME IN STORAGE CALCULATION/RATING	M-X DEMANDS ÷ CURRENT USE CALCULATION/RATING	CURRENT USE + M-X DEMANDS ÷ PERENNIAL YIELD CALCULATION/RATING	LEGAL RATING DESIGNATED[6]	SPRING INTER-FERENCE RATING[7]	TOTAL RATING SCORES[9]
Coyote Spring	6.0/3	0.114/5	0.98[5]/3	5	5	23
Milford	7.2/3	0.108/5	1.24/5	5	1	21
Beryl	7.2/3	0.075/3	2.46/5	5	1	19[8]
Delta	2.4/1	0.029/1	1.90/5	5	1	17
Ely	3.2/1	0.166/5	0.90/3	5	1	17

4178

[1]Abstracted from USGS Professional Paper 813-G (1976); determined for upper 100 ft of saturated valley fill in acre-ft/ft x 10^3.

[2]Abstracted from Fugro National, Inc., 2 Sept. 1980.

[3]Published by State of Utah DNR and State of Nevada DWR; Coyote Site analysis includes Muddy River Springs area.

[4]Total demands assumed to last 30 years; includes all local demands.

[5]Includes White Pine Power Project use of 26 acre-ft x 10^3.

[6]Designated areas by respective State Engineers.

[7]Proximity to principal springs with significantly large importance.

[8]Beryl rating considered too low due to failure in analysis technique to account for relative extreme overdraft situation beyond a "high" rating.

[9]Distinctions between rating scores were arbitrarily drawn to reflect relative ranking; scores were assigned as 1 (low); 3 (medium); and 5 (high).

Continued or increased mining will reduce the groundwater availability by removing water from storage and could potentially reduce the storage capacity by a permanent dewatering)compaction) of some areas. As substantial amounts of water are removed from storage, water quality could also be degraded by inducement of poor quality water into the area and by removing water and leaving salts (evapor-transpiration).

M-X impacts would be felt mostly by irrated agriculture since the economic sector makes up 80 percent or more of the total water usage (Price, 1979 and Utah DWR, 1978). Impacts would increase pumping costs due to accelerated water level declines and reduced well yields.

In general, springs in the area of the potential base are elevated above the valley fill aquifer and additional development or a change in the present development probably will have no large impact on spring flow in the area.

4.4 COYOTE SPRING VALLEY

GENERAL (4.4.1)

The Coyote Spring Valley site is proposed as a first operating base in the Proposed Action and in Alternative 1, 2, 3, and 8. It would be used as a second operating base in Alternatives 4 and 6. The proposed site is about 34 mi from Nellis Air Force Base. Figure 4.4.1-1 presents the proposed base site. Its proximity to the Muddy River Springs should be noted. The facilities included at a first or second OB are the same as those listed for the proposed Beryl site.

IMPACTS RELATIVE TO SURFACE WATER (4.4.2)

Impacts relative to surface waters will be similar to those discussed for the proposed Beryl site.

M-X WATER DEMANDS (4.4.3)

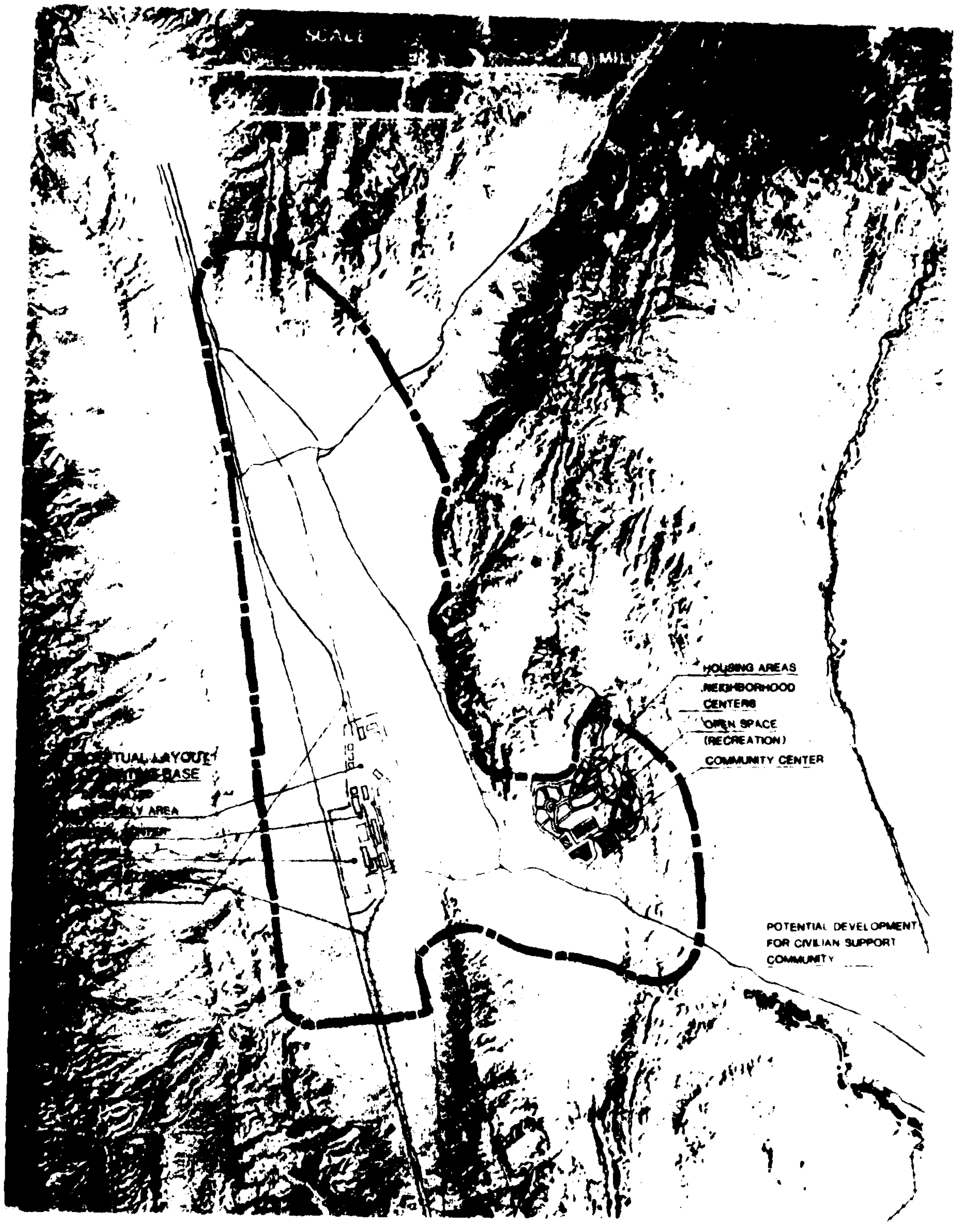
Construction (4.4.3.1)

Construction activities similar to those in the DDA will require water. The quantities required depend upon the facilities constructed. The Coyote Spring site could be a first or second OB depending upon the final alternative chosen. Estimated water demands for construction of an OB at Coyote Spring are the same as those presented for Beryl.

Operation (4.4.3.2)

The operational water requirements are the same as those presented for Beryl. The OB and community water requirements assume 80 percent of military personnel and dependents live onbase and 20 percent offbase.

The operation of the OBs will cause an in-migration of people to work at the base and provide services to those working at the base. The people will settle in present communities near the OB site or new communities may be developed. Table 4.4.3.2-1 present potential additional water demands in affected communities near



[illegible] 4.1.1-1. Water resources and use in vicinity of Coyote Spring [illegible] with more visible detail see [illegible] 4.1.1-[illegible] in [illegible].

Table 4.4.3.2-1. Increase in water demands at support communities.

BASE TYPE	ADDITIONAL DEMANDS IN NEARBY COMMUNITIES				
	COMMUNITY OR AREA	PEAK YEAR DEMANDS ($X 10^3$ AC-FT)		PERMANENT YEARLY DEMANDS ($X 10^3$ AC-FT)	
		RANGE	MPQ	RANGE	MPQ
First OB	Las Vegas	2.1-5.6	3.5	0.4-1.0	0.6
	Moapa Valley	0.8-2.0	1.2	0.1-0.3	0.2
	Alamo	0.6-1.5	0.9	0.1-0.1	0.1
Second OB	Las Vegas	1.6-4.4	2.8	0.3-0.8	0.5
	Moapa Valley	0.7-1.5	0.9	0.1-0.3	0.2
	Alamo	0.6-1.6	1.0	0.1-0.2	0.1

4054

the Coyote Spring site. Demands are presented in acre-ft per year for convenience in determining the size of additional water rights needed. Since water use for the proposed OB is mainly domestic, additional water could be available as reuse of treated wastewater. This would reduce the effective consumptive use of the demands presented by about 50 percent.

GROUNDWATER RELATED IMPACTS (4.4.4)

The site lies in close prximity to an area which has been designated a critical groundwater basin (Moapa Springs) by the Nevada State Engineer (see Figure 4.4.1-1). This area has the major discharge point (springs in the Moapa area) of a regional groundwater flow system defined by the drainage of the White River (see Figure 4.4.4-1). Since it is thought that the flow from springs in the Moapa area derive their recharge from this regional system, a disturbance (water removal) could have some effect downstream. Since the Coyote Spring Valley site is upstream from the Moapa Springs, the groundwater pumpage at the OB site could reduce the flow in those springs. Current development of springs in the Moapa areas is such that essentially all the flow is beneficially used. The Muddy River Springs "are the base of the agricultural economy of the Moapa Valley" (Eakin, 1964) and agriculture is the base of the Moapa Reservation.

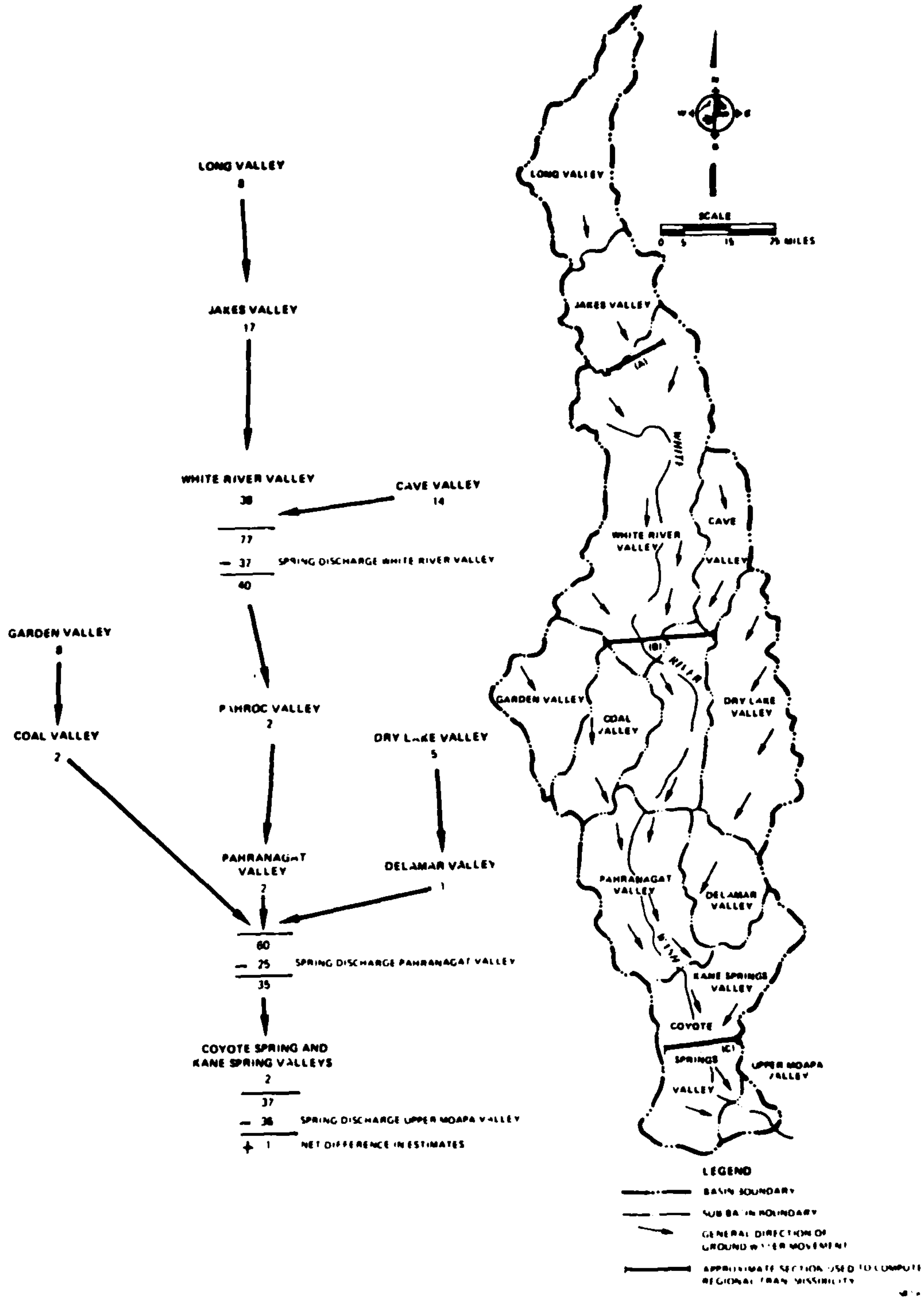
With M-X withdrawals, socioeconomic and biological impacts could occur as well as direct impacts to the groundwater resource. Socioeconomic impacts would stem from reduction of the supply available to spring appropriations. These impacts may result in spring appropriators having to drill wells in order to obtain a water supply or possibly deal with a permanent loss of supply if a new type of supply is not economically feasible. Loss of wildlife habitat could also occur due to a reduction of flow from Moapa Springs; certain protected and endangered species would be adversely impacted by a reduction in the springs flow.

The relationships of current use, proposed M-X use, perennial yield, and storage were presented in Figures 4.3.4-1 and 4.3.4-2 in the Beryl discussion. It is seen that the demands (present plus projected MX) are below the estimated perennial yield. This should indicate an allowance situation. However, the perennial yield use is based partly on inclusion of regional flows. The effect of withdrawing part of these regional flow-on downstream uses is not known. This site has the smallest available storage of all the potential basing areas. This makes it the most sensitive to any stress.

4.5 DELTA OB SITE

GENERAL (4.5.1)

The Delta area is proposed as a site for a second operating base in Alternative 2. Figure 4.5.1-1 presents the proposed location of a base in the Delta area. The large amount of irrigated land can be seen to the northeast of the siting area. The heavy use of water for irrigation has caused an overdraft condition in this area. The Intermountain Power Project is planned for this area. Necessary water rights transfers have been tentatively approved.



(Thomas E. Eakin, 1966)

Figure 4.4.4-1. Interbasin groundwater system.

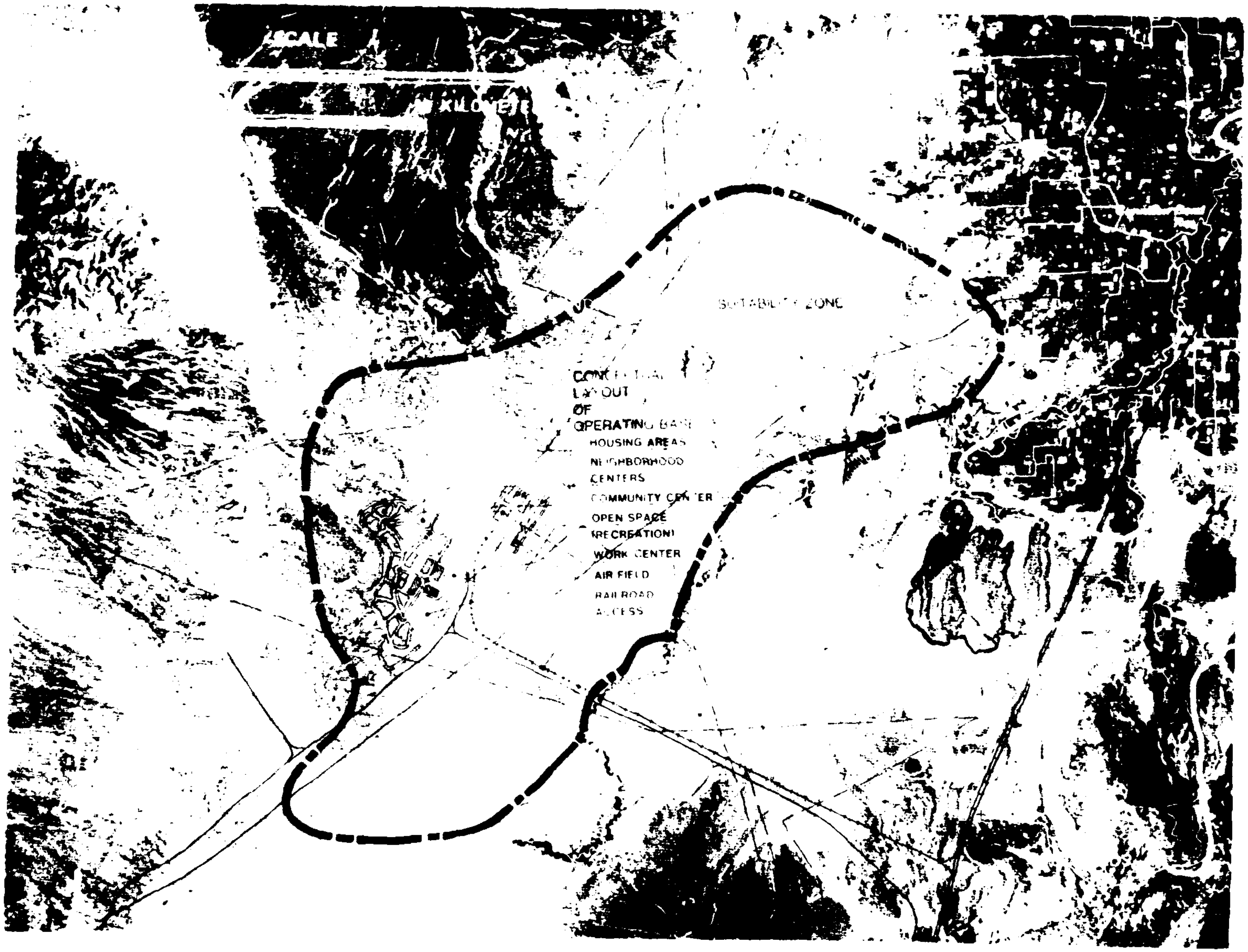


Figure 4.5.1-1. Water resources and use in the vicinity of the proposed Delta OB (for color print with more visible detail see Figure 4.3.1.1-11) in DEIS.

IMPACTS RELATIVE TO SURFACE WATERS (4.5.2)

Impacts relative to surface waters will be similar to those discussed for the proposed Beryl site. The potential for these occurring is lower than for Beryl, Coyote Spring, and Ely. This is due to limited runoff, relatively low construction density, the level topography and the present slight erosion of most of the predominating soils in the region.

M-X WATER DEMANDS (4.5.3)

Construction (4.5.3.1)

Construction activities similar to those in the DDA will require water. The quantities required depend upon the facilities constructed. Estimated water demands for construction of an OB at Delta are the same as those presented for a second OB at Beryl.

Operation (4.5.3.2)

The operational water requirements are the same as those presented for a second OB at Beryl. The OB and community water requirements assume 80 percent of military personnel and dependents live onbase and 20 offbase.

The operation of the OBs will cause an im-migration of people to work at the base and provide services to those working at the base. The people will settle in present communities near the OB site or new communities may be developed. Table 4.5.3.2-1 presents potential additional water demands in affected communities near the Delta site. Demands are presented in acre-ft for convenience in determining the size of additional water rights needed. Since water use for the proposed OB is mainly domestic, additional water could be available as reuse of treated waste-water. This would reduce the effective consumptive use of the demands presented by about 50 percent.

GROUNDWATER RELATED IMPACTS (4.5.4)

Irrigation demands are satisfied mostly by groundwater which has resulted in a declining water table. Some secondary effects such as reduced surface water flows have also been noted. The heavy use has resulted in the State Engineer closing the basin to future water resources development.

Water rights which were acquired for the IPP could result in a reduction in irrigated lands. The potential for impact due to this reduction is so great that the State Engineer has indicated that additional transfer of water rights may not be allowed within this basin. If this constraint is enforced, water would have to be imported. This could result in a favorable impact as this quantity could become available for reduction of consumptive uses.

Present use of the resource is almost entirely for irrigation. Because new appropriations are not being approved, M-X-induced demands would have to be met by acquisition of water rights from present users. This acquisition would result in the removal from production of about 15 percent of the irrigated land in the Delta area. This change in use could be permanent and effect the economic structure of the area. However, economic changes directly resulting from locating an OB in the area far overshadow those from reductions in irrigated acreage for all except the individuals whose rights would be purchased and perhaps for them as well.

Table 4.5.3.2-1. Increase in water demands at support communities.

BASE TYPE	COMMUNITY OR AREA	PEAK YEARLY DEMANDS ($X\ 10^3$ AC-FT)		PERMANENT YEARLY DEMANDS ($X\ 10^3$ AC-FT)	
		RANGE	MPQ	RANGE	MPQ
Second OB	Delta	1.8-4.8	3.0	0.6-1.5	0.9
	Holden	0.2-0.6	0.4	0.1-0.2	0.1
	Fillmore	0.4-1.0	0.6	0.1-0.3	0.2
	Nephi	0.7-1.8	1.1	0.1-0.3	0.2
	Milford	0.4-1.1	0.7	M	M

4055

When compared with other alternative sites in Nevada/Utah (see Figures 4.3.4-1 and 4.3.4-2), relative potential for impacts at Delta appears moderate due mostly to the large amount of water in storage. Significant impact potential exists, however, because the system is currently under stress and the addition of M-X demands would increase that stress.

M-X construction and operations water usage would represent about 1.4 percent of present water usage, and it would be anticipated that if the State Engineer granted appropriation rights in nonagricultural areas, additional waterlevel decline due to the M-X project would be small. Springs in this basin are located above the valley floor and do not appear to be part of the valley-fill aquifer system; therefore the project might have no effect on their discharge rates.

The presence of the IPP will significantly effect the potential for long term impacts occurring in the Delta area. M-X will compete not only with present users, but also with this large energy project.

4.6 ELY OB SITE

GENERAL (4.6.1)

The Ely site is proposed as a second operating base in Alternatives 3 and 5. The OB facilities would occupy approximately 4,000 acres and include an airfield, support facilities, clear zones, and a railroad spur. Three possible locations are being considered for an Ely OB and these are presented in Figures 4.6.1-1 and 4.6.1-2.

IMPACTS RELATIVE TO SURFACE WATER (4.6.2)

Impacts relative to surface water will be similar to those discussed for Beryl.

M-X WATER DEMANDS (4.6.3)

Construction (4.6.3.1)

Construction activites, similar to those in the DDA, will require water. The quantities required depend upon the facilities constructed. Estimated water demands for construction of an OB at Ely are similar to those for a second OB at Beryl, and are presented in Table 4.3.3.1-1.

Operation (4.6.3.2)

The operational water requirements are similar to those for a second OB at Beryl, and are presented in Table 4.3.3.2-1. The OB and community water requirements assume 80 percent of military personnel and dependents live onbase and 20 percent offbase.

The operating base requirements are essentially independent of the region. A first OB requires more water because people are required for the DAA and OBTS.

The operation of the OBs will cause an inmigration of people to work at the base and provide service to those working at the base. The people will settle in

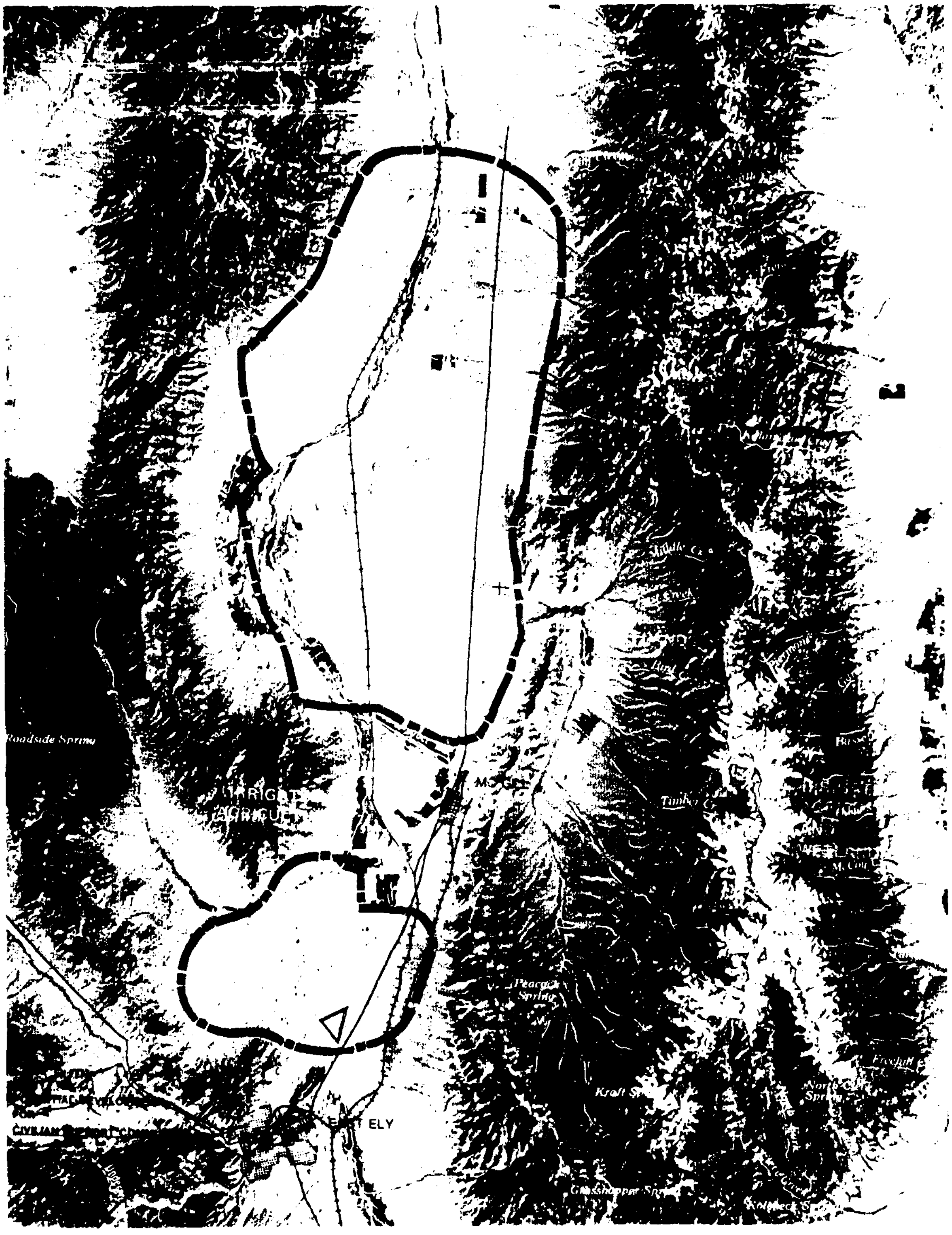


Figure 4.6.1-1. Water resources and use in the vicinity of the proposed Ely OB, central and north sites (for color print with more visible detail see Figure 4.3.1.3-13 in DEIS).

Figure 4.[illegible].1-2. Water resources and use in the vicinity of the [illegible] Ely OB, south site (for color print with [illegible] detail see Figure 4.3.1.1-1[illegible] in [illegible]).

present communities near the OB site, or new communities may be developed. Table 4.6.3.2-1 presents potential additional water demands in affected communities near the Beryl site. Demands are presented in acre-ft for convenience in determining the size of additional water rights needed. Since water use for the proposed OB is mainly domestic, additional water could be available as reuse of treated wastewater. This would reduce the effective consumptive use of the demands presented by about 50 percent.

POTENTIAL IMPACTS (4.6.4)

This site lies within an area which is designated a critical groundwater basin by the Nevada State Engineer. The designation is mainly due to an application for appropriation by the White Pine Power Project which, if used in total, could put usage over the estimated perennial yield. Current use in Steptoe Valley is estimated to be 53,000 acre-ft/year (Cardinalli, 1979) and 32,000 acre-ft/year (DRI, Cochran et. al, 1980), while perennial yield is estimated to be 70,000 acre-ft/year (Eakin, Hughes and More, 1967). The difference in current use estimates could well be the difference between withdrawal and consumption. It is evident, however, that the groundwater system is under considerable use.

Since withdrawals for any of the three Ely sites would lower water levels, impacts could be felt at Ely's groundwater wells. Impacts would increase pumping costs due to lowered water table and possibly reduce well yields due to compaction. Several springs and Commins Lake are among the possible areas of impact to current appropriators and wildlife habitats.

When using the analysis technique described in Section 4.1.3.3, it is estimated that, when compared with the other alternative sites in Nevada/Utah, the relative potential for impact at Ely would be low, mostly because Ely's groundwater resource is currently under less stress than that of any of the other OB site areas.

Table 4.3.4-1 summarizes the basic criteria used to assign the potential for impact ranking for the OB sites in Nevada/Utah. Distinctions between low, moderate, and high potential for impacts were arbitrarily drawn. For graphic representation of the relationships in the analysis, see Figures 4.3.4-1 and 4.3.4-2.

Although Steptoe Valley is a designated critical groundwater basin, current groundwater usage is less than the perennial yield, and sufficient quantities may exist for M-X operating base purposes. MX withdrawals could effect widely separate stock wells which provide water for the other uses, although no severe impact on water levels and groundwater storage from M-X withdrawals would be anticipated. Extractions may reduce underflow to the south through the deep carbonate rock aquifer. The springs do not appear to issue directly from the valley-fill aquifer system, so the project probably should have no large effect on their discharge rates. Increased surface runoff during major storms would be minimal; local increases in sheet and stream-channel erosion may occur. Construction activities could degrade surface-water quality during thunderstorms, but no significant impact on groundwater quality would be expected.

Table 4.6.3.2-1. Increase in water demands at support communities, Ely OB.

BASE TYPE	COMMUNITY OR AREA	ADDITIONAL DEMANDS IN NEARBY COMMUNITIES			
		PEAK YEAR DEMANDS (X 10^3 AC-FT)		PERMANENT YEARLY DEMANDS (X 10^3 AC-FT)	
		RANGE	MPQ	RANGE	MPQ
Second OB	Ely	2.0-5.4	3.4	0.6-1.2	1.0
	Ruth	0.2-0.6	0.4	0.1-0.2	0.2
	McGill	0.2-0.6	0.4	0.1-0.2	0.2

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4.7 MILFORD OB SITE

GENERAL (4.7.1)

The Milford site is proposed as a first operating base in Alternatives 5 and 6 and a second OB for the Proposed Action. As a first OB, it would occupy about 6,000 acres including an airfield, support facilities, clear zones, a Designated Transportation Network, and a railroad spur. As a second OB, it would occupy about 4,000 acres and include no DDA or OBTS and house fewer personnel. The site for the proposed base is shown in Figure 4.7.1-1.

IMPACTS RELATIVE TO SURFACE WATER (4.7.2)

Impacts relative to surface waters will be similar to those discussed for the proposed Beryl site. The potential for these occurring is lower than for Beryl, Coyote Spring, and Ely. This is due to limited runoff, relatively low construction density, the level topography, and the present slight erosion hazard of most of the predominating soils in the region.

