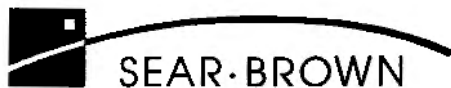


Hydro-geology Report for Johnson's Up-On-Top Mesa  
Grand County, Utah; 2001.

Contents

- 1) Sear - Brown Report Letter
- 2) Horrocks Invoice
- 3) Drinking Water Source Protection Plan; George White Wells.
- 4) Source Protection User's Guide; State of Utah.
- 5) Ground-water conditions in the Grand County area, Utah, with emphasis on the Mill Creek-Spanish Valley area; Blanchard.
- 6) Geology and water resources of the Spanish Valley area, Grand and San Juan Counties, Utah; Sumison.





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ENGINEERING Salt Lake City, UT 84111  
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February 6, 2001

Mr. Richard Grice  
Grand County Planning Department  
125 East Center Street  
Moab, Utah 84532

**RE: Hydro-geology Report for Johnson's Up-On-Top Mesa, Grand County, Utah**

Dear Mr. Grice

This report is written as a response to the hydro-geology questions raised in the Grand County Planning and Zoning Commission Meeting of December 6, 2000. The Planning Staff recommended the submission of a ground water geologic report or other technical evidence to demonstrate that the proposed development will have no adverse impacts on the aquifer.

Sear Brown has compiled and reviewed numerous studies, reports and plans regarding the Hydro-geology around the vicinity of this project. The information we were able to obtain is as follows:

Drinking Water Source Protection Plan  
George White Wells No. 4 and No. 5  
Grand Water and Sewer Service  
Agency, Moab Utah  
Sunrise Engineering  
December 29, 1999

Drinking Water Source Protection  
R309-113  
Department of Environmental Quality  
Division of Drinking Water  
State of Utah  
July 26, 1995

Source Protection Users Guide  
Department of Environmental Quality  
Division of Drinking Water  
State of Utah  
October 1998

Recharge Areas and Quality of Ground  
Water for the Glen Canyon and Valley-  
Fill Aquifers, Spanish Valley Area,  
Grand and San Juan Counties, Utah  
U.S. Geological Survey  
1997

Geology and Water Resources of the  
Spanish Valley Area  
Grand and San Juan Counties, Utah  
Technical Publication No. 32  
State of Utah  
Department of Natural Resources  
1971

Ground-Water Conditions in the Grand  
County Area, Utah with Emphasis on  
the Mill Creek-Spanish Valley Area.  
Technical Publication No. 100  
State of Utah  
Department of Natural Resources  
1990



Copies of this information has been included as supplement to this report in the Appendix.

The Drinking Water Source Protection Plan for George White Wells No. 4 and No. 5 was the only completed source protection plan available. There are two other well protection plans in progress and we were unable to obtain mapping for one of the plans. The existing George White plan appears to be more inclusive than any other mapping we have seen. We therefore feel our recommendations in this letter are conservative. Portions of the proposed development falls within Zone 2 of the George White plan and will need to conform with those requirements. A Drinking Water Source Protection Zone 2 has the following definition:

Zone 2 - The area within a 250 day ground-water time of travel to the well head or margin of the spring collection area. The Public Water System should prevent the future location of "pollution sources" within Zone 2, unless the potential pollution source agrees to implement design or operating standards which prevent discharges to the groundwater.

"Pollution Source" has the following definition:

Pollution Source - Point source discharges of contaminants to ground water or potential discharges of the liquid forms of "extremely hazardous substances" which are stored in containers in excess of "applicable threshold planning quantities" as specified in SARA Title III. Examples of possible pollution sources include, but are not limited to the following: Storage facilities that store liquid forms of extremely hazardous substances, septic tanks, drain fields, Class V underground injection wells, landfills, open dumps, land filling of sludge and septage, manure piles, salt piles, pit privies, drain lines, and animal feeding operations with more than ten animal units.

None of the land uses proposed for Joushon's-Up-On-Top Mesa development are defined as "Pollution sources".

The State of Utah Drinking Water Source Protection Rules R309-113 also identifies "Potential Contamination Sources"

Potential Contamination Source - Any facility or site which employs an activity or procedure which may potentially contaminate ground water. A pollution source is also a potential contamination source.

A checklist of Potential Contamination Sources is given in the State of Utah Source Protection Users Guide. It lists 58 potential contamination sources, three of those sources are included in the Johnson's Up-On-Top Meas. A copy of this list follows:



## POTENTIAL CONTAMINATION SOURCES

| NUMBER | DESCRIPTION                                                                                                                                                                                     | PRESENCE |
|--------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|
| 1      | Active and abandoned wells                                                                                                                                                                      | No       |
| 2      | Agricultural pesticide, herbicide, and fertilizer storage, use, filling, and mixing areas                                                                                                       | No       |
| 3      | Airport maintenance and fueling sites                                                                                                                                                           | No       |
| 4      | Animal feeding operations with more than ten animal units                                                                                                                                       | No       |
| 5      | Animal watering troughs located near unfenced wells and springs that attract livestock                                                                                                          | No       |
| 6      | Auto washes                                                                                                                                                                                     | No       |
| 7      | Beauty salons                                                                                                                                                                                   | No       |
| 8      | Boat builders and refinishers                                                                                                                                                                   | No       |
| 9      | Chemical reclamation facilities                                                                                                                                                                 | No       |
| 10     | Chemigation wells                                                                                                                                                                               | No       |
| 11     | Concrete, asphalt, tar, and coal companies                                                                                                                                                      | No       |
| 12     | Dry cleaners                                                                                                                                                                                    | No       |
| 13     | Farm dump sites                                                                                                                                                                                 | No       |
| 14     | Farm maintenance garages                                                                                                                                                                        | No       |
| 15     | Feed lots                                                                                                                                                                                       | No       |
| 16     | Food processors, meat packers, and slaughter houses                                                                                                                                             | No       |
| 17     | Fuel and oil distributors and storers                                                                                                                                                           | No       |
| 18     | Furniture strippers, painters, finishers, and appliance repairers                                                                                                                               | No       |
| 19     | Grave yards, golf courses, parks, and nurseries                                                                                                                                                 | No       |
| 20     | Heating oil storers                                                                                                                                                                             | No       |
| 21     | Industrial manufacturers: chemicals, pesticides, herbicides, paper and leather products, textiles, rubber, plastic, fiberglass, silicone, glass, pharmaceutical, and electrical equipment, etc. | No       |
| 22     | Industrial waste disposal/impoundment areas and municipal wastewater treatment plants, landfills, dumps, and transfer stations                                                                  | No       |
| 23     | Junk and salvage yards                                                                                                                                                                          | No       |
| 24     | Laundromats                                                                                                                                                                                     | No       |
| 25     | Machine shops, metal platers, heat treaters, smelters, annealers, and descalers                                                                                                                 | No       |
| 26     | Manure piles                                                                                                                                                                                    | No       |
| 27     | Medical, dental, and veterinarian offices                                                                                                                                                       | No       |
| 28     | Mortuaries                                                                                                                                                                                      | No       |
| 29     | Mining operations                                                                                                                                                                               | No       |
| 30     | Muffler shops                                                                                                                                                                                   | No       |
| 31     | Pesticide and herbicide storers and retailers                                                                                                                                                   | No       |
| 32     | Photo processors                                                                                                                                                                                | No       |
| 33     | Print shops                                                                                                                                                                                     | No       |
| 34     | Radiological mining operations                                                                                                                                                                  | No       |
| 35     | Railroad yards                                                                                                                                                                                  | No       |

| NUMBER | DESCRIPTION                                                                                                      | PRESENCE |
|--------|------------------------------------------------------------------------------------------------------------------|----------|
| 36     | Research laboratories                                                                                            | No       |
| 37     | Residential pesticide, herbicide, and fertilizer storage, use, filing, and mixing areas                          | Yes      |
| 38     | Residential underground storage tanks                                                                            | No       |
| 39     | Salt and sand-salt piles                                                                                         | No       |
| 40     | Sand and gravel mining operations                                                                                | No       |
| 41     | School vehicle maintenance barns                                                                                 | No       |
| 42     | Sewer lines                                                                                                      | Yes      |
| 43     | Single-family septic tank/drain-field systems                                                                    | No       |
| 44     | Sites of reported spills                                                                                         | No       |
| 45     | Small engine repair shops                                                                                        | No       |
| 46     | Stormwater impoundment sites and snow dumps                                                                      | Yes      |
| 47     | Subdivisions using subsurface wastewater disposal systems (large and individual septic tank/drain field systems) | No       |
| 48     | Submersible pumps used to pump wells                                                                             | No       |
| 49     | Taxi cab maintenance garages                                                                                     | No       |
| 50     | Tire shops                                                                                                       | No       |
| 51     | Toxic chemical and oil pipelines                                                                                 | No       |
| 52     | Vehicle chemical supply storers and retailers                                                                    | No       |
| 53     | Vehicle dealerships                                                                                              | No       |
| 54     | Vehicle quick lubes                                                                                              | No       |
| 55     | Vehicle rental shops                                                                                             | No       |
| 56     | Vehicle repair, body shops, and rust proofers                                                                    | No       |
| 57     | Vehicle service stations and terminals                                                                           | No       |
| 58     | Wood Preservers                                                                                                  | No       |
|        |                                                                                                                  | No       |

The table shows that three Potential Contamination Sources exist. They are: (37)Residential pesticide, herbicide and fertilizer use, (42)Sewer lines and (46)Storm water impoundment sites. The development is proposing prevention measures as recommended in the Drinking Water Source Protection Plan.

The desert environment and low density proposed will generate a very minimal amount of lawns and planted areas. The project will maintain 80% of the land as natural open space. The development does not have golf courses, agriculture orf large expanses of landscaping. Water use for irrigation will be discouraged and natural desert landscaping implemented. As a result, the use of pesticides, herbicides and fertilizers will also be minimal. We have included restrictive covenants to limit the use of these materials in the Development Agreement.

The proposed sewer lines will be constructed to State of Utah and Grand County standards, thus reducing the potential for spills and leakage. Sewer construction will be inspected and all pipes air tested prior to backfilling. All wastewater will flow through these sewer lines to the Treatment Plant in



Moab. This risk is considerably less than the risk from livestock grazing which currently exists. The proposed equestrian center has been located outside of the zone 2 source protection area.

Some isolated storm water impoundment sites will be constructed on the Mesa. These sites will be necessary to control flooding and erosion. Their potential for contaminating is rare because the drainage basins will not contain any pollution sources. Vehicular travel on the project site is discouraged as part of the total experience. Parking areas are limited and will have oil water separators built into the drainage systems.

#### CONCLUSION

The Johnson's Up-On-Top Mesa Project is a residential, condominium and wilderness lodge development. It will not contain point source discharges of pollutants. It is common in Drinking Water Source Protection Zone 2 boundaries to contain this type of development.

This development does not fall into the category of defined pollution sources. The developer will enter into a "Land Use Agreement" as described in the State of Utah Drinking Water Regulations R309-113-6.1.n. as part of the development agreement. This is a written agreement wherein the owner agrees not to allow location of pollution sources within Zone 2 of wells in unprotected aquifers. The restriction is binding on all heirs, successors and assigns. Land use agreements must be recorded with the property description in the county recorder's office.

Chapter 6 of the Drinking Water Source Protection Zone Plan for the George White Wells No. 4 and No. 5 gives specific directions for management of development in the protections zones. The Grand Water and Sewer Service Agency and Grand County should assess the Potential Contamination Sources and implement measures to control and regulate the sources.

#### FINDINGS

The proposed land uses and infrastructure in the Johnson's Up-On-Top Mesa development are compatible with the Zone 2 designation of the Water Source Protection Plan. The development will not contain point source discharges of pollutants. The proposed plan is in compliance with the State of Utah Water Regulations R309-113 the "Drinking Water Source Protection Plans".

Please review our findings and feel free to call with any additional comments or questions.

Sincerely,  
Sear Brown



Brian Bangerter, P.E.  
Project Manager







HORROCKS ENGINEERS, INC.

ONE WEST MAIN  
P.O. BOX 377  
AMERICAN FORK, UT 84003

Invoice

Invoice Number: 14951  
Invoice Date: January 05, 2001

To: Grand County  
125 East Center Street  
Moab, UT 84532  
Attention: Mary Hoffine

Contract Number:

Project: 50 9906 Grand County Drinking Water Facilities Plan  
Manager: Rex V. Harrison, P.E.  
Professional Services for the Period: 12/1/00 to 12/31/00

Billing Group: 001

Contract Maximum: \$33,549.00  
Previous Billings Against Maximum: \$29,675.85  
Current Billings Against Maximum: \$3,300.00  
Balance After This Invoice: \$573.15

Outside Services

| Expense                | Units | Charge     |
|------------------------|-------|------------|
| Subconsultant          | 1.00  | \$3,300.00 |
| Outside Services Total |       | \$3,300.00 |

Billing Group 001 Totals:

Billing Group Total \$3,300.00

Project Totals:

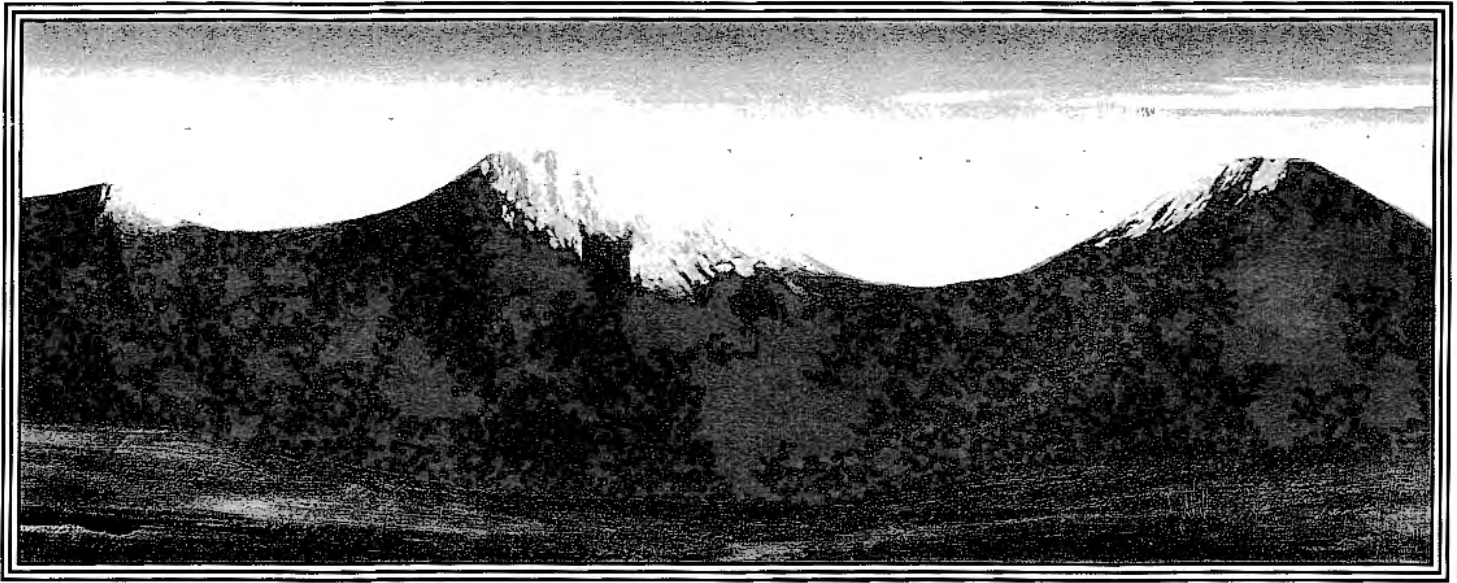
\*\*\* Total Project Invoice Amount \*\*\* \$3,300.00

| Aged Receivables: |         |         |          |          |
|-------------------|---------|---------|----------|----------|
| CURRENT           | 31 - 60 | 61 - 90 | 91 - 120 | OVER 120 |
| \$3,300.00        | \$0.00  | \$0.00  | \$0.00   | \$0.00   |









## **DRINKING WATER SOURCE PROTECTION PLAN**

**George White Wells No. 4 and No. 5  
Grand Water and Sewer Service Agency  
Moab, Utah**

**Sunrise Project No. E8209.44  
December 29, 1999**

*Prepared for:*

**Mr. Dale F. Pierson  
Grand Water and Sewer Service Agency  
P.O. Box 1048  
Moab, UT 84532**

*Prepared by:*

**Sunrise Engineering, Inc.  
12227 South Business Park Drive, Suite 220  
Draper, UT 84020  
Phone: 801-523-0100  
Fax: 801-523-0990**







## **SUNRISE ENGINEERING INC.**

12227 South Business Park Drive • Suite 220  
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TEL (801) 743-6151 • FAX (801) 743-7900

FILLMORE, UT  
MESA, AZ  
AFTON, WY  
SALT LAKE CITY, UT  
PRESCOTT VALLEY, AZ  
WASHINGTON, UT  
BULLHEAD CITY, AZ

December 29, 1999

Mr. Dale F. Pierson  
Grand Water and Sewer Service Agency  
P.O. Box 1048  
Moab, UT 84532

**RE: Drinking Water Source Protection Plan  
George White Wells No. 4 and No. 5  
Grand Water and Sewer Service Agency (Water System No. 10023)  
Sunrise Project No. E8209.44**

Dear Mr. Pierson:

The Drinking Water Source Protection (DWSP) Plan for the above referenced two wells is enclosed herein. The delineation of the DWSP zones, a prioritized inventory of potential contamination sources, management strategies to protect the drinking water sources, a contingency plan and a section regarding pesticide and volatile organic chemical monitoring waiver are contained in this report and the attached appendices.

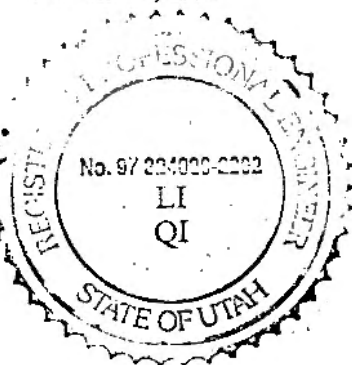
The information in this report relates only to the subject wells and should not be extrapolated or construed to apply to any other sources. The information, recommendations and conclusions provided herein apply to the subject wells as they existed at the time when this DWSP plan report was prepared.

If you have any questions, please feel free to contact us at (801) 523-0100.

Sincerely,  
**SUNRISE ENGINEERING, INC.**

Prepared by:

  
Li Qi, P.E.  
Project Engineer



Reviewed by:

Dan L. Crawford, P.G.  
Senior Hydrogeologist

## EXECUTIVE SUMMARY

This report presents a Drinking Water Source Protection (DWSP) Plan for George White Wells No. 4 and No. 5 in the Grand Water and Sewer Service Agency Water System (Water System No. 10023). In compliance with relevant Utah Division of Drinking Water rules, this report includes a delineation section, an inventory of potential contamination sources, an assessment of potential contamination source hazards, a management program for existing potential contamination sources, a management program for future potential contamination sources, an implementation schedule, a resource evaluation, a recordkeeping section, a contingency plan and a section regarding pesticide and volatile organic chemical (VOC) monitoring waivers.

As part of our identification of the source protection areas, the projected maximum pumping rate from George White Wells No. 4 and No. 5 were respectively set at 1250 and 650 gallons per minute (gpm). These pumping rates were then used to delineate the 250-day, 3-year and 15-year DWSP time of travel zones for the wells. The dimensions of the three DWSP zones, delineated basically using numerical modeling, are summarized below:

| <u>Time of Travel</u> | <u>Zone #</u> | <u>Maximum<br/>Down-gradient<br/>Distance (ft)</u> | <u>Maximum<br/>Up-gradient<br/>Distance (ft)</u> | <u>Maximum<br/>Width<br/>(ft)</u> |
|-----------------------|---------------|----------------------------------------------------|--------------------------------------------------|-----------------------------------|
| 250 Days              | 2             | 350                                                | 9,500                                            | 7,600                             |
| 3 Years               | 3             | 350                                                | 27,000                                           | 19,100                            |
| 15 Years              | 4             | 350                                                | 28,200                                           | 19,600                            |

An inventory of existing potential contamination sources has been completed and the management programs have been developed. A management program to control or prohibit any future pollution sources to be located within the protection zones of the wells has been prepared. A contingency plan for the entire water system has also been prepared and is included in the report.

According to Utah Rule 309-113-6 (1)(v), the producing aquifer of the wells cannot be classified as a protected aquifer.

It is recommended that a use waiver for the VOC and pesticide groups be granted for George White Wells No. 4 and No. 5.



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# **DRINKING WATER SOURCE PROTECTION PLAN**

**George White Wells No. 4 and No. 5  
Grand Water and Sewer Service Agency  
Moab, Utah**

**Sunrise Project No. E8209.44  
December 29, 1999**

## **1.0 INTRODUCTION**

Sunrise Engineering, Inc. (Sunrise) has completed a Drinking Water Source Protection (DWSP) Plan for George White Wells No. 4 and No. 5 in the Grand Water and Sewer Service Agency Water System (System No. 10023) in compliance with Utah DWSP Rule R309-113. According to the State of Utah Division of Drinking Water, or DDW (1998), a DWSP plan for a single source should include a delineation section, an inventory of potential contamination sources, an assessment of potential contamination source hazards, a management program for existing potential contamination sources, a management program for future potential contamination sources, an implementation schedule, a resource evaluation, a recordkeeping section and a section regarding pesticide and volatile organic chemical (VOC) monitoring waivers. A contingency plan is required for an entire water system and submitted to the DDW concurrently with the submission of the first DWSP plan for the system.

### **1.1 System Information**

The Grand Water and Sewer Service Agency Water System includes two existing wells, George White Wells No. 4 and No. 5, and the associated water storage and distribution facilities. Well No. 4 was brought on line to the public system in 1981 and Well No. 5 in 1992. Currently, the system supplies water to 902 connections. The system information is summarized in **Table 1**.

**Table 1. Water System Information**

|                     |                                         |
|---------------------|-----------------------------------------|
| Water System Name   | Grand Water and Sewer Service Agency    |
| Water System Number | 10023                                   |
| Address             | P.O. Box 1048, Moab, UT 84532           |
| Type of System      | Community System, Political Subdivision |

### **1.2 Source Information**

George White Wells No. 4 and No. 5 are located approximately four miles southeast of the City of Moab, on northeastern side of Spanish Valley, at the southwestern foot of the Johnson's Up On Top

Mesa. Specifically, Well No. 4 is located at North 330 feet and East 2,280 feet from the Southwest corner of Section 23, Township 26 South, Range 22 East, Salt Lake Base and Meridian, and Well No. 5 is situated at North 1,240 feet and East 1,900 feet from the Southwest corner of Section 23, Township 26 South, Range 22 East, Salt Lake Base and Meridian.

**Figure 1**, consisting of portions from the U.S. Geologic Survey (USGS) 7.5-Minute Series Topographic Quadrangle Maps for Rill Creek (USGS, 1985), and Warner Lake, Utah-Grand Counties (USGS, 1985), shows the well locations. The wellhead elevations of George White Wells No. 4 and No. 5 are approximately 4,670 and 4,680 feet above mean sea level (MSL), respectively. Well No. 4 is currently equipped to produce 1,000 gallons per minute (gpm) of water, and Well No. 5 can be pumped at 600 gpm.

### **1.3 Designated Person**

Presently, Mr. Dale F. Pierson is responsible for management of the DWSP plan for the Grand Water and Sewer Service Agency Water System. He can be contacted at (435) 259-8121. His mailing address is: Grand Water and Sewer Service Agency, P.O. Box 1048, Moab, UT 84532.

### **2.0 DELINEATION OF DWSP ZONES**

This wellhead protection delineation is prepared in compliance with Utah DWSP Rule R309-113. Two procedures to delineate source protection areas are described in the DWSP rule: the preferred delineation procedure and the optional two-mile radius delineation procedure. Sunrise applied the preferred delineation procedure in the delineation of the following four protection zones for groundwater management purposes:

1. Zone one is called the **accident prevention zone**, consisting of an area within a 100-foot radius from the wellhead or margin of the spring collection area. No future pollution sources will be allowed to be located in this area.
2. Zone two is called the **attenuation zone**, comprising an area within a 250-day groundwater time of travel (TOT) to the wellhead or margin of the spring collection area. The public water system (PWS) should prohibit the future location of pollution sources within zone two, unless the potential pollution source agrees to implement design or operating standards which prevent discharges to the groundwater.
3. Zone three is called the **waiver criteria zone**, comprising an area within a 3-year groundwater TOT to the wellhead or margin of the spring collection area. This zone was

established to match the source monitoring waiver reevaluation period of 3 years. The waiver was designed for analysis of water samples collected from the drinking water source for VOCs and pesticides. Waivers for these two parameter groups can be issued to systems that delineate protection zones and list the potential contamination sources within these zones. Since waivers are reevaluated every three years, systems should delineate a 3-year groundwater TOT protection area around their sources on which to base their waiver.

4. Zone four is called the **remedial action zone**, comprising an area within a 15-year groundwater TOT to the wellhead or margin of the spring collection area. Its purpose is to provide protection to the drinking water source and to afford sufficient time for remediation or developing a new source in case of a contamination incident.

The following section summarizes the information required by the Utah DWSP Rule for the delineation of estimated DWSP zones including: geologic data, well construction data, aquifer data, hydrogeologic methods and calculations, and maps showing boundaries of the DWSP zones for George White Wells No. 4 and No. 5.

## **2.1 Geologic Data**

### **2.1.1 General Geology and Hydrology**

Local geology in the vicinity of the two wells is shown in **Figure 2**, a portion of which was modified and enlarged from the Map of the Spanish-Moab Valley area, Grand and San Juan Counties, Utah (Sumsion, 1971). The Spanish-Moab Valley area, or the Mill Creek-Pack Creek drainage basin, extends from southeast to northwest between a drainage divide along the lofty crests of the La Sal Mountains and a base level at the Meanders of the turbid Colorado River. The elongated, crag-walled structural trough that forms Spanish Valley and Moab Valley is located at the western edge of the drainage basin. Its surface has an average slope of about 120 ft/mile. The southeastern part of the trough is Spanish Valley, and the northwestern, topographically lower part in the vicinity of Moab City, is Moab Valley. Geologic structures throughout the Spanish-Moab Valley area control the drainage-basin hydrology, recharge and groundwater movement (Sumsion, 1971).

In the Spanish-Moab Valley area, Pack Creek enters Spanish Valley from the southeast, flows into Moab Valley, and joins the Colorado River at the northwestern end of the valley. Mill Creek flows west from the mountains and then northwest for 8.6 miles, parallel to Spanish Valley before entering Moab Valley where it joins Pack Creek. North Fork Mill Creek generally flows from east to west and joins Mill Creek before entering Moab Valley.



The Triassic and Jurassic Glen Canyon Group (Jkgc), consisting of the Navajo Sandstone, the Kayenta Formation, and the Wingate Sandstone, is mapped along the northeastern wall of Spanish-Moab Valley. A copy of the associated geologic descriptions is attached in **Appendix A**. The Navajo Sandstone is surficially exposed and its maximum thickness is 400 feet. The Kayenta Formation, underling the Navajo Sandstone, is composed of siltstone and sandstone. Its thickness ranges from 0 to 240 feet. The Wingate Sandstone lies at the bottom of the Glen Canyon Group and the thickness varies between 0 and 350 feet. According to Steiger and Susong (1997), the Navajo Sandstone and Wingate Sandstone can yield a substantial amount of water. Blanchard (1990) noted that the Navajo Sandstone and Wingate Sandstone are in hydraulic connection because the intervening Kayenta Formation is mostly sandstone, and all the three formations are jointed and fractured. Blanchard (1990) also showed that the direction of groundwater movement in the Glen Canyon Aquifer is generally to the west and southwest, nearly perpendicular to the eastern canyon wall of the valley. Water from the Glen Canyon Aquifer discharges to numerous springs and wells (including the subject wells) along eastern edge of Spanish Valley.

The Glen Canyon Aquifer is covered by shallow deposits of eolian sand or sandy soil northeast of Spanish Valley. These sands and soils provide storage where precipitation can quickly infiltrate and then move into the underlying Glen Canyon Aquifer. Rock formations along the margin of the Spanish-Moab Valley and its adjacent northeastern area are extensively fractured parallel to its axis. Mill Creek gains water from the Glen Canyon Aquifer in its upper reaches and loses water to the aquifer in the last 8.6 miles as it parallels Spanish Valley (Blanchard, 1990). The North Fork of Mill Creek gains water from the Glen Canyon Aquifer along its entire length (Blanchard, 1990).

The geologic structures of Spanish-Moab Valley vary along its length. The valley structure may be divided into three segments: the Moab anticline near the Colorado River, the normal Spanish Valley syncline near the central part of the valley, and the faulted Pack Creek synclinal graben near the eastern margin of the area (**Figure 2**). Along the northeastern wall of Spanish-Moab Valley, the Glen Canyon Group formations dip to southwest with the dip angles ranging from 1° to 9° (very flat bedding).

### **2.1.2 Well Logs**

The driller's logs for George White Wells No. 4 and No. 5 are attached in **Appendix B**. The materials encountered during drilling of the wells are summarized in **Tables 2-1** and **2-2**.

**Table 2-1. Materials Encountered during Drilling George White Well No. 4**

| Depth below Ground Surface (ft) |     | Description |
|---------------------------------|-----|-------------|
| From                            | To  |             |
| 0                               | 8   | Red Sand    |
| 8                               | 174 | Sandstone   |

The driller's log for Well No. 4, **Appendix B** and **Table 2-1**, indicates that Well No. 4 was drilled through eight feet of red sand followed by 166 feet of sandstone. The total depth of the well is 174 feet below grade. Groundwater was encountered within the sandstone and the static water level was 75 feet (March 9, 1971) below ground surface (BGS). It is clear that the well taps water from the Navajo Sandstone of the upper Glen Canyon Group (Jkgc) as described in section 2.1.1.

**Table 2-2. Materials Encountered during Drilling George White Well No. 5**

| Depth below Ground Surface (ft) |     | Description   |
|---------------------------------|-----|---------------|
| From                            | To  |               |
| 0                               | 10  | Red Sand      |
| 10                              | 180 | Red Sandstone |

Well No. 5 reflects similar subsurface conditions, 10 feet of red sand followed by 170 feet of red sandstone, as shown in **Appendix B** and **Table 2-2**. The well was drilled to 180 BGS, and groundwater was first encountered at 105 feet BGS.

## 2.2 Well Construction Data

George White Wells No. 4 and No. 5 were drilled to the depths of 174 and 180 feet BGS, using the cable tool and rotary drilling methods, by H.E. Beeman in 1971 and 1990, respectively. The summaries of the well construction data are presented in **Tables 3-1** and **3-2**.

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**Table 3-1. Well Construction Summary (George White Well No. 4)**

|                                            |                                                 |
|--------------------------------------------|-------------------------------------------------|
| Well Completion Date                       | February 25, 1971                               |
| Well Driller's Log                         | Refer to <b>Table 2-1</b> and <b>Appendix B</b> |
| Elevation of Wellhead                      | 4,670 feet above MSL                            |
| Well Diameter                              | 16 inches                                       |
| Total Depth of Completed Well              | 174 feet                                        |
| Length of Screened or Perforated Intervals | No perforation                                  |
| Perforated Depths                          | N/A                                             |
| Grouting Depth/Surface Seal                | No Surface Seal                                 |
| Depth to Static Water Level                | 75 ft BGS (03/09/71)                            |
| Method of Drilling                         | Cable Tool                                      |
| Casing Type                                | Welded                                          |
| Current Maximum Pumping Rate               | 1,000 gpm                                       |
| Projected Maximum Pumping Rate             | 1,250 gpm                                       |
| Maximum Well Yield                         | 1,250 gpm                                       |
| Pump Type                                  | Submersible Deep Well Turbine, 100 HP           |
| Installation Depth of Pump                 | 120 feet BGS                                    |

**Table 3-2. Well Construction Summary (George White Well No. 5)**

|                                            |                                                 |
|--------------------------------------------|-------------------------------------------------|
| Well Completion Date                       | April 17, 1990                                  |
| Well Driller's Log                         | Refer to <b>Table 2-2</b> and <b>Appendix B</b> |
| Elevation of Wellhead                      | 4,780 feet above MSL                            |
| Well Diameter                              | 10 inches                                       |
| Total Depth of Completed Well              | 180 feet                                        |
| Length of Screened or Perforated Intervals | 140 feet                                        |
| Perforated Depths                          | 33 to 173 feet BGS                              |
| Grouting Depth/Surface Seal                | No Surface Seal                                 |
| Depth to Static Water Level                | 75 feet BGS (Current)                           |
| Method of Drilling                         | Rotary                                          |
| Casing Type                                | Welded                                          |
| Current Maximum Pumping Rate               | 600 gpm                                         |
| Projected Maximum Pumping Rate             | 650 gpm                                         |
| Maximum Well Yield                         | Unknown                                         |
| Pump Type                                  | Submersible                                     |
| Installation Depth of Pump                 | 135 feet BGS                                    |

## **2.3 Aquifer Data Summary**

As required by Utah State Rule 119-9. (4) (a) (ii), this section summarizes the saturated thickness of the water bearing unit, the hydraulic conductivity/transmissivity, assumed porosity, hydraulic gradient and groundwater flow direction.

### **2.3.1 Saturated Thickness of the Producing Aquifer**

Well No. 4 According to the driller's well log (**Appendix B**) this well taps groundwater from the Navajo Sandstone that extends between eight feet BGS and the bottom of the well (174 feet BGS). The casing was installed from ground surface to 120 feet BGS, and the producing aquifer is a 54-foot open hole section (from 120 to 174 feet BGS).

Well No. 5 The driller's well log (**Appendix B**) indicates that groundwater was first encountered at 105 feet BGS. Although the perforated well casing interval is 140 feet, between 33 and 173 feet BGS, the perforated section above 105 feet BGS cannot be counted as part of the water-bearing layer. Therefore, the aquifer thickness was calculated as  $(173 - 105 =) 68$  feet.

The smaller the saturated thickness of the producing aquifer used in the protection delineation, the greater the estimated TOT zones. Based on the analysis above, the saturated thickness of the producing aquifer was conservatively assumed to be 54 feet.

### **2.3.2 Hydraulic Conductivity/Transmissivity**

Mr. Mark Jensen of the Utah DDW conducted a constant-rate-pumping test at Well No. 4 on December 14, 1993. Drawdowns versus pumping time data were recorded during the test and are attached in **Appendix C**. The static water level was 73 feet BGS before the pumping started. After a 210-minute period pumping at a pumping rate of 1,250 gpm, the water level stabilized at 84 feet BGS, which indicated a 11-foot drawdown. The time-drawdown graph was plot and is also attached in **Appendix C**. It appears that the pumping rate of 1,250 gpm, which already reached the pump capacity, was too low to stress the aquifer. The 11 feet of steady-state drawdown might result from the well loss created when groundwater entered the well from the aquifer. The thickness of water-bearing formation, Glen Canyon Group (Jkgc, refer to Section 2.1), is up to 1,000 feet, and Well No. 4 is a partially penetrating well with a depth of 174 feet. Therefore, data obtained from the existing pumping test may not result in an analyzable time-drawdown curve.

Pumping test data from three pumping tests at Well No. 5 are also attached in **Appendix C**. These data are not analyzable for the same reasons as stated above.



Because the available pumping test data cannot be used to determine the value of hydraulic conductivity/transmissivity, these aquifer characteristics have to be obtained or estimated based on available published literature and site-specific investigations. A groundwater condition study in the Grand County area was completed by the Utah Department of Natural Resources Division of Water Rights (Blanchard, 1990). According to this report, the estimate of hydraulic conductivity for the Navajo Sandstone in the Grand County area ranges from less than 0.4 feet/day in the northeast to about 1 feet/day in the southwest. Sunrise personnel conducted a site visit on May 26, 1999 and recently completed a Hydrogeologic Assessment/Well Siting Study (Sunrise, 1999) in this area. According to this study, the Navajo Sandstone Formation is highly fractured to the east/northeast of the subject wells. Steiger and Susong (1997) has mapped the highly fractured area (HFA) in their report, and part of this map is attached in **Appendix D**. It appears that the estimated value of hydraulic conductivity for the Navajo aquifer mentioned in Blanchard's study (1990) is too small.

The driller's log for George White Well No. 4 indicates that a pumping test was performed when the well was completed in 1971. The pumping test information required by the Utah DWSP Rule R309-113 is partially available and presented in **Table 4**.

**Table 4. Pumping Test Information**

|                               |                      |
|-------------------------------|----------------------|
| Wellhead Elevation            | 4,670 feet above MSL |
| Pre-pumping Water Level       | 75 feet BGS          |
| Constant Pump Rate            | 1,600 gpm            |
| Time-Drawdown Data            | N/A                  |
| Total Drawdown in Pumped Well | 48 feet              |
| Duration of Drawdown Test     | 1 hours              |
| Recovery Test?                | N/A                  |

Because no time-drawdown data were available, we used the following empirical formula developed by Farri (1997) to estimate the aquifer transmissivity

$$T = 0.85 SC^{1.07} \quad (1)$$

where,  $T$  is the estimated transmissivity ( $m^2/day$ ), and  $SC$  is the specific capacity ( $m^2/day$ ) of the well. Based on the information listed in **Table 4**,  $SC$  was calculated as:  $(1,600 \text{ gpm} / 448.8 \text{ gpm/cfs} / 3.281^3 \text{ ft}^3/m^3 \times 86400 \text{ s/day}) / (48 \text{ ft} / 3.281 \text{ ft/m}) = 596.1 \text{ m}^2/day$ .  $T$  is then obtained as  $792.5 \text{ m}^2/day$  or  $8,532 \text{ ft}^2/day$  by use of equation (1).

The relationship between transmissivity and hydraulic conductivity is as follows:

$$K = T / B \quad (2)$$

where,  $T$  is the aquifer transmissivity (feet<sup>2</sup>/day),  $K$  is the aquifer hydraulic conductivity (feet/day) and  $B$  is the saturated thickness of the aquifer (feet). For the subject wells,  $B = 54$  feet, and  $T = 8,532$  ft<sup>2</sup>/day. Thus,  $K$  is calculated as 158 feet/day.

Based on the analysis above, a conservative value of hydraulic conductivity, 158 feet/day, for the highly fractured Navajo Sandstone was used to delineate the DWSP TOT zone boundaries. If the groundwater travel distance under a given TOT extends beyond the northeastern boundary of the mapped fractured area, which is shown in **Appendix D** (Steiger and Susong, 1997), the maximum value published by Blanchard (1990), 1 foot/day, would be used to continue the delineation.

### 2.3.3 Direction of Groundwater Flow and Hydraulic Gradient

As related in Section 2.1.1, the direction of groundwater movement in the Glen Canyon Aquifer is generally to the west and southwest, nearly perpendicular to the eastern canyon wall of the valley (Blanchard, 1990). In Sunrise's study (1999), the static groundwater level contours were mapped for the Spanish-Moab Valley area. This map is attached in **Appendix E**. The direction of groundwater flow in the potential recharge area in the vicinity of the subject wells was estimated to be between S55°W and S90°W. The hydraulic gradients were measured as 0.030 feet/foot (140 feet / 4,600 feet) in the S55°W direction, and 0.037 feet/foot (110 feet / 3,000 feet) in the S90°W direction.

### 2.3.4 Assumed Porosity

There is no specific information available on the effective porosity of the materials comprising the aquifer recharging the subject wells. Porosity values were therefore chosen from ranges published by Nielsen (1991), and Freeze and Cherry (1979). These values are summarized in **Table 5**.

**Table 5. Effective Porosity Values Used in Delineation Calculation**

| Bedrock Material      | Porosity Value Used | Published Range |
|-----------------------|---------------------|-----------------|
| Fractured Sandstone   | 0.20                | ? to 0.50       |
| Unfractured Sandstone | 0.10                | 0.05 to ?       |

## 2.4 Hydrogeologic Methods and Calculations

### 2.4.1 Hydrogeologic Method

There are several methods to determine the TOT for delineating the DWSP zones. Sunrise used a two-dimensional semi-analytical flow model (WHPA) which can offer reasonable accuracy at the least cost. This approach is accepted by the DDW if the model is applicable to the hydrogeologic setting of interest.

For a porous medium, groundwater flow is governed by Darcy's law

$$v = Q/A = Ki \quad (3)$$

where,  $v$  is specific discharge (feet/day),  $Q$  is discharge rate (feet<sup>3</sup>/day),  $A$  is area of the cross-section (feet<sup>2</sup>), and  $i$  is hydraulic gradient (feet/feet).

The average linear velocity  $v_a$  through the portion occupied by voids in a porous medium is given by

$$v_a = v/n \quad (4)$$

where  $n$  is porosity of the material comprising the porous medium.

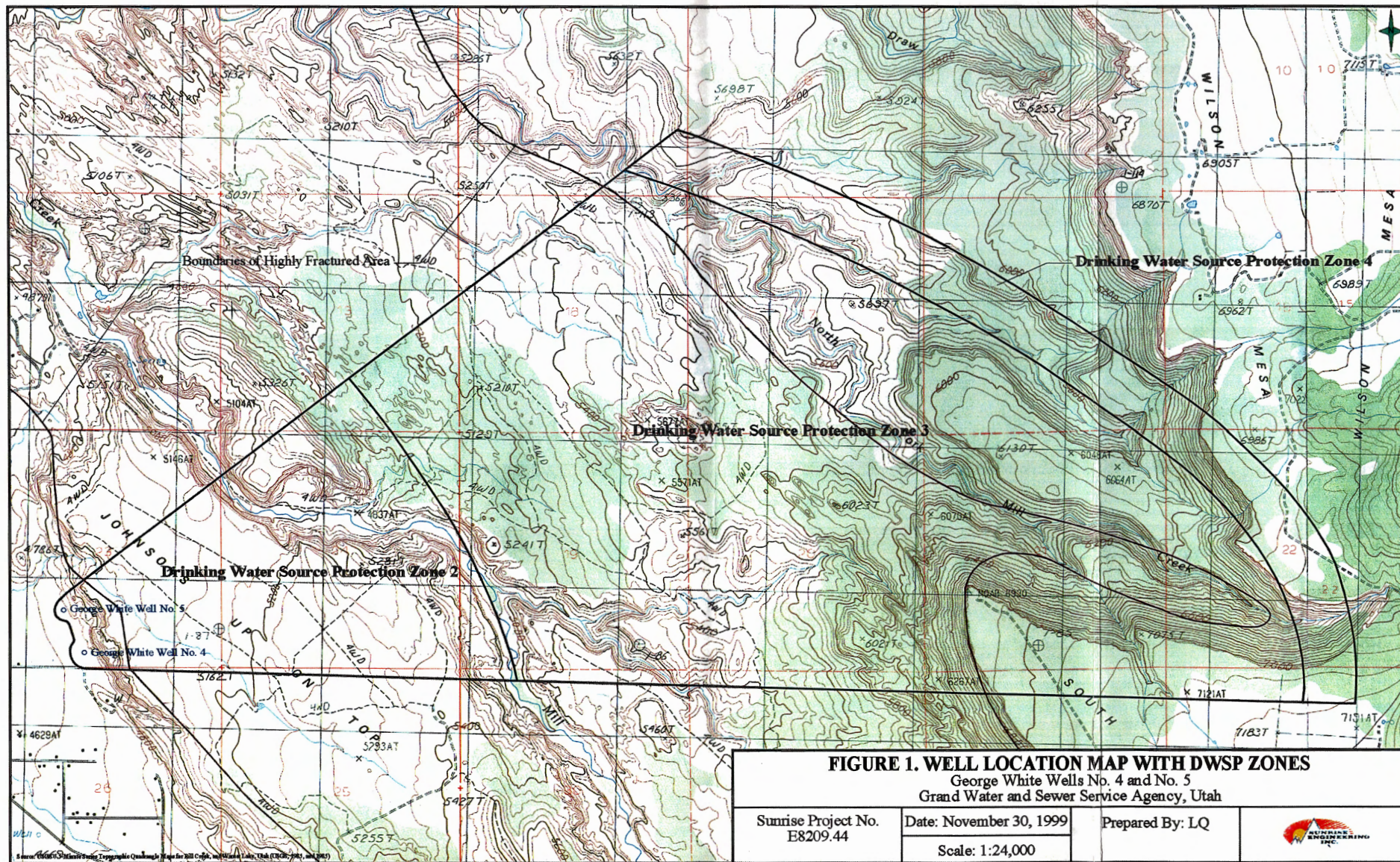
Conceptually, calculation of the TOT boundary can be simplified based on the following equation:

$$d = v_a t \quad (5)$$

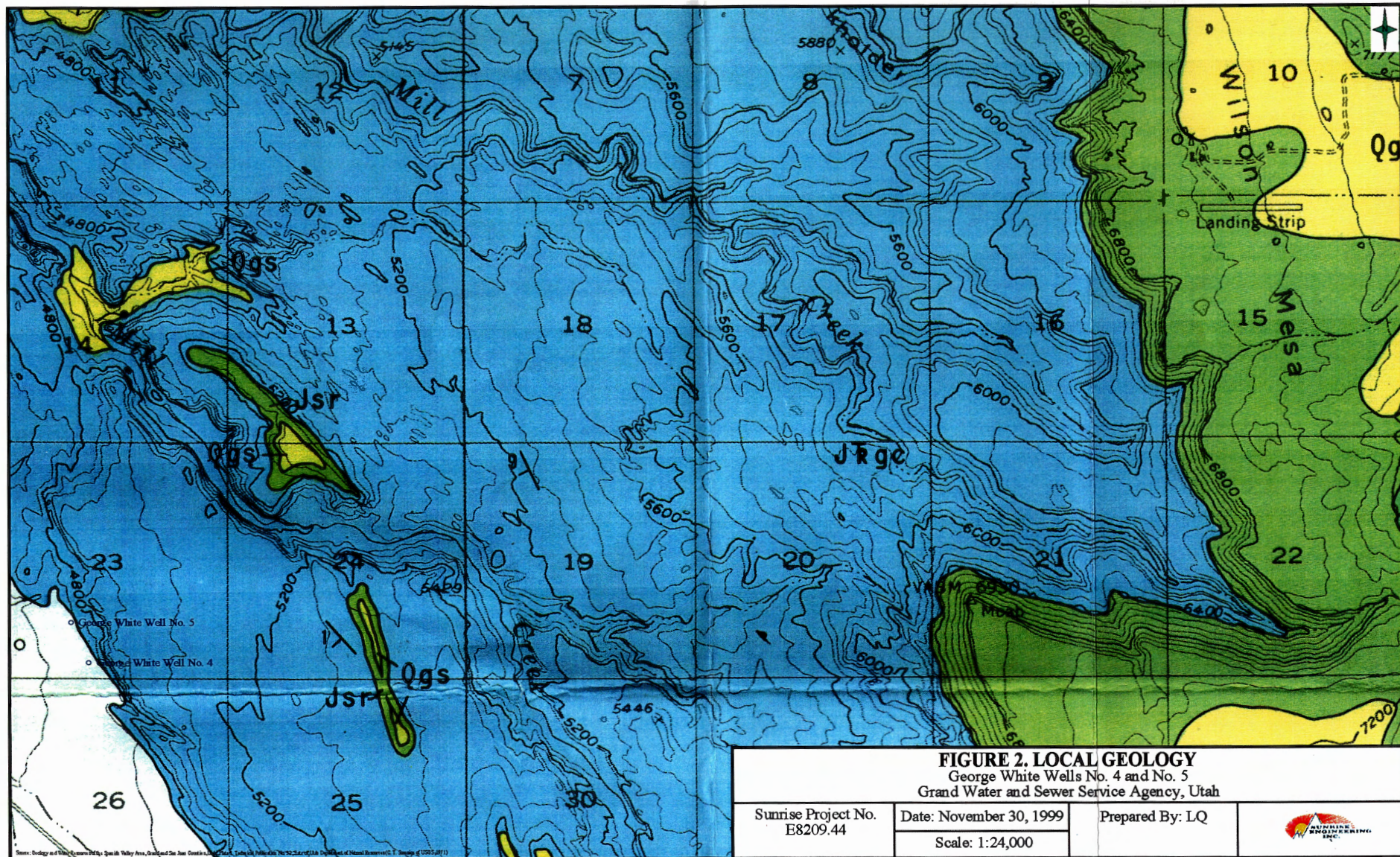
where  $d$  is the radial distance from the well to the TOT boundary line (feet), and  $t$  is the given time of travel (e.g. 250 days, 3 years or 15 years).

The particle tracking method is often used for delineating the DWSP zones. Time related capture zones are delineated by placing a series of water particles at sequential locations along the perimeter of a small circle representing the well boundary. Individual path-lines for each of these particles are then traced using reverse tracking. The capture zone consists of the entire region enclosed by the delineated path-lines.











#### 2.4.2 Delineation of Protection Zones within the HFA

The delineation was performed through particle tracking as computed using the semi-analytical model WHPA, which was developed by the EPA (Blandford and Huyakorn, 1991), and later modified by the International Ground Water Modeling Center in 1993. As related in Sections 2.1 and 2.3, George White Wells No. 4 and No. 5 tap water from the highly fractured Navajo Sandstone formation. According to Freeze and Cherry (1979), if the fracture spacing is sufficiently dense, fractured media can be treated as porous media. Therefore, because we believe the HFA represents this geologic condition, the analysis of groundwater flow in the potential DWSP area of the subject wells can be carried out with WHPA, the Darcy's law based numerical model.

Input parameters required by WHPA include: well discharge rate, transmissivity, regional hydraulic gradient, effective porosity, groundwater flow direction, aquifer thickness, boundary conditions and well location. The primary input parameters for WHPA model for delineating the TOT zones are tabulated in Table 6.

**Table 6. Parameter Values Used in WHPA Model for Down-Gradient TOT Zones**

| Model Parameter           | Symbol | Unit                           | Value             |
|---------------------------|--------|--------------------------------|-------------------|
| Transmissivity            | $T$    | feet <sup>2</sup> /day         | 8,532             |
| Aquifer Thickness         | $B$    | feet                           | 54                |
| Effective Porosity        | $n$    | dimensionless                  | 0.20              |
| Hydraulic Gradient        | $i$    | dimensionless                  | 0.030 and 0.037   |
| Angle Ambient of Flow     | --     | degree                         | S55°W and S90°W   |
| Time of Travel            | $t$    | days                           | 250, 1095, 5475   |
| Well No. 4 Discharge Rate | $Q_1$  | feet <sup>3</sup> /day / (gpm) | 240,680 / (1,250) |
| Well No. 4 Radius         | $r_1$  | feet                           | 0.667             |
| Well No. 5 Discharge Rate | $Q_2$  | feet <sup>3</sup> /day / (gpm) | 125,150 / (650)   |
| Well No. 5 Radius         | $r_2$  | feet                           | 0.417             |

The WHPA model outputs for the calculated 250-day, 3-year and 15-year TOT zones are attached in the first part of Appendix F.

#### 2.4.3 Well Interference Analysis

A water right search was performed by Sunrise and many wells were identified in the down- and cross-gradient directions in vicinity of the George White Wells No. 4 and No. 5. Most of these are shallow wells tapping the unconsolidated alluvial aquifer.

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According to the information obtained through the source search, conversation with the manager of Grand Water and Sewer Service Agency and field inspections, well interference is anticipated from 12 public and private wells, which are summarized in **Table 7**. The pumping rates listed in **Table 7** were obtained based on the available well logs and the permissible removals by the water rights.

**Table 7. Interferential Wells**

| Well          | Diameter<br>(inches) | Depth<br>(feet) | Pumping Rate<br>(gpm) | Location<br>(Township 26 S, Range 22 E, SLB&M) |
|---------------|----------------------|-----------------|-----------------------|------------------------------------------------|
| City of Moab  | 12                   | 222             | 1,400                 | S 4 and W 848, NE Corner of Section 22         |
| City of Moab  | 12                   | 240             | 1,400                 | S 830 and W 653, NE Corner of Section 22       |
| City of Moab  | 14                   | 300             | 1,400                 | S 585 and E 1,248, NW Corner of Section 23     |
| Irrigation    | 12                   | 250             | 1,350                 | S 2,000 and E 700, NW Corner of Section 23     |
| Irrigation    | 12                   | 250             | 1,350                 | N 3,000 and E 0, SW Corner of Section 23       |
| Irrigation    | 12                   | 250             | 1,350                 | N 1,800 and E 500, SW Corner of Section 23     |
| Irrigation    | 12                   | 250             | 1,350                 | N 1,200 and E 1,600, SW Corner of Section 23   |
| I. F. Kerby   | 6                    | 110             | 185                   | N 857 and E 665, SW Corner of Section 23       |
| White Ranches | 16                   | 174             | 2,030                 | N 70 and W 820, SE Corner of Section 22        |
| Irrigation    | 12                   | 250             | 1,350                 | N 0 and E 0, N4 Corner of Section 26           |
| Irrigation    | 12                   | 250             | 1,350                 | N 4,200 and W 2,400, SE Corner of Section 26   |
| Irrigation    | 12                   | 250             | 1,350                 | N 2,900 and W 1,600, SE Corner of Section 26   |

Most of the wells are used seasonally and not expected to be pumped simultaneously with George White Wells No. 4 and No. 5. Conservatively, we reran the WHPA model to estimate the maximum possible interference from all these wells, although not much interference is anticipated from those seasonally used wells. The outputs for calculated 250-day, 3-year and 15-year TOT zones from WHPA are attached in the second part of **Appendix F**.

The model outputs suggest that well interference enlarged the TOT zones in the up-gradient direction, narrowed them in the lateral-gradient direction and shortened them in the down-gradient direction compared with those TOT zones modeled without well interference (**Appendix F**). Conservatively, the width and areal extent of the TOT zones were determined by overlaying the two sets of model outputs, with and without well interference, and the results are attached in the third part of **Appendix F**.

#### **2.4.4 Delineation of Protection Zones beyond the HFA**

The up-gradient extent of the 3-year TOT zone extends beyond the boundary of the highly fractured Navajo Sandstone formation. As related in Section 2.3.2, for unfractured sandstone in this area, the

hydraulic conductivity ( $K$ ) was estimated to be 1 foot/day, and the effective porosity ( $n$ ) was chosen as 0.1. Because the WHPA model can handle only one  $K$  value, in the area outside the HFA boundary, the TOT distances were calculated using equation (5). This technique is a type of hydrogeologic mapping. The calculation details are listed in Table 8.

**Table 8. Groundwater Travel Distance Calculation**

| Azimuth | $K$ (ft/day) | $n$ | $i$   | Distance of 3-Year TOT                                  | Distance of 15-Year TOT                                   |
|---------|--------------|-----|-------|---------------------------------------------------------|-----------------------------------------------------------|
| S55°W   | 158          | 0.2 | 0.03  | Travel 15,500 feet from the boundary of HFA in 654 days | Travel 15,500 feet from the boundary of HFA in 654 days   |
|         | 1            | 0.1 | 0.03  | Travel additional 132 feet out of the HFA in 441 days   | Travel additional 1,446 feet out of the HFA in 4,821 days |
| S90°W   | 158          | 0.2 | 0.037 | Travel 26,300 feet from the boundary of HFA in 900 days | Travel 26,300 feet from the boundary of HFA in 900 days   |
|         | 1            | 0.1 | 0.037 | Travel additional 72 feet out of the HFA in 195 days    | Travel additional 1,693 feet out of the HFA in 4575 days  |

The calculated total distances of the 3-year TOT are 15,632 (= 15,500 + 132) feet in the S55°W direction and 26,372 (26,300 + 72) feet in the S90°W direction. The total distances of the 15-year TOT are 16,946 (15,500 + 1,446) feet in the S55°W direction and 27,993 (26,300 + 1,693) feet in the S90°W direction. The final DWSP Zones were conservatively determined by extending the calculated TOT distances for several hundred feet in both directions, and the up-gradient boundaries were generated by tracing smooth curves.

## 2.5 Maps Showing Boundaries of DWSP Zones

The DWSP zones for 250-day, 3-year and 15-year TOT are shown in Figure 1. The dimensions of Zones 2 through 4 are summarized in Table 9.

**Table 9. Dimensions of DWSP Zones**

| Zone /Description   | Delineation Identification | Maximum Length in Down-gradient Direction (ft) | Maximum Length in Up-gradient Direction (ft) | Maximum Width in Cross-gradient Direction (ft) |
|---------------------|----------------------------|------------------------------------------------|----------------------------------------------|------------------------------------------------|
| 2 – Attenuation     | 250-Day TOT                | 350                                            | 9,500                                        | 7,600                                          |
| 3 – Waiver Criteria | 3-Year TOT                 | 350                                            | 27,000                                       | 19,100                                         |
| 4 – Remedial Action | 15-Year TOT                | 350                                            | 28,200                                       | 19,600                                         |



## **2.6 Protected Aquifer Conditions**

According to Utah Rule 309-113-6 (1)(v), for an aquifer to be classified as being under protected conditions, the following conditions must be met: (a) a natural protective layer of clay, at least 30 feet in thickness, is present above the aquifer; (b) the public water system provides data to indicate the lateral continuity of the clay layer to the extent of zone two; and (c) the well has been grouted from the ground surface to a depth of at least 100 feet and for a thickness of at least 30 feet through the protective clay layer.

Based on the evidence stated in section 2.2 and shown in the driller's logs for George White Wells No. 4 and No. 5 (Tables 2-1, 2-2 and Appendix B), the aquifer does not meet protected aquifer requirements. Therefore, according to the DDW (1998), the aquifer cannot be classified as a protected aquifer.

## **3.0 INVENTORY OF POTENTIAL CONTAMINATION SOURCES**

A checklist of potential contamination sources (PCSs), as listed in Chapter Five of Source Protection User's Guide prepared by the DDW (1998), was completed through review of USGS topographic maps, historic aerial photographs and site inspections, and is attached in Appendix G.

### **3.1 Potential Contamination Sources**

The delineated DWSP area for George White Wells No. 4 and No. 5 covers approximately 8 square miles of mountainous terrain on the northeastern side of Spanish Valley. No residential homes are located in this area. The only PCSs that were identified within the DWSP Zones 1 through 4 are two submersible pumps installed in Wells No. 4 and No. 5.

### **3.2 Hazard Identification**

Submersible pumps may contain such harmful lubricants as petroleum products, polychlorinated biphenyl (PCB) or mercury.

### **3.3 Prioritized Inventory**

Because the submersible pumps installed in George White Wells No. 4 and No.5 are the only PCSs within the DWSP zones of the wells, it is not necessary to complete a prioritized inventory of PCSs. The contact information of the PCSs is shown in Table 10.