M-X WATER DEMANDS (4.7.3)

Construction (4.7.3.1)

Construction activities, similar to those in the DDA, will require water. This will most likely be obtained from the groundwater supply. The quantities required depend upon the facilities constructed. Water demands at the Milford site are similar to those at the Beryl site, and could be a first or a second OB, depending upon a final alternative chosen. Estimated water demands for construction of an OB at Beryl are presented in Table 4.3.3.1-1.

Operation (4.7.3.2)

The operational water requirements are similar to those for Beryl and are presented in Table 4.3.3.2-1. The OB and community water requirements assume 80 percent of military personnel and dependents live onbase and 20 percent offbase.

The operating base requirements are essentially independent of the region. A first OB requires more water because additional people are required for the DAA and OBTS.

The operation of the OBs will cause an in-migration of people to work at the base and provide services to those working at the base. The people will settle in present communities near the OB site or new communities may be developed. Table 4.7.3.2-1 presents potential additional water demands in affected communities near the Beryl site. Demands are presented in acre-ft for convenience in determining the size of additional water rights needed. Since use at the proposed OB is mainly domestic, treated wastewater could be available for reuse. With this expected reuse, water demands shown may be thought of as about 50 percent consumptive and only as withdrawals.

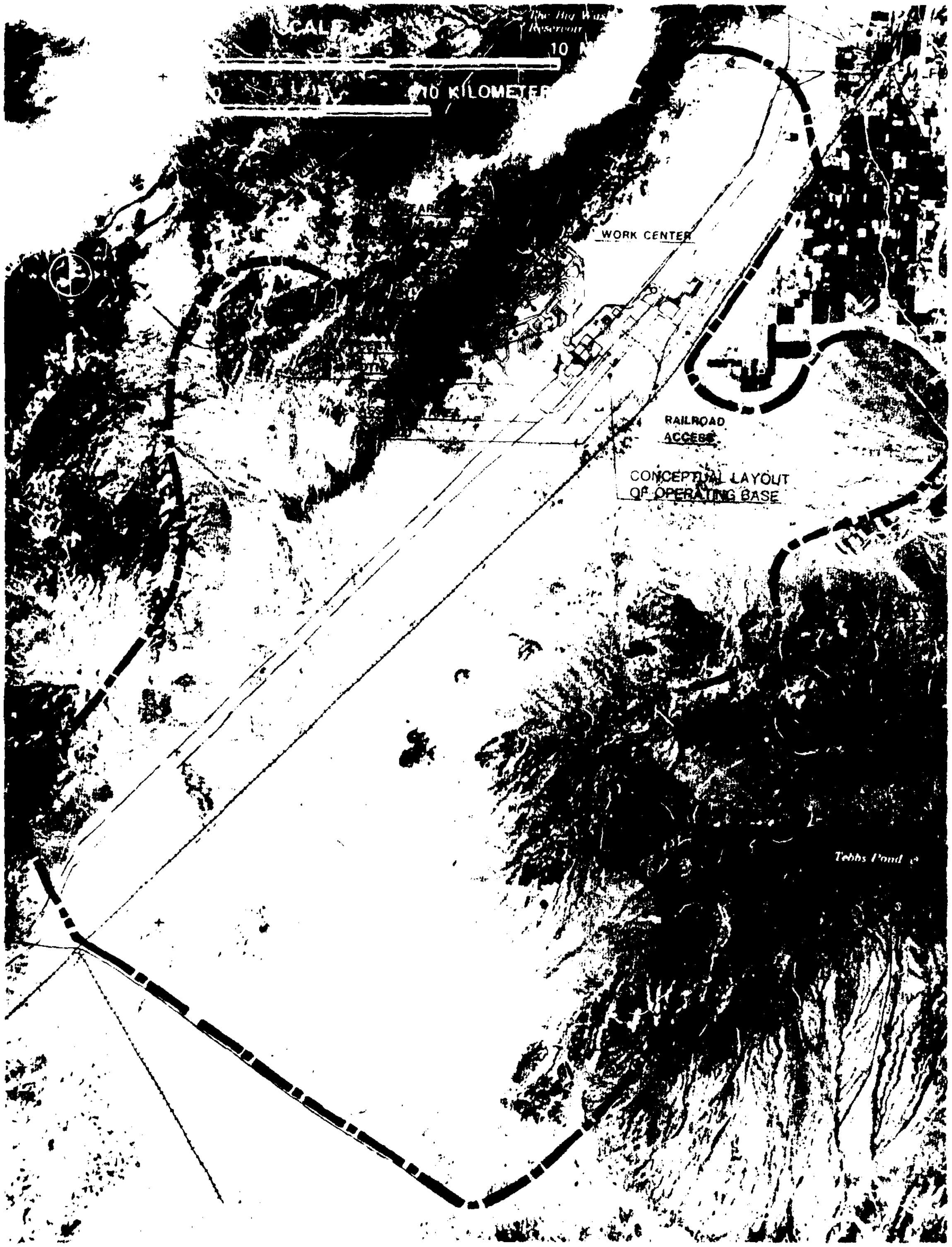

Figure 4.7.1-1. Water resources and use in the vicinity of the proposed Milford OB (for color print with more visible detail see Figure 4.3.1.1-9 in DEIS).

Table 4.7.3.2-1. Increase in water demands at support communities, Milford OB.

BASE TYPE	ADDITIONAL DEMANDS IN NEARBY COMMUNITIES				
	COMMUNITY OR AREA	PEAK YEAR DEMANDS (x 10 AC-FT)		PERMANENT YEARLY DEMANDS (x 10 AC-FT)	
		RANGE	MPQ	RANGE	MPQ
FIRST OB	Milford	1.4-3.8	2.3	0.6-1.6	1.0
	Minersville	0.7-1.9	1.2	0.3-0.8	0.5
	Beaver	0.3-0.6	0.4	0.1-0.3	0.2
	Cedar City	0.5-1.3	0.8	0.3-0.9	0.6
	Delta	0.7-1.9	1.2	M	M
	St. George	0.2-0.4	0.3	M	M
SECOND OB	Milford	1.0-2.8	1.8	0.3-1.1	0.7
	Minersville	0.6-1.5	0.9	0.2-0.6	0.3
	Beaver	0.2-0.4	0.2	0.1-0.2	0.1
	Cedar City	0.3-0.9	0.6	0.2-0.7	0.4
	Delta	0.7-1.9	1.2	M	M
	St. George	0.1-0.3	0.2	0.1-0.1	0.1

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GROUNDWATER RELATED IMPACTS (4.7.4)

This site lies within an area designated a critical groundwater basin by the Utah State Engineer. The area's inhabitants are currently mining its groundwater resources. The estimated perennial yield of 58,000 acre-ft per year (Fugro, 1980) is less than the estimated groundwater consumption rate of 65,000 acre-ft per year (Gates, et. al., 1978). This groundwater mining is reducing the groundwater availability by removing water from storage and probably reducing the storage capacity of permanent dewatering (compaction) of some areas. As substantial amounts of water are removed from storage, water quality will also be degraded (Mower and Cordova, 1974).

Since irrigated agriculture represents about 98 percent of the current water use (Gates, et. al., 1978), M-X impacts would be primarily felt by agriculture. Water table declines caused by M-X withdrawals would appear as impacts of increased pumping costs.

An MX operating base at the Milford site would need approximately 7,000 acre-ft per year for 30 years. This withdrawal would increase the current aquifer depletion rate (current use above perennial yield amounts to 7,000 acre-ft per year) by 50 percent, a very significant impact.

When compared with the other alternative sites in Nevada/Utah, the relative potential for impacts at Milford would be moderate. The severity of this rating is due mostly to the large M-X effect on the aquifer depletion rate although there is a large volume of water remaining in storage. Significant impact potential exists because the groundwater resource is currently under stress and the addition of M-X demands would significantly increase that stress.

Table 4.3.4-1 summarized the basic criteria used to assign the potential for impact ranking in Nevada/Utah for OB sites. Destinations between low, moderate, and high were arbitrarily drawn.

M-X water requirements, combined with present usage rates, exceed perennial yield, and Utah State Engineer's office will probably not permit additional groundwater withdrawals appropriations in the Milford area. M-X withdrawals for construction would represent an amount equal to 5.3 percent of current water usage and 5.9 percent of perennial yield; annual withdrawals for MX operations would represent an amount equal to 6.5 percent of current usage and 7.2 percent of perennial yield. For graphic representation of the relationships of the factors, see Figures 4.3.4-1 and 4.3.4-2. The impact on groundwater levels, underflow, or groundwater storage would be minor. In general, springs are elevated above the valley-fill deposits, and withdrawals would not be expected to impact spring flow.

4.8 CLOVIS OB SITE

GENERAL (4.8.1)

An M-X operating base (OB) might be located about 10 mi west from Clovis, New Mexico, adjacent to Cannon Air Force Base. The OB would include the existing Cannon Air Force Base airfield, some existing support facilities and clear zones, and necessary additional facilities consistent with use of the base as either a first OB or as an OB under the split basing mode (see Figure 4.8.1-1). Including the existing airfield, the base would occupy about 6,000 acres.

Figure 4.8.1-1. Water resources and use in the vicinity of the proposed Clovis CB (for color print with more visible detail see Figure 4.3.1.1-17 in DEIS.

IMPACTS RELATIVE TO SURFACE WATER (4.8.2)

Construction and maintenance of the operating base could have an impact on surface water due to increase in runoff and erosion. Storm runoff could be increased by the introduction of impermeable surfaces and channelization. Water quality may be effected in increased sediment loads due to construction. If surface rights are purchased, stream volumes may be locally reduced but reduction of total surface water volume will be partially offset by return flow after treatment, especially during the maintenance phase.

Water erosion impacts at the Clovis OB would be expected to be low due to th nearly level topography. Where local areas of sloping toography exist or are constructed, disturbed soils should be revegetated and proper engineering design should be employed. Long term impacts would be expected to be insignificant if mitigation measures are followed.

Surface water would not be generally available for use, due to prior appropriation of this water. The only possible exception would be importation of surface water from Ute reservoir which presently has appropriated, but unused, water in necessary quantity to meet M-X demands.

Playa lakes are present in the Clovis base siting area and could be affected by siting OB complex in this area.

M-X WATER DEMANDS (4.8.3)

Construction (4.8.3.1)

Construction activities, similar to those in the DDA, will acquire water. The quantities required depend upon the facilities constructed. The Clovis site could be a first or a split basing OB, depending upon the final alternative chosen. The facilities required for a first OB include the OB, DDA, and OBTS. There is no OBTS at the split base OB. Estimated water demands for construction of an OB an Clovis are presented in the discussion for a first OB at Beryl (see Table 4.3.3.1-1).

Operation (4.8.3.2)

The operational water requirements are the same as discussed for Beryl (see Table 4.3.3.2-1). The OB and community water requirements assume 80 percent of military personnel and dependents live onbase and 20 percent offbase.

The operation of the OBs will cause an in-migration of people to work at the base and provide services to those working at the base. The people will settle in present communities near the OB site or new communities may be developed. Table 4.8.3-1 presents potential additional water demands in affected communities near the Clovis site. Demands are presented in acre-ft for continuence in determining the size of additional water rights needed. Since water use for the proposed OB is mainly domestic, additional water could be available as reuse of treated wastewater. This would reduce the effective consumptive use of the demands presented by about 50 percent.

Table 4.8.3-1. Increase in water demands at support communities, Clovis OB.

BASE TYPE	ADDITIONAL DEMANDS IN NEARBY COMMUNITIES				
	COMMUNITY OR AREA	PEAK YEAR DEMANDS ($X\ 10^3$ AC-FT)		PERMANENT YEARLY DEMANDS ($X\ 10^3$ AC-FT)	
		RANGE	MPQ	RANGE	MPQ
First OB	Clovis			0.3-0.8	0.5
	Metrose			M-0.1	M
	Portalos			M-0.1	M
	Lubbock			M	M
Split OB	Clovis			0.3-0.8	0.5
	Metrose			M-0.1	M
	Portalos			M-0.1	M
	Lubbock			M	M

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GROUNDWATER RELATED IMPACTS (4.8.4)

The Clovis area has experienced major depletion of groundwater. Most of the depletion is due to agricultural usage. The operation of the OB will place an additional demand upon the aquifer. The operating base demand will be greater than 5 percent of the present depletion rate (see Figure 4.3.4-1). Since the demand occurs over a projected 30-year period, it is considered quite significant.

The significance of M-X withdrawals is further enhanced by the short projected economic life of the Ogallala Aquifer in Region VII and by the priximity of the proposed OB to the city of Clovis. Competition between the operating base and Clovis for the available groundwater resource could increase the rate of aquifer depletion in the area.

4.9 DALHART OB SITE

GENERAL (4.9.1)

Under Alternative 7, an operating base II (OB II) would be located in Texas about 20 mi southwest of Dalhart (see Figure 4.9.1-1). The second OB would include an airfield, support facilities, clear zones, a railroad spur, and additional facilities consistent with use of the base under either a split or full deployment basing mode. The operating base would occupy about 4,000 acres.

EFFECTS ON SURFACE WATER (4.9.2)

Construction and maintenance of the operating base could have an impact on surface water due to increases in runoff and erosion. Storm runoff would be increased by the introduction of impermeable surfaces and channelization loads due to construction. If surface rights are purchased, stream volumes may be locally reduced but reduction of total surface water volume would be partially offset by return flow after treatment, especially during the maintenance phase.

Water erosion impacts at the Dalhart OB site would be low due to the nearly level topography. Where local areas of sloping topography exist or are constructed, disturbed soils should be revegetated and proper engineering design should employed. Long term impacts are expected to be insignificant if mitigation measures are followed.

M-X WATER DEMANDS (4.9.3)

Construction (4.9.3.1)

Construction activities similar to those in the DDA will require water. The quantities required depend upon the facilities constructed. The Dalhart site is being considered for a second OB in Alternative 7. There is no DDA or OBTS at the second OB. Estimated water demands for construction of an OB at Dalhart are the same as those presented for a second OB at Beryl (see Figure 4.3.3.1-1).

Operation (4.9.3.2)

The operational water requirements are the same as those presented for a second OB at Beryl (Figure 4.3.3.2-1) and community water requirements assume 80 percent of military personnel and dependents live onbase and 20 percent offbase.

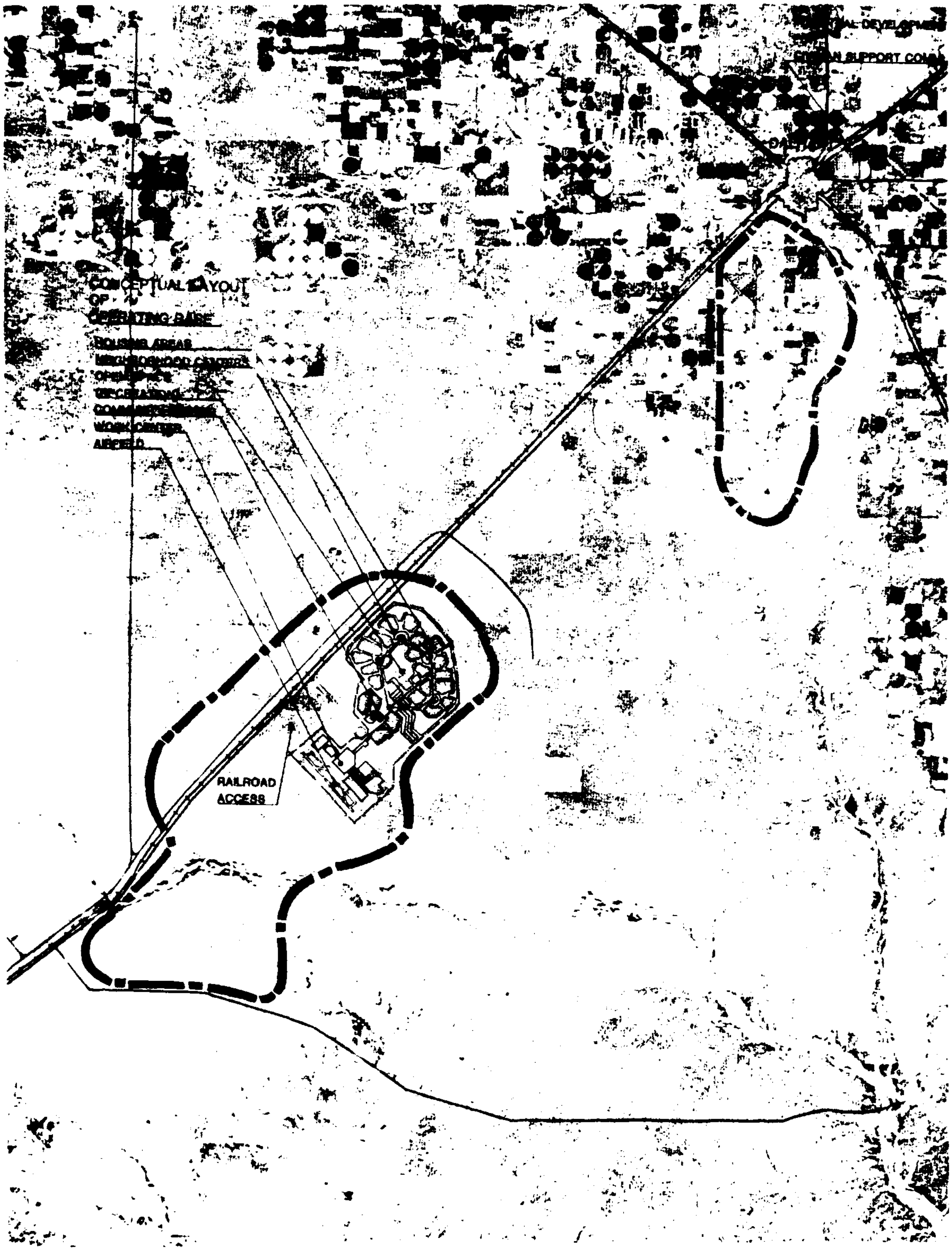

Figure 4.9.1-1. Water resources and use in the vicinity of the proposed Dalhart OB (for color print with more visible detail see Figure 4.3.1.1-18 in DEIS).

The operation of the OBs will cause an in-migration of people to work at the base and provide services to those working at the base. The people will settle in present communities near the OB site or new communties may be developed. Table 4.9.3-1 presents potential additional water demands in affected communities near the Dalhart site. Demands are presented in acre-ft for convenience in determining the size of additional water rights needed. Since water use for the proposed OB is mainly domestic, additional water could be available as reuse of treated waste-water. This would reduce the effective consumptive use of the demands presented by about 50 percent.

GROUNDWATER RELATED IMPACTS (4.9.4)

Large volumes of economically recoverable groundwater are available in storage in groundwater Region III (see Figure 4.8.1-1). M-X uses represent less than 1 percent of the current aquifer depletion rate and though some localized impacts may be felt near M-X pumping centers the overall potential for significant regional impacts on groundwater availability is judged to be low.

Table 4.9.3-1. Increase in water demands at support communities, Dalhart OB.

BASE TYPE	ADDITIONAL DEMANDS IN NEARBY COMMUNITIES				
	COMMUNITY OR AREA	PEAK YEAR DEMANDS (X 10^3 AC-FT)		PERMANENT YEARLY DEMANDS (X 10^3 AC-FT)	
		RANGE	MPQ	RANGE	MPQ
Second OB	Dalhart Hartley			0.3-0.5 M	0.4 M

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5.0 MITIGATION

5.1 SURFACE WATER

WATER EROSION/SEDIMENTATION

Several means are available to mitigate water erosion impacts. During construction, disturbances of the natural vegetation cover should be minimized. After construction, all disturbed areas should be revegetated with the natural vegetation or erosion-preventing vegetation.

During the rough grading process, provision must be made for transport of sheet drainage, intercepted by the roadway, to natural drainage channels. This is accomplished by graded ditches paralleling the roadway. Provision also must be made for erosion control in the roadside ditches when slopes exceed certain values, depending on soil characteristics and the quantity of water to be transported.

Natural drainage channels must be provided with roadway undercrossing, generally pipe or cast-in-place concrete box culverts. In some instances, rerouting of the natural drainage channels will be required. Drop structures and various erosion control measures will be required to protect the roadways and the culverts from damage due to erosion and undermining. Where natural drainage channels are rerouted and disturbed, erosion control structures are often required to stabilize and prevent eroding of the channel bed.

Roadway undercrossings are generally designed to handle the maximum runoff generated by "design" storms. Alternatives may be available for handling maximum runoffs. Where terrain permits, temporary ponding of peak flow may be possible, either integral with the roadway embankment and culvert or a control structure upstream of the undercrossing. Riprap may be required on some portions of the channel embankments for protection during high runoff. Another option which might be investigated where terrain permits, or requires, and sufficient bank protection can be provided, would be infrequent overtopping of the roadway by high storm flows.

Provision must be made for maintaining surface water runoff during the road construction activities. This is generally accomplished by installation of drainage structures immediately prior to commencing the rough-grading phase. Temporary and minor relocation of the natural drainage channel may sometimes be desirable where the drainage structure is to be located in the natural channel. However, due to the arid climate and intermittent nature of the natural drainage ways, this requirement may be minimized.

The quantity and rate of runoff from the impervious surfaces will be greater than the relatively pervious soils existing prior to construction. This increased runoff will tend to increase erosion. If, due to topography, soil conditions, drainage channel instability or other problems, the increased runoff would create adverse effects that are not permissible, control measures can be implemented. An effective means of reducing the runoff rate from developed areas is to provide retention ponds with controlled release of the runoff. Other measures might include channel improvements and bank protection.

5.2 GROUNDWATER

WATER MANAGEMENT PLAN (5.2.1)

Impacts on springs (environment) and on nearby wells (other water users) by groundwater development for water during the construction phase will be minimized by well-field design. A monitoring system will be set up to track possible effects on local sources and assess any needed redesign of operations.

Wells will be located according to guidelines set by the State Engineer's office governing set-back distances from other wells and from springs. There will be an occasional divergence from these distances because of local conditions.

During the drilling and construction of wells, an experienced hydrogeologist will be at the site to collect geologic and hydrologic data and to ensure that the wells are installed properly, according to conditions found during drilling. At the completion of well construction, an aquifer test will be conducted to assess aquifer characteristics which control the design of the pumping plant and to determine the impact of the design on other nearby wells in the system. The impacts of groundwater withdrawal will be minimized by developing an optimum well-field design for each siting area. If significant impacts are projected, pumping patterns or the rate of withdrawal in selected wells will be altered to prevent or minimize significant impacts on springs or existing wells.

WATER SUPPLY ALTERNATIVES (5.2.2)

Because of potential hydrologic, economic, legal, and environmental constraints, the M-X missile system may be unable to rely on a single water source. It is likely that a combination of surface and groundwater development, the lease or purchase of existing water rights, interbasin transfer of water, and special water development systems will be employed to fulfill MX water requirements. In most MX siting valleys within Utah and Nevada, sufficient water supplies can be developed through the construction of conventional water wells to tap the valley-fill aquifers. Wells will probably be 16 to 24 in. in diameter and will be drilled to depths ranging from 500 to 1,000 ft, depending upon the depths to water and favorable aquifers. The volume of water delivered from such wells depends upon the hydrologic conditions, but yields of 250 to 750 gallons per minute can be expected in most valleys. The early construction of wells and storage reservoirs offers a viable alternative to reduce both the number of wells required and the annual groundwater withdrawal rate. For example, one well and storage reservoir could be constructed a year or more before actual cluster construction begins in a valley. By filling the reservoir with groundwater prior to construction, the peak stress upon the water resources could be greatly reduced.

An alternative source of construction water is the carbonate aquifers in local areas where development of the valley-fill aquifers is not advisable. The potential of these carbonate aquifers as a source of water for the M-X system is not well known at this time, but the Air Force is currently conducting a test drilling program to determine the feasibility and evaluate the impacts of carbonate aquifer development.

Another alternative source of water for construction is the lease or purchase of the existing water rights. Water obtained in this manner would not increase the quantity of existing groundwater withdrawals in the valley. The lease or purchase of water rights in this manner can be used for the acquisition of both surface and groundwater supplies. Surface impoundments (reservoirs) built to store snowmelt runoff can be used as a supplemental water source during construction phases.

To supply M-X water requirements to designated valleys or valleys with insufficient ground water supplies, it may be possible to transport water from adjacent or distant water-rich areas.

It should be noted that any method of water supply may create negative impacts to the source as well as beneficial impacts to the user. It is expected that, with careful planning, the beneficial effects will be greater than the negative ones.

NEVADA/UTAH (5.2.3)

DDA

It is expected that most M-X DDA demands can be supplied from local valley-fill aquifers as new appropriations. Some areas have been designated by the State Engineers and local appropriations may not be allowed. It is possible that a temporary water use above the estimated perennial may be allowed due to the relatively short construction period. There is precedent for temporary groundwater mining in both Nevada and Utah.

Water could be imported from water rich areas to supply all DDA demands. Since a pipeline is already planned to parallel the DTN, the pipeline could be enlarged to accomodate all DDA water supply needs. Water could be pumped from water rich areas such as Railroad Valley, Spring Valley, and Snake Valley and piped throughout the project to satisfy demands.

It is not expected that new appropriations will be approved in sufficient quantities to fully met the projected M-X OB demands. To lease or buy local water rights could be a viable alternative for most Nevada/Utah sites. This may not be possible for the Delta site as the State Engineer has indicated that additional transfer of water rights may not be allowed. to import water could be a viable alternative. Water could be pumped from a water rich area and piped to an OB site, Water could be pumped from Spring Valley and piped to Ely or Coyote Spring. Water could be pumped from Snake Valley and piped to Beryl, Milford, or Delta. Additionally, water could be bought from Las Vegas and piped to Coyote Spring. There is precedent for piping water over state and local boundaries.

TEXAS/NEW MEXICO (5.2.4)

As an alternative source of water, the existing water rights could be leased or purchased from current users, such as in declared basins in Chaves, northern DeBaca, and northern Roosevelt Counties, for the one or two years of construction in the region. Water obtained in this manner would not increase the quantity of groundwater withdrawals in the region above existing levels. Water stored in surface reservoirs would be desireable, because it could be used year-round for the construction phase of the project.

To supply M-X water requirements to designated regions, or to regions with insufficient groundwater supplies, it may be possible to transport water from adjacent or distant "water rich" regions. For example, water from Regions V and VI (each has a life of aquifer in excess of 100 years) could be pumped to Regions IV, VII, and IX (which have seriously overdrafted groundwater basins). The diversion of the 15,000 acre-ft per year available at Ute Reservoir is a potential mitigation for the groundwater problem in Region VIII.

6.0 REFERENCES

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APPENDIX A

GENERATION OF M-X WATER REQUIREMENTS

1.0 DEDICATED DEPLOYMENT AREA CONSTRUCTION WATER REQUIREMENTS

For a project of this magnitude in these proposed areas, water is a significant resource. Many of the activities of construction require water. These include:

- Earthwork, such as compaction
- Concrete and concrete plants
- Sand and aggregate plants
- Dust control
- Irrigation of revegetation
- Construction personnel

The unit quantities of water used for estimating the most probable quantity (MPQ) of water required for each system component of the DDA are shown in Table 1-1. These quantities are based on preliminary studies by other firms and an engineering judgement. The actual quantities would vary from valley-to-valley, county-to-county, and mile-to-mile. The values listed are believed to be representative averages for the regions studied. The ranges listed in other sections are intended to allow for these variations. These values are generally independent of the alternative evaluated. The irrigation quantity is the same for Texas/New Mexico and Nevada/Utah, but was derived by different methods, as explained later. Irrigation of revegetation was not included for "MPQ" estimates in Texas and New Mexico, but was included in Nevada/Utah alternatives for protective structures.

The MPQs presented on hydrographic area and county bases were derived by different methods depending on whether or not there were construction camps proposed. For those areas without construction camps, the earthwork, irrigation (if used), and protective structure dust control quantities in Table 1-1 were summed for each system component and multiplied times the number of protective structures, miles of DTN, and miles of cluster roads, respectively, in the area. Irrigation only contributed to the MPQ calculations for protective structures in Nevada/Utah. An example is shown in Table 1-2.

For those areas with proposed construction camps the earthwork and irrigation quantities were estimated in the same manner as those areas without construction camps. The quantities of water required for concrete and concrete plants, aggregate and aggregate plants, dust control for the roads, and construction personnel were determined by system component and multiplied times the number of protective structures, miles of DTN, and miles of cluster roads, respectively, in the construction segment. An example is shown in Table 1-2. If Deaf Smith County had not had a construction camp proposed, the water requirements would have been only 4,000 acre-feet.

Construction requirements were determined by computer analysis for each alternative by year for the duration of construction. For each alternative and each year the computer also estimated construction quantities for each county, hydrographic area and construction segment. The water requirements presented in other sections represent selected quantities from these analyses, as well as combinations of quantities.

Table 1-1. Unit water requirements for construction by construction activity.

UNIT	UNIT QUANTITY/ SHELTER OR MILE PROTECTIVE STRUCTURE (a)	MPQ[1]	
		GALLONS/UNIT QUANTITY (b)	ACRE-FT/PROTECTIVE STRUCTURE OR MILE (c)
Protective Structures			
Aggregate Facilities	506 CY	150	0.24
Concrete	624 CY	40	0.077
Concrete Plants	624 CY	20	0.038
Subgrade Compaction	500 CY	48	0.074
Backfill Compaction	17,840 CY	48	2.64
Slope Stabilization	3,640 SY	.25	0.0028
Dust Control	1.9 AC	48,400	0.28
Irrigation	7.5 AC	326,000	7.5
New DTN			
Aggregate Facilities	7,720 CY	150	3.55
Clear & Grub	7.8 AC	2,420	0.058
Scarify & Recompact	20,000 SY	32	1.98
Aggregate Base Compaction	5,460 CY	45	0.76
Embankment Compaction	15,000 CY	48	2.21
Fine Grading	12.4 AC	2,400	0.091
Dust Control	4.2 AC	112,000	1.44
Irrigation	6.0 AC	326,000	6.0
Cluster Roads			
Aggregate	6,120 CY	150	2.80
Clear & Grub	8.1 AC	2,420	0.06
Scarify & Recompact	21,700 SY	32	2.14
Aggregate Base Compaction	6,120 CY	45	0.85
Embankment Compaction	7,000 CY	48	1.04
Fine Grading	13.5 AC	2,400	0.10
Dust Control	4.5 AC	57,000	0.79
Irrigation	6.0 AC	326,000	6.0
Construction Personnel		85 gal per capita per working day	

2513-1

[1]Most probable quantity.

Note: $(c) = (a) \times (b) \times \frac{\text{acre-ft}}{325{,}900 \text{ gal.}}$

Table 1-2. Examples of total project requirements calculations.

CONSTRUCTION ACTIVITY	SYSTEM COMPONENT[1]	QUANTITY OF SYSTEM COMPONENT (a)	WATER PER UNIT SYSTEM COMPONENT (b) (acre ft)	TOTAL WATER (a x b) (acre-ft)
Parmer County, TX (Alternative 5) Without Construction Camp				
Earthwork	PS	138	2.71	370
Earthwork	DTN	90	4.34	390
Dust Control	CR	179	3.34	600
Irrigation	PS	138	0.28	40
Total				1,400
Deaf Smith County, TX (Alternative 5) With Construction Camp				
Earthwork/Dust Control/Irrigation	PS	506	2.99	1,500
Earthwork	DTN	78	4.34	340
Earthwork	CR	658	3.34	2,200
Aggregate/Concrete	PS	621	0.345	210
Aggregate/Concrete/ Dust Control	DTN	147	5.75	850
Aggregate/Concrete/ Dust Control	CR	807	4.44	3,600
Construction Personnel	PS DTN CR	621 147 807		440
Total				8,700

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[1]System Components are:

PS = Protective Structures
DTN = Dedicated Transportation Network
CR = Cluster Roads

Based on a peak construction rate of 0.44 protective structures per day and 0.72 mi of cluster road per day, water would have to be supplied at a rate between 2,000 and 2,500 gpm for eight hours. If irrigation of revegetation at the protective structure sites is done concurrently with construction, an additional 1,200 gpm would be needed. Based on a construction rate of 0.25 mi of DTN per day, a well along the road would need to be able to supply 1,100 gpm for eight hours. To supply water for construction camp activities (aggregate and concrete plants, dust suppressant for the roads, and construction personnel) a well would need to be able to pump 2,200 to 3,000 gpm for eight hours; an option would be to pump at 1,100 to 1,500 gpm for 16 hours and provide storage of 500,000 to 800,000 gallons.

1.1 COMPACTION/EARTHWORK

The water required for compaction and other earthwork was estimated for several subcategories including scarification and recompaction, backfill and subgrade compaction, slope stabilization, and fine grading. The amount required per unit quantity of earthwork is dependent on the type of soil at the site and the degree of compaction required. The quantities of soil to be compacted and recompacted were based on average cross-sections of the protective structures and roads. The total soil quantities required are also a function of system design and the ground slopes. The values used in determining water quantities are based on 48 gal/cy including a factor of 25 percent for waste and loss; they are listed in Table 1-1. Making an exact determination will require a thorough road survey and soils investigation. Based on preliminary investigations, the soil was assumed to be sandy silt. The degree of compaction will vary with the type of soil and with the system components. The source of water for this purpose would most likely be wells located at intervals along the DTN and at each cluster site.

Water quantities for slope stabilization, clearing and grubbing, and fine grading represent surficial applications. Scarification and recompaction, embankment compaction, subgrade compaction, and backfill compaction represent thorough moistening of the soil to engineering specifications. The compaction and earthwork quantities are essentially fixed quantities; they are required for completion of the project and will only increase or decrease by a more extensive acre by acre and mile by mile site survey and soils investigation, which was beyond the scope of this report

1.2 CONCRETE

The major use of concrete is for the protective structures. The water required for concrete is a fixed quantity that will not change unless the system design, the strength of the concrete or the concrete mix design changes. It is proposed to use 7,500 psi air-entrained concrete. The mix design includes the following quantities per cubic yard of concrete:

- 280 lb. water
- 770 lb. cement
- 115 lb. fly ash
- 1,055 lb. fine aggregate
- 1,750 lb. coarse aggregate

The quantity of water required for concrete listed in Table 1-1 includes a factor of ten percent for waste and loss. This water is almost totally removed from the hydrologic cycle.

Whether the concrete is precast or cast-in-place, the concrete plants will require water for washdown, spillage, dust control and aggregate spray cooling. Some of this water can be reused after settling. This water cannot be discharged to waterways without treatment.

The water for concrete should be of reasonably good quality; water that is suitable for drinking is generally suitable for concrete. The water source at each plant location should be tested to determine its acceptability and the need for treatment. The most likely constituents associated with groundwater sources in the study area that could affect concrete are total dissolved solids, chlorides, and bicarbonates. Surface water sources present an additional possible concern if algae are present. Excessive concentrations of these or other impurities can reduce the strength of the concrete, affect the setting time, corrode reinforcement, stain, or cause efflorescence.

The most likely source of water will be wells near the clusters for batch plants or in the construction camp for precast plants. There will be more wells with the cast-in-place method because it is necessary to keep haul distances to a minimum. Each batch plant well, however, would require less pumping than a well at a precast plant.

1.3 AGGREGATE PLANTS

Aggregate will be used in the concrete for the protective structures, on the new DTN roads for base and asphalt, and on the road surfaces of the cluster roads. The quantity of aggregate is a fixed quantity based on system design - road cross-sections, concrete mix design, road lengths, and protective structure size. Aggregate plants require water for washing the aggregate and for dust suppression during crushing and separation operations. The quantity of 150 gal/cy listed in Table 1-1 is based on 10 gpm of water per cubic yard of aggregate per hour and assumes 75 percent of the used water is recycled. This rate of usage is dependent on the quality of the aggregate and how much washing is required. This quantity could be less - perhaps by as much as half if the aggregate contains few fine particles. Most of this water is returned to the hydrologic cycle via evaporation.

1.4 DUST CONTROL

Dust control is recommended in order to minimize maintenance of equipment, to minimize air pollution, and to provide a better working environment. There are many different methods of dust suppression. Water is the proposed method for the areas around the protective structures because most other methods are deleterious to plant growth. Emulsified asphalt is the proposed method of dust control for the DTN and cluster roads; the proposed type of emulsified asphalt is fifty percent water. The quantity required is dependent on weather, soil conditions, and type of traffic. The quantities in Table 1-1 are estimated to be the rate of application averaged over a year. Dust control for the protective structures is based on 0.25 gal/sq. yd. of water applied four times daily for 10 days over an area of 1.9 acres. Dust control for the new DTN is based on 0.25 gal/sq. yd. of asphalt emulsion (of which 0.125 gal/sq. yd. is water) applied once a day for 375 days over 4.2 acres/mile. Depending on the type of weather and how long it takes to construct the facilities, water for the protective structures could range from once a day for ten days to eight applications per day for a month. If a different type of emulsified asphalt is used, the water requirements for roads could increase by as much as 70 percent. Depending on the type of traffic, soil and weather conditions, the quantity needed could be decreased by as much as a factor of five.

1.5 REVEGETATION

While not absolutely necessary, revegetation should be done whenever possible, as stated in Air Force manuals. Restoration of vegetation prevents loss of soil, prevents flood and sediment damage, prevents water pollution and reclaims the areas to the uses for which they are best suited. Irrigation for revegetation substantially increases the chance of establishing ground cover in the disturbed areas. The lower the average annual precipitation, the greater the need for irrigation to avoid revegetation failures. The probability of successful revegetation without irrigation increases when the average annual precipitation is greater than 8 in.

The majority of the valleys in the project area in Nevada and Utah receive less than 12 in. on the valley floors where most of the disturbed areas would be; 6 in. of precipitation is typical. Studies indicate that one and one-half to two times the average annual precipitation is needed during the first growing season in order to be beneficial and establish vegetation. The rate of 326,000 gal/acre in Table 1-1 is based on twice an average precipitation rate of 6 in. per year.

The project area in Texas and New Mexico averages 15 to 20 inches of precipitation per year. With careful timing and planning, irrigation for revegetation may not be necessary. However, the project area is subject to drought, in which case irrigation would be desirable. A reasonable rate of application would be 12 in. and is the basis for the value in Table 1-1 of 326,000 gal/acre.

Irrigation can be very expensive. Standard practice by state highway departments in the alternative project areas is to not irrigate along roadways away from urban areas except where vegetative stabilization is necessary to protect highway erodible soils and steep cut or fill slopes. However, due to the magnitude of the construction and because there will be wells throughout the system, some disturbed areas would be more easily irrigated than others. These include the area around the protective structures, roadsides within a mile of a well, and the construction camp, aggregate plant and concrete plant sites.

The "most probable quantities" estimated include water for revegetation of 7.5 acres at the protective structure sites in Nevada and Utah, but not in Texas and New Mexico.

1.6 CONSTRUCTION WORKERS

The water requirements for construction personnel includes domestic water use by all persons working in the field at the construction sites and by support personnel located in the construction camps. This does not include dependents. The total quantity could vary depending on the number of workers, the length of time to construct different components of the system, the degree to which water conservation is practiced, and personal habits.

Toilets and bathing account for about 75 percent of all domestic water consumption. There are a number of devices that can reduce these quantities. The rate of consumption for persons living in the construction camps could vary between 60 and 125 gpcd. The rate of 85 gpcd was used assuming some water conservation practices and devices would be used. The total quantity determined is based on the number of working days (5 days per week) and assumes most of the workers leave the construction camps on the weekend.

2.0 CONSTRUCTION WATER REQUIREMENTS FOR THE OPERATING BASE

The construction quantities requiring water and the resultant water is listed in Tables 2-1. The quantities for the operating base include the Area Support Centers. The unit water quantities for earthwork, concrete, aggregate, and construction personnel are the same as described in Section 1.0; the "most probable quantity" numbers were used.

In a full deployment alternative the quantities required for a First OB would include the OB, DAA, OBTS from Table 2-1 and appropriate construction personnel. The quantities required for a Second OB include only those quantities listed under OB and construction personnel.

In split basing alternatives, the construction water in Nevada/Utah would include water for the OB, DAA, OBTS and appropriate construction personnel. The construction water in Texas/New Mexico would include the OB, DAA, and appropriate construction personnel.

Table 2-1. Construction quantities for operating base.

ITEM	OB	DAA	OBTS
Earthwork, CY	4,200,000	463,000	126,000
Concrete, CY	874,000	33,000	4,500
Aggregate, T	4,600,000	346,000	36,000
Water, Ac-ft	1,800	150	30

2506-1

3.0 OPERATIONAL WATER REQUIREMENTS

The water required for operation of the M-X system is predominantly for domestic purposes. Based on preliminary indications it has been assumed that non-domestic water use will be minor and that the per capita water consumption will cover non-domestic water requirements. The water for domestic use includes water for household use, some lawn watering, and car washing, commercial businesses and dry industries, and public facilities including golf courses and swimming pools.

The estimated water requirements were based on rates of usage for several categories of population in different locations. The population categories locations and water rates are listed in Table 3-1. It is difficult to know the exact rate of consumption, therefore, ranges of values are presented. The quantities listed represent an average year; there would be daily, monthly and seasonal peak rates also. Factors that would tend to result in the lower water usage include water conserving devices, water metering, rainfall, landscaping that requires minimal irrigation, fewer children, reusing treated wastewater for some activities such as golf course irrigation, less commercial, recreational, and industrial development, and high water billing rates.

The rate of 150-400 gallons per capita per day (gpcd) for military and civilian personnel and dependents who live in the community is based on the minimum recommended design rate for new facilities (150 gcpd) and on actual water demands of local communities in the project area (some as high as 400 gpcd). The primary reasons for the higher rates appear to be lack of water metering and deteriorating water distribution systems. If homes of the military personnel and civilians are required to be metered and to use some water conserving devices, the rate should be able to be lowered to no more than 200-250 gpcd averaged over a year. The rate of 250 gpcd was used for determining most probable quantity.

The rate of 150-200 gpcd was used for military personnel and dependents who live onbase because it is anticipated that the connections would be metered and some water conserving devices would be used. In addition, the system will be new and with good design and construction should not significantly deteriorate over the life of the project. The rate of 200 gpcd was used for determining most probable quantity.

Personnel at the area support centers, assembly and checkout personnel, and base construction workers are temporary residents. A lower rate of 85 gpcd was used for these people because there would be few, if any, children associated with these groups and there would be minimal irrigation, business, industrial and recreational demands. It allows for generous personal habits while assuming some water-conserving devices will be used.

The water requirements for operation of the bases are independent of siting or deployment alternatives; First OBs are expected to have the same water needs; Second OBs are assumed to have approximately the same water needs.

The water used at the operating bases assumes a work force of 8,500 military and 1,000 civilian personnel at the First OB and 6,100 military and 900 civilian personnel at the Second OB. Though the civilian personnel will work on the operating bases, they and their dependents will live offbase. Most of the military

Table 3-1. Water consumption rates for system operation.

POPULATION TYPE	CONSUMPTION RATE, GPCD[1]	LOCATION OF CONSUMPTION[2]
Military personnel and dependents who live and work on the base	150-200	OB
Military personnel who work at the base but live offbase	50 100-350	OB Community
Military dependents who live offbase	150-400	Community
Personnel at the Area Support Centers	85	ASC
Civilians who work onbase but live offbase	50 100-350	OB Community
Civilians who work and live in the community	150-400	Community
Civilian dependents	150-400	Community
Assembly and Checkout personnel	85	OB
Base construction workers	85	OB

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[1]Gallons per capita per day

[2]OB - Operating Base
ASC- Area Support Center

personnel and their dependents will live onbase; however, some of the military personnel and their dependents may live offbase.

Those permanent residents in the community are assumed to have total water needs of 150 to 400 (gpcd) with a most probably quantity of 250 gpcd. Of this total quantity it has been assumed that 50 gpcd will be used onbase by those civilian and military personnel who work at the OBs but live in the community.

OB water requirements were determined for 80 percent of military personnel and their dependents living onbase and 20 percent living offbase.

Tables 3-2 and 3-3 list the quantities of water required for OBs; it includes water for those who live and work onbase as well as water for those who only work on the base. In Table 3-3 only one set of numbers is provided because the peak year requirements are the same as the permanent requirements.

The most probable water requirements for the First OB range from 2.1 to 3.6 MGD (3,000 to 4,000 acre/ft/yr) for permanent operations; this is approximately 1 MGD (approximately 1,000 acre/ft/yr) more than Second OB requirements. First OB peak year requirements are approximately 3.1-3.9 MGD (approximately 3,500-4,400 acre/ft/yr) more than peak year requirements for a Second OB.

The water demands imposed upon the support community are, unlike the OBs, dependent on the siting and deployment alternatives. The number of people that would migrate into the communities was determined by computer analysis; the factors affecting the analysis are discussed in other reports.

Table 3-2. First OB operational water requirements in MGD.

*(thousand of acre/ft/yr)

OB POPULATION COMPONENT	NUMBER OF PEOPLE	WATER REQUIREMENTS	
		RANGE	MPQ[1]
Peak Year - 1987			
Military-Living Offbase	1,700	0.09	0.09
Military and Dependents	17,100	2.56-3.42	3.42
Civilians	1,000	0.05	0.05
A&CO[2]	4,500	0.38	0.38
Base Construction Workers	0	—	—
Total		3.1-3.9 (3.5-4.4)*	3.9 (4.4)*
Permanent			
Military-Living Offbase	1,700	0.09	0.09
Military and Dependents	17,100	2.56-3.42	3.42
Civilians	1,000	0.05	0.05
A&CO[2]	0	—	—
Base Construction Workers	0	—	—
Total		2.7-3.6 (3.0-4.0)*	3.6 (4.0)*

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[1]Most probable quantity.

[2]Assembly and Checkout personnel.

Table 3-3. Second OB operational water requirements in MGD.

*(thousands of acre/ft/yr)

OB POPULATION COMPONENT	NUMBER OF PEOPLE	WATER REQUIREMENTS	
		RANGE	MPQ[1]
Military-Living Offbase	1,220	0.06	0.06
Military and Dependents	12,300	1.8-2.5	2.5
Civilians	900	0.05	0.05
A&CO[2]	0	—	—
Base Construction Workers	0	—	—
Total		2.0-2.6 (2.2-2.9)*	2.6 (2.9)*

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[1]Most probable quantity.

[2]Assembly and checkout personnel.

APPENDIX B

NUMERICAL SIMULATION OF WATER RESOURCES

1.0 HYDROLOGIC MODELS

The response of the hydrologic system to applied stresses, such as pumping from wells or changes in precipitation, can best be evaluated by the use of numerical models. These models provide the hydrologist with the ability to integrate the many inter-related compnents of the hydrologic system in response to changes in the system. In all but the simplest hydrologic systems, equations governing the hydraulics of the systems are either too numerous or too complicated to be solved without a computer. The following section presents two solutions to determining the problems of determining the area affected by the pumping of a well. The first approach was developed by C.V. theis and is accepted in most situations. The second in a new approach presently under development that hopes to simplify the field procedures necessary for the theis solution. The material presented is based on a set of theorical data. It is not intended to present a solution for a particular situation, but only to indicate the types of solutions that may be obtained.

The second part of this section presents the results of a preliminary analysis of the change in the hydrology of a valley which might occur due to the construction of M-X facilities. This presentation utilizes a computer code which seeks to tie together the hydrology of both the surface and groundwaters. As hard physical data is scarce in the region, input variables were obtained from various reports and maps. Where necessary data was not available, appropriate assumptions were made.

2.0 LOCAL IMPACTS

GENERAL

Immediate effects of groundwater withdrawal peak in the vicinity of a well. Influence of well pumping on the water table increases toward the point of groundwater withdrawal; the water table elevation at the well is less than it is farther from the well.

Figure B-1 defines the terminology used in the following discussion of the effects of pumping wells on the water table. The well draws water only near its base (not along its entire length) thereby producing the highest velocity of water flow in this same region of the aquifer. To support this flow velocity, the pressure gradient in the water-saturated strata is also greatest here. The water table must slope from the horizontal in order to support a pressure gradient in the aquifer below the water table. Consequently, as the velocity of the water near the well increases, the topography of the water table also changes.

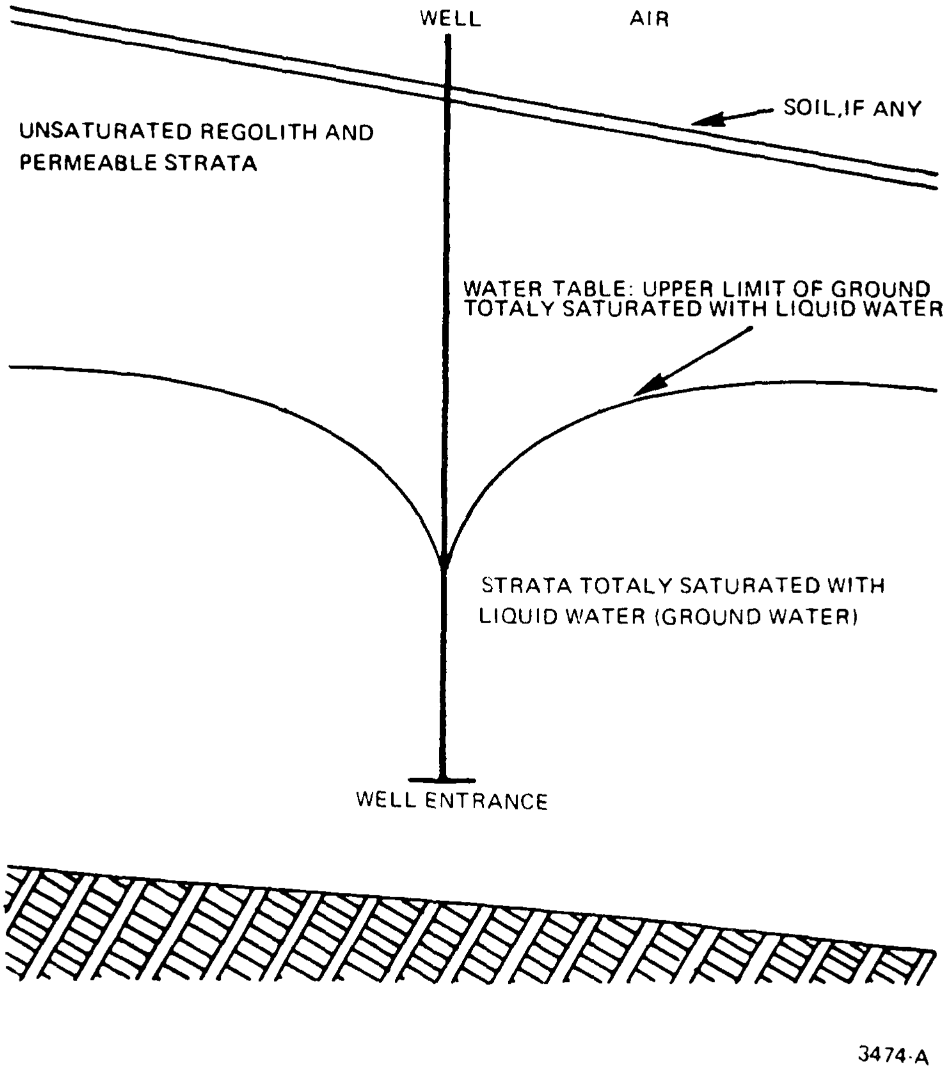

Figure B-1. Pictorial definitions of terms used in describing the influence of pumping wells on water table elevation.

The well-influenced shape of the water table, when viewed in cross section, is a curve-sided cone having its base at the elevation of the equilibrium water table and its apex at the well entrance. This cone-shaped feature is termed the cone of depression. When viewed from the surface of the overlying ground, the cone-of-depression constant-elevation contours are elliptical and centered at the well. Surface features dependent on depth of the water table will change with distance from the well.

The cone of depression will change from one well to another, depending upon the physical characteristics of the regolith or permeable stratum affecting ground-water movement. Projections of drawdowns in different aquifers can be obtained from two alternative approaches. One approach depends on site-specific experimental measurements of water table drawdown with change in groundwater withdrawal rate. The measured relationship is summarized in values for transmissibility and storage coefficient and the Theis equation. The other approach assumes values for the physical properties of the porous and permeable material constituting the aquifer matrix. The key physical properties are porosity, grain size, and tortuosity. These properties are all anistropic and vary from one point in the aquifer to the next. They are defined as follows:

- Porosity is the fraction of the area of any vertical cross section through an elemental volume of aquifer through which water can pass. The porosity changes with the orientation of the vertical cross section because the prosity is anisotropic.
- Grain size is that length which represents the average radius of flow channels throughs an elemental volume of aquifer.
- Tortuosity is a numerical parameter which identifies the characteristic length of the flow channels through an elemental volume of aquifer.

Both characterizations of the water flow in the aquifer allow drawdown to be calculated for ranges of pumping rate, well depth, and aquifer properties. The first approach requires the aquifer to be penetrated by several wells before calculation can usefully begin. The second can start with knowledge of only the stratigraphy of the well site and of properties typical of the materials constituting the successive strata.

The First Approach

The first approach was developed by C.V. Theis[1] in the 1930s and has enjoyed much successful use in the application for which it is appropriate. In this approach, observation wells are first drilled at carefully chosen distances from the specified pumping well. Rates of pumping and water levels in the observation wells provide the data for calculation of the transmissibility. The transmissibility is then used in calculating the aquifer storage coefficient. Use of these values for transmissibility and storage coefficient in the nonequilibrium form of the Theis equation projects the shape and depth of a cone of depression for any pumping rate of interest for the specified pumping well. The reliability of this first approach is predicated upon the following assumptions.

- The aquifer extends infinitely far in all directions below the water table.

- The aquifer matrix consists of a homogenous and isotropic permeable and porous material.
- The aquifer has no hydraulic gradient influencing water movement.
- The aquifer receives no recharge.

Theis drawdowns have been calculated for a hypothetical well penetrating an appropriate aquifer. Table B-1 identified the three sets of conditions assumed in calculating drawdown curves for this well. The curves shown in Figures B-2 through B-4 illustrate the consequences of each of these three sets of conditions on the drawdown produced in the first 1 (red), 6 (blue), and 24 (yellow) hours of pumping from a virgin aquifer.

Each well's drawdown has its own distinctive features. In the low transmissibility aquifer, after 24 hours of pumping the water table has moved sharply downward in the immediate vicinity of the well forming a deep and slender cone of depression. the cone of depression for this well in the aquifer having highest transmissibility is widest showing the broadest areal extent. The well withdrawing water from an aquifer having middle range transmissibility has a somewhat narrower cone than the highest transmissibility aquifer with noticeably larger areal influence than does the well in the lowest transmissibility aquifer.

In the second approach, rather than the Theis algebraic equation the integral conservation equations are used to describe the physical assumptions that mass and momentum are conserved throughout the hydrologic subunit at all times. While the Theis equation describes the water flow with reference to a particular well, the integral conservation equations apply to all underground flow whether there are any wells at all. The integral conservation equations provide a more general model for projecting the influence of adjacent wells on each others' drawdown. The integral conservation equations must be supplemented with additional information before they can be used in calculation of drawdown. This additional information includes:

- Dimensions of the aquifer
- Areal extent of surface drainage
- Ground surface configuration (topography) measured as slope
- Hydraulic gradient distribution over the hydrologic subunit
- Amount and locations of aquifer echarge
- Distribution of pore size in the aquifer matrix material over the hydrologic subunit
- Distribution of grain size in the aquifer matrix material over the hydrologic subunit
- Distribution of tortuosity of the aquifer matrix material over the hydrologic subunit
- Specific locations and dimensions of channelized surface flows
- Locations and dimensions of surface structures

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[1]Theis, C.V. (1938). "The Significane and Nature of the Cone of Depression in Ground-Water Bodies," Economic Geology, XXXIII(8), 889-902. Urbana, Illinois: Economic Geology Publishing Company.

Table B-1. Conditions assumed for each of the three Theis drawdown calculations.

AQUIFER STRUCTURE (typical grain size)	STORAGE COEFFICIENT[1]	TRANSMISSIBILITY[2]
Coarse	0.00019	100,000
Medium	0.0017	60,000
Fine	0.0071	10,000

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[1]Coefficient of storage is a dimensionless empirical parameter defined by the nonequilibrium of their equation (Groundwater and Wells, St. Paul, Minn., Johnson Division of VOP, Inc., 1975).

[2]Transmissibility is the rate of flow in gallons per day through a vertical cross section of an aquifer whose height is the thickness of the aquifer and whose width is one ft when the hydraulic gradient is equal to 1.0.

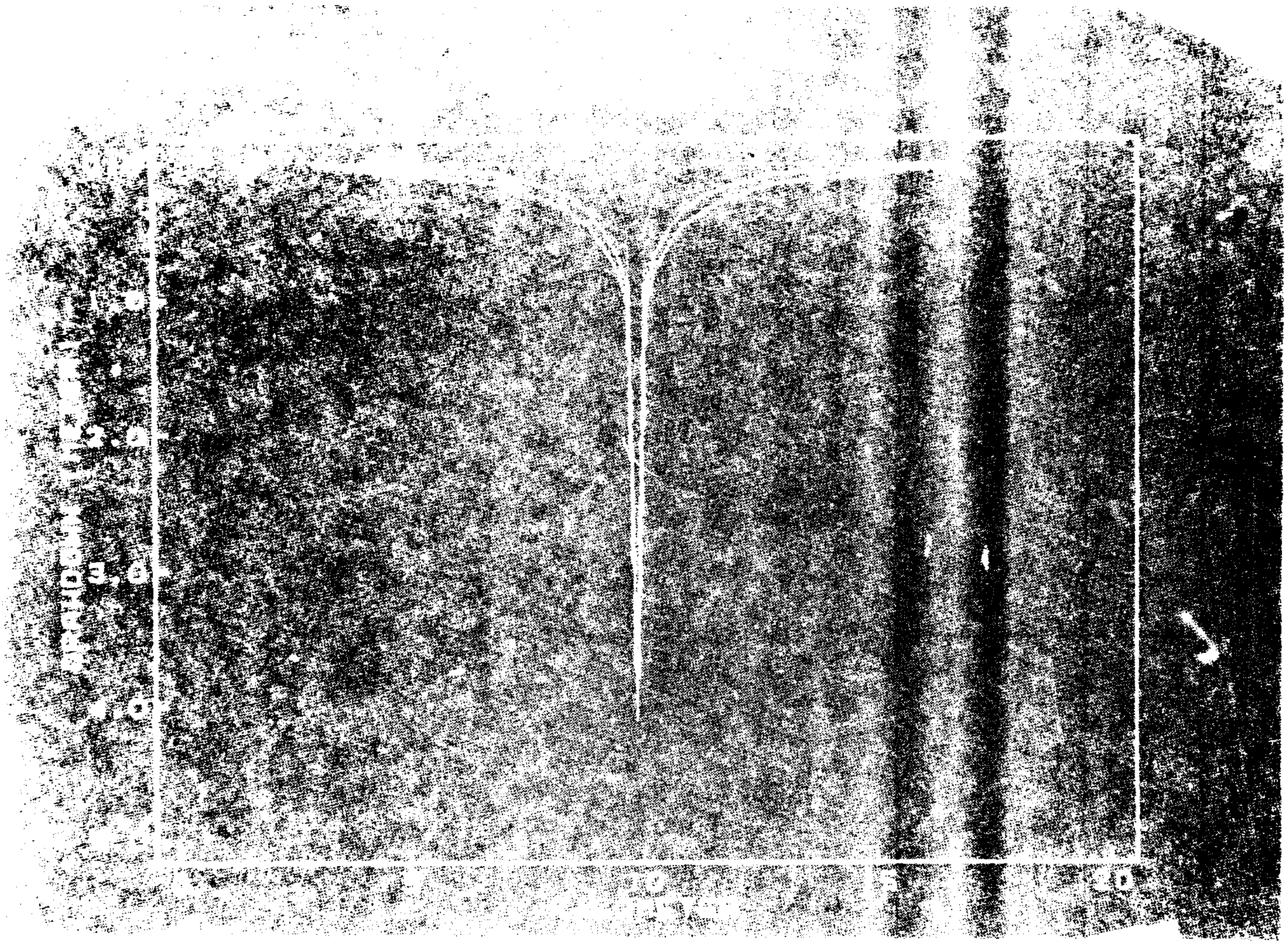


Figure B-2. Cone of depression for coarse-structured aquifer at 1, 6, and 24 hours after start of pumping virgin aquifer. Cone shape computed by Theis calculation with a pumping rate of 120 m^3/h.