**Table 10. PCS Contacts**

| PCSs                                                  | Contact         | Address                          | Telephone #  |
|-------------------------------------------------------|-----------------|----------------------------------|--------------|
| Submersible Pump Used to Pump George White Well No. 4 | Dale F. Pierson | P.O. Box 1,048<br>Moab, UT 84532 | 435-259-8121 |
| Submersible Pump Used to Pump George White Well No. 5 | Dale F. Pierson | P.O. Box 1,048<br>Moab, UT 84532 | 435-259-8121 |

#### **4.0 ASSESSMENT OF POTENTIAL CONTAMINATION SOURCE HAZARDS**

There are four types of hazard controls. They are regulatory, best management and pollution prevention practices (BMPs), physical, and negligible quantity controls. Hazards of PCSs identified within the DWSP zones of the subject wells, as described in Section 3.2 and 3.3, were assessed as following category:

Negligible quality control is applicable to the submersible pumps installed in George White Wells No. 4 and No. 5. Should petroleum products, PCB, or mercury be contained in the pumps and released to groundwater, the quality is negligible compared to the volume of water pumped. Therefore, the submersible pumps are considered as adequately controlled.

This control will be reassessed on a three-year basis.

#### **5.0 MANAGEMENT PROGRAM FOR EXISTING POTENTIAL CONTAMINATION SOURCES**

Because the submersible pumps installed in George White Wells No. 4 and No. 5, the only PCSs located within the DWSP zones of the subject wells, are adequately controlled, no management programs for existing PCSs need to be developed.

#### **6.0 MANAGEMENT PROGRAM FOR FUTURE POTENTIAL CONTAMINATION SOURCES**

The 100-foot radius areas (DWSP Zone 1) around George White Wells No. 4 and No. 5 are controlled by the Grand Water and Sewer Service Agency, and no future activities that may cause subsurface contamination will be allowed within these areas. The management program for future PCSs within the entire DWSP area (DWSP Zones 2 through 4) will involve working with community, the Grand County planners and the U.S. Forest Service because the Grand Water and Sewer Service Agency does not have zoning authority for the land within these zones.

To control and prohibit future location of pollution sources within the DWSP zones where the Grand County has the zoning authority, Grand Water and Sewer Service Agency will submit a copy of the approved DWSP plan to the county planning and engineering department, and the health department. These departments can then evaluate more thoroughly any proposed land uses that may become pollution sources to the wells. It is believed that county engineers understand the importance of protecting groundwater resources and follow the U.S. Public Law 100-4: the Clean Water Act and Utah 1993 Administrative Code R317-6: Administrative Rules for Ground Water Quality Protection, when they review new land development applications. If the Clean Water Act and Rules for Ground Water Quality Protection are followed, any future pollution sources can be controlled or prohibited. Grand Water and Sewer Service Agency will also request that Grand County implement a Drinking Water Source Protection Ordinance to control and prohibit future location of pollution sources within the DWSP zones of the wells. An example of this ordinance prepared by the DDW (1998) is attached in **Appendix H**.

Furthermore, when a new development is proposed within the DWSP zones, the following will happen:

1. Grand Water and Sewer Service Agency will contact the county government to determine the type of PCS that will accompany that development.
2. The county will be made aware that the development is within the management area of the wells.
3. Each PCS will be assessed as controlled or not controlled. Individual homeowners and applicable PCSs will be added to the PCS inventory.

Most portions of the land within the DWSP zones of George White Wells No. 4 and No 5 are within the Manti-La Sal National Forest which is owned by the U.S. Forest Service. Therefore, the management program for the wells shall benefit from the environmental protection that goes along with the National Forest. Grand Water and Sewer Service Agency will coordinate with representatives of the U.S. Forest Service to prohibit future location of any potential pollution sources within the DWSP zones of the wells. It is expected that the U.S. Forest Service will not allow location of any pollution sources within the forested area.

## **7.0 IMPLEMENTATION SCHEDULE**

Once this DWSP Plan is approved by the Utah DDW, the Grand Water and Sewer Service Agency will request that Grand County prepare and implement the Drinking Water Source Protection Ordinance. This process may take six months to one year. Coordination with representatives of the U.S. Forest Service will be on an "as-needed" basis.



## **8.0 RESOURCE EVALUATION**

The Grand Water and Sewer Service Agency will use the existing staff to implement the DWSP plan. Therefore, no extra expense is anticipated. The other cost to implement this DWSP plan is minimal and will be funded from monthly service charges or connection fees.

## **9.0 RECORDKEEPING**

All the records have been and will be kept in the Agency Office.

## **10.0 CONTINGENCY PLAN**

This contingency plan focuses on the identification and possible solutions to problems that may arise in the event that groundwater protection and pollution prevention measures fail. Additionally, this plan addresses problems that the Grand Water and Sewer Service Agency Water System needs to solve in the event of water shortages or contamination incidents that may impact its ability to supply safe drinking water to its users. This emergency plan was developed in accordance with the Emergency Response Handbook prepared by the DDW (1996).

### **10.1 Emergency Response Plan**

An emergency response plan focuses on short-term solutions for problems encountered due to accidents and natural disasters.

#### **10.1.1 Line of Authority**

Table 11 identifies personnel responsible for coordinating activities during an emergency or disaster.

**Table 11. Line of Authority**

| <b>Title</b>                                         | <b>Contact</b>  | <b>Telephone #</b>               |
|------------------------------------------------------|-----------------|----------------------------------|
| Public Relations Coordinator & Emergency Coordinator | Dale F. Pierson | (435) 259-8121                   |
| Assessment Coordinator & Crew Foreman                | Dale F. Pierson | (435) 259-8121                   |
| DDW Emergency                                        | DDW             | (801) 536-4123<br>(801) 536-4200 |
| Utah Pollution Prevention Coordinator                | Sonja Wallace   | (801) 536-4477                   |
| Utah Environmental Hotline                           |                 | (800) 458-0145                   |

According to the DDW (1996), the Emergency Coordinator would coordinate all emergency actions, water system personnel and equipment within the drinking water system. The Emergency Coordinator would also coordinate with the law enforcement, fire fighting, medical personnel and any other requests for aid, volunteer efforts, mutual assistance (other neighboring water system personnel or equipment and any contracted private assistance). The Public Relations Coordinator would be responsible for news releases to the media, issuing emergency information bulletins to the public and act as liaison between the drinking water system and general public in answering questions and addressing concerns. The Assessment Coordinator would coordinate the inspection of all physical facilities in the drinking water system to determine the degree of damage to the facility and, in coordination with the Emergency Coordinator, prioritize the repair, replacement or abandonment of any physical facilities in the system. The Crew Foreman would coordinate, supervise and schedule personnel, equipment and materials to facilitate the repair or replacement of critical facilities, which have been identified and prioritized by the Assessment and Emergency Coordinators.

#### **10.1.2 Clarification of Emergency or Disaster**

The Emergency Coordinator will classify the degree of the emergency or disaster. This will prioritize response, expedite activities and establish action level of response.

**LEVEL I - NORMAL (ROUTINE):** Personnel and equipment presently on duty can handle system problems. The "Emergency Control Center" will not be activated or manned.

**LEVEL II - ALERT (MINOR EMERGENCY):** Personnel and equipment presently on duty can handle system problems, but may require off duty or additional personnel to be put on alert, be re-routed to other than their normal working areas, or work additional shifts. The "Emergency Control Center" will be activated or manned.

**LEVEL III - MAJOR EMERGENCY:** Problems are somewhat beyond the capabilities of the drinking water system personnel and equipment, and may require a "Declaration of Emergency" to authorize shortcut procedures. Employees may be required to work additional shifts. Additional assistance of personnel and equipment may need to be provided by either mutual aid or private contractors. The "Emergency Control Center" will be activated or manned.

**LEVEL IV - DISASTER:** Problems are clearly and immediately beyond the capabilities of the drinking water system. Recovery time will exceed one week, costs will be great, large amounts of assistance of personnel and equipment by mutual aid or private contractors will be required.

Extended shifts will be needed for at least one week. A "Declaration of Emergency" will be required and the "Emergency Control Center" will be activated or manned.

### **10.1.3 Facility Damage Assessment**

The Assessment Coordinator will determine the preliminary assessment priorities. The physical status of all physical facilities would be assessed. The need to repair, replace or abandon drinking water physical facilities is required at this point. A cost estimate including manpower and equipment will be necessary to restore the facility in order to help prioritize the repair work.

The assessment coordinator will consider the possible effects of the repairs or replacement of facilities on the integrity of the drinking water system itself after the emergency. The assessment will address the following items:

- Identification and description of separate components of entire system
  1. Source (wells)
  2. Transmission line (tank to distribution system)
  3. Storage tank
  4. Distribution system
  5. Personnel
  6. Power supply
  7. Materials and supplies
  8. Communications
  9. Present emergency plans
  10. Mutual-aid agreements and/or interconnections
- Development of disaster characteristics
  1. Flood or mudslide
  2. Earthquake
  3. Windstorm
  4. Explosion
- Estimation of water requirements
  1. Fire fighting
  2. Potable water

3. Decontamination and sanitary

- Estimation of the system capacity to meet the water requirements

This point is a "balance point". If capacities exceed requirements, there is an estimated margin of safety and it could be expected that priorities be relaxed. If requirements exceed capacities, there is indicated urgency for improving or "upgrading" the system.

- Identification of critical system components

These components are basis for immediate restudy for improving capacities.

#### **10.1.4 Requirement Prioritization and Program Specification**

The Emergency Coordinator, in coordination with the Assessment Coordinator, will evaluate data gathered during the damage assessment and prioritize system components for repair and replacement.

- Establishment of baseline on water quality levels
- Determination of needs and priorities
  1. Allocation of water under assumed conditions for potable use and sanitary decontamination.
  2. Preparation of guidelines for water allowances, priorities, rationing and time phasing of estimated water requirements.
  3. Establishment of procedures for emergency treatment, pumping and distribution of water and for service stations of emergency water.

#### **10.1.5 Implementation**

The Emergency Coordinator will implement the necessary plan and notify the users of the system through the Public Relations Coordinator. Information will be released to the public in accordance with the following guidelines:

- Only the Emergency Coordinator or designated representative will speak with the media or press.
- The Emergency Coordinator will set up public meetings to routinely inform the users of the status of system improvements, progress and details.



## **10.2 Rationing Plans**

This rationing plan establishes a course of action to be implemented when water shortages occur. These shortages may be caused by drought, seasonal overuse, contamination or accidents. This plan is broad and encompassing, highlighting the different factors that need to be considered before implementing and enforcing a water-rationing plan.

### **10.2.1 Personnel**

Mr. Dale F. Pierson, Manager of the Grand Water and Sewer Service Agency, will be responsible for assessing supply and demand requirements and implementing a water conservation program.

### **10.2.2 Determination of Action Level**

Based on the following factors, an "action level" will be determined to indicate the appropriate level of rationing. Environmental factors include:

- Forecast duration of shortage (short term vs. long term)
- Reason for shortage (draught, loss of storage capacity, mechanical malfunction)
- Time of the year which the shortage is forecast

Water system factors that need to be evaluated include:

- Current supply
- Current storage capacity
- Current number of connections to the system
- Current demand projections
- Current system user conservation practices

Water resources available to alleviate short-term shortages that will be investigated include:

- Emergency water supply (wells serve as backups for each other)
- Replacement mechanical equipment (spare parts)

### **10.2.3 Public Education**

The users of the water system will be notified immediately of the current or potential water shortage problem and any rationing or conversation measures to be implemented.

### **10.3 Water Supply Decontamination Plans**

The Grand Water and Sewer Service Agency Water System water supply decontamination includes the following steps:

1. The ongoing routine water supply decontamination is achieved through chlorinating.
2. Decontamination technical support from the Rural Water Association of Utah.

### **10.4 Source Development Plans**

As previously described in Section 1.2, George White Wells No. 4 and No. 5 can generally be relied upon to supply 1,600 gpm of water to the Grand Water and Sewer Service Agency Water System. Presently, water supplied by the system is barely enough to meet the demands. Therefore, Grand Water and Sewer Service Agency plans to develop a new drinking water well. Sunrise (1999) has performed a hydrogeologic study to determine the proper well location.

## **11.0 PESTICIDE AND VOC MONITORING WAIVERS**

According to the DDW (1998), there are three types of monitoring reduction waivers for either the pesticides or volatile organic chemical (VOC) parameter group available to public water suppliers: reliably and consistently waiver, use waiver and susceptibility waiver.

A use waiver can be issued for either the pesticides or VOC parameter group if a system can verify that none of the chemicals or pesticides in these parameter groups have been used in a given protection area in the past five years. If a source does not qualify for a use waiver, the DDW will evaluate the historical laboratory results of water samples collected from the source and establish an appropriate water quality-monitoring program for VOCs and pesticides. If the laboratory results consistently show good water quality produced by the source, the DDW may consider issuing a reliably and consistently waiver. If a system does not qualify for a use waiver and a reliably and consistently waiver has not been issued, a susceptibility waiver may be issued if the drinking water source meets the requirements listed in the Chapter 11 of the Source Protection User's Guide (DDW, 1998).

A dated statement (**Appendix I**), prepared by Mr. Dale F. Pierson, Manager of Grand Water and Sewer Service Agency, indicates that none of the VOCs or pesticides listed by the DDW has or will be used, disposed of, stored, transported or manufactured within the protection zones of the wells. Therefore, a use waiver should be issued to George White Wells No. 4 and No. 5 in the Grand Water and Sewer Service Agency Water System.

## 12.0 REFERENCES

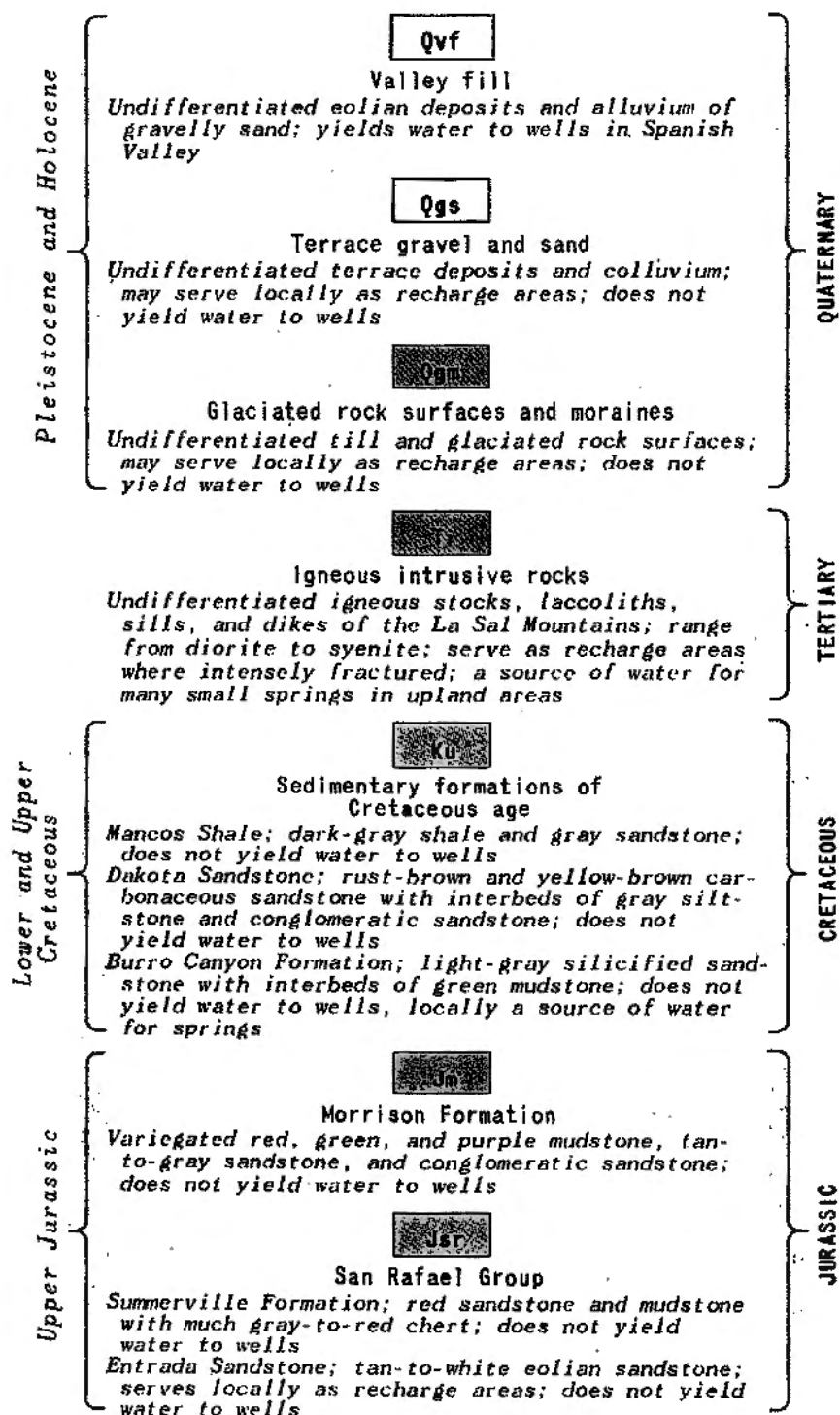
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**Grand Water and Sewer Service Agency**  
**DWSP Plan for George White Wells No. 4 and No. 5**  
**Moab, Utah**  
**Sunrise Project No. E8209.44**

Sunrise Engineering, Inc., 1999. Hydrogeologic Assessment / Well Siting Study for Spanish Valley  
Water and Sewer Improvement District.



## FIGURES



## **APPENDICES**

**Appendix A**  
**Description of Geologic Units**



Upper Triassic,  
Upper Triassic(?),  
and Lower Jurassic

**JKgc**

**Glen Canyon Group**

**Navajo Sandstone**; yellowish-orange and reddish-brown eolian sandstone; serves generally as recharge areas; yields water to springs and wells northeast of Spanish Valley  
**Kayenta Formation**; red, gray, and lavender siltstone and sandstone; an aquitard, does not yield water to wells  
**Wingate Sandstone**; reddish-orange eolian sandstone; serves generally as recharge areas; yields water to springs and will yield water to wells northeast of Spanish Valley

TRIASSIC AND JURASSIC

Middle Pennsylvanian, Lower and Middle(?),  
Upper Pennsylvanian, Triassic and Upper  
Triassic  
and Permian

**Tu**

**Sedimentary formations of  
Triassic age**

**Chinle Formation**; variegated red-brown and gray-brown siltstone, red-gray sandstone, and gray-green conglomeratic sandstone; does not yield water to wells  
**Moenkopi Formation**; red and dark-red siltstone with thin lenses of gray micaceous sandstone and conglomerate; does not yield water to wells

TRIASSIC

**Pm**

**Sedimentary formations of  
Pennsylvanian and Permian age**

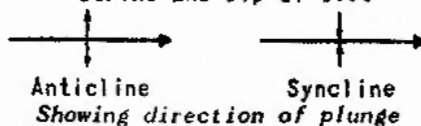
**Cutler Formation**; red, brown, and dark-red arkose and arkosic conglomerate with sparse thin layers of gray limestone; yields small amounts of water to wells locally at the southwest side of Spanish Valley  
**Rico Formation**; red-brown and green-gray sandstone and gray limestone; does not yield water to wells  
**Hermosa Formation**; blue-gray limestone and dolomite with gray sandstone; lower part is of light-gray evaporites and black shale; does not yield water to wells

PERMIAN AND PENNSYLVANIAN

Contact

19

Strike and dip of beds



Fault

Dashed where concealed

Drainage divide

Spring

Well

Number indicates more than  
one well at the site

**Appendix B**  
**Driller's Well Logs**



PRICE

USE OTHER SIDE FOR ADDITIONAL REMARKS

**Appendix C**  
**Pumping Test Data**



## AQUIFER TEST DATA

 Owner Grand Co. WCB Address Moab County Grand State UT

 Date 6 March 1992 Company performing test \_\_\_\_\_ Measured by \_\_\_\_\_

 Well No. B.W. no. 4 Distance from pumping well 0 Type of test Drawdown Test No. \_\_\_\_\_

 Measuring equipment Airline 150' long

| Time Data                 |            |                         |                         | Water Level Data             |                         |                          |             | Discharge Data             |                       |      |  | Comments on factors affecting test data |
|---------------------------|------------|-------------------------|-------------------------|------------------------------|-------------------------|--------------------------|-------------|----------------------------|-----------------------|------|--|-----------------------------------------|
| Pump on: Date             | Time       | (t <sub>1</sub> )       |                         | Static water level           |                         |                          |             | How Q measured             |                       |      |  |                                         |
| Pump off: Date            | Time       | (t <sub>2</sub> )       |                         | Measuring point              |                         |                          |             | Depth of pump/air line     |                       |      |  |                                         |
| Duration of aquifer test: |            |                         |                         | Elevation of measuring point |                         |                          |             | Previous pumping? Yes      | No                    |      |  |                                         |
| Pumping                   | Recovery   |                         |                         |                              |                         |                          |             | Duration                   | End                   |      |  |                                         |
| Date                      | Clock time | Time since pump started | Time since pump stopped | t/r                          | Water level measurement | Correction or Conversion | Water level | Water level change s or s' | Discharge measurement | Rate |  |                                         |
|                           |            | 15 sec.                 |                         |                              | 80                      |                          |             |                            |                       |      |  |                                         |
|                           |            | 30                      |                         |                              | 80                      |                          |             |                            |                       |      |  |                                         |
|                           |            | 45                      |                         |                              | 80                      |                          |             |                            |                       |      |  |                                         |
|                           |            | 1 min.                  |                         |                              | 80                      |                          |             |                            |                       |      |  |                                         |
|                           |            | 15                      |                         |                              | 80                      |                          |             |                            |                       |      |  |                                         |
|                           |            | 30                      |                         |                              | 80                      |                          |             |                            |                       |      |  |                                         |
|                           |            | 45                      |                         |                              | 80                      |                          |             |                            |                       |      |  |                                         |
|                           |            | 2 min.                  |                         |                              | 80                      |                          |             |                            |                       |      |  |                                         |
|                           |            | 15                      |                         |                              | 80                      |                          |             |                            |                       |      |  |                                         |
|                           |            | 30                      |                         |                              | 80                      |                          |             |                            |                       |      |  |                                         |
|                           |            | 45                      |                         |                              | 80                      |                          |             |                            |                       |      |  |                                         |
|                           |            | 3 min.                  |                         |                              | 80                      |                          |             |                            |                       |      |  |                                         |
|                           |            | 30                      |                         |                              | 80                      |                          |             |                            |                       |      |  |                                         |
|                           |            | 4 min.                  |                         |                              | 80                      |                          |             |                            |                       |      |  |                                         |
|                           |            | 30 sec.                 |                         |                              | 80                      |                          |             |                            |                       |      |  |                                         |
|                           |            | 5 min.                  |                         |                              | 80                      |                          |             |                            |                       |      |  |                                         |
|                           |            | 30                      |                         |                              | 81                      |                          |             |                            |                       |      |  |                                         |
|                           |            | 6 min.                  |                         |                              | 81                      |                          |             |                            |                       |      |  |                                         |
|                           |            | 30                      |                         |                              | 81                      |                          |             |                            |                       |      |  |                                         |
|                           |            | 7 min.                  |                         |                              | 81                      |                          |             |                            |                       |      |  |                                         |
|                           |            | 30 sec.                 |                         |                              | 81                      |                          |             |                            |                       |      |  |                                         |
|                           |            | 8                       |                         |                              | 81                      |                          |             |                            |                       |      |  |                                         |
|                           |            | 30                      |                         |                              | 81                      |                          |             |                            |                       |      |  |                                         |
|                           |            | 9                       |                         |                              | 81                      |                          |             |                            |                       |      |  |                                         |
|                           |            | 30 sec.                 |                         |                              | 81                      |                          |             |                            |                       |      |  |                                         |
|                           |            | 10 minutes              |                         |                              | 81                      |                          |             |                            |                       |      |  |                                         |
|                           |            | 11 minutes              |                         |                              | 81                      |                          |             |                            |                       |      |  |                                         |
|                           |            | 12                      |                         |                              | 81                      |                          |             |                            |                       |      |  |                                         |
|                           |            | 13                      |                         |                              | 81                      |                          |             |                            |                       |      |  |                                         |

~ 1060  
~ 11.5 gpm. large  
note needed

### Measuring equipment

[illegible]

## AQUIFER TEST DATA

Owner Grand CO. WCD Address Moe, Utah County Grand State UT  
 Date 12/14/93 Company performing test RWAU, ~~GLWCD~~, DDC Measured by \_\_\_\_\_  
 Well No. G.W. #4 Distance from pumping well 0 Type of test Drawdown pumping Test No. \_\_\_\_\_

Measuring equipment \_\_\_\_\_

| Time Data                                                                                                                              |            |                              |                               | Water Level Data                                                                                 |                          |             |                               | Discharge Data                                                                                                           |      | Comments on factors affecting test data |
|----------------------------------------------------------------------------------------------------------------------------------------|------------|------------------------------|-------------------------------|--------------------------------------------------------------------------------------------------|--------------------------|-------------|-------------------------------|--------------------------------------------------------------------------------------------------------------------------|------|-----------------------------------------|
| Pump on: Date _____ Time _____ (P)<br>Pump off: Date _____ Time _____ (P)<br>Duration of aquifer test:<br>Pumping _____ Recovery _____ |            |                              |                               | Static water level <u>73 feet</u><br>Measuring point _____<br>Elevation of measuring point _____ |                          |             |                               | How Q measured _____<br>Depth of pump/air line _____<br>Previous pumping? Yes _____ No _____<br>Duration _____ End _____ |      |                                         |
| Date                                                                                                                                   | Clock time | Time since pump started<br>t | Time since pump stopped<br>t' | Water level measurement                                                                          | Correction or Conversion | Water level | Water level change<br>s or s' | Discharge measurement                                                                                                    | Rate |                                         |
|                                                                                                                                        |            |                              |                               | 73                                                                                               |                          |             |                               |                                                                                                                          |      |                                         |
|                                                                                                                                        |            | 10 seconds                   |                               | 82                                                                                               |                          |             |                               |                                                                                                                          |      |                                         |
|                                                                                                                                        |            | 20                           |                               | 81                                                                                               |                          |             |                               |                                                                                                                          |      |                                         |
|                                                                                                                                        |            | 30                           |                               | 82                                                                                               |                          |             |                               |                                                                                                                          |      |                                         |
|                                                                                                                                        |            | 40                           |                               | 81                                                                                               |                          |             |                               |                                                                                                                          |      |                                         |
|                                                                                                                                        |            | 50                           |                               | 81                                                                                               |                          |             |                               |                                                                                                                          |      |                                         |
|                                                                                                                                        |            | 1 minute                     |                               | 81                                                                                               |                          |             |                               |                                                                                                                          |      |                                         |
|                                                                                                                                        |            | 10                           |                               | 81                                                                                               |                          |             |                               |                                                                                                                          |      |                                         |
|                                                                                                                                        |            | 20                           |                               |                                                                                                  |                          |             |                               |                                                                                                                          |      |                                         |
|                                                                                                                                        |            | 30                           |                               |                                                                                                  |                          |             |                               |                                                                                                                          |      |                                         |
|                                                                                                                                        |            | 40                           |                               | 81                                                                                               |                          |             |                               |                                                                                                                          |      |                                         |
|                                                                                                                                        |            | 50                           |                               | 80                                                                                               |                          |             |                               |                                                                                                                          |      |                                         |
|                                                                                                                                        |            | 2 minutes                    |                               | 80                                                                                               |                          |             |                               |                                                                                                                          |      |                                         |
|                                                                                                                                        |            | 2.5                          |                               | 80                                                                                               |                          |             |                               |                                                                                                                          |      |                                         |
|                                                                                                                                        |            | 3.0                          |                               | 80                                                                                               |                          |             |                               |                                                                                                                          |      |                                         |
|                                                                                                                                        |            | 3.5                          |                               | 80                                                                                               |                          |             |                               |                                                                                                                          |      |                                         |
|                                                                                                                                        |            | 4.0                          |                               | 80                                                                                               |                          |             |                               |                                                                                                                          |      |                                         |
|                                                                                                                                        |            | 4.5                          |                               |                                                                                                  |                          |             |                               |                                                                                                                          |      |                                         |
|                                                                                                                                        |            | 5.0                          |                               | 80                                                                                               |                          |             |                               |                                                                                                                          |      |                                         |
|                                                                                                                                        |            | 6                            |                               | 80                                                                                               |                          |             |                               |                                                                                                                          |      |                                         |
|                                                                                                                                        |            | 7                            |                               |                                                                                                  |                          |             |                               |                                                                                                                          |      |                                         |
|                                                                                                                                        |            | 8                            |                               | 80                                                                                               |                          |             |                               |                                                                                                                          |      |                                         |
|                                                                                                                                        |            | 9                            |                               |                                                                                                  |                          |             |                               |                                                                                                                          |      |                                         |
|                                                                                                                                        |            | 10                           |                               | 81                                                                                               |                          |             |                               |                                                                                                                          |      |                                         |
|                                                                                                                                        |            | 11                           |                               | 81                                                                                               |                          |             |                               |                                                                                                                          |      |                                         |
|                                                                                                                                        |            | 12                           |                               | 81                                                                                               |                          |             |                               |                                                                                                                          |      |                                         |
|                                                                                                                                        |            | 13                           |                               | 81                                                                                               |                          |             |                               |                                                                                                                          |      |                                         |
|                                                                                                                                        |            | 14                           |                               | 81                                                                                               |                          |             |                               |                                                                                                                          |      |                                         |
|                                                                                                                                        |            | 15                           |                               | 81                                                                                               |                          |             |                               |                                                                                                                          |      |                                         |

### AQUIFER TEST DATA

Owner \_\_\_\_\_ Address \_\_\_\_\_ County \_\_\_\_\_ State \_\_\_\_\_

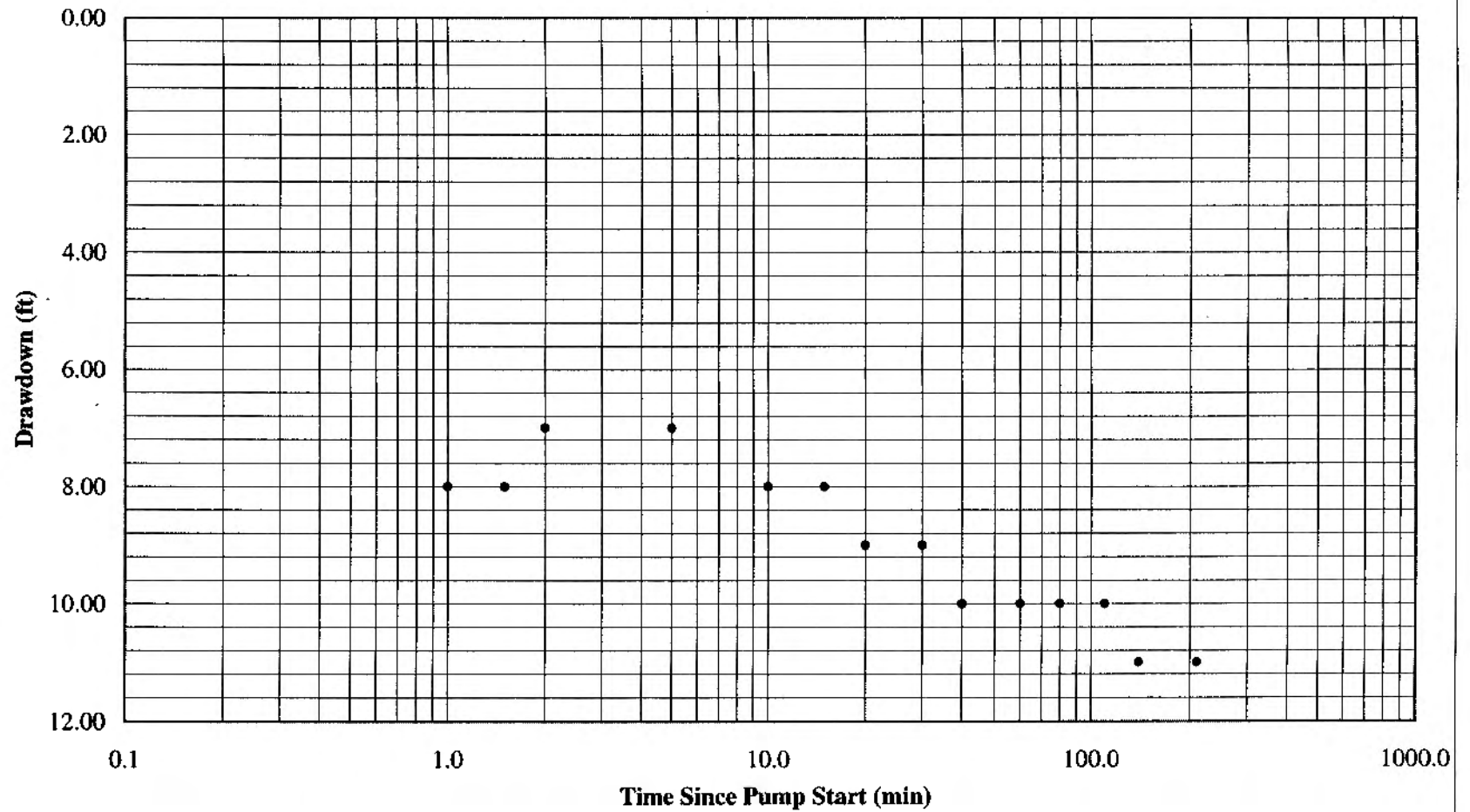
Date \_\_\_\_\_ Company performing test \_\_\_\_\_ Measured by \_\_\_\_\_

Well No. \_\_\_\_\_ Distance from pumping well \_\_\_\_\_ Type of test \_\_\_\_\_ Test No. \_\_\_\_\_

### Measuring equipment

[illegible]

**Time-Drawdown Curve**  
**Pumping Test for George White Well #4**







Measuring equipment Air line 173° 10-75

| Time Data                                       |            |                                      |                            | Water Level Data                   |                              |                          |             | Discharge Data                                                                        |                       |                                           |  | Comments on factors affecting test data |
|-------------------------------------------------|------------|--------------------------------------|----------------------------|------------------------------------|------------------------------|--------------------------|-------------|---------------------------------------------------------------------------------------|-----------------------|-------------------------------------------|--|-----------------------------------------|
| Pump on: Date <u>12/13</u> Time <u>7:15</u> (t) |            | Pump off: Date _____ Time _____ (t') |                            | Static water level _____           |                              | Measuring point _____    |             | How Q measured _____                                                                  |                       | Depth of pump/air line <u>173'</u>        |  |                                         |
| Duration of aquifer test:                       |            |                                      |                            | Elevation of measuring point _____ |                              |                          |             | Previous pumping? Yes <input checked="" type="checkbox"/> No <input type="checkbox"/> |                       | Duration _____ End <u>19 hrs</u> previous |  |                                         |
| Date                                            | Clock time | Time since pump started t            | Time since pump stopped t' | 11'                                | 126' Water level measurement | Correction or Conversion | Water level | Water level change s or s'                                                            | Discharge measurement | Rate                                      |  |                                         |
| 12/13                                           |            |                                      |                            |                                    | 125                          |                          |             |                                                                                       |                       |                                           |  |                                         |
|                                                 |            | 10 sec.                              |                            |                                    | 125                          |                          |             |                                                                                       |                       |                                           |  |                                         |
|                                                 |            | 20                                   |                            |                                    | 124                          |                          |             |                                                                                       |                       |                                           |  |                                         |
|                                                 |            | 30                                   |                            |                                    | 124                          |                          |             |                                                                                       |                       |                                           |  |                                         |
|                                                 |            | 40                                   |                            |                                    | 124                          |                          |             |                                                                                       |                       |                                           |  |                                         |
|                                                 |            | 50                                   |                            |                                    | 124                          |                          |             |                                                                                       |                       |                                           |  |                                         |
|                                                 |            | <del>1.00</del>                      |                            |                                    |                              |                          |             |                                                                                       |                       |                                           |  |                                         |
|                                                 |            | 1.00 min.                            |                            |                                    | 124                          |                          |             |                                                                                       |                       |                                           |  |                                         |
|                                                 |            | 10                                   |                            |                                    | 124                          |                          |             |                                                                                       |                       |                                           |  |                                         |
|                                                 |            | 20                                   |                            |                                    |                              |                          |             |                                                                                       |                       |                                           |  |                                         |
|                                                 |            | 30                                   |                            |                                    | 124                          |                          |             |                                                                                       |                       |                                           |  |                                         |
|                                                 |            | 40                                   |                            |                                    | "                            |                          |             |                                                                                       |                       |                                           |  |                                         |
|                                                 |            | 50                                   |                            |                                    | "                            |                          |             |                                                                                       |                       |                                           |  |                                         |
|                                                 |            | 2 min.                               |                            |                                    | 124                          |                          |             |                                                                                       |                       |                                           |  |                                         |
|                                                 |            | 2.5                                  |                            |                                    | 124                          |                          |             |                                                                                       |                       |                                           |  |                                         |
|                                                 |            | 3.0                                  |                            |                                    | 124                          |                          |             |                                                                                       |                       |                                           |  |                                         |
|                                                 |            | 3.5                                  |                            |                                    | 124                          |                          |             |                                                                                       |                       |                                           |  |                                         |
|                                                 |            | 4.0                                  |                            |                                    | "                            |                          |             |                                                                                       |                       |                                           |  |                                         |
|                                                 |            | 4.5                                  |                            |                                    |                              |                          |             |                                                                                       |                       |                                           |  |                                         |
|                                                 |            | 5.0                                  |                            |                                    | 124                          |                          |             |                                                                                       |                       |                                           |  |                                         |
|                                                 |            | 6                                    |                            |                                    | 124                          |                          |             |                                                                                       |                       |                                           |  |                                         |
|                                                 |            | 7                                    |                            |                                    | 124                          |                          |             |                                                                                       |                       |                                           |  |                                         |
|                                                 |            | 8                                    |                            |                                    | 124                          |                          |             |                                                                                       |                       |                                           |  |                                         |
|                                                 |            | 9                                    |                            |                                    |                              |                          |             |                                                                                       |                       |                                           |  |                                         |
|                                                 |            | 10                                   |                            |                                    |                              |                          |             |                                                                                       |                       |                                           |  |                                         |

pumping at ~~520~~ 80  
 measured in well hole  
 at well #4, gauge  
 1000 gallons in  
 1 minute ~~51~~ sec

Air gauge did not seem to be working properly, so I stopped the test and

### AQUIFER TEST DATA

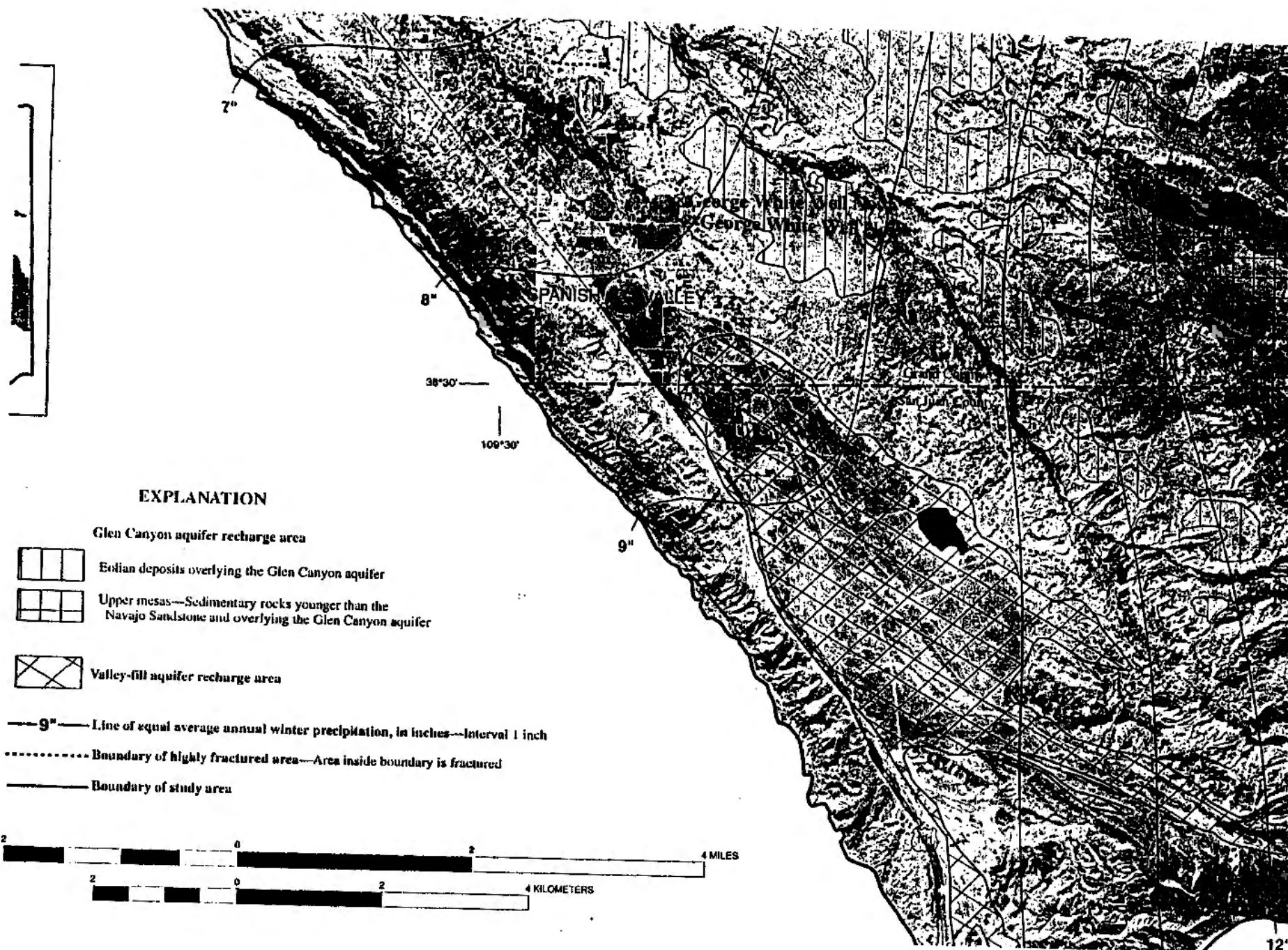
Owner Grand County Address \_\_\_\_\_ County \_\_\_\_\_ State \_\_\_\_\_  
Date 12/14/93 Company performing test \_\_\_\_\_ Measured by Ken Oken  
Well No. G.W. #5 Distance from pumping well \_\_\_\_\_ Type of test Abandon, observation well Test No. \_\_\_\_\_  
Measuring equipment Observation well as well no. 4 was pumped.

| Time Data                           |                                      |                                 |                               |                | Water Level Data         |                          |                                    |                               | Discharge Data               |                                      |                          | Comments on factors affecting test data |
|-------------------------------------|--------------------------------------|---------------------------------|-------------------------------|----------------|--------------------------|--------------------------|------------------------------------|-------------------------------|------------------------------|--------------------------------------|--------------------------|-----------------------------------------|
| Pump on: Date _____ Time _____ (t.) | Pump off: Date _____ Time _____ (t') | Duration of aquifer test: _____ | Pumping _____                 | Recovery _____ | Static water level _____ | Measuring point _____    | Elevation of measuring point _____ | How Q measured _____          | Depth of pump/air line _____ | Previous pumping? Yes _____ No _____ | Duration _____ End _____ |                                         |
| Date                                | Clock time                           | Time since pump started<br>t    | Time since pump stopped<br>t' | t/t'           | Water level measurement  | Correction or Conversion | Water level                        | Water level change<br>s or s' | Discharge measurement        | Rate                                 |                          |                                         |
| 12-13                               | 000                                  |                                 |                               |                | 117                      |                          |                                    |                               |                              |                                      |                          |                                         |
|                                     | 10                                   |                                 |                               |                | 118                      |                          |                                    |                               |                              |                                      |                          |                                         |
|                                     | 20                                   |                                 |                               |                | 118                      |                          |                                    |                               |                              |                                      |                          |                                         |
|                                     | 30                                   |                                 |                               |                |                          |                          |                                    |                               |                              |                                      |                          |                                         |
|                                     | 40                                   |                                 |                               |                |                          |                          |                                    |                               |                              |                                      |                          |                                         |
|                                     | 50                                   |                                 |                               |                |                          |                          |                                    |                               |                              |                                      |                          |                                         |
|                                     | 60                                   |                                 |                               |                |                          |                          |                                    |                               |                              |                                      |                          |                                         |
|                                     | 110                                  |                                 |                               |                |                          |                          |                                    |                               |                              |                                      |                          |                                         |
|                                     | 120                                  |                                 |                               |                |                          |                          |                                    |                               |                              |                                      |                          |                                         |
|                                     | 130                                  |                                 |                               |                |                          |                          |                                    |                               |                              |                                      |                          |                                         |
|                                     | 140                                  |                                 |                               |                |                          |                          |                                    |                               |                              |                                      |                          |                                         |
|                                     | 150                                  |                                 |                               |                |                          |                          |                                    |                               |                              |                                      |                          |                                         |
|                                     | 200                                  |                                 |                               |                | 118                      |                          |                                    |                               |                              |                                      |                          |                                         |
|                                     | 230                                  |                                 |                               |                | 118                      |                          |                                    |                               |                              |                                      |                          |                                         |
|                                     | 500                                  |                                 |                               |                | 118                      |                          |                                    |                               |                              |                                      |                          |                                         |
|                                     | 601                                  |                                 |                               |                | 118                      |                          |                                    |                               |                              |                                      |                          |                                         |
|                                     |                                      |                                 |                               |                |                          |                          |                                    |                               |                              |                                      |                          |                                         |
|                                     | 800                                  |                                 |                               |                | 118                      |                          |                                    |                               |                              |                                      |                          |                                         |
|                                     |                                      |                                 |                               |                |                          |                          |                                    |                               |                              |                                      |                          |                                         |
|                                     | 1200                                 |                                 |                               |                | 118                      |                          |                                    |                               |                              |                                      |                          |                                         |
|                                     |                                      |                                 |                               |                |                          |                          |                                    |                               |                              |                                      |                          |                                         |
|                                     | 1500                                 |                                 |                               |                | 118                      |                          |                                    |                               |                              |                                      |                          |                                         |
|                                     |                                      |                                 |                               |                |                          |                          |                                    |                               |                              |                                      |                          |                                         |
|                                     | 2000                                 |                                 |                               |                | 118                      |                          |                                    |                               |                              |                                      |                          |                                         |
|                                     | 2500                                 |                                 |                               |                | 118                      |                          |                                    |                               |                              |                                      |                          |                                         |
|                                     | 3000                                 |                                 |                               |                | 118                      |                          |                                    |                               |                              |                                      |                          |                                         |
|                                     | 4000                                 |                                 |                               |                | 118                      |                          |                                    |                               |                              |                                      |                          |                                         |

[illegible]

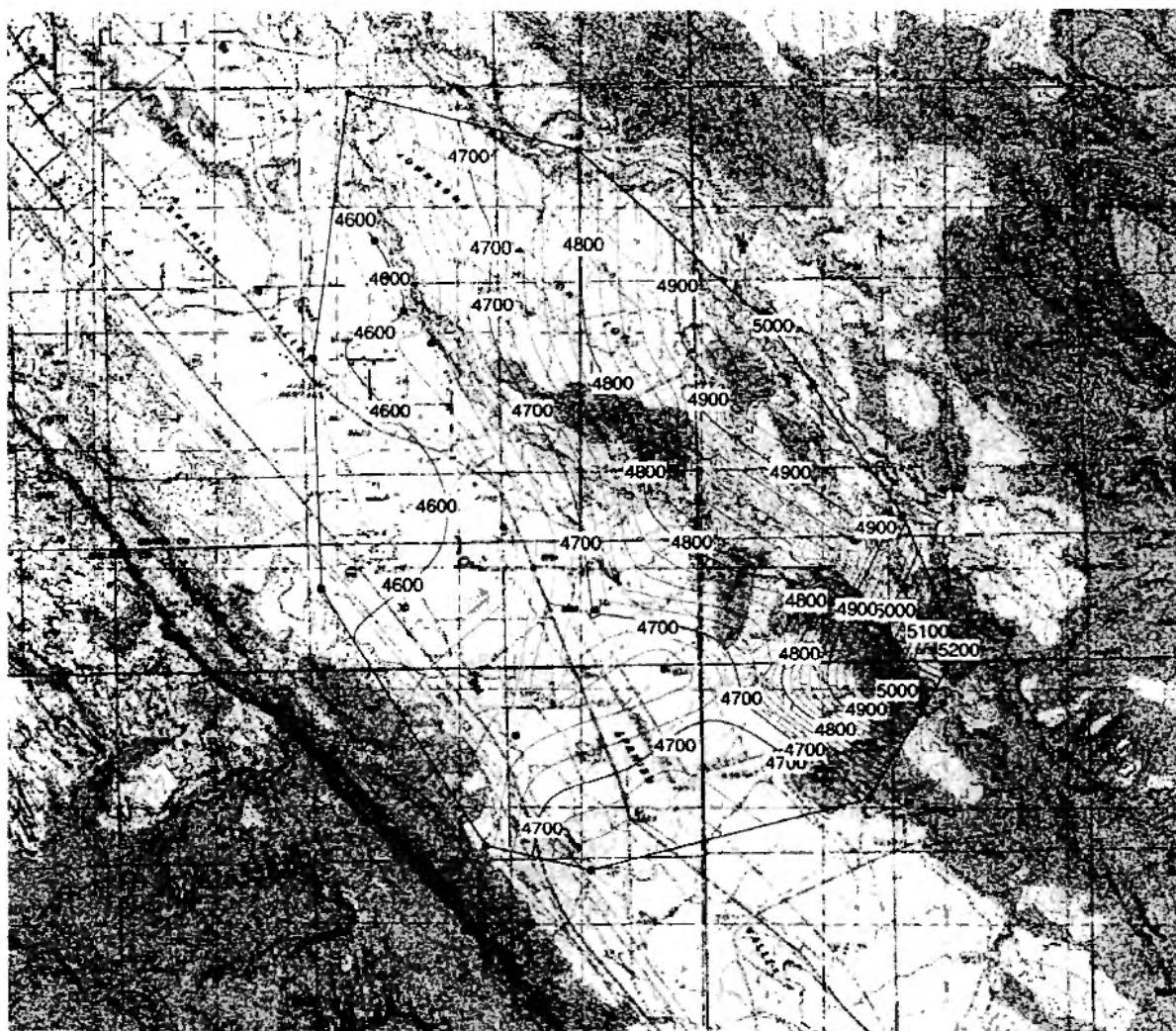
**Appendix D**  
**Map Showing the Fractured Area**





**Appendix E**  
**Groundwater Level Contour Map**

## Groundwater Level Contour Map



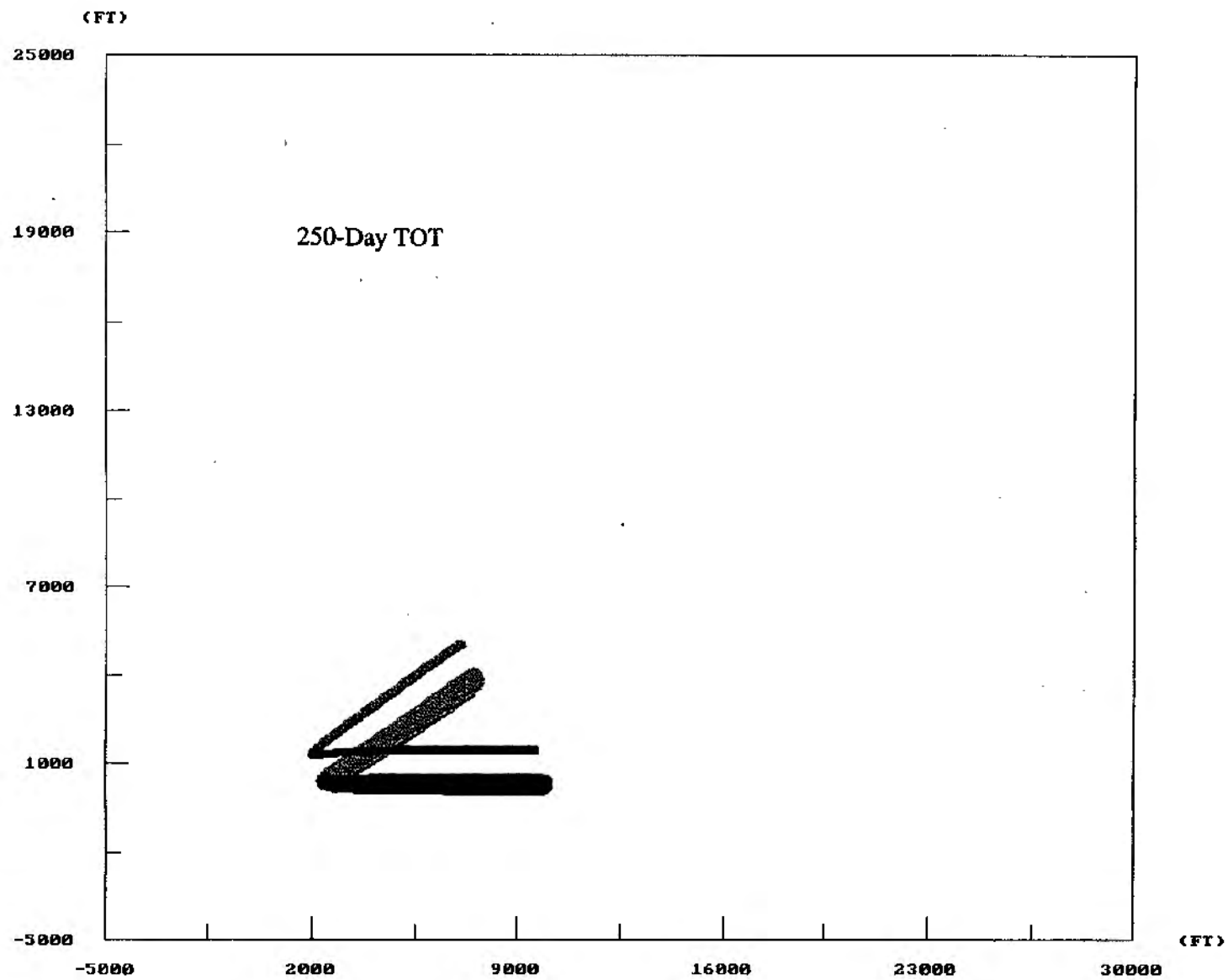
Scale: 1 inch = 1 mile

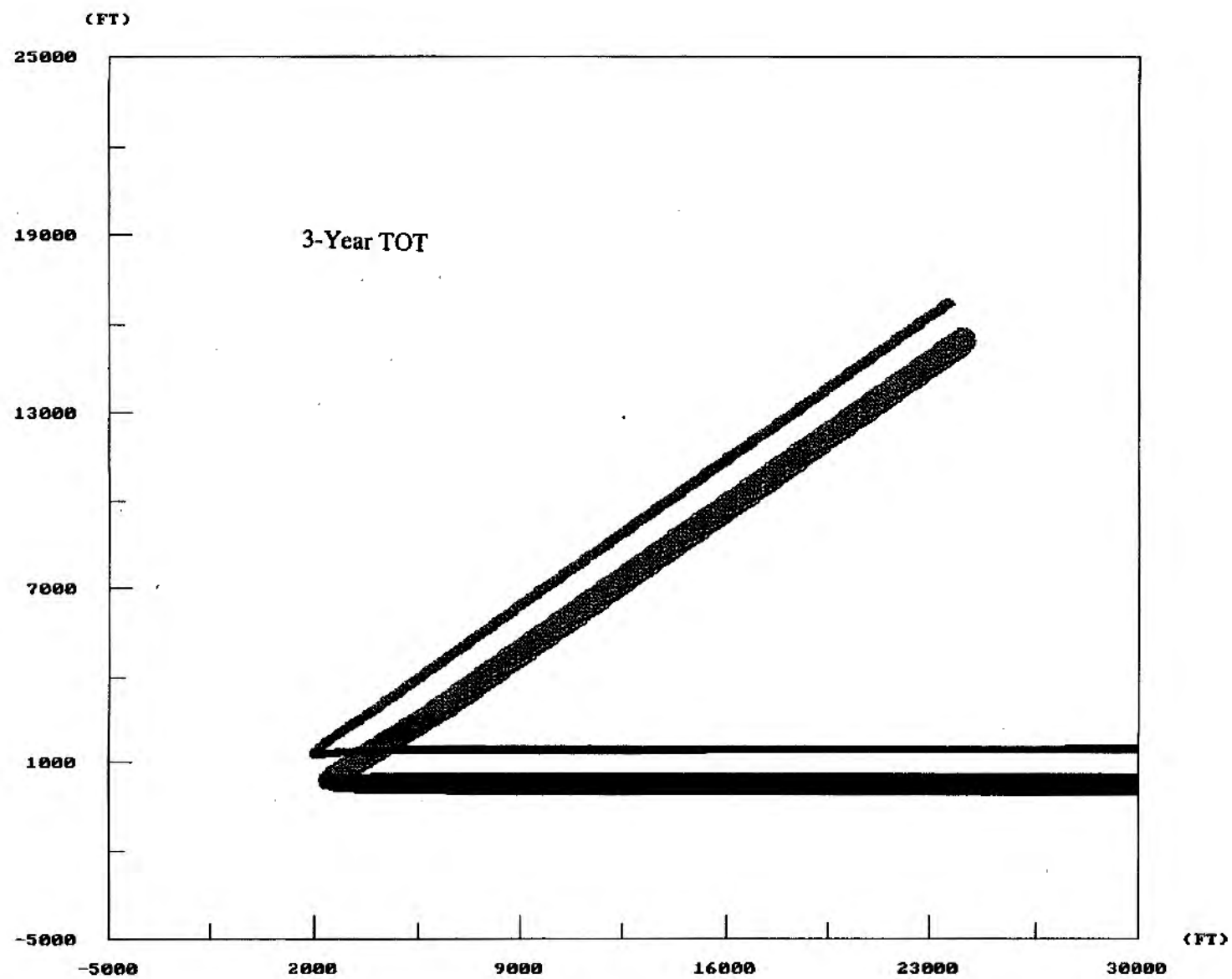
Source: Hydrogeologic Assessment / Well Siting Study  
for Spanish Valley W&S Improvement District (Sunrise, 1999)

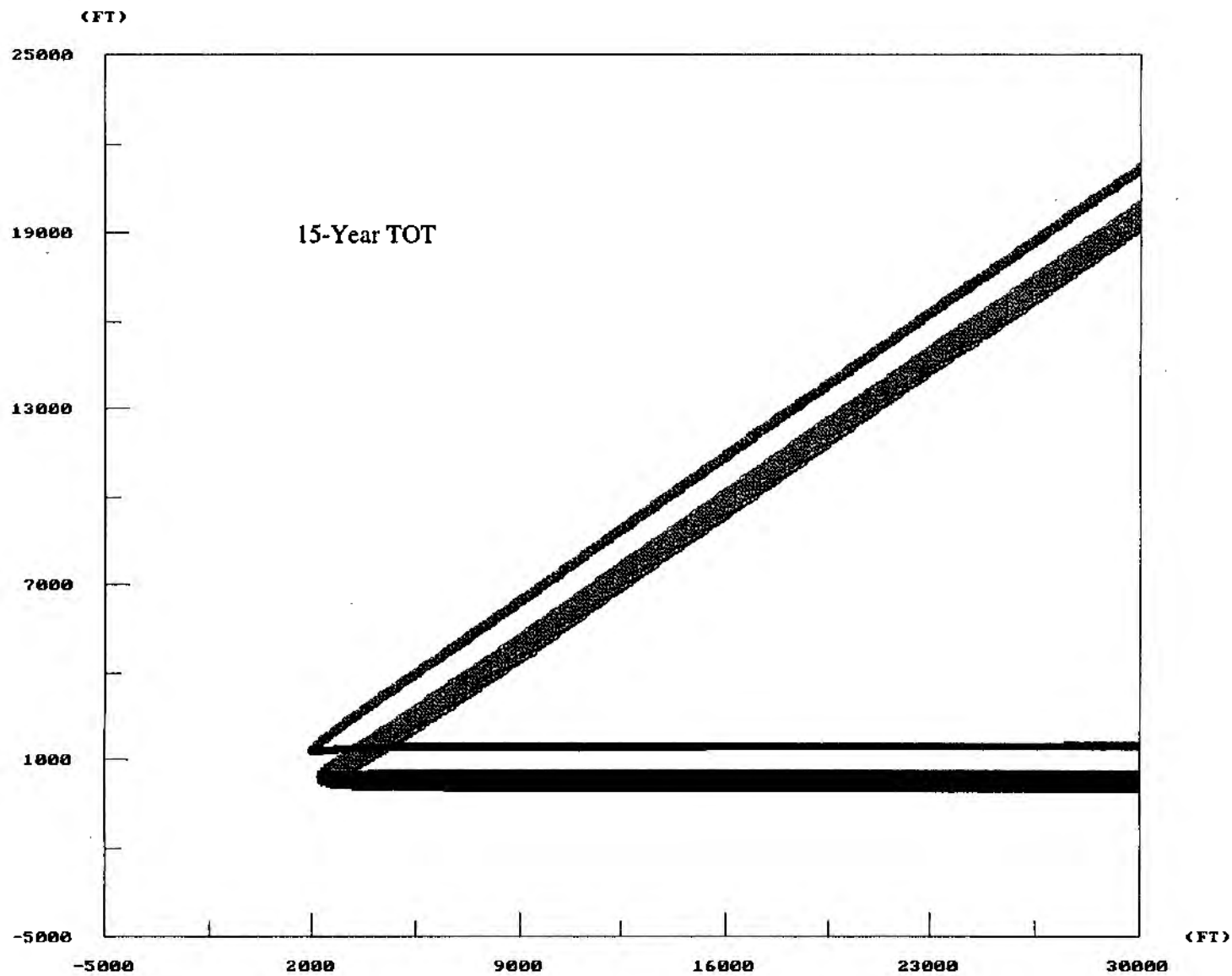
**Appendix F**  
**Model Output from WHPA**

**F-I**  
**Without Well Interference**

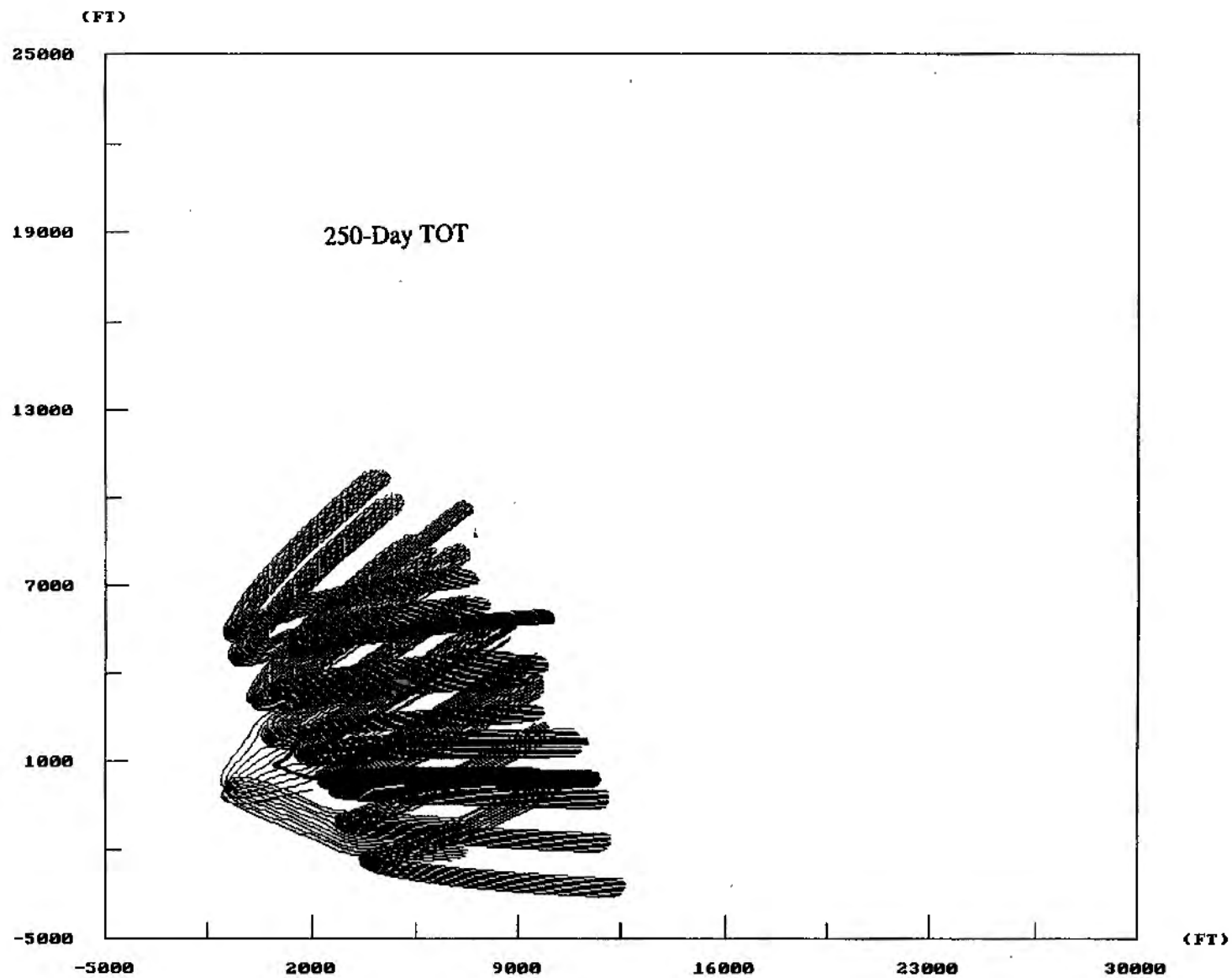




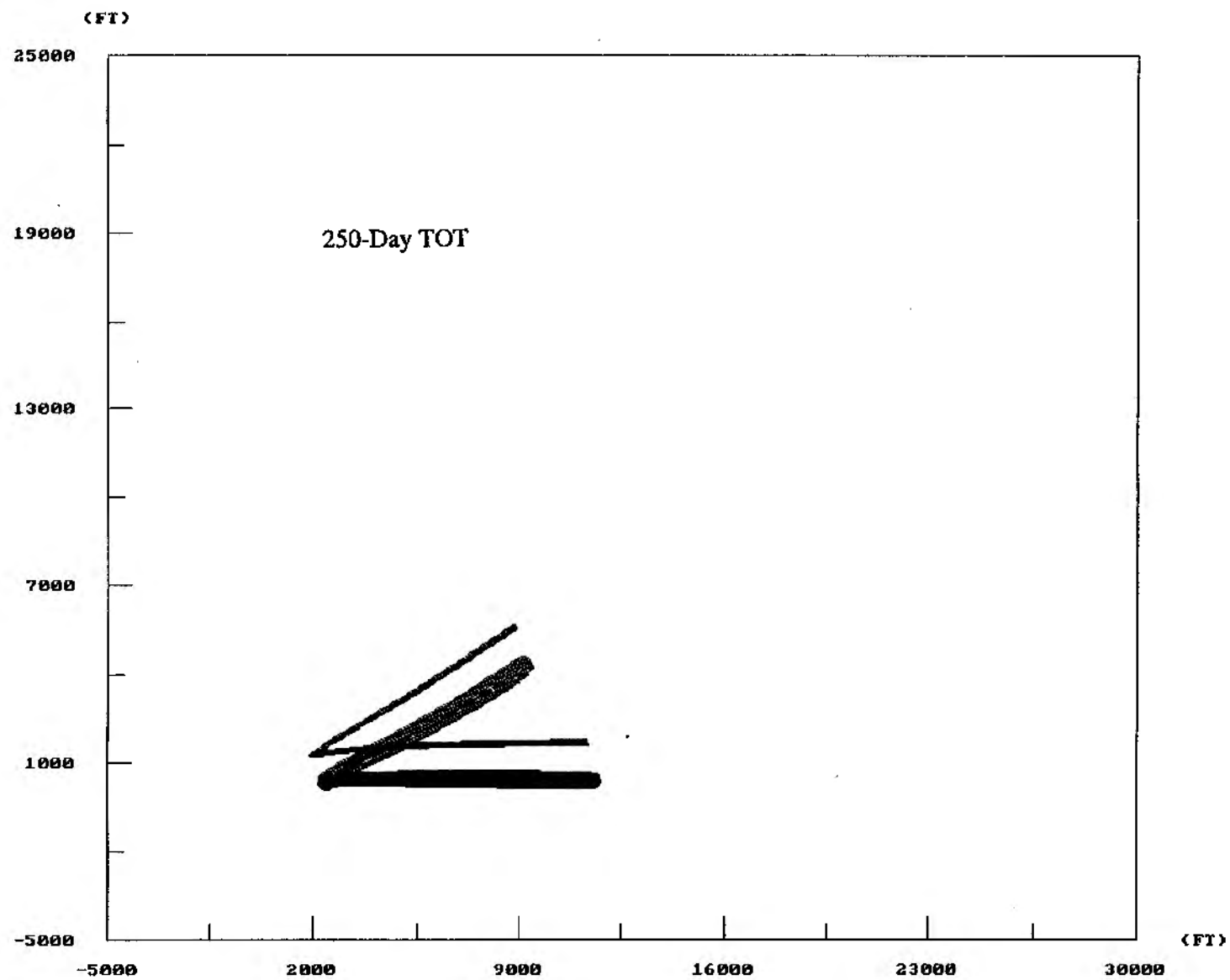


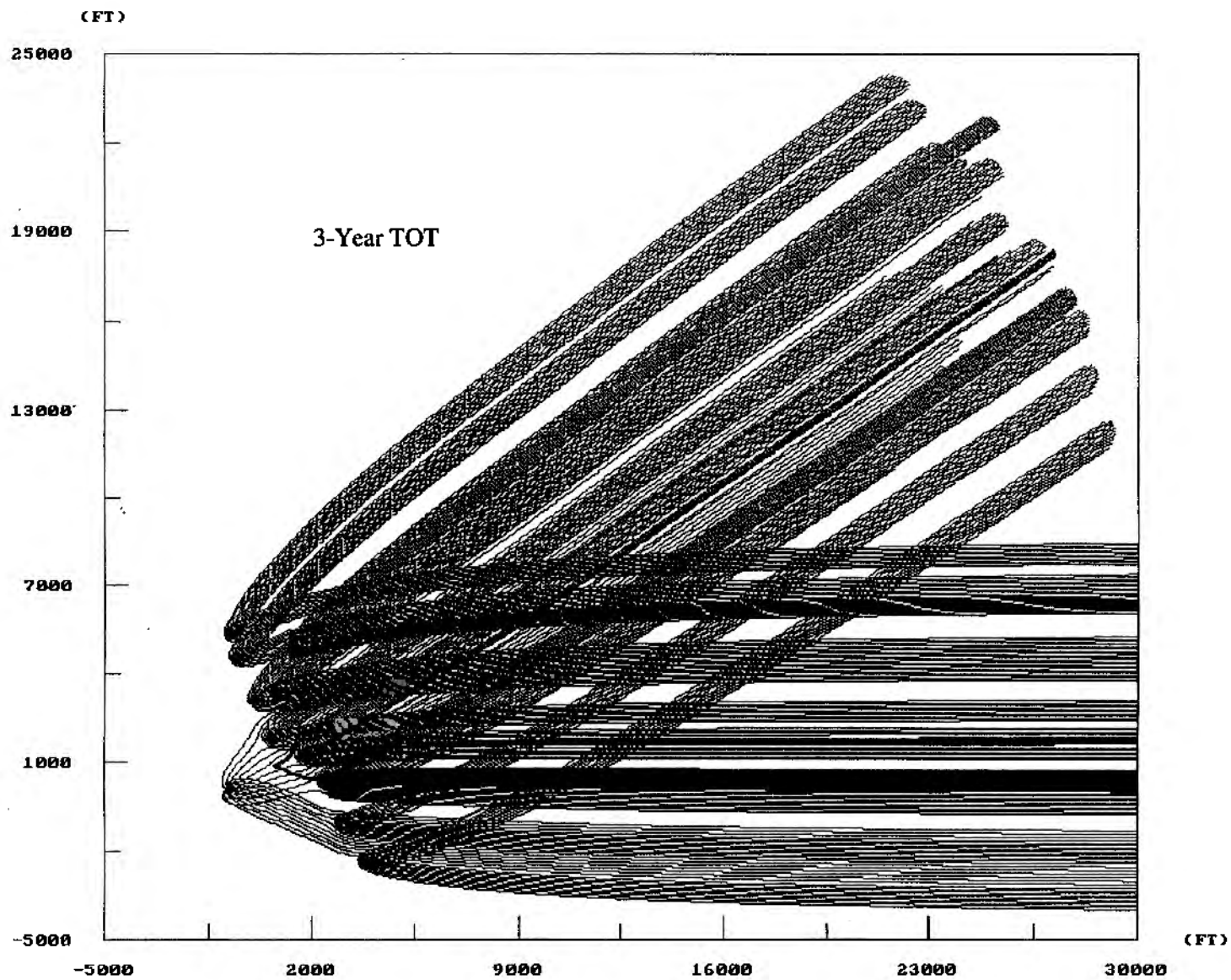


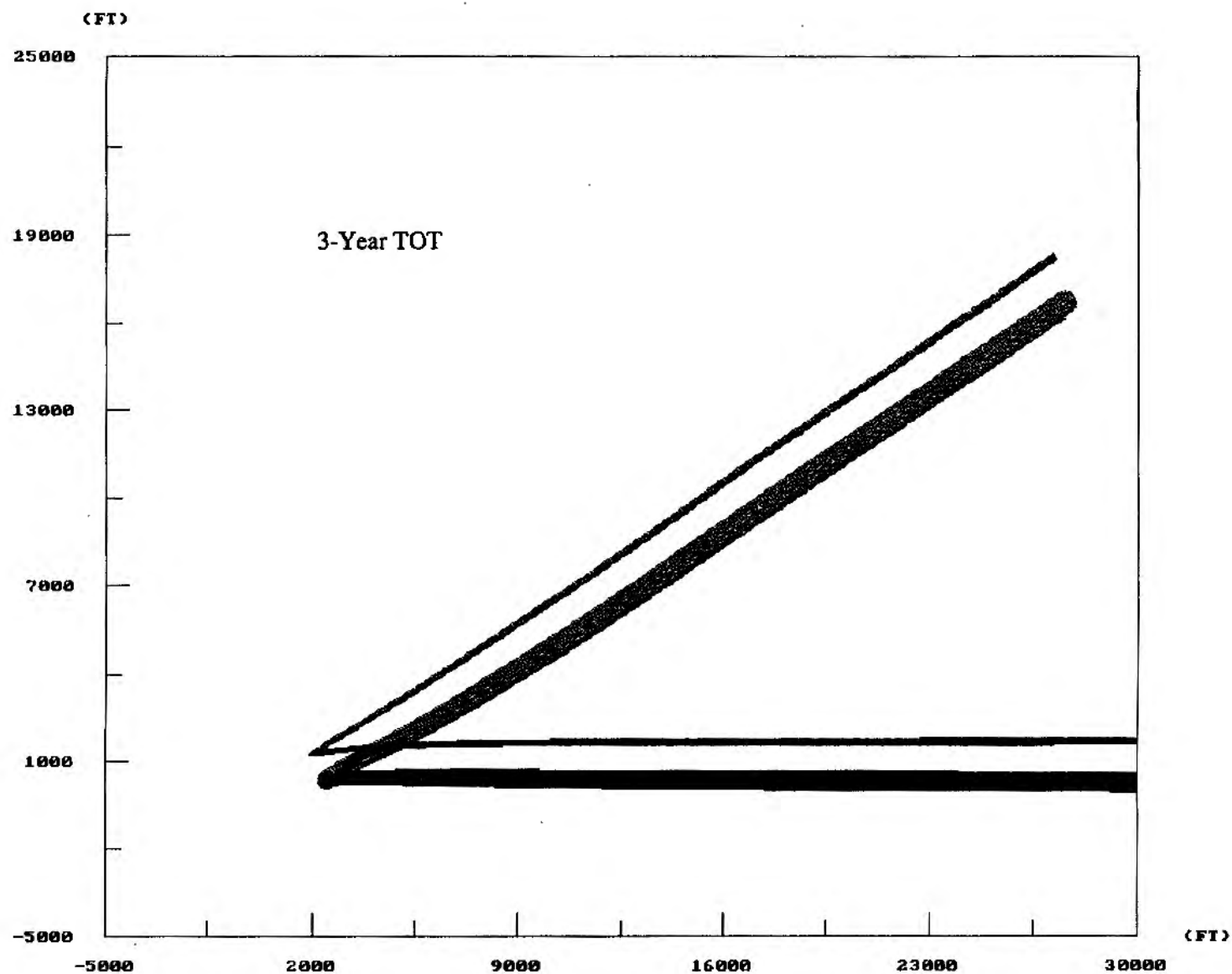
**F-II**  
**Well Interference Analysis**

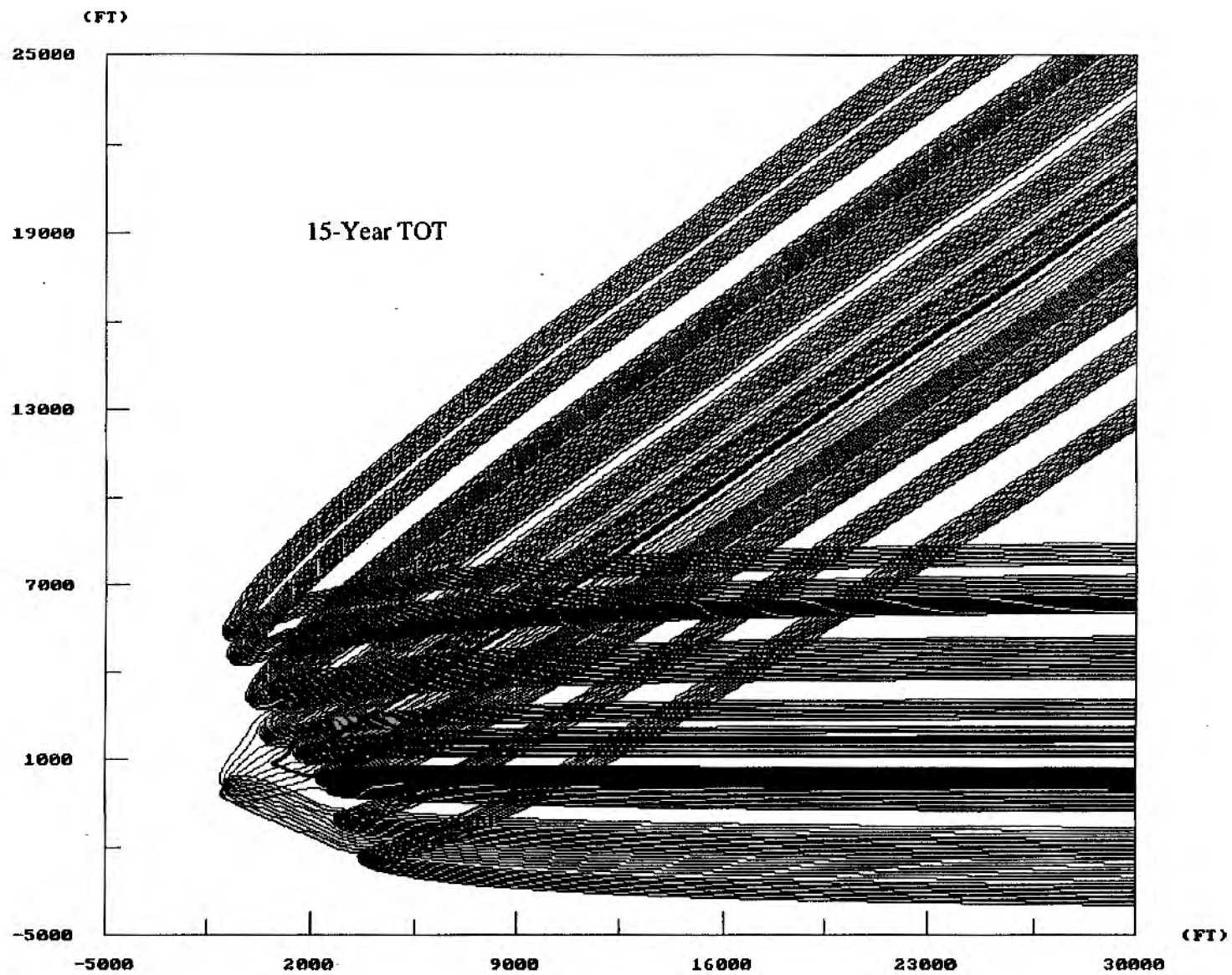


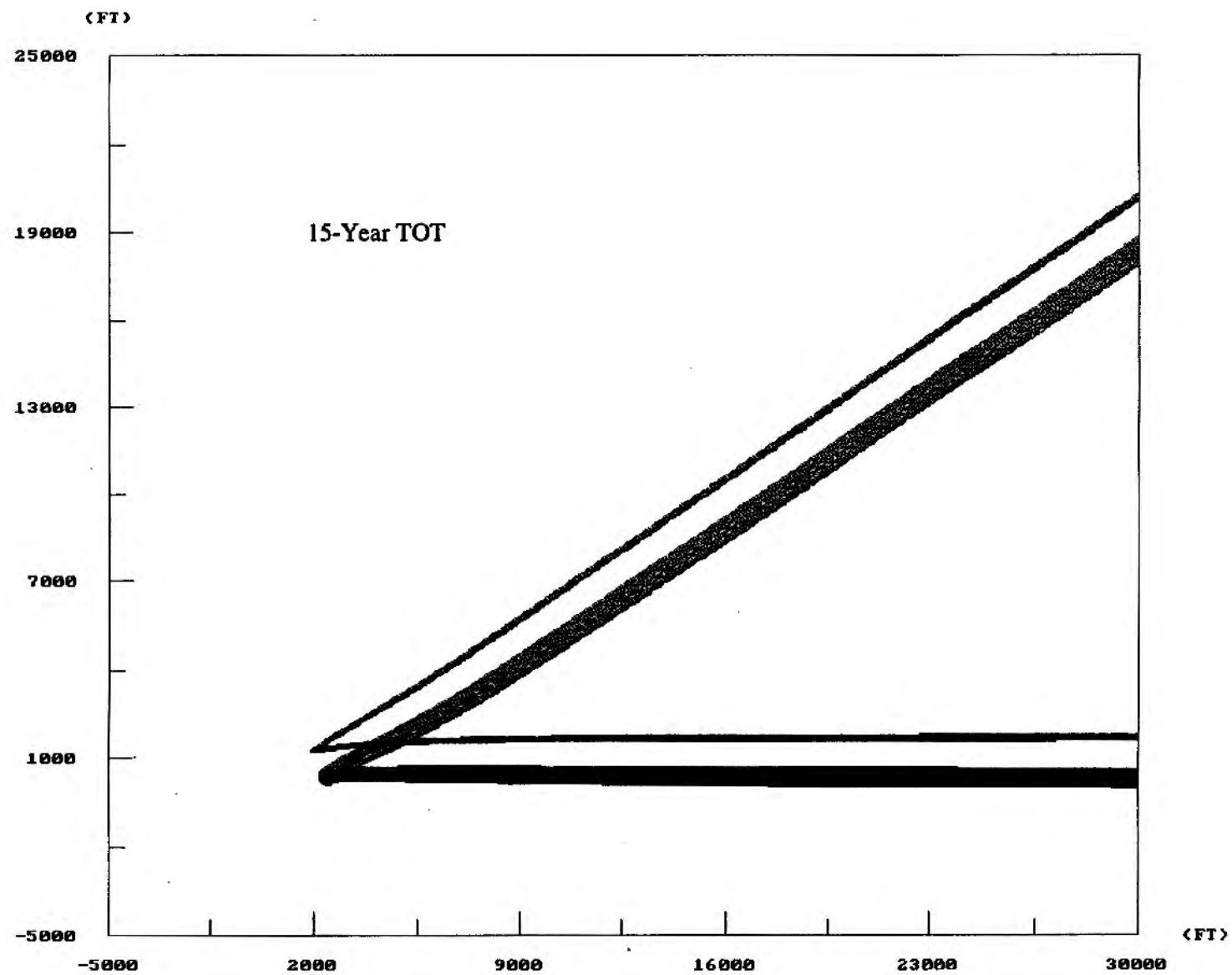






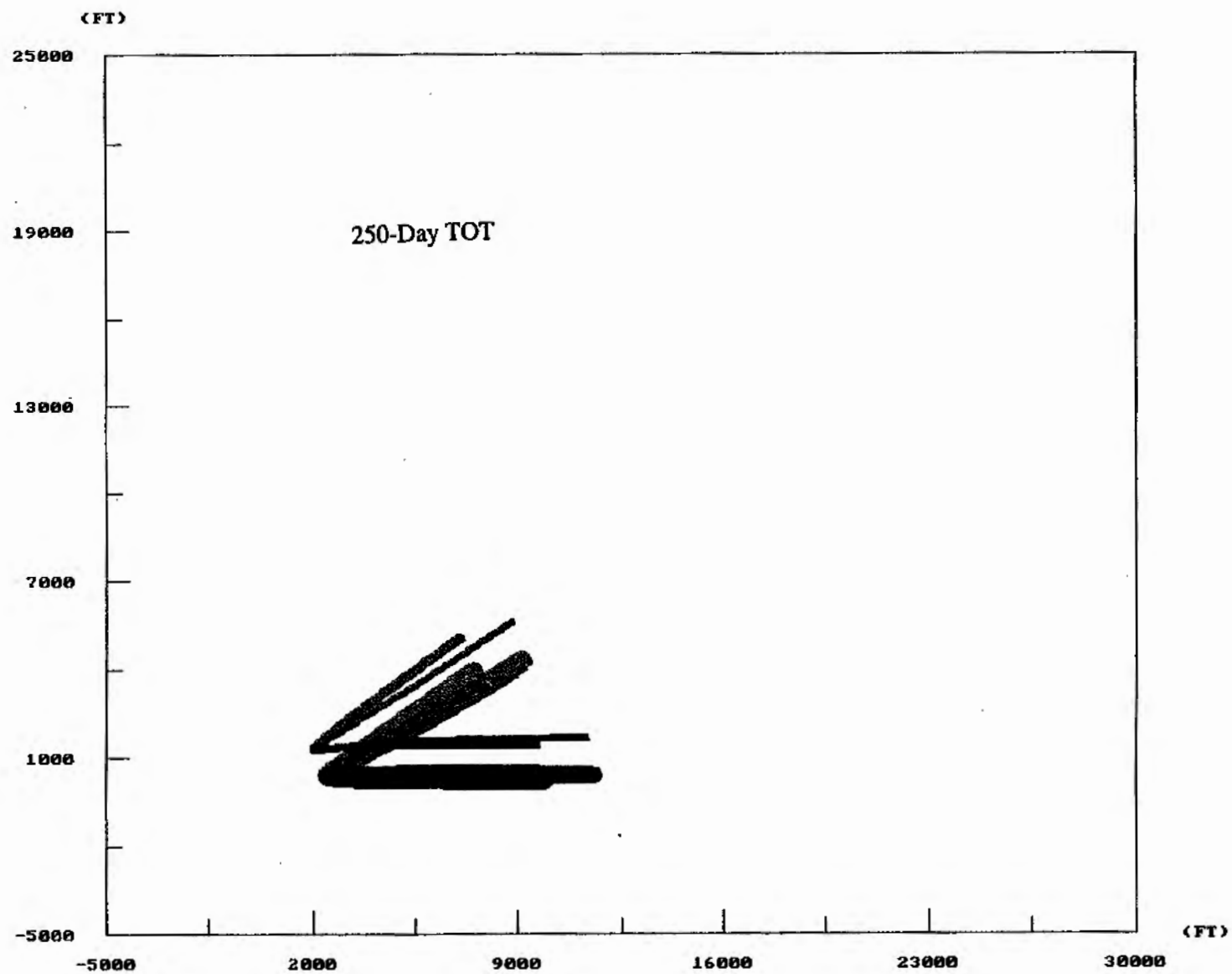


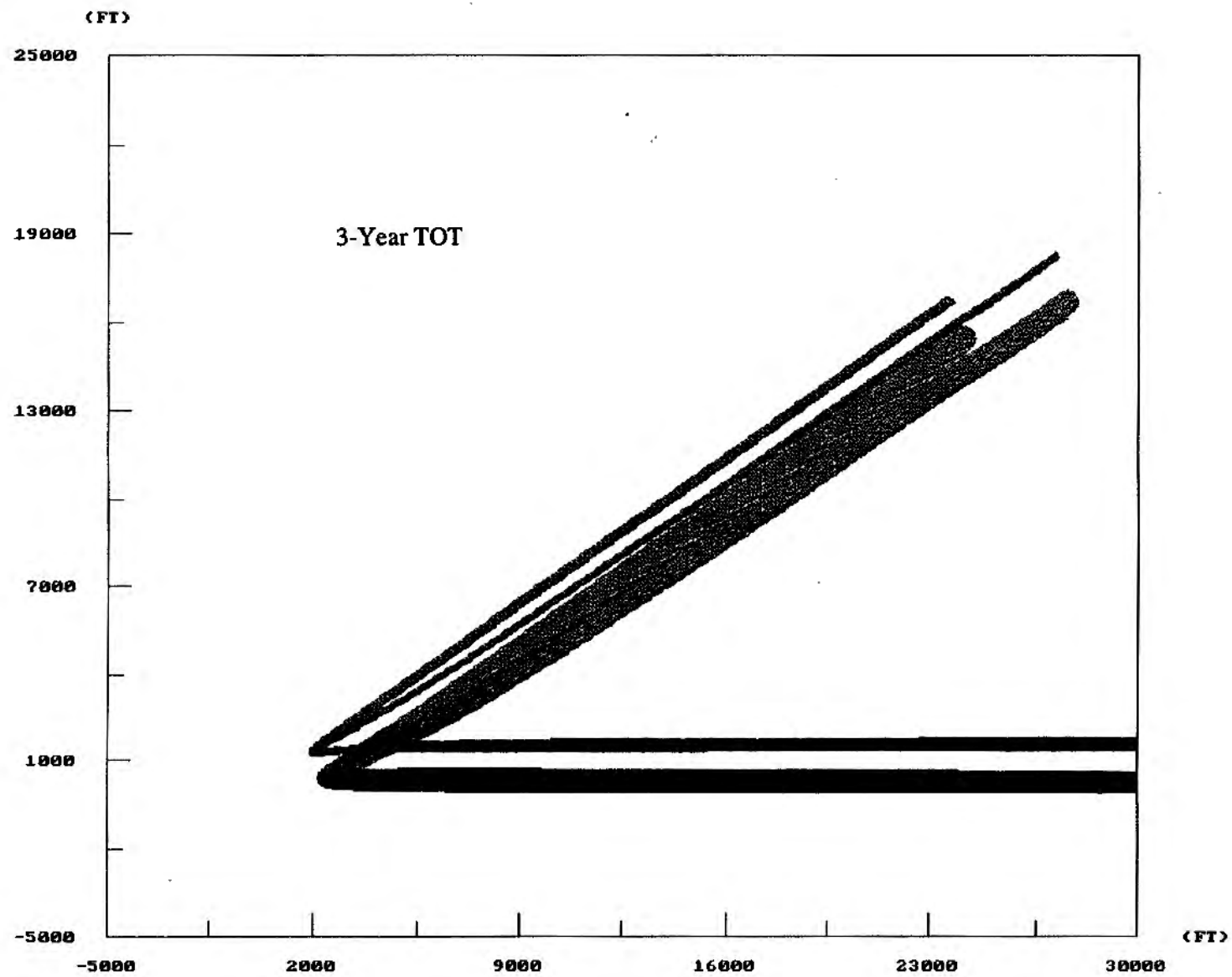


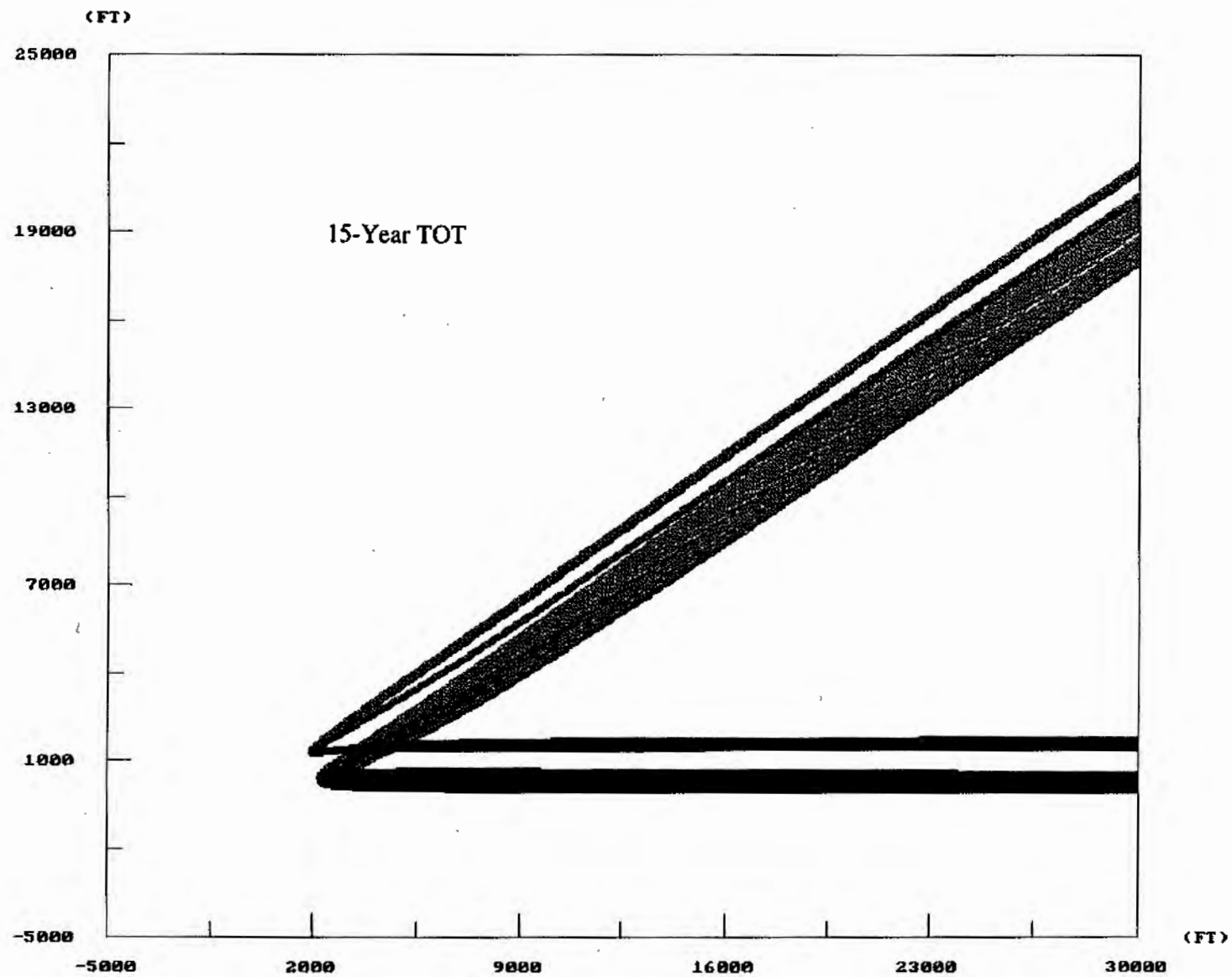


**F-III**  
**Combination of Outputs F-I and F-II**









**Appendix G**  
**Checklist of Potential Contamination Sources**

**Checklist of Potential Contamination Sources**  
**Gorge White Wells No.4 and No. 5**  
**Grand County Water and Sewer Service Agency**  
**Moab, Utah**

| Source # | Potential Contamination Source                                                                                                                                                     | Within<br>Zone<br>One | Within<br>Zone<br>Two | Within<br>Zone<br>Three | Within<br>Zone<br>Four |
|----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|-----------------------|-------------------------|------------------------|
| 1        | Active and abandoned wells                                                                                                                                                         | None                  | None                  | None                    | None                   |
| 2        | Agricultural pesticide, herbicide and fertilizer storage, use, filling and mixing                                                                                                  | None                  | None                  | None                    | None                   |
| 3        | Airport maintenance and fueling sites                                                                                                                                              | None                  | None                  | None                    | None                   |
| 4        | Animal feeding operations with more than ten units                                                                                                                                 | None                  | None                  | None                    | None                   |
| 5        | Animal watering troughs located near unfenced wells and springs that attract livestock                                                                                             | None                  | None                  | None                    | None                   |
| 6        | Auto washes                                                                                                                                                                        | None                  | None                  | None                    | None                   |
| 7        | Beauty salons                                                                                                                                                                      | None                  | None                  | None                    | None                   |
| 8        | Boat builder and refinishers                                                                                                                                                       | None                  | None                  | None                    | None                   |
| 9        | Chemical reclamation facilities                                                                                                                                                    | None                  | None                  | None                    | None                   |
| 10       | Chemigation wells                                                                                                                                                                  | None                  | None                  | None                    | None                   |
| 11       | Concrete, asphalt, tar and coal companies                                                                                                                                          | None                  | None                  | None                    | None                   |
| 12       | Dry cleaners                                                                                                                                                                       | None                  | None                  | None                    | None                   |
| 13       | Farm dump sites                                                                                                                                                                    | None                  | None                  | None                    | None                   |
| 14       | Farm maintenance garages                                                                                                                                                           | None                  | None                  | None                    | None                   |
| 15       | Feed lots                                                                                                                                                                          | None                  | None                  | None                    | None                   |
| 16       | Food processors, meat packers and slaughter houses                                                                                                                                 | None                  | None                  | None                    | None                   |
| 17       | Fuel and oil distributors and storers                                                                                                                                              | None                  | None                  | None                    | None                   |
| 18       | Furniture strippers, painters, finishers and appliance repairers                                                                                                                   | None                  | None                  | None                    | None                   |
| 19       | Grave yards, golf courses, parks and nurseries                                                                                                                                     | None                  | None                  | None                    | None                   |
| 20       | Heating oil storers                                                                                                                                                                | None                  | None                  | None                    | None                   |
| 21       | Industrial manufacturers: chemicals, pesticides, paper and leather products, textiles, rubber, plastic, fiberglass, silicone, glass, pharmaceutical and electrical equipment, etc. | None                  | None                  | None                    | None                   |
| 22       | Industrial waste disposal/improvement areas and municipal wastewater treatment plants, landfills, dumps and transfer stations                                                      | None                  | None                  | None                    | None                   |
| 23       | Junk and salvage yards                                                                                                                                                             | None                  | None                  | None                    | None                   |
| 24       | Laundromats                                                                                                                                                                        | None                  | None                  | None                    | None                   |
| 25       | Machine shops, metal platers, heat treaters, smelters, annealers and descalers                                                                                                     | None                  | None                  | None                    | None                   |
| 26       | Manure piles                                                                                                                                                                       | None                  | None                  | None                    | None                   |
| 27       | Medical, dental and veterinarian offices                                                                                                                                           | None                  | None                  | None                    | None                   |
| 28       | Mortuaries                                                                                                                                                                         | None                  | None                  | None                    | None                   |
| 29       | Mining operations                                                                                                                                                                  | None                  | None                  | None                    | None                   |
| 30       | Muffler shops                                                                                                                                                                      | None                  | None                  | None                    | None                   |

**Checklist of Potential Contamination Sources**  
**Gorge White Wells No.4 and No. 5**  
**Grand County Water and Sewer Service Agency**  
**Moab, Utah**

| Source # | Potential Contamination Source                                                                                   | Within<br>Zone<br>One | Within<br>Zone<br>Two | Within<br>Zone<br>Three | Within<br>Zone<br>Four |
|----------|------------------------------------------------------------------------------------------------------------------|-----------------------|-----------------------|-------------------------|------------------------|
| 31       | Pesticide and herbicide storers and retailers                                                                    | None                  | None                  | None                    | None                   |
| 32       | Photo processors                                                                                                 | None                  | None                  | None                    | None                   |
| 33       | Print shops                                                                                                      | None                  | None                  | None                    | None                   |
| 34       | Radiological mining operations                                                                                   | None                  | None                  | None                    | None                   |
| 35       | Railroad yards                                                                                                   | None                  | None                  | None                    | None                   |
| 36       | Research laboratories                                                                                            | None                  | None                  | None                    | None                   |
| 37       | Residential pesticide, herbicide and fertilizer storage, use, filling and mixing areas                           | None                  | None                  | None                    | None                   |
| 38       | Residential underground storage tanks                                                                            | None                  | None                  | None                    | None                   |
| 39       | Salt and sand-salt piles                                                                                         | None                  | None                  | None                    | None                   |
| 40       | Sand and gravel mining operations                                                                                | None                  | None                  | None                    | None                   |
| 41       | School vehicle maintenance barns                                                                                 | None                  | None                  | None                    | None                   |
| 42       | Sewer lines                                                                                                      | None                  | None                  | None                    | None                   |
| 43       | Single-family septic tank/drain-field systems                                                                    | None                  | None                  | None                    | None                   |
| 44       | Sites of reported spills                                                                                         | None                  | None                  | None                    | None                   |
| 45       | Small engine repair shops                                                                                        | None                  | None                  | None                    | None                   |
| 46       | Stormwater impoundment sites and snow dumps                                                                      | None                  | None                  | None                    | None                   |
| 47       | Subdivisions using subsurface wastewater disposal systems (large and individual septic tank/drain-field systems) | None                  | None                  | None                    | None                   |
| 48       | Submersible pumps used to pump wells                                                                             | 2                     | None                  | None                    | None                   |
| 49       | Taxi cab maintenance garages                                                                                     | None                  | None                  | None                    | None                   |
| 50       | Tire shops                                                                                                       | None                  | None                  | None                    | None                   |
| 51       | Toxic chemical and oil pipelines                                                                                 | None                  | None                  | None                    | None                   |
| 52       | Vehicle chemical supply storers and retailers                                                                    | None                  | None                  | None                    | None                   |
| 53       | Vehicle dealerships                                                                                              | None                  | None                  | None                    | None                   |
| 54       | Vehicle quick lubes                                                                                              | None                  | None                  | None                    | None                   |
| 55       | Vehicle rental shops                                                                                             | None                  | None                  | None                    | None                   |
| 56       | Vehicle repair, body shops and rust proofers                                                                     | None                  | None                  | None                    | None                   |
| 57       | Vehicle service stations and terminals                                                                           | None                  | None                  | None                    | None                   |
| 58       | Wood preservers                                                                                                  | None                  | None                  | None                    | None                   |



**Appendix H**  
**Example of Drinking Water Source Protection Ordinance**

## DRINKING WATER SOURCE PROTECTION ORDINANCE

The following is an example of a source protection ordinance. Wellhead Protection Technology Transfer Centerpiece Workshop (EPA/600/K-92/015) was used as a reference. It has been changed to reflect recommendations in the Drinking Water Source Protection Rule, R309-113 of the Utah Administrative Code.

BE IT ORDAINED by the Mayor and Council of the City of \_\_\_\_\_ in Council duly assembled and it is hereby ordained by the authority of same that the following ordinance known as the Drinking Water Source Protection Ordinance is adopted and made a part of the Code of Ordinance of the City of \_\_\_\_\_, to wit:

### Section 1. Short title and purpose.

- (a) This ordinance shall be known as the "Drinking Water Source Protection Ordinance."
- (b) The purpose of this ordinance is to insure the provision of a safe and sanitary drinking water supply for the City by the establishment of drinking water source protection zones surrounding the wellheads for all wells which are the supply sources for the City water system and by the designation and regulation of property uses and conditions which may be maintained within such zones.

Section 2. Definitions. When used in this ordinance the following words and phrases shall have the meanings given in this Section:

- (a) Design standard - means a control which is implemented by a potential contamination source to prevent discharges to the ground water. Spill protection is an example of a design standard.
- (b) Land management strategies - means zoning and non-zoning controls which include, but are not limited to, the following: zoning and subdivision ordinances, site plan reviews, design and operating standards, source prohibitions, purchase of property and development rights, public education programs, ground-water monitoring, household hazardous waste collection programs, water conservation programs, memoranda of understanding, written contracts and agreements, and so forth.
- (c) Pollution source - means point source discharges of contaminants to ground water or potential discharges of the liquid forms of "extremely hazardous substances" which are stored in containers in excess of "applicable threshold planning quantities" as specified in SARA Title III. Examples of possible pollution sources include, but are not limited to, the following: storage facilities that store the liquid forms of extremely hazardous substances, septic tanks, drain fields, class V underground injection wells, landfills, open dumps, landfilling of sludge and septage, manure

piles, salt piles, pit privies, and animal feeding operations with more than ten animal units. The following clarify the definition of pollution source:

- (1) Animal feeding operation - means a lot or facility where the following conditions are met: animals have been or will be stabled or confined and fed or maintained for a total of 45 days or more in any 12 month period, and crops, vegetation forage growth, or post-harvest residues are not sustained in the normal growing season over any portion of the lot or facility. Two or more animal feeding operations under common ownership are considered to be a single feeding operation if they adjoin each other, if they use a common area, or if they use a common system for the disposal of wastes.
- (2) Animal unit - means a unit of measurement for any animal feeding operation calculated by adding the following numbers; the number of slaughter and feeder cattle multiplied by 1.0, plus the number of mature dairy cattle multiplied by 1.4, plus the number of swine weighing over 55 pounds multiplied by 0.4, plus the number of sheep multiplied by 0.1, plus the number of horses multiplied by 2.0.
- (3) Extremely hazardous substances - means those substances which are identified in the Sec. 302(EHS) column of the "TITLE III LIST OF LISTS - Consolidated List of Chemicals Subject to Reporting Under SARA Title III," (EPA 560/4-91-011).
- (d) Potential contamination source - means any facility or site which employs an activity or procedure which may potentially contaminate ground water. A pollution source is also a potential contamination source.
- (e) Regulatory agency - means any governmental agency with jurisdiction over hazardous waste as defined herein.
- (f) Sanitary landfill - means a disposal site where solid wastes, including putrescible wastes, or hazardous wastes, are disposed of on land by placing earth cover thereon.
- (g) Septic tank/drain-field systems - means a system which is comprised of a septic tank and a drain-field which accepts domestic wastewater from buildings or facilities for subsurface treatment and disposal. By their design, septic tank/drain-field system discharges cannot be controlled with design standards.
- (h) Wellhead - means the upper terminal of a well, including adapters, ports, seals, valves and other attachments.

Section 3. Establishment of drinking water source protection zones. There is hereby established use districts to be known as zones one, two, three, and four of the drinking water source protection area, identified and described as follows:

- (a) Zone one is the area within a 100-foot radius from the wellhead.
- (b) Zone two is the area within a 250-day ground-water time of travel to the wellhead, the boundary of the aquifer(s) which supplies water to the ground-water source, or the ground-water divide, whichever is closer.
- (c) Zone three (waiver criteria zone) is the area within a 3-year ground-water time of travel to the wellhead or margin of the collection area, the boundary of the aquifer(s) which supplies water to the ground-water source, or the ground-water divide, whichever is closer.
- (d) Zone four is the area within a 15-year ground-water time of travel to the wellhead, the boundary of the aquifer(s) which supplies water to the ground-water source, or the ground-water divide, whichever is closer.

Section 4. Permitted uses. The following uses shall be permitted within drinking water source protection zones:

- (a) Any use permitted within existing agricultural, single family residential, multi-family residential, and commercial districts so long as uses conform to the rules and regulations of the regulatory agencies.
- (b) Any other open land use where any building located on the property is incidental and accessory to the primary open land use.

Section 5. Prohibited uses. The following uses or conditions shall be and are hereby prohibited within drinking water sources protection zones, whether or not such use or condition may otherwise be ordinarily included as a part of a use permitted under Section 4 of the ordinance.

- (a) Zone one - The location of any pollution source as defined herein.
- (b) Zone two - The location of a pollution source unless its contaminated discharges can be controlled with design standards.
- (c) Zones three and four - The location of a potential contamination source unless it can be controlled through land management strategies.

Section 6. Administration. The policies and procedures for administration of any source protection zone established under this ordinance, including without limitation those applicable to nonconforming uses, exception, enforcement and penalties, shall be the same as provided in the existing zoning ordinance for the City of \_\_\_\_\_ as the same is presently enacted or may from time to time be amended.

This Ordinance shall be effective as of \_\_\_\_\_ (date). All ordinances and parts or ordinances in conflict herewith shall not be and the same are hereby repealed.

ENACTED AND ADOPTED this \_\_\_\_\_ day of \_\_\_\_\_, 19\_\_.

\_\_\_\_\_  
Mayor

Attest: \_\_\_\_\_  
City Clerk

**Appendix I**  
**Dated Statement Regarding VOC and Pesticide Use**



Grand Water and Sewer Service Agency  
P.O. Box 1048  
Moab, UT 84532

I, Dale F. Pierson, of Grand Water and Sewer Service Agency verify that none of the following volatile organic chemicals (VOCs) and pesticides have been or will be used, disposed of, stored, transported, or manufactured within the protection zones of the George White Wells No. 4 and No. 5 in the Grand Water and Sewer Service Agency Water System.

VOCs

|                      |                            |                          |
|----------------------|----------------------------|--------------------------|
| Vinyl chloride       | Benzene                    | Carbon tetrachloride     |
| 1,2-Dichloroethane   | Trichloroethylene          | para-Dichlorobenzene     |
| 1,1-Dichloroethylene | 1,1,1-Trichloroethane      | cis-1,2-Dichloroethylene |
| 1,2-Dichloropropane  | Ethylbenzene               | Monochloroethylene       |
| o-Dichlorobenzene    | Styrene                    | Tetrachloroethylene      |
| Toluene              | trans-1,2-Dichloroethylene | Xylenes (total)          |
| Dichloromethane      | 1,2,4-Trichlorobenzene     | 1,1,2-Trichloroethane    |

Pesticides

|                           |                           |                           |
|---------------------------|---------------------------|---------------------------|
| Alachlor                  | Aldicarb                  | Aldicarb Sulfoxide        |
| Aldicarb Sulfone          | Atrazine                  | Carbofuran                |
| Chlordane                 | Dibromochloropropane      | 2,4-D                     |
| Ethylene Dibromide        | Heptachlor                | Heptachlor Epoxide        |
| Lindane                   | Methoxychlor              | Polychlorinated Biphenyls |
| Penachlorophenol          | Toxaphene                 | 2,4,5-TP                  |
| Benzp(a)pyrene            | Dalapon                   | Di(2-ethylhexyl)adipate   |
| Di(2-ethylhexyl)phthalate | Dinoseb                   | Diquat                    |
| Endothall                 | Endrin                    | Glyphosate                |
| Hexachlorobenzene         | Hexachlorocyclopentadiene | Oxamyl (Vydate)           |
| Picloram                  | Simazine                  | 2,3,7,8-TCDD (Dioxin)     |

  
(Signature)

Date 11-30-99



**R309-113.**  
**Drinking Water Source Protection**  
**Effective July 26, 1993**  
**Revised July 26, 1995**

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**R309-113**  
**Drinking Water Source Protection**

**R309-113-1. Authority.**

Under authority of Section 19-4-104(1)(a)(iv), the Drinking Water Board adopts this rule which governs the protection of ground-water sources of drinking water.

**R309-113-2. Purpose.**

Public Water Systems (PWSs) are responsible for protecting their sources of drinking water from contamination. R309-113 sets forth minimum requirements to establish a uniform, statewide program for implementation by PWSs to protect their ground-water sources of drinking water. PWSs are encouraged to enact more stringent programs to protect their sources of drinking water if they decide they are necessary.

R309-113 applies to all ground-water sources of drinking water which are used by PWSs to supply their systems except sources which are under the influence of surface water and are treated in accordance with surface water treatment rules. Additionally, compliance with this rule is voluntary for existing ground-water sources of drinking water which are used by public non-community water systems.

**R309-113-3. Implementation.**

- (1) New Ground Water Sources - Each PWS shall submit a Preliminary Evaluation Report or a Drinking Water Source Protection (DWSP) Plan in accordance with R309-113-13(2) or R309-113-7(1) for each of its new ground-water sources to the Division of Drinking Water (DDW).
- (2) Existing Ground Water Sources - Each PWS shall submit a DWSP Plan in accordance with R309-113-7(1) for each of its existing ground-water sources to DDW according to the following schedule. Well fields or groups of springs may be considered to be a single source.

**TABLE 1**

| Population Served by PWS: | Percent of Sources | DWSP Plans Due by: |
|---------------------------|--------------------|--------------------|
| Over 10,000               | 50% of Wells       | December 31, 1995  |
| Over 10, 000              | 100% of Wells      | December 31, 1996  |
| 3,300 - 10,000            | 100% of Wells      | December 31, 1997  |
| Less than 3,300           | 100% of Wells      | December 31, 1998  |
| Springs and other sources | 100%               | December 31, 1999  |

- (3) PWSs shall maintain all land use agreements which were established under previous rules to protect their ground-water sources of drinking water from contamination. Additionally, PWSs shall maintain land ownership and land-use agreements established under previous

rules with new owners which prohibit these new owners from locating pollution sources within protection zones.

**R309-113-4. Exceptions.**

- (1) Exceptions to the requirements of R309-113 or parts thereof may be granted by the Executive Secretary to PWSs if: due to compelling factors (which may include economic factors), a PWS is unable to comply with these requirements, and the granting of an exception will not result in an unreasonable risk to health.
- (2) Within one year of granting an exception, the Executive Secretary may prescribe a schedule by which the PWS must come into compliance with the requirements of R309-113.

**R309-113-5. Designated Person.**

- (1) A designated person shall be appointed and reported in writing to the Executive Secretary by each PWS within 180 days of the effective date of R309-113. The designated person's address and telephone number shall be included in the written correspondence.
- (2) Each PWS shall notify the Executive Secretary in writing within 30 days of any changes in the appointment of a designated person.

**R309-113-6. Definitions.**

- (1) The following terms are defined for the purposes of this rule:
  - (a) "Collection area" means the area surrounding a ground-water source which is underlain by collection pipes, tile, tunnels, infiltration boxes, or other ground-water collection devices.
  - (b) "Controls" means the codes, ordinances, rules, and regulations currently in effect to regulate a potential contamination source.
  - (c) "Criteria" means the conceptual standards that form the basis for DWSP area delineation to include distance, ground-water time of travel, aquifer boundaries, and ground-water divides.
  - (d) "Criteria threshold" means a value or set of values selected to represent the limits above or below which a given criterion will cease to provide the desired degree of protection.
  - (e) "DDW" means Division of Drinking Water.
  - (f) "DWSP Program" means the program to protect drinking water source protection zones and management areas from contaminants that may have an adverse effect on the health of persons.

- (g) "DWSP Zone" means the surface and subsurface area surrounding a ground-water source of drinking water supplying a PWS, through which contaminants are reasonably likely to move toward and reach such ground-water source.
- (h) "Designated person" means the person appointed by a PWS to ensure that the requirements of R309-113 are met.
- (i) "Executive Secretary" means the individual authorized by the Drinking Water Board to conduct business on its behalf.
- (j) "Existing ground-water source of drinking water" means a public supply ground-water source for which plans and specifications were submitted to DDW on or before July 26, 1993.
- (k) "Ground-water Source" means any well, spring, tunnel, adit, or other underground opening from or through which ground-water flows or is pumped from subsurface water-bearing formations.
- (l) "Hydrogeologic methods" means the techniques used to translate selected criteria and criteria thresholds into mappable delineation boundaries. These methods include, but are not limited to, arbitrary fixed radii, analytical calculations and models, hydrogeologic mapping, and numerical flow models.
- (m) "Land management strategies" means zoning and non-zoning controls which include, but are not limited to, the following: zoning and subdivision ordinances, site plan reviews, design and operating standards, source prohibitions, purchase of property and development rights, public education programs, ground-water monitoring, household hazardous waste collection programs, water conservation programs, memoranda of understanding, written contracts and agreements, and so forth.
- (n) "Land use agreement" means a written agreement wherein the owner(s) agrees not to locate or allow the location of potential contamination sources within zone one of new wells in protected aquifers. The owner(s) must also agree not to locate or allow the location of pollution sources within zone two of new wells in unprotected aquifers and new springs unless the pollution source agrees to install design standards which prevent contaminated discharges to ground water. This restriction must be binding on all heirs, successors, and assigns. Land use agreements must be recorded with the property description in the local county recorder's office. Refer to R309-113-13(4).

Land use agreements for protection areas on publicly owned lands need not be recorded in the local county recorder office. However, a letter must be obtained from the Administrator of the land in question and meet the requirements described above.
- (o) "Management area" means the area outside of zone one and within a two-mile radius where the Optional Two-mile Radius Delineation Procedure has been used to identify a protection area.

For wells, land may be excluded from the DWSP management area at locations where it is more than 100 feet lower in elevation than the total drilled depth of the well.

For springs and tunnels, the DWSP management area is all land at elevation equal to or higher than, and within a two-mile radius, of the spring or tunnel collection area. The DWSP management area also includes all land lower in elevation than, and within 100 horizontal feet, of the spring or tunnel collection area. The elevation datum to be used is the point of water collection. Land may also be excluded from the DWSP management area at locations where it is separated from the ground-water source by a surface drainage which is lower in elevation than the spring or tunnel collection area.

- (p) "New ground-water source of drinking water" means a public supply ground-water source of drinking water for which plans and specifications are submitted to DDW after July 26, 1993.
- (q) "Nonpoint source" means any conveyance not meeting the definition of point source.
- (r) "PWS" means public water system.
- (s) "Point source" means any discernible, confined, and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, animal feeding operation with more than ten animal units, landfill, or vessel or other floating craft, from which pollutants are or may be discharged. This term does not include return flows from irrigated agriculture.
- (t) "Pollution source" means point source discharges of contaminants to ground water or potential discharges of the liquid forms of "extremely hazardous substances" which are stored in containers in excess of "applicable threshold planning quantities" as specified in SARA Title III. Examples of possible pollution sources include, but are not limited to, the following: storage facilities that store the liquid forms of extremely hazardous substances, septic tanks, drain fields, class V underground injection wells, landfills, open dumps, landfilling of sludge and septage, manure piles, salt piles, pit privies, drain lines, and animal feeding operations with more than ten animal units.