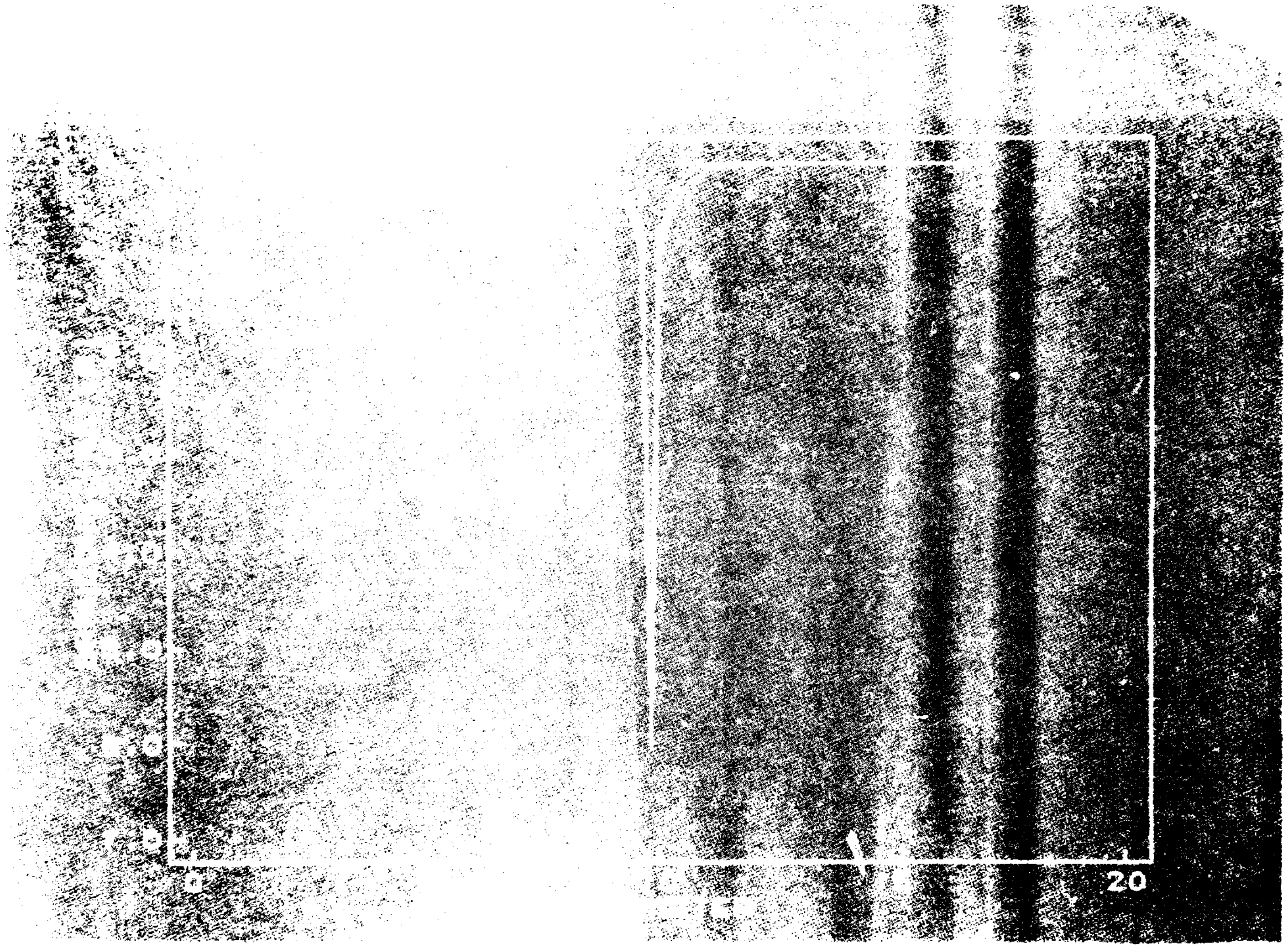
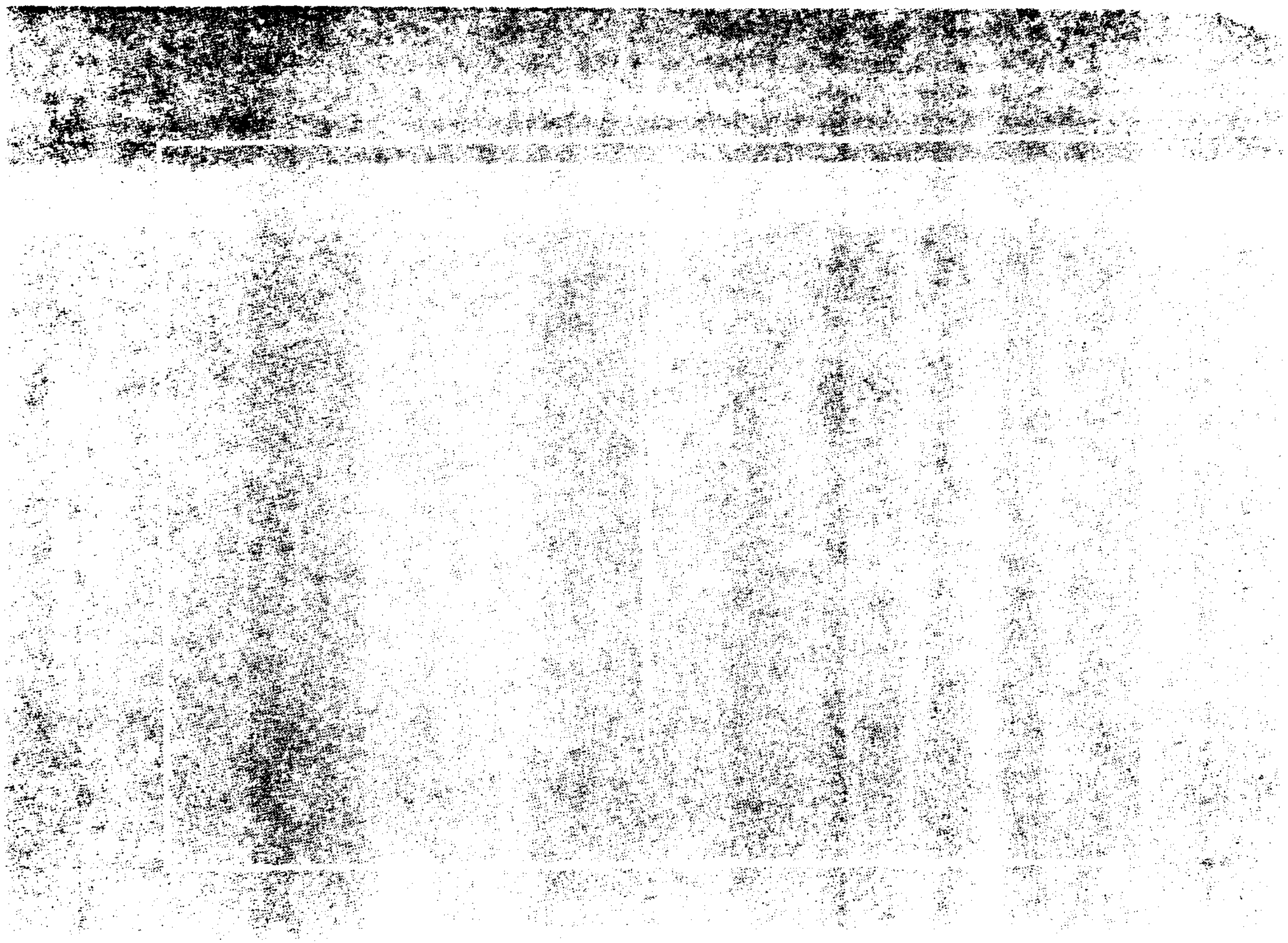


Figure B-3. Cone of depression for medium-structured aquifer at 1, 6, and 24 hours after start of pumping virgin aquifer. Cone shape computed by Theis calculation with a pumping rate of 120 m^3/h.



[illegible] after start of pumping [illegible] computed by [illegible] calculation with a pumping rate of [illegible] m^3/[illegible].

- Locations and pumping rates of wells
- Distribution, amount, and intensity of precipitation
- Locations and density of geophysical hindrances to water flow.

Solving the integral conservation equations requires sophisticated numerical analysis techniques. In the application of these techniques, whose technical name is "fluid in discrete elements in porous media," a three-dimensional lattice is used to represent the space occupied by the earth in the hydrologic subunit. The lattice defines a set of parallelograms (elements) completely filling the space. The computation algorithm for solving the integral conservation equations throughout the lattice involves calculating the hydrostatic pressure in and flow of water through each of these elements.

The algorithm has so many steps a digital computer is used to perform them. (The algorithm written as a computer code is named AQUFER.) The performance of the algorithm starts by computing estimates of the representative values of porosity, grain size, and tortuosity for each of the elements. The use of the computer code in projecting the distribution and flow of water in the hydrologic subunit is termed simulation.

The simulation computes, for example, values for the elevation of the water table for each point in a lattice of points covering the entire surface of the hydrologic subunit from the few actual groundwater level measurements that are available. It also computes the depth of water standing on the ground and the average speed and direction (velocity) of the flow of water at the same points during and following a rainfall event. This average is a representation of the entire flow of water from the water table up to the top of the water standing on the ground. Use of this simulation assumes:

- The dynamic response of an entire hydrologic subunit can be represented mathematically by reproducing the physical conditions in discrete spatial elements.

The boundary condition assumptions used in the first approach were used as boundary conditions in the simulation. The computer code was also adjusted to represent a well positioned in the middle of the area underlain by the aquifer.

The simulation-computed depth-to-water-table contours shown in Figures B-5 through B-10 suggest that drawdown proceeds quickly once pumping starts but even at 1 hour of pumping the areal influence of the pumping remains close to the well. The average-velocity arrows in Figures B-9 and B-10 show the water movement to be relatively slower in the fine-structured aquifer than in the coarse-structured represented in Figures B-5 and B-6. The isometric cross sections shown in Figures B-11 through B-13 highlight how the three cones of depression differ in depth and range of influence at 24 hours of pumping.

Of the three smallest-depth contours, the smallest-depth (outermost) contour for the coarse-structured aquifer has enclosed the largest region. Average-velocity arrows indicate the rapidity of water movement in the vicinity of each well showing the highest speed of movement near the well in the coarse-structured aquifer. Cross sections shown in Figures B-14 through B-16 corresponding to

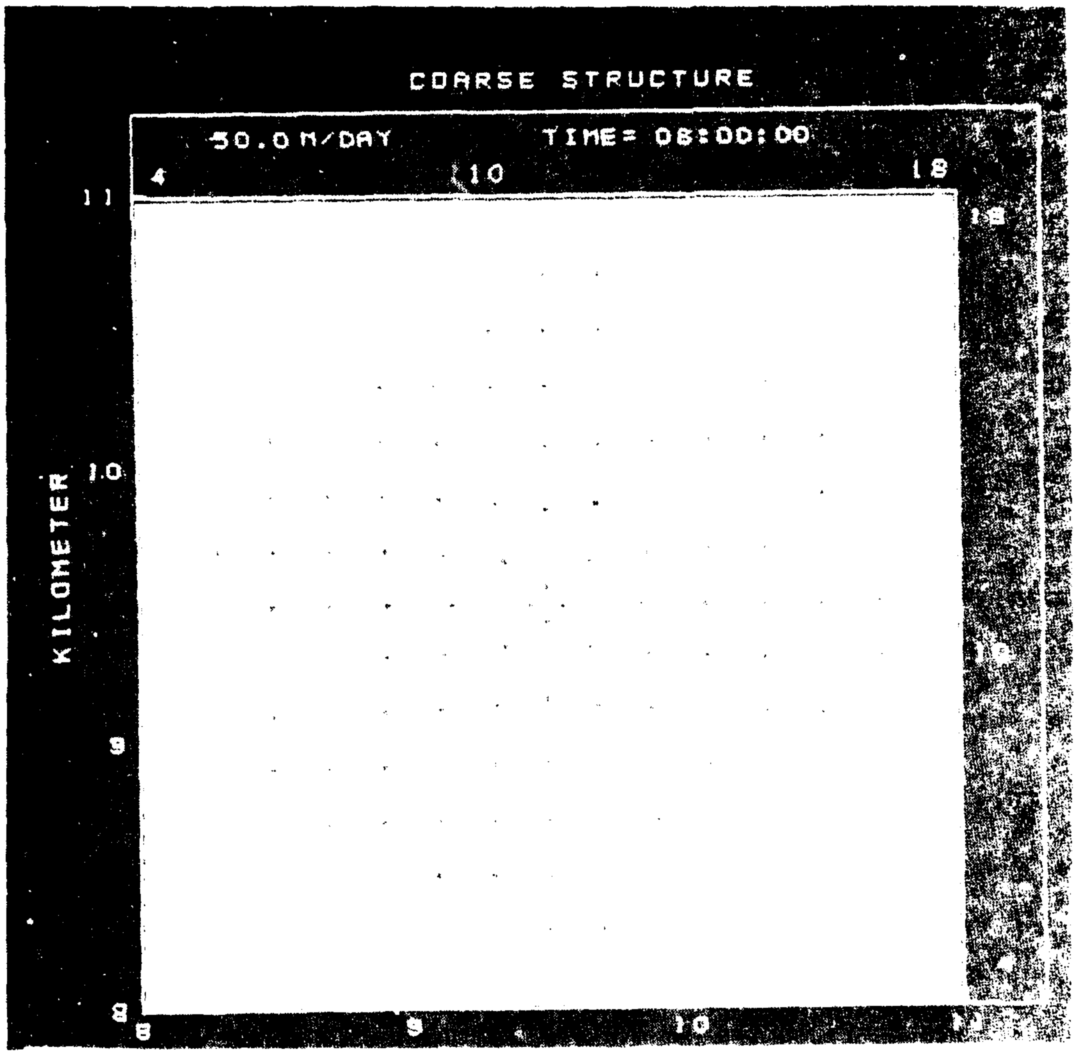


Figure B-5. Computed constant-drawdown contours (0.2 m drawdown steps) and average-velocity field after 6 hours pumping coarse-structured virgin aquifer at a constant rate of 120 m^3/h.

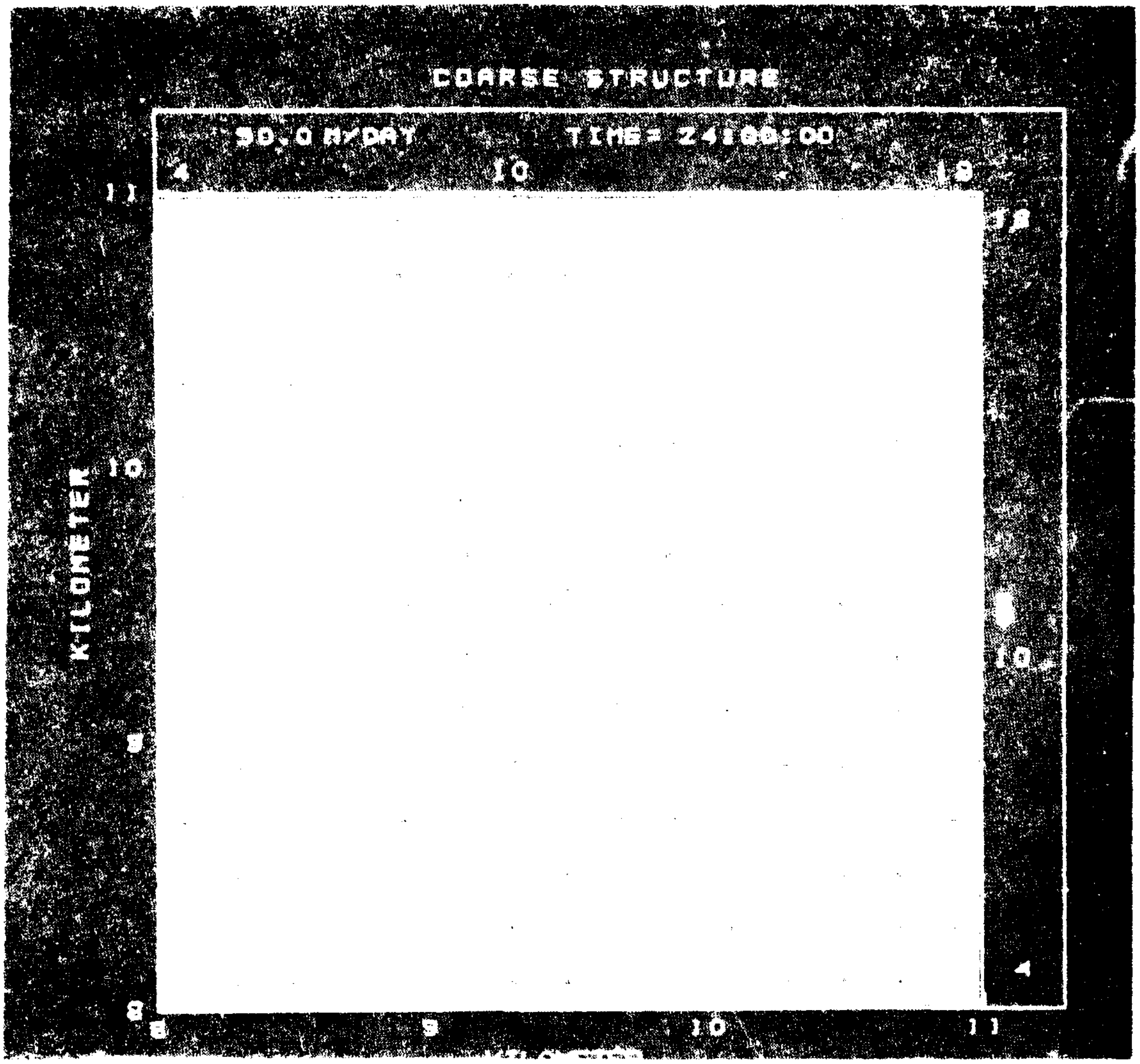


Figure B-6. Computed constant drawdown contours (0.2 m drawdown steps) and average-velocity field after 24 hours pumping coarse-structured virgin aquifer at a constant rate of 120 m^3/h.

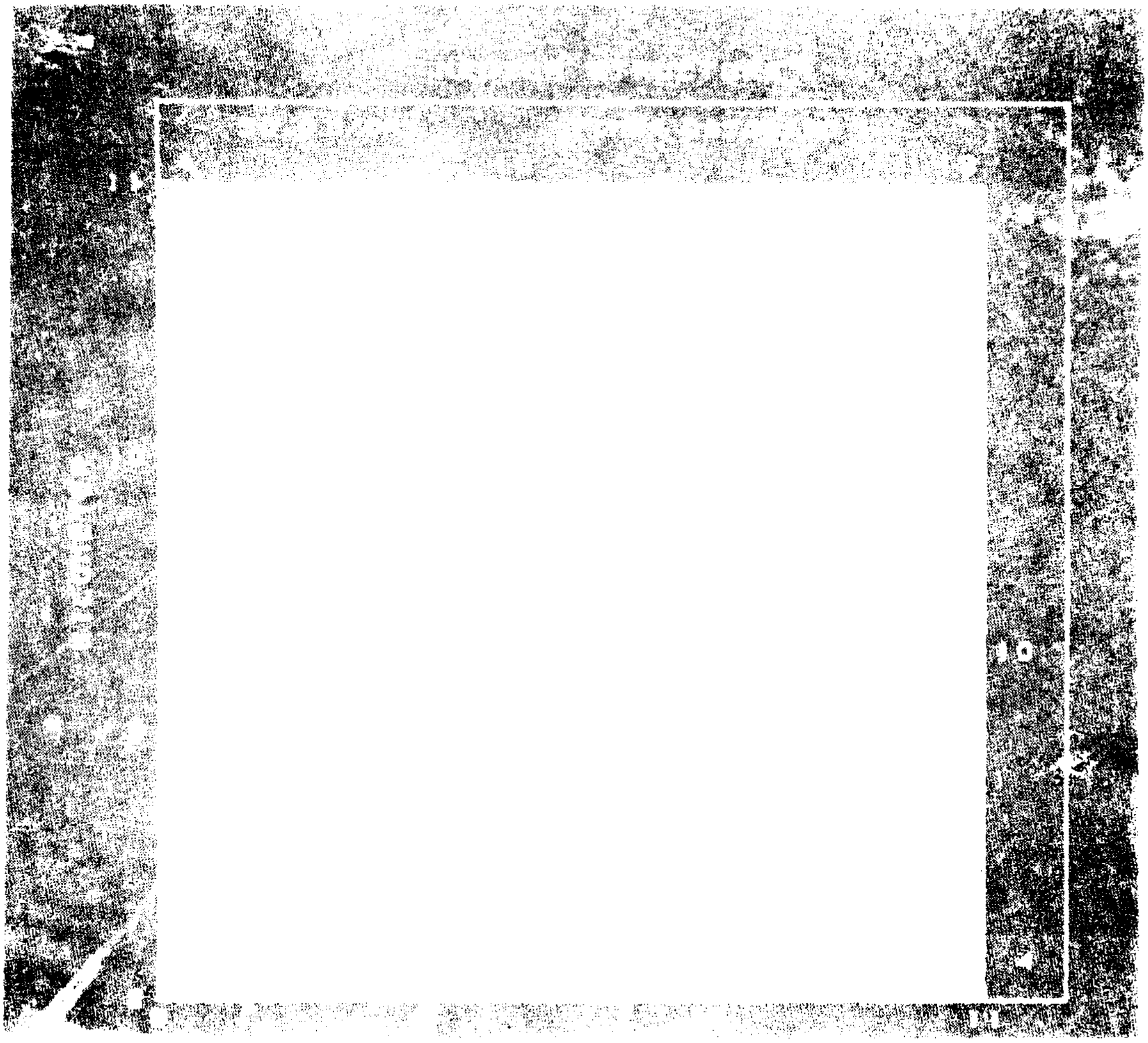


Figure B-7. Computed constant drawdown contours (0.2 m drawdown steps) and average-velocity field after 6 hours pumping medium-structured virgin aquifer at a constant rate of 120 m^3/h.

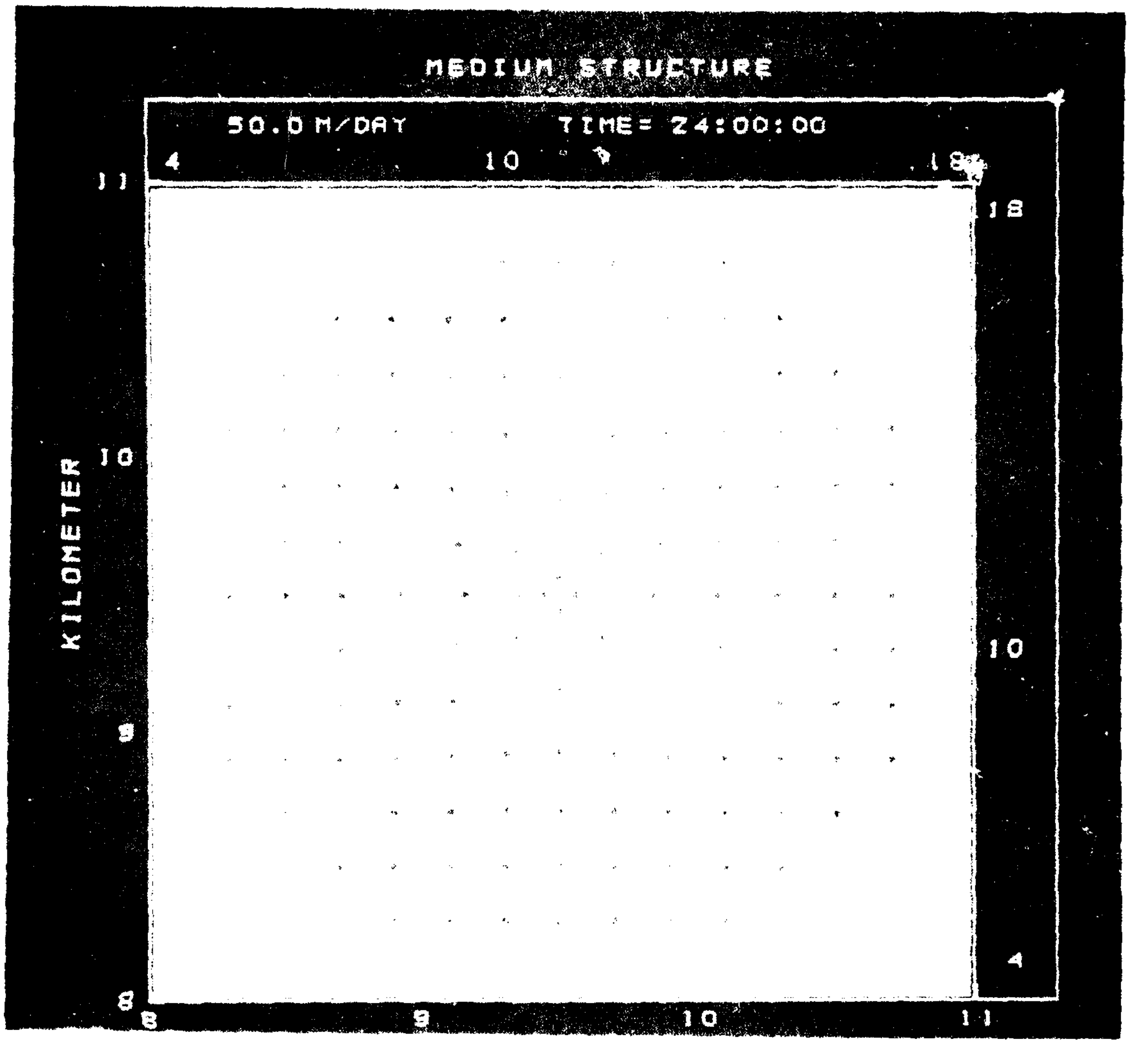


Figure B-8. Computed constant drawdown contours (0.2 m drawdown steps) and average-velocity field after 24 hours pumping medium-structured virgin aquifer at a constant rate of 120 m^3/h.

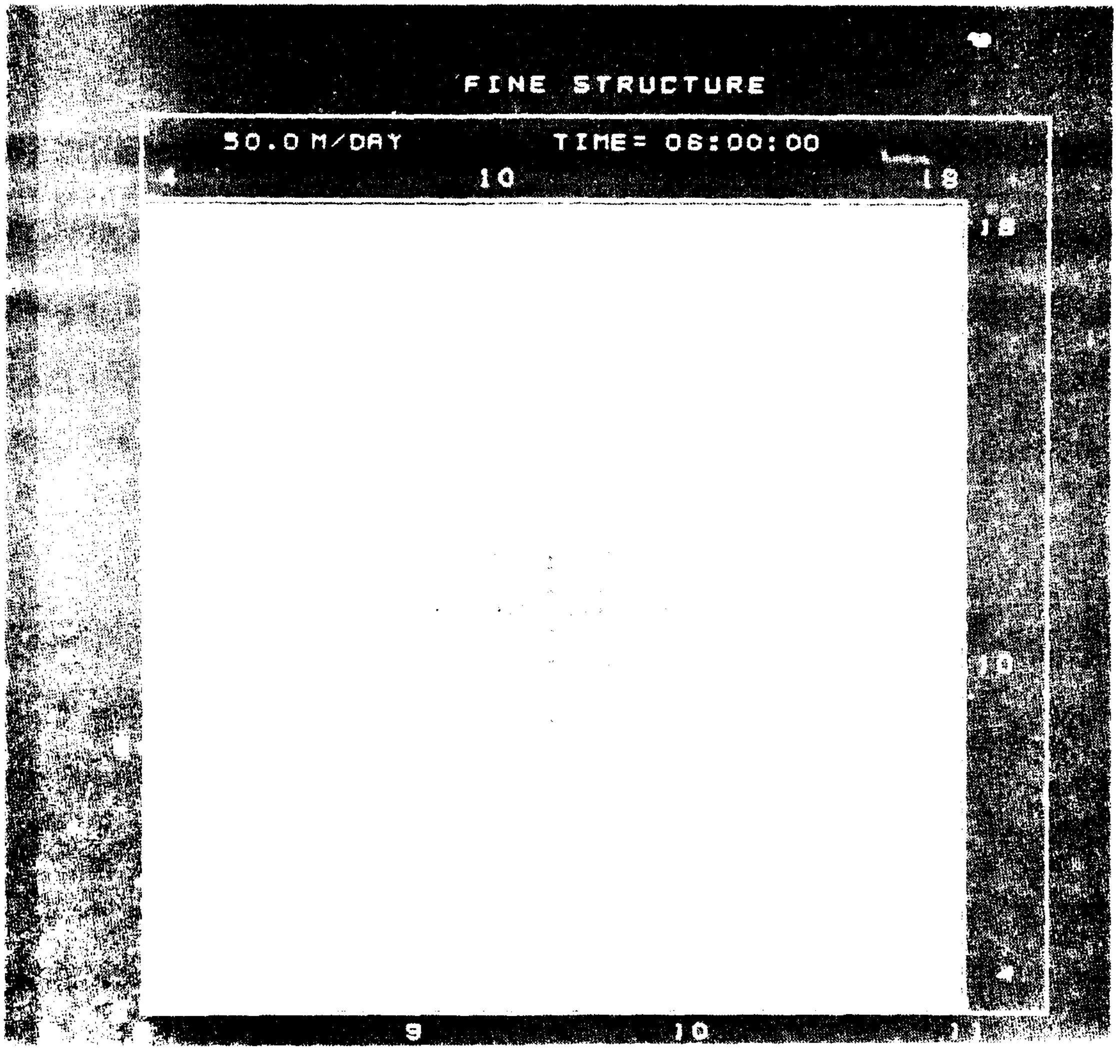


Figure B-9. Computed constand drawdown contours (0.2 m drawdown steps) and average-velocity field after 6 hours pumping fine-structured virgin aquifer at a constant rate of 120 m^3/h.

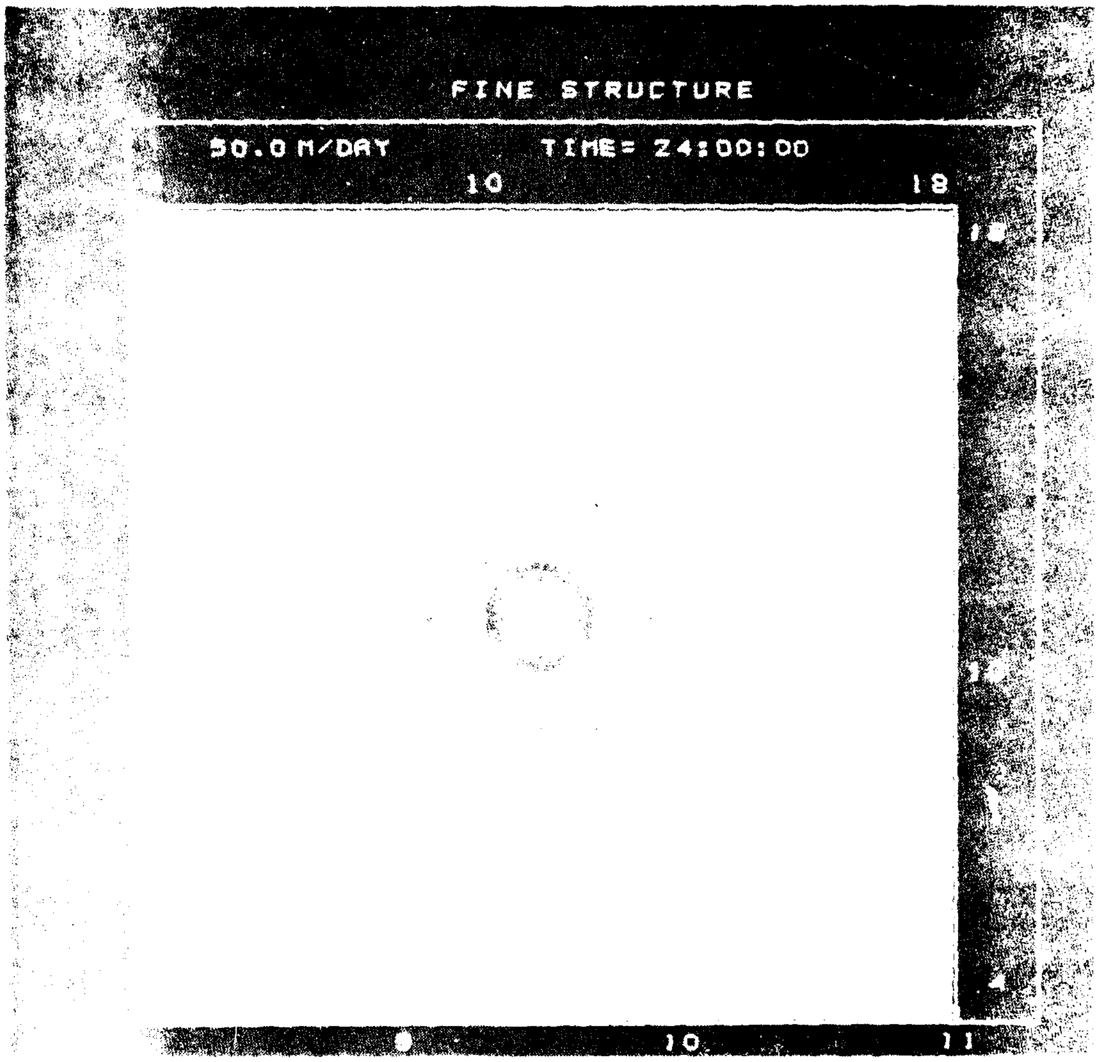


Figure B-10. Computed constant drawdown contours (0.2 m drawdown steps) and average-velocity field after 24 hours pumping fine-structured virgin aquifer at a constant rate of 120 m^3/h.