The following definitions are part of R309-113 and clarify the meaning of "pollution source:"

- (i) "Animal feeding operation" means a lot or facility where the following conditions are met: animals have been or will be stabled or confined and fed or maintained for a total of 45 days or more in any 12 month period, and crops, vegetation forage growth, or post-harvest residues are not sustained in the normal growing season over any portion of the lot or facility. Two or more animal feeding operations under common ownership are considered to be a single feeding operation if they adjoin each other, if they use a common area, or if they use a common system for the disposal of wastes.



- (ii) "Animal unit" means a unit of measurement for any animal feeding operation calculated by adding the following numbers; the number of slaughter and feeder cattle multiplied by 1.0, plus the number of mature dairy cattle multiplied by 1.4, plus the number of swine weighing over 55 pounds multiplied by 0.4, plus the number of sheep multiplied by 0.1, plus the number of horses multiplied by 2.0.
- (iii) "Extremely hazardous substances" means those substances which are identified in the Sec. 302(EHS) column of the "TITLE III LIST OF LISTS - Consolidated List of Chemicals Subject to Reporting Under SARA Title III," (EPA 560/4-91-011). A copy of this document may be obtained from: Section 313 Document Distribution Center, P.O. Box 12505, Cincinnati, OH 45212.
- (u) "Potential contamination source" means any facility or site which employs an activity or procedure which may potentially contaminate ground water. A pollution source is also a potential contamination source.
- (v) "Protected aquifer" means a producing aquifer in which the following conditions are met:
  - (i) A naturally protective layer of clay, at least 30 feet in thickness, is present above the aquifer;
  - (ii) the PWS provides data to indicate the lateral continuity of the clay layer to the extent of zone two; and
  - (iii) the public-supply well is grouted with a grout seal that extends from the ground surface down to at least 100 feet below the surface, and through the protective clay layer.
- (w) "Time of travel" means the time required for a particle of water to move in the saturated zone from a specific point to a ground-water source of drinking water.
- (x) "Unprotected aquifer" means any aquifer that does not meet the definition of a protected aquifer.
- (y) "Wellhead" means the physical structure, facility, or device at the land surface from or through which ground water flows or is pumped from subsurface, water-bearing formations.

**R309-113-7. DWSP Plans.**

- (1) Each PWS shall develop, submit, and implement a DWSP Plan for each of its ground-water sources of drinking water. These DWSP Plans may be used to support use and susceptibility waivers for pesticides and volatile organic chemicals (VOCs). For the purposes of a waiver, the plan must identify contaminants that may result from potential contamination sources

found in zones one, two, and three and management areas. Refer to Chapter Seven of the "Source Protection User's Guide." This guide may be obtained from DDW.

**Required Sections for DWSP Plans** - DWSP Plans must include the following seven sections:

- (a) **DWSP Delineation Report** - A DWSP Delineation Report in accordance with R309-113-9(5) is the first section of a DWSP Plan.
  - (b) **Potential Contamination Source Inventory and Assessment of Controls** - A Prioritized Inventory of Potential Contamination Sources and an assessment of their controls in accordance with R309-113-10 is the second section of a DWSP Plan.
  - (c) **Management Program to Control Each Preexisting Potential Contamination Source** - A Management Program to Control Each Preexisting Potential Contamination Source in accordance with R309-113-11 is the third section of a DWSP Plan.
  - (d) **Management Program to Control or Prohibit Future Potential Contamination Sources for Existing Drinking Water Sources** - A Plan for Controlling or Prohibiting Future Potential Contamination Sources is the fourth section of a DWSP Plan. This must be in accordance with R309-113-12, consistent with the general provisions of this rule, and implemented to an extent allowed under the PWS's authority and jurisdiction. A land ownership map in accordance with R309-113-13-(2)(e) is required for new ground-water sources of drinking water.
  - (e) **Implementation Schedule** - Each PWS shall develop a step-by-step implementation schedule which lists each of its proposed land management strategies with an implementation date for each strategy.
  - (f) **Resource Evaluation** - Each PWS shall assess the financial and other resources which may be required for it to implement each of its DWSP Plans and determine how these resources may be acquired.
  - (g) **Recordkeeping** - Each PWS shall document changes in each of its DWSP Plans as they are continuously updated to show current conditions in the protection zones and management areas. As a DWSP Plan is executed, the PWS shall document any land management strategies that are implemented. These documents may include any of the following: ordinances, codes, permits, memoranda of understanding, public education programs, and so forth.
- (2) **DWSP Plan Administration** - DWSP Plans shall be submitted, corrected, retained, implemented, updated, and revised according to the following:
- (a) **Submitting DWSP Plans** - Each PWS shall submit a DWSP Plan to DDW in accordance with the schedule in R309-113-3(2) for each of its ground-water sources of drinking water.
  - (b) **Correcting Deficiencies** - Each PWS shall correct any deficiencies in a disapproved DWSP Plan and resubmit it to DDW within 90 days of the disapproval date.

- (c) **Retaining DWSP Plans** - Each PWS shall retain on its premises a current copy of each of its DWSP Plans. DWSP Plans shall be made available to the public upon request.
- (d) **Implementing DWSP Plans** - Each PWS shall begin implementing each of its DWSP Plans in accordance with its schedule in R309-113-7(1)(e), within 180 days after submittal if they are not disapproved by DDW.
- (e) **Updating DWSP Plans** - Each PWS shall update its DWSP Plans as often as necessary to ensure they show current conditions in the DWSP zones and management areas, and resubmit them to DDW at least every six years.
- (f) **Revising DWSP Plans** - Each PWS shall submit a revised DWSP Plan to DDW within 180 days after the reconstruction or redevelopment of any ground-water source of drinking water which addresses changes in source construction, source development, hydrogeology, delineation, potential contamination sources, and proposed land management strategies.

**R309-113-8. DWSP Plan Review.**

- (1) DDW shall review each DWSP Plan submitted by PWSs and "concur," "concur with recommendations," or "disapprove" the plan.
- (2) DDW may "disapprove" DWSP Plans for any of the following reasons:
  - (a) An inaccurate DWSP Delineation Report, a report that uses a non-applicable delineation method, or a DWSP Plan that is missing this report or any of the information and data required in it (refer to R309-113-9(5));
  - (b) an inaccurate Prioritized Inventory of Potential Contamination Sources or a DWSP Plan that is missing this report or any of the information required in it (refer to R309-113-10(1));
  - (c) an inaccurate assessment of current controls or a DWSP Plan that is missing this assessment or any of the information required in it (refer to R309-113-10(4));
  - (d) a missing Management Program to Control Each Preexisting Potential Contamination Source which has been assessed as "not adequately controlled" by the PWS (refer to R309-113-11(1));
  - (e) a missing Management Program to Control or Prohibit Future Potential Contamination Sources for Existing or New Drinking Water Sources (refer to R309-113-12 and R309-113-13(4));
  - (f) a missing Implementation Schedule, Resource Evaluation, Recordkeeping Section, or Contingency Report (refer to R309-113-7(1)(e)-(g) and R309-113-14).

- (3) DDW may "concur with recommendations" when PWSs propose management programs to control preexisting potential contamination sources or management programs to control or prohibit future potential contamination sources for existing or new drinking water sources which appear inadequate or ineffective.

**R309-113-9. Delineation of Protection Zones and Management Areas.**

- (1) PWSs shall delineate protection zones or a management area around each of their ground-water sources of drinking water using the Preferred Delineation Procedure or the Optional Two-mile Radius Delineation Procedure. The hydrogeologic method used by PWSs shall produce protection zones or a management area in accordance with the criteria thresholds below. PWSs may also choose to verify protected aquifer conditions to reduce the level of management controls applied in applicable protection areas.
- (2) Criteria Thresholds for Ground-water Sources of Drinking Water:
  - (a) Preferred Delineation Procedure - Four zones are delineated for management purposes:
    - (i) Zone one is the area within a 100-foot radius from the wellhead or margin of the collection area.
    - (ii) Zone two is the area within a 250-day ground-water time of travel to the wellhead or margin of the collection area, the boundary of the aquifer(s) which supplies water to the ground-water source, or the ground-water divide, whichever is closer. If the available data indicate a zone of increased ground-water velocity within the producing aquifer(s), then time-of-travel calculations shall be based on this data.
    - (iii) Zone three (waiver criteria zone) is the area within a 3-year ground-water time of travel to the wellhead or margin of the collection area, the boundary of the aquifer(s) which supplies water to the ground-water source, or the ground-water divide, whichever is closer. If the available data indicate a zone of increased ground-water velocity within the producing aquifer(s), then time-of-travel calculations shall be based on this data.
    - (iv) Zone four is the area within a 15-year ground-water time of travel to the wellhead or margin of the collection area, the boundary of the aquifer(s) which supplies water to the ground-water source, or the ground-water divide, whichever is closer. If the available data indicate a zone of increased ground-water velocity within the producing aquifer(s), then time-of-travel calculation shall be based on this data.
  - (b) Optional Two-mile Radius Delineation Procedure - In place of the Preferred Delineation Procedure, PWSs may choose to use the Optional Two-mile Radius Delineation Procedure to delineate a management area. This procedure is best applied in rural areas where few if any potential contamination sources are located. Refer to R309-113-6(1)(o) for the definition of a management area.

- (3) **Protected Aquifer Classification** - PWSs may choose to verify protected aquifer conditions to reduce the level of management controls for a public-supply well which produces water from a protected aquifer(s). Refer to R309-113-6(1)(v) for the definition of a "protected aquifer."
- (4) **Special Conditions** - Special scientific or engineering studies may be conducted to support a request for an exception (refer to R309-113-4) due to special conditions. These studies must be approved by DDW before the PWS begins the study. Special studies may include confined aquifer conditions, ground water movement through protective layers, wastewater transport and fate, etc.
- (5) **DWSP Delineation Report** - Each PWS shall submit a DWSP Delineation Report to DDW for each of its ground-water sources using the Preferred Delineation Procedure or the Optional Two-mile Radius Delineation Procedure.
  - (a) **Preferred Delineation Procedure** - Delineation reports for protection zones delineated using the Preferred Delineation Procedure shall include the following information and a list of all sources or references for this information:
    - (i) **Geologic Data** - A summary description of the geology in the well and nearby area of the ground-water source of drinking water. This should include the formal or informal formation name(s), general rock type, grain sizes, sorting, degree of natural cementation, and description of fractures and solution cavities (size, abundance, spacing, orientation) and faults (brief description of location in or near the well, and orientation). Description of grain sizes, sorting, etc., can be obtained from surface hand samples or well cuttings; core samples and laboratory analyses are not necessary. Fractures, solution cavities, and faults should be described from surface outcrops or drill logs.
    - (ii) **Well Construction Data** - If the source is a well, the report shall include the well drillers log, elevation of the wellhead, borehole radius, casing radius, total depth of the well, depth and length of the screened or perforated interval(s), well screen or perforation type, casing type, method of well construction, type of pump, location of pump in the well, and the maximum projected pumping rate of the well.
    - (iii) **Spring Construction Data** - If the source is a spring or tunnel the report shall include a description or diagram of the collection area and method of ground-water collection.
    - (iv) **Aquifer Data for New Wells** - A summary report including the calculated hydraulic conductivity of the aquifer, transmissivity, hydraulic gradient, direction of ground-water flow, estimated effective porosity, and saturated thickness of the producing aquifer(s). The PWS shall obtain the hydraulic conductivity of the aquifer from a constant-rate aquifer test and provide the data as described in R309-106-5(6)(a). This report shall include graphs, data, or printouts showing the interpretation of the aquifer test.

- (v) **Aquifer Data for Existing Wells** - A summary report including the calculated hydraulic conductivity of the aquifer, transmissivity, hydraulic gradient, direction of ground-water flow, estimated effective porosity, and saturated thickness of the producing aquifer(s). The PWS shall obtain the hydraulic conductivity of the aquifer from a constant-rate aquifer test using the existing pumping equipment. Aquifer tests using observation well are encouraged, but are not required. If a previously performed aquifer test is available and includes the required data described below, data from that test may be used instead. This report shall include graphs, data, or printouts showing the interpretation of the aquifer test.

If a constant-rate aquifer test is not practical, then the PWS shall obtain hydraulic conductivity of the aquifer using another appropriate method, such as data from a nearby well in the same aquifer, specific capacity of the well, published hydrogeologic studies of the same aquifer, or local or regional ground-water models. A constant-rate test may not be practical for such reasons as insufficient drawdown in the well, inaccessibility of the well for water-level measurements, or insufficient overflow capacity for the pumped water.

The constant-rate test shall:

- (A) Provide for continuous pumping for at least 24 hours or until stabilized drawdown has continued for at least six hours. Stabilized drawdown is achieved when there is less than 0.5 foot of change of ground-water level in the well within a six-hour period.
- (B) Provide data as described in R309-106-5(6)(a)(v) through (vii).
- (vi) **Additional Data for Observation Wells** - If the aquifer test is conducted using observation wells, the report shall include the following information for each observation well: location and surface elevation; total depth; depth and length of the screened or perforated intervals; radius, casing type, screen or perforation type, and method of construction; prepumping ground-water level; the time-drawdown or distance-drawdown data and curve; and the total drawdown.
- (vii) **Hydrogeologic Methods, Procedures, and Calculations** - These include the hydrogeologic method used to delineate the protection zones, all applicable equations, values, and the calculations which determine the delineated boundaries of zones two, three, and four.
- (viii) **Map Showing Boundaries of the DWSP Zones** - A 1:24,000 scale map showing the location of the ground-water source of drinking water and the boundary for each DWSP zone. Although zone one (100-foot radius around the well or margin of the collection area) need not be on the map, the boundaries for zones two, three, and four must be drawn and labeled. More detailed maps are encouraged, but are optional.

The PWS shall also include a written description of the distances which define the delineated boundaries of zones two, three, and four. These

written descriptions must include the maximum distances upgradient from the well, the maximum distances downgradient from the well, and the maximum widths of each protection zone.

- (b) Optional Two-Mile Radius Delineation Procedure - Delineation Reports for protection areas delineated using the Optional Two-mile Radius Delineation Procedure shall include the following information:
  - (i) Map Showing Boundaries of the DWSP Management Area - A 1:24,000 scale map showing the location of the ground-water source of drinking water and the DWSP management area boundary. Although zone one (100-foot radius around the well or margin of the collection area) need not be on the map, the two-mile radius must be drawn and labeled. More detailed maps are encouraged but are optional.
  - (ii) Hydrogeologic Report for Potential Contamination Sources - Unless the PWS chooses the option in R309-113-9(5)(b)(iii) below, it shall submit a hydrogeologic report for each potential contamination source within zone one and the management area. This report must explain the potential for contamination to move from the contamination source to the ground-water source and its potential impact on the drinking water quality of the ground-water source.
  - (iii) Hydrogeologic Report Not Required - A hydrogeologic report for pollution sources within zone one and the management area is not required if these pollution sources implement design standards which prevent contaminated discharges to ground water. Additionally, a hydrogeologic report is not required for potential contamination sources if the PWS meets the requirements in R309-113-11 and 12.
- (6) Protected Aquifer Conditions - If a PWS chooses to verify protected aquifer conditions, it shall submit the following additional data to DDW for each of its public-supply wells for which the protected aquifer conditions apply:
  - (a) Thickness, depth, and lithology of the protective clay layer;
  - (b) data to indicate the lateral continuity of the protective clay layer over the extent of zone two. This may include such data as correlation of beds in multiple wells, published hydrogeologic studies, stratigraphic studies, potentiometric surface studies, and so forth; and
  - (c) evidence that the well has been grouted or otherwise sealed through the protective clay layer in accordance with R309-106-5(5)(g) and R309-113-6(1)(v).



**R309-113-10. Potential Contamination Source Inventory and Identification and Assessment of Controls.**

- (1) **Prioritized Inventory of Potential Contamination Sources** - Each PWS shall list all potential contamination sources within each DWSP zone or management area in priority order and state the basis for this order. This priority ranking shall be according to relative risk to the drinking water source. Additionally, each PWS shall identify each potential contamination source as to its location in zone one, two, three, four or in a management area and plot it on the map required in R309-113-9(5)(a)(vii) or R309-113-9(5)(b)(i).
- (2) **List of Potential Contamination Sources** - A List of Potential Contamination Sources is found in Chapter Three of the "Source Protection User's Guide." This document may be obtained from DDW. This list may be used by PWSs as a guide to inventorying potential contamination sources within their DWSP zones and management areas.
- (3) **Refining, Expanding, Updating, and Verifying Potential Contamination Sources** - Each PWS shall update its list of potential contamination sources to show current conditions within DWSP zones or management areas. This includes adding potential contamination sources which have moved into DWSP zones or management areas, deleting potential contamination sources which have moved out, improving available data about potential contamination sources, and all other appropriate refinements.
- (4) **Identification of Current Controls** - The PWS shall list each of the current controls that are in effect for each potential contamination source. Refer to Appendix E of the "Source Protection User's Guide" for a list of government agencies and the programs they administer to control potential contamination sources. This guide may be obtained from DDW.
- (5) **Assessment of Current Controls** - The PWS shall assess whether current controls are stringent enough to prevent pollution from a potential contamination source from reaching a ground-water source of drinking water.

For the purpose of meeting the requirements of R309-113, DDW will consider a PWS's assessment that a potential contamination source which is covered by a permit or approval under one of the regulatory programs listed below sufficient to demonstrate that the source is adequately controlled unless otherwise determined by the Executive Secretary. For all other state programs, the PWS's assessment is subject to review by DDW; as a result, a PWS's DWSP Plan may be disapproved if DDW does not concur with its assessment(s).

In determining if a potential contamination source is permitted or approved under these programs, the PWS should contact the state agency responsible for these programs. In the event that a potential contamination source is contacted directly, the PWS should understand that they are usually under no obligation to furnish requested information.

- (a) The Utah Ground Water Quality Protection program established by Section 19-5-104 and R317-6;
- (b) closure plans or Part B permits under authority of the Resource Conservation and Recovery Act (RCRA) of 1984 regarding the monitoring and treatment of ground water;

- (c) the Utah Pollutant Discharge Elimination System (UPDES) established by Section 19-5-104 and R317-8;
  - (d) the Underground Storage Tank Program established by Section 19-6-403 and R311-200 through R311-208; and
  - (e) the Underground Injection Control (UIC) Program for classes I-IV established by Sections 19-5-104 and 40-6-5 and R317-7 and R649-5.
- (6) Assessment Determines Source to be Adequately Controlled - If the assessment in R309-113-10(5) determines that a particular potential contamination source is adequately controlled, the PWS shall report this appraisal in the DWSP Plan and indicate that no further land management strategies will be proposed or implemented unless conditions change.

**R309-113-11. Management Program to Control Each Preexisting Potential Contamination Source.**

- (1) PWSs shall plan land management strategies to control each preexisting potential contamination source in accordance with their authority and jurisdiction. Land management strategies must be consistent with the provisions of R309-113, designed to control potential contamination, and may be regulatory or non-regulatory. Each potential contamination source listed on the inventory required in R309-113-10(1) and assessed as "not adequately controlled" must be addressed. Land management strategies must be implemented according to the schedule required in R309-113-7(1)(e).
- (2) PWSs with overlapping protection zones and management areas may cooperate in controlling a particular preexisting potential contamination source if one PWS will agree to take the lead in planning and implementing land management strategies and the remaining PWS(s) will assess the preexisting potential contamination source as "adequately controlled."

**R309-113-12. Management Program to Control or Prohibit Future Potential Contamination Sources for Existing Drinking Water Sources.**

PWSs shall plan land management strategies to control or prohibit future potential contamination sources within each of its DWSP zones or management areas consistent with the provisions of R309-113 and to an extent allowed under its authority and jurisdiction. Land management strategies must be designed to control potential contamination and may be regulatory or non-regulatory. Additionally land management strategies must be implemented according to the schedule required in R309-113-7(1)(e).

Protection areas may extend into neighboring cities, towns, and counties. Since it may not be possible for some PWSs to enact regulatory land management strategies outside of their jurisdiction, except as described below, it is recommended that these PWSs contact their neighboring cities, towns, and counties to see if they are willing to implement protective ordinances to prevent ground-water contamination under joint management agreements.

Cities and towns have extraterritorial jurisdiction in accordance with section 10-8-15 of the Utah Code Annotated to enact ordinances to protect a stream or "source" from which their water is taken... "for 15 miles above the point from which it is taken and for a distance of 300 feet on each side of such stream..." Section 10-8-15 includes ground-water sources.

Zoning ordinances are an effective means to control potential contamination sources that may want to move into protection areas. They allow PWSs to prohibit facilities that would discharge contaminants

directly to ground water. They also allow PWSs to review plans from potential contamination sources to ensure there will be adequate spill protection and waste disposal procedures, etc. If zoning ordinances are not used, PWSs must establish a plan to contact potential contamination sources individually as they move into protection areas, identify and assess their controls, and plan land management strategies if they are not adequately controlled.

**R309-113-13. New Ground-water Sources of Drinking Water.**

- (1) Prior to constructing a new ground-water source of drinking water, each PWS shall develop a Preliminary Evaluation Report or a DWSP Plan which demonstrates whether the source meets the requirements of this section and submit it to DDW. PWSs shall submit Preliminary Evaluation Reports or DWSP Plans and other required information in accordance with R309-106-5(2) or R309-106-6(2) to DDW concurrently; review of source protection reports and engineering specifications by DDW shall also be conducted concurrently. DDW will not grant plan approval to a PWS in accordance with R309-106-5(2) or R309-106-6(2) until the requirements set forth in this section are also met. Construction standards relating to protection zones and management areas (fencing, diversion channels, sewer lines, and grouting, etc.) are found in R309-106. After the source is constructed a DWSP Plan shall be developed, submitted, and implemented accordingly. Land use agreement requirements are also identified.
- (2) Preliminary Evaluation Report for New Sources of Drinking Water - Preliminary Evaluation Reports shall cover all four zones or the entire management area. PWSs shall include the following five sections in each Preliminary Evaluation Report:
  - (a) Delineation Report for Estimated DWSP Zones - PWSs shall use the Preferred Delineation Procedure to delineate protection zones for new wells. The same requirements apply as in R309-113-9(5), except that the hydrogeologic data for the Preliminary Evaluation Report may be obtained from surrounding wells, published information, surface geologic mapping, or best available data.
  - (b) Inventory of Potential Contamination Sources and Identification and Assessment of Controls - The same requirements apply as in R309-113-10(1).
  - (c) Management Program to Control Each Preexisting Potential Contamination Source - The same requirements apply as in R309-113-11.
  - (d) Management Program to Control or Prohibit Future Potential Contamination Sources for New Drinking Water Sources in accordance with R309-113-13(4). Land use agreements obtained in conjunction with Preliminary Evaluation Reports may be notarized "letters of intent" from the owner. These letters must include the language required in a land use agreement and a statement that the owner will record a land use agreement with the county recorder's office if the source proves to be an acceptable source. A copy of the land use agreement which has been recorded with the county recorder's office must be submitted to DDW and an approval letter must be issued before the PWS will be permitted to introduce the new source into its public system.

- (e) **Land Ownership Map** - A land ownership map which includes all land within zones one and two or the entire management area.
- (3) **DWSP Plan for New Sources of Drinking Water** - If a Preliminary Evaluation Report was developed, the PWS shall submit a DWSP Plan in accordance with R309-113-7(1) for any new ground-water source of drinking water within one year after the date of DDW's concurrence letter. In developing this DWSP Plan, PWSs shall refine the information in the Preliminary Evaluation Report by applying any new, as-constructed characteristics of the source (i.e., pumping rate, aquifer test, etc.).
- (4) **Management Program to Control and Prohibit Future Potential Contamination Sources for New Drinking Water Sources** - PWSs shall plan land management strategies to control or prohibit future potential contamination sources within each of their DWSP zones and management areas consistent with the provisions of R309-113 and to an extent allowed under their authority and jurisdiction. Land management strategies must be designed to control potential contamination and may be regulatory or non-regulatory. Land management strategies must be implemented according to the schedule required in R309-113-7(1)(e).

Zoning ordinances are an effective means to control potential contamination sources that may want to move into protection areas. They allow PWSs to prohibit facilities that would discharge contaminants directly to ground water. They also allow PWSs to review plans from potential contamination sources to ensure there will be adequate spill protection and waste disposal procedures, etc. If zoning ordinances are not used, PWSs must establish a plan to contact potential contamination sources individually as they move into protection areas, identify and assess their controls, and plan land management strategies if they are not adequately controlled. PWSs shall enact the following restrictions:

- (a) **Additional Requirements for Protection Areas Delineated using the Preferred Delineation Procedure in Protected Aquifers** - A PWS shall not locate a new ground-water source of drinking water where a potential contamination source exists within zone one. Additionally, the PWS shall prohibit the future location of any potential contamination sources within zone one. These restrictions shall be accomplished through zoning controls or land use agreements with the land owner(s).
- (b) **Additional Requirements for Protection Areas Delineated using the Preferred Delineation Procedure in Unprotected Aquifers:**
  - (i) **Zone One** - The same requirements apply as in R309-113-13(4)(a).
  - (ii) **Zone Two** - PWSs shall not locate a new ground-water source of drinking water where a pollution source exists within zone two in an unprotected aquifer unless the pollution source implements design standards which prevent contaminated discharges to ground water. Additionally, PWSs shall prohibit the future location of pollution sources within zone two unless the pollution source implements design standards which prevent contaminated discharges to ground water. These restrictions shall be accomplished through zoning controls or land use agreements with the land owner(s).
- (c) **Additional Requirements for Management Areas Delineated using the Optional Two-Mile Radius Delineation Procedure in Unprotected Aquifers:**

- (i) Zone One - The same requirements apply as in R309-113-13(4)(a).
- (ii) DWSP Management Area - PWSs shall not locate a new spring where a pollution source exist within a management area unless: the hydrogeologic report in R309-113-9(5)(b)(ii) verifies that it does not impact the spring; or the pollution source implements design standards which prevent contaminated discharges to ground water.

Additionally, PWSs shall prohibit the future location of any pollution source unless: the hydrogeologic report in R309-113-9(5)(b)(ii) verifies that it will not impact the ground water source; or the pollution source implements design standards which prevent discharges to ground water. These restriction shall be accomplished through zoning controls or land use agreements with the land owner(s).

- (5) Sewers Within DWSP Zones and Management Areas - The Executive Secretary may permit sewer lines within DWSP zones and management areas if precautions in accordance with R309-106-5(4)(b) are taken.

#### **R309-113-14. Contingency Plans.**

PWSs shall submit a Contingency Plan which includes all sources of drinking water for their entire water system to DDW concurrently with the submission of their first DWSP Plan. Guidance for developing Contingency Plans may be found in Chapter Five of the "Source Protection User's Guide." This document may be obtained from DDW.

**KEY: drinking water, environmental health**  
**July 26, 1995**

**19-4-104(1)(a)(iv)**





# ***SOURCE PROTECTION***

## ***USER'S GUIDE***

*October 1998*

**STATE OF UTAH  
DEPARTMENT OF ENVIRONMENTAL QUALITY  
DIVISION OF DRINKING WATER**

**Drinking Water Source Protection  
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## **INTRODUCTION**

Protecting wells and springs is critical because they are vulnerable to contamination. The best way to protect a drinking water source is to develop and carry out a Drinking Water Source Protection (DWSP) plan. If you follow the advice in this User's Guide, it will help you gather important information about your drinking water sources and identify the potential contamination sources (PCSs) which threaten them. This information will, in turn, help you plan strategies to protect your wells and springs.

It is the responsibility of PWSs to protect their wells and springs from contamination. The purpose of the DWSP Rule is to provide the procedure for PWSs to fulfill this responsibility. The Division of Drinking Water (DDW) does not have the authority to control the activities of PCSs. However, city, town, and county governments do. Local governments can protect wells and springs from contamination by passing ordinances to control land use within protection zones. If local government is unable or unwilling to provide protection for PWSs, these protection issues may be addressed through other means, such as land ownership, land use agreements, and public education programs.

There are other reasons for establishing source protection. A quality source of drinking water is a source of community pride. Sources of drinking water are valuable community assets and protecting them protects the capital the community has invested in them. It is very difficult and usually illegal for local government to restrict a potentially polluting activity just as its development plans are made public, especially if they comply with current zoning ordinances. Source protection plans anticipate potential problems and establish a process for dealing with them.

### **Source Protection User's Guide**

This User's Guide is divided into two parts: Part I, provides guidance for writing a Preliminary Evaluation Report for proposed new wells, springs, and tunnels; Part II, provides guidance for writing DWSP Plans for existing wells, springs, and tunnels and for new sources with PERs that have been approved within the last year.

### **Submittal Schedule for Proposed Wells and Springs**

Submit a Preliminary Evaluation Report (PER) and construction specifications to DDW for each new well, spring, or tunnel for review and approval before construction begins. A new source is any source for which plans and specification were submitted after July 26, 1993. A refined report that meets the requirements of a DWSP plan must then be submitted to us within one year of when the PER approval letter is dated. Refer to Chapters 1 & 2, for information on developing a PER for new sources.

### **Submittal Schedule for Existing Wells and Springs**

A source protection plan must be submitted for each existing well, spring, and tunnel which is used by a PWS to supply their system except sources which are under the influence of surface water and are treated in accordance with the Surface Water Treatment Rule. Compliance with this rule is voluntary for existing ground-water sources of drinking water which are used by public (transient) non-community water systems. However, please be aware that this Rule does apply to non-transient, non-community water systems. Refer to Chapter 3, for information on developing a DWSP Plan for existing sources. The following table identifies the deadlines for submitting DWSP plans for *all other existing* ground-water sources of drinking water:

| Population Served by PWS:        | Percent of Sources:    | DWSP plans Due by: |
|----------------------------------|------------------------|--------------------|
| Over 10,000                      | 50% of Existing Wells  | December 31, 1995  |
| Over 10,000                      | 100% of Existing Wells | December 31, 1996  |
| 3,300 - 10,000                   | 100% of Existing Wells | December 31, 1997  |
| Less than 3,300                  | 100% of Existing Wells | December 31, 1998  |
| Existing Springs & Other Sources | 100%                   | December 31, 1999  |

TABLE 1 - Submit DWSP plans for *existing* wells and springs according to this schedule.

### Consulting Services

If you choose to employ the services of a consultant to assist you in source protection, be sure to specify that you require a plan that is written for you; demand one that is easy to understand. You should be specific about which sections you want them to write and which ones you want to write. It is especially critical that you have input in developing the management sections of the plan. Additionally, you should be able to tell exactly what you need to do to implement the plan. The implementation schedule is one of the most important sections of the DWSP plan because it is a summary list containing every land management strategy and beginning implementation date that is to be carried out by the PWS. Tables and checklist are also very important for summarizing many of the other sections of an effective DWSP plan.

### The Source Protection Team

We strongly recommend that you form a source protection team to assist you in developing and carrying out the management strategies of source protection. This is because the most successful source protection programs across the United States have been planned by teams. A team will help ensure that your source protection plan works. Refer to Appendix C for information about putting a source protection team together.

### Partial Reimbursement for DWSP Plans

Small PWSs serving populations less than 3,300 may be eligible for 50%, not to exceed \$2,500, of the actual costs for each ground-water source of drinking water for which they prepare and submit to DDW a complete DWSP Plan. To be eligible for these funds, a small PWS must:

- ▶ Have been in existence as of the initial effective date of R309-113 (July 26, 1993);
- ▶ have more than 50 percent of the dwelling units served by the system occupied by permanent, year-round residents;
- ▶ have a median adjusted gross income that is less than the state-wide median adjusted gross income for Utah; however, if a group of small PWSs located in the same geographic area selects a single consultant who prepares and submits all their source protection plans together, and at least 50% of the systems in the group meet this income level criterion, then all systems in the group, or the group as a whole, shall be deemed to meet this criterion;
- ▶ be a community water system, or a non-transient, non-community water system that is not associated with or owned by a for-profit entity, and is not owned/operated by a federal or state government agency; and
- ▶ submit complete DWSP Plans to DDW by the due dates indicated in R309-113-3.
- ▶ Additionally, only DWSP Plans prepared for drinking water sources that were existing (approved by DDW) as of July 26, 1993 shall be eligible for these funds.

Please call DDW at (801) 536-4200, to request an application if you are eligible for these funds and would like to be partially reimbursed for your DWSP plans.

### **Additional Resources**

We have tried to address the specific needs of PWS personnel in this *Source Protection User's Guide*. We have not tried to separate what is mandatory from what is not. If you would like to know what is mandatory, please request a copy of the Drinking Water Source Protection Rule (R309-113, Utah Administrative Code). DDW has prepared a *Standard Report Format for New Wells and Springs* and a *Standard Report Format for Existing Wells and Springs* to assist PWSs in developing PERs and DWSP Plans. We strongly advise that you follow these formats to ensure that none of the important parts of these documents are left out. Call (801) 536-4200 to request the rule or the standard report formats.

Other guidance is also available. Wellhead Protection: A Guide for Small Communities, (EPA/625/R-93/002) may be obtained from the Environmental Protection Agency (EPA), along with other EPA references cited later in the User's Guide. To order EPA publications, call (800) 490-9198. Internet access for ordering EPA publications is found at "<http://www.epa.gov/ncepihom/index.html>."

### **Additional Source Protection Assistance**

The Rural Water Association of Utah manages a program to help PWSs develop DWSP plans. Additionally, they periodically sponsor DWSP workshops and address DWSP topics in their annual and semi-annual conventions. Contact Ken Orton at (800) 649-0821.



The Utah Geological Survey may be able to help some communities with delineating their protection zones. Contact Mark Jensen at (801) 536-4199, if you would like to request this assistance.

The U.S. Geological Survey may be able to help some communities in various aspects of delineating protection zones. Contact Jerry Spangler at (801) 975-3394.

# **Part I**

## **PRELIMINARY EVALUATION REPORTS FOR PROPOSED NEW GROUND WATER SOURCES**

Use this part of the User's Guide to develop a Preliminary Evaluation Report for proposed new wells, springs, and tunnels. Remember that this report must be reviewed and approved before you begin constructing these sources. Preliminary Evaluation Reports must be refined to meet the requirements of Drinking Water Source Protection plans within one year of their approval date. Part II, contains the guidance to develop Drinking Water Source Protection Plans.



## **CHAPTER 1 - THE PRELIMINARY EVALUATION REPORT**

A Preliminary Evaluation Report (PER) is required for all new wells, springs, and tunnels which are used as sources of drinking water by public water systems (PWSs) except for replacement wells and sources which are under the direct influence of surface water. The PER and the Engineering Plans and Specifications should be submitted concurrently allowing for concurrent review. The Division of Drinking Water (DDW) will not grant approval to begin construction, and subsequently, to use a source until both of these documents are reviewed and approved.

### **Replacement Wells**

A PER is not required for proposed wells, if the PWS receives written notification from DDW that the well is classified as a replacement well. The PWS must submit a letter requesting that the well be classified as a replacement well and include documentation to show that the following definition and conditions are met: Replacement well means a public-supply well drilled for the sole purpose of replacing an existing public-supply well which is impaired or made useless by structural difficulties and in which the following conditions are met:

- ▶ The proposed well location shall be within a radius of 150 feet from an existing ground-water supply well, as defined in R309-113-6(1)(j); and
- ▶ the PWS provides a copy of the replacement application approved by the State Engineer (refer to Section 73-3-28 of the Utah Code Annotated).

If a proposed well is classified as a replacement well, the PWS is still required to submit: A Drinking Water Source Protection (DWSP) Plan in accordance with R309-113-13(6); and the Outline of Well Approval Process (refer to R309-204-6(5)).

### **PERs are Due Before the Source is Developed**

One of the purposes of the source protection program is to ensure that PWSs will have the ability to protect their proposed new wells and springs *before* they are constructed. Because of this, PERs and construction specifications must be submitted to DDW before a new source is constructed.

A detailed description of what to include in a PER is included in *The Standard Report Format for New Wells and Springs*, call us at 536-4200, if you would like to request a copy of this document.

***It is very important that the PER be approved before construction begins. PWSs take an enormous risk if they drill a well or develop a spring before its PER is approved. The money that has been invested in the construction cost of a new source may be lost if a subsequent review of the PER reveals that it cannot be approved.***

If a new public source of drinking water is being planned for a system, approval from DDW and a permit from the Division of Water Rights (DWR) is required. ***It is very important to obtain both an approval from DDW and a permit from DWR before the well is drilled.*** R309-113-13(1) states: "PWSs shall submit PERs and Engineering Plans and Specifications to DDW concurrently; review by DDW shall also be conducted concurrently. DDW will not grant plan approval to a PWS

in accordance with R309-204-6(5) until the requirements set forth in this section are met." A new source development rule (R309-204-6(5)) became effective on January 1, 1998, and replaced the old one in R309-106-5(2).

### **Purpose of Preliminary Evaluation Reports**

PERs and Drinking Water Source Protection (DWSP) Plans are the primary means for PWSs to use to protect their sources of drinking water from contamination. These documents should not be developed just to meet the "letter of the law" required by the Rule. *They should be working documents that will be used on a regular basis by the PWS. The DWSP plan should be written as a "how-to" handbook for a water system to protect their sources of drinking water now and in the future.* They should be logical and the protection strategies should be easily understood.

### **Drinking Water Source Protection Plans**

The PER must be refined to meet the requirements of a Drinking Water Source Protection (DWSP) Plan within one year of the date of the PER approval letter. Additional sections and specific information regarding the properties of the source and any changes to the protection zones must be included in the DWSP. Part II, of this guide will give you the specific information required to develop the DWSP plan.

### **Delineation Procedure for New Wells**

The Preferred Delineation Procedure must be used to delineate protection zones for new wells.

### **Protected and Unprotected Aquifers**

New wells are no longer classified as *deep* or *shallow*. The Rule now classifies them as being in *protected* or *unprotected* aquifers. New wells in protected aquifers are required to have land use agreements for zone one (refer to Chapter 4, for an explanation of protection zones). New wells in unprotected aquifers are required to have land use agreements for zones one and two. This is because unprotected aquifers are more vulnerable to contamination. Land use agreements assure that land owners are willing to safeguard your water sources by agreeing not to locate uncontrolled PCSs or pollution sources within specified areas.

To be classified as a well in a protected aquifer the following conditions must be met:

1. A naturally protective layer of clay, at least 30 feet in thickness, is present above the aquifer;
2. the PWS provides data to indicate the lateral continuity of the clay layer throughout the extent of zone two; and
3. the public-supply well is grouted with a grout seal that extends from the ground surface down to at least 100 feet below the surface, and through the protective clay layer.

## **Required Sections of a PER**

An explanation of each section of a PER follows:

*The Delineation Report* (refer to Chapter 4) - The delineation report describes the protection zones and the scientific procedures which are used to define them. Because there is no specific information available from the proposed well, such as an aquifer test, the best available data may be used to determine the protection zones. The zones should be developed keeping in mind that they may change when more specific information about the aquifer is available after the well is drilled and tested.

*The Inventory of Potential Contamination Sources* (refer to Chapter 5) - The inventory is a prioritized list of all of the PCSs within the protection area. DDW cannot approve a source for public use if there are uncontrolled PCSs in Zone 1 of a well in a protected aquifer or if there are uncontrolled PCSs in zone 1 or pollution sources that cannot be controlled by design standards in Zone 2 of a well or spring in an unprotected aquifer.

Sewer lines that have at least five feet of suitable soil under them are permitted if they are set back at least 10 feet from the well and are specially constructed within zone one in accordance with R309-204-6(4). Suitable soils contain adequate sand/silt/clay to act as an effective effluent filter within its depth for the removal of pathogenic organisms and fill the voids between coarse particles such as gravel, cobbles, and angular rock fragments.

Sewer lines that have unsuitable soil within five feet under them must be set back from the well or spring at least 300 feet and be specially constructed within zones one and two in accordance with R309-204-6(4). Unsuitable soil is defined as soil that is so large grained that it will not treat wastewater, is saturated by seasonal ground water, or is bedrock.

*Land Ownership Map And List* - A land ownership map which includes all land within zones one and two or the entire management area is required. Additionally, a list which exclusively identifies the land owners in zones one and two or the management area and specifies the zone or management area in which they own land is required. A land ownership map and list are not required if ordinances are used to protect these zones.

*Land Use Agreements, Letters Of Intent, Or Zoning Ordinances* - Land use agreements are required in zone one for wells in protected aquifers. They are also required in zones one and two for wells in unprotected aquifers and for springs. Land use agreements must be in writing wherein an owner agrees not to locate uncontrolled PCSs within zone one. Additionally, an owner must agree not to locate pollution sources in zone two unless design standards are implemented to prevent contaminated discharges. Any restrictions must be binding on all heirs, successors, and assigns and must be recorded with the property description in the local county recorder's office. This provision applies even if the land owner and the PWS are the same person. Copies of this recording must be submitted to DDW.

Land use agreements on publicly owned lands need not be recorded in the county recorder's office. However, a written statement from the administrator is required. This statement must contain the same information for land use agreements that is described above.

Two examples of land use agreements follow. The first is for a well in an unprotected aquifer:

*1. I(we), the undersigned landowner(s), acknowledge the Drinking Water Source Protection Plan for the Greenville, Utah, Big Well. We agree not to locate or allow the location of any uncontrolled potential contamination sources, as defined in R309-113-6(1)(u) of the Utah Administrative Code, within zone one. We also agree not to locate or allow the location of any pollution sources, as defined in R309-113-6(1)(t) of the Utah Administrative Code, within zone two unless design standards are implemented to prevent contaminated discharges. This agreement is binding on all heirs, successors, and assigns.*

The second is for a spring in an unprotected aquifer:

*2. The U. S. Forest Service acknowledges the Drinking Water Source Protection Plan for the Greenville, Utah, Bounty Spring. We understand that protection areas are delineated for this spring and agree not to allow any potential contamination sources, as defined in R309-113-6(1)(u) of the Utah Administrative Code, to be located within zone one. We also agree not to allow any pollution sources, as defined in R309-113-6(1)(t) of the Utah Administrative Code, within the two-mile radius management area unless design standards are implemented to prevent contaminated discharges or unless a hydrogeologic report shows that discharges will not affect the spring.*

*Letters of Intent to Record a Land Use Agreement* - Notarized letters of intent from the land owner(s) may be used when initially submitting a PER. These letters must include the language required in a land use agreement and a statement that, the owner(s) will record a land use agreement in the county recorder's office if the source proves to be an acceptable source. A copy of the land use agreement which has been recorded in the county recorder's office must be submitted to DDW and an approval letter must be issued before the PWS will be permitted to introduce the new source into its public system.

*Zoning Ordinances* - Zoning ordinances may be used in place of land use agreements if they contain the same restrictions as land use agreements. In other words, uncontrolled PCSs must be restricted from zone one for wells in protected and unprotected aquifers. Pollution sources that cannot be controlled by design standards must be restricted from zone two for wells and springs in unprotected aquifers. It is the responsibility of the PWS to cite and quote references and interpret the zoning ordinance to substantiate these restrictions. Please do not send a zoning ordinance and expect DDW to do this research.

*Waivers (only required if you want to maintain or apply for waivers)* - You must submit verification that certain pesticides and VOCs are not used within zones one, two, and three



to be eligible for a Use Waiver for a new well. These pesticides and VOCs are identified in the *Water Quality Maximum Contaminant Levels, Rule R309-103 Summary*. Guidance for obtaining these waivers is included in Chapter 11. If pesticides and VOCs are used within zones one, two, and three, you may be eligible for a Susceptibility Waiver; however, you can only apply for Susceptibility Waivers in the DWSP plan that is due within one year after the PER is approved.

## CHAPTER 2 - CHECKLIST FOR LOCATING AND DEVELOPING A NEW DRINKING WATER SOURCE

*In addition to finding water, there are other things to consider when locating a well.*

### To Do Before Construction

#### □ Preliminary Evaluation Report

- **Delineation Report** - The expertise of a ground-water professional is usually required to develop a delineation report. This report will provide the public water system (PWS) with a map that delineates the four protection zones required by the Drinking Water Source Protection Rule (R309-113 of the Utah Administrative Code). It will also report whether the well is in a protected or an unprotected aquifer.

Is the well located in a protected aquifer?

*Consideration:* If a new well is located in a protected aquifer, land use agreements that restrict uncontrolled potential contamination sources (PCSs) are only needed in zone one. If the well is located in an unprotected aquifer, land use agreements that restrict pollution sources, unless they can be controlled by design standards, are also needed in zone two.

*Consideration:* Protected aquifer status is the most important consideration when the Division of Drinking Water evaluates the system's eligibility for a pesticide and/or VOC susceptibility reduced monitoring waiver.

- **Inventory of Potential Contamination Sources** - An inventory which includes any facility or site which employs an activity or procedure which may potentially contaminate ground water. Further, for it to be a PCS, a hazardous substance is usually associated with the processes used at the facility. This includes use, storage, manufacture, transportation, and disposal of hazardous substances. They may be chemical, biological, or radiological.

Are there uncontrolled PCSs within zone one?

*Consideration:* A new well cannot be approved if there are uncontrolled PCSs within zone one.

Are there uncontrolled pollution sources within zone two?

*Consideration:* If a new well is located in an unprotected aquifer, it cannot be approved if there are uncontrolled pollution sources within zone two.

Are there sewer lines within zones one and two?

*Consideration:* Sewer lines that have at least five feet of suitable soil under them are permitted if they are set back at least 10 feet from the well and are specially

constructed within zone one in accordance with R309-204-6(4). If there are unsuitable soil conditions (ground water or bedrock) within 5 feet under any sewer lines they must be set back at least 300 feet from the well and be specially constructed within zone two.

Are there any PCSs on the inventory that may be impossible to control?

*Consideration:* Even though, public water systems may work with existing PCSs through memoranda of agreement, best management practices, and public education, etc., some may still be so difficult to control that the PWS may want to consider a different location for the well.

- **Land Ownership Map** - A land ownership map which includes all land within zones one and two is required. Additionally, include a list which exclusively identifies the land owners in zones one and two or the management area, the parcel(s) of land which they own, and the zone(s) in which they own land. A land ownership map and list are not required if ordinances are used to protect these areas.
- **Land Use Agreements, Letters of Intent, or Zoning Ordinances** - Land use agreements which meet the requirements of the definition in R309-113-6(1)(n) is required. Zoning ordinances which are already in effect or letters of intent may be substituted for land use agreements; however, they must accomplish the same level of protection that is required in a land use agreement. Letters of intent must be notarized, include the same language that is required in land use agreements, and contain the statement that "the owner agrees to record the land use agreement in the county recorder's office, if the source proves to be an acceptable drinking water source." The PWS shall not introduce a new source into its system until copies of all applicable recorded land use agreements are submitted to DDW.

Will the land owners within zone one (and zone two, if the well is in an unprotected aquifer) sign land use agreements? If the land owners will not sign land use agreements, are zoning restrictions possible?

*Consideration:* **A new well cannot be approved without the necessary land use agreements or zoning restrictions.**

- **Waivers** - A use waiver for the pesticide and/or VOC parameter groups may be issued if the chemicals in these parameter groups have not been used, disposed, stored, transported, or manufactured within zones one, two, and three for the past five years. Additionally, initial sampling must indicate that none of the chemicals within these parameter groups are present.

*If a use waiver is not possible, the PWS may consider applying for a susceptibility waiver when the Drinking Water Source Protection Plan is submitted.*

Are pesticides and VOCs used within zone three?

*Consideration:* Pesticide and VOC use waivers cannot be issued if pesticides and VOCs are used within zone three within the past five years.

- **Engineering Plans and Specifications** - Engineering plans and specifications governing well drilling must be prepared and submitted to the Engineering Section. The PER must be prepared and submitted to the Special Services Section. A letter which covers the approval of both the engineering plans and specifications and the PER must be received by the PWS before well drilling commences.

#### **To Do During Construction**

- **Grouting Inspection during Well Construction** - An engineer from DDW, or a district engineer from the Department of Environmental Quality, or an authorized representative of the State Engineer's Office shall be contacted at least three days before the anticipated beginning of the well grouting procedure (see R309-204-6(6)(i)). The well grouting procedure shall be witnessed by one of these individuals or their designee.

#### **To Do After Construction**

The following applicable information must be submitted after the source is constructed in order for the PWS to obtain an Operation Permit which allows them to introduce a source into the system:

- A copy of the "Report of Well Driller";
- a copy of the letter certifying that the well was grouted in accordance with the well drilling specifications and the requirements of the R309-204;
- a copy of the pump test including the yield vs. drawdown test as described in R309-204-6(10)(b);
- a copy of the chemical analyses required by R309-204-4(5);
- documentation indicating that the water system owner has a right to divert water for domestic or municipal purposes from the well source;
- a copy of the complete plans and specifications covering the well equipment and diversion piping necessary to introduce the water from the well into the distribution system;
- a bacteriological analysis of the water obtained from the well after the installation of permanent equipment, disinfection, and flushing; and
- if *letter of intent* was submitted, then a copy of the recorded *land use agreement* must be submitted.

## Part II

### DRINKING WATER SOURCE PROTECTION PLANS

Use this part of the Source Protection User's Guide to develop Drinking Water Source Protection plans. The schedule for submitting plans is in the introduction. A concise description of what needs to be in each section of a plan is in the *Standard Report Format for Existing Wells and Springs*. Call us at 536-4200, to request a copy of this report.



## **CHAPTER 3 - THE DRINKING WATER SOURCE PROTECTION PLAN**

A Drinking Water Source Protection (DWSP) plan is required for each well, spring, and tunnel which is used as a source by a public water system (PWS). There are two exceptions: 1) sources which are under the direct influence of surface water and are treated in accordance with the Surface Water Treatment Rule, and 2) compliance with this rule is voluntary for existing sources which are used by transient non-community water systems. Transient non-community systems must still submit and meet the requirements for Preliminary Evaluation Reports (PERs) and DWSP plans for any new sources that are developed. Also, be aware that source protection is required for non-transient, non-community systems. Additionally, PERs for new wells, springs, and tunnels must be refined to meet the requirements for DWSP plans within one year of the PER approval letter date. The submittal schedules for these source protection documents are found in the Introduction of this User's Guide. DWSP plans are briefly described below; a detailed description is in the *Standard Report Format for Existing Wells and Springs*. Call us at 536-4200, to request a copy of this document.

### **Purpose of Drinking Water Source Protection Plans**

DWSP Plans are the primary means for PWSs to use to protect their sources of drinking water from contamination. These plans should not be developed just to meet the "letter of the law" required by the Rule. *They must be working documents that will be used on a regular basis by the PWS. The DWSP plan should be written as a "how-to" handbook for the water system to protect their sources of drinking water now and in the future.* They should be logical and easily understood. The implementation schedule is one of the most important sections of the DWSP plan because it is a summary list containing every land management strategy and beginning implementation date that is to be carried out by the PWS.

### **Required Sections of DWSP Plans**

A brief explanation of each section of a DWSP plan follows:

*The Delineation Report* (refer to Chapter 4) - The delineation report describes the protection zones and the scientific procedures which are used to define them.

*The Inventory of Potential Contamination Sources* (refer to Chapter 5) - The inventory is a prioritized list of all of the PCSs within the protection area.

*The Assessment of Potential Contamination Source Hazards* (refer to Chapter 6) - The assessment allows you to determine which PCSs are adequately controlled and which are not.

*The Management Program for Existing Potential Contamination Sources* (refer to Chapter 7) - The program you develop to control each of the PCSs within your protection area.



*The Management Program for Future Potential Contamination Sources* (refer to Chapter 8) - The program you develop to control PCSs that may want to move into your protection areas.

*The Implementation Schedule* (refer to Chapter 9) - A summary list of the land management strategies you have identified in your management programs and the date you will begin to implement each of them.

*The Resource Evaluation* (refer to Chapter 9) - An assessment of the financial and other resources that you estimate will be required to carry out your DWSP plan. It also includes an evaluation of how you plan to acquire these resources.

*The Recordkeeping Section* (refer to Chapter 9) - A section of the plan for you to document the implementation of each land management strategy you identify in the Implementation Schedule. Documents may include zoning ordinances, codes, permits, memoranda of understanding, public education programs, land use agreements, etc.

*The Contingency Plan* (refer to Chapter 10) - A plan submitted concurrently with your first DWSP plan. It may address emergencies, rationing, cleanup, and new source development.

*Pesticide and VOC Waivers* (refer to Chapter 11) - Explains use and susceptibility monitoring waivers for pesticides and VOCs.

The remaining chapters and appendices of this User's Guide will help you ensure that each section of your DWSP plan is complete and fulfills the requirements of the DWSP Rule.

## CHAPTER 4 - THE DELINEATION REPORT

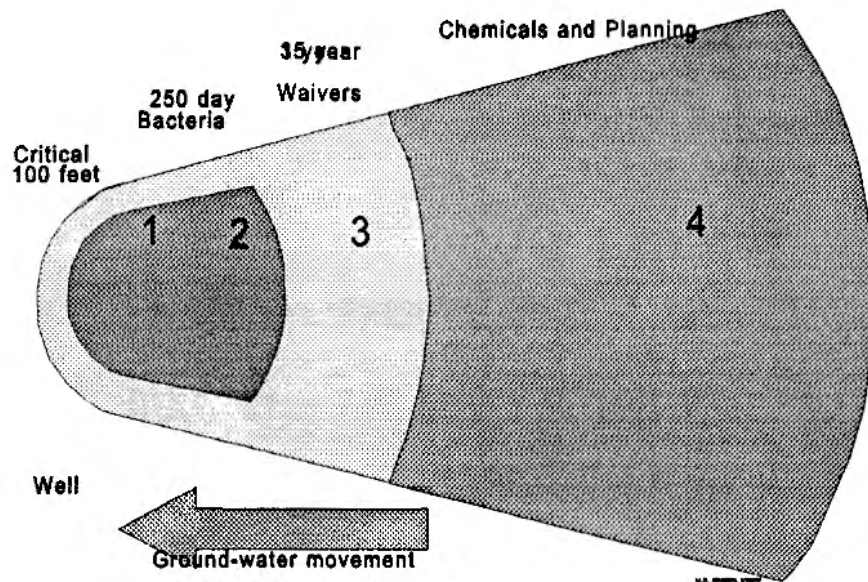
A drinking water source protection area is the surface and subsurface area surrounding a well, spring, or tunnel through which contaminants are likely to move toward and contaminate the source. Hydrogeologic methods are available to define these drinking water source protection areas. These methods rely on scientific procedures to identify reasonably accurate source protection areas. Once source protection areas are delineated, the public water system (PWS) can focus their attention on inventorying potential contamination sources (PCSs) and strategies to control them.

### Drinking Water Source Protection Zones

Two procedures to delineate source protection areas are described in Utah's DWSP Program: the Preferred Delineation Procedure and the Optional Two-Mile Radius Delineation Procedure. Thresholds for four zones are established by the Preferred Procedure:

- ▶ *Zone One* is the area within a 100-foot radius from the wellhead or margin of the collection area.
- ▶ *Zone Two* is the area within a 250-day ground-water time of travel to the wellhead or margin of the collection area, the boundary of the aquifer(s) which supplies water to the ground-water source, or the ground-water divide, whichever is closer.
- ▶ *Zone Three* (waiver criteria zone) is the area within a 3-year ground-water time of travel to the wellhead or margin of the collection area, the boundary of the aquifer(s) which supplies water to the ground-water source, or the ground-water divide, whichever is closer. Zone three is a three year time-of-travel zone because use and susceptibility waivers must be renewed every three years. Refer to Chapter 11, for more information about waivers.
- ▶ *Zone Four* is the area within a 15-year ground-water time of travel to the wellhead or margin of the collection area, the boundary of the aquifer(s) which supplies water to the ground-water source, or the ground-water divide, whichever is closer.

If the aquifer test or driller's log indicate a layer within the producing aquifer(s) with higher ground-water velocity, then time-of-travel calculations must be based on that layer.



The Optional Two-Mile Radius Delineation Procedure is best applied in remote areas where no PCSs threaten the ground water. This is because it is usually impractical to manage an area this large if there are very many PCSs located in it. **Additionally, the two-mile radius delineation procedure cannot be used for new wells.** One protection zone and a management area are established by the Optional Two-Mile Radius Delineation Procedure:

- ▶ *Zone One* is the area within a 100-foot radius from the well or margin of the collection area.
- ▶ *For Wells the DWSP Management Area* is the area outside the 100-foot radius and within the two-mile radius of a well. Land may be excluded from the DWSP management area at locations where it is more than 100 feet lower in elevation than the total drilled depth of the well.

- ▶ *For Springs and Tunnels the DWSP Management Area* is all land at elevations equal to or higher than, and within a two-mile radius of, the spring or tunnel collection area. The DWSP management area also includes all land lower in elevation than, and within 100 horizontal feet of, the spring or tunnel collection area. The elevation datum to be used is the point of water collection. Land can be excluded from the DWSP management area at locations where it is separated from the ground-water source by a surface drainage which is lower in elevation than the spring or tunnel collection area.

### **The Preferred Delineation Procedure**

The Delineation Report which is developed using the preferred procedure includes a description of the geology in the area of the water source, construction and aquifer data, and a description of the hydrogeologic methods which were used. This information is then used to determine the boundaries of the source protection area. Refer to the *Standard Report Formats for Existing or New Wells and Springs* for more information.

Having an accurate preferred delineation may save you time and money as you complete further phases of your DWSP plan. The DWSP Rule does not require that ground-water professionals be certified; however, the delineation report is best completed by someone that is knowledgeable and has experience with ground water. The information required in it can be very technical, and hydrogeologic consulting services are recommended. Appendix A contains a list of consultants that may be able to help you. If you choose to employ a consultant to delineate your protection area, use the same care you would use in obtaining the services of any other professional firm. Also refer to R309-113-9(5)(a).

### **Delineation Reports for the Optional Two-Mile Radius Delineation Procedure**

You should be able to develop the delineation report for the optional two-mile radius delineation procedure without the assistance of a hydrogeologic consultant, unless a hydrogeologic report is necessary for any of the PCSs within Zone one or the management area. The management area must be plotted on a map showing the location of the ground-water source of drinking water and the DWSP management area boundary. The base map shall be a 1:24,000-scale (7.5-minute series) topographic map, such as is published by the U.S. Geological Survey. Although zone one (100-foot radius around the well or margin of the collection area) need not be on the map, the complete two-mile radius must be drawn and labeled. More detailed maps are optional and may be submitted in addition to the map required above.

You have two options to address any PCSs located within the two-mile radius:

- ▶ The first is to assume that these PCSs could contaminate your ground-water source, then plan and implement land management strategies to control them.
- ▶ Otherwise, you must submit the hydrogeologic report for each PCS, as required in R309-113-9(5)(b)(ii). The purpose of this report is to determine if it is possible for a particular PCS to contaminate your well, spring, or tunnel. Hydrogeologic reports can be commissioned by

owners of PCSs to determine their potential to contaminate. If a report proves there is no potential to contaminate, there is no need to plan or implement control strategies.

## CHAPTER 5 - THE INVENTORY OF POTENTIAL CONTAMINATION SOURCES

The inventory of potential contamination sources identifies the facilities within your protection zones that could possibly contaminate drinking water unless you plan and implement a protection program.

Once you have an inventory of PCSs, it must be prioritized from the PCS that poses the greatest risk to the one that poses the least risk. Additionally, the location of each PCS must be identified and plotted on a map.

### Potential Contamination Source Definition

*Potential contamination source (PCS)* means any facility or site which employs an activity or procedure which may potentially contaminate ground water. Further, for it to be a PCS, a hazardous substance is usually associated with the procedures employed at the facility. This includes use, storage, manufacture, transportation, and disposal of hazardous substances. They may be chemical, biological, or radiological. List only PCSs that are currently located within your protection zones; **don't list possible future PCSs, they are covered in Chapter 8.**

### Survey Methods

Windshield, door-to-door, mail, and telephone surveys are some of the different types of surveys available to help you compile a complete inventory. Any reasonable survey method or combination of methods is acceptable. Use the type of survey that will meet your needs. However, be sure to use a survey form to conduct the survey. The Division of Drinking Water has one you may request at 536-4200, or you may design your own.

Surveys are designed by combining a number of discrete steps, including designing the survey, obtaining a list of contacts, mailing the survey or telephoning the contacts, following up on responses to the survey, and finally, tabulating and interpreting the results. Although windshield surveys may be time consuming, one study found that they identified the highest percentage of total sources among the source inventory methods that were used. Door-to-door surveys are ideal for gathering detailed inventories; although, it is usually necessary to train a service group, such as Retired Senior Volunteer Program (RSVP) members, to conduct the survey because of the large number of homes and businesses that usually need to be contacted.

### Potential Contamination Source Inventory

Using your survey form and the following list as a guide, compile your list of PCSs. If you find other potentially contaminating activities that are not on this list, be sure to include them also:

- |                                          |                                                                                              |
|------------------------------------------|----------------------------------------------------------------------------------------------|
| 1. Active and abandoned wells            | 2. Agricultural pesticide, herbicide, and fertilizer storage, use, filling, and mixing areas |
| 3. Airport maintenance and fueling sites | 21. Industrial manufacturers: chemicals,                                                     |

4. Animal feeding operations with more than ten animal units
5. Animal watering troughs located near unfenced wells and springs that attract livestock
6. Auto washes
7. Beauty salons
8. Boat builders and refinishers
9. Chemical reclamation facilities
10. Chemigation wells
11. Concrete, asphalt, tar, and coal companies
12. Dry cleaners
13. Farm dump sites
14. Farm maintenance garages
15. Feed lots
16. Food processors, meat packers, and slaughter houses
17. Fuel and oil distributors and storers
18. Furniture strippers, painters, finishers and appliance repairers
19. Grave yards, golf courses, parks, and nurseries
20. Heating oil storers
36. Research laboratories
- pesticides, herbicides, paper and leather products, textiles, rubber, plastic, fiberglass, silicone, glass, pharmaceutical, and electrical equipment, etc.
22. Industrial waste disposal/impoundment areas and municipal wastewater treatment plants, landfills, dumps, and transfer stations
23. Junk and salvage yards
24. Laundromats
25. Machine shops, metal platers, heat treaters, smelters, annealers, and descalers
26. Manure piles
27. Medical, dental, and veterinarian offices
28. Mortuaries
29. Mining operations
30. Muffler shops
31. Pesticide and herbicide storers and retailers
32. Photo processors
33. Print shops
34. Radiological mining operations
35. Railroad yards
48. Submersible pumps used to pump



- |                                                                                                                      |                                                   |
|----------------------------------------------------------------------------------------------------------------------|---------------------------------------------------|
| 37. Residential pesticide, herbicide, and fertilizer storage, use, filing, and mixing areas                          | 49. Taxi cab maintenance garages                  |
| 38. Residential underground storage tank                                                                             | 50. Tire shops                                    |
| 39. Salt and sand-salt piles                                                                                         | 51. Toxic chemical and oil pipelines              |
| 40. Sand and gravel mining operations                                                                                | 52. Vehicle chemical supply storers and retailers |
| 41. School vehicle maintenance barns                                                                                 | 53. Vehicle dealerships                           |
| 42. Sewer lines                                                                                                      | 54. Vehicle quick lubes                           |
| 43. Single-family septic tank/drain-field systems                                                                    | 55. Vehicle rental shops                          |
| 44. Sites of reported spills                                                                                         | 56. Vehicle repair, body shops, and rust proofers |
| 45. Small engine repair shops                                                                                        | 57. Vehicle service stations and terminals        |
| 46. Stormwater impoundment sites and snow dumps                                                                      | 58. Wood preservers                               |
| 47. Subdivisions using subsurface wastewater disposal systems (large and individual septic tank/drain-field systems) |                                                   |

## Data Bases

Data bases maintained by various agencies may also help you identify PCSs within your protection zones. These data bases may contain valuable information about PCSs within your protection zones. Other sources of information include old and new telephone books, assessors' maps and records, city business licenses, and aerial photographs. Other data bases may be available, these are some that we know about:

- *State Geographic Information Database (SGID)*: The Utah Automated Geographic Reference Center maintains this data base. It can tell you the locations of abandoned mines, CERCLA sites, RCRA sites, SARA Title III sites, underground storage tanks, class V injection wells, coal deposit sites, ground water permit sites, toxic release inventory sites, etc. There is a fee to obtain this information. This office is located in the State Office Building, 450 N Main, SLC, UT, and can be contacted at 538-3163.

- ▶ **Local Emergency Planning Committees:** These committees maintain information about toxic substances that are stored or used at PCS facilities. SARA Title III requires these committees to maintain information about toxic chemicals that are stored, used, or manufactured at these facilities above certain threshold amounts. The information they maintain is available to the public upon request. Local Emergency Planning Committees may also be able to furnish you with Material Safety Data Sheets (MSDSs). These information sheets provide information about the properties and health effects of the toxic chemicals used at these sites. If they can't furnish you with the specific MSDSs you need, the chemical manufacturer is required to provide them to you upon request. MSDSs are also available on the Internet, one site is located at "<http://MSDS.PDC.CORNELL.EDU/issearch/msdssrch.htm>." Refer to appendix E for a list of the Local Emergency Planning Committees in Utah.
- ▶ **The Division of Water Rights:** This division of state government maintains information about the locations of wells that have been drilled in Utah. Additionally, they maintain files containing the Report of Well Driller for these wells. This division is located at 1636 W North Temple, SLC, UT, and can be contacted at 538-7240.
- ▶ **The Department of Community and Economic Development:** This department publishes the *Directory of Business and Industry*. It contains listings for business and manufacturing firms that have more than ten employees. These listings are classified by a "standard industrial code." This department is located at 324 S State, SLC, UT, and can be contacted at 538-8700.

Even if information from data bases is readily available, the listings will only identify facilities that have complied with requirements to file notification or obtain permits. Other inventory approaches must be used to identify unpermitted facilities.

### **Point and Nonpoint Sources of Contamination**

Point sources of pollution are usually easy to inventory because they are visible and discrete; nonpoint sources are diffuse and often hard to trace to their sources. Another characteristic of nonpoint source pollution is that it is usually not adequately controlled by rules or regulations. Since many of these types of potential sources are unregulated, your effort should be focused on locating and inventorying them so effective control measures can be planned. Following are some examples of both point and nonpoint PCSs that are usually not adequately controlled and are often difficult to locate and inventory:

- ▶ Petroleum and other toxic chemicals that are stored underground for certain uses or below certain threshold quantities.
- ▶ Petroleum and other toxic chemicals that are stored above ground.
- ▶ Light industry processes that store and use toxic chemicals, but do not produce a "waste stream." The storage and use of these chemicals by light industry also increases the potential for accidental spills involving transfers from one container to another or leaks caused by

rupture or corrosion of containers. Small spills or leaks in the same area over a long period of time have been linked to major contamination problems.

- ▶ On-site wastewater disposal systems (septic tanks/drain-fields) have controls on their construction and site locations, but very few controls on their maintenance or what is actually disposed in them. Improper disposal of toxic chemicals in septic systems have been sources of major contamination incidents. Despite efforts to regulate their placement and use, septic systems still represent the largest reported cause of ground-water contamination resulting in disease outbreaks in the United States.
- ▶ Water wells and other types of wells that have been improperly constructed, maintained, repaired, or abandoned may provide a conduit which can contaminate aquifers used for drinking water sources.
- ▶ Under certain geologic conditions, some pesticides applied to the land can leach to ground water even from normal application procedures.
- ▶ Pesticides may enter ground water through irrigation wells connected to chemigation systems unequipped with check valves to prevent back-siphonage of chemicals into the wells. When check valves are used at the wellhead to protect aquifers, they should be routinely tested and adequately maintained to ensure their integrity.
- ▶ Small but repeated pesticide spills over long periods of time in the same location by bulk handlers have been identified as significant sources of contamination.
- ▶ Fertilizers leaching into the ground water and increasing nitrate to high levels have been associated with methemoglobinemia ("blue-baby syndrome") in infants.

## **Hazards**

Identifying potential sources of contamination is meaningless unless steps are taken to further identify the specific hazards employed at each facility. This information gathering step may be completed as the survey is carried out or you may choose to make a personal contact at a later time with a representative of the PCS. Hazardous substances may be chemical, biological, or radiological. They are usually labeled and display one or more of the following properties:

- ▶ Ignitable - capable of burning or causing a fire
- ▶ Corrosive - capable of eating away materials and destroying living tissue
- ▶ Explosive - capable of causing an explosion or releasing poisonous vapors when exposed to air, water, or other chemicals
- ▶ Toxic - capable of poisoning someone, either immediately (acutely toxic) or over a long period of time (chronically toxic)
- ▶ Radioactive - capable of damaging and destroying cells

Telephone contact is appropriate for some personal interviews to gather information about the hazards used certain PCSs; a site visit is valuable to help you understand the hazards at certain other facilities. There should be a place on your survey form to document hazard information. The personal interview is a critical step in the information gathering process. Don't try to avoid it by sending letters or by thinking that you understand the potential hazards at a particular potential contamination facility. This information must be accurate in order for control strategies to effectively prevent contamination. Also, a personal interview is an excellent opportunity for you to convey the idea that both the PWS and the PCS should be working toward the same ground-water protection goals. Do your best to avoid adversarial relationships because uncooperative PCS personnel may defeat some of your source protection goals.

### **The Priority Order**

The list of PCSs is arranged in priority order to help direct your resources to activities that are the highest risk to your well or spring. Although, you must explain the basis for the way you prioritize the inventory, your judgement is usually all that is necessary to arrange this list into a priority order. Managing Ground Water Contamination Sources in Wellhead Protection Areas - A Priority Setting Approach, (EPA 570/9-91-023) or some other priority setting guidelines may be used to establish an order if, in your judgement, there are circumstances that require a more precise order.

### **Identify and Plot Location**

The location of each actual PCS must be identified in the inventory (zone 1-4 or the management area) and be plotted on the delineation map.

### **Inventory Maintenance**

Maintaining a list of PCSs is a continuous effort. This list should be updated often enough to ensure that it reflects current conditions in your protection areas. This includes adding PCSs that have moved into your protection areas, deleting sources that have moved out, and updating the data you are gathering to improve your knowledge about the potential sources in your protection areas.

## CHAPTER 6 - THE ASSESSMENT OF POTENTIAL CONTAMINATION HAZARDS

There are four types of hazard controls: Regulatory, best management/pollution prevention, physical, and negligible quantity controls. PWSs are not required to plan and implement land management strategies for PCS hazards that are assessed as *adequately controlled*. Hazards that are assessed *adequately controlled* must be reassessed periodically to ensure that conditions do not worsen without your knowledge. A reassessment date must be established according to the instructions which follow.

Any hazard that is not assessed as *adequately controlled* will be considered to be *not adequately controlled*. Additionally, if the hazards at a PCS cannot be identified, the PCS must be assessed as not adequately controlled. Many PCS hazards have no controls and must to be assessed as *not adequately controlled*. Refer to Chapter 7, for a discussion about planning land management strategies for these PCSs. It is usually redundant to identify more than one hazard control; therefore, only one hazard control should be identified for each hazard. The instructions for assessing each type of control must be followed exactly or the assessment will be considered to be incomplete. Refer to Appendix D, for a list of government agencies and the programs they administer to control PCSs.

### Regulatory Controls

Regulatory controls are the codes, ordinances, rules, and regulations, that are in effect to regulate a PCS hazard. The following six steps are required to assess a hazard as adequately controlled by a regulatory control:

1. Identify the enforcement agency.
2. Quote and/or cite specific references in the regulation, rule, or ordinance which pertain to controlling this hazard.
3. Explain how this regulatory control will prevent ground-water contamination.
4. Verify that this PCS hazard is actually being regulated by the enforcement agency.
5. Assess the hazard as *adequately controlled* and indicate that no further land management strategies will be planned and implemented unless conditions change.
6. Set a date to reassess this control.

### Best Management and Pollution Prevention Practices

Identify the best management and pollution prevention practices that are currently being used by the PCS to control the hazardous substances at the facility. The following five steps are required to assess a hazard as adequately controlled by best management/pollution prevention practices:

1. List the best management /pollution prevention practice which are being used to control this hazard.
2. Indicate that PCS management is willing to continue the use of these best management/pollution prevention practices to prevent ground-water contamination.

3. Explain how these best management/pollution prevention practices will prevent ground-water contamination.
4. Assess the hazard as *adequately controlled* and indicate that no further land management strategies will be planned and implemented unless conditions change.
5. Set a date to reassess this control.

### Physical Controls

Physical controls are man-made structures and impoundments, such as spill protection, that are in place to prevent a hazard from entering the ground water. The following four steps are required before you can assess a hazard as adequately controlled by a physical control:

1. Identify the physical control(s) which has been constructed to control this hazard.
2. Explain how these controls prevent contamination.
3. Assess the hazard as *adequately controlled* and indicate that no further land management strategies will be planned and implemented unless conditions change.
4. Set a date to reassess this control.

### Negligible Quantity Controls

Negligible quantity controls refer to the amount or toxicity of a hazardous substance that is used by a PCS at their facility. It means that the risk of ground-water contamination is so negligible that it is not worth the time and effort to plan land management strategies to control it. The following four steps are required before you can assess a hazard as adequately controlled by a physical control:

1. Identify the hazardous substance and the quantity that is being used, disposed, stored, or transported.
2. Explain why this amount should be considered a negligible quantity.
3. Assess the hazard as *adequately controlled* and indicate that no further land management strategies will be planned and implemented unless conditions change.
4. Set a date to reassess this control.

Once you have separated the *adequately controlled* PCSs from the *not adequately controlled* PCSs, you can begin to plan land management strategies for the ones that are *not adequately controlled*. You need to plan land management strategies for each one of these. The next chapter discusses The Management Plan for Existing PCSs.



## **CHAPTER 7 - THE MANAGEMENT PROGRAM FOR EXISTING POTENTIAL CONTAMINATION SOURCES**

The Rule requires that land management strategies be planned for potential contamination source (PCS) hazards that are *not adequately controlled*. Public water systems (PWSs) have complete discretion to choose the land management strategies that will work best for them. The Division of Drinking Water (DDW) understands that these are local problems that require local solutions. We will not disapprove a plan because we disagree with management strategies. We may offer suggestions, but the PWS must be responsible to make the final decisions about the land management strategies it implements.

### **Regulatory and Non-regulatory Land Management Strategies**

Land management strategies may be either regulatory or non-regulatory. Some examples of regulatory land management strategies are zoning and subdivision ordinances, site plan reviews, design and operating standards, and source prohibitions. Some examples of non-regulatory land management strategies are public education programs, purchase of property or development rights, household hazardous waste collection programs, ground-water monitoring, water conservation programs, memoranda of understanding, and written contracts and agreements. Refer to **Wellhead Protection Programs: Tools For Local Governments**, (EPA 440/6-89-002) for more information.

Don't make the mistake of thinking that the most effective land management strategies will always be regulatory. Remember that regulations usually require enforcement and there are many activities that are very difficult to enforce. These include pesticide and fertilizer application, waste disposal in septic tanks, the use and disposal of household hazardous waste, etc. Public education programs and memoranda of understanding which identify specific BMPs are much more effective in addressing these types of activities.

### **Best Management Practices for Commercial, Industrial, and Agricultural PCSs**

Commercial, industrial, and agricultural PCSs that have been assessed as *not adequately controlled* should be contacted and informed that they are within the system's source protection zones. The PWS should provide them with a list of general best management practices (BMPs) that apply to their standard operational procedures. Explain that following these BMPs is the first step in preventing drinking water contamination. DDW can provide general BMPs for the following facilities: Dry cleaners, metal finishers, print shops, vehicle maintenance, and use of pesticides and fertilizers. More facilities will be added to this list, so check with us at (801) 536-4200, from time to time to see what is available.

The next step is to persuade PCSs to develop their own facility specific BMPs. Each PCS's goal should be to prevent hazardous chemicals from coming in contact with the ground. Suggest the following procedure: Identify each hazardous chemical used at the facility which could contaminate ground water; draw a separate flow chart for each chemical which details its flow through the facility; and finally, identify the critical points in the flow charts where each chemical could potentially come



in contact with the ground and subsequently enter the ground water and contaminate it. This can usually be accomplished with a simple drawing and a few questions:

- ▶ How is it received and checked into inventory?
- ▶ Where is it stored?
- ▶ How is it used at the facility?
- ▶ Is there a waste stream from it that must be disposed?
- ▶ If so, how is it disposed?

Once they have identified the critical points where chemicals could be spilled or deposited on the ground, the next step is fairly simple: Develop a list of BMPs for each hazardous chemical to prevent it from being spilled or deposited on the ground. An employee training program to implement the facility specific BMPs is the last and most important step of this process. Additionally, the PCS should post their facility specific BMPs in work areas and share them with the water system so they can be documented in the recordkeeping section of the source protection plan. A memorandum of agreement which lists the BMPs and is signed by both the PWS and the PCS is also very important so that what is expected from each party is clearly understood.

Additionally, you may request a fact sheet from DDW by calling 536-4200, which explains pollution prevention programs. Pollution prevention programs are very similar to BMPs, and are another common sense approach in preventing ground water contamination.

### **Residential PCSs**

Residential PCSs may be more effectively addressed using a different approach. You may be able to address them collectively through public education programs. Bill stuffers, newspaper or newsletter articles, and workshops provide an effective vehicle for these public education programs. The critical topics for residential PCSs include pesticide and fertilizer application, use and disposal of household hazardous waste, and proper use and maintenance of septic tank/drain-field systems. We have developed fact sheets for each of these topics that you may request at 536-4200.

### **Information Sheets**

Appendix G lists the PCS information sheets that are available from DDW. Refer to this material for guidance in identifying current controls and assessing them. It also contains suggestions about best management and pollution prevention practices. DDW can supply you with some fill-in-the-blank forms to help you record and organize the information you gather about each PCS. Please call 536-4200 to request this material.

## **CHAPTER 8 - THE MANAGEMENT PROGRAM FOR FUTURE POTENTIAL CONTAMINATION SOURCES**

The Rule requires that a program be established to manage potential contamination sources (PCSs) that may want to locate within your protection zones some time in the future. This management program must be consistent with the provisions of the Rule to an extent allowed under your authority and jurisdiction. This may be a local program that establishes a process to identify PCSs that can control their contamination and those PCSs that cannot. Those that can and will control their contamination should be allowed to locate within protection areas and those that cannot should not be permitted.

### **Minimum Requirement for a Controlling Future PCSs**

The PWS must establish and write into their plan the following process to fulfill the minimum requirement for controlling future PCSs:

1. Contact each PCS as it locates within your protection zones,
2. add it to the inventory of potential contamination sources,
3. identify and assess its controls, and
4. plan and implement land management strategies, if it is not adequately controlled.

### **Planning and Zoning Ordinances**

The intent of the Rule is that you address such issues as: What if a subdivision, recreational facility, mining, or logging company wanted to locate or operate in your protection areas. We recommend that you address these issues by examining land ownership and future potential uses. Then you can pursue appropriate land management strategies depending on whether the land is public or privately owned. If you don't seek to address these issues now they will be much more difficult to address as future intended land uses are made known by various developers.

Adopting zoning ordinances is the most effective way to control future PCSs. Zoning ordinances allow you to:

- ▶ Control subdivision development and industrial growth at desirable levels,
- ▶ conduct site plan reviews,
- ▶ evaluate design and operating standards,
- ▶ ensure adequate spill protection and waste disposal procedures, and
- ▶ prohibit facilities that would discharge contamination to your aquifer.

Refer to Appendix F, for an example of a Source Protection Zoning Ordinance.

### **Authority and Jurisdiction**

The Rule requires that land management strategies be planned which are consistent with its provisions and to an extent allowed under the authority and jurisdiction of the PWS. Cities, towns, and counties have the authority to pass and enforce zoning ordinances to control potential contamination. Some PWSs are owned by municipal governments and some are not. However, even those that are owned by municipal government may have protection zones that extend outside of their boundaries. Many PWSs lack the authority or jurisdiction to pass and enforce zoning ordinances within their protection zones. Planning and carrying out effective land management strategies may be difficult under these circumstances but in most situations it is still possible. Consider the following solutions:

- ▶ Protecting our drinking water should be an objective of all local governments. Because of this, the city, town, or county outside of your jurisdiction may be willing to pass zoning ordinances to protect your sources of drinking water. Draft a protection strategy and discuss it with them in one of their meetings. They may ask you to work with their planner to develop an ordinance that is agreeable to all concerned.
- ▶ Section 10-8-15 of the Utah Code gives cities and towns the extraterritorial authority to enact ordinances to protect a stream or source from which their drinking water is taken,... "for 15 miles above the point from which it is taken and for a distance of 300 feet on each side of such stream..." Class I cities (greater than 100,000 population) are granted authority to protect their entire watersheds. Section 10-8-15 applies to ground-water sources of drinking water.

### **Subdivisions**

Many subdivisions provide a water supply for their development through a public water system. They must also meet the requirements of source protection. Since subdivision developers own the land, they should provide for source protection to an extent required by the Rule. This includes providing setbacks and open spaces to provide a buffer area free of PCSs. Additionally, public education programs relating to the household use of pesticides and fertilizers, household hazardous waste, and disposal practices in septic tank/drain-field systems may be required.

## **CHAPTER 9 - THE IMPLEMENTATION SCHEDULE, RESOURCE EVALUATION & RECORDKEEPING SECTIONS**

Following are guidelines to help you complete the Implementation Schedule, Resource Evaluation, and Recordkeeping sections of your plans.

### **Implementation Schedule**

The Implementation Schedule is a summary list of land management strategies which identifies a beginning implementation date for each one. This summary list contains all of the land management strategies that you have identified in the management programs for both existing and future potential contamination sources (PCSs). Each *not adequately controlled* PCS hazard must be addressed. The Rule requires that land management strategies be implemented according to this schedule.

### **Resource Evaluation**

This section allows you to evaluate the financial and other resources you need to plan and carry out your Drinking Water Source Protection Plan. It also helps you assess the resources you will need to acquire before it can be implemented. Do you have adequate staff support? Will community volunteers help make up any resources you are lacking? Do you need to increase your fees or water rates? The Resource Evaluation may be as brief or as detailed as you choose.

### **Recordkeeping**

The implementation of each land management strategy that you have listed in the Implementation Schedule must be documented in this section of the plan. You can do this by inserting copies of zoning ordinances, public education program materials, permits, memoranda of agreements, contracts, and notes for record, etc., into this section of the plan.

## CHAPTER 10 - THE CONTINGENCY PLAN

Contingency Plans should focus on the identification and possible solution of problems that may arise in the event that the Drinking Water Source Protection (DWSP) plan fails. Additionally, Contingency Plans address problems public water systems (PWSs) need to solve in the event of water shortages or contamination incidents that may impact their ability to supply safe drinking water to the public. Contingency planning includes emergency response, rationing, remediation, and new source development plans. Prior planning helps PWSs avoid crisis planning during emergency situations. Refer to Guide To Ground-Water Supply Contingency Planning For Local And State Governments, (EPA 440/6-90-003) for more information.

PWSs shall submit a Contingency Plan that includes all sources of drinking water for the entire water system to DDW concurrently with the submission of their first DWSP Plan.

There are four possible parts to Contingency Plans: 1. Emergency Response; 2. Rationing; 3. Remediation; and 4. Source Development Plans. PWSs should coordinate their contingency plans with plans developed in accordance with SARA Title III by local Emergency Planning Committees. *Guidelines for developing the four possible parts of a Contingency Plan are discussed in the remainder of this chapter. Since these guidelines may not apply to every PWS or every emergency situation, each PWS should design a contingency plan that specifically addresses their needs.*

### Emergency Response Plans

Emergency response planning focuses on short-term solutions to likely problems the PWS may encounter because of accidents and natural disasters. The solutions will likely require the mobilization of resources for repairing the physical structure of the water system and sampling or issuing a "boil order" to assure that water is safe to drink. Please refer to the Emergency Response Handbook, available from DDW at 536-4200, for detailed guidelines on emergency response planning.

### Rationing Plans

Rationing plans establish a course of action to be implemented when water shortages occur. These shortages may be caused by drought, seasonal overuse, contamination, or accidents. Plans should contain clearly defined, step-by-step procedures that assure the public a sufficient water supply for basic hygienic and culinary needs. Consider the following:

1. Each PWS should determine the "action level" caused by a water shortage which will initiate their rationing plan. An "action level" is the critical point of water shortage that signals a PWS to implement their rationing plan.
2. List the positions and administrative duties of each person in the chain-of-command responsible for implementing the rationing plan.

3. Determine the resources available to the water system in dealing with water shortages. The following should be assessed: alternate water supplies; emergency water supply equipment; replacement equipment; technical assistance; and communication equipment.
4. Develop a step-by-step procedure for implementing the conservation measures to be taken.
5. Identify the public education, follow-through, and compliance actions to be taken to ensure consumers are following the rationing directives.
6. Determine how consumers and the media will be kept informed of the status of the emergency situation and the augmentation of the rationing plans.

### **Water Supply Decontamination Plans**

The technology is available for reducing some contaminants in drinking water to acceptable levels. The most common example of this approach is disinfection to remove microbiological contamination. Another example is air stripping to remove volatile organic compounds, such as solvents. As contamination continues to threaten drinking water sources throughout the country, new remediation technology is being developed. Water system management should keep up on what is currently available in the field of remediation technology. After protection zones have been delineated around each wellhead and spring collection area, and PCSs have been inventoried, it is recommended that the PWS identify the technology available to remediate each specific potential contaminant. There is only one alternative to not remediating a contaminated water supply and that is to abandon the drinking water source.

### **Source Development Plans**

Developing new water supply sources is an important enterprise for a growing public drinking water system. It is also an important enterprise for any water system in the event their present sources are compromised due to contamination or water shortages. In evaluating source development, the following are important considerations:

1. Identify all undeveloped sources of water that have a potential for future development as drinking water sources. Start by listing backup wells and springs currently in the system, then list wells and springs which are abandoned, but could possibly be reclaimed and redeveloped. Finally, list potential springs and new well sites along with possible surface sources. PWSs may want to keep this information confidential to prevent others from filing a claim on a water right first. This information need not be submitted to DDW with the Contingency Plan.

Proposed alternative sources may draw from the same aquifer as an existing water source that could potentially be lost to contamination. Therefore, when identifying potential alternative water supply sources for future development, the PWS should, if possible, first identify sources from different aquifers. If sources in a different aquifer are not possible, it is preferable to identify sources which would draw from parts of the aquifer up gradient from existing sources.

2. Determine the probable production of each of these sources and the percentage of your current and projected needs that would be supplied by each potential source.
3. List the steps required to obtain ownership and water rights for each potential new source. PWSs may be granted water rights based on anticipated water demand.
4. Determine the approximate protection zones around each potential new well or spring. Consider purchasing land or development rights, and enacting protective ordinances or land use agreements to protect the water source within the protection zones.
5. Inventory all PCSs within each approximate protection zone which may affect the quality of the drinking water now or in the future.
6. Identify the microbiological, chemical, and radiological quality of each potential drinking water source. Ensure that all parameters are below established maximum contaminant levels (MCLs).
7. Estimate when each new drinking water source will need to be introduced into the system to meet projected supply requirements.
8. Determine the financial resources that may be required for each drinking water source development project. List possible sources of revenue.
9. List the positions and administrative duties of each person responsible for implementing the drinking water source development plan.
10. Submit a Preliminary Evaluation Report to DDW concurrently with engineering plans and specifications before construction begins on any new ground-water source of drinking water.



## **CHAPTER 11 - PESTICIDE & VOC MONITORING REDUCTION WAIVERS**

Certain monitoring waivers can potentially save Utah's public water systems (PWSs) a substantial amount of money each year. Systems currently pay about \$875 per sample for pesticide group analysis, \$190 per sample for Volatile Organic Chemical (VOC) group analysis, and \$190 per sample for unregulated group analysis. Reduced monitoring waivers for these parameter groups can be issued to systems based on their Source Protection Program.

### **Types of Monitoring Reduction Waivers**

Three types of monitoring waivers are available to PWSs. They are: reliably and consistently, use, and susceptibility. The criteria for establishing a reliably and consistently waiver is set forth in R309-104. The criteria for use and susceptibility waivers follows.

If a source's DWSP plan is due according to the schedule in R309-113-3, and is not submitted to the Division of Drinking Water (DDW), its use and susceptibility waivers for the VOC and pesticide parameter groups will expire unless an exception (refer to R309-113-4) for a new due date has been granted. Additionally, current use and susceptibility waivers for the VOC, pesticide and unregulated parameter groups will expire upon review of a DWSP plan, if these waivers are not addressed in the plan.

### **Use Waivers**

If the chemicals within the VOC and/or pesticide parameter group(s) have not been used within the past five years within zones one, two, and three, the source may be eligible for a use waiver. To qualify for a VOC and/or pesticide use waiver, a PWS must complete the following two steps:

1. List the chemicals which are used, disposed, stored, transported, and manufactured at each potential contamination source within zones one, two, and three where the use of the chemicals within the VOC and pesticide parameter groups are likely; and
2. submit a dated statement which is signed by the system's designated person that none of the VOCs and pesticides within these respective parameter groups have been used, disposed, stored, transported, or manufactured within the past five years within zones one, two, and three.

### **Susceptibility Waivers**

If a source does not qualify for use waivers, and if reliably and consistently waivers have not been issued, it may be eligible for susceptibility waivers. Susceptibility waivers tolerate the use, disposal, storage, transport, and manufacture of chemicals within zones one, two, and three as long as the PWS can demonstrate that the source is not susceptible to contamination from them. To

qualify for a VOC and/or pesticide susceptibility waiver, a PWS must complete the following three steps:

1. Submit the monitoring results of at least one applicable sample from the VOC and/or pesticide parameter group(s) that has been taken within the past five years. A non-detectable analysis for each chemical within the parameter group(s) is required;
2. submit a dated statement from the designated person verifying that the PWS is confident that a susceptibility waiver for the VOC and/or pesticide parameter group(s) will not threaten public health; and
3. verify that the source is developed in a protected aquifer, as defined in R309-113-6(1)(v), and have a public education program which addresses proper use and disposal practices for pesticides and VOCs which is described in the management sections of the DWSP plan.

### **Special Waiver Conditions**

Special scientific or engineering studies or best management practices may be developed to support a request for an exception to paragraph R309-113-15(4)(c) due to special conditions. These studies must be approved by DDW before the PWS begins the study. Special waiver condition studies may include:

- ▶ geology and construction/grout seal of the well to demonstrate geologic protection;
- ▶ memoranda of agreement which addresses best management practices for VOCs and/or pesticides with industrial, agricultural, and commercial facilities which use, store, transport, manufacture, or dispose of the chemicals within these parameter groups;
- ▶ public education programs which address best management practices for VOCs and/or pesticides;
- ▶ contaminant quantities;
- ▶ affected land area; and/or
- ▶ fate and transport studies of the VOCs and/or pesticides which are listed as hazards at the PCSs within zones one, two, and three, and any other conditions which may be identified by the PWS and approved by DDW.

### **Pesticide and VOC Parameter Groups**

We have not included the actual listing of these parameter groups in the User's Guide because they are subject to change. These pesticides and VOCs are identified in the *Water Quality Maximum Contaminant Levels, Rule R309-103 Summary*. You may request a copy from us, a 536-4200. Contact "<http://ace.ace.orst.edu/info/extoxnet/>" on the Internet to help you convert the chemical names of pesticides to commercial names.

## **Protect Your Waivers**

Once a PWS is granted *use* or *susceptibility* waivers it should take steps to ensure that it will not lose these waivers in the future. Protection areas should be guarded against new PCSs moving into protection areas and using or misusing VOCs or pesticides within the parameter groups.

# Appendices

## SUPPLEMENTAL GUIDANCE FOR DEVELOPING SOURCE PROTECTION PLANS



## APPENDIX A - CONSULTING GROUND-WATER PROFESSIONALS

The DWSP Rule does not require that a consultant generate the delineation report, however, the delineation work must be completed by someone that is knowledgeable and has experience with ground water. The information required in the report is quite technical and consulting services are recommended. This appendix contains a list of consultants that have asked to be included; it is not intended to be an endorsement of their capabilities. Additionally, it is not a complete listing of all of the consultants doing this type of work for public water systems in Utah. If you choose to employ a consultant to delineate your protection area, use the same care you would use in obtaining the services of any other professional firm. For other persons or companies who may be qualified to provide these delineations consult listings, such as telephone books, under the headings of hydrologists, geologists, hydrogeologists, engineers-environmental, engineers-geological, and engineers-geotechnical.

| Firm                                                 | Address                                                   | Phone        |
|------------------------------------------------------|-----------------------------------------------------------|--------------|
| Access Environmental Services, Inc.                  | 1217 East 8725 South<br>Sandy, UT 84094                   | 561-8279     |
| Alpha Engineering and Surveying                      | 987 N Main St #1<br>Cedar City, UT 84720                  | 586-0852     |
| Paul B. Anderson<br>Consulting Geologist             | 807 E South Temple<br>Salt Lake City, UT 84102            | 364-6613     |
| Aquifer Science, Inc.<br>Gary Colgan                 | 3322 E Joyce Drive<br>Salt Lake City, UT 84109            | 484-8423     |
| Barnett Intermountain Water Consulting               | 106 W 500 S #101<br>Bountiful, UT 84010                   | 292-4662     |
| Bingham Engineering                                  | 5160 Wiley Post Way<br>Salt Lake City, UT 84116           | 532-2520     |
| Bulloch Brothers Engineering                         | 36 N 300 W<br>Cedar City, UT 84720                        | 586-9592     |
| CH2M Hill                                            | 4001 S 700 E #700<br>Salt Lake City, UT 84107-2122        | 281-2426     |
| Dames & Moore                                        | 127 S 500 E #300<br>Salt Lake City, UT 84102              | 521-9255     |
| Delta Geotechnical Consultants                       | 466 W Lawndale Drive<br>South Salt Lake, UT 84115         | 487-7754     |
| ERM - Rocky Mountain, Inc                            | 102 W 500 S #650<br>Salt Lake City, UT 84101              | 595-4800     |
| Earth Fax Engineering                                | 7324 S 1300 E<br>Midvale, UT 84047                        | 561-1555     |
| Eckhoff, Watson & Preator                            | 3995 S 700 E<br>Murray, UT 84107                          | 261-0090     |
| Environmental & Engineering Solutions<br>John Carter | PO Box 280<br>Mendon, UT 84325                            | 435-753-6062 |
| EnviroSearch International                           | 2319 Foothill Drive #180<br>Salt Lake City, UT 84108-1488 | 801-461-0888 |

| Firm                                                                                                    | Address                                                                        | Phone                |
|---------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------|----------------------|
| Dr. Craig Forster<br>(aquifers in mountainous terrain, fractured-rock<br>aquifers, and special studies) | University of Utah<br>135 S 1460 E Room 719<br>Salt Lake City, Utah 84112-0111 | 581-3864             |
| Franson-Noble & Associates                                                                              | P.O. Box 606<br>American Fork, UT 84003                                        | 756-0309             |
| Geo Consultants                                                                                         | 580 N Main<br>Cedar City, UT 84720                                             | 586-8089             |
| Scott Goodwin, P.E.                                                                                     | 267 S 500 W<br>Richfield, UT 84701                                             | 896-4814             |
| Preston L. Hafen<br>Consulting Geologist                                                                | 115 S Main<br>Veyo, UT 84782                                                   | 574-2760             |
| Hansen Allen & Luce                                                                                     | 6771 S 900 E<br>Midvale, UT 84047                                              | 566-5599             |
| JBR Environmental Consultants Inc                                                                       | 8160 S Highland Drive #A4<br>Sandy, UT 84093                                   | 943-4144             |
| Bruce N. Kaliser<br>Hydrogeologist                                                                      | 2951 Nila Way<br>Salt Lake City, UT 84124                                      | 272-2720             |
| Kleinfelder<br>Ken Adams                                                                                | 2749 E Parley's Way #100<br>Salt Lake City, UT 84109                           | 466-6769             |
| LarWest Engineering                                                                                     | 1770 N Research Parkway #130<br>North Logan, UT 84341                          | 753-0153             |
| Mayo and Associates                                                                                     | 710 E 100 N<br>Lindon, UT 84042                                                | 785-2385             |
| Montgomery Watson Engineers                                                                             | 4525 S Wasatch #200<br>Holladay, UT 84117                                      | 272-1900             |
| North American Mine Services, Inc.<br>Brian Vinton                                                      | 497 N Main<br>Kaysville, UT 84037                                              | 569-7014<br>546-6453 |
| R B & G Engineering                                                                                     | 1435 W 820 N<br>Provo, UT 84601                                                | 374-5771             |
| Reed W. Mower<br>Hydrologist                                                                            | PO Box 67<br>Fairview, UT 84629                                                | 427-9447             |
| Jack R. Rogers, Geologist<br>LASR Geo Consulting                                                        | P.O. Box 1103<br>Castle Dale, UT 84513                                         | 381-5359             |
| Rosenberg & Associates<br>Robert Oliver                                                                 | 649 Red Rock Road<br>St. George, UT 84770                                      | 634-1792             |
| SHB Agra Inc                                                                                            | 4137 S 500 W<br>Murray, UT 84107                                               | 266-0720             |
| Scott Clark - Geologist<br>SHC Consulting                                                               | 279 West 100 South<br>Logan, UT 84321                                          | (435) 752-6897       |



| <b>Firm</b>                                                | <b>Address</b>                                                        | <b>Phone</b>               |
|------------------------------------------------------------|-----------------------------------------------------------------------|----------------------------|
| Secor International                                        | 4001 S 700 E #250<br>Salt Lake City, UT 84107-2178                    | 266-7100                   |
| Shick International Inc<br>Engineering Consulting Services | 3010 First Commerce Center<br>175 W 200 S<br>Salt Lake City, UT 84101 | 359-3012                   |
| Strata Consultants                                         | 330 S 300 E #200<br>Salt Lake City, UT 84111-2525                     | 355-0633                   |
| Tahoma Companies<br>Gary F. Player, Principal Geologist    | 444 S Main St #C7<br>Cedar City, UT 84720                             | 865-0161                   |
| Terracon Consultants Western, Inc.                         | 92 W 3900 S #100<br>Salt Lake City, UT 84107                          | 266-2100                   |
| Wall Engineering<br>Lynn Wall, P.E.                        | 55 South Main #2<br>P.O. Box 39<br>Fillmore, UT 84631                 | 743-6800<br>743-4214       |
| Weston Engineering, Inc.                                   | P.O. Box 682007<br>Park City, UT 84068                                | 467-9866<br>(800) 784-9866 |
| Wilding Engineering                                        | 12411 S. Fort St.<br>Draper, UT 84020                                 | (801) 553-8112             |

## **APPENDIX B - GUIDANCE FOR GROUND-WATER PROFESSIONALS**

### **Delineation of Drinking Water Source Protection Zones**

This guidance is intended for experienced ground-water professionals that are performing delineation work for public water systems (PWSs). Requirements for delineation reports are specified in Section 9 of the Drinking Water Source Protection (DWSP) Rule (R309-113-9, Utah Administrative Code) and in the *Standard Report Formats for New and Existing Wells and Springs*. Call us at 536-4200 to request these documents. Many subjects discussed in this section are not explicitly explained in the DWSP Rule, but are generally accepted hydrogeologic standards or policies of the Division of Drinking Water (DDW).

A DWSP delineation report may be disapproved if the report is inaccurate or is missing any of the required information. When delineating the Source Protection zones, you must use the best data that is reasonably available. Protection zones must be accurate, but the cost of determining them should not be prohibitively expensive for the PWS.

#### **References or Sources of Hydrogeologic Information**

The sources for the hydrogeologic data in the delineation report must be documented. Documentation of your work is standard scientific/professional practice, and the delineation work must be documented in case the public water supplier receives inquiries concerning the delineation.

#### **Aquifer Thickness (saturated thickness of the producing aquifer(s))**

A generally accepted hydrogeologic method to determine aquifer thickness is to use the screened or perforated interval in the well. Another method is to use the thickness of aquifer layers adjacent to the screened interval as shown on the geologic log or Report of Well Driller. When only limited data are available, the aquifer thickness should not be extended below the depth of the well. If available, geologic logs of nearby wells, geologic cross sections, or other data may be used to demonstrate a greater aquifer thickness. If a well only partially penetrates the aquifer, use applicable interpretation and delineation methods.

Fine-grained layers (such as clay and silt) are generally not considered part of a producing aquifer. If the aquifer is confined, the confining layer(s) and all layers above or below it are not part of the producing aquifer. The producing aquifer will generally not include the complete saturated interval shown in the well.

#### **Maximum Pump Rate**

The maximum anticipated pump rate for the well must be used for determining the protection zones. Using average values for the pump rate will not give accurate results, because it does not take into account the effects of drawdown such as the higher near well ground-water velocities created by the change in the potentiometric surface.

## **Effective Porosity of the Producing Aquifer**

When estimating effective porosity of the aquifer use only the lithology of the producing aquifer; do not use an average of all lithologies described in the Report of Well Driller log. Reports published by the Utah Division of Water Rights, the Utah Geological Survey, or the U.S. Geological Survey often list porosity values determined for specific aquifers. If these are not available for the area of your well, porosity may be estimated from textbooks or other reports. Values for effective porosity should not exceed 30% unless there is direct evidence, such as laboratory analyses, that demonstrate a higher value.

## **Hydraulic Gradient and Ground Water Flow Direction**

If hydraulic gradient or flow direction change through the extent of the protection zones, adjustments must be made in the calculations. If the protection zones include a change from an alluvial aquifer to bedrock, this change must also be considered in the delineation.

A cone of depression develops in the potentiometric surface around most pumping wells. Because the hydraulic gradient in the cone of depression is significantly steeper than the regional hydraulic gradient, you can not use the ground-water velocity equation ( $v=Ki/n$ ) for ground-water velocity to wells. Delineations completed in this manner will underestimate ground-water velocity near the well, and will yield inaccurate protection zones.

## **Hydraulic Conductivity and Aquifer Testing**

A constant rate aquifer test is required for every new well. A constant rate aquifer test is also required for all existing wells, unless the necessary data can be obtained from previously-run aquifer test. Aquifer tests to determine hydraulic conductivity and transmissivity must be conducted and interpreted properly to obtain meaningful results. Each aquifer test should be designed, conducted, and interpreted by an experienced ground-water professional.

Delineation reports may be disapproved if the aquifer test is conducted improperly or the interpretation method is not appropriate for the test or aquifer environment. Graphs, field data, and printouts showing the interpretation of the aquifer test must be included in the delineation report. Requirements for aquifer tests are explained in two sections of the Utah Rules for Public Drinking Water Systems:

- ▶ Source Development chapter, Well Development section (R309-204-6(10)(b)), and
- ▶ Drinking Water Source Protection chapter, Delineation of Protection Zones section (R309-113-9(5)).

If the tested well is pumping from an alluvial aquifer, the values determined from the aquifer test can only be used in the alluvial aquifer. If the well is located near bedrock and the protection zones reach into bedrock areas, then adjustments must be made in the hydraulic conductivity where the ground water is moving through bedrock.

Many books and professional papers have been written that discuss aquifer testing and ground-water hydraulics. A few of these publications include:

- Dawson, K.J., and Istok, J.D., 1991, *Aquifer Testing: Design and Analysis of Pumping and Slug Tests*: Lewis Publishers, Chelsea, Michigan, 344 p.
- Driscoll, F.G., 1986, *Groundwater and Wells*, second edition: Johnson Division, St. Paul, Minnesota, 1089 p.
- Kruseman, G.P., and deRidder, N.A., 1994, *Analysis and Evaluation of Pumping Test Data*, Second Edition: International Institute for Land Reclamation and Improvement, The Netherlands, 377 p.
- Lohman, S.W., 1979, *Ground-water hydraulics*: U.S. Geological Survey Professional Paper 708, 70 p.
- Nelson, Dennis, 1995, How to prepare for your aquifer test: Pipeline, Drinking Water Program, Oregon Health Division, v. 10, issue 3, p. 1-4.
- Osborne, P.S., 1993, *Suggested Operating Procedures for Aquifer Pumping Tests*: Ground Water Issue, U.S. Environmental Protection Agency, 23 p.
- Rovey, C. W., II, and Cherkauer, D.S., 1995, Scale dependency of hydraulic conductivity measurements: *Ground Water*, v. 33, no. 5, p. 769-780.
- Stallman, R.W., 1983, *Aquifer-test design, observation, and data analysis*: Techniques of Water-Resources Investigations of the United States Geological Survey, Book 3, Chapter B1, 26 p.
- Walton, W.C., 1970, *Ground Water Resource Evaluation*: McGraw-Hill Book Co., New York, 400 p.
- Walton, W.C., 1987, *Groundwater Pumping Tests*: Lewis Publishers, Chelsea, Michigan, 201 p.

During an aquifer test, water level readings should be taken at the proper intervals from the pumping well and available observation wells. An example of time intervals for water level readings is shown in Table 1. This example may need to be modified for different testing methods, or hydrogeologic or well characteristics. Recovery tests may yield better data than the pumping portion of the test.

**Table 1. Example aquifer-test time intervals for recording water level in wells.**

| Time Since Pumping Started | Time Interval |
|----------------------------|---------------|
| 0 - 2 minutes              | 10 seconds    |
| 0 - 5 minutes              | 30 seconds    |
| 5 - 15 minutes             | 1 minute      |
| 15 - 60 minutes            | 5 minutes     |
| 1 - 2 hours                | 10 minutes    |
| 2 - 8 hours                | 30 minutes    |
| 8 - 24 hours               | 1 hour        |
| 1 - 4 days                 | 4 hours       |
| 4 days - end of test       | 1 day         |

If the constant-rate aquifer test does not work or is not practical to run, you may use another appropriate method to determine hydraulic conductivity. If hydraulic conductivity is determined from a nearby well or a published report, the values must be for the same aquifer. If the aquifer test does not work or cannot be conducted, explain in your report why you cannot use the aquifer test to determine aquifer parameters. The best method to determine hydraulic conductivity of an aquifer is an aquifer test. Other methods include specific capacity, drill-stem tests, slug tests, and laboratory tests.

### **Ground-Water Boundaries**

Ground-water boundaries may also be used in delineation. Topographic divides and surface-water divides are not always ground-water divides. If a topographic divide is used in a delineation as a ground-water divide, evidence for the ground-water divide must be explained in the delineation report. Geologic structure and stratigraphy may be important in determination of ground-water divides.

### **Well Fields**

In some situations it is useful to group nearby wells together as one source for delineation of protection zones. A group of wells may be considered a well field if two or more wells are located very close together, the wells are producing from the same aquifer, and there is significant well interference between the wells.

### **Fractured Bedrock Aquifers**

If the aquifer is in fractured or faulted bedrock, then the delineation must account for these structures. Hydrogeologic mapping in the field is often necessary to determine fracture location, orientation, density, and aperture. Most ground-water models are designed for areally extensive homogeneous aquifers, and may yield inaccurate results in fractured bedrock areas (Wisconsin Geological and Natural History Survey, 1991). If you use a ground-water model in a fractured rock aquifer, you must explain why the fractured aquifer can be modeled as a homogeneous porous medium.

### **Ground-Water Models**

There are many different ground-water models available, from simple analytical equations to complex numerical computer models. The DWSP Rule does not specify one model or method for delineation, but the method must be accurate and appropriate for the aquifer setting. The choice of hydrogeologic methods should be based on the type and complexity of the aquifer setting, limitations of the ground-water model, surrounding wells, and nearby PCSs. Before choosing and applying a ground water model, the scientist must have a good concept of the ground-water environment, and must understand the assumptions and limitations of the model.

The simple ground-water velocity equation ( $v=Ki/n$ ) cannot be used for pumping wells. This equation does not include calculations for the increase in the ground-water gradient near the well (in the cone of depression), and the protection zones would therefore be inaccurately small.

### **Interference Between Wells**

Interference between pumping wells affects the size and shape of protection zones. When other pumping wells are located nearby, interference between wells must be a part of the delineation in order to calculate accurate protection zones. Some of the analytical and numerical computer models can model interference between wells.

### **References and Suggested Reading**

#### General Ground Water References

- Fetter, C.W., Jr., 1988, *Applied Hydrogeology*: Merrill Publishing Company, Columbus, Ohio, 92 p.
- Freeze, R.A., and Cherry, J.A., 1979, *Groundwater*: Prentice-Hall, Inc., New Jersey, 604 p.
- Heath, R.C., 1989, *Basic Ground-Water Hydrology*: U.S. Geological Survey Water-Supply Paper 2220, 84 p.
- Todd, D.K., 1980, *Groundwater Hydrology*, second edition: New York, John Wiley, 535 p.

#### Delineation of Protection Zones

- Bair, E.S., Springer, A.E., and Roadcap, G.S., 1991, Delineation of Traveltime-Related Capture Areas of Wells Using Analytical Flow Models and Particle-Tracking Analysis: *Ground Water*, v. 29, no. 3, p. 387-397.
- Bureau of Economic Geology, The University of Texas at Austin, 1991, *Wellhead Protection Strategies for Confined-Aquifer Settings*: U.S. EPA Office of Ground Water and Drinking Water, 168 p.
- Forster, C.B., Lachmar, T.E., and Oliver, D.S., 1997, Comparison of models for delineating wellhead protection areas in confined to semiconfined aquifers in alluvial basins: *Ground Water*, v. 35, no. 4, p. 689-697.
- Kawecki, M.W., 1995, Meaningful interpretation of step-drawdown tests: *Ground Water*, v. 33, no. 1, p. 23-32.
- Pettyjohn, W.A., *Practical Approaches to the Delineation of Wellhead Protection Areas*: Ground Water Protection Council, Oklahoma City, 56 p. plus appendix.
- U.S. Environmental Protection Agency, 1993, *Guidelines for Delineation of Wellhead Protection Areas*: Office of Water, Washington, D.C., EPA document 4405-93-001.
- van der Heijde, Paul, and Beljin, M.S., 1988, *Model Assessment for Delineating Wellhead Protection Areas*: U.S. EPA Office of Ground Water Protection, 33 p. plus appendices.
- van der Heijde, Paul K.M., and Elnaway, O.A., 1993, *Compilation of Ground-Water Models*: U.S. EPA Office of Research and Development, 87 p. plus appendices.
- Walton, W.C., 1988, *Practical Aspects of Ground Water Modeling*, third edition: National Water Well Association, Worthington, Ohio, 588 p.

- Wisconsin Geological and Natural History Survey, 1991, Delineation of Wellhead Protection Areas in Fractured Rocks: U.S. EPA Office of Ground Water and Drinking Water, Washington, D.C., 144 p.
- Wuol, R.W., Dahlstrom, D.J., and Fairbrother, M.D., Wellhead protection area delineation using the Analytic Element Method of ground-water modeling: *Ground Water*, v. 33, no. 1, p. 71-83.

*Specialized Studies*

- Greene, E.A., and Rahn, P.H., 1995, Localized anisotropic transmissivity in a karst aquifer: *Ground Water*, v. 33, no. 5, p. 806-816.
- Kreamer, D.K., Hodge, V.F., Rabinowitz, I., and others, 1996, Trace element geochemistry in water from selected springs in Death Valley National Park, California: *Ground Water*, v. 34, no. 1, p. 95-103.
- Larkin, R.G., and Sharp, J.M., Jr., 1992, On the relationship between river-basin geomorphology, aquifer hydraulics, and ground-water flow direction in alluvial aquifers: *Geological Society of America Bulletin*, v. 104, p. 1608-1620.



## **APPENDIX C - THE SOURCE PROTECTION TEAM**

Community involvement is the primary characteristic of a successful Drinking Water Source Protection (DWSP) program; organizing a source protection team helps get the community involved. Members of the source protection team should then seek to involve the rest of the community at even greater levels. Team members should represent the various interests of the community. Public water system (PWS) personnel, local governmental representatives, health department personnel, community residents, and industrial, agricultural, and commercial representatives, etc. should be members of the team.

### **Source Protection Team Responsibilities**

A team leader should be appointed by the PWS or chosen by the team. This person should have organizational and consensus-building skills and have the support of the other team members and the community.

Once the source protection team is established, its members should determine their long-term goals. These should include defining a protection area, inventorying PCSs, and determining management approaches. After the long-term goals are established, they should be broken down into short-term tasks and assigned to members of the team.

### **Source Protection Team Functions**

Many PWSs use a source protection team for the planning process and then disband it. However, since source protection is not static and is never really complete, it is a good idea to keep a source protection team active as long as protecting ground water is an objective of your system. With the experience team members acquire during the planning process they will be valuable resources in working with both existing and new PCSs, continuing community education programs, and following through to ensure that management approaches are effectively implemented.

### **Suggestions for the Team to Help with Delineation**

The source protection team may want to collect certain data and information about the ground-water source and the producing aquifer. The collection of this information will be valuable to your own technical staff, and may save you the money a consulting firm would charge if it were to collect this data for you.

- ▶ *Geologic Data* - Any geologic data that may have been collected when choosing the site for the well, during drilling and development of the well, and that the PWS may have acquired since the well was drilled.
- ▶ *Aquifer Test* - Provide data and results from pumping or aquifer tests performed using the well. Your consultant will probably need to conduct an aquifer test at the well site to determine aquifer properties such as hydraulic conductivity and transmissivity. An

experienced person should conduct and interpret the test; however, the source protection team members may be able to assist.

- ▶ *Well Data* - Some or all of this data is probably stored in your system's files. It includes the Report of Well Driller and well construction data. If you don't have your Report of Well Driller, it can probably be obtained from the Utah Division of Water Rights, located at 1636 W. North Temple, Salt Lake City, Utah. The Division of Water Rights also has regional offices in different parts of Utah.
- ▶ *Pump Data* - Again, this information is probably in your system files. It includes the model, type, make, series, and rating of your pump along with its installation date.

Here are a few ideas to further involve the community:

- ▶ Announce all of the meetings of the source protection team and report its progress in your local newspaper.
- ▶ Train a service group, such as Retired Senior Volunteer Program (RSVP) members, a Boy Scout troop, or a school science class, etc., to compile information for the plan.
- ▶ Some counties in have organized Water Quality Task Forces through their County Extension Service. Contact your County Extension Agent if you would like to request the assistance of these folks in developing various parts of your DWSP plan.
- ▶ Educate the community or appropriate segments of the community concerning subjects, such as the use and disposal of household hazardous waste, the use and maintenance of septic tank systems, disposal of used oil, etc.
- ▶ Some people in the community may come forward with information about historic potential contamination sites if they read or hear about your source protection objectives.

## **APPENDIX D - STATE, LOCAL, AND FEDERAL AUTHORITIES**

### **State Agencies**

#### **The Division of Water Quality**

*Ground Water Quality Protection Rule - R317-6, Utah Administrative Code (UAC)* - The Ground Water Quality Protection Rule establishes a permit system to regulate contaminated discharges to ground water. Any contamination source that discharges contaminants to ground water must obtain a permit from the Division of Water Quality. The Ground Water Quality Protection Rule contains five sections: 1. ground water quality standards; 2. ground water classification; 3. protection levels; 4. ground water classification procedures; and 5. ground water discharge permit system.

*Underground Injection Control Rule - R317-7, UAC* - The Underground Injection Control Rule regulates the subsurface emplacement of fluids through bored, drilled, or driven wells; or through dug wells, where the depth of the dug well is greater than the largest surface dimension. Examples of underground injection wells include floor drains in service stations that discharge into sumps dug into the ground or drilled wells into which wastewater or other fluids are discharged.

This rule establishes a permit system to regulate underground injection wells. The Underground Injection Control Rule contains five parts: 1. classification of injection wells; 2. prohibition of unauthorized injection; 3. permit requirements; 4. technical requirements; and 5. hazardous waste injection restrictions.

Class II underground injection wells are regulated by the Division of Oil, Gas and Mining.

*Utah Pollutant Discharge Elimination System Rule - R317-8, UAC* - The Utah Pollutant Discharge Elimination System (UPDES) program requires permits for the discharge of pollutants from any point source into waters of the State. The program also applies to owners or operators of any treatment works treating domestic sewage.

*Large Underground Wastewater Disposal System Rule - R317-5 of the UAC* - The Large Underground Wastewater Disposal System Rule applies to large underground disposal systems for domestic wastewater discharges which exceed 5,000 gallons per day (gpd) and all other domestic wastewater discharges not covered under the definition of an "Individual wastewater disposal system." Usually these systems should not be designed for over 15,000 gpd. In general, it is not acceptable to dispose of industrial wastewater in an underground disposal system.

#### **The Division of Solid and Hazardous Waste**

*Hazardous Waste Rules - Resource Conservation and Recovery (RCAC) - R315-1 through R315-15 and R315-50, UAC* - The Hazardous Waste rules provide for "cradle-to-grave" management of substances classified as hazardous wastes. Their objective is to prevent contamination of the environment, which includes ground water, and potential adverse effects on human health. These

rules also identify those solid wastes which are subject to regulation as hazardous wastes and to notification, transportation, and disposal requirements. Facilities that treat, store, or dispose of hazardous waste are regulated by this rule.

*Solid Waste Permitting and Management Rules (Landfills)* - R315-301 through R315-320, UAC - The Solid Waste Permitting and Management Rules are promulgated under the authority of the Solid and Hazardous Waste Act, Chapter 6 of Title 19, to protect human health, to prevent land, air and water pollution, and to conserve the state's natural, economic and energy resources by setting minimum performance standards for the proper management of solid wastes originating from residential, commercial, agricultural, and other sources.

## **The Division of Environmental Response and Remediation**

*Underground Storage Tank Rules* - R311-200 through R311-211, UAC - The Underground Storage Tank Rules protect ground water resources by preventing and detecting leaks and spills from underground storage tanks. Sites that are contaminated by leaking underground storage tanks must be cleaned up. Also, a fund has been established in the state to make sure that owners and operators of underground storage tanks can pay for correcting the problems they create if their underground storage tanks leak.

*Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA commonly called Superfund)* - Section 19-6-301 through Section 19-6-325 of the Utah Code Annotated - The Hazardous Substances Mitigation Act authorizes the executive director of the Department of Environmental Quality to regulate hazardous substances releases by making rules consistent with the substantive requirements of CERCLA, to establish the requirements for remedial investigation studies and remedial action plans.