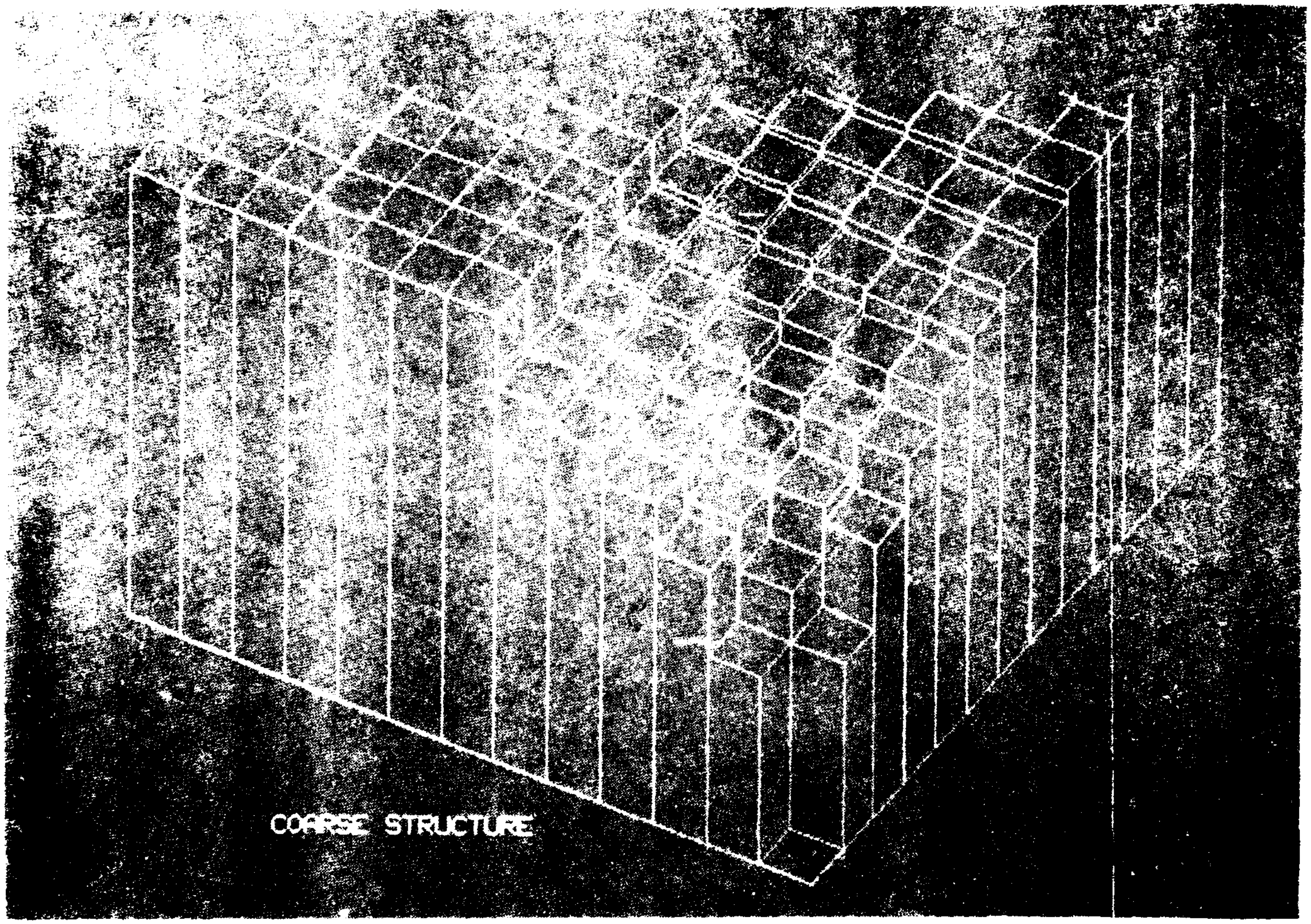


Figure B-11. Cross-sectional view of the drawdown after 24 hours pumping coarse-structured virgin aquifer at a constant rate of 120 m^3/h.

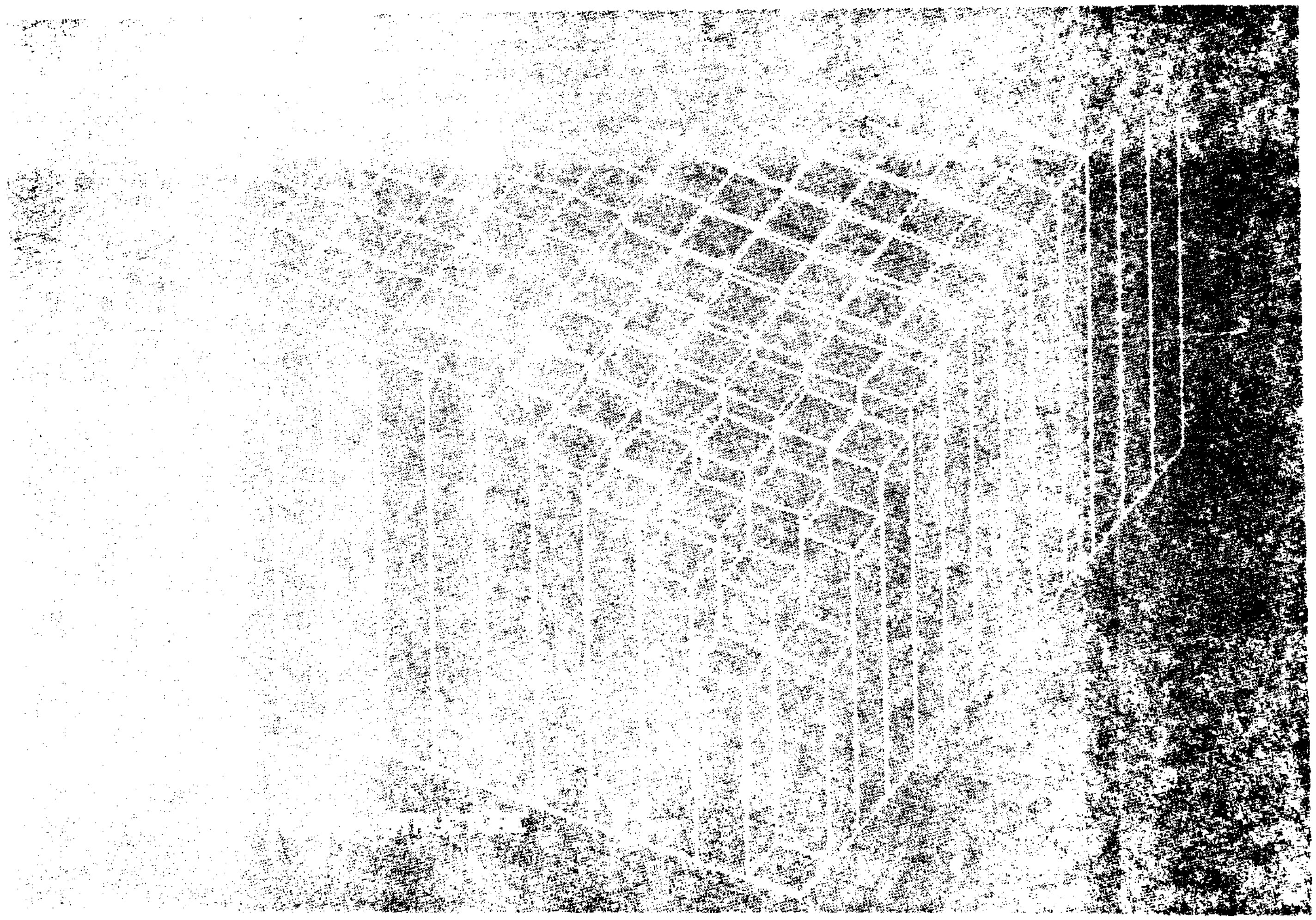


Figure B-12. Cross-sectional view of the drawdown after 24 hours pumping medium-structured virgin aquifer at a constant rate of 120 m^3/h.

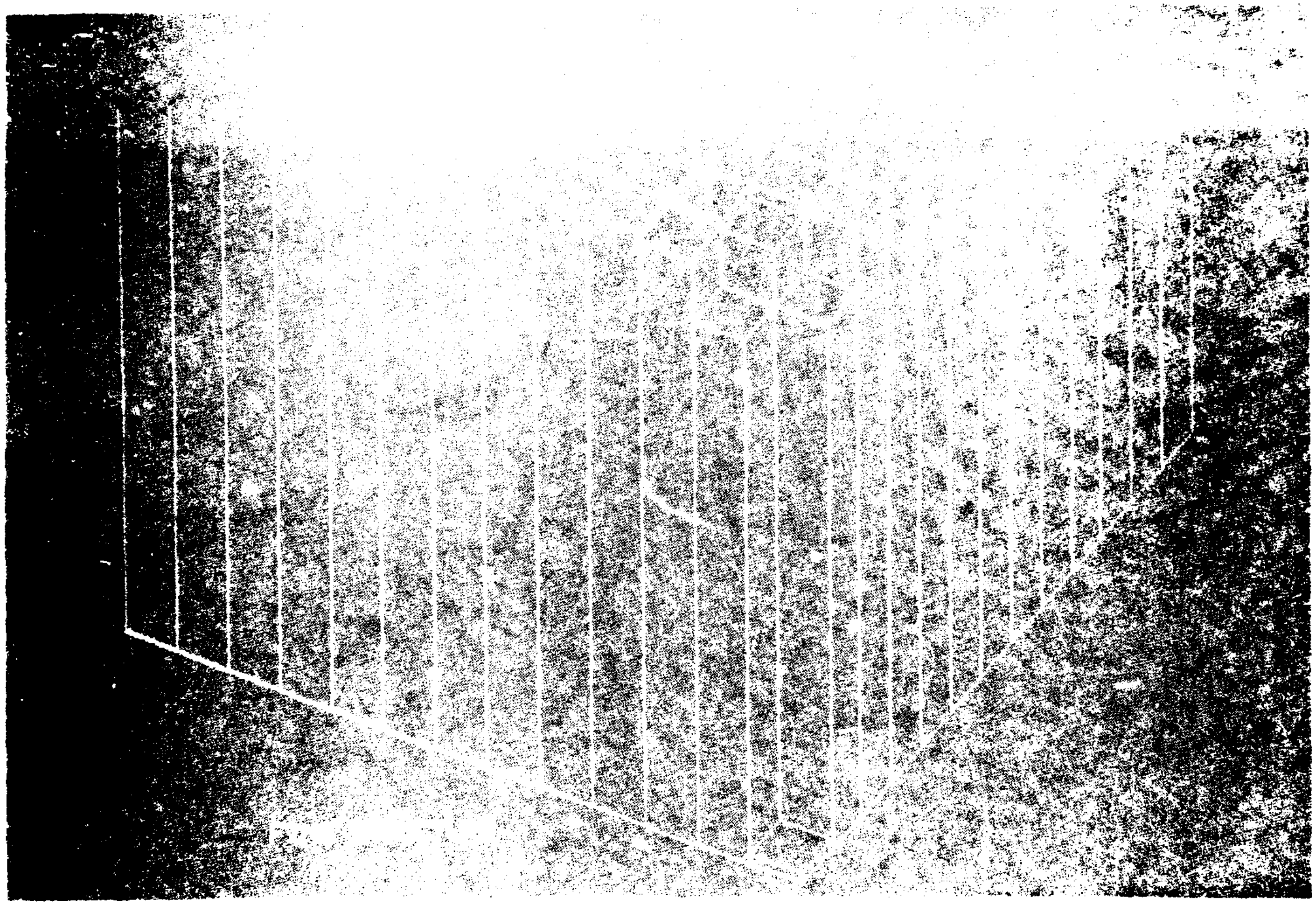


Figure E-13. Cross-sectional view of the drawdown after 24 hours pumping fine-structured virgin aquifer at a constant rate of 120 m^3/h.

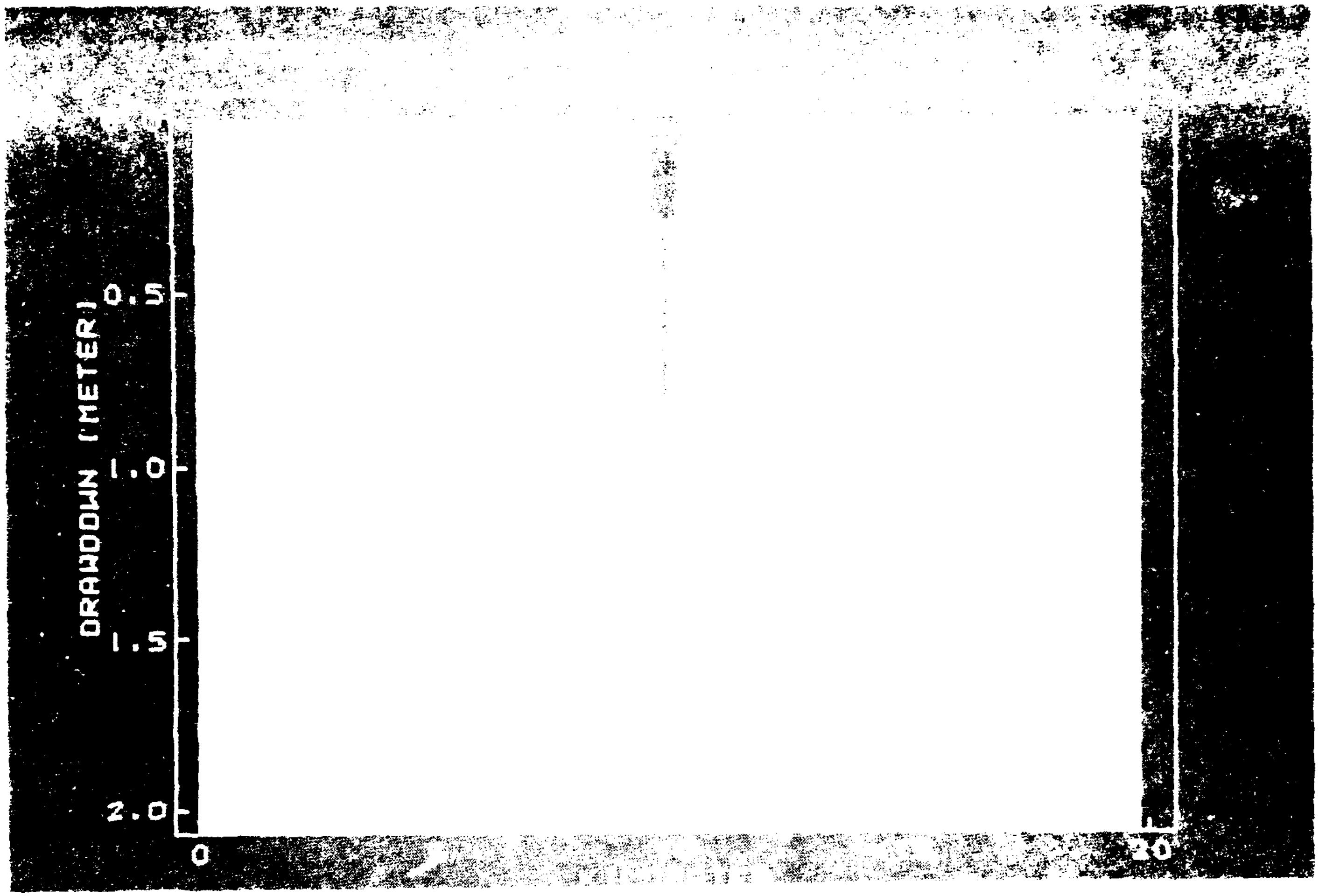


Figure B-14. Computed histogram representation of depression cone after 1, 6, and 24 hours pumping coarse-structured aquifer at a constant rate of 120 m^3/h.

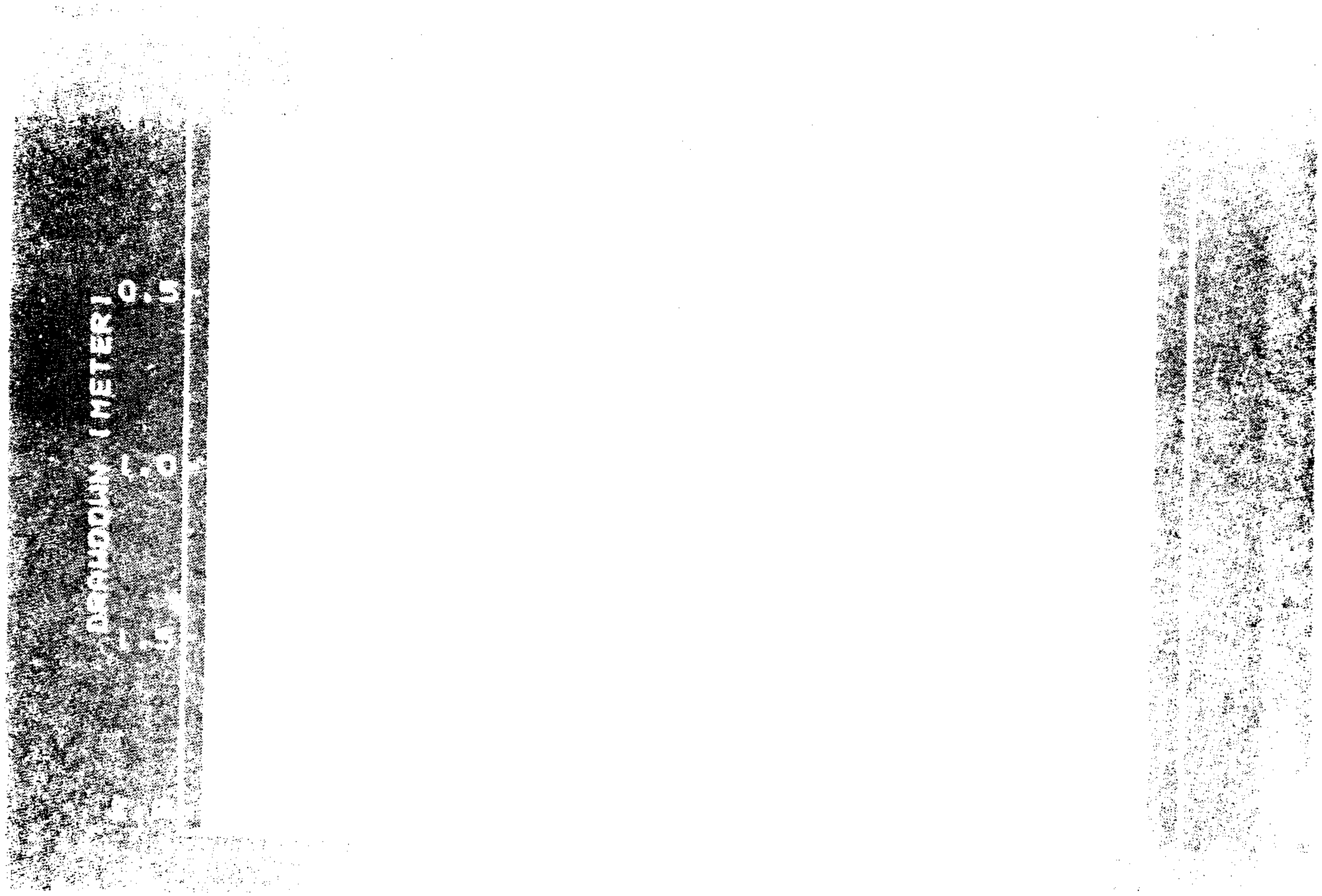


Figure B-15. Computed histogram representation of depression cone after 1, 6, and 24 hours pumping medium-structured aquifer at a constant rate of 120 m^3/h.

Figure 2-16. Computed histogram representation of depression cone after 1, 6, and 24 hours pumping fine-structured aquifer at a constant rate of 120 m^3/h.

24 hours of pumping the virgin aquifer, indicate how the cones' of depression growth down the well and broadening in the near subsurface strata depend on the pore structure of the strata. The effect of an almost impervious fault located 600 m from the well on the drawdown contours is illustrated in Figures B-17 through B-19.

Comparison of Approaches

Both approaches to computing drawdown produce correct projections for the appropriate situations, i.e., if they are correctly applied. The precisions of these projections differ, however. The first approach produces a continuous variation of drawdown with distance from the well, the second a discontinuous variation. No prediction of drawdown at the well can be made with the second approach, only a prediction of the average drawdown in a cylindrical element which includes the well. This predicted average drawdown is necessarily, then, less than the drawdown at the well predicted by the first approach. The merit of the second approach is not in its ability to precisely predict the drawdown at the well but rather to predict the drawdown at various distances from the well in situations for which the first approach is not applicable, for example, pumping a closely spaced well field.

The approaches use different types of input data. The first uses empirically determined values of transmissibility and coefficient of storage. The second uses estimates of the properties of the porous and permeable material constituting the aquifer matrix. It calculates the dynamic response of water as it moves through the aquifer to project the temporal response of the water in the hydrologic subunit to rainfall and pumping.

3.0 POTENTIAL IMPACTS OF M-X CONSTRUCTION AND OPERATIONS IN A REPRESENTATIVE HYDROLOGIC SUBUNIT

General

The geotechnically suitable areas for the M-X deployment area (DDA) in Nevada/Utah are distributed among the valleys constituting a major portion of the Great Basin. The use of water in the construction of the M-X system may draw from local supplies in the aquifers underlying these valleys. This use and the construction itself could alter the geohydrologic conditions controlling water availability in the valleys.

Drainage

The rate of recharge of the groundwater reservoir in a typical Great Basin valley depends critically on the associated hydrologic subunit's drainage characteristics. These characteristics determine the flows of near subsurface groundwater and of water in the intermittent streams and watercourses, over the surface of the ground, and in the perennial streams. In a typical DDA valley there are few if any perennial streams and, in general, the contribution of perennial streams to the recharge of the DDA valley's groundwater reservoir is negligible.

The drainage includes both the surface and near subsurface water flows; the valley-fill includes some highly porous sand and gravel layers near the surface. Drainage is greatly affected by the local channelization characteristics of the

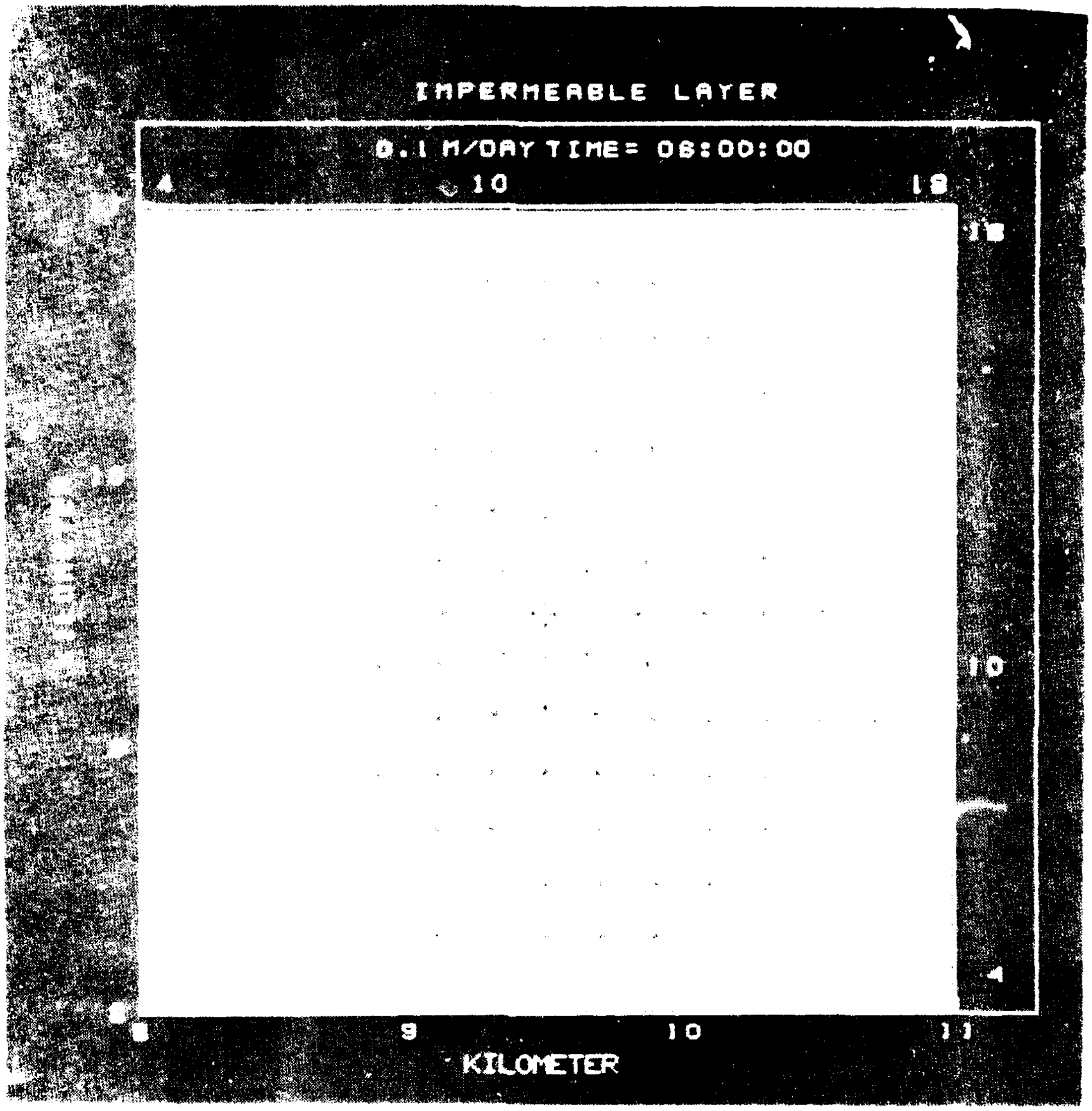


Figure B-17. Computed constant drawdown contours (0.2 m drawdown steps) and average-velocity field with the effect of an almost impervious fault located 600 m from the well after 6 hours pumping medium-structured virgin aquifer at a rate of 120 m^3/h.

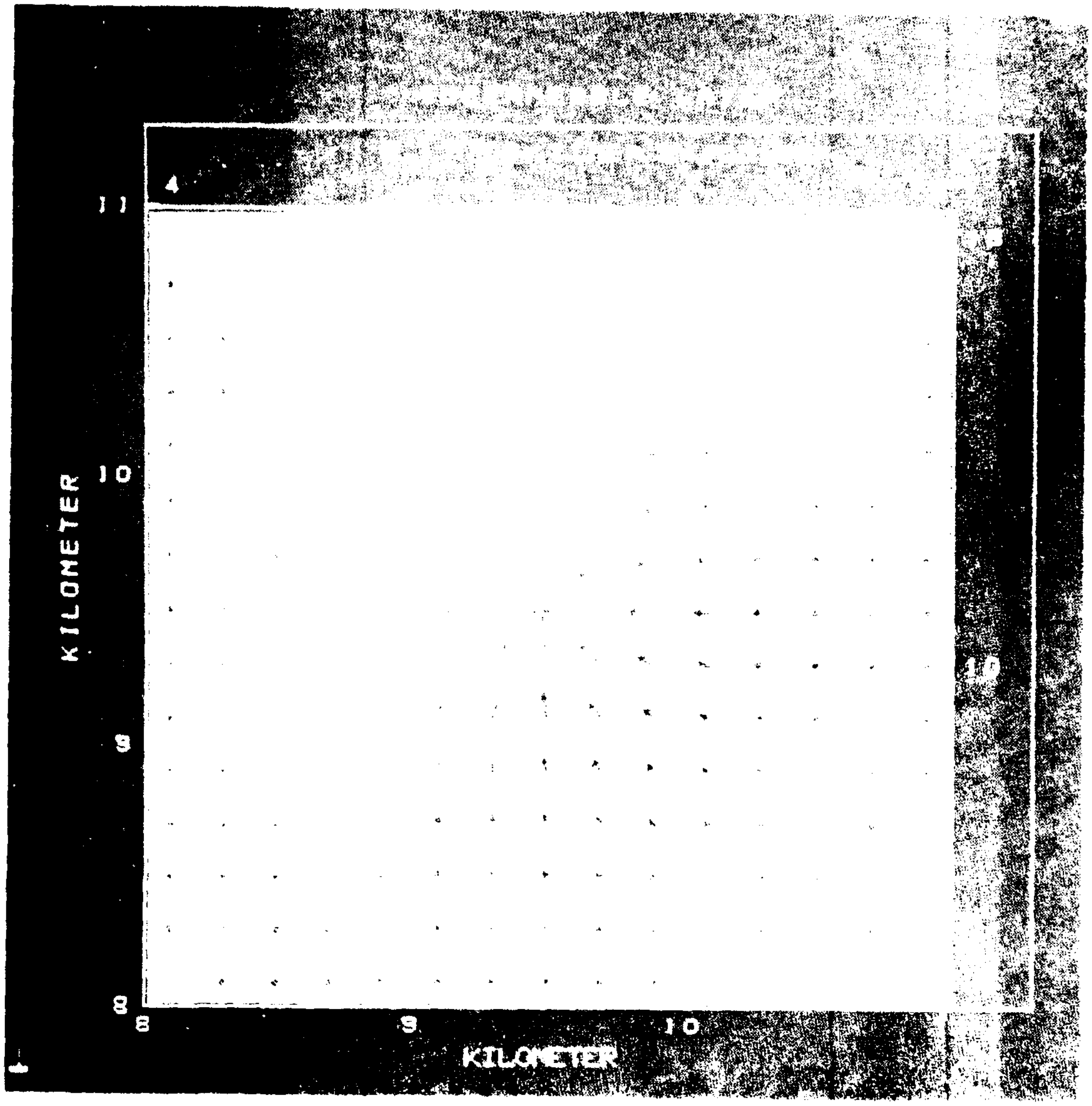


Figure B-18. Computed constant drawdown contours (0.2 m drawdown steps) and average-velocity field with the effect of an almost impervious fault located 600 m for the well after 24 hours pumping medium-structured virgin aquifer at a rate of 120 m^3/h.

Figure B-19. Computed histogram representation of depression cone with the effect of a almost impervious fault located 600 m from the well after 1, 6, and 24 hours pumping medium-structured virgin aquifer at a rate of 120 m^3/h.

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UNCLASSIFIED M-X-ETR-12 AFSC-TR-81-27 NL

ground surface. These characteristics include the large and relatively deep watercourses (intermittent streams) and also the systems of numerous small, shallow, and interlacing channels which behave as though they were highly porous fill.

The porosity, permeability, and other geological (geophysical) characteristics of the valley fill control the near subsurface flow and exhibit large spatial variations over the area of the valley floor. For these reasons the drainage (surface and near subsurface) rates also exhibit large variations related to variations of geological and channelization characteristics over the valley floor.

Drainage rates are also affected by the rate of infiltration of water through the permeable layers of earth. Cracks, faults, and solution holes, in carbonate rocks and through the relatively impermeable clay layers under the valley floor, facilitate water percolation but are limited to specific locations in the valley. Drainage rates are affected by the slope of the ground surface, the slopes of the watercourses, and the spatial variations of the slopes of the less permeable layers in the valley fill. And finally, drainage rates can be affected by construction of roads, berms, and paved areas in the valley floor.

Moderate rain will allow much of the drainage to use the near subsurface channels. Heavy rain, on the other hand, produces flows over the surface of the ground and through the watercourses as well. The surface drainage characteristics determine where surface water accumulates in different regions of the valley.

Water reaches the aquifer through percolation and infiltration from the surface water. The complex interdependence of surface and near subsurface flows plays a critically important role in the recharge of the groundwater reservoirs.

M-X Wells

Pumping of an M-X well field in Nevada/Utah could alter the natural flow of water in the DDA valleys. Heavy pumping could cause the following impacts. The aquifer may be damaged by stresses caused by withdrawal of water. The characteristics of both the groundwater and aquifer may change. Water levels and hydraulic potential of the aquifer may change. Groundwater originally spilling into the streams might come from the streams so that the streams may dry up, especially during low flow periods. Pumping costs may increase for other users.

Pumping of an M-X well field, even in a geotechnically suitable hydrologic subunit, could so alter the geohydrological conditions in different parts of an aquifer as to appreciably modify groundwater movement in the aquifer. Drainage characteristics affect the rate of recharge of a valley's groundwater reservoir. Possible impacts on the groundwater availability through impacts on the drainage characteristics of the associated hydrological subunits can be estimated through numerical simulation.

Computer Code for Simulating Impacts

Identification and estimation of the effects of M-X well fields in a typical hydrological subunit are obtained through numerical simulation. The simulation uses the "second approach" discussed earlier under local impacts. The simulation model, AQUFER, was developed specifically to represent simultaneous surface, subsurface, and aquifer flows. The interdependence of these flows in a typical hydrological subunit is realistically simulated through the use of AQUFER.

This water resources model can properly digest detailed information about:

- The spatial variation of the geological characteristics of valley fill...
- The spatial variations in the channelization conditions including descriptions of large and relatively deep watercourses and of numerous small shallow interlaced channels.
- The spatial variation of the valley floor's slope.
- The slopes of the watercourses and channels in the hydrologic subunit.
- The spatial and temporal variations of flow from the mountains enclosing the valley during rainstorms.
- The spatial and fast-transient temporal variations of the rain on the valley and on the mountains enclosing the valley.
- The spatial variation of infiltration conditions related to the locations of cracks, faults, and solution holes in the carbonate rock and/or relatively impermeable strata under the valley floor.
- The spatial variation of rates of water uptake by plants and/or the rates of evapotranspiration from the ground.
- Pump locations and fast-transient or uniform pumping conditions of one or more wells at different locations in the valley.

This water resources model appropriately represents:

- The temporally and spatially varying surface and subsurface water flows including rapid surface flow in the watercourses of the hydrologic subunit.
- The interactions of subsurface and groundwater flows reflected in springs and small streams fed by groundwater.

The computer code for the model provides computer graphics capabilities for presenting the calculated drainage flow velocity and the surface and/or subsurface water depth conditions in the valley.

Numerical simulation using the AQUFER code can project for a valley the time dependence of water flow paths and fluxes, variation of water levels with time and location, and change in aquifer behavior with changes in valley floor topography and permeability. It can project the temporal and spatial topography and permeability. It can project the temporal and spatial variation of surface and subsurface runoff flows associated with each particular engineering design alternative for M-X deployment in the valley. It can project the long-term behavior of the aquifers with respect to water withdrawal schedules, the availability of water to the vegetation and animals at specific locations for each engineering design alternative, the water table elevation for either transient or uniform well pumping, the optimal spacing of wells, and the aquifer's transmissibility and storage coefficient.

The hydrological subunit modeled has natural drainage representative of that of the DDA valleys. Drainage feeding its aquifer recharge system originates from precipitation received on the surrounding mountains. All water collected from precipitation over the hydrologic subunit drains toward the playa located in the center of the valley where the ground surface elevation is lowest. The playa collects all surface waters not able to percolate into the earth at higher elevations where most evaporates. Cracks, faults, and solution holes in clay strata and carbonate rocks and allow percolation of water through these relatively impermeable layers of the valley fill are located near the mountains enclosing the valley.

The depth to the groundwater in the valley fill limits evapotranspiration losses of groundwater. Plants growing in the watercourses and streams life water from the soil, however, and lose it to the air through transpiration.

In the hydrologic subunit modeled, groundwater in the deep aquifer flows only into a second hydrological subunit to the south-southwest. The valley receives water from the aquifer in the hydrologic subunit to the north.

Simulation of surface and subsurface drainage requires geomorphological and climatological information or assumptions about:

1) Distribution of slope of the valley floor surface (available from USGS topographical maps)

2) Watercourse and channel size and location and dimensions of ephemeral streams (available from USGS topographic maps)

3) Depth of the first impermeable stratum in the valley floor

4) The maximum depth of the porous ground for the surface and near subsurface flows (assumed to be more than 30 meters)

5) Depth to the stationary water level (assumed to be 100 meters below surface of ground)

6) Areas of watershed within the hydrological subunit (available from USGS topographical maps)

7) Soil and valley-fill properties (composite directional values can be estimated from data and assumptions about valley-fill stratigraphy). The estimate ranges are:

   The north-south area porosity, 0.12 to 0.40
   The east-west area prosity, 0.20 to 0.40
   The area porosity along the bedrock, 0.40 to 0.20

The north-south and east-west conduit characteristic length (including channelization effects), 0.5 to 1.0 meter

The north-south and east-west friction coefficient (for the Blasius power-law form of the friction effect), 0.02

The AQUFER computer code was applied in simulating the flow conditions in Dry Lake Valley hydrologic subunit after a typical one-hour rainstorm in which the rain fell at the rate of 2 cm/h. The simulation was done for the undisturbed valley and for a set of conditions attempting to represent the valley with the M-X system deployed in it, the disturbed valley.

Figures B-20 through B-25 show the undisturbed and disturbed average-velocity distribution representing both surface and subsurface flows above the water table at 1, 6, and 12 hours after the end of the rainstorm. The figures show fully developed flow patterns for all three times for both the undisturbed and the disturbed valley. Comparison of the figures shows that in the disturbed valley the water is delayed at the higher elevations in the valley floor reflecting the effects of roads, berms and paved areas. In the northern part of the valley, movement of some water is separated from the main flow toward the playa.

Figures B-26 through B-37 show both surface and subsurface water accumulation at various times after the end of a one-hour rainstorm over the hydrologic subunit for the undisturbed and the disturbed valleys. In the north part of the hydrologic subunit, in the disturbed valley, more water appears to accumulate than accumulates in the undisturbed valley. The water is much deeper at the higher elevations in the disturbed valley. Because of the natural large watercourses with wide deep channels, the water accumulated in the playa 6 hours after the end of the rainstorm is only 3 to 8 cm less deep in the disturbed valley than it is in the undisturbed valley. Retention of water at the higher elevations could mean that more water will evaporate in the disturbed valley and the rechage of the aquifer will be less.

While the results of the simulation of the flows of surface and subsurface water in the Dry Lake Valley hydrologic subunit suggest that disturbing the valley by M-X deployment could impede aquifer recharge, the analysis can be carried farther. The simulation has not taken into account the rate of evaporation of water fromthe ground and the rate of transpiration of plants. It has not taken into account the effects of winds on the evaporation rate from open ponds. Precise assessment of the potential impacts of M-X construction on water resources would require extensive field work to determine the geological and climatological parameters more precisely.

The simulation of the water flows and accumulations in the undisturbed valley was continued out to 265 days after the end of the rainstorm but nine wells started pumping 240 hours after the end of the rainstorm. The water from the rain storm percolated into subsurface and produced saturated soils under the places where water has accumulated on the surface. Figures B-38 through B-41 show the development of the cones of depression in the initially virgin aquifer. In the course of pumping, the cross section of the cone of depression of the well nearest the center of the playa changed from an elliptical to a circular one indicating the anisotropy of the porosity and permeability of the strata under the playa. The wells at the south end of the valley influence each others' cones of depression so much that they have in effect just one common cone. The four wells in the northern part of the valley are more separated and fail to influence each others' drawdown even after 255 days of pumping.

The computed recharge when nine wells are pumped indicates the possibility of no significant groundwater impact for the particular hydrologic subunit. The four wells located more than seven kilometers from each other appear not to influence each other's drawdown; however, the simulation shows five wells located within two kilometers of each other at the very southernmost part of the subunit to influence each other's drawdown. Drawdowns computed for the first four wells were 202 cm, 165 cm, 150 cm, and 135 cm respectively for the northernmost well through the southernmost. the corresponding radii of the cones of depression computed for these four wells ranged from four to five kilometers. The computed maximum drawdown among the five closely spaced wells was 258 cm while the computed minimum drawdown was 218 cm. The simulation suggests closely space wells influence one another's drawdown out to as much as seven kilometers.

The simulation shows very little interaquifer transfer of water. Flow within an aquifer changes to accomodate the demands of well pumps but the change damps out before the bottom of the first aquifer is reached. The net transfer of water out of the hydrologic subunit by natural causes was close to the input rate.

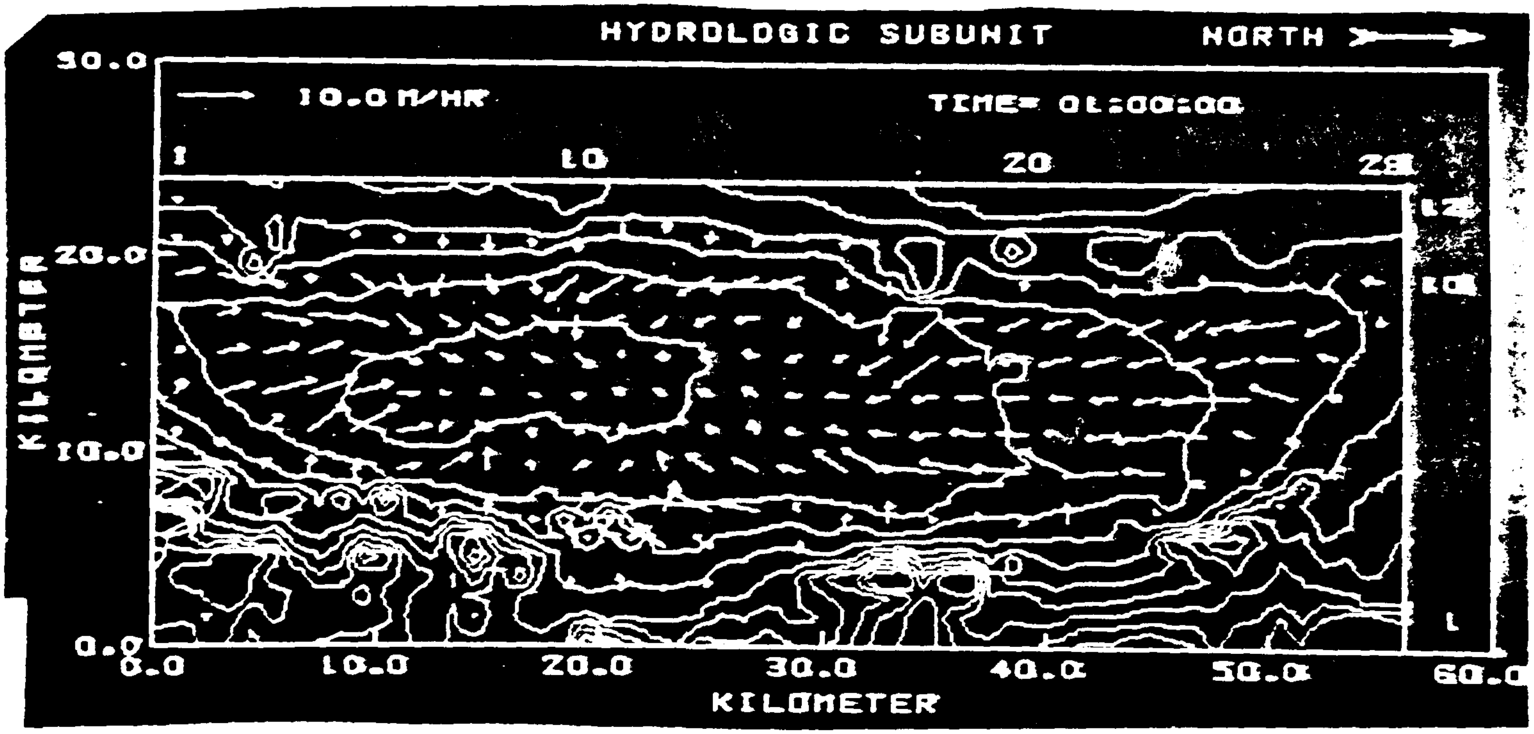

Figure B-20. Computed average water velocity (blue arrows) representing both surface and subsurface flows with topographic contours at 1 hour after end of one-hour rainstorm over undisturbed Dry Lake Valley hydrologic subunit.

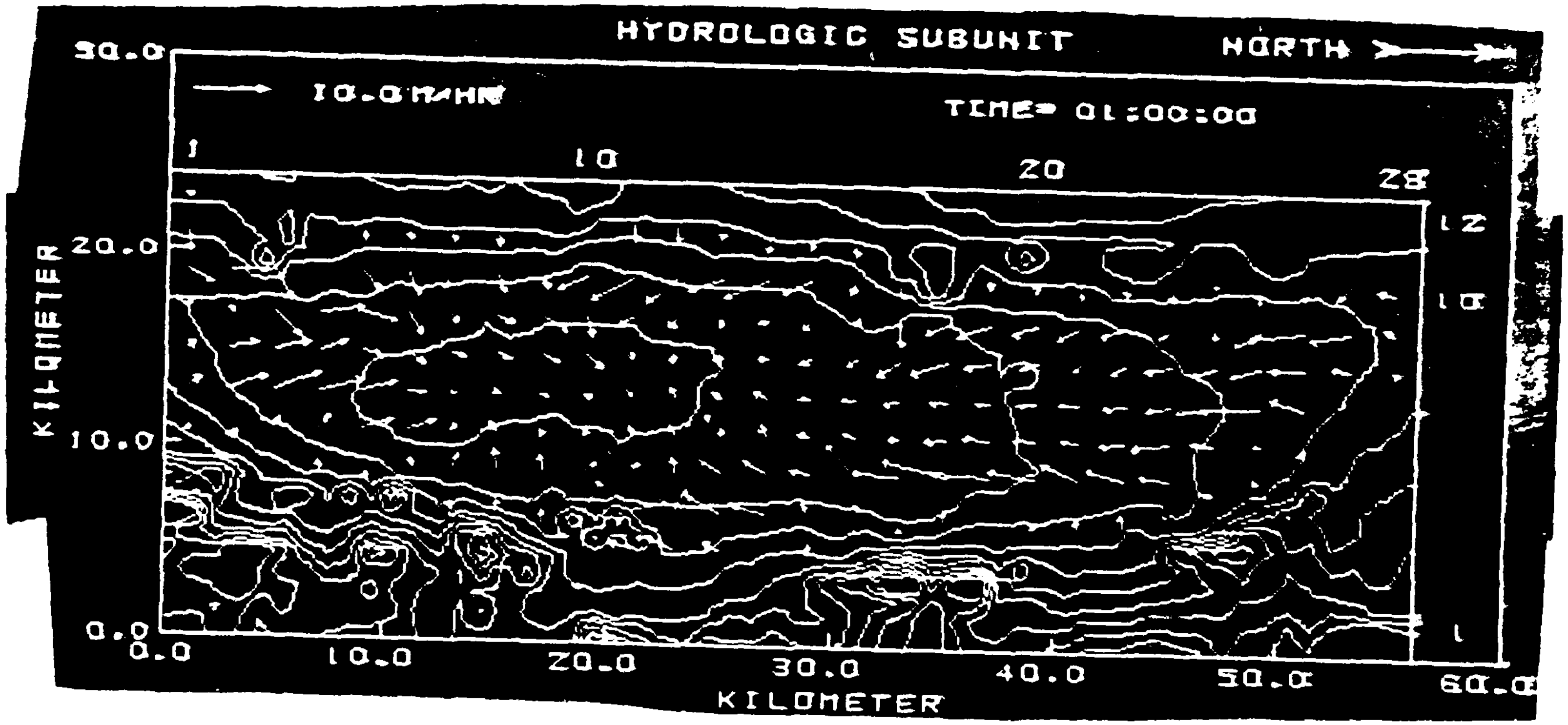

Figure B-21. Computed average water velocity (blue arrows) representing both surface and subsurface flows with topographic contours at 1 hour after end of one-hour rainstorm over disturbed Dry Lake Valley hydrologic subunit.

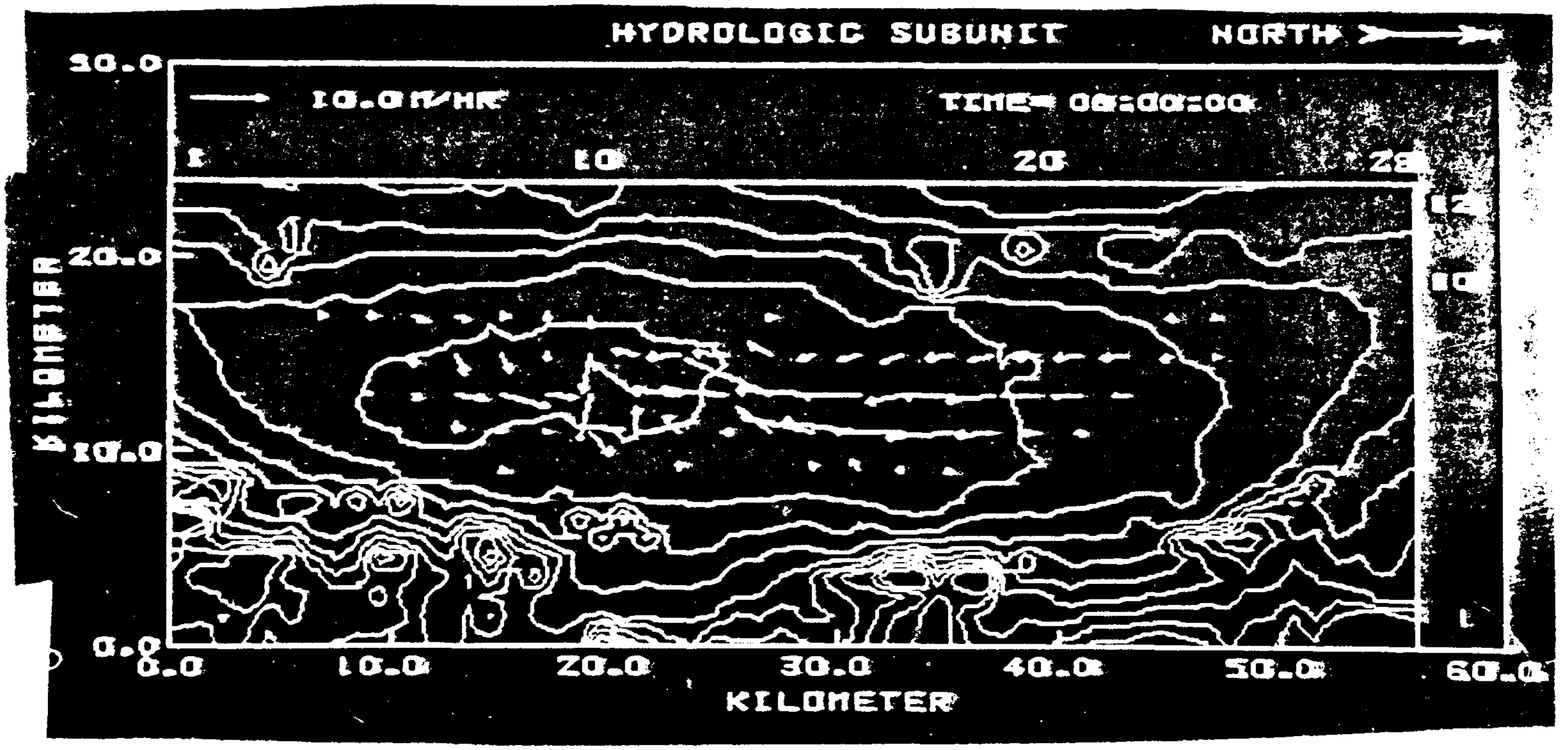

Figure B-22. Computed average water velocity (blue arrows) representing both surface and subsurface flows with topographic contours at 6 hours after end of one-hour rainstorm over undisturbed Dry Lake Valley hydrologic subunit.

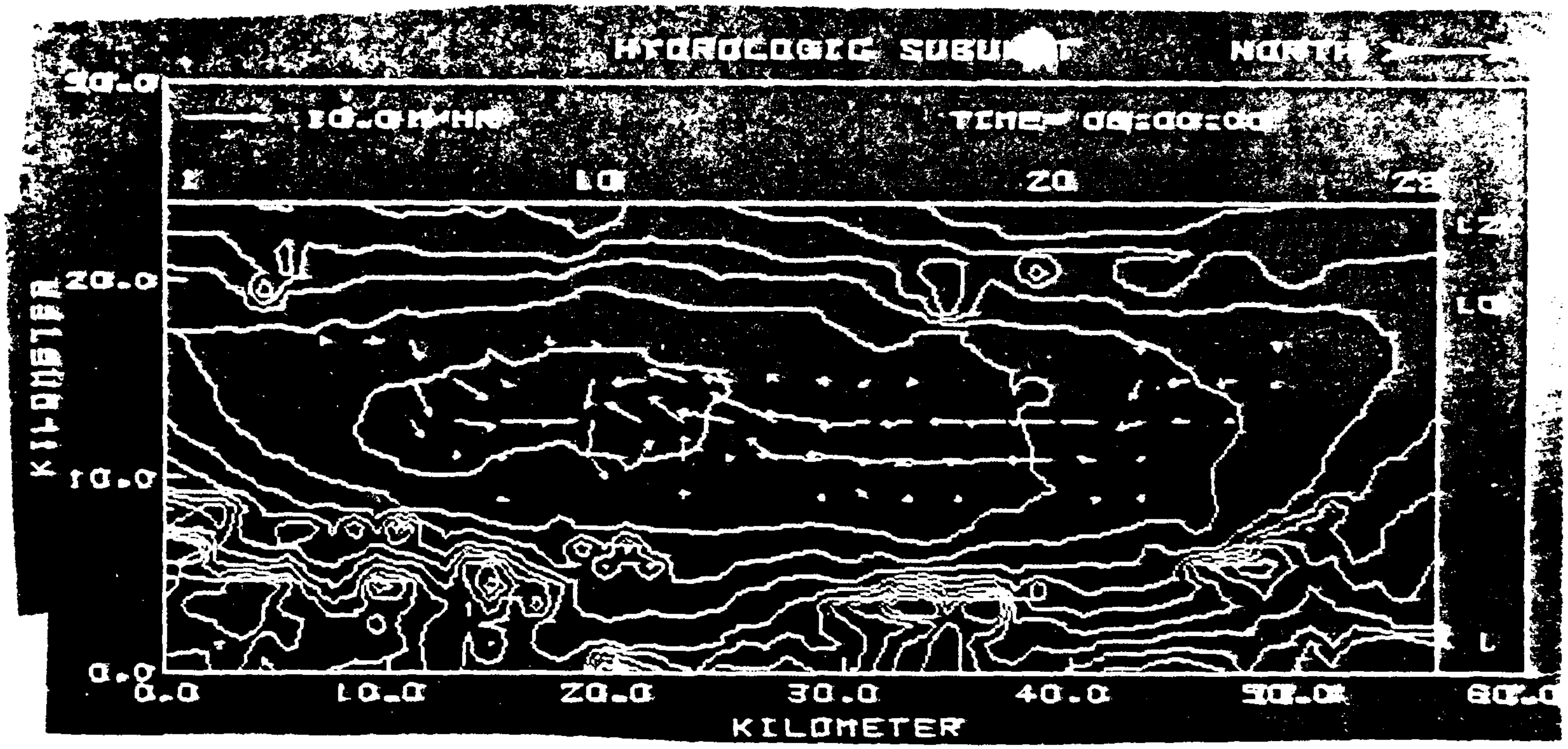

Figure B-23. Computed average water velocity (blue arrows) representing both surface and subsurface flows with topographic contours at 6 hours after end of one-hour rainstorm over disturbed Dry Lake Valley hydrologic subunit.

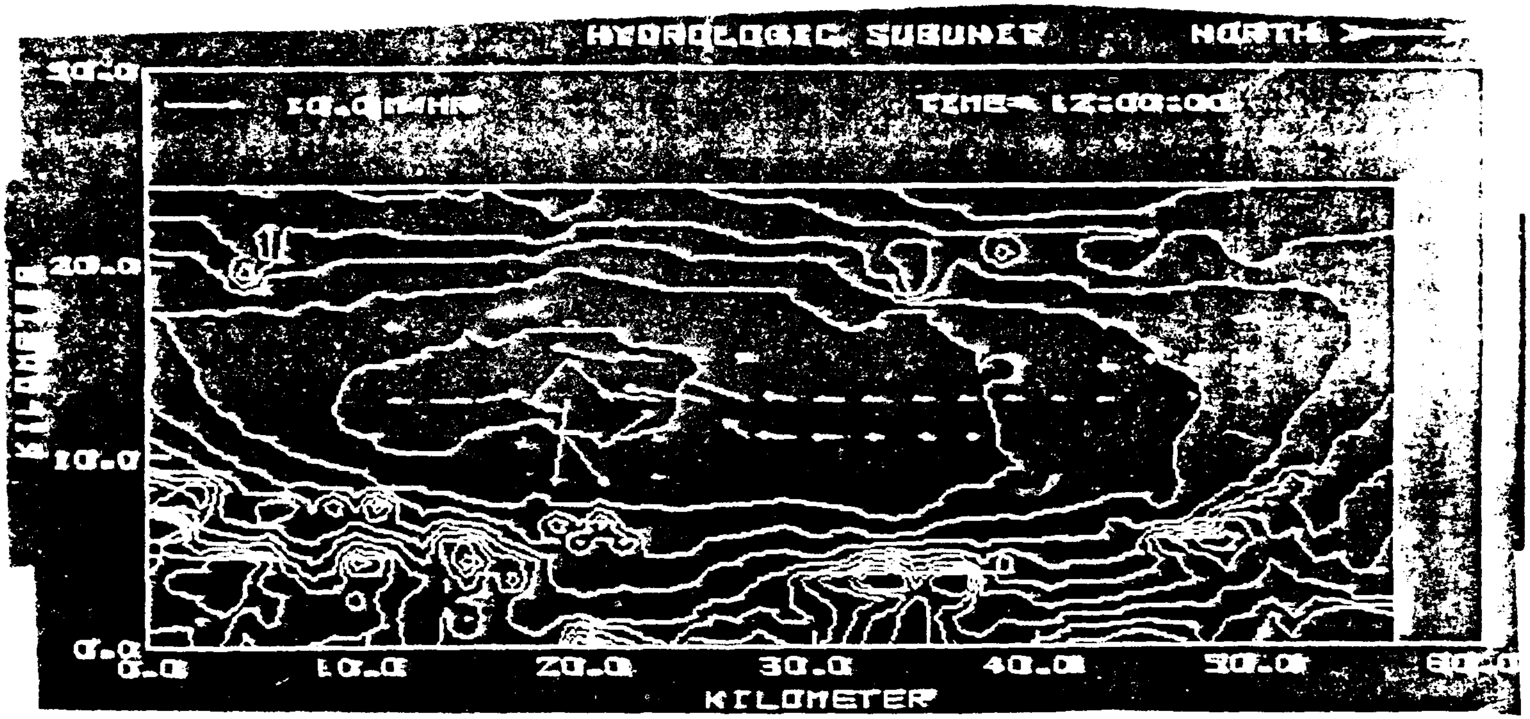

Figure B-24. Computed average water velocity (blue arrows) representing both surface and subsurface flows with topographic contours at 12 hours after end of one-hour rainstorm over undisturbed Dry Lake Valley hydrologic subunit.

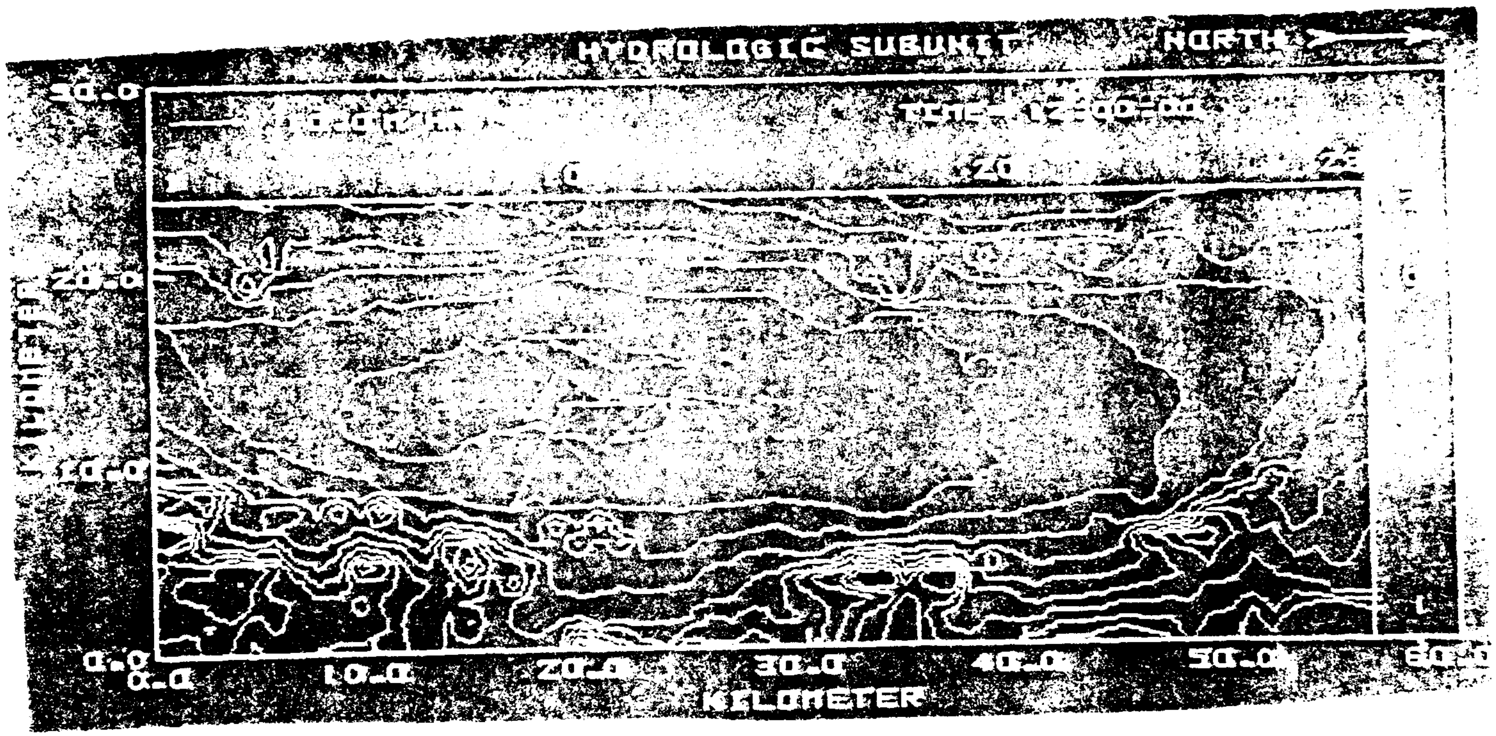

Figure B-25. Computed average water velocity (blue arrows) representing both surface and subsurface flows with topographic contours at 12 hours after end of one-hour rainstorm over disturbed Dry Lake Valley hydrologic subunit.