40 CFR Part 300 of the Code of Federal Regulations - The National Oil and Hazardous Substances Pollution Contingency Plan establishes the organizational structure and specifies the procedures for remediating pollution when oil or hazardous substances are discharged or released into the environment.

*SARA Title III* - 40 CFR part 355 of the Code of Federal Regulations - SARA Title III provides early comprehensive emergency planning for responding to potential releases of toxic chemicals.

Facilities must notify the local emergency planning committee (refer to Appendix C for local emergency planning committees in Utah) when an "extremely hazardous substance" is present in an amount greater than the appropriate "threshold planning quantity." These facilities are required to prepare or have available a material safety data sheet (MSDS) for each hazardous chemical and submit it to the appropriate local emergency planning committee.

This regulation requires public access to information submitted to local emergency planning committees. Each emergency response plan, MSDS, inventory form, toxic chemical release form,

and follow-up emergency release notification is to be made available to the general public during normal working hours at the location designated for the local emergency planning committee.

### **The Division of Water Rights**

*Water Well Rule - R655-4, UAC* - The Water Well Rule assists in the orderly development of underground water, insures that minimum construction standards are achieved in the drilling and repairing of water wells, **prevents pollution of aquifers within the state**, prevents wasting of flowing wells, obtains accurate records of well drilling operations, and insures compliance with the state engineer's authority for appropriating water.

**Abandoned Water Wells - R655-4-12, UAC** - These requirements are part of the Water Well Rule. When any well is temporarily removed from service, the top of the well shall be sealed with a water-tight cap or seal. If the well is temporarily abandoned during construction, it shall be assumed that the well is permanently abandoned after 90 days. Any well that is to be permanently abandoned shall be completely filled in such a manner as to prevent vertical movement of water within the borehole as well as preventing the annular space surrounding the well casing from becoming a conduit for possible contamination of the groundwater supply.

### **The Division of Oil, Gas, and Mining**

*Oil, Gas and Mining; Abandoned Mine Reclamation - R643, UAC* - The Abandoned Mine Reclamation Rule establishes land and water eligibility requirements, reclamation project objectives and standards, and project selection factors. These provisions apply to all reclamation projects to be carried out with money from the Account and administered by the Division. Lands and water are eligible for reclamation activities if:

- ▶ They were mined or affected by mining processes;
- ▶ They were mined prior to August 3, 1977, and left or abandoned in either an unreclaimed or inadequately reclaimed condition; and
- ▶ There is no continuing responsibility for reclamation by the operator, permittee, or agent of the permittee under statutes of the state or federal government, or the state as a result of bond forfeiture. Bond forfeiture will render lands or water ineligible only if the amount forfeited is sufficient to pay the total cost of the necessary reclamation. In cases where the forfeited bond is insufficient to pay the total cost of reclamation, additional moneys from the Account may be sought.

*Oil, Gas and Mining; Non-Coal - R647, UAC* - The Non-Coal Rule establishes land and water eligibility requirements for non-coal reclamation. Non-coal lands and water are eligible for reclamation if:

- ▶ They were mined or affected by mining processes;

- ▶ They were mined prior to August 1977, and left or abandoned in either an unreclaimed or inadequately reclaimed condition;
- ▶ There is no continuing responsibility for reclamation by the operator, permittee, or agent of the permittee under statutes of the state or federal government or the state as a result of bond forfeiture. Bond forfeiture will render lands or water ineligible only if the amount forfeited is sufficient to pay the total cost of the necessary reclamation. In cases where the forfeited bond is insufficient to pay the total cost of reclamation, additional moneys from the Account may be sought;
- ▶ The reclamation has been requested by the Governor;
- ▶ The reclamation is necessary for the protection of the public health and safety or all coal related reclamation has been accomplished; and
- ▶ Moneys allocated to the Division are available for the work.

Oil, Gas and Mining; Coal - R645, UAC - The Coal Rule applies to coal exploration and coal mining and reclamation operations.

*Oil, Gas and Mining; Oil and Gas* - R649, UAC - The Oil and Gas Rule applies to all lands in the state in order to conserve the natural resources of oil and gas in the state, to protect human health and the environment, to prevent waste, to protect the correlative rights of all owners and to realize the greatest ultimate recovery of oil and gas.

*Class II Injection Wells* - R649-5, UAC - These requirements are part of the Oil and Gas Rule. Class II injection wells must be completed and operated to prevent pollution or damage to any Underground Source of Drinking Water. The application for injection must include evidence that the proposed injection will not initiate fractures in overlying strata that could allow the injected fluid to enter the fresh water strata. The application must also include a review of all wells within a one-half mile radius of the injection well to determine that a conduit does not exist for fluids to move up or down the well bore to enter other strata. The casing of the injection well must be pressure tested before use, and thereafter the well must be tested at least once every five years, or the pressure may be monitored during injection operations.

## **The Department of Agriculture**

*Pesticide Control Rule* - R68-7 of the UAC - The Pesticide Control Rule requires that pesticide application be consistent with the label for that pesticide and that pesticide application not violate the restrictions on the use of that pesticide.

## **Local Health Departments**

Section 26A-1-114-(1)(a) of the Utah Code authorizes local health departments to "enforce state and local laws, regulations, and standards relating to public health and sanitation." Cities, towns, and counties are encouraged to enact local ordinances in conjunction with their source protection programs. Local health departments can strengthen local protection programs since they can enforce the ordinances relating to public health and sanitation.

*Individual Wastewater Disposal Systems (Septic Tank/Drain-fields) - R317-501, UAC -* These rules apply to individual wastewater disposal systems for domestic wastewater discharges which do not exceed 5,000 gallons per day. Plans, specifications, and a site evaluation are required to be submitted to the local health department having jurisdiction for review and approval prior to construction of these systems. Construction standards apply to the building sewer, septic tank, and drain-field. Isolation distances are required to protect wells, springs, surface water, and any other waters that might be affected by the pollutants discharged by individual wastewater disposal systems.

The site evaluation reports information about the proposed location of the system, such as, soil percolation rates, soil classifications, and distances to ground water and bedrock. A final inspection by a registered sanitarian from the local health department is required to ensure the system is constructed as per plans and specifications prior to backfilling the system.

*Scavenger Waste Disposal - R317-550, UAC -* The Scavenger Waste Disposal Rule pertains to the collection, storage, transportation, and disposal of all wastes by liquid scavenger operators and requires that they be accomplished in a sanitary manner. It also requires these processes do not create a public health hazard or nuisance, or adversely affect the quality of the waters of the State.

*Vault and Earthen Pit Privies - R317-560, UAC -* The Vault and Earthen Pit Privy Rule permits privies as a substitute for water closets, for temporary or limited use in remote locations where provisions for water supply or wastewater disposal pose a significant problem. The intended primary use of vault and pit privies in this rule is for facilities such as labor camps, semi-developed and semi-primitive recreational camps, temporary mass gatherings, and other approved uses. Potable water under pressure may or may not be available.

Requests for the use of vault privies or earthen pit privies shall be evaluated on a case-by-case basis by the local health department having jurisdiction and must receive the written approval of the local health officer or his designated representative prior to the installation of such devices.

## **Federal Requirement**

Under the Federal Safe Drinking Water Act Amendments of 1986, any department or agency of the federal government having jurisdiction over any potential source of contaminants within drinking water source protection zones or management areas identified by a State Drinking Water Source Protection Program, is subject to, and must comply with, all requirements of the State's Program. This includes the payment of reasonable charges and fees levied in connection with the



management or remediation of potential sources of ground-water contamination within drinking water source protection zones or management areas.

## **APPENDIX E - LOCAL EMERGENCY PLANNING COMMITTEES**

SARA Title III requires Local Emergency Planning Committees to maintain information about toxic chemicals that are stored, used, or manufactured at potential contamination sources above certain threshold amounts. The information they maintain is available to the public upon request. They may also be able to furnish you with Material Safety Data Sheets (MSDSs) for the chemicals at the PCSs within their county. MSDSs can also be obtained on the Internet at "<http://MSDS.PDC.CORNELL.EDU/issearch/msdssrch.htm>"

When hazardous material spills occur on roads and highways within your protection zones, the chairperson of your local emergency planning committee will take charge of coordinating emergency response. You should contact this committee, provide them with a map of your protection zones, and ask them to notify you if there is a spill so you can provide them with important information about your well or spring. Your DWSP plan contains hydrogeologic information that is a valuable resource in emergency response decisions. This information includes:

- ▶ What is the approximate time of travel from the spill to your well or spring,
- ▶ direction of ground-water flow, and
- ▶ whether the aquifer is protected or unprotected.

### **LOCAL EMERGENCY PLANNING COMMITTEES FOR COUNTIES**

| <b>County</b> | <b>Chairperson</b>      | <b>Address</b>                                       | <b>Phone</b>   |
|---------------|-------------------------|------------------------------------------------------|----------------|
| Beaver        | Dale R. Maples          | PO Box 391<br>Beaver, UT 84731                       | (435) 438-2862 |
| Box Elder     | Sherry Vasa             | 250 American Way MS B-3640<br>Brigham City, UT 84302 | (435) 734-6006 |
| Cache         | Jeff Peterson           | 50 W 200 N Suite D<br>Logan, UT 84321                | (435) 750-7493 |
| Carbon        | Dennis Dooley           | 120 E Main<br>Price, UT 84501                        | (435) 636-3290 |
| Daggett       | Don Williams            | PO Box 429<br>Manilla, UT 84046                      | (435) 784-3582 |
| Davis         | Brian Law               | PO Box 618<br>Farmington, UT 84025                   | (801) 451-4129 |
| Duchesne      | Georg Adams             | PO Box 298<br>Duchesne, UT 84021                     | (435) 738-1181 |
| Emery         | Bryant Anderson, Acting | PO Box 417<br>Castle Dale, UT 84513                  | (435) 381-5374 |
| Garfield      | Chris Hatch, Acting     | PO Box 370<br>Panguitch, UT 84759                    | (435) 676-2678 |
| Grand         | Doug Squire             | 125 E Center                                         | (435) 259-8115 |

| County     | Chairperson          | Address                                                 | Phone          |
|------------|----------------------|---------------------------------------------------------|----------------|
|            |                      | Moab, UT 84532                                          |                |
| Iron       | Dave Bentley         | PO Box 622<br>Cedar City, UT 84720                      | (435) 586-6511 |
| Juab       | Gary Corbin, Acting  | PO Box 133<br>Nephi, UT 84648                           | (435) 623-1349 |
| Kane       | Dave Owens           | 76 N Main<br>Kanab, UT 84741                            | (435) 644-2551 |
| Millard    | Forrest Roper        | Star Route Box 50<br>Fillmore, UT 84631                 | (435) 743-5302 |
| Morgan     | Terry Turner         | Courthouse, PO Box 886<br>Morgan, UT 84050              | (435) 845-4048 |
| Piute      | Cordell Peterson     | PO Box 145<br>Junction, UT 84740                        | (435) 577-2893 |
| Rich       | Dan Ames             | 109 N 200 E<br>Laketown, UT 84038                       | (435) 946-2907 |
| Salt Lake  | Dennis Stanley       | 440 S 300 E<br>SLC, UT 84111                            | (801) 535-5969 |
| San Juan   | Rick Bailey          | PO Box 9<br>Monticello, UT 84535                        | (435) 587-3225 |
| Sanpete    | Bevin Blackham       | 185 N 400 E<br>Fairview, UT 84629                       | (435) 283-4021 |
| Sevier     | Jim Porter           | 180 N Main<br>Richfield, UT 84701                       | (435) 896-4890 |
| Summit     | Al Cooper            | 110 Zermat Strasse (Summit Park)<br>Park City, UT 84098 | (435) 649-9439 |
| Tooele     | Harry Shinton        | 47 S Main<br>Tooele, UT 84047                           | (435) 882-3335 |
| Unitah     | Clay Johnson         | PO Box 307<br>Vernal, UT 84078                          | (435) 789-0920 |
| Utah       | Coy Porter           | 80 S 300 W<br>Provo, UT 84601                           | (801) 379-6321 |
| Wasatch    | Kent J. Berg, Acting | 805 W 100 S<br>Heber City, UT 84032                     | (435) 654-1661 |
| Washington | Dean Cox             | 197 E Tabernacle<br>St George, UT 84770                 | (435) 673-4824 |
| Wayne      | Vicky Taft           | PO Box 313<br>Bicknell, UT 84715                        | (435) 836-2831 |
| Weber      | Max V. Jackson       | 363 W Independence<br>Harrisville, UT 84404             | (801) 782-4100 |

**LOCAL EMERGENCY PLANNING COMMITTEES FOR CITIES**

| <b>City</b>         | <b>Chairperson</b> | <b>Address</b>                                  | <b>Phone</b>   |
|---------------------|--------------------|-------------------------------------------------|----------------|
| Sandy               | Andrew Glad        | 9010 S 150 E<br>Sandy, UT 84070                 | (801) 568-2930 |
| West Valley<br>City | John Evans         | 3699 Constitution Blvd<br>West Valley, UT 84119 | (801) 963-3337 |

## **APPENDIX F - DRINKING WATER SOURCE PROTECTION ORDINANCE**

The following is an example of a source protection ordinance. Wellhead Protection Technology Transfer Centerpiece Workshop (EPA/600/K-92/015) was used as a reference. It has been changed to reflect recommendations in the Drinking Water Source Protection Rule, R309-113 of the Utah Administrative Code.

BE IT ORDAINED by the Mayor and Council of the City of \_\_\_\_\_ in Council duly assembled and it is hereby ordained by the authority of same that the following ordinance known as the Drinking Water Source Protection Ordinance is adopted and made a part of the Code of Ordinance of the City of \_\_\_\_\_, to wit:

### **Section 1. Short title and purpose.**

- (a) This ordinance shall be known as the "Drinking Water Source Protection Ordinance."
- (b) The purpose of this ordinance is to insure the provision of a safe and sanitary drinking water supply for the City by the establishment of drinking water source protection zones surrounding the wellheads for all wells which are the supply sources for the City water system and by the designation and regulation of property uses and conditions which may be maintained within such zones.

**Section 2. Definitions.** When used in this ordinance the following words and phrases shall have the meanings given in this Section:

- (a) Design standard - means a control which is implemented by a potential contamination source to prevent discharges to the ground water. Spill protection is an example of a design standard.
- (b) Land management strategies - means zoning and non-zoning controls which include, but are not limited to, the following: zoning and subdivision ordinances, site plan reviews, design and operating standards, source prohibitions, purchase of property and development rights, public education programs, ground-water monitoring, household hazardous waste collection programs, water conservation programs, memoranda of understanding, written contracts and agreements, and so forth.
- (c) Pollution source - means point source discharges of contaminants to ground water or potential discharges of the liquid forms of "extremely hazardous substances" which are stored in containers in excess of "applicable threshold planning quantities" as specified in SARA Title III. Examples of possible pollution sources include, but are not limited to, the following: storage facilities that store the liquid forms of extremely hazardous substances, septic tanks, drain fields, class V underground injection wells, landfills, open dumps, landfilling of sludge and septage, manure piles, salt piles, pit

privies, and animal feeding operations with more than ten animal units. The following clarify the definition of pollution source:

- (1) Animal feeding operation - means a lot or facility where the following conditions are met: animals have been or will be stabled or confined and fed or maintained for a total of 45 days or more in any 12 month period, and crops, vegetation forage growth, or post-harvest residues are not sustained in the normal growing season over any portion of the lot or facility. Two or more animal feeding operations under common ownership are considered to be a single feeding operation if they adjoin each other, if they use a common area, or if they use a common system for the disposal of wastes.
- (2) Animal unit - means a unit of measurement for any animal feeding operation calculated by adding the following numbers; the number of slaughter and feeder cattle multiplied by 1.0, plus the number of mature dairy cattle multiplied by 1.4, plus the number of swine weighing over 55 pounds multiplied by 0.4, plus the number of sheep multiplied by 0.1, plus the number of horses multiplied by 2.0.
- (3) Extremely hazardous substances - means those substances which are identified in the Sec. 302(EHS) column of the "TITLE III LIST OF LISTS - Consolidated List of Chemicals Subject to Reporting Under SARA Title III," (EPA 560/4-91-011).
- (d) Potential contamination source - means any facility or site which employs an activity or procedure which may potentially contaminate ground water. A pollution source is also a potential contamination source.
- (e) Regulatory agency - means any governmental agency with jurisdiction over hazardous waste as defined herein.
- (f) Sanitary landfill - means a disposal site where solid wastes, including putrescible wastes, or hazardous wastes, are disposed of on land by placing earth cover thereon.
- (g) Septic tank/drain-field systems - means a system which is comprised of a septic tank and a drain-field which accepts domestic wastewater from buildings or facilities for subsurface treatment and disposal. By their design, septic tank/drain-field system discharges cannot be controlled with design standards.
- (h) Wellhead - means the upper terminal of a well, including adapters, ports, seals, valves and other attachments.

Section 3. Establishment of drinking water source protection zones. There is hereby established use districts to be known as zones one, two, three, and four of the drinking water source protection area, identified and described as follows:

- (a) **Zone one** is the area within a 100-foot radius from the wellhead.
- (b) **Zone two** is the area within a 250-day ground-water time of travel to the wellhead, the boundary of the aquifer(s) which supplies water to the ground-water source, or the ground-water divide, whichever is closer.
- (c) **Zone three** (waiver criteria zone) is the area within a 3-year ground-water time of travel to the wellhead or margin of the collection area, the boundary of the aquifer(s) which supplies water to the ground-water source, or the ground-water divide, whichever is closer.
- (d) **Zone four** is the area within a 15-year ground-water time of travel to the wellhead, the boundary of the aquifer(s) which supplies water to the ground-water source, or the ground-water divide, whichever is closer.

**Section 4. Permitted uses.** The following uses shall be permitted within drinking water source protection zones:

- (a) Any use permitted within existing agricultural, single family residential, multi-family residential, and commercial districts so long as uses conform to the rules and regulations of the regulatory agencies.
- (b) Any other open land use where any building located on the property is incidental and accessory to the primary open land use.

**Section 5. Prohibited uses.** The following uses or conditions shall be and are hereby prohibited within drinking water sources protection zones, whether or not such use or condition may otherwise be ordinarily included as a part of a use permitted under Section 4 of the ordinance.

- (a) **Zone one** - The location of any pollution source as defined herein.
- (b) **Zone two** - The location of a pollution source unless its contaminated discharges can be controlled with design standards.
- (c) **Zones three and four** - The location of a potential contamination source unless it can be controlled through land management strategies.

**Section 6. Administration.** The policies and procedures for administration of any source protection zone established under this ordinance, including without limitation those applicable to nonconforming uses, exception, enforcement and penalties, shall be the same as provided in the existing zoning ordinance for the City of \_\_\_\_\_, as the same is presently enacted or may from time to time be amended.



This Ordinance shall be effective as of \_\_\_\_\_ (date). All ordinances and parts or ordinances in conflict herewith shall not be and the same are hereby repealed.

ENACTED AND ADOPTED this \_\_\_\_\_ day of \_\_\_\_\_, 19\_\_.

\_\_\_\_\_  
Mayor

Attest: \_\_\_\_\_  
City Clerk

## **APPENDIX G - POTENTIAL CONTAMINATION SOURCE FACT SHEETS**

General information about potential contamination sources (PCSs) is contained in the Fact Sheets listed below. They are intended to be used to provide information about PCSs and to make general best management and pollution prevention practice recommendations. They are **not** intended to be used as a "cookbook" for source protection. Public water systems may find them helpful in getting started; however, best management and pollution prevention strategies should be tailored to fit the specific situations at each PCS. *You are encouraged to develop well thought out protection strategies that will effectively protect the quality of your drinking water.*

The following *Potential Contamination Source Fact Sheets* are available from the Division of Drinking Water. Call 536-4200 to request copies:

Dry Cleaning

Fertilizer

Household Hazardous Waste

Metal Finishers

Pesticides

Pollution Prevention

Printing Shops

Septic Tank/Drain-field Systems

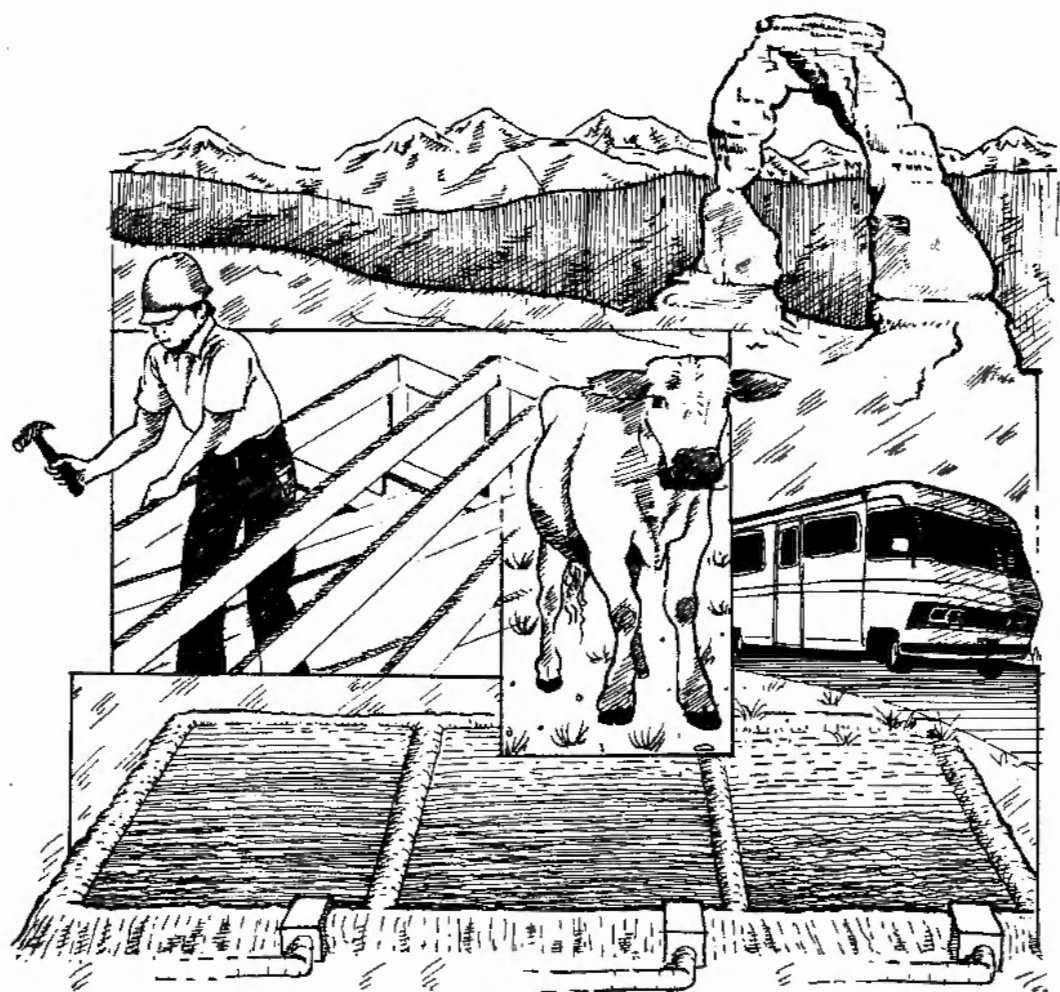
Vehicle Maintenance & Repair







# GROUND-WATER CONDITIONS IN THE GRAND COUNTY AREA, UTAH, WITH EMPHASIS ON THE MILL CREEK- SPANISH VALLEY AREA



Technical Publication No. 100  
State of Utah  
DEPARTMENT OF NATURAL RESOURCES  
1990

**NORMAN H. BANGERTER**  
Governor

This report was prepared as a part of the Statewide cooperative water-resource investigation program administered jointly by the Utah Department of Natural Resources, Division of Water Rights and the U.S. Geological Survey. The program is conducted to meet the water administration and water-resources data needs of the State, as well as the water information needs of many units of government and the general public.

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Division of Water Rights

Copies available at  
Utah Department of Natural Resources  
Division of Water Rights  
1636 West North Temple, Room 220  
Salt Lake City, Utah 84116

STATE OF UTAH  
DEPARTMENT OF NATURAL RESOURCES

Technical Publication No. 100

GROUND-WATER CONDITIONS IN THE GRAND COUNTY AREA, UTAH,  
WITH EMPHASIS ON THE MILL CREEK-SPANISH VALLEY AREA

by

Paul J. Blanchard

Prepared by the  
United States Geological Survey  
in cooperation with the  
Utah Department of Natural Resources  
Division of Water Rights

1990

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## CONVERSION FACTORS AND RELATED INFORMATION

For use of readers who prefer to use metric (International System) units, conversion factors for inch-pound units used in this report are listed below:

| <u>Multiply inch-pound unit</u>              | <u>By</u> | <u>To obtain metric unit</u>  |
|----------------------------------------------|-----------|-------------------------------|
| acre                                         | 0.4047    | square hectometer             |
|                                              | 0.004047  | square kilometer              |
| acre-foot (acre-ft)                          | 0.001233  | cubic hectometer              |
|                                              | 1233.     | cubic meter                   |
| cubic foot per second (ft <sup>3</sup> /s)   | 0.02832   | cubic meter per second        |
| foot                                         | 0.3048    | meter                         |
| foot per day (ft/d)                          | 0.3048    | meter per day                 |
| foot squared per day (ft <sup>2</sup> /d)    | 0.0929    | meter squared per day         |
| gallon                                       | 3.785     | liter                         |
|                                              | 0.003785  | cubic meter                   |
| gallon per minute (gal/min)                  | 0.06309   | liter per second              |
| gallon per minute per foot<br>[(gal/min)/ft] | 0.2070    | liter per second per<br>meter |
| inch                                         | 25.4      | millimeter                    |
|                                              | 2.54      | centimeter                    |
| mile                                         | 1.609     | kilometer                     |
| square mile                                  | 2.590     | square kilometer              |

Chemical concentration and water temperature are given only in metric units. Chemical concentration is given in milligrams per liter (mg/L) or micrograms per liter (µg/L). Milligrams per liter is a unit expressing the concentration of chemical constituents in solution as weight (milligrams) of solute per unit volume (liter of water). One thousand micrograms per liter is equivalent to 1 milligram per liter. For concentrations less than 7,000 milligrams per liter, the numerical value is about the same as for concentrations in parts per million.

Chemical concentration in terms of ionic interacting values is given in milliequivalents per liter. Milliequivalents per liter is numerically equal to equivalents per million.

Radioactivity is measured in picocuries per liter (pCi/L), or one-trillionth of a curie per liter. One picocurie is equal to  $3.7 \times 10^{-2}$  disintegrations per second.

Water temperature is given in degrees Celsius (°C), which can be converted to degrees Fahrenheit (°F) by the following equation:

$$^{\circ}\text{F} = 1.8 (^{\circ}\text{C}) + 32$$

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)—a geodetic datum derived from a general adjustment of the first order level nets of both the United States and Canada, formerly called "Sea Level Datum of 1929."

GROUND-WATER CONDITIONS IN THE GRAND COUNTY AREA, UTAH,  
WITH EMPHASIS ON THE MILL CREEK-SPANISH VALLEY AREA

By Paul J. Blanchard

ABSTRACT

The Grand County area includes all of Grand County, the Mill Creek and Pack Creek drainages in San Juan County, and the area between the Colorado and Green Rivers in San Juan County. The Grand County area includes about 3,980 square miles, and the Mill Creek-Spanish Valley area includes about 44 square miles. The three principal consolidated-rock aquifers in the Grand County area are the Entrada, Navajo, and Wingate aquifers in the Entrada Sandstone, the Navajo Sandstone, and the Wingate Sandstone, and the principal consolidated-rock aquifer in the Mill Creek-Spanish Valley area is the Glen Canyon aquifer in the Glen Canyon Group, comprised of the Navajo Sandstone, the Kayenta Formation, and the Wingate Sandstone.

Recharge to the Entrada, Navajo, and Glen Canyon aquifers typically occurs where the formations containing the aquifers crop out or are overlain by unconsolidated sand deposits. Recharge is enhanced where the sand deposits are saturated at a depth of more than about 6 feet below the land surface, and the effects of evaporation begin to decrease rapidly with depth. Recharge to the Wingate aquifer typically occurs by downward movement of water from the Navajo aquifer through the Kayenta Formation, and primarily occurs where the Navajo Sandstone, Kayenta Formation, and the Wingate Sandstone are fractured.

The principal area of discharge from the Glen Canyon aquifer in the Mill Creek-Spanish Valley area occurs in and near the City of Moab well field, near the northeast canyon wall of Spanish Valley. Discharge from one well in the well field is reportedly as large as 2,000 gallons per minute, and discharge from one spring near the well field is reportedly as large as 390 gallons per minute.

Discharge from springs issuing from the Entrada, Navajo, and Wingate aquifers typically is less than about 10 gallons per minute, and discharge from wells completed in these aquifers ranges from 5 to 30 gallons per minute. In the Mill Creek-Spanish Valley area, discharge from springs issuing from the Glen Canyon aquifer ranges from 15 to 390 gallons per minute, and discharge from wells completed in the Glen Canyon aquifer ranges from less than 10 to more than 1,000 gallons per minute. The larger discharge rates occur where the formations in the Glen Canyon Group are fractured and faulted.

Water levels in the Glen Canyon aquifer declined from the early 1960's to about 1979, and rose as much as 39.5 feet from 1979 to 1987. The larger-than-normal amount of precipitation beginning in 1977 probably is a substantial factor in the rising water levels.

Water-quality characteristics typical of water in the Entrada, Navajo, Wingate, and Glen Canyon aquifers are: (1) Concentrations of dissolved solids are less than about 220 milligrams per liter; (2) the water type is calcium bicarbonate or calcium magnesium bicarbonate; and (3) the water is moderately

hard to hard. In the Mill Creek-Spanish Valley area, concentrations of dissolved solids and sulfate increase west and south of the City of Moab well field because an increasingly larger proportion of the ground water comes from other sources to the southeast, farther up Spanish Valley, and a smaller proportion comes from the Glen Canyon aquifer. Concentrations of dissolved solids in the Navajo aquifer also are higher along the Moab fault.

Other consolidated-rock aquifers investigated were in the Cedar Mountain Formation, the Brushy Basin Shale and Salt Wash Sandstone Members of the Morrison Formation, the undifferentiated Cutler Formation, and the White Rim Sandstone Member of the Cutler Formation. Concentrations of dissolved solids ranged from 270 milligrams per liter in water from the White Rim Sandstone Member in Canyonlands National Park to 3,450 milligrams per liter in water from the undifferentiated Cutler Formation in Castle Valley. Water from the undifferentiated Cutler Formation in Castle Valley also had the largest concentration of selenium, 30 micrograms per liter, which is three times the State of Utah primary drinking-water standard of 10 micrograms per liter.

## INTRODUCTION

The temperate climate and appealing scenery in the Grand County area have attracted growing numbers of people, creating increased demands for ground water in the area. Federal, State, and local water managers, water users, and other interested parties need information about the availability and quality of ground water in consolidated-rock aquifers of the Grand County area in order to plan for future development of ground-water resources. In order to provide the interested parties with current (1987) information on ground-water quantity and quality in the consolidated-rock aquifers, a study was conducted by the U.S. Geological Survey in cooperation with the Utah Department of Natural Resources, Division of Water Rights.

The area investigated includes all of Grand County, the Mill Creek and Pack Creek drainages in San Juan County, and the area between the Colorado and Green Rivers in San Juan County and will be referred to as the Grand County area in this report. The Mill Creek-Spanish Valley area includes parts of the Mill Creek and Pack Creek drainages (fig. 1). The Grand County area includes about 3,980 square miles, including about 300 square miles in San Juan County. Altitudes in the Grand County area range from about 3,900 feet above sea level where the Green River enters the Colorado River to 12,646 feet above sea level at the summit of Mt. Mellenthin in the La Sal Mountains. The Mill Creek-Spanish Valley area includes about 44 square miles.

### Purpose and Scope

This report presents results of a reconnaissance of ground-water conditions in the bedrock aquifers of Grand County and small parts of San Juan County, Utah, with emphasis on ground-water conditions in the Entrada Sandstone, the Navajo Sandstone, and the Wingate Sandstone of the Glen Canyon Group. Ground-water conditions in the Navajo Sandstone, the Kayenta Formation, and the Wingate Sandstone of the Glen Canyon Group in the Mill Creek-Spanish Valley area near Moab, Utah, were investigated in more detail because this area is where most ground-water development is expected to occur.

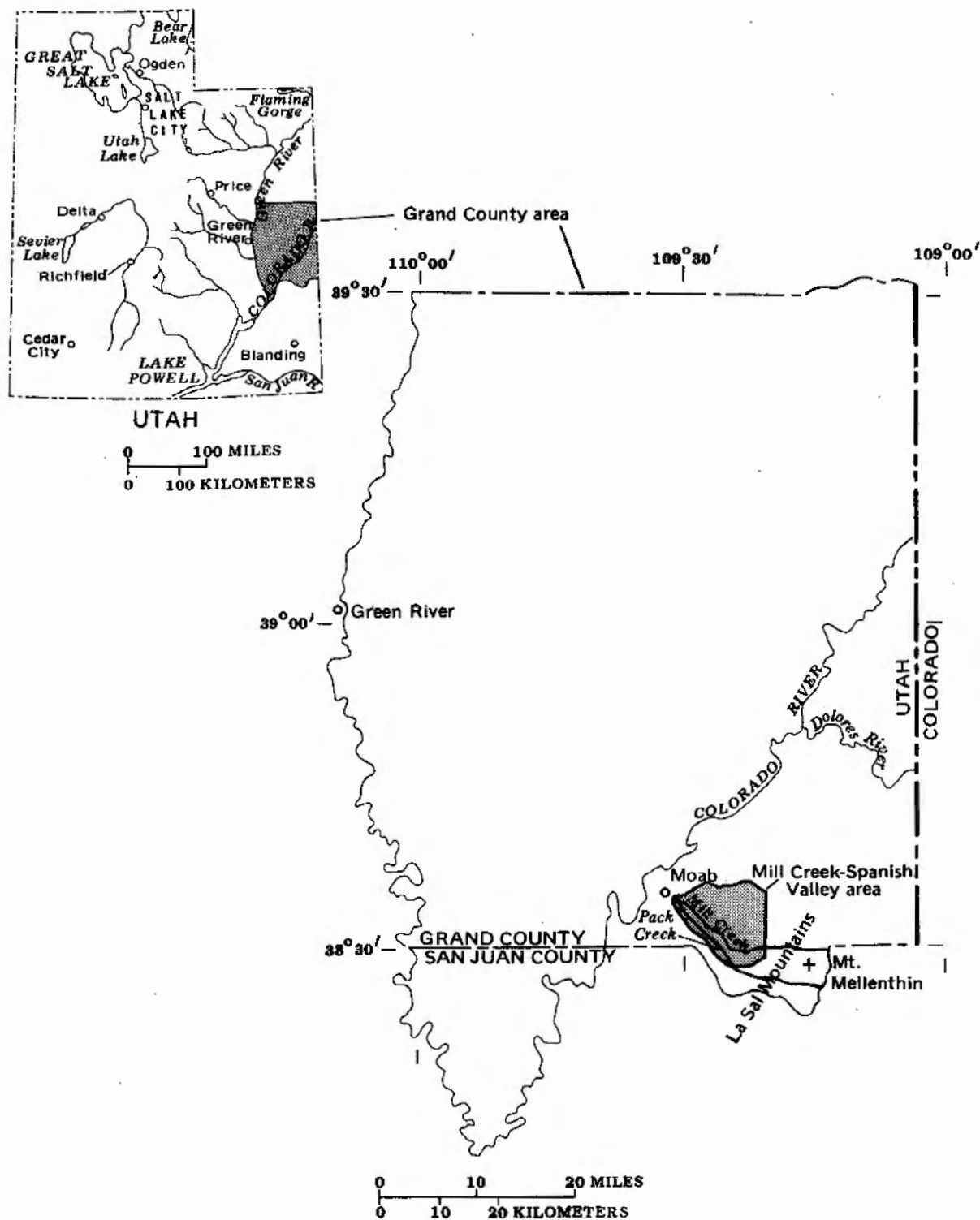


Figure 1.--Location of the Grand County and Mill Creek-Spanish Valley areas.



Field work was conducted from April 1985 through October 1986, and consisted of an inventory of wells and springs in the area, monthly measurements of water levels in wells in the Mill Creek-Spanish Valley area, a streamflow gain-loss study in the Mill Creek and the North Fork Mill Creek drainages, and an 8-day, multiple-well aquifer test in the City of Moab well field. The inventory of wells and springs included water-level measurements at wells, and discharge measurements, on-site water-quality measurements, and water-sample collection at wells and springs. The inventoried sites are shown on plate 1. Chemical analyses of water samples were made by the National Water-Quality Laboratory of the U.S. Geological Survey in Denver, Colorado.

#### Previous Investigations

Several hydrologic studies have been conducted in the Grand County area. Sumsion (1971) studied the geology and water resources of the Spanish Valley area, and Eychaner (1977) developed a digital model of the same area, using data from Sumsion (1971). Both studies primarily addressed the water resources of unconsolidated Quaternary deposits. Two studies addressed aquifer characteristics at specific wells drilled for the U.S. Department of Energy (Rush and others, 1980; Wollitz and others, 1982). Three studies addressed the regional hydrology of parts of the Paradox Basin (Rush and others, 1982; Weir, Maxfield, and Hart, 1983; Weir, Maxfield, and Zimmerman, 1983). Parts of each of the areas addressed are in the Grand County area.

#### General Description of the Grand County Area

The Grand County area contains known and potential reserves of oil, gas, coal, and uranium. Uranium has been mined and processed intermittently in the area since the 1950's, and continual exploration for oil, coal, and gas is occurring. Potash is presently solution-mined, and further development of potash reserves is anticipated. Further development of any of these resources would require additional development of water resources.

The Grand County area is a center for recreation. National Parks, a National Recreation Area, U.S. National Forest campgrounds, and U.S. Bureau of Land Management campgrounds and primitive areas are in and near the study area. The City of Moab is a center for accommodations for tourists, and further development of tourism will require additional development of water resources.

The climate of most of the Grand County area is dry according to the classification of Trewartha (1968, p. 248-250), with annual potential evaporation exceeding annual precipitation. A highland climate (Trewartha, 1968, p. 358-369) occurs at higher altitudes in the La Sal Mountains and in the Book Cliffs. At Monticello, about 40 miles south of the Grand County area, the altitude is about 7,000 feet above sea level, and the mean annual temperature is 46.0 °F. The mean annual temperature at Monticello is representative of similar altitudes in the Grand County area. At Moab, the altitude is about 4,000 feet above sea level, and the mean annual temperature is 56.6 °F. The mean annual temperature of the plateaus in the Grand County area is between that at Monticello and that at Moab, depending on altitude. Two formation classes of vegetation in the Grand County area are "semidesert" in the canyons and on the plateaus, and "needleleaf forest" at higher



altitudes in the La Sal Mountains and in the Book Cliffs (Strahler, 1970, p. 235-240).

Most of the land in the Grand County area is administered by the Federal government. Arches National Park, Canyonlands National Park, and the Glen Canyon National Recreation Area are administered by the National Park Service, and the Manti-La Sal National Forest is administered by the U.S. Forest Service. The extreme northwestern part of the Grand County area is part of the Uintah and Ouray Indian Reservation. The remainder of the Federally owned land is administered by the U.S. Bureau of Land Management. Most of the land in Spanish Valley is privately owned, and there are small private land holdings throughout the Grand County area within the Federally owned land administered by the U.S. Bureau of Land Management.

Population of the Grand County area presently (1987) is about 8,000 persons and, therefore, the average population density is about two persons per square mile. Most of the population is concentrated in the Moab-Spanish Valley area. About 5,000 people live in Moab and about 2,000 people live in the unincorporated part of Spanish Valley. Several hundred people live in Castle Valley. Only about 300 people live northwest of the Colorado River.

#### Numbering System for Hydrogeologic-Data Sites

The system of numbering wells and springs in Utah is based on the cadastral land-survey system of the U.S. Government. The number, in addition to designating the well, spring, or other site, describes its position on the land net. In the land-survey system, the State is divided into four quadrants by the Salt Lake Base Line and Meridian, and these quadrants are designated by the upper-case letters A, B, C, and D, indicating, respectively, the northeast, northwest, southwest, and southeast quadrants. Numbers designating, respectively, the township and range follow the quadrant letter, and all three are enclosed in parentheses. For half townships or ranges the letter "T" or "R", respectively, precedes the parentheses. The number after the parentheses indicates the section and is followed by three letters indicating the quarter section, the quarter-quarter section, and the quarter-quarter-quarter section--generally 10 acres<sup>1</sup>. The letters a, b, c, and d indicate, respectively, the northeast, northwest, southwest, and southeast quarters of each subdivision. The number after the letters is the serial number of the well or spring within the 10-acre tract; the letter "S" preceding the serial number denotes a spring. If a well or spring cannot be located within a 10-acre tract, one or two location letters are used and the serial number is omitted. Thus (D-26-22)22aab-1 designates the first well constructed or visited in the NW $\frac{1}{4}$  NE $\frac{1}{4}$  NE $\frac{1}{4}$  sec. 22, T. 26 S., R. 22 E., and (D-27-19)22bbc-S1 designates the first spring inventoried in the SW $\frac{1}{4}$  NW $\frac{1}{4}$  NW $\frac{1}{4}$  sec. 22, T. 27 S., R. 19 E. The numbering system without serial numbers is used to show the location of data sites other than wells and springs. The numbering system is illustrated in figure 2.

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<sup>1</sup>Although the basic land unit, the section, is theoretically 1 square mile, many sections are irregular. Such sections are subdivided into 10-acre tracts, generally beginning at the southeast corner, and the surplus or shortage is taken up in the tracts along the north and west sides of the section.

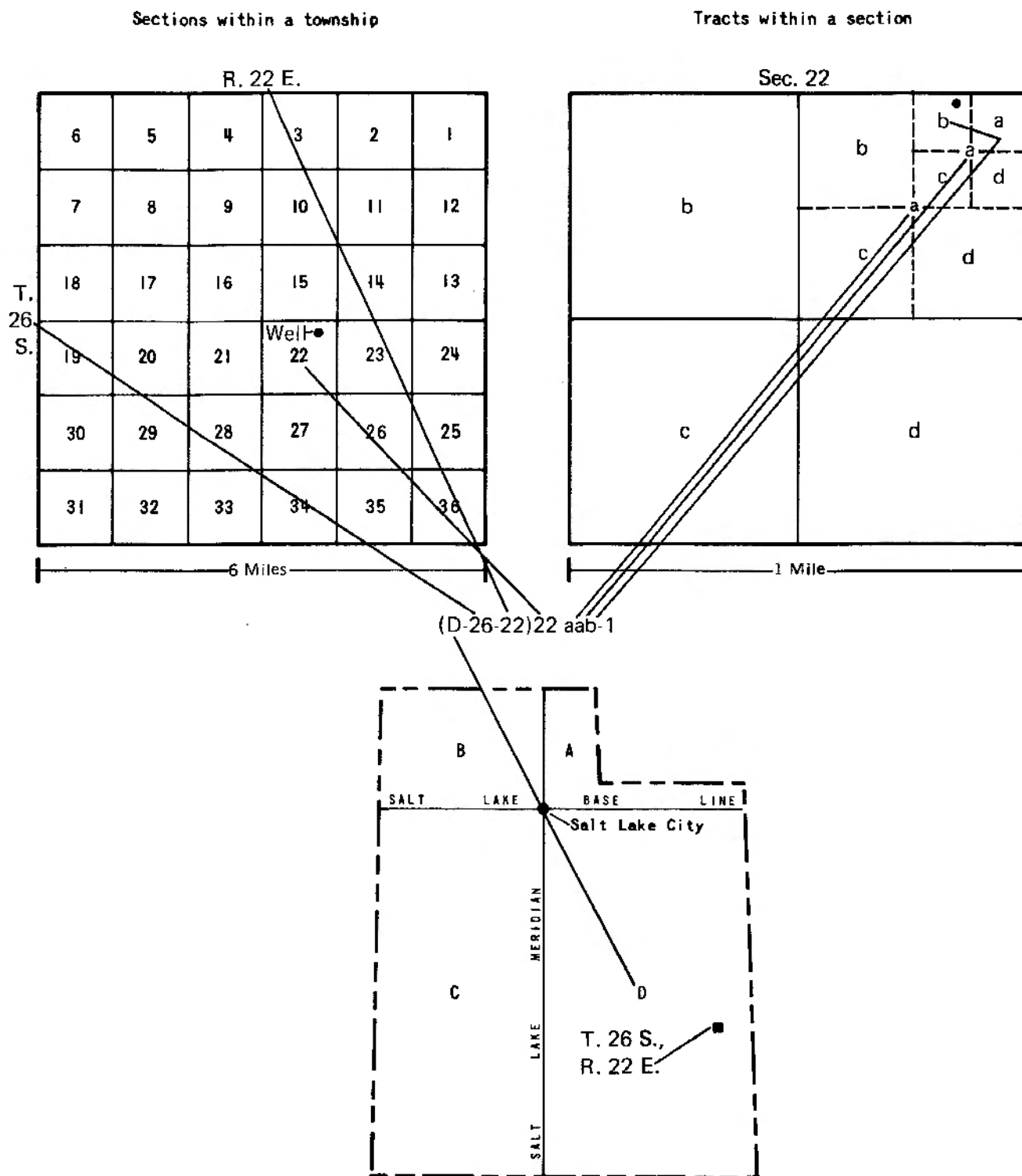


Figure 2.--Numbering system for hydrogeologic-data sites.

Locally, there may be some inconsistency between locations based on geographic features and those based on the land-survey system because of the small scale of some maps used in this report. Where such inconsistency exists, data sites have been plotted with reference to the local geography, resulting in apparent mislocation with reference to the land-survey system.

#### Terms Describing Aquifer Characteristics and Water Quality

The hydraulic conductivity (K) of a water-bearing material is the volume of water that will move through a unit cross section of the material in unit time under a unit hydraulic gradient (Lohman, 1979, p. 6). The units for K are cubic feet per day per square foot, which reduces to feet per day (ft/d).

Transmissivity (T) is the rate at which water is transmitted through a unit width of the aquifer under a unit hydraulic gradient (Lohman, 1979, p. 6). The units for T are cubic feet per day per foot, which reduces to feet squared per day (ft<sup>2</sup>/d).

Specific capacity is a measure of the productivity of a well and is calculated by dividing the pumping rate of the well by the drawdown in the well. The units for specific capacity are gallons per minute per foot of drawdown [(gal/min)/ft].

In this report, chemical classification of water is according to the system of Davis and Dewiest (1966, p. 119). In the system, only ions present in quantities greater than 20 percent of the total milliequivalents per liter of cations or anions are used to name the water type. An ion present in quantities greater than 60 percent of the total milliequivalents of cations or anions is used alone to name the cation or anion type. In mixed water types, ions present in quantities greater than 20 percent, but less than 60 percent, of the total milliequivalents of cations or anions present are listed in descending order of concentration. For example, for the sample collected from well (D-25-21)20add-2 on August 19, 1986 (table 9), 38 percent of the total cation milliequivalents was sodium, 36 percent was calcium, and 24 percent was magnesium. Forty-one percent of the total anion milliequivalents was sulfate, 36 percent was bicarbonate, and 23 percent was chloride. This water sample is classified as a sodium calcium magnesium sulfate bicarbonate chloride type.

Classification of water in terms of concentration of dissolved solids is as described by Robinove and others (1958):

| Classification         | Concentration<br>(milligrams per liter) |
|------------------------|-----------------------------------------|
| Fresh.....             | Less than 1,000                         |
| Slightly saline.....   | 1,000-3,000                             |
| Moderately saline..... | 3,000-10,000                            |
| Very saline.....       | 10,000-35,000                           |
| Briny.....             | More than 35,000                        |

Classification of water in terms of hardness is as described by Durfor and Becker (1964, p. 27):

| Classification       | Range of hardness<br>(milligrams per liter) |
|----------------------|---------------------------------------------|
| Soft.....            | 0-60                                        |
| Moderately hard..... | 61-120                                      |
| Hard.....            | 121-180                                     |
| Very hard.....       | More than 180                               |

#### Acknowledgments

Special thanks are given to people in the following Federal agencies and offices that contributed significantly to this study: The U.S. Bureau of Land Management, Moab District and Grand Resource Area offices, and the U.S. National Park Service at Arches and Canyonlands National Parks. Mark Page of the State of Utah Department of Natural Resources, Division of Water Rights office in Price, Utah, provided valuable information. John Keough and Larry Johnson of the City of Moab and Dale Pierson of the Grand County Water Conservancy District provided information and records of their agencies, knowledge of the area, and technical support during the study.

Appreciation is expressed to well owners who allowed access to their wells for inventory. In addition to allowing access to their wells, Bob Norman provided well records and other information for significant parts of the study area, and Doctor and Mrs. Dail Magee provided weather and climatological data for the Mill Creek-Spanish Valley area.

#### GEOLOGIC SETTING

The Grand County area is part of the Colorado Plateaus physiographic province (Fenneman, 1931, p. 274-325). Parts of two sections of the province are included in the Grand County area: The Uinta Basin section is north of the Book Cliffs and the Canyon Lands section is south of the Book Cliffs. According to Fenneman, the Colorado Plateaus physiographic province generally consists of nearly flat-lying sedimentary strata that have been deeply incised by streams and interrupted by generally north-south trending monoclines, synclines, anticlines, and elongate structural domes and basins. Extrusive and intrusive igneous features are widely scattered throughout the province.

Strata in the Grand County area generally dip gently to the north and northwest, typically at less than 10 degrees. Consequently, continuously younger strata crop out in a generally northerly direction (pl. 2). Rocks of Permian age crop out in Canyonlands National Park and rocks of Tertiary age crop out north of the Book Cliffs. The general decrease in altitude in a northerly direction of a particular stratigraphic horizon is illustrated in figure 3, which shows the altitudes of the top of the Entrada Sandstone and the base of the Wingate Sandstone for selected parts of the Grand County area.

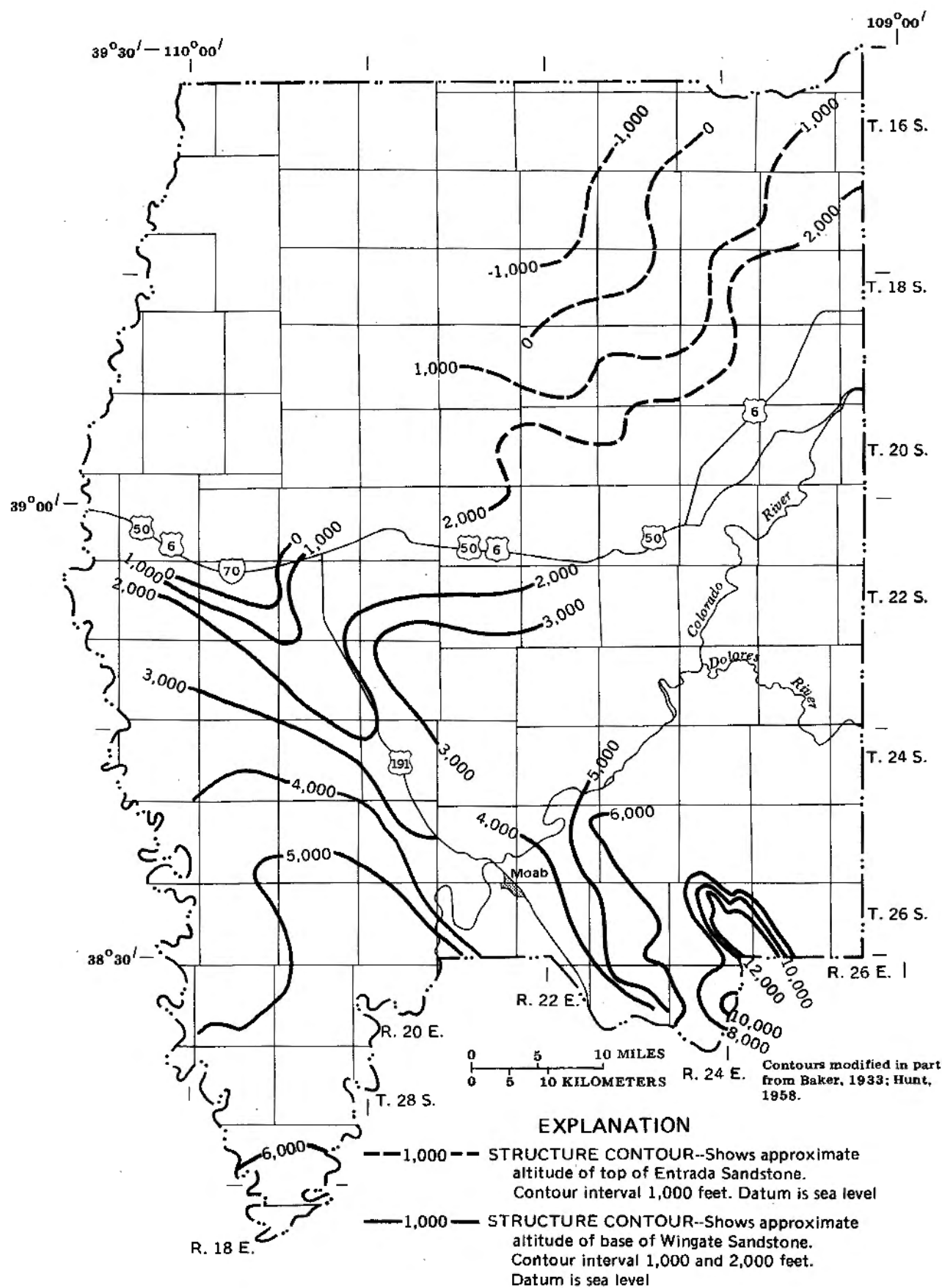


Figure 3.--Approximate altitude of the top of the Entrada Sandstone and the base of the Wingate Sandstone.

The principal structural feature in the Grand County area is a series of northwest-trending salt anticlines, described by Weir, Maxfield, and Hart (1983) as "elongated wrinkles" (pl. 2). A series of synclines alternates with and generally parallels the salt anticlines. Areas where strata dip more than 10 degrees are located near the Salt Valley anticline, the Elephant Butte folds, and Spanish Valley (pl. 2). In the canyon walls which bound Spanish Valley, strata dip as much as 26 degrees near the southern end of the Courthouse syncline and near the Spanish Valley syncline.

Porphyritic intrusive igneous rocks of Tertiary age form the cores of the La Sal Mountains. The intrusions have caused doming of the otherwise gently dipping strata, and the dip of the strata on the flanks of the mountains is in some places as much as 80 degrees (pl. 2).

The age of consolidated sedimentary rocks exposed in the study area ranges from Pennsylvanian to Tertiary (pl. 2). Location of outcrops and brief descriptions of the geologic and hydrologic characteristics of the exposed geologic units are described in table 1.

The oldest exposed consolidated sedimentary-rock unit in the Grand County area is the Paradox Member of the Hermosa Formation of Pennsylvanian age. It is exposed in small areas of Salt Valley, Moab Valley, and in the Onion Creek drainage (pl. 2). The youngest exposed sedimentary-rock unit is the Parachute Creek Member of the Green River Formation of Tertiary age. It is extensively exposed north of the Book Cliffs. Igneous rocks of Precambrian age are exposed near the Colorado River in the eastern part of the Grand County area, and igneous rocks of Tertiary age are exposed in the La Sal Mountains.

The principal formations investigated in this report are, from oldest to youngest, the Wingate Sandstone of Triassic age, the Kayenta Formation of Triassic(?) age, the Navajo Sandstone of Triassic(?) and Jurassic age, and the Entrada Sandstone of Jurassic age. The Wingate Sandstone, the Kayenta Formation, and the Navajo Sandstone form the Glen Canyon Group. Typical outcrops of the Wingate, Kayenta, and Navajo are shown in figure 4, and typical outcrops of the Navajo and the Dewey Bridge, Slick Rock, and Moab Sandstone Members of the Entrada Sandstone are shown in figure 5.

The Wingate Sandstone is a massive, fine-grained, thickly crossbedded, eolian sandstone (fig. 4). It erodes to vertical cliffs, which are commonly coated with a dusky-red desert varnish. Thickness of the Wingate ranges from about 300 to 400 feet.

The Kayenta Formation is an irregularly interbedded fluvial fine- to coarse-grained sandstone, siltstone, and shale (fig. 4). Thin beds of shale-pellet conglomerate and freshwater limestone locally are present. The sandstone facies predominate. In many places there is a prominent siltstone bed near the top of the formation, which locally perches water in the overlying parts of the Kayenta Formation and the Navajo Sandstone. The Kayenta erodes to cliffs and benches, and caps many mesas and narrow benches. Thickness of the Kayenta is about 240 feet in the western part of the Grand County area and decreases to nearly zero in the eastern part of the area.