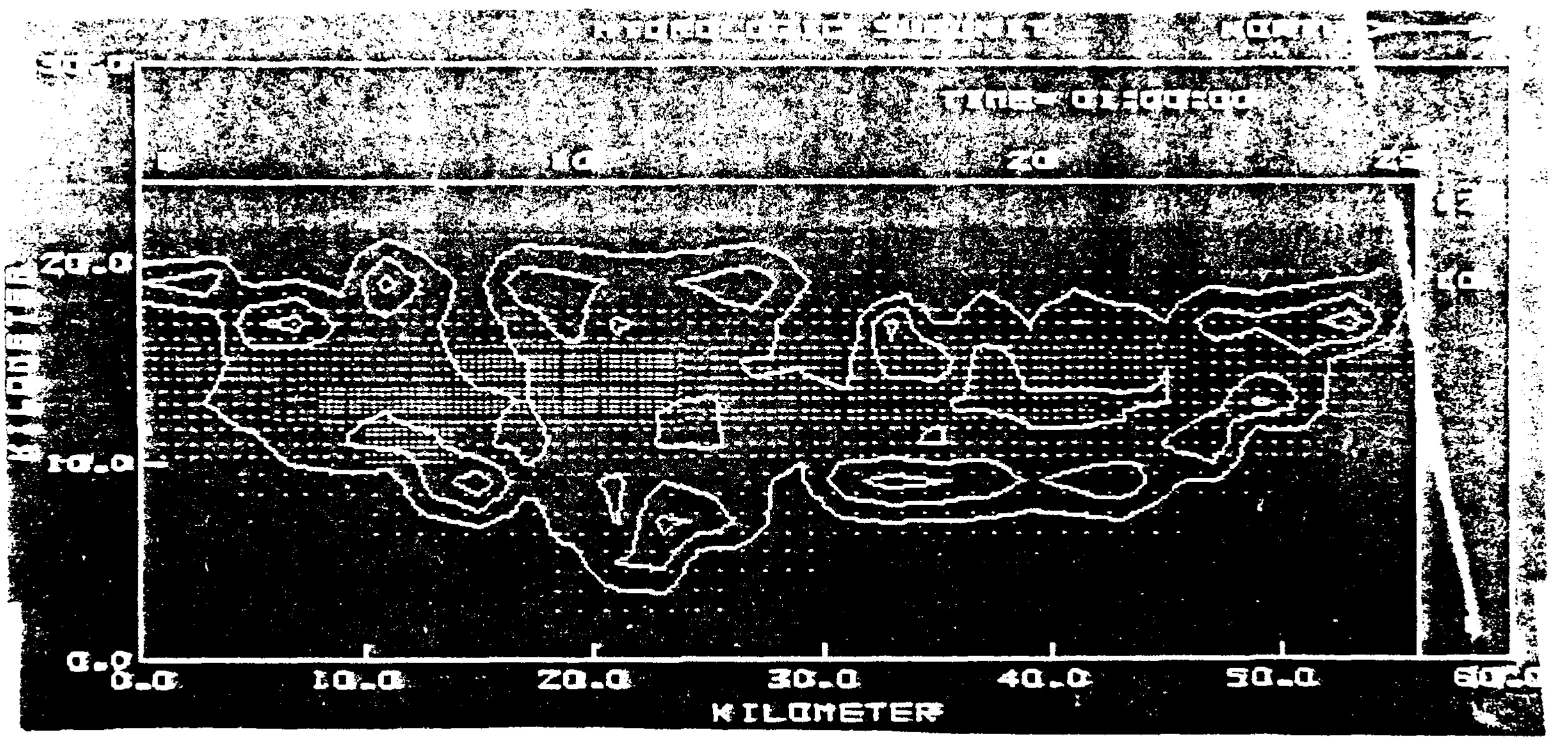

Figure B-26. Computed constant-depth contours representing both surface and subsurface water accumulations with porosity (permeability) distribution (dot pattern) at 1 hour after end of one-hour rainstorm over undisturbed Dry Lake Valley hydrologic subunit.

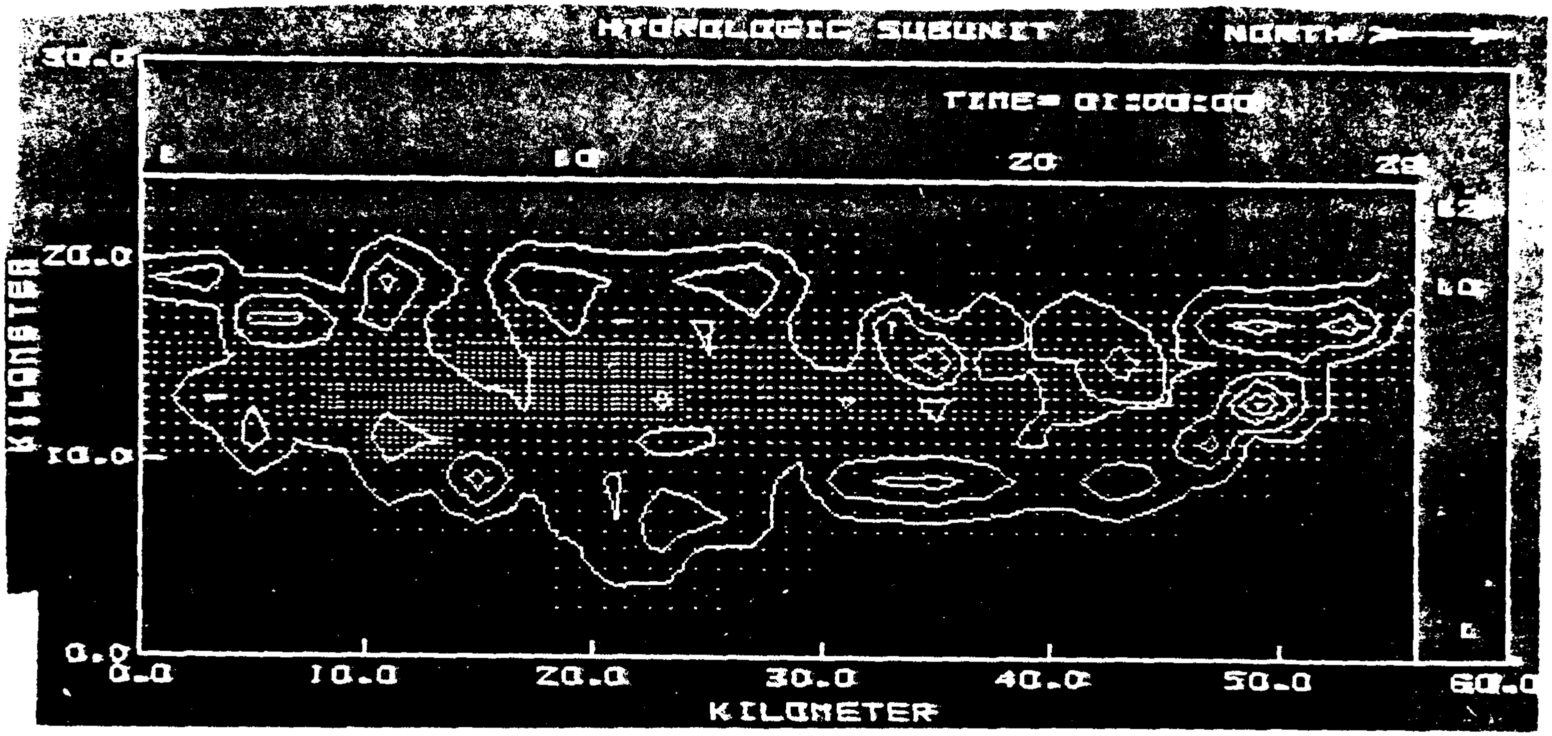

Figure B-27. Computed constant-depth contours representing both surface and subsurface water accumulations with porosity (permeability) distribution (dot pattern) at 1 hour after end of one-hour rainstorm over disturbed Dry Lake Valley hydrologic subunit.

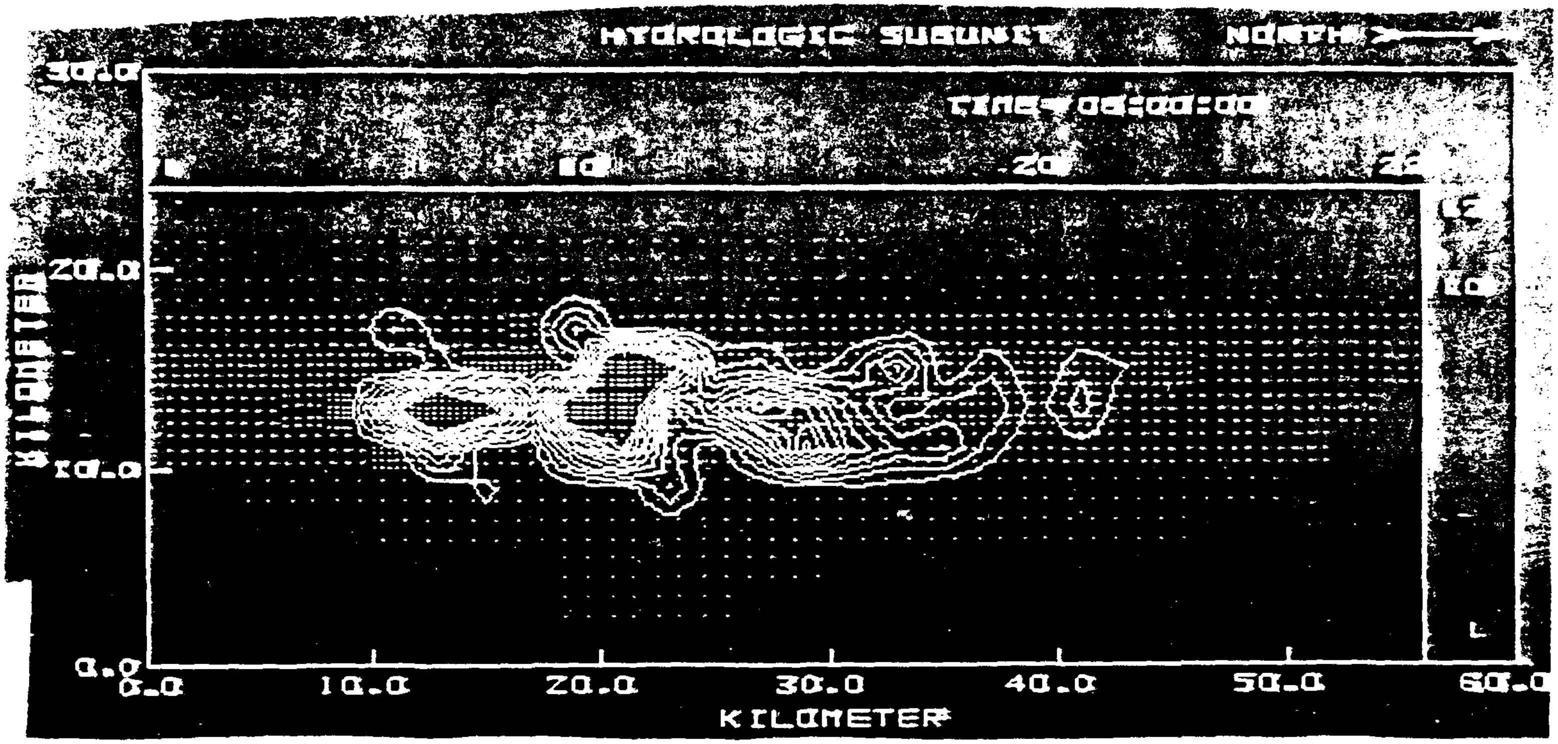

Figure B-28. Computed constant-depth contours representing both surface and subsurface water accumulations with porosity (permeability) distribution (dot pattern) at 6 hours after end of one-hour rainstorm over undisturbed Dry Lake Valley hydrologic subunit.

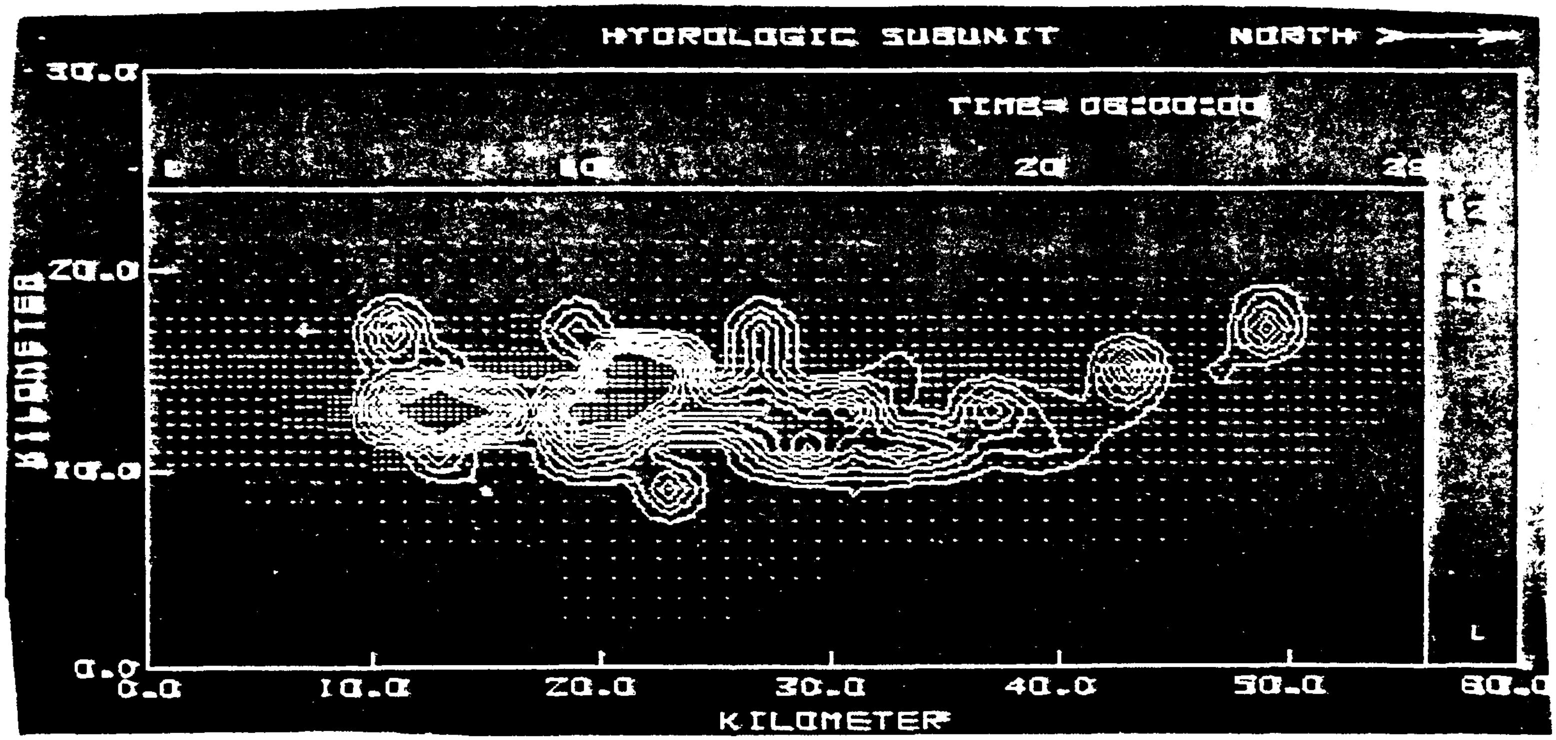

Figure B-29. Computed constant-depth contours representing both surface and subsurface water accumulations with porosity (permeability) distribution (dot pattern) at 6 hours after end of one-hour rainstorm over disturbed Dry Lake Valley hydrologic subunit.

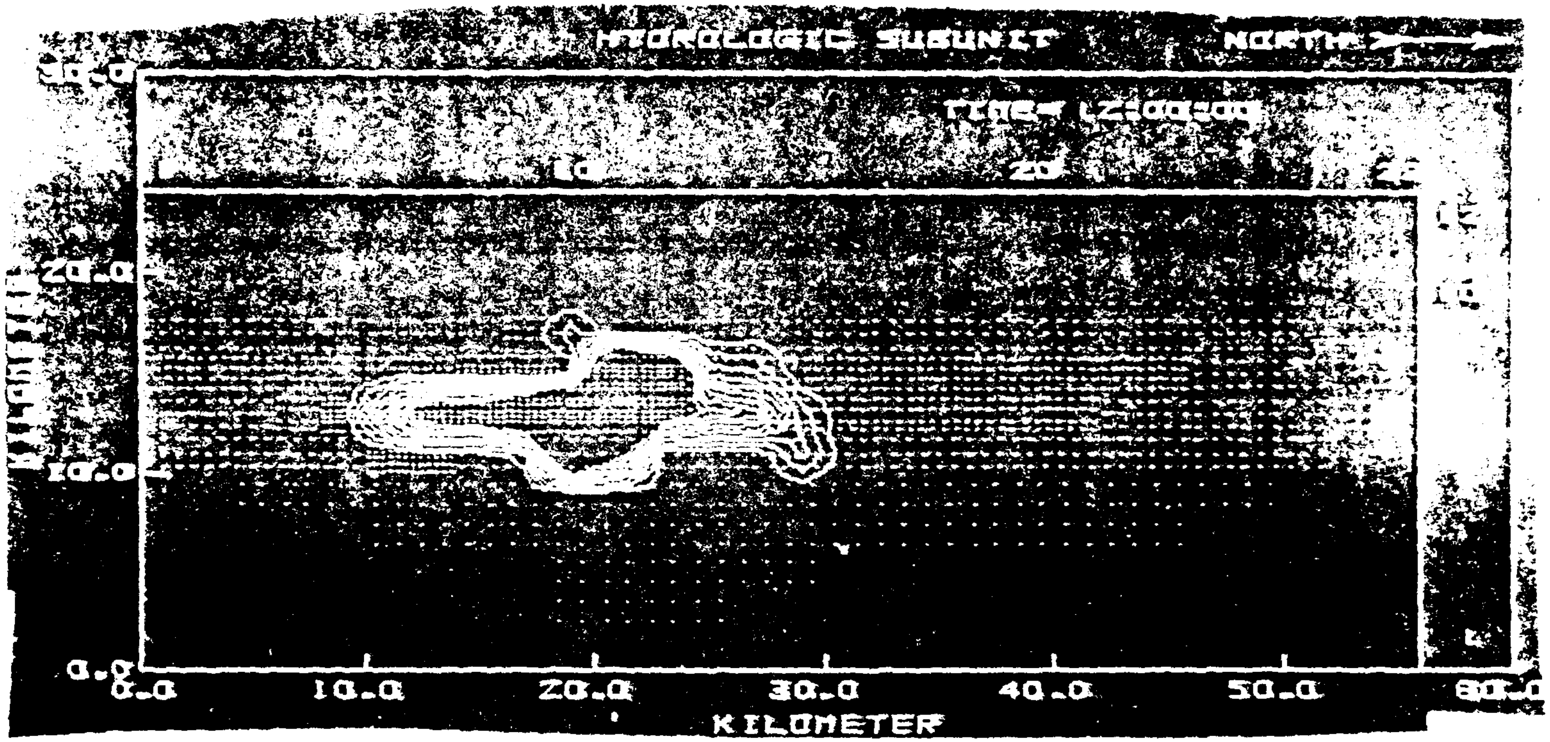

Figure B-30. Computed constant-depth contours representing both surface and subsurface water accumulations with porosity (permeability) distribution (dot pattern) at 12 hours after end of one-hour rainstorm over undisturbed Dry Lake Valley hydrologic subunit.

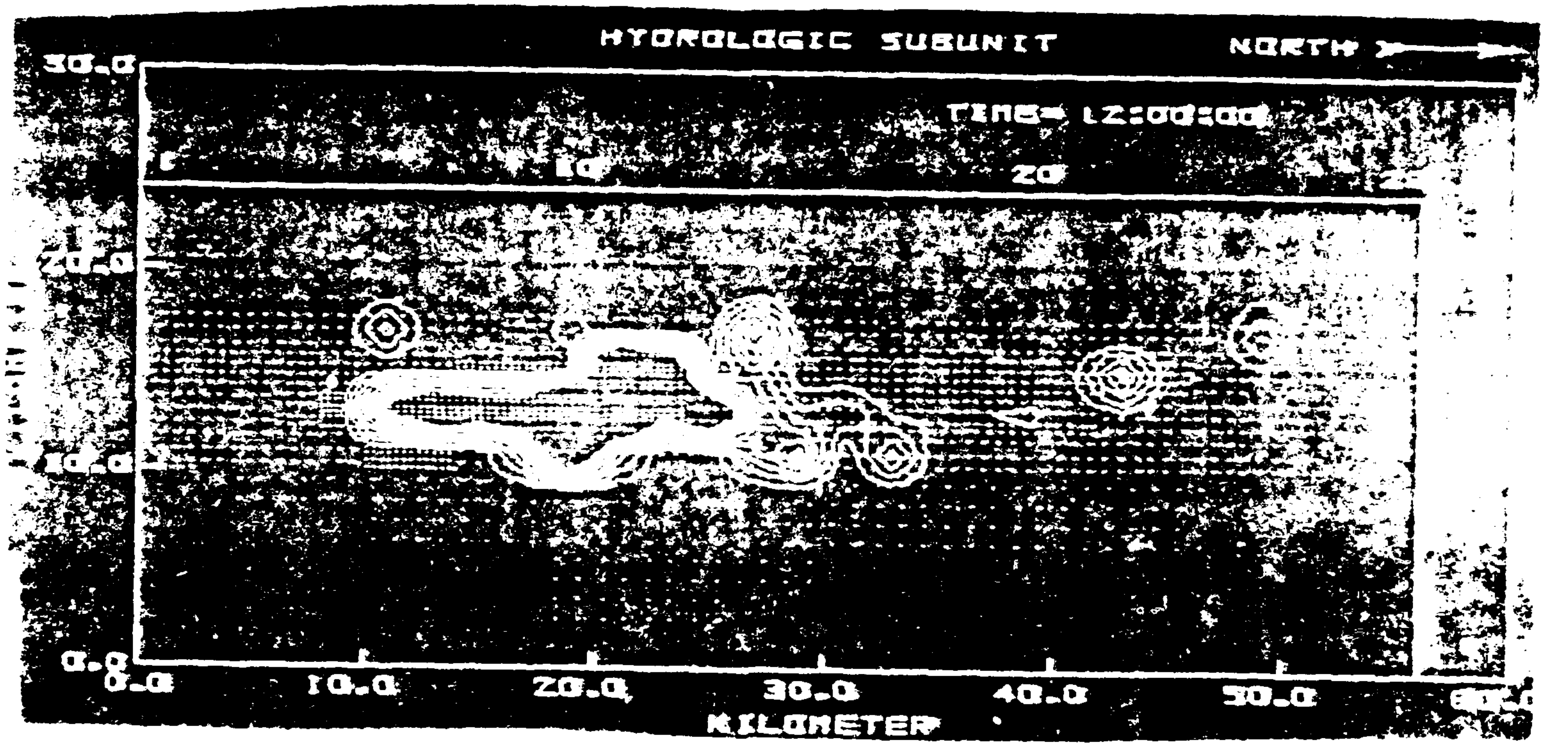

Figure B-31. Computed constant-depth contours representing both surface and subsurface water accumulations with porosity (permeability) distribution (dot pattern) at 12 hours after end of one-hour rainstorm over disturbed Dry Lake Valley hydrologic subunit.

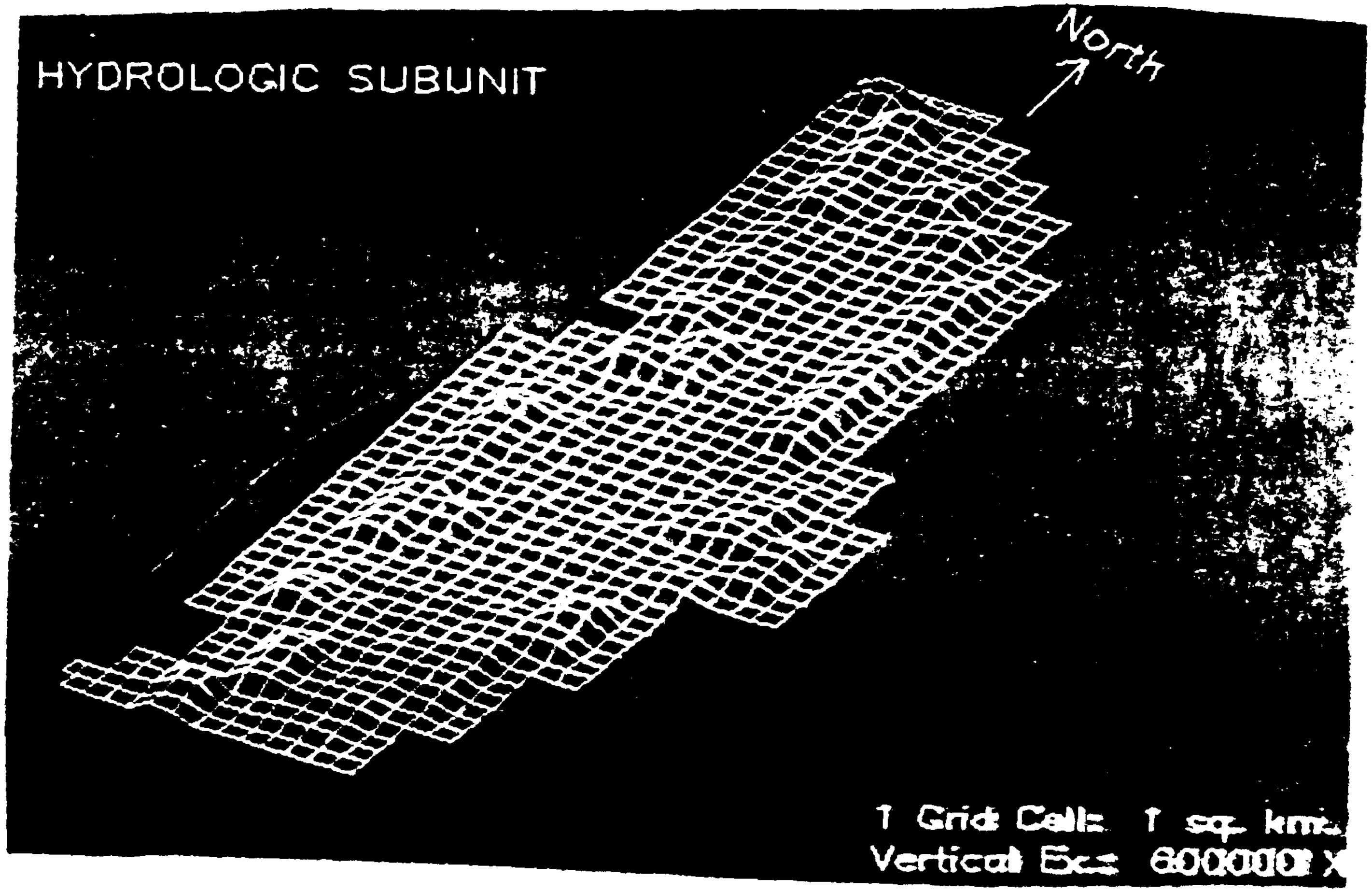

Figure B-32. Computed distribution of amount of water accumulated both on the surface and in the strata above the aquifer 1 hour after end of one-hour rainstorm over undisturbed Dry Lake Valley hydrologic subunit.

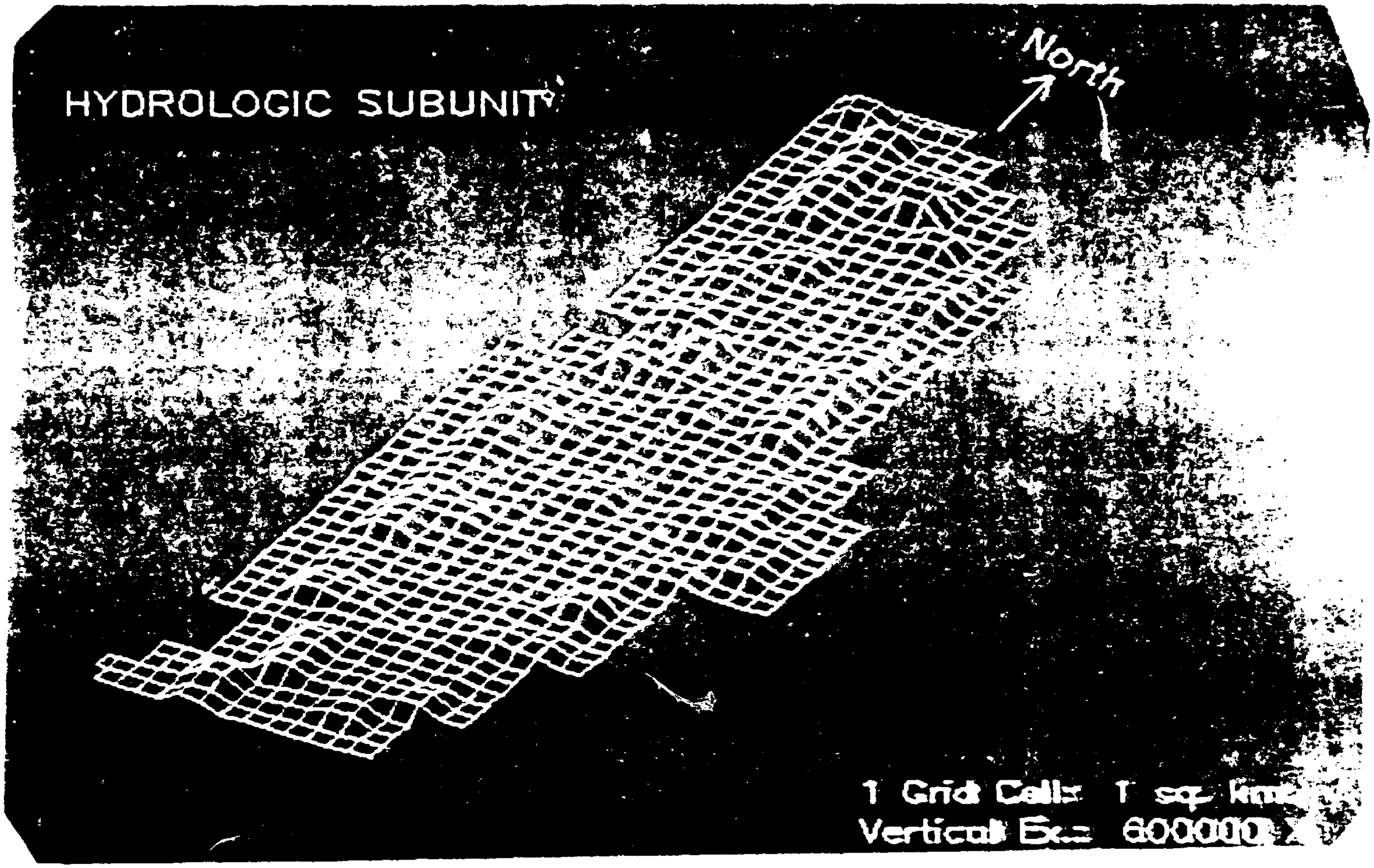

Figure B-33. Computed distribution of amount of water accumulated both on the surface and in the strata above the aquifer 1 hour after end of one-hour rainstorm over disturbed Dry Lake Valley hydrologic subunit.