Table 1.—Description of geologic units exposed in the Grand County area

[Geologic characteristics modified from Stokes (1964), Williams (1964), and Cashion (1973)]

| Geologic unit                                                        | Principal outcrop locations<br>(plate 2)                                                                                                                                            | Geologic characteristics                                                                                                                                  | Hydrologic characteristics                                                                                                                                                       |
|----------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Relatively younger alluvial deposits: primarily along active streams | Southwest and southeast of the Book Cliffs, in Terrible Canyon, along the Green River upstream from the City of Green River, in Spanish and Castle Valleys near the Colorado River. | Sand, silt, and gravel.                                                                                                                                   | Yields freshwater to wells in Spanish Valley and Castle Valley.                                                                                                                  |
| Gravel surfaces                                                      | Intermittent throughout southern half of Grand County area.                                                                                                                         | Mainly terraces and pediments undergoing erosion. May not be associated with active streams.                                                              | Recharge medium.                                                                                                                                                                 |
| Glaciated ground and moraines, undifferentiated                      | Small areas on flanks of La Sal Mountains.                                                                                                                                          | Includes bare rock and moraines of all types.                                                                                                             | Not known to yield water.                                                                                                                                                        |
| Covering deposits                                                    | Intermittent throughout southern half of Grand County area.                                                                                                                         | Chiefly windblown silt lacking dune form. Includes some patches of soil and alluvium. Underlain by thick valley fill in Spanish Valley and Castle Valley. | Valley fill yields freshwater to wells in Spanish Valley and Castle Valley. In Spanish Valley, dissolved-solids concentrations range from about 700 to 900 milligrams per liter. |
| Tertiary and Quaternary deposits or surfaces, undifferentiated       | Castle Valley.                                                                                                                                                                      | Conglomerate.                                                                                                                                             | May yield small amounts of water of unknown quality to springs.                                                                                                                  |
| Tertiary porphyritic intrusive rocks                                 | Southeastern part of Grand County area.                                                                                                                                             | Diorite porphyry.                                                                                                                                         | Not known to yield water.                                                                                                                                                        |
| Green River Formation<br>Parachute Creek Member                      | Northern part of Grand County area.                                                                                                                                                 | Chiefly marlstone and oil shale, with some sandstone, siltstone, and tuff.                                                                                | Yields freshwater to springs, from less than 1 to about 20 gallons per minute.                                                                                                   |
| Wasatch Formation                                                    | do.                                                                                                                                                                                 | Chiefly continental deposits, ranging from coarse conglomerate to fine claystone.                                                                         | Known to yield freshwater to one spring, about 30 gallons per minute.                                                                                                            |
| North Horn Formation                                                 | Northwestern part of Grand County area.                                                                                                                                             | Fluvial sandstone, variegated shale, and some conglomerate.                                                                                               | Not known to yield water.                                                                                                                                                        |
| Tuscher Formation                                                    | Southwestern part of the Book Cliffs.                                                                                                                                               | Conglomeratic, fluvial sandstone.                                                                                                                         | Do.                                                                                                                                                                              |
| Mesaverde Group                                                      | Southern and southeastern part of the Book Cliffs.                                                                                                                                  | Mixed sandstone, shale, and coal beds.                                                                                                                    | Do.                                                                                                                                                                              |



**Table 1.—Description of geologic units exposed in the  
Grand County area—Continued**

| Geologic unit              | Principal outcrop locations<br>(plate 2)                                                                                                           | Geologic characteristics                                                                               | Hydrologic characteristics                                                                                                            |
|----------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------|
| Price River Formation      | Southwestern part of the Book Cliffs.                                                                                                              | Interbedded sandstone and mudstone.                                                                    | Not known to yield water.                                                                                                             |
| Castlegate Sandstone       | Band along margin of the Book Cliffs.                                                                                                              | Cliff-forming, deltaic sandstone.                                                                      | Do.                                                                                                                                   |
| Blackhawk Formation        | Band along southern and southwestern margin of the Book Cliffs.                                                                                    | Sandstone, mudstone, shale, and coal.                                                                  | Known to yield freshwater to one spring, about 18 gallons per minute.                                                                 |
| Mancos Shale               | South, southwest, and southeast of the Book Cliffs.                                                                                                | Gray to black marine shale with thin sandstone beds at various horizons.                               | Not known to yield water.                                                                                                             |
| Ferron Sandstone Member    | In a band southwest, south, and southeast of the Book Cliffs.                                                                                      | Fine-grained, thin-bedded sandstone and sandy shale near base of Mancos Shale.                         | Do.                                                                                                                                   |
| Tununk Shale Member        | do.                                                                                                                                                | Gray marine siltstone and claystone.                                                                   | Do.                                                                                                                                   |
| Dakota Sandstone           | East-west trending band about 10 miles south of the Book Cliffs.                                                                                   | Sandstone and conglomeratic sandstone with interbedded carbonaceous shale.                             | Do.                                                                                                                                   |
| Burro Canyon Formation     | Southeast part of Grand County area, east of the Colorado River only.                                                                              | Fine- to coarse-grained sandstone interbedded with siltstone, shale, mudstone, and impure limestone.   | Do.                                                                                                                                   |
| Cedar Mountain Formation   | East-west trending band about 10 miles south of the Book Cliffs, west of the Colorado River only.                                                  | Nodular shale with fluvial sandstone beds.                                                             | Occasionally yields fresh to slightly saline water to seeps.                                                                          |
| Morrison Formation         | East-west trending band about 10 miles south of the Book Cliffs; eastern part of area just north of the Colorado River; southeastern part of area. |                                                                                                        |                                                                                                                                       |
| Brushy Basin Shale Member  |                                                                                                                                                    | Bentonitic mudstone and siltstone with a few lenses of fluvial sandstone, limestone, and conglomerate. | Known to yield slightly saline water, less than 1 gallon per minute, to one flowing well.                                             |
| Salt Wash Sandstone Member |                                                                                                                                                    | Interbedded fluvial sandstone and fluvial mudstone, with thin limestone lenses near base.              | Yields water of unknown quality to seeps and small springs in outcrop area; yields slightly saline water to one spring on South Mesa. |

Table 1.--Description of geologic units exposed in the  
Grand County area--Continued

| Geologic unit         | Principal outcrop locations<br>(plate 2)                           | Geologic characteristics                                                                                                              | Hydrologic characteristics                                                                                                                                                                                                                                                                                              |
|-----------------------|--------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Summerville Formation | Small areas in central and east-central part of Grand County area. | Sandstone, sandy shale, siltstone, and mudstone.                                                                                      | Not known to yield water; is a confining unit.                                                                                                                                                                                                                                                                          |
| Entrada Sandstone     | Southern half of Grand County area.                                |                                                                                                                                       | Entrada aquifer.                                                                                                                                                                                                                                                                                                        |
| Moab Sandstone Member |                                                                    | Medium-grained, massive, crossbedded sandstone.                                                                                       | Recharge occurs, especially where fractured.                                                                                                                                                                                                                                                                            |
| Slick Rock Member     |                                                                    | Medium-grained, massive, crossbedded, eolian sandstone.                                                                               | Principal water-yielding sandstone of the Entrada aquifer. Yields freshwater, generally less than 5 gallons per minute, to seeps and springs throughout its outcrop area.                                                                                                                                               |
| Dewey Bridge Member   |                                                                    | Fine-grained sandstone and siltstone.                                                                                                 | Confining unit. Substantially less transmissive than overlying Slick Rock Member.                                                                                                                                                                                                                                       |
| Carmel Formation      | South of the City of Green River.                                  | Marine gypsum, limestone, shale, and calcareous sandstone.                                                                            | Not known to yield water.                                                                                                                                                                                                                                                                                               |
| Navajo Sandstone      | Southern half of Grand County area.                                | Fine-grained, crossbedded eolian sandstone with prominent vertical joints in most outcrops. Limestone horizons near top of formation. | Navajo aquifer. Recharge occurs where outcrops are fractured or jointed, or where formation is mantled by unconsolidated deposits. Yields freshwater to seeps, springs, and wells. Spring discharge ranges from less than 5 to more than 300 gallons per minute. Well discharge is as much as 2,000 gallons per minute. |
| Kayenta Formation     | do.                                                                | Interbedded shale, siltstone, and fine- to coarse-grained sandstone.                                                                  | Less permeable than the overlying Navajo Sandstone and the underlying Wingate Sandstone. Generally functions as a confining unit. Is more permeable in the Mill Creek-Spanish Valley area and, along with the Navajo Sandstone and the Wingate Sandstone, forms the Glen Canyon aquifer.                                |
| Wingate Sandstone     | Intermittent areas in southern half of Grand County area.          | Fine-grained, massive crossbedded, eolian sandstone. Forms vertical cliffs in most exposures.                                         | Wingate aquifer. Yields freshwater to seeps and springs in the Moab Valley-Colorado River area.                                                                                                                                                                                                                         |

Table 1.—Description of geologic units exposed in the  
Grand County area—Continued

| Geologic unit                      | Principal outcrop locations<br>(plate 2)                                                                              | Geologic characteristics                                                                                             | Hydrologic characteristics                                                                                                                     |
|------------------------------------|-----------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------|
| Chinle Formation                   | South and southeastern parts<br>of Grand County area.                                                                 | Terrestrial sedimentary rocks,<br>siltstone interbedded with<br>sandstone and shale.                                 | Confining unit.                                                                                                                                |
| Moss Back Member                   | Canyonlands National Park.                                                                                            | Calcareous fluvial sandstone,<br>grit, and mudstone.                                                                 | Not known to yield water.                                                                                                                      |
| Moenkopi Formation                 | South and southeastern part of<br>Grand County area.                                                                  | Shale, sandy mudstone, sand-<br>stone, conglomerate, and<br>locally, gypsum beds.                                    | Confining unit.                                                                                                                                |
| Cutler Formation                   | South and southeastern part<br>of Grand County area.                                                                  | Mostly fluvial arkose and<br>arkosic conglomerate.                                                                   | Yields water to wells on south-<br>western side of Castle Valley.                                                                              |
| White Rim Sandstone<br>Member      | Canyonlands National Park.                                                                                            | Medium- to coarse-grained,<br>crossbedded eolian sandstone.                                                          | Yields slightly saline water to<br>wells in Taylor Canyon; yields<br>freshwater to seeps along mar-<br>gin of outcrop.                         |
| Cedar Mesa Sandstone<br>Member     | Near confluence of Green and<br>Colorado Rivers.                                                                      | Fine-grained, thickly cross-<br>bedded, eolian sandstone.                                                            | May be an aquifer, but not known<br>to yield water in study area.                                                                              |
| Rico Formation                     | do.                                                                                                                   | Fine- to medium-grained,<br>crossbedded, fluvial sand-<br>stone; cherty, marine lime-<br>stone, and micaceous shale. | Do.                                                                                                                                            |
| Hermosa Formation                  | In canyon of Colorado River in<br>northeast part of Canyonlands<br>National Park; Moab Valley<br>near Colorado River. | Limestone, siltstone, arkose,<br>and conglomerate.                                                                   | Do.                                                                                                                                            |
| Paradox Member                     | Salt Valley; Onion Creek<br>drainage; Moab Valley near<br>Colorado River.                                             | Salt, gypsum, anhydrite,<br>shale, sandstone, and<br>limestone.                                                      | Yields moderately saline to very<br>saline water to wells in Salt<br>Valley and very saline water to<br>one spring in Onion Creek<br>drainage. |
| Precambrian crystal-<br>line rocks | Eastern part of Grand County<br>area near Colorado River.                                                             | Crystalline rocks.                                                                                                   | May yield water to springs where<br>fractured.                                                                                                 |

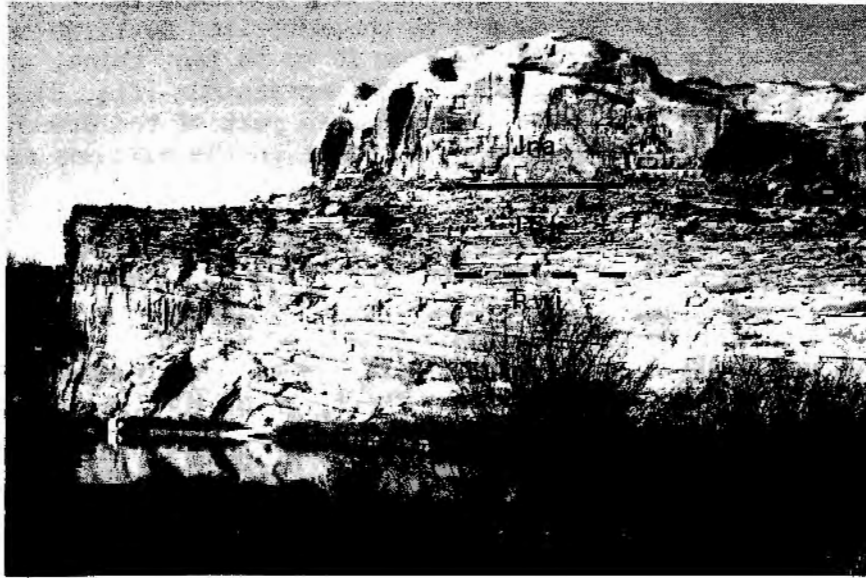


Figure 4.--Outcrop of the Navajo Sandstone (Jna), Kayenta Formation (JRk), and Wingate Sandstone (Rwi), at location (D-25-21)26b.

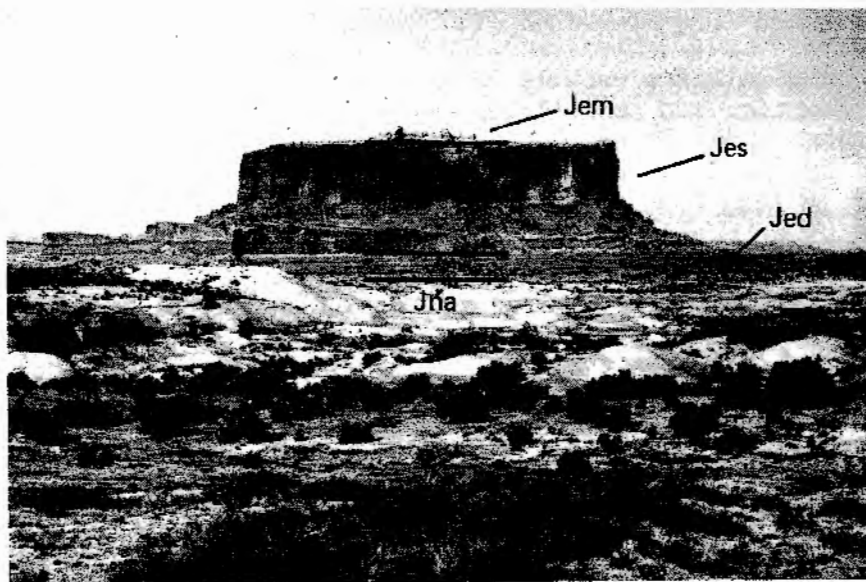


Figure 5.--Outcrop of the Moab Sandstone (Jem), Slick Rock (Jes), and Dewey Bridge (Jed) Members of the Entrada Sandstone, and the Navajo Sandstone (Jna), at location (D-25-20)5b.

The Navajo Sandstone is a massive, fine-grained, thickly crossbedded, eolian sandstone (fig. 4). The Navajo is characterized by large-scale, high-angle crossbedding in sets generally from 20 to 50 feet thick, and it erodes to massive cliffs and domes alternating with depressions (fig. 5). Thickness of the Navajo is about 400 feet in the western part of the Grand County area and decreases to the east. The Navajo is absent in the extreme eastern part of the area.

The Entrada Sandstone is divided into three members: The Dewey Bridge Member, the Slick Rock Member, and the Moab Sandstone Member (fig. 5). The Dewey Bridge Member is composed of siltstone and fine-grained sandstone. The Slick Rock Member is a massive, medium-grained, crossbedded, eolian sandstone. The Moab Sandstone Member is a single crossbed set of medium-grained, massive, sandstone at the top of the formation. Thickness of the Entrada Sandstone is as much as 550 feet in the western part of the area and decreases to the east.

## HYDROLOGIC SETTING

### Precipitation

Average annual precipitation in the Grand County area generally increases with altitude and ranges from less than 6 inches along the Green River near the city of Green River to more than 30 inches in the La Sal Mountains (pl. 1). Average May through September precipitation also generally increases with altitude and ranges from less than 3 inches along the Green River to more than 10 inches in the La Sal Mountains (pl. 1). Average annual precipitation on the Book Cliffs ranges from about 10 to about 20 inches. Between the Book Cliffs and the Colorado River, average annual precipitation is generally less than 8 inches, and it increases nearly uniformly from about 8 inches at the Colorado River to about 20 inches at the base of the La Sal Mountains.

Summer precipitation usually is in the form of thunderstorms, which are localized, intense, and short-lived. There is little time for precipitation from such storms to infiltrate the rocks and recharge the ground-water system, and most of the precipitation becomes evapotranspiration or runoff. Winter precipitation is less localized, less intense, and of longer duration. At higher altitudes it usually is in the form of snow. The gradual melting of the snow allows more time for precipitation to infiltrate the rocks and recharge the ground-water system, especially at higher altitudes during spring melting of the winter snowpack. The rate of evapotranspiration also is much smaller during winter and spring.

Except in the La Sal Mountains, May-September precipitation constitutes about four-tenths of the annual precipitation. In the La Sal Mountains, above about 10,000 feet, May-September precipitation constitutes about one-third of the annual precipitation.

The variation in annual precipitation at the Moab airport for 1951-86 is shown in figure 6. In figure 6, a horizontal line segment would indicate no change in departure from the average annual precipitation, and therefore would indicate precipitation of 8 inches. A downward-trending line segment indicates a time period when precipitation was less than 8 inches, and an

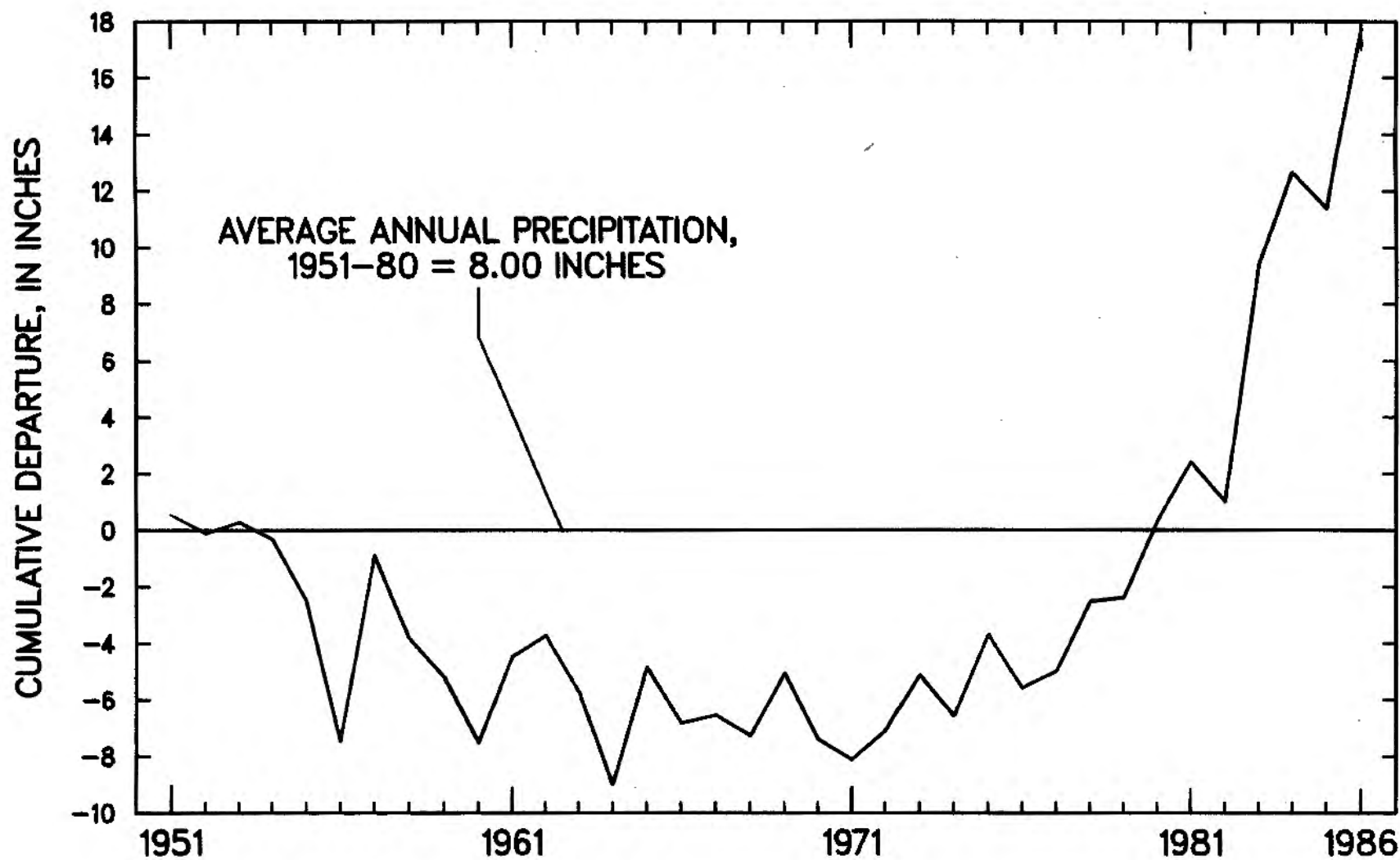


Figure 6.--Cumulative departure from average annual 1951-80 precipitation at Moab Airport, for years shown.

upward-trending line segment indicates a period when precipitation was more than 8 inches. The general downward trend in figure 6 from 1951 to 1971 shows that precipitation generally was less than 8 inches per year for that period, and the general upward trend from 1971 to 1986 shows that precipitation generally was more than 8 inches per year for that period.

#### Surface Water

Three major, perennial streams flow within or along the borders of the Grand County area: The Dolores River, the Green River, and the Colorado River. The Dolores and the Green Rivers are tributary to the Colorado River.

North of the Book Cliffs, in the Uinta Basin section of the Colorado Plateaus physiographic province, runoff generally is to the north and drains into the Green River. South of the Book Cliffs, in the Canyon Lands section of the Colorado Plateaus physiographic province, surface water drains to the Colorado River and, in the western part of the area, to the Green River. Water that runs off of the La Sal Mountains to the north and east drains into the Dolores River.

Active and discontinued U.S. Geological Survey streamflow-gaging stations are shown on plate 1, and a summary of data collected at both active and discontinued stations is presented in table 2. Mill Creek and Pack Creek, both near Moab, and Cottonwood Wash near I-70 are the only other streams besides the Dolores, Green, and Colorado Rivers that do not have recorded periods of no flow.

#### Ground Water

At several locations water was observed discharging from Quaternary unconsolidated deposits; however, the quantity and quality of water discharging from these deposits was not investigated during this study. In two areas, water from the unconsolidated deposits is used extensively. There are drillers' reports on file with the State Engineer's Office for about 100 wells completed in Quaternary unconsolidated deposits in the Castle Valley area, and Sumsion (1971) reported records of about 200 wells completed in Quaternary unconsolidated deposits in the Spanish Valley area. The dissolved-solids concentration of samples collected from 9 wells ranged from 169 to 1,020 mg/L (Sumsion, 1971). Other unconsolidated Quaternary deposits that can be recharged by the large precipitation associated with the La Sal Mountains may also contain usable quantities of ground water.

Rush and others (1982), Weir, Maxfield, and Hart (1983), and Weir, Maxfield, and Zimmerman (1983) have divided the stratigraphic section in the Grand County area into two ground-water systems: The "upper ground-water system", which includes all stratigraphic units above the Paradox Member of the Hermosa Formation, and the "lower ground-water system", which includes all stratigraphic units below the Paradox Member. The upper ground-water system is the main focus of this report.



Table 2.—Selected streamflow data from the Grand County area

[From published records of the U.S. Geological Survey. Abbreviations: mi<sup>2</sup>, square miles; ft<sup>3</sup>/s, cubic feet per second; acre-ft/yr, acre-feet per year; —, no data]

| Station number<br>(plate 1) | Station name                                | Drainage area<br>(mi <sup>2</sup> ) | Period of record                                                  | Average discharge  |            |       | Discharge extremes            |          |                               |          |
|-----------------------------|---------------------------------------------|-------------------------------------|-------------------------------------------------------------------|--------------------|------------|-------|-------------------------------|----------|-------------------------------|----------|
|                             |                                             |                                     |                                                                   | ft <sup>3</sup> /s | acre-ft/yr | years | Maximum<br>ft <sup>3</sup> /s | date     | Minimum<br>ft <sup>3</sup> /s | date     |
| 09315000                    | Green River at Green River                  | 44,850                              | Oct. 1894–Oct. 1899<br>Oct. 1904–present                          | 6,391              | 4,630,000  | 86    | 68,100                        | 6/27/17  | 255                           | 11/26/31 |
| 09316100                    | Floy Wash near Green River                  | 56.6                                | Apr. 1983–present                                                 | .94                | 678        | 2     | 2,170                         | 7/29/85  | ( <sup>1</sup> )              | —        |
| 09163675                    | Cottonwood Wash near I-70                   | 170                                 | Apr. 1973–Sept. 1986                                              | 6.16               | 4,460      | 3     | 541                           | 8/29/86  | 0.3                           | 7/19/85  |
| 09180000                    | Dolores River                               | 4,580                               | Oct. 1950–present                                                 | 835                | 605,000    | 35    | 17,400                        | 4/21/58  | 3.4                           | 9/23/56  |
| 09180500                    | Colorado River near Cisco                   | 24,100                              | Jan. 1895–present                                                 | 7,724              | 5,596,000  | 74    | 76,800                        | 6/19/17  | 558                           | 7/21/34  |
| 09181500                    | Rock (Professor) Creek near Moab            | —                                   | July 1950–Sept. 1953                                              | 2.11               | 1,530      | 3     | 3,330                         | 8/29/51  | ( <sup>1</sup> )              | —        |
| 09182000                    | Castle Creek above diversions               | 7.6                                 | July 1950–Sept. 1955<br>Apr. 1957–Sept. 1975                      | 1.16               | 840        | 23    | 27                            | 8/11/67  | ( <sup>1</sup> )              | —        |
| 09182500                    | Castle Creek near Moab                      | 53.1                                | July 1950–Sept. 1955<br>May 1957–Sept. 1958                       | 5.25               | 3,800      | 6     | 11,000                        | 8/13/54  | ( <sup>1</sup> )              | —        |
| 09182900                    | Courthouse Wash at Arches high-way crossing | 143                                 | Oct. 1958–July 1966                                               | 1.47               | 1,060      | 7     | 4,530                         | 9/09/61  | ( <sup>1</sup> )              | —        |
| 09183000                    | Courthouse Wash near Moab                   | 162                                 | Oct. 1949–Sept. 1955<br>Apr. 1957–Sept. 1957<br>July 1966–present | 1.86               | 1,350      | 25    | 12,300                        | 8/05/57  | ( <sup>1</sup> )              | —        |
| 09183500                    | Mill Creek near Shelley tunnel              | 27.4                                | Oct. 1954–Sept. 1959                                              | 11.4               | 8,250      | 5     | 204                           | 8/30/57  | ( <sup>1</sup> )              | —        |
| 09184000                    | Mill Creek near Moab                        | 74.9                                | July 1949–Sept. 1971<br>Oct. 1972–present                         | 14.3               | 10,360     | 30    | 5,110                         | 8/21/53  | 0.2                           | 2/15/54  |
| 09184500                    | Pack Creek at M-4 Ranch                     | 15.8                                | Oct. 1954–Sept. 1959                                              | 2.54               | 1,840      | 5     | 1,200                         | 7/26/55  | 0.3                           | 9/02/56  |
| 09185000                    | Pack Creek near Moab                        | 57                                  | Oct. 1954–Sept. 1959                                              | 4.02               | 2,910      | 5     | 510                           | 10/08/54 | 0.7                           | 8/27/56  |

(<sup>1</sup>) No flow at times.

In this report, the upper ground-water system is divided into four hydrologic units: The Parachute Creek aquifer; the upper confining unit in Tertiary and Cretaceous rocks; the sandstone aquifers in Mesozoic rocks; and the lower confining unit in Mesozoic and Upper Paleozoic rocks. The Parachute Creek aquifer consists of the Parachute Creek Formation. The upper confining unit in Tertiary and Cretaceous rocks includes the stratigraphic section from the top of the Wasatch Formation to the bottom of the Mancos Shale. The sandstone aquifers in Mesozoic rocks include the stratigraphic section from the top of the Dakota Sandstone to the bottom of the Wingate Sandstone. The Entrada, Navajo, Wingate, and Glen Canyon aquifers are included in this unit. The lower confining unit in Mesozoic and Upper Paleozoic rocks includes the stratigraphic section from the top of the Chinle Formation to the top of the Paradox Member of the Hermosa Formation. The latter three units are analogous to the "Tertiary and Cretaceous confining beds", "Mesozoic sandstone aquifer", and "Mesozoic and Upper Paleozoic confining beds" of Rush and others (1982), Weir, Maxfield, and Hart (1983), and Weir, Maxfield, and Zimmerman (1983). The hydrologic units used in this report and the geologic units they contain are shown in table 3.

Table 3.--Correlation of geologic units and hydrologic units  
in the upper ground-water system

| Hydrologic units                                                 | Geologic units                                                                                                                                                                                                                                                                                                                                               |
|------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Parachute Creek<br>aquifer                                       | Parachute Creek Member of<br>Green River Formation                                                                                                                                                                                                                                                                                                           |
| Upper confining unit in<br>Tertiary and Cretaceous<br>rocks      | Tuscher Formation<br>Mesaverde Group<br>Price River Formation<br>Castlegate Sandstone<br>Blackhawk Formation<br>Mancos Shale<br>Ferron Sandstone Member<br>Tununk Shale Member                                                                                                                                                                               |
| Sandstone aquifers in<br>Mesozoic rocks                          | Dakota Sandstone<br>Burro Canyon Formation<br>Cedar Mountain Formation<br>Morrison Formation<br>Brushy Basin Shale Member<br>Salt Wash Sandstone Member<br>Summerville Formation<br>Entrada Sandstone<br>Moab Sandstone Member<br>Slick Rock Member<br>Dewey Bridge Member<br>Carmel Formation<br>Navajo Sandstone<br>Kayenta Formation<br>Wingate Sandstone |
| Entrada aquifer                                                  |                                                                                                                                                                                                                                                                                                                                                              |
| Navajo aquifer                                                   |                                                                                                                                                                                                                                                                                                                                                              |
| Glen Canyon aquifer                                              |                                                                                                                                                                                                                                                                                                                                                              |
| Wingate aquifer                                                  |                                                                                                                                                                                                                                                                                                                                                              |
| Lower confining unit in<br>Mesozoic and upper<br>Paleozoic rocks | Chinle Formation<br>Moss Back Member<br>Moenkopi Formation<br>Cutler Formation<br>White Rim Sandstone Member<br>Cedar Mesa Sandstone Member<br>Rico Formation<br>Hermosa Formation                                                                                                                                                                           |

About 60 wells and springs were inventoried during this study. At wells and springs, discharge rates and on-site water-quality parameters (water temperature, specific conductance and pH) were measured and water-quality samples were collected. Water levels were measured at wells. Discharge and water-quality data collected during previous studies were used to supplement the data collected during this study. The results of about 50 water-quality analyses for major ions and selected trace elements are given in table 4. In addition, the results of 16 analyses for uranium, 17 analyses for alpha-particle and beta-particle activity, and 15 analyses for radium activity are given in table 5.

#### Occurrence, Discharge, and Water Quality

The U.S. Forest Service has identified over 200 springs on the flanks of the La Sal Mountains. Nearly all of the springs occur at altitudes higher than 7,500 feet above sea level. Several representative spring sites were visited, and all were discharging from unconsolidated material overlying the upper ground-water system. Most of the springs identified by the U.S. Forest Service also probably discharge from unconsolidated material.

Feltis (1966, p. 52-69) reported values for concentrations of dissolved solids in water that was collected from the lower ground-water system in nine petroleum-exploration holes. The sites are located in western and southwestern parts of the Grand County area, and the concentrations of dissolved solids ranged from about 7,100 to about 230,000 mg/L.

#### Parachute Creek aquifer and the upper confining unit in Tertiary and Cretaceous rocks

About 70 springs north of the Book Cliffs, in the Uinta Basin section of the Colorado Plateaus physiographic province, are identified on U.S. Geological Survey 7½- and 15-minute topographic maps. Nearly all of the springs discharge from the Parachute Creek Member of the Green River Formation of Tertiary age, the youngest consolidated sedimentary rock unit in the Grand County area.

Discharge and water-quality information has been collected by previous investigators at 12 of the springs north of the Book Cliffs, 11 that discharge from the Parachute Creek Member of the Green River Formation and one that discharges from the Wasatch Formation of Tertiary age (Conroy and Fields, 1977, p. 202-242; Conroy, 1979, p. 168-190; Conroy, 1980, p. 160-163). Discharge typically ranges from less than 1 to about 20 gal/min. Concentrations of dissolved solids were less than 500 mg/L in samples from the Parachute Creek Member and about 600 mg/L in samples from the Wasatch Formation. The water type is mixed, typically calcium magnesium bicarbonate. Concentrations of selected trace elements were all less than the State of Utah primary drinking-water standards listed in table 4.

Table 4.—Chemical analyses of selected major

[Abbreviations used in headings: °C, degrees Celsius;  $\mu\text{S}/\text{cm}$ , milligrams per liter;  $\mu\text{g}/\text{L}$ , micrograms per liter; <, the actual value

State of Utah primary drinking-water standard: Maximum Contaminant Level (MCL) allowable by Utah Department of Health. U.S. Environmental Protection Agency (EPA) criterion: Recommended limit for human health (H) or welfare (W).

Well or spring number: See "Numbering system for hydrogeologic-data sites", p. 5 and figure 2.

Geologic Source: 112ALVM, alluvium of Quaternary age; 200MSZC, Mesozoic undifferentiated; 217CDRM, Cedar Mountain Formation; 221ENRD, Entrada Sandstone; 227GLNC, Glen Canyon Group; 227NVJO, Navajo Sandstone; 231WNGT, Wingate

| Well or spring number                                          | Geo-logic source | Date sampled | Temperature (°C) | Specific conductance ( $\mu\text{S}/\text{cm}$ ) | pH (stand-ard units) | Solids, residue at 180 °C dis-solved | Calcium, dis-solved (mg/L as Ca) | Magne-sium, dis-solved (mg/L as Mg) | Sodium, dis-solved (mg/L as Na) | Potas-sium, dis-solved (mg/L as K) |
|----------------------------------------------------------------|------------------|--------------|------------------|--------------------------------------------------|----------------------|--------------------------------------|----------------------------------|-------------------------------------|---------------------------------|------------------------------------|
| State of Utah primary drinking-water standard<br>EPA Criterion |                  |              |                  | 6.5-9.0                                          | 2,000                |                                      |                                  |                                     |                                 |                                    |
| (D-22-23)25bac- 1                                              | 217CDRM          | 07-21-86     | 22.5             | 2,670                                            | 8.3                  | 1,470                                | 11                               | 4.0                                 | 530                             | 4.3                                |
| (D-22-23)29ada- 1                                              | 221BRSB          | 08-18-85     | 26.5             | 1,630                                            | 7.6                  | 1,020                                | 48                               | 18                                  | 290                             | 5.1                                |
| (D-23-21)27bcd- 1                                              | 231WNGT          | 08-07-86     | 20.0             | 515                                              | 7.8                  | 280                                  | 28                               | 29                                  | 35                              | 6.0                                |
| (D-24-20)19caa- 1                                              | 221ENRD          | 11-24-85     | 14.0             | 335                                              | 7.8                  | 182                                  | 39                               | 17                                  | 5.5                             | 3.8                                |
| (D-25-20)21ddb- 1                                              | 231WNGT?         | 10-29-85     | 15.0             | 1,190                                            | --                   | 1,120                                | 14                               | 15                                  | 390                             | 7.1                                |
| (D-25-21)20add- 2                                              | 227NVJO          | 08-07-86     | 19.0             | 1,000                                            | 7.4                  | 584                                  | 70                               | 29                                  | 85                              | 6.1                                |
| (D-25-21)21bdc- 1                                              | 227NVJO          | 08-07-86     | 19.0             | 1,690                                            | 7.4                  | 1,000                                | 97                               | 38                                  | 200                             | 10                                 |
| (D-25-22)12aad- 1                                              | 310CTLR          | 09-30-86     | 16.0             | 3,260                                            | 7.3                  | 2,740                                | 380                              | 130                                 | 150                             | 14                                 |
| (D-25-23)18baa- 1                                              | 310CTLR          | 09-30-86     | 15.0             | 3,950                                            | 7.5                  | 3,450                                | 500                              | 160                                 | 260                             | 14                                 |
| (D-25-23)20adb- 1                                              | 310CTLR          | 09-30-86     | 15.0             | 1,940                                            | 7.3                  | 1,420                                | 250                              | 66                                  | 85                              | 4.1                                |
| (D-26-22) 8bad- 1                                              | 227GLNC          | 09-05-85     | 15.5             | 365                                              | 7.6                  | 203                                  | 38                               | 13                                  | 17                              | 1.7                                |
| (D-26-22) 9ddc- 1                                              | 227GLNC          | 07-11-86     | 18.0             | 265                                              | 7.8                  | 151                                  | 31                               | 12                                  | 5.5                             | 1.2                                |
| (D-26-22)14cba- 1                                              | 227GLNC          | 06-22-86     | 16.0             | 255                                              | 8.2                  | 150                                  | 30                               | 11                                  | 5.3                             | 1.1                                |
| (D-26-22)15acb- 1                                              | 227GLNC          | 08-05-86     | 15.0             | 270                                              | 7.7                  | 150                                  | 30                               | 11                                  | 5.1                             | 1.1                                |
| (D-26-22)15cca- 1                                              | 227GLNC          | 08-09-86     | 16.0             | 330                                              | 7.7                  | 194                                  | 36                               | 15                                  | 9.2                             | 1.3                                |
| (D-26-22)15daa- 2                                              | 227GLNC          | 08-15-85     | 15.5             | 255                                              | 7.8                  | 154                                  | 33                               | 11                                  | 5.7                             | 1.1                                |
| (D-26-22)15dca- 1                                              | 227GLNC          | 03-06-69     | 15.0             | 268                                              | 8.0                  | 154                                  | 30                               | 16                                  | 5.4                             | 1.2                                |
| Do.                                                            |                  | 08-15-85     | 15.0             | 360                                              | 7.7                  | 214                                  | 41                               | 14                                  | 16                              | 1.2                                |
| (D-26-22)22aab- 1                                              | 227GLNC          | 11-19-68     | 13.5             | 273                                              | 7.6                  | 218                                  | 30                               | 13                                  | 6.5                             | 1.0                                |
| (D-26-22)22aac- 1                                              | 227GLNC          | 11-19-68     | 15.0             | 286                                              | 7.4                  | 166                                  | 32                               | 14                                  | 7.6                             | 1.0                                |
| Do.                                                            |                  | 08-16-85     | 15.5             | 280                                              | 7.9                  | 165                                  | 33                               | 12                                  | 6.9                             | 1.2                                |
| (D-26-22)22abc- 1                                              | 227GLNC          | 08-05-86     | 15.0             | 620                                              | 7.4                  | 388                                  | 72                               | 28                                  | 12                              | 1.7                                |
| (D-26-22)22dad- 1                                              | 227GLNC          | 07-12-86     | 16.5             | 380                                              | 7.7                  | 238                                  | 42                               | 17                                  | 13                              | 1.6                                |
| (D-26-22)22dcd- 1                                              | 112ALVM          | 07-09-68     | 16.0             | 930                                              | 7.6                  | 664                                  | 110                              | 38                                  | 48                              | 2.2                                |
| (D-26-22)23cdd- 1                                              | 227GLNC          | 08-28-85     | 16.0             | 445                                              | 7.8                  | 283                                  | 54                               | 19                                  | 15                              | 1.7                                |
| (D-26-22)26acd- 1                                              | 227GLNC          | 08-09-86     | 17.0             | 685                                              | 7.5                  | 420                                  | 67                               | 25                                  | 25                              | 2.2                                |
| (D-26-22)26dbd- 1                                              | 227GLNC          | 08-19-85     | 17.0             | 920                                              | 7.5                  | 674                                  | 120                              | 33                                  | 47                              | 2.7                                |
| (D-26-22)26dda- 1                                              | 227GLNC          | 07-12-86     | 18.0             | 705                                              | 7.6                  | 503                                  | 81                               | 29                                  | 33                              | 2.4                                |
| (D-26-22)35ada- 1                                              | 110ALVM          | 07-08-69     | 14.0             | 1,230                                            | 7.6                  | 962                                  | 180                              | 38                                  | 54                              | 2.1                                |
| (D-26-22)35bdd- 2                                              | 110ALVM          | 09-05-68     | 10.0             | 980                                              | 7.7                  | 739                                  | 140                              | 28                                  | 43                              | 2.1                                |
| (D-21-24)36bbc-S1                                              | 200MSZC          | 09-08-85     | 15.0             | 5,480                                            | 8.0                  | 4,240                                | 730                              | 44                                  | 600                             | 8.4                                |
| (D-22-21)32aac-S1                                              | 217CDRM          | 12-13-85     | --               | 1,600                                            | 8.4                  | 1,020                                | 14                               | 5.0                                 | 360                             | 1.6                                |
| (D-22-25)12bda-S1                                              | 400PCMB          | 09-07-85     | 15.0             | 680                                              | 8.2                  | 406                                  | 79                               | 36                                  | 26                              | 4.2                                |
| (D-22-25)18cdb-S1                                              | 200MSZC          | 09-08-85     | 15.5             | 1,100                                            | 7.4                  | 666                                  | 130                              | 16                                  | 86                              | 4.0                                |
| (D-23-21)23dad-S1                                              | 221ENRD          | 08-08-86     | 14.0             | 255                                              | 8.2                  | 146                                  | 41                               | 4.1                                 | 4.6                             | 1.7                                |

# constituents and trace elements at selected sites

microsiemens per centimeter at 25 degrees Celsius; mg/L,  
is unknown but is less than the indicated value; --, no data]

Formation; 221BRSB, Brushy Basin Shale Member of Morrison Formation; 221SLMS, Salt Wash Sandstone Member of Morrison Sandstone; 310CTLR, Cutler Formation; 400PCMB, Precambrian crystalline rocks.

| Chloride, dissolved (mg/L as Cl) | Sulfate, dissolved (mg/L as SO <sub>4</sub> ) | Fluoride, dissolved (mg/L as F) | Alkalinity, lab. (mg/L as CaCO <sub>3</sub> ) | Carbon dioxide, dissolved (mg/L as CO <sub>2</sub> ) | Silica, dissolved (mg/L as SiO <sub>2</sub> ) | Hardness, total (mg/L as CaCO <sub>3</sub> ) | Hardness, noncarbonate (mg/L as CaCO <sub>3</sub> ) | Arsenic, dissolved (μg/L as As) | Barium, dissolved (μg/L as Ba) | Iron, dissolved (μg/L as Fe) | Selenium, dissolved (μg/L as Se) | Strontium, dissolved (μg/L as Sr) |
|----------------------------------|-----------------------------------------------|---------------------------------|-----------------------------------------------|------------------------------------------------------|-----------------------------------------------|----------------------------------------------|-----------------------------------------------------|---------------------------------|--------------------------------|------------------------------|----------------------------------|-----------------------------------|
| 250 W                            | 1,000 250 W                                   |                                 |                                               |                                                      |                                               |                                              |                                                     | 50 0 H                          | 1,000 1,000 H                  | 300 300 W                    | 10 10 H                          |                                   |
| 560                              | 160                                           | 0.6                             | 275                                           | 2.6                                                  | 10                                            | 46                                           | 0                                                   | <1                              | <100                           | 100                          | <1                               | 1,500                             |
| 30                               | 400                                           | .8                              | 365                                           | 18                                                   | 11                                            | 200                                          | 0                                                   | 1                               | 21                             | 2,100                        | <1                               | 1,900                             |
| 38                               | 41                                            | .3                              | 172                                           | 5.3                                                  | 9.4                                           | 190                                          | 18                                                  | <1                              | 30                             | <10                          | 2                                | 820                               |
| 6.1                              | 16                                            | .3                              | 147                                           | 4.5                                                  | 9.2                                           | 170                                          | 21                                                  | <1                              | 110                            | 5                            | 1                                | 390                               |
| 440                              | 79                                            | .9                              | 290                                           | --                                                   | 5.6                                           | 97                                           | 0                                                   | 7                               | 30                             | 380                          | --                               | 470                               |
| 78                               | 190                                           | .3                              | 174                                           | 13                                                   | 12                                            | 300                                          | 120                                                 | <1                              | 20                             | 20                           | 8                                | 1,600                             |
| 280                              | 260                                           | .4                              | 188                                           | 14                                                   | 12                                            | 400                                          | 210                                                 | <1                              | 10                             | <10                          | 5                                | 2,600                             |
| 160                              | 1,700                                         | .4                              | 115                                           | 11                                                   | 17                                            | 1,500                                        | 1,400                                               | <1                              | <100                           | 40                           | 21                               | 7,700                             |
| 140                              | 2,300                                         | .3                              | --                                            | 0                                                    | 15                                            | 1,900                                        | 0                                                   | <1                              | <100                           | 30                           | 30                               | 11,000                            |
| 150                              | 760                                           | .7                              | 140                                           | 14                                                   | 14                                            | 900                                          | 760                                                 | <1                              | 16                             | 6                            | 4                                | 4,800                             |
| 15                               | 28                                            | .2                              | 123                                           | 6.0                                                  | 9.5                                           | 150                                          | 26                                                  | 1                               | 87                             | 14                           | <1                               | 430                               |
| 1.8                              | 31                                            | .2                              | 104                                           | 3.2                                                  | 9.5                                           | 130                                          | 23                                                  | <1                              | 82                             | 27                           | <1                               | 440                               |
| 1.9                              | 33                                            | .2                              | 99                                            | 1.2                                                  | 9.2                                           | 120                                          | 22                                                  | <1                              | 82                             | 7                            | <1                               | 400                               |
| 2.0                              | 28                                            | .2                              | 96                                            | 3.7                                                  | 9.1                                           | 120                                          | 25                                                  | <1                              | 40                             | <10                          | <1                               | 450                               |
| 4.0                              | 64                                            | .1                              | 104                                           | 4.0                                                  | 9.6                                           | 150                                          | 48                                                  | <1                              | 40                             | 10                           | 1                                | 570                               |
| 44                               | 46                                            | .1                              | 93                                            | 2.8                                                  | 9.2                                           | 130                                          | 35                                                  | <1                              | 100                            | 14                           | <1                               | 450                               |
| 2.4                              | 48                                            | .4                              | --                                            | 1.9                                                  | 7.7                                           | 140                                          | 42                                                  | --                              | --                             | 570                          | --                               | --                                |
| 6.4                              | 60                                            | .2                              | 108                                           | 4.2                                                  | .7                                            | 160                                          | 53                                                  | <1                              | 68                             | 26                           | 1                                | 550                               |
| 2.7                              | 38                                            | .3                              | --                                            | 4.9                                                  | 9.5                                           | 130                                          | 26                                                  | 10                              | --                             | 90                           | 0                                | --                                |
| 2.9                              | 39                                            | .4                              | --                                            | 8.1                                                  | 11                                            | 140                                          | 33                                                  | 10                              | --                             | 170                          | 0                                | --                                |
| 2.4                              | 41                                            | .1                              | 91                                            | 2.2                                                  | .3                                            | 130                                          | 41                                                  | 1                               | 58                             | 11                           | <1                               | 480                               |
| 8.0                              | 150                                           | .3                              | 164                                           | 13                                                   | 12                                            | 300                                          | 130                                                 | <1                              | 30                             | 40                           | 4                                | 1,000                             |
| 7.0                              | 70                                            | .1                              | 116                                           | 4.5                                                  | 11                                            | 180                                          | 60                                                  | <1                              | 44                             | 12                           | 1                                | 660                               |
| 16                               | 300                                           | .5                              | --                                            | 8.7                                                  | 14                                            | 420                                          | 240                                                 | --                              | --                             | 20                           | --                               | --                                |
| 10                               | 98                                            | .6                              | 103                                           | 3.2                                                  | 11                                            | 210                                          | 110                                                 | <1                              | 56                             | 25                           | 2                                | 760                               |
| 17                               | 190                                           | .2                              | 119                                           | 7.3                                                  | 11                                            | 270                                          | 150                                                 | <1                              | 45                             | 12                           | 4                                | 1,200                             |
| 27                               | 210                                           | .3                              | 137                                           | 8.4                                                  | 14                                            | 440                                          | 300                                                 | <1                              | 27                             | 210                          | 5                                | 2,000                             |
| 16                               | 220                                           | .3                              | 124                                           | 6.0                                                  | 12                                            | 320                                          | 200                                                 | <1                              | 56                             | 14                           | 4                                | 1,400                             |
| 30                               | 450                                           | .5                              | --                                            | 9.7                                                  | 17                                            | 610                                          | 410                                                 | --                              | --                             | 100                          | --                               | --                                |
| 11                               | 310                                           | .9                              | --                                            | 8.4                                                  | 14                                            | 470                                          | 260                                                 | 10                              | --                             | --                           | 0                                | --                                |
| 820                              | 1,700                                         | 3.6                             | 152                                           | 2.9                                                  | 20                                            | 2,000                                        | 1,900                                               | 1                               | 100                            | 80                           | <1                               | 8,100                             |
| 100                              | 310                                           | 1.2                             | 418                                           | 3.2                                                  | 10                                            | 56                                           | 0                                                   | 3                               | 27                             | 23                           | 2                                | 540                               |
| 13                               | 31                                            | 2.2                             | 325                                           | 3.9                                                  | 30                                            | 350                                          | 22                                                  | 1                               | 180                            | 22                           | <1                               | 930                               |
| 120                              | 190                                           | 2.1                             | 201                                           | 15                                                   | 16                                            | 390                                          | 190                                                 | 3                               | 29                             | 3                            | 2                                | 1,200                             |
| 4.4                              | 11                                            | .1                              | 116                                           | 1.4                                                  | 8.7                                           | 120                                          | 4                                                   | <1                              | 360                            | <3                           | <1                               | 220                               |

Table 4.—Chemical analyses of selected major

| Well or spring number | Geologic source | Date sampled | Temperature (°C) | Specific conductance (μS/cm) | pH (standard units) | Solids, residue at 180 °C dissolved | Calcium, dissolved (mg/L as Ca) | Magnesium, dissolved (mg/L as Mg) | Sodium, dissolved (mg/L as Na) | Potassium, dissolved (mg/L as K) |
|-----------------------|-----------------|--------------|------------------|------------------------------|---------------------|-------------------------------------|---------------------------------|-----------------------------------|--------------------------------|----------------------------------|
| (D-23-22)17cab-S1     | 221ENRD         | 06-10-85     | 15.0             | 255                          | 8.2                 | 146                                 | 45                              | 4.5                               | 4.8                            | 2.3                              |
| (D-23-23)11dbc-S1     | 227NVJO         | 11-23-85     | 12.5             | 560                          | 7.9                 | 349                                 | 39                              | 32                                | 34                             | 6.8                              |
| (D-23-23)12dba-S1     | 227NVJO         | 12-17-85     | 13.0             | 670                          | 7.6                 | 385                                 | 57                              | 27                                | 59                             | 13                               |
| (D-24-18) 7aaa-S1     | 227NVJO         | 11-26-85     | 12.5             | 220                          | 8.2                 | 135                                 | 35                              | 4.9                               | 6.8                            | 1.6                              |
| (D-24-19)10dcd-S1     | 221ENRD         | 11-26-85     | 14.0             | 205                          | 7.9                 | 119                                 | 32                              | 4.7                               | 3.9                            | 2.9                              |
| (D-24-21)31dab-S1     | 221ENRD         | 09-15-70     | 13.0             | 225                          | 7.7                 | 143                                 | 43                              | 3.2                               | 2.3                            | 1.6                              |
| (D-25-18) 9ddc-S1     | 227NVJO         | 06-21-86     | 17.0             | 320                          | 7.7                 | 182                                 | 37                              | 13                                | 7.0                            | 3.3                              |
| (D-25-21) 5abb-S1     | 221ENRD         | 09-15-70     | 12.5             | 270                          | 8.0                 | 157                                 | 49                              | 4.1                               | 3.8                            | 1.7                              |
| (D-25-21) 5bbb-S1     | 221ENRD         | 09-15-70     | 13.0             | 250                          | 7.4                 | 145                                 | 49                              | 3.3                               | 2.6                            | 1.1                              |
| (D-25-21)26bdc-S1     | 231WNGT         | 10-08-58     | 17.0             | 300                          | 8.1                 | --                                  | 33                              | 10                                | --                             | --                               |
| (D-25-21)26bdc-S2     | 231WNGT         | 08-17-85     | 16.0             | 295                          | 8.0                 | 161                                 | 30                              | 12                                | 12                             | 2.0                              |
| (D-25-21)35aaa-S1     | 231WNGT         | 10-19-67     | 14.5             | 296                          | 7.5                 | 168                                 | 32                              | 12                                | 13                             | 0.6                              |
| Do.                   |                 | 08-15-85     | 17.5             | 290                          | 8.0                 | 174                                 | 32                              | 13                                | 14                             | 1.7                              |
| (D-26-22)14acc-S1     | 227NVJO         | 11-19-68     | 16.0             | 305                          | 7.6                 | 171                                 | 35                              | 16                                | 5.3                            | 1.2                              |
| (D-26-22)15cbb-S1     | 227GLNC         | 10-19-67     | 14.0             | 295                          | 7.6                 | 172                                 | 35                              | 12                                | 8.2                            | .5                               |
| (D-26-22)15cdc-S1     | 227GLNC         | 08-16-85     | 16.0             | 460                          | 7.6                 | 287                                 | 49                              | 21                                | 14                             | 1.7                              |
| (D-26-22)22aaa-S1     | 227GLNC         | 08-16-85     | 15.0             | 280                          | 7.6                 | 163                                 | 33                              | 12                                | 6.5                            | 1.3                              |
| (D-26-22)22aad-S1     | 227GLNC         | 08-15-85     | 16.0             | 285                          | 7.4                 | 174                                 | 34                              | 13                                | 8.1                            | 1.2                              |
| (D-26-23)26dcc-S1     | 221SLWS         | 07-27-86     | 15.0             | 1,640                        | 7.6                 | 1,160                               | 120                             | 72                                | 130                            | 3.7                              |
| (D-27-19)22bbc-S1     | 227NVJO         | 07-10-86     | 15.0             | 190                          | 8.2                 | 102                                 | 21                              | 9.5                               | 2.3                            | 1.8                              |

<sup>1</sup> If the concentration of dissolved solids is larger than 1,000 mg/L, the supplier shall satisfactorily demonstrate that water with a smaller concentration of dissolved solids is not available.

<sup>2</sup> If the concentration of sulfate is larger than 500 mg/L, the supplier shall satisfactorily demonstrate that water with a smaller concentration of sulfate is not available, and the water shall not be available for human commercial establishments.

Formations in the Mesaverde Group and the Mancos Shale, both of Cretaceous age, crop out in a band about 10 to 20 miles wide southwest, south, and southeast of the Book Cliffs (pl. 2). None of these formations yields substantial quantities of water to wells or springs in the Grand County area, and the Mesaverde Group and the Mancos Shale probably effectively inhibit downward movement of water into the underlying sandstone aquifers in Mesozoic rocks in most places. Several springs shown on U.S. Geological Survey 7½- and 15-minute topographic maps are located where they would appear to discharge from the Mesaverde Group or the Mancos Shale, but typically they discharge from overlying alluvium.

#### Sandstone aquifers in Mesozoic rocks

The Dakota Sandstone, and the Cedar Mountain, Burro Canyon, and Morrison Formations crop out in a band about 5 miles wide, about 10 to 20 miles south



constituents and trace elements at selected sites—Continued

| Chloride,<br>dis-<br>solved<br>(mg/L<br>as Cl) | Sulfate,<br>dis-<br>solved<br>(mg/L<br>as SO <sub>4</sub> ) | Fluoride,<br>dis-<br>solved<br>(mg/L<br>as F) | Alkalinity,<br>lab.<br>(mg/L<br>as<br>CaCO <sub>3</sub> ) | Carbon<br>dioxide,<br>dis-<br>solved<br>(mg/L<br>as CO <sub>2</sub> ) | Silica,<br>dis-<br>solved<br>(mg/L<br>as<br>SiO <sub>2</sub> ) | Hard-<br>ness,<br>total<br>(mg/L<br>as<br>CaCO <sub>3</sub> ) | Hard-<br>ness,<br>noncar-<br>bonate<br>(mg/L<br>as<br>CaCO <sub>3</sub> ) | Arsenic,<br>dis-<br>solved<br>(µg/L<br>as As) | Barium,<br>dis-<br>solved<br>(µg/L<br>as Ba) | Iron,<br>dis-<br>solved<br>(µg/L<br>as Fe) | Selen-<br>ium,<br>dis-<br>solved<br>(µg/L<br>as Se) | Stron-<br>tium,<br>dis-<br>solved<br>(µg/L<br>as Sr) |
|------------------------------------------------|-------------------------------------------------------------|-----------------------------------------------|-----------------------------------------------------------|-----------------------------------------------------------------------|----------------------------------------------------------------|---------------------------------------------------------------|---------------------------------------------------------------------------|-----------------------------------------------|----------------------------------------------|--------------------------------------------|-----------------------------------------------------|------------------------------------------------------|
| 4.9                                            | 11                                                          | .2                                            | 100                                                       | 1.2                                                                   | 9.8                                                            | 130                                                           | 32                                                                        | <1                                            | 480                                          | 3                                          | 1                                                   | 350                                                  |
| 20                                             | 71                                                          | .3                                            | 207                                                       | 5.0                                                                   | 10                                                             | 230                                                           | 24                                                                        | 1                                             | 76                                           | 3                                          | 5                                                   | 2,000                                                |
| 24                                             | 85                                                          | .4                                            | 251                                                       | 12                                                                    | 13                                                             | 260                                                           | 5                                                                         | <1                                            | 75                                           | <3                                         | 3                                                   | 2,100                                                |
| 5.2                                            | 14                                                          | .2                                            | 88                                                        | 1.1                                                                   | 8.2                                                            | 110                                                           | 20                                                                        | <1                                            | 110                                          | 4                                          | 1                                                   | 260                                                  |
| 3.4                                            | 9.9                                                         | .1                                            | 94                                                        | 2.0                                                                   | 8.5                                                            | 100                                                           | 6                                                                         | 2                                             | 200                                          | 13                                         | <1                                                  | 240                                                  |
| 3.5                                            | 6.5                                                         | .4                                            | --                                                        | 4.2                                                                   | 10                                                             | 120                                                           | 0                                                                         | 0                                             | --                                           | 0                                          | 37                                                  | --                                                   |
| 9.9                                            | 22                                                          | .3                                            | 125                                                       | 4.8                                                                   | 11                                                             | 150                                                           | 21                                                                        | <1                                            | 100                                          | 5                                          | 1                                                   | 280                                                  |
| 5.0                                            | 12                                                          | .5                                            | --                                                        | 2.5                                                                   | 11                                                             | 140                                                           | 11                                                                        | 0                                             | --                                           | 0                                          | 55                                                  | --                                                   |
| 5.0                                            | 10                                                          | .5                                            | --                                                        | 9.4                                                                   | 9.5                                                            | 140                                                           | 0                                                                         | 0                                             | --                                           | 0                                          | 89                                                  | --                                                   |
| 12                                             | 36                                                          | --                                            | --                                                        | 1.7                                                                   | 11                                                             | 120                                                           | 0                                                                         | --                                            | --                                           | --                                         | --                                                  | --                                                   |
| 9.8                                            | 30                                                          | .2                                            | 99                                                        | 1.9                                                                   | 9.0                                                            | 120                                                           | 26                                                                        | <1                                            | 77                                           | 4                                          | 1                                                   | 410                                                  |
| 14                                             | 31                                                          | .3                                            | --                                                        | 6.4                                                                   | 11                                                             | 130                                                           | 0                                                                         | --                                            | --                                           | 0                                          | --                                                  | --                                                   |
| 11                                             | 32                                                          | .2                                            | 100                                                       | 1.9                                                                   | 9.3                                                            | 130                                                           | 34                                                                        | 1                                             | 80                                           | 7                                          | <1                                                  | 420                                                  |
| 2.7                                            | 11                                                          | .1                                            | --                                                        | 7.3                                                                   | 8.9                                                            | 150                                                           | 2                                                                         | 0                                             | --                                           | --                                         | 0                                                   | --                                                   |
| 4.3                                            | 39                                                          | .3                                            | --                                                        | 5.3                                                                   | 8.9                                                            | 140                                                           | 0                                                                         | --                                            | --                                           | 0                                          | --                                                  | --                                                   |
| 9.3                                            | 100                                                         | .1                                            | 112                                                       | 5.4                                                                   | 10                                                             | 210                                                           | 98                                                                        | <1                                            | 50                                           | 5                                          | 2                                                   | 780                                                  |
| 2.3                                            | 39                                                          | .2                                            | 94                                                        | 4.6                                                                   | 9.4                                                            | 130                                                           | 38                                                                        | 1                                             | 72                                           | 8                                          | <1                                                  | 480                                                  |
| 2.9                                            | 46                                                          | .2                                            | 93                                                        | 7.2                                                                   | 9.7                                                            | 140                                                           | 46                                                                        | <1                                            | 64                                           | 18                                         | <1                                                  | 510                                                  |
| 81                                             | 480                                                         | .4                                            | 269                                                       | 13                                                                    | 18                                                             | 600                                                           | 330                                                                       | 2                                             | 41                                           | 3                                          | 8                                                   | 2,800                                                |
| 2.7                                            | 4.4                                                         | .2                                            | 90                                                        | 1.1                                                                   | 10                                                             | 92                                                            | 2                                                                         | <1                                            | 370                                          | <3                                         | <1                                                  | 110                                                  |

of the Book Cliffs, and locally on the flanks of the La Sal Mountains (pl. 2). These formations locally yield water to seeps, springs, and flowing wells. Discharge typically is less than 1 gal/min.

South of the Book Cliffs, concentrations of dissolved solids in water samples from a flowing well [(D-22-23)25bac-1] and a spring [(D-22-21)32aac-S1] discharging from the Cedar Mountain Formation and from a flowing well [(D-22-23)29ada-1] discharging from the Brushy Basin Shale Member of the Morrison Formation ranged from 1,020 mg/L to 1,470 mg/L (table 4). Sodium was the cation type at all three sites, but the anion type varied from site to site. On the flanks of the La Sal Mountains, the concentration of dissolved solids in water discharging from a spring in the Salt Wash Sandstone Member of the Morrison Formation was 1,160 mg/L (table 4), and the water type was mixed, calcium magnesium sodium sulfate bicarbonate.



Table 5.—*Chemical analyses of selected radionuclides in ground water at selected sites*

[Abbreviations used in headings: pCi/L, picocuries per liter; <, the actual value is unknown but is less than the indicated value; --, no data]

State of Utah primary drinking-water standard: Maximum Contaminant Level (MCL) allowable by Utah Department of Health.

Well or spring number: See "Numbering system for hydrogeologic-data sites", p. 5 and figure 2.

Geologic source: 200MSZC, Mesozoic undifferentiated; 217CDRM, Cedar Mountain Formation; 221BRSB, Brushy Basin Shale Member of Morrison Formation; 221ENRD, Entrada Formation; 227GLNC, Glen Canyon Group; 227NVJO, Navajo Sandstone; 231WNGT, Wingate Sandstone.

| Well or spring number                          | Geologic source | Date sampled | Uranium, natural, dissolved (pCi/L as U) | Radium 226, dissolved, radon method (pCi/L) | Gross alpha, dissolved (pCi/L as U-Nat) | Gross beta, dissolved (pCi/L as Cs-137) | Gross beta, dissolved (pCi/L as Sr/Yt-90) |
|------------------------------------------------|-----------------|--------------|------------------------------------------|---------------------------------------------|-----------------------------------------|-----------------------------------------|-------------------------------------------|
| State of Utah primary drinking-water standard: |                 |              |                                          | 15                                          | 15                                      | 50                                      | 50                                        |
| (D-22-23)29ada- 1                              | 221BRSB         | 08-18-85     | 13.6                                     | 0.06                                        | 15                                      | 23                                      | 15                                        |
| (D-24-20)19caa- 1                              | 221ENRD         | 11-24-85     | 0.9                                      | --                                          | 0.7                                     | 5.2                                     | 3.9                                       |
| (D-25-20)21ddb- 1                              |                 | 10-29-85     | 0.5                                      | 0.02                                        | <6.5                                    | 16                                      | 9.9                                       |
| (D-26-22) 8bad- 1                              | 227GLNC         | 09-05-85     | 0.6                                      | 0.08                                        | 1.1                                     | 2.7                                     | 2.2                                       |
| (D-26-22)15daa- 2                              | 227GLNC         | 08-15-85     | 0.8                                      | 0.05                                        | 0.9                                     | 1.1                                     | 0.9                                       |
| (D-26-22)23cdd- 1                              | 227GLNC         | 08-28-85     | 1.3                                      | 0.05                                        | 3.7                                     | 3.5                                     | 2.5                                       |
| (D-26-22)26dbd- 1                              | 227GLNC         | 08-19-85     | 2.1                                      | 0.03                                        | 2.9                                     | 5.3                                     | 3.4                                       |
| (D-21-24)36bbc-S1                              | 200MSZC         | 09-08-85     | 0.3                                      | --                                          | <31                                     | 13                                      | 9.1                                       |
| (D-22-21)32aac-S1                              | 217CDRM         | 12-13-85     | <0.3                                     | 0.08                                        | <6.1                                    | 5.2                                     | 3.5                                       |
| (D-22-25)18cdb-S1                              | 200MSZC         | 09-08-85     | 6.7                                      | 0.08                                        | 10.9                                    | 6.6                                     | 6.9                                       |
| (D-23-21)23dad-S1                              | 221ENRD         | 08-08-86     | --                                       | 0.09                                        | 1.1                                     | 2.0                                     | 1.6                                       |
| (D-23-22)17cab-S1                              | 221ENRD         | 06-10-85     | 0.6                                      | 0.19                                        | <2.3                                    | 2.7                                     | 2.3                                       |
| (D-23-23)11dbc-S1                              | 227NVJO         | 11-23-85     | <0.3                                     | 0.12                                        | 3.3                                     | 9.8                                     | 7.3                                       |
| (D-23-23)12dba-S1                              | 227NVJO         | 12-17-85     | 2.4                                      | 0.05                                        | 4.3                                     | 16                                      | 12                                        |
| (D-24-19)10dcd-S1                              | 221ENRD         | 11-26-85     | <0.3                                     | 0.15                                        | 1.4                                     | 5.5                                     | 4.3                                       |
| (D-25-21)35aaa-S1                              | 231WNGT         | 08-15-85     | 0.7                                      | 0.06                                        | 1.3                                     | 3.1                                     | 2.3                                       |
| (D-26-22)22aaa-S1                              | 227GLNC         | 08-16-85     | 0.9                                      | 0.05                                        | 2.2                                     | 2.2                                     | 1.6                                       |
| Median value for Grand County area:            |                 |              | 0.8                                      | 0.06                                        | 2.2                                     | 5.2                                     | 3.5                                       |

<sup>1</sup>Radium 226 and 228, combined.

Water discharging from the unnamed spring in the Cedar Mountain Formation had beta and radium activities near the median values for the Grand County area (table 5). The uranium activity was less than one-half the median value of 0.8 pCi/L (picocuries per liter) for the Grand County area.

Water discharging from the flowing well in the Brushy Basin Shale Member of the Morrison Formation had the largest beta and uranium activities and the second-largest alpha activity of all the samples in the Grand County area; however, the beta activity was less than one-half of the State of Utah primary drinking-water standard of 50 pCi/L, and the alpha activity was 15 pCi/L, which is equal to the State of Utah primary drinking-water standard (table 5). A relatively large quantity of radionuclide activity in water from the Morrison is not unexpected. The Morrison contains large, commercially important quantities of uranium, and the formation has been mined for uranium in the Grand County area.

Feltis (1966, p. 44-69) reported the concentrations of dissolved solids and major ions in water samples from four oil-test holes and one water well completed in the Morrison Formation (table 6). The depth to the Morrison in these wells ranged from about 400 to 2,500 feet below land surface. Concentrations of dissolved solids in water samples from these wells ranged from 2,090 to 25,700 mg/L, and the water type typically was sodium chloride (fig. 7; table 6). Unpublished data from the files of the U.S. Geological Survey indicate that the concentration of dissolved solids in water collected from the Morrison Formation at two sites ranged from about 10,000 to 22,900 mg/L, and the concentration of dissolved solids in water collected from the Dakota Sandstone at one site was 1,800 mg/L (fig. 7; table 6).

The Entrada Sandstone, the Navajo Sandstone, the Kayenta Formation, and the Wingate Sandstone crop out extensively in the southern one-third of the Grand County area (pl. 2) and contain the principal aquifers of the area. Regionally, the Kayenta Formation is considered a confining unit because it is less permeable than the overlying Navajo Sandstone and underlying Wingate Sandstone. In the Mill Creek-Spanish Valley area, however, the Kayenta is sandy, and the Navajo Sandstone, Kayenta Formation, and Wingate Sandstone of the Glen Canyon Group form a single aquifer, designated the Glen Canyon aquifer in this report.

Discharge from the Entrada Sandstone, the Navajo Sandstone, and the Wingate Sandstone typically occurs as seeps and small springs near the bases of the formations, typically where canyons cut through the formations. Water is perched in each of the formations by less permeable underlying units. The Moab Sandstone and Slick Rock Members of the Entrada Sandstone are underlain by the less permeable Dewey Bridge Member of the Entrada Sandstone. The Slick Rock and Dewey Bridge Members of the Entrada Sandstone are not shown individually on the geologic map (pl. 2) but are included in the map unit, Je. The Navajo Sandstone is underlain by the generally less permeable Kayenta Formation, and the Wingate Sandstone is underlain by the less permeable Chinle Formation. Rates of discharge from the formations range from nearly zero at seeps from canyon walls to a reported 2,000 gal/min from well (D-26-22)15dca-1 in the City of Moab well field, where the aquifer is fractured.

Concentrations of dissolved solids in water from the principal aquifers near their outcrop areas typically range from about 100 to about 500 mg/L (table 4). The water type typically is calcium bicarbonate, calcium magnesium bicarbonate, or calcium magnesium bicarbonate sulfate.

#### Lower confining unit in Mesozoic and upper Paleozoic rocks

On the southwestern side of Castle Valley, the undifferentiated Cutler Formation is the source of water for about 30 wells. Thirteen of the wells were tested for specific capacity following drilling. Specific capacity of eight of the wells ranged from less than 0.01 (gal/min)/ft, where a well produced 1 gal/min for 1 hour with 260 feet of drawdown, to 4.0 (gal/min)/ft, where a well produced 20 gal/min for 1 hour with 5 feet of drawdown. Five wells were pumped for 2 hours at discharge rates ranging from 20 to 40 gal/min with no measurable drawdown.

Table 6.—*Dissolved-solids concentration  
in ground water at selected sites*

Site number: See "Numbering system for hydrogeologic-data sites in Utah", p. 5 and figure 2.

Geologic source: Kd, Dakota Sandstone; Jm, Morrison Formation; Je, Entrada Sandstone; Pwr, White Rim Sandstone Member of Cutler Formation.

Dissolved solids: mg/L, milligrams per liter.

Interval sampled: Feet below land surface; —, no data.

Source of information: Unpublished data of the U.S. Geological Survey.

| Site number      | Geologic source | Dissolved solids (mg/L) | Interval sampled (feet) | Source of information |
|------------------|-----------------|-------------------------|-------------------------|-----------------------|
| (D-21-20)17bcb   | Kd              | 1,800                   | —                       | USGS                  |
| (D-19-24)35dbc   | Jm              | 25,700                  | 1,484-1,508             | Feltis, 1966          |
| (D-19-25)10abd   | Jm              | 7,350                   | 595- 602                | Do.                   |
| (D-20-21)23bba   | Jm              | 22,900                  | —                       | USGS                  |
| (D-20-22)30bd    | Jm              | 22,600                  | 2,388-2,456             | Feltis, 1966          |
| (D-20-23)14baa   | Jm              | 9,960                   | —                       | USGS                  |
| (D-20-24)29cda   | Jm              | 6,880                   | 384- 400                | Feltis, 1966          |
| Do.              | Jm              | 5,510                   | 762- 772                | Do.                   |
| Do.              | Jm              | 2,090                   | 872- 888                | Do.                   |
| (D-22-19)16abb   | Jm              | 13,900                  | 1,118-1,155             | Do.                   |
| T(D-15-22)35cdd  | Je              | 104,000                 | —                       | USGS                  |
| (D-16-26)29ccb   | Je              | 47,500                  | —                       | Do.                   |
| Do.              | Je              | 13,500                  | —                       | Do.                   |
| (D-17-24) 9dca   | Je              | 86,600                  | 5,247-5,290             | Feltis, 1966          |
| (D-17-24)12dca   | Je              | 58,400                  | 5,160                   | Do.                   |
| (D-17-25)11dab   | Je              | 4,330                   | —                       | USGS                  |
| Do.              | Je              | 4,850                   | —                       | Do.                   |
| (D-19-21)29dbb   | Je              | 6,800                   | —                       | Do.                   |
| (D-19-25)10abd   | Je              | 9,470                   | 875- 905                | Feltis, 1966          |
| (D-21-19)33cdd   | Je              | 10,300                  | 1,736-1,758             | Do.                   |
| R(D-27-17) 1ddc  | Pwr             | 2,730                   | 260- 380                | Huntoon, 1977         |
| Do.              | Pwr             | 1,990                   | do.                     | Do.                   |
| (D-27-18) 9baa   | Pwr             | 2,570                   | 415- 585                | Do.                   |
| (D-27-18)10aaa   | Pwr             | 1,720                   | 485- 585                | Do.                   |
| (D-28-19)11aac-S | Pwr             | 270                     | —                       | Do.                   |
| (D-28-19)15bbb-S | Pwr             | 308                     | —                       | Do.                   |

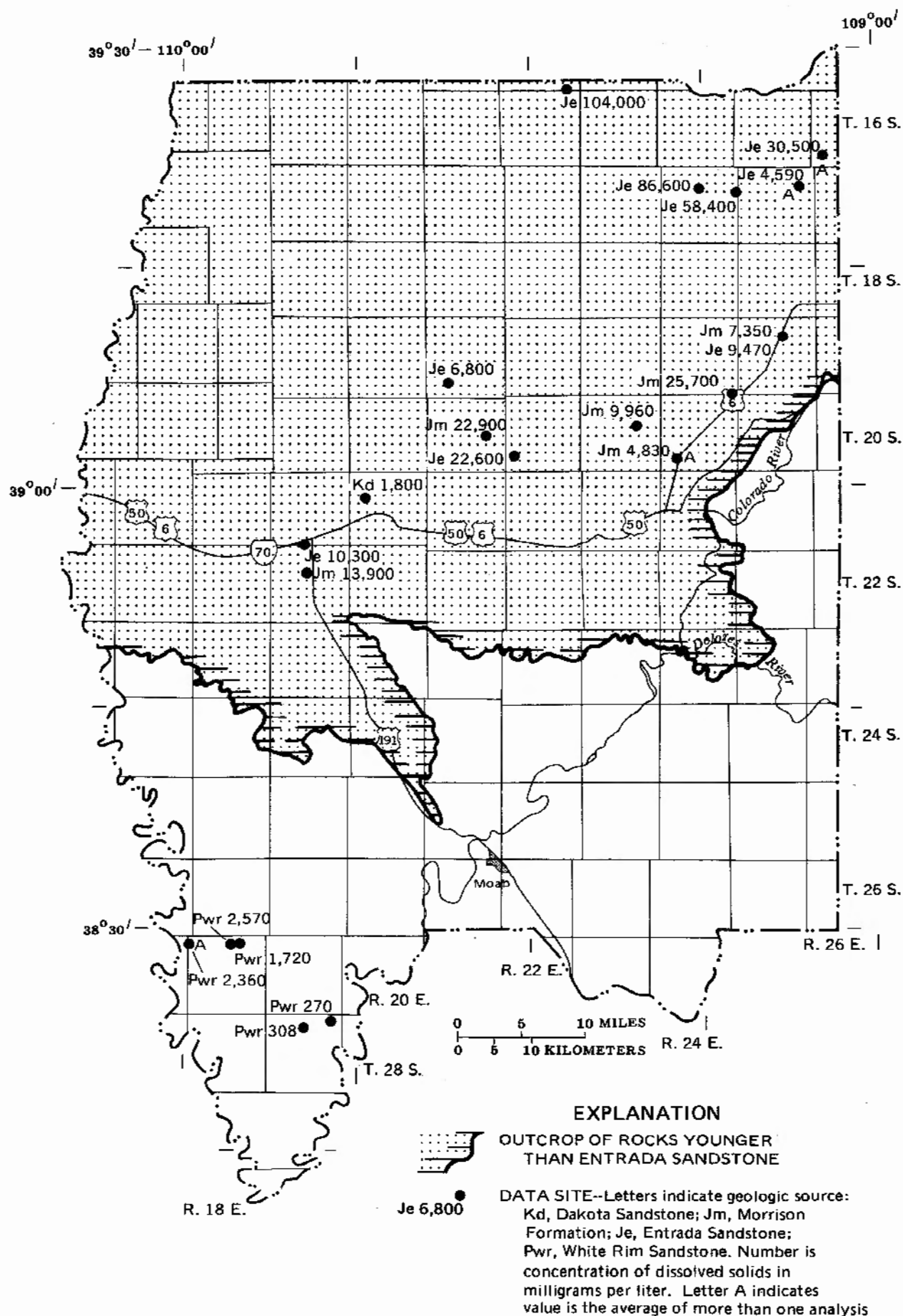


Figure 7.--Concentration of dissolved solids in ground water at selected sites.

Water from three wells completed in the undifferentiated Cutler Formation was collected and analyzed during this study. Concentrations of dissolved solids ranged from 1,420 to 3,450 mg/L, and the water type was either calcium magnesium sulfate or calcium magnesium sodium sulfate. The water was very hard, ranging from 900 to 1,900 mg/L. At two of the wells, the concentration of sulfate was larger than the State of Utah primary drinking-water standard of 1,000 mg/L (table 4). At the same two wells, concentrations of selenium were two and three times the State of Utah primary drinking-water standard of 10 µg/L (table 4).

Huntoon (1977) characterized the White Rim Sandstone Member of the Cutler Formation in Canyonlands National Park and in the area immediately north of the Park. Where the White Rim is cut by canyons, ground water discharges in "an almost continuous series of small springs and seeps along its lower contact." Huntoon reported the chemical quality of ground water in the White Rim that was collected from two springs and three wells (fig. 7 and table 6). Concentrations of dissolved solids in water from the two springs were 270 mg/L and 308 mg/L, and the water types were calcium magnesium bicarbonate and calcium magnesium sodium bicarbonate. Dissolved-solids concentrations of four samples collected from the three wells ranged from 1,720 to 2,730 mg/L. The water types were mixed, and varied from sample to sample.

#### Quality of water near faults

Ground-water discharges at several locations near the trace of the Moab fault. Sites of discharge include Brink Spring, (D-24-19)10dcd-S1; a flowing well in Tusher Canyon, (D-24-20)19caa-1; and two water-supply wells completed in the Navajo Sandstone in Arches National Park, (D-25-21)20add-2 and (D-25-21)21bdc-1 (pl. 1).

The Entrada Sandstone may be the source of water for Brink Spring and the flowing well. In the area of the two sites, the Entrada is at the surface on the upthrown side of the Moab fault, and the water quality resembles that of the Entrada at other locations. Concentrations of dissolved solids at the two sites were less than 200 mg/L (table 4), and the water types were calcium bicarbonate and calcium magnesium bicarbonate.

The two water-supply wells in Arches National Park are completed in the Navajo Sandstone, but the quality of water in the wells is different from that in the Navajo aquifer at other locations. The concentration of dissolved solids in well (D-25-21)20add-2 was 584 mg/L (table 4), and the water type was sodium calcium magnesium sulfate bicarbonate chloride. The concentration of dissolved solids in well (D-25-21)21bdc-1 was 1,000 mg/L (table 4), and the water type was sodium calcium chloride sulfate bicarbonate.

Ground-water discharge also occurs in an area of faulting in the eastern part of the Grand County area, southeast of the Colorado River. Water samples from Cane Spring, (D-21-24)36bbc-S1, and from an unnamed spring, (D-22-25)18cdb-S1, were collected and analyzed. The geologic setting is similar at both springs: Each spring is located near a fault and, at both sites, the Kayenta Formation is at the surface on the upthrown side of the fault. At Cane Spring, the Summerville Formation is at the surface on the

downthrown side of the fault, and at the unnamed spring, the Entrada Sandstone is at the surface on the downthrown side of the fault.

The concentration of dissolved solids in water from Cane Spring was 4,240 mg/L (table 4), and the water type was calcium sodium sulfate chloride. The concentration of dissolved solids in water from the unnamed spring was 666 mg/L (table 4), and the water type was calcium sodium bicarbonate sulfate chloride.

Water from the two springs had some similarities, but also had major differences. Calcium and sodium were significant cations and sulfate and chloride were significant anions at both springs, but bicarbonate was not significant at Cane Spring. At Cane Spring, the concentration of dissolved solids was about six times that at the unnamed spring.

It appears that in areas of faulting, the chemical quality of the ground-water resource is not predictable. It may, or may not, resemble the chemical quality of ground water in the formations that are at the surface on either side of the fault.

#### Recharge and Ground-Water Movement

The La Sal Mountains (pl. 1) are a principal recharge area for the aquifers in consolidated sedimentary rocks in the Grand County area. The La Sal Mountains with winter snowpack are shown in figure 8. Average annual precipitation in the mountains is about 30 inches, and about two-thirds of the precipitation falls from October to April, mostly as snow. The peaks of the mountains mostly are talus slopes, and these slopes probably accept a substantial amount of the winter snowpack as recharge when the snowpack melts in the spring. Sedimentary strata are upturned and fractured on the flanks of the mountains, and are capable of accepting more recharge than is possible when the strata are not fractured. Recharge in the the La Sal Mountains ultimately provides water to unconsolidated Quaternary deposits in Spanish Valley and Castle Valley. Sumsion (1971) estimated recharge to the part of the La Sal Mountains area that is drained by Mill Creek and Pack Creek to be about 22,000 acre-ft/yr (acre-feet per year), and the Mill Creek and Pack Creek drainages are only a small part of the entire La Sal Mountains area.

The approximate altitude of the potentiometric surface and the general direction of ground-water movement in the upper ground-water system were modified from Rush and others (1982), Weir, Maxfield, and Hart (1983), and Weir, Maxfield, and Zimmerman (1983), and are shown in figure 9. General movement of ground water is toward the major perennial streams. Northwest of the Colorado River, the direction of ground-water movement is toward the Colorado River and the Green River, with a ground-water divide separating the two directions of flow. Southeast of the Colorado River, the direction of ground-water movement generally is from the La Sal Mountains toward the Colorado River.





Figure 8.--La Sal Mountains with winter snowpack.

### Principal Bedrock Aquifers

This section presents data and interpretation of ground-water conditions in the three principal aquifers in the Grand County area: The Entrada aquifer, the Navajo aquifer, and the Wingate aquifer. Areas of recharge and discharge, direction of ground-water movement, chemical quality of water in the aquifers, and characteristics of the aquifers will be discussed. Ground-water conditions in the Glen Canyon aquifer in the Mill Creek-Spanish Valley area will be discussed in a separate section.

#### The Entrada aquifer

The Entrada Sandstone crops out primarily in and near Arches National Park, east of Arches National Park, in the upper reaches of the Mill Creek drainage, and south and west of the Moab fault in T. 24 S., R. 19 and 20 E. (pl. 2). The Entrada aquifer is contained in the Entrada Sandstone.

Recharge to the Entrada aquifer probably occurs where the Entrada Sandstone crops out or where it is mantled by unconsolidated deposits. The rate of infiltration to the Entrada aquifer probably is much larger where the Entrada Sandstone is fractured or jointed. In the Arches National Park area, recharge probably occurs on the flanks of the Salt Valley anticline, and movement of water is away from the anticline, particularly toward the Courthouse syncline to the west.



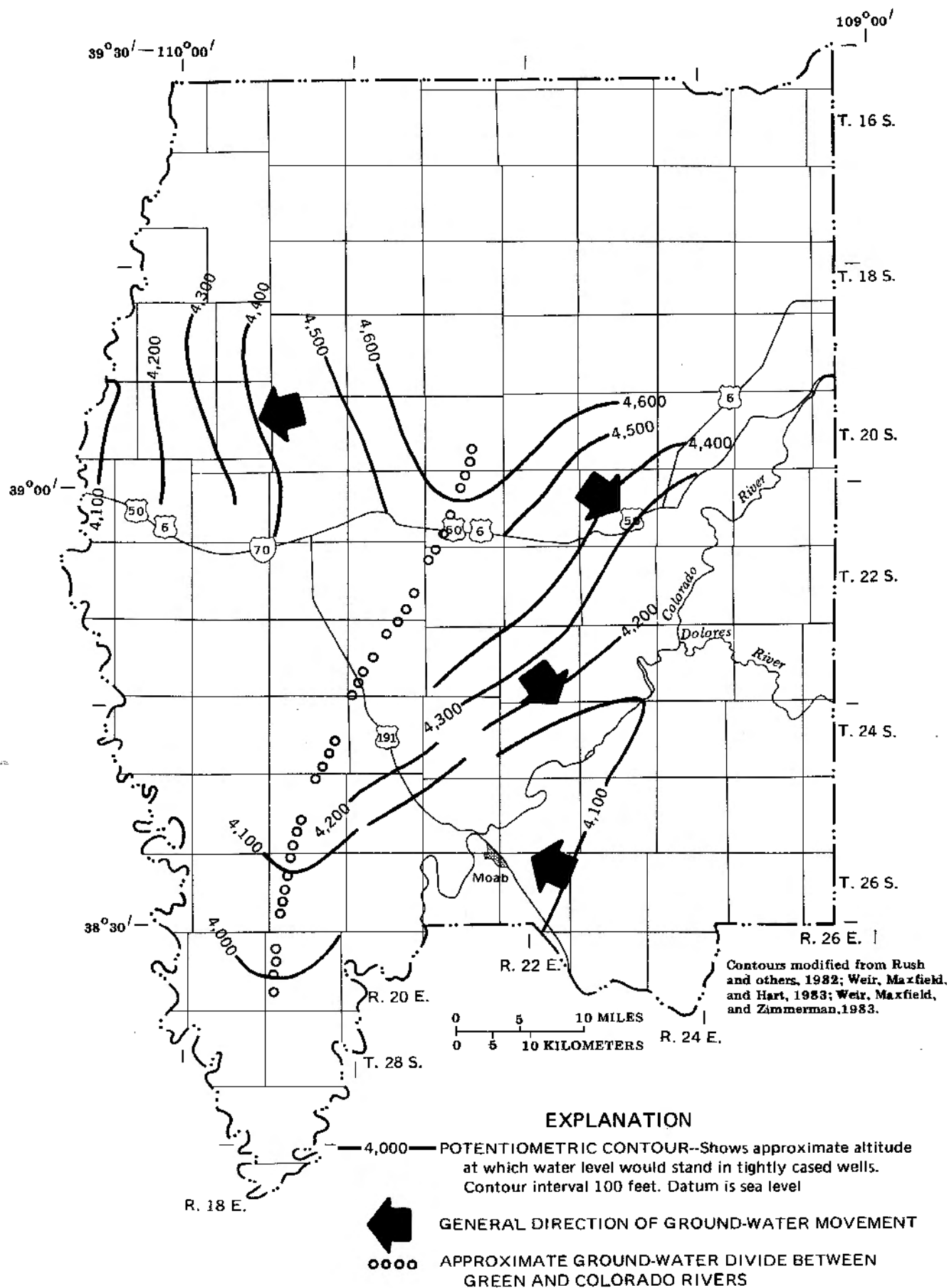


Figure 9.—Approximate potentiometric surface and general direction of movement of water in the upper ground-water system.

Spring and seep discharge from the Entrada aquifer occurs where vertical hydraulic conductivity is decreased by contacts between crossbed sets or by the finer grained Dewey Bridge Member of the Entrada Sandstone that underlies the Slick Rock Member of the Entrada Sandstone. Several alcoves at the base of the Slick Rock Member are shown in figure 10. The alcoves are the result of ground water discharging from the Slick Rock Member because the underlying Dewey Bridge Member impedes further downward flow. Ground water moving to the discharge area dissolves the calcium carbonate cement from the sandstone of the Slick Rock Member, which weakens the sandstone, and it eventually crumbles off the outcrop.



Figure 10.--Alcoves at different stages of development at the base of the Slick Rock Member of the Entrada Sandstone (Jes), at location (D-25-19)11d. Dewey Bridge Member of Entrada Sandstone (Jed), underlies Slick Rock Member.

One of the principal areas of spring discharge from the Entrada aquifer is in the canyon of Courthouse Wash and in Sevenmile Canyon near its mouth (pl. 1). Courthouse Wash and the axis of the Courthouse syncline are coincident in this area. Seepage occurs from the walls of both canyons, and several springs discharge from alcoves in the northeast canyon wall of Courthouse Wash. Several of the springs were inventoried by Sumsion (C.T. Sumsion, U.S. Geological Survey, written commun., 1971), and discharge from the springs ranged from 0.1 to 11.1 gal/min. Information collected during the inventory at Alcove Spring [(D-24-21)3ldab-S1], Antler Pool Spring [(D-25-21)5abb-S1], and Mossy Pool Spring [(D-25-21)5bbb-S1], is shown in table 7.

Two springs, Lost Spring [(D-23-22)17cab-S1] and an unnamed spring [(D-23-21)23dad-S1], are known to discharge from the Entrada aquifer east of the Salt Valley anticline, and Brink Spring [(D-24-19)10dcd-S1] and a flowing well [(D-24-20)19caa-1] are known to discharge along the Moab fault (pl. 1; tables 7 and 8). These sites were inventoried during this study. Discharge from the springs ranged from 0.5 to 2.5 gal/min, and discharge from the flowing well was about 15 gal/min. The discharge point of the unnamed spring, at an intersection of a fracture and a contact between crossbed sets, is shown in figure 11A. Water moves from the discharge point in a rivulet under watercress and other vegetation for about 200 feet, and then appears flowing over talus (fig. 11B).

Water samples from Alcove Spring, Antler Pool Spring, and Mossy Pool Spring inventoried by Sumsion (C.T. Sumsion, U.S. Geological Survey, written commun., 1971), and from the three springs and the flowing well inventoried during this study were collected and analyzed. Results of the analyses are given in table 4.

Concentrations of dissolved solids ranged from 143 to 157 mg/L in the Arches National Park area and from 119 to 182 mg/L along the Moab Fault. The water type was calcium carbonate in the Arches National Park area and calcium carbonate or calcium magnesium carbonate along the Moab Fault. Hardness ranged from 100 to 170 mg/L, or from hard to very hard. Concentrations of arsenic, barium, iron, and selenium were less than the State of Utah primary drinking-water standards.

Four water samples from a well completed in the Entrada aquifer at location (D-24-19)17abc were collected and analyzed in 1982 and 1983 (J.L. Proffitt, written commun., 1983). The median concentration of dissolved solids in the four samples was 300 mg/L, and the water type of all four samples was magnesium calcium bicarbonate.

Feltis (1966, p. 44-69) reported concentrations of major ions and dissolved solids in water samples that were collected from the Entrada aquifer in three oil-test holes and one water well. The sites are located north of the Entrada Sandstone outcrop area (fig. 7), and the depth to the Entrada Sandstone ranged from about 900 to about 5,300 feet below land surface. The concentration of dissolved solids ranged from 9,470 mg/L to about 86,600 mg/L, and the water type at each site was sodium chloride (fig. 7; table 6). In unpublished data from the files of the U.S. Geological Survey, the concentration of dissolved solids in water collected from the Entrada aquifer at four sites located north of the Entrada Sandstone outcrop area ranged from 4,330 to 104,000 mg/L (fig. 7; table 6).

Table 7.--Records of selected springs

[Abbreviations: gal/min, gallons per minute; °C, degrees Celsius;  
 µS/cm, microsiemens per centimeter at 25 degrees Celsius; --, no data]

Spring number: See "Numbering system for hydrogeologic-data sites", p. 5 and figure 2.

Geologic source: 200MSZC, Mesozoic undifferentiated; 217CDRM, Cedar Mountain Formation; 221SLWS, Salt Wash Sandstone Member of Morrison Formation; 221ENRD, Entrada Sandstone; 227GLNC, Glen Canyon Group; 227NVJO, Navajo Sandstone; 231WNGT, Wingate Sandstone.

Altitude: In feet above sea level.

Discharge: Method of measurement--P, modified Parschall flume; V, volumetrically; M, not specified; H, Hoff meter; F, in-line flowmeter; E, estimated.

| Spring number     | Spring name          | Geologic source | Altitude (feet) | Discharge (gal/min) | Date discharge measured | Temperature (°C) | Specific conductance (µS/cm) | pH (units) | Date parameters measured |
|-------------------|----------------------|-----------------|-----------------|---------------------|-------------------------|------------------|------------------------------|------------|--------------------------|
| (D-21-24)36bbc-S1 | Cane Spring          | 200MSZC         | 4,200           | 43.5 P              | 09-08-85                | 15.0             | 5,290                        | 8.0        | 09-08-85                 |
| (D-22-21)32aac-S1 | Unnamed Spring       | 217CDRM         | 4,700           | --                  | --                      | --               | 1,600                        | 8.4        | 12-13-85                 |
| (D-22-25)12bda-S1 | Burn Spring          | 400PCMB         | 5,720           | 42.0 V              | 09-07-85                | 15.0             | 680                          | 8.2        | 09-07-85                 |
| (D-22-25)18cdb-S1 | Unnamed Seep         | 200MSZC         | 4,520           | 20.0 E              | 09-08-85                | 15.5             | 1,100                        | 7.4        | 09-08-85                 |
| (D-23-20)32dca-S1 | Burro Seep           | --              | 4,580           | .2 V                | 07-26-86                | 22.5             | 610                          | 7.0        | 07-26-86                 |
| (D-23-21)23dad-S1 | Unnamed Spring       | 221ENRD         | 4,520           | 2.0 V               | 08-08-86                | 14.0             | 255                          | 8.2        | 08-08-86                 |
| (D-23-22)17cab-S1 | Lost Spring          | 221ENRD         | 4,660           | .5 V                | 06-10-85                | 15.0             | 255                          | 8.2        | 06-10-85                 |
| (D-23-23)11dbc-S1 | Unnamed Spring       | 227NVJO         | 4,420           | --                  | --                      | 12.5             | 560                          | 7.9        | 11-23-85                 |
| (D-23-23)12dba-S1 | Buck Spring          | 227NVJO         | 4,240           | 2.5 V               | 12-17-85                | 13.0             | 670                          | 7.6        | 12-17-85                 |
| (D-24-18)7aaa-S1  | Dripping Spring      | 227NVJO         | 4,400           | 2.5 E               | 11-26-85                | 12.5             | 220                          | 8.2        | 11-26-85                 |
| (D-24-19)10dcd-S1 | Brink Spring         | 221ENRD         | 4,720           | 2.5 V               | 11-26-85                | 14.0             | 205                          | 8.0        | 11-26-85                 |
| (D-24-21)31dab-S1 | Alcove Spring        | 221ENRD         | 4,240           | 8.2 M               | 09-01-70                | 13.0             | 225                          | 7.7        | 09-15-70                 |
| (D-24-24)21ddb-S1 | Stinking Spring      | 324PRDX         | 4,960           | 2.0 E               | 07-13-86                | 15.0             | 18,000                       | --         | 07-13-86                 |
| (D-25-18)9ddc-S1  | Deadman Spring       | 227NVJO         | 5,040           | .3 V                | 06-21-86                | 17.0             | 320                          | 7.7        | 06-21-86                 |
| (D-25-21)5abb-S1  | Antler Pool Spring   | 221ENRD         | 4,240           | 6.0 M               | 09-15-70                | 12.5             | 270                          | 8.0        | 09-15-70                 |
| (D-25-21)5bbb-S1  | Mossy Pool Spring    | 221ENRD         | 4,240           | 11.0 M              | 09-15-70                | 13.0             | 250                          | 7.4        | 09-15-70                 |
| (D-25-21)26bdc-S1 | Lions Club Spring    | 231WNGT         | 4,040           | 7.0 M               | 01-00-68                | 17.0             | 300                          | 8.1        | 10-08-58                 |
| (D-25-21)26bdc-S2 | Goatman Spring       | 231WNGT         | 4,040           | --                  | --                      | 16.0             | 295                          | 8.0        | 08-17-85                 |
| (D-25-21)26bdd-S1 | Matrimony Spring     | 231WNGT         | 4,000           | 6.5 V               | 07-26-86                | 16.0             | 285                          | 8.1        | 11-06-86                 |
| (D-25-21)35aaa-S1 | Skakeel Spring       | 231WNGT         | 4,080           | 240 E               | 10-19-67                | 17.5             | 290                          | 8.0        | 08-15-85                 |
| (D-26-22)14acc-S1 | Deep Cut Spring      | 227NVJO         | 4,660           | 90.0 M              | 11-19-68                | 16.0             | 305                          | 7.6        | 11-19-68                 |
| (D-26-22)15cbb-S1 | Birch Spring         | 227GLNC         | 4,460           | 90.0 E              | 10-00-67                | 14.0             | 295                          | 7.6        | 10-19-67                 |
| (D-26-22)15cca-S1 | Somerville Spring    | 227GLNC         | 4,480           | 15.0 V              | 08-09-86                | 15.0             | 350                          | 7.7        | 11-06-86                 |
| (D-26-22)15cdc-S1 | Moab Spring Number 1 | 227GLNC         | 4,480           | 50.0 M              | 03-01-69                | 16.0             | 460                          | 7.6        | 08-16-85                 |
| (D-26-22)22aaa-S1 | Moab Spring Number 2 | 227GLNC         | 4,580           | 330 H               | 08-29-85                | 15.0             | 280                          | 7.6        | 08-16-85                 |
| (D-26-22)22aad-S1 | Moab Spring Number 3 | 227GLNC         | 4,580           | 390 F               | 08-29-85                | 16.0             | 285                          | 7.4        | 08-15-85                 |
| (D-26-23)26dcc-S1 | Unnamed Spring       | 221SLWS         | 7,440           | 0.25 V              | 07-27-86                | 15.0             | 1,640                        | 7.6        | 07-27-86                 |
| (D-27-19)22bbc-S1 | Neck Spring          | 227NVJO         | 5,680           | <5 E                | 07-10-86                | 15.0             | 190                          | 8.2        | 07-10-86                 |



A.



B.

Figure 11.--A) unnamed spring (D-23-21)23dad-S1, discharging from the Entrada aquifer at the intersection of a fracture and a contact between crossbed sets; and B) discharge surfacing about 200 feet from point of discharge from bedrock.

Table 8.--Records of selected

[Abbreviations used in headings: gal/min, gallons per minute; (gal/min)/ft, gallons per minute per foot of

Well number: See "Numbering system for hydrogeologic-data sites", p. 5 and figure 2.

Geologic source: 110ALVM, alluvium of Quaternary age; 217CDRM, Cedar Mountain Formation; 221BRSB, Brushy Basin Shale Member of 310CTLR, Outler Formation.

Type of opening: P, perforated; X, open hole without casing.

| Well number      | Owner                          | Date of construction | Altitude of land surface (feet) | Geologic source | Diameter of well (inches) | Diameter of casing (inches) | Depth of well (feet) | Depth to aquifer (feet) | Bottom of casing (feet) |
|------------------|--------------------------------|----------------------|---------------------------------|-----------------|---------------------------|-----------------------------|----------------------|-------------------------|-------------------------|
| (D-22-23)25bac-1 | U.S. Bureau of Land Management | --                   | 4,220                           | 217CDRM         | --                        | --                          | --                   | --                      | --                      |
| (D-22-23)29ada-1 | U.S. Bureau of Land Management | --                   | 4,380                           | 221BRSB         | --                        | --                          | --                   | 0                       | --                      |
| (D-23-21)27bcd-1 | U.S. National Park Service     | 10-00-62             | 5,200                           | 231WNGT         | 8.00                      | 6.00                        | 900                  | 765                     | 900                     |
| (D-24-18)25dba-1 | U.S. Bureau of Land Management | 02-00-37             | 5,300                           | 227NVJO         | --                        | 8.25                        | 604                  | --                      | 19.0                    |
| (D-24-19)36bba-1 | U.S. Bureau of Land Management | --                   | 4,880                           | 227NVJO         | --                        | 5.5                         | --                   | --                      | --                      |
| (D-24-20)19caa-1 | U.S. Bureau of Land Management | --                   | 4,680                           | 221ENRD         | --                        | --                          | --                   | 0                       | --                      |
| (D-25-20)21dbb-1 | U.S. Bureau of Land Management | --                   | 5,080                           | --              | --                        | --                          | --                   | --                      | --                      |
| (D-25-20)32dbc-1 | U.S. Bureau of Land Management | --                   | 5,240                           | --              | --                        | 7.0                         | 225                  | --                      | --                      |
| (D-25-21)20add-2 | U.S. National Park Service     | 11-12-58             | 4,120                           | 227NVJO         | 8.00                      | 8.0                         | 123                  | 0                       | 123                     |
| (D-25-21)21bdc-1 | U.S. National Park Service     | 05-19-78             | 4,080                           | 227NVJO         | 12.00                     | 8.0                         | 172                  | 0                       | 172                     |
| (D-25-22)12aad-1 | Devore, Kenneth                | 04-13-80             | 4,600                           | 310CTLR         | 4.00                      | 4.00                        | 233                  | 40                      | 233.0                   |
| (D-25-23)18baa-1 | D'Agnese, Denise               | 07-15-78             | 4,800                           | 310CTLR         | 6.00                      | 6.00                        | 166                  | 35                      | 40.0                    |
| (D-25-23)20adb-1 | Degles, Robert                 | 11-20-77             | 5,040                           | 310CTLR         | --                        | 6.00                        | 230                  | 40                      | 40.0                    |
| (D-26-22)8bad-1  | Grand Co. Water Cons. District | 06-30-80             | 4,240                           | 227GLNC         | --                        | --                          | 610                  | 0                       | --                      |
| (D-26-22)8bdb-1  | Dunkin, E.                     | 07-25-83             | 4,520                           | 227GLNC         | 5.5                       | 6.63                        | 460                  | 0                       | 100                     |
| (D-26-22)8dda-1  | Norman, L.                     | 11-12-79             | 4,460                           | 227GLNC         | 5.62                      | 7.00                        | 150                  | 15                      | 28.0                    |
| (D-26-22)8dda-2  | Haaland, Martin                | 07-17-85             | 4,440                           | 227GLNC         | 5.88                      | 4.5                         | 188                  | 0                       | 188                     |
| (D-26-22)9ddc-1  | Norman, Robert R.              | --                   | 4,600                           | 227GLNC         | --                        | --                          | --                   | --                      | --                      |
| (D-26-22)14cba-1 | Norman, Robert R.              | 07-27-84             | 4,820                           | 227GLNC         | 10.62                     | 6.63                        | 460                  | 3                       | 102                     |
| (D-26-22)14cbd-1 | Redd, Thomas                   | 06-20-78             | 4,780                           | 227GLNC         | 6.75                      | 6.00                        | 320                  | 0                       | 320                     |
| (D-26-22)15acb-1 | Turvey, Paul                   | 05-03-78             | 4,660                           | 227GLNC         | 7.00                      | 6.00                        | 270                  | 5                       | 270                     |
| (D-26-22)15acc-1 | Larsen, Ray                    | 06-03-77             | 4,600                           | 227GLNC         | 8.00                      | 6.00                        | 200                  | 10                      | 200                     |
| (D-26-22)15bbb-1 | Cochran, John M.               | 08-17-77             | 4,560                           | 227GLNC         | 6.00                      | 5.50                        | 250                  | 0                       | 236                     |
| (D-26-22)15bcc-1 | Magee, Dail                    | 01-03-78             | 4,520                           | 227GLNC         | 6.00                      | 6.00                        | 140                  | 10                      | 20                      |
| (D-26-22)15bdb-1 | Grand Co. Water Cons. District | 12-03-64             | 4,620                           | 227GLNC         | 8.00                      | 6.00                        | 160                  | 2                       | 20                      |
| (D-26-22)15cca-1 | Day, Max                       | 08-05-77             | 4,480                           | 227GLNC         | 8.0                       | 6.6                         | 119                  | 4                       | 111                     |
| (D-26-22)15daa-2 | City of Moab Well Number 10    | 07-15-76             | 4,660                           | 227GLNC         | 12.0                      | 10.0                        | 300                  | 0                       | 300                     |
| (D-26-22)15dca-1 | City of Moab Well Number 6     | 02-01-69             | 4,600                           | 227GLNC         | 14.0                      | 14.0                        | 181                  | 25                      | 181                     |
| (D-26-22)15ddc-1 | City of Moab Well Number 7     | 10-27-72             | 4,590                           | 227GLNC         | 16.0                      | 16.0                        | 325                  | 15                      | 325                     |
| (D-26-22)17aaa-2 | McCormick, Richard E.          | 03-15-81             | 4,460                           | 227GLNC         | 8.8                       | 10.8                        | 180                  | 1                       | 16.0                    |
| (D-26-22)17aba-3 | Oliver, Harold                 | 10-21-62             | 4,320                           | 227GLNC         | 7.0                       | 7.0                         | 100                  | 0                       | 100                     |
| (D-26-22)22aab-1 | City of Moab Well Number 4     | 05-18-61             | 4,580                           | 227GLNC         | 12.0                      | 12.8                        | 100                  | 16                      | 63.0                    |
| (D-26-22)22aab-2 | City of Moab Well Number 4A    | 10-00-72             | 4,580                           | 227GLNC         | --                        | 16.0                        | 222                  | --                      | 222                     |
| (D-26-22)22aac-1 | City of Moab Well Number 5     | 08-20-62             | 4,570                           | 227GLNC         | 12.8                      | 12.8                        | 238                  | 11                      | 238                     |
| (D-26-22)22abc-1 | Ritchie, Robert                | 08-05-65             | 4,520                           | 227GLNC         | 6.0                       | 6.0                         | 80                   | 6                       | 66                      |
| (D-26-22)22daa-1 | Broughton, B.                  | 04-30-69             | 4,600                           | 227GLNC         | 12.0                      | 12.0                        | 200                  | 18                      | 150                     |
| (D-26-22)22dad-1 | Rattle, Paul S.                | 03-23-73             | 4,600                           | 227GLNC         | 8.0                       | 8.0                         | 110                  | 0                       | 87                      |
| (D-26-22)22dcd-1 | White, George M.               | 06-19-59             | 4,580                           | 110ALVM         | --                        | 16.0                        | 70                   | 0                       | --                      |
| (D-26-22)23bba-1 | City of Moab Well Number 9     | 04-07-75             | 4,640                           | 227GLNC         | 14.0                      | 14.0                        | 450                  | 18                      | 235                     |
| (D-26-22)23odd-1 | Grand Co. Water Cons. District | 02-25-71             | 4,680                           | 227GLNC         | 16.0                      | 16.0                        | 174                  | 8                       | 120                     |
| (D-26-22)26acd-1 | Whitney, Susan                 | --                   | 4,740                           | 227GLNC         | --                        | --                          | --                   | --                      | --                      |
| (D-26-22)26dbc-1 | Axtell, Larry                  | 04-25-79             | 4,700                           | 110ALVM         | 6.0                       | 6.0                         | 235                  | 0                       | 234                     |
| (D-26-22)26dbd-1 | City of Moab Well Number 11    | 07-29-70             | 4,710                           | 227GLNC         | 16.0                      | 14.0                        | 210                  | 140                     | 190                     |
| (D-26-22)26dda-1 | Jolly, James                   | 00-00-75             | 4,740                           | 227GLNC         | 5.0                       | 5.0                         | 220                  | 0                       | 156                     |
| (D-26-22)35ada-1 | Bull, L.W.                     | 02-18-62             | 4,740                           | 110ALVM         | 5.5                       | 5.5                         | 185                  | 0                       | 185                     |
| (D-26-22)35bdd-2 | Callor, J.                     | 04-01-63             | 4,740                           | 110ALVM         | 6.0                       | 6.0                         | 247                  | 0                       | 247                     |



# water wells

drawdown; °C, degrees Celsius;  $\mu\text{S}/\text{cm}$ , microsiemens per centimeter at 25 degrees Celsius; --, no data]

Morrison Formation; 221ENRD, Entrada Sandstone; 227GLNC, Glen Canyon Group; 227NWJO, Navajo Sandstone; 231WNGT, Wingate Sandstone;

| Top of open interval (feet) | Type of opening | Water level (feet) | Date water level measured | Discharge (gal/min) | Drawdown (feet) | Pumping period (hours) | Specific capacity [(gal/min)/ft] | Date measured | Temperature (°C) | Specific conductance ( $\mu\text{S}/\text{cm}$ ) | pH (units) | Date parameter measured |
|-----------------------------|-----------------|--------------------|---------------------------|---------------------|-----------------|------------------------|----------------------------------|---------------|------------------|--------------------------------------------------|------------|-------------------------|
| --                          | --              | --                 | --                        | 0.20                | --              | --                     | --                               | 07-21-86      | 22.5             | 2,670                                            | 8.3        | 07-21-86                |
| 819                         | P               | 747                | 10-30-62                  | 8.00                | --              | --                     | --                               | 08-18-85      | 26.5             | 1,630                                            | 7.6        | 08-18-85                |
| 19.0                        | X               | 562                | 06-20-86                  | 5.00                | 20.0            | --                     | 0.25                             | 04-16-79      | 20.0             | 515                                              | 7.8        | 08-07-86                |
| --                          | --              | 193                | 09-04-85                  | --                  | --              | --                     | --                               | 02-05-37      | --               | --                                               | --         | --                      |
| --                          | --              | --                 | --                        | 15.0                | --              | --                     | --                               | 11-24-85      | 14.0             | 335                                              | 7.8        | 11-24-85                |
| --                          | --              | 400                | 10-16-85                  | --                  | --              | --                     | --                               | --            | 15.0             | 1,190                                            | --         | 10-29-85                |
| --                          | --              | 65.0               | 10-17-85                  | --                  | --              | --                     | --                               | --            | --               | --                                               | --         | --                      |
| 98.4                        | P               | 91.7               | 12-20-58                  | 12.0                | 7.00            | 6.0                    | 1.7                              | 12-20-58      | 19.0             | 1,000                                            | 7.4        | 08-07-86                |
| 112                         | P               | 114                | 05-19-78                  | 30.2                | 2.08            | 24.0                   | 14.5                             | 05-23-78      | 19.0             | 1,690                                            | 7.4        | 08-07-86                |
| 200                         | P               | 172                | 04-13-80                  | 15.0                | --              | --                     | --                               | 04-13-80      | 16.0             | 3,260                                            | 7.3        | 09-30-86                |
| 40.0                        | X               | 100                | 07-15-78                  | 25.0                | 0               | 2.0                    | --                               | 07-15-78      | 15.0             | 3,950                                            | 7.5        | 09-30-86                |
| 40.0                        | X               | 190                | 11-30-77                  | 10.0                | 0               | 1.0                    | --                               | 11-20-77      | 15.0             | 1,940                                            | 7.3        | 09-30-86                |
| --                          | --              | 56.9               | 07-25-86                  | 360                 | --              | --                     | --                               | 06-30-80      | 15.5             | 365                                              | 7.6        | 09-05-86                |
| 100                         | X               | 332                | 04-30-86                  | --                  | --              | --                     | --                               | --            | --               | --                                               | --         | --                      |
| 28.0                        | X               | 101                | 07-11-86                  | --                  | --              | --                     | --                               | --            | --               | --                                               | --         | --                      |
| 120                         | P               | 114                | 04-29-86                  | 10.0                | --              | --                     | --                               | --            | --               | --                                               | --         | --                      |
| --                          | --              | --                 | --                        | --                  | --              | --                     | --                               | --            | 18.0             | 265                                              | 7.8        | 07-11-86                |
| 102                         | X               | 215                | 06-22-86                  | --                  | --              | --                     | --                               | 07-27-84      | 16.0             | 255                                              | 8.2        | 06-22-86                |
| 310                         | P               | 156                | 06-22-86                  | 12.0                | 0               | 2.0                    | --                               | 06-20-78      | 15.0             | 245                                              | 7.6        | 11-05-86                |
| 251                         | P               | 125                | 03-26-86                  | 12.0                | 0               | 3.0                    | --                               | 05-03-78      | 15.0             | 270                                              | 7.7        | 08-05-86                |
| 170                         | P               | 77.8               | 03-25-86                  | 8.0                 | 0               | 4.0                    | --                               | 06-03-77      | --               | --                                               | --         | --                      |
| 220                         | P,X             | 185                | 03-26-86                  | 10.0                | 40.0            | 4.0                    | 0.25                             | 08-17-77      | 15.0             | 260                                              | 7.9        | 11-05-86                |
| 20                          | X               | 51.6               | 03-26-86                  | --                  | --              | --                     | --                               | --            | 15.0             | 385                                              | 7.8        | 11-05-86                |
| 20                          | X               | 90.5               | 11-20-85                  | 42.5                | 21.0            | 5.3                    | 2.0                              | 05-08-77      | --               | --                                               | --         | --                      |
| 111                         | X               | 15.5               | 03-26-86                  | 20.0                | 4.00            | 1.00                   | 5.0                              | 08-05-77      | 16.0             | 330                                              | 7.7        | 08-09-86                |
| 180                         | P               | 122                | 01-10-87                  | 750                 | 22.0            | --                     | 34.1                             | 10-00-78      | 15.5             | 255                                              | 7.8        | 08-15-85                |
| 105                         | P               | 49.8               | 01-27-86                  | 938                 | 12.0            | --                     | 78.2                             | 10-00-78      | 15.0             | 360                                              | 7.7        | 08-15-85                |
| 105                         | P               | 30.5               | 01-10-87                  | 322                 | 33.0            | --                     | 9.8                              | 10-00-78      | 15.0             | 370                                              | 7.7        | 11-05-86                |
| 16.0                        | X               | 105                | 03-25-86                  | 35.0                | 1.5             | 1.00                   | 23.3                             | 03-15-81      | 16.5             | 285                                              | 7.8        | 11-05-86                |
| 89.0                        | P               | 31.8               | 03-25-86                  | 32.0                | 0               | 3.00                   | --                               | 10-21-62      | --               | --                                               | --         | --                      |
| 20.0                        | P,X             | 26.4               | 01-10-87                  | 600                 | 40.0            | 8.00                   | 15.0                             | 05-18-61      | 13.5             | 275                                              | 7.6        | 11-19-68                |
| 70.0                        | P               | 27.2               | 01-10-87                  | 1,190               | 30.0            | --                     | 39.7                             | 12-00-72      | --               | --                                               | --         | --                      |
| 114                         | P               | 2.4                | 01-10-87                  | 180                 | 231             | --                     | 0.8                              | 08-00-78      | 15.5             | 280                                              | 7.9        | 08-16-85                |
| 66.0                        | X               | 11.9               | 02-26-86                  | 25                  | 0               | 1.0                    | --                               | 08-05-65      | 15.0             | 620                                              | 7.4        | 08-05-86                |
| 77.0                        | X               | 10.8               | 02-26-86                  | 200                 | 20.0            | 24.0                   | 10.0                             | 04-30-69      | --               | --                                               | --         | --                      |
| 87.0                        | X               | 10.4               | 02-26-86                  | 160                 | --              | --                     | --                               | 03-23-73      | 16.5             | 380                                              | 7.7        | 07-12-86                |
| --                          | --              | 34.0               | 06-19-59                  | 100                 | 51.0            | --                     | 2.0                              | 06-19-59      | 16.0             | 930                                              | 7.6        | 07-09-68                |
| 110                         | P,X             | 12.9               | 01-10-87                  | 180                 | 205             | --                     | 0.9                              | 10-00-78      | --               | --                                               | --         | --                      |
| 120                         | X               | 75.0               | 03-09-71                  | 1,600               | 48              | 1.0                    | 33.3                             | 02-25-71      | 16.0             | 445                                              | 7.8        | 08-28-85                |
| --                          | --              | 125                | 02-26-86                  | --                  | --              | --                     | --                               | --            | 17.0             | 685                                              | 7.5        | 08-09-86                |
| --                          | P               | 80.2               | 02-26-86                  | 50.0                | 13              | 6.0                    | 3.8                              | 04-25-79      | 15.0             | 1,050                                            | 7.2        | 11-05-86                |
| 140                         | P,X             | 101                | 02-26-86                  | 1,500               | 9               | 12                     | 167                              | 07-29-70      | 17.0             | 920                                              | 7.5        | 08-19-85                |
| 156                         | X               | 137                | 02-26-86                  | --                  | --              | --                     | --                               | --            | 18.0             | 705                                              | 7.6        | 07-12-86                |
| 185                         | P               | 154                | 02-18-62                  | 7.0                 | 0               | 1.0                    | --                               | 02-18-62      | 14.0             | 1,230                                            | 7.6        | 07-08-69                |
| 230                         | P               | --                 | --                        | 30.0                | 0               | 1.0                    | --                               | 04-01-63      | 10.0             | 980                                              | 7.7        | 09-05-68                |



The data discussed in the preceding paragraphs indicate that the Entrada aquifer typically contains freshwater in and near outcrop areas of the Entrada Sandstone, but the water is hard to very hard. Water in the Entrada aquifer is moderately saline at two locations about 6 miles north of the outcrop area, and generally is more saline farther north of the outcrop area, where the Entrada Sandstone is more deeply buried (fig. 7). Based on this evidence, fresh water in the Entrada aquifer probably is present only for a short distance north of the outcrop area.

Water from the unnamed spring and Lost Spring near the eastern border of Arches National Park, and from well (D-24-20)19caa-1 and Brink Spring near the Moab fault was analyzed for the activity of radionuclides (table 5). The activities of radium in water from Lost Spring and Brink Spring (0.19 pCi/L and 0.15 pCi/L) were the two largest of 15 samples collected and analyzed in the Grand County area; however, the activity was less than 5 percent of the State of Utah primary drinking-water standard of 5.0 pCi/L. Alpha and beta activities were about 10 percent or less of the State of Utah primary drinking-water standards of 15 and 50 pCi/L. Beta activities near the Moab fault, however, were about twice as large as those near the eastern border of Arches National Park.

Jobin (1962, figs. 23 and 24) estimated values of hydraulic conductivity and transmissivity for the Entrada aquifer in the Grand County area. Jobin's estimate of hydraulic conductivity ranged from about 0.1 ft/d in the western part of the area to more than 1.1 ft/d in the eastern part of the area, and his estimate of transmissivity ranged from about 50 ft<sup>2</sup>/d in the western part of the area to more than 150 ft<sup>2</sup>/d in the eastern part of the area.

#### The Navajo aquifer

The Navajo Sandstone crops out extensively in the southern part of the Grand County area. Principal areas of outcrop are in the southern part of Arches National Park, east of Arches National Park along the Colorado River, east of Spanish Valley in the Mill Creek drainage, west of Spanish Valley, in and directly north of Canyonlands National Park, and in a large area about 10 to 15 miles north of Canyonlands National Park (pl. 2). The Navajo Sandstone contains the Navajo aquifer. Two water-supply wells in Arches National Park are completed in the Navajo aquifer, and small springs provide water from the Navajo aquifer for stock watering in several locations.

Recharge to the Navajo aquifer typically occurs by direct infiltration of precipitation where the Navajo Sandstone is at the surface or by indirect