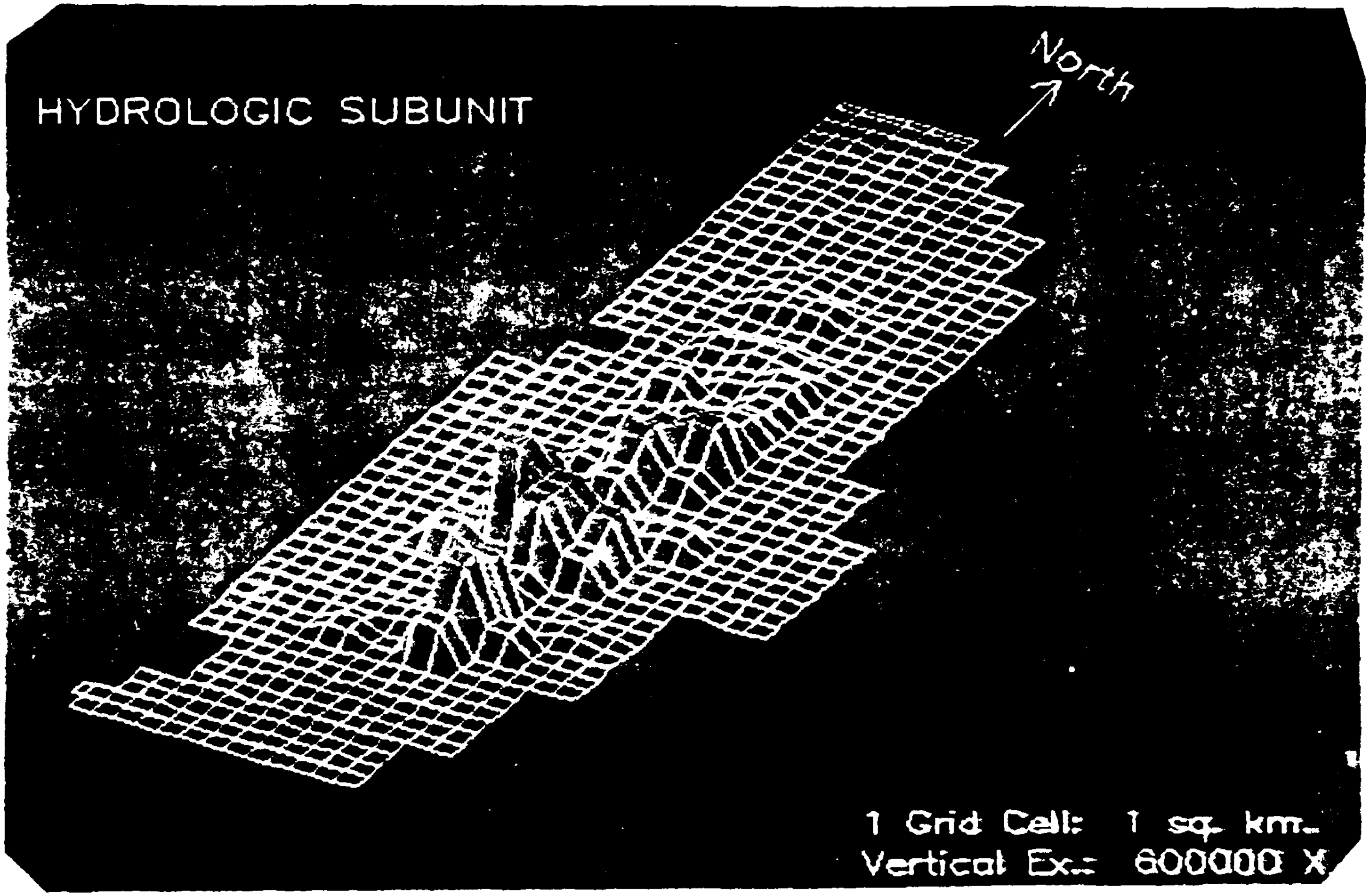

Figure B-34. Computed distribution of amount of water accumulated both on the surface and in the strata above the aquifer 6 hours after end of one-hour rainstorm over undisturbed Dry Lake Valley hydrologic subunit.

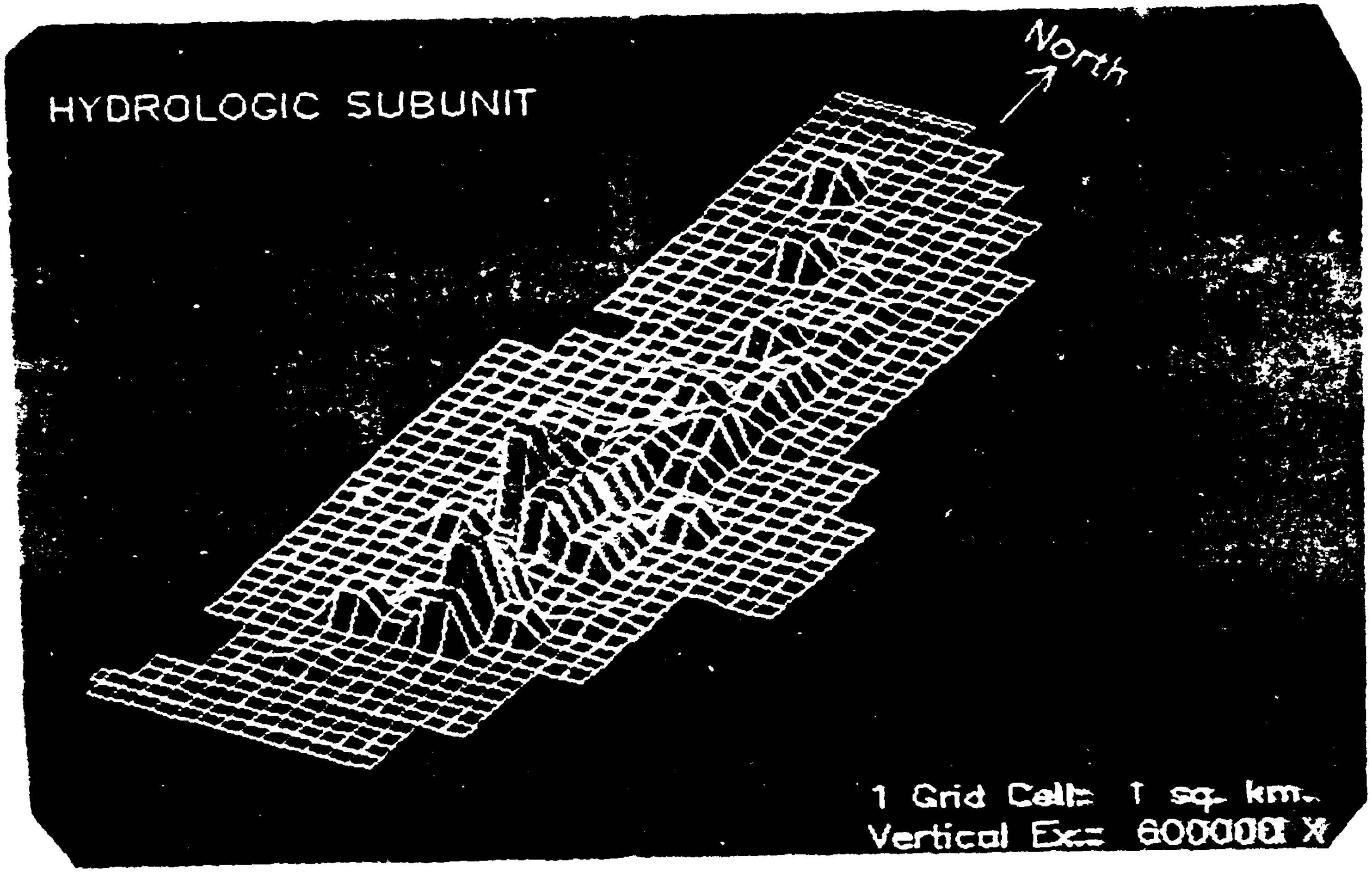

Figure B-35. Computed distribution of amount of water accumulated both on the surface and in the strata above the aquifer 6 hours after end of one-hour rainstorm over disturbed Dry Lake Valley hydrologic subunit.

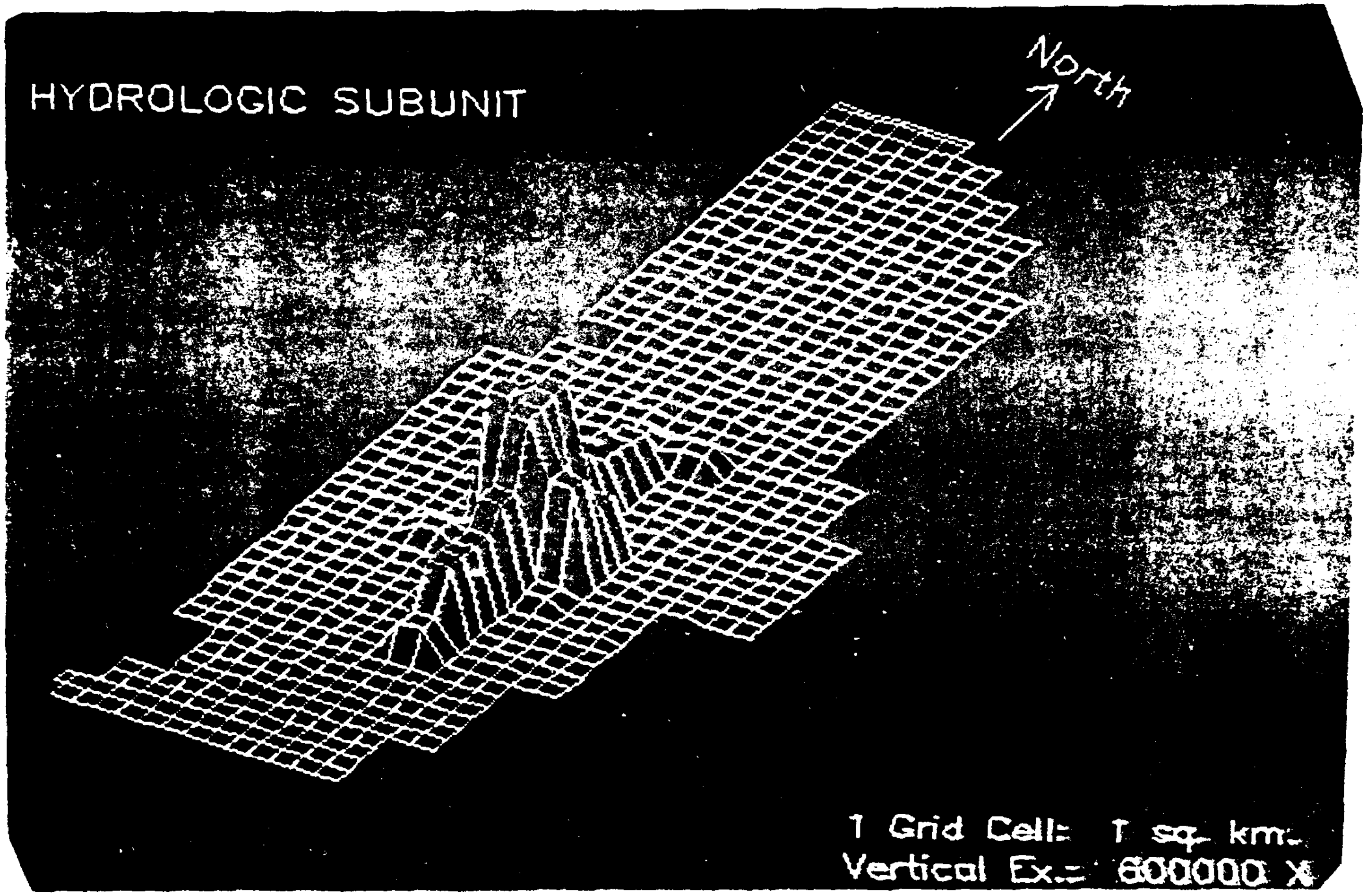

Figure B-36. Computed distribution of amount of water accumulated both on the surface and in the strata above the aquifer 12 hours after end of one-hour rainstorm over undisturbed Dry Lake Valley hydrologic subunit.

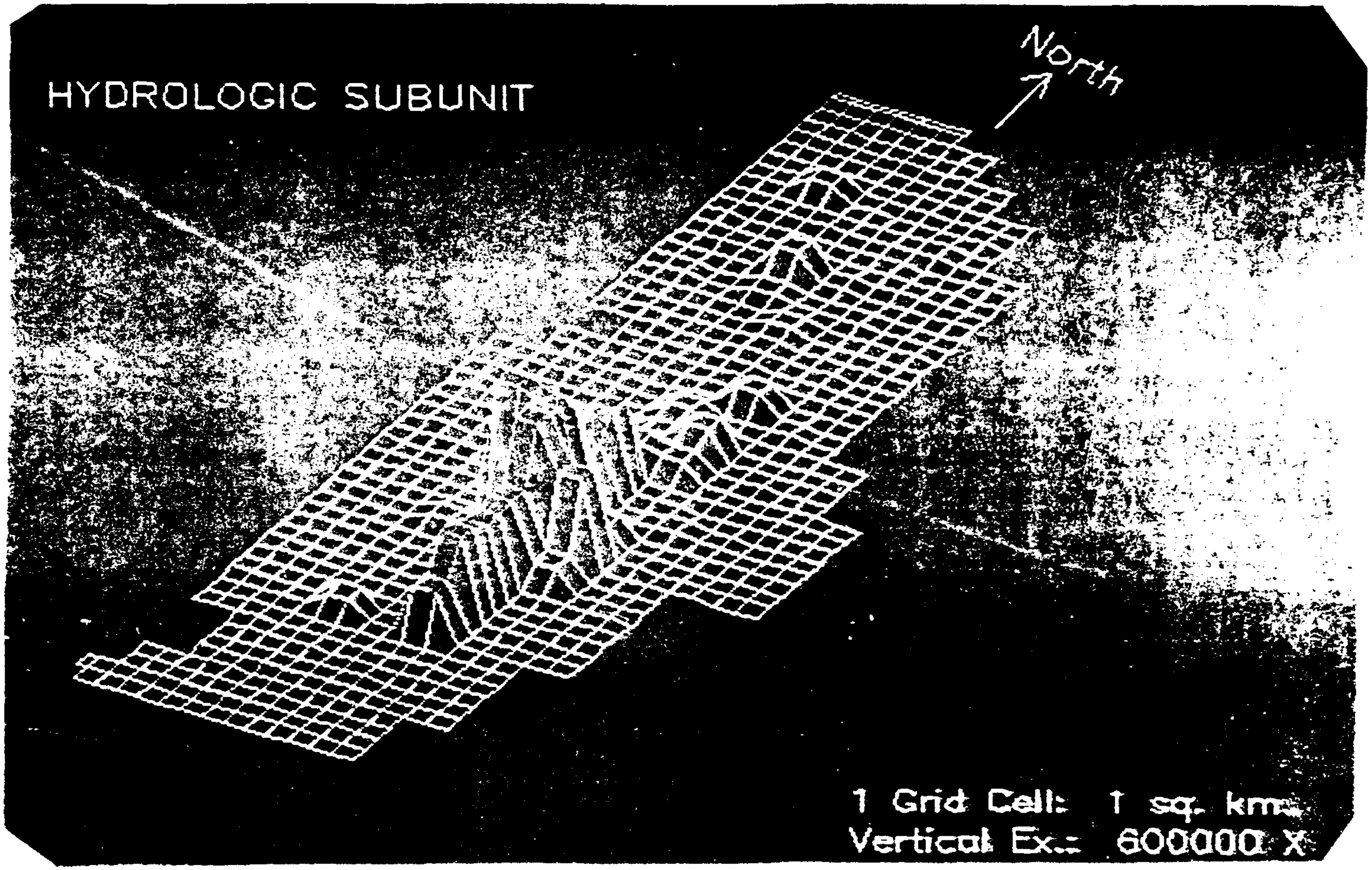

Figure B-37. Computed distribution of amount of water accumulated both on the surface and in the strata above the aquifer 12 hours after end of one-hour rainstorm over disturbed Dry Lake Valley hydrologic subunit.

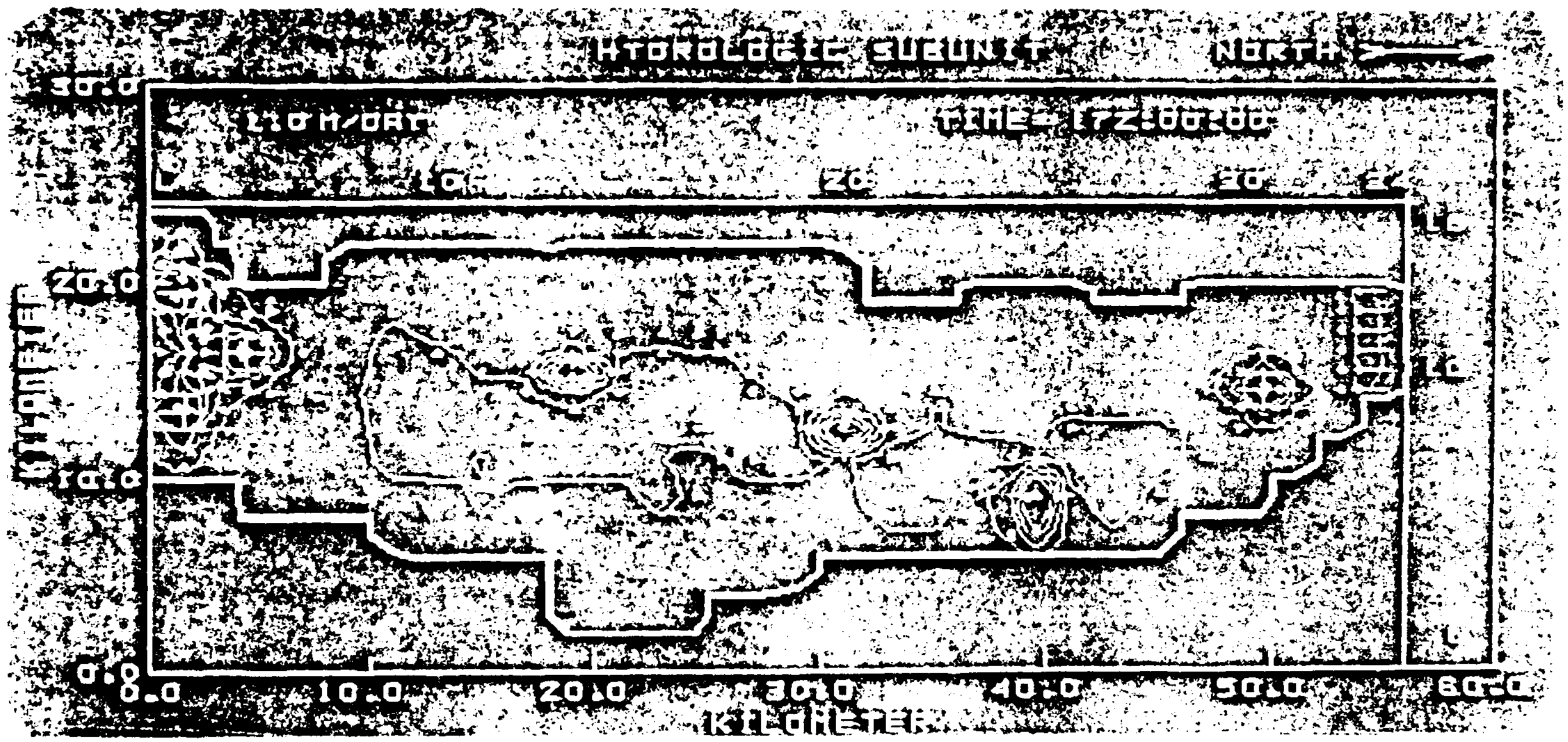

Figure B-38. Computed average water velocity (blue arrows) representing water flows in the aquifer and the drawdown contours 17 days after end of one-hour rainstorm over Dry Lake Valley hydrologic subunit undisturbed except for nine wells which have been pumping for 7 days.

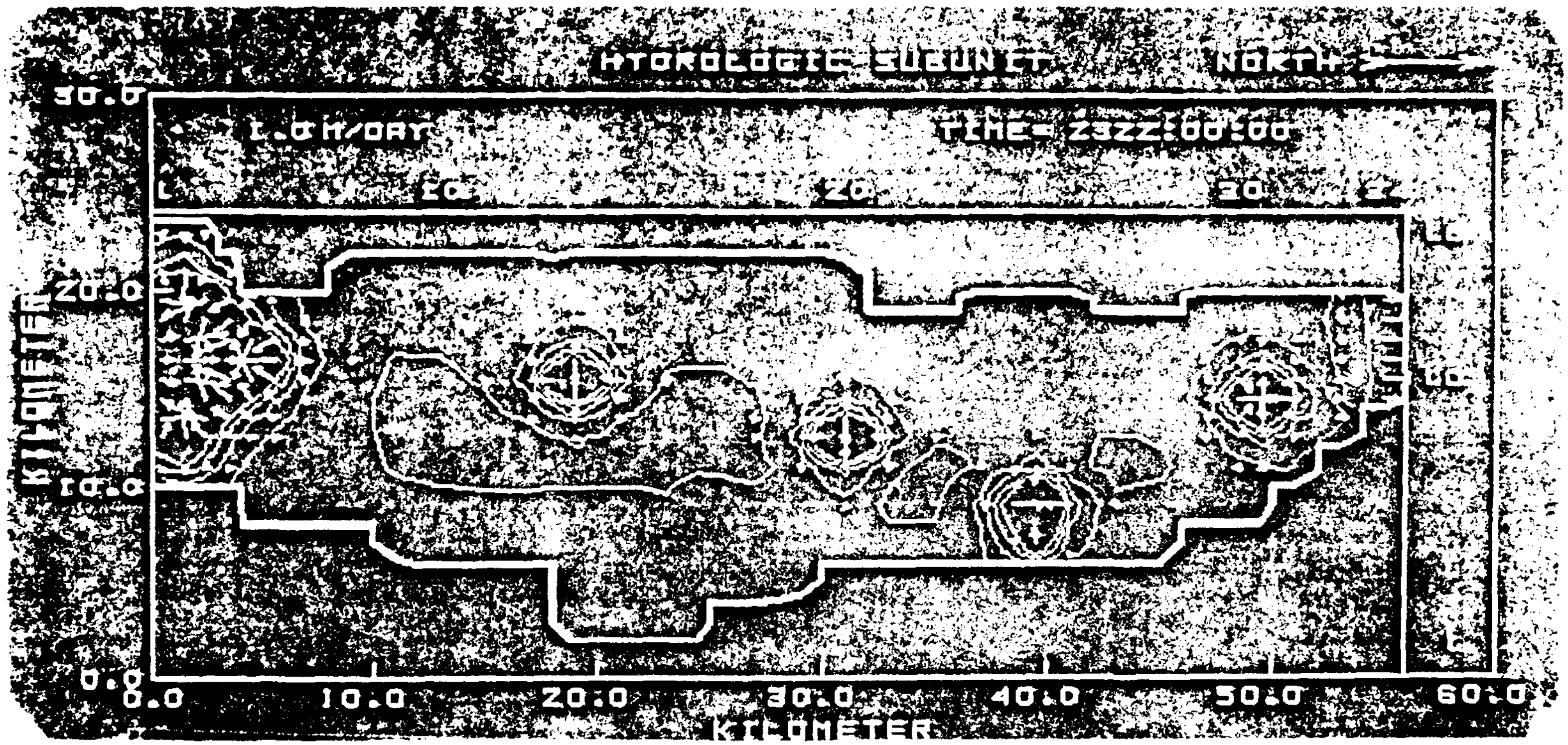

Figure B-39. Computed average water velocity (blue arrows) representing water flows in the aquifer and the drawdown contours 106 days after end of one-hour rainstorm over Dry Lake Valley hydrologic subunit undisturbed except for nine wells which have been pumping for 97 days.

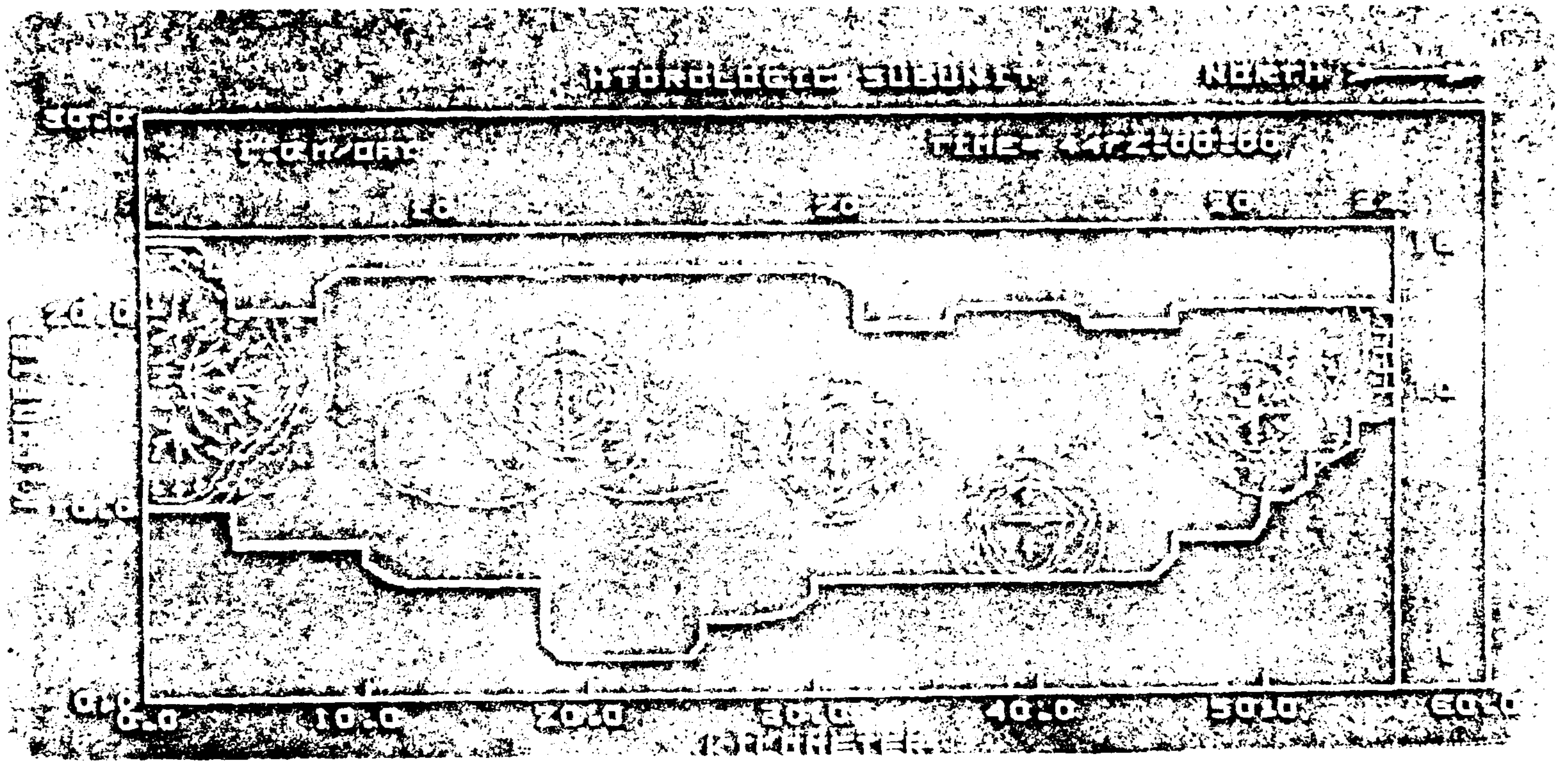

Figure B-40. Computed average water velocity (blue arrows) representing water flows in the aquifer and the drawdown contours at 196 days after end of one-hour rainstorm over Dry Lake Valley hydrologic subunit undisturbed except for nine wells which have been pumping for 106 days.

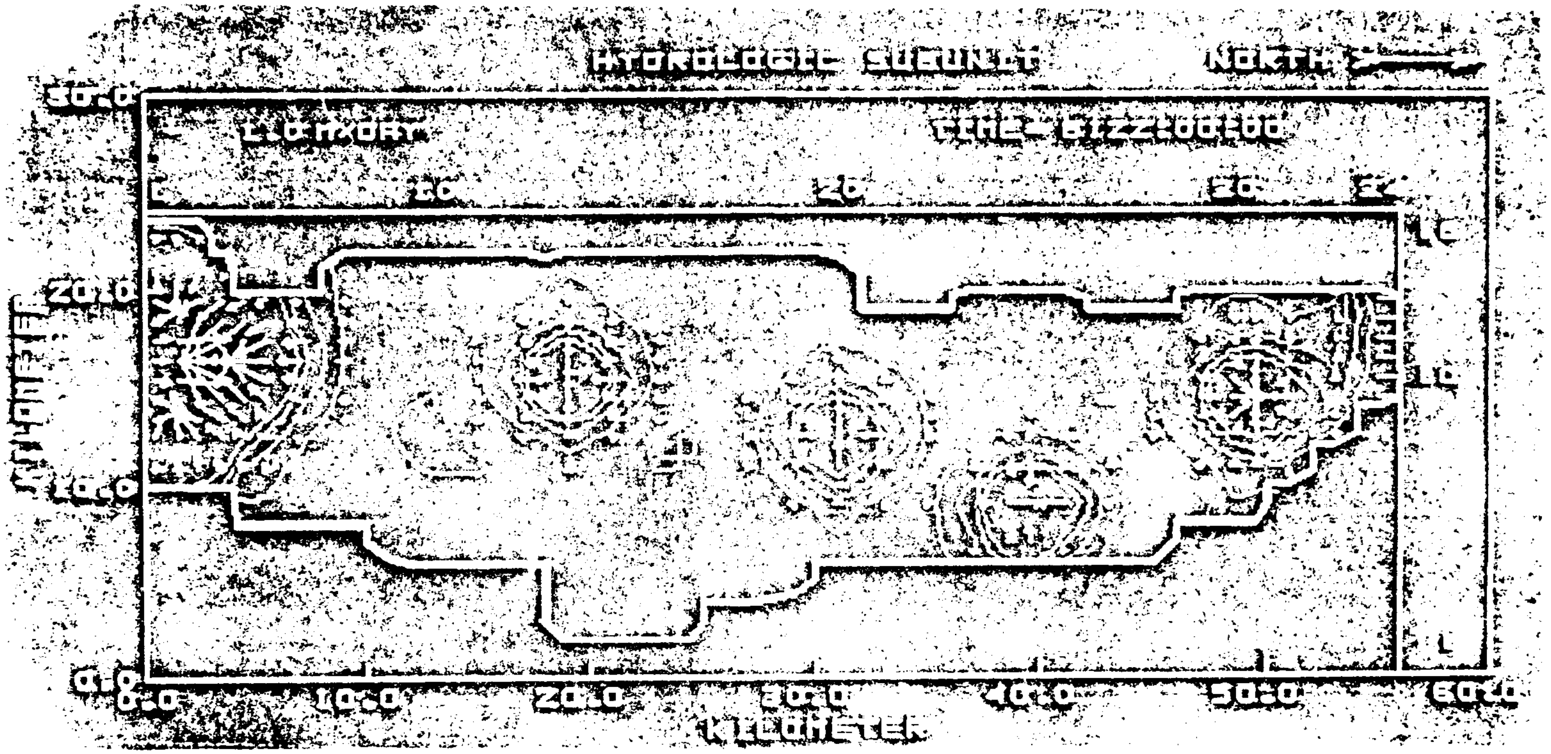

Figure B-41. Computed average water velocity (blue arrows) representing water flows in the aquifer and the drawdown contours at 265 days after end of one-hour rainstorm over Dry Lake Valley hydrologic subunit undisturbed except for nine wells which have been pumping for 255 days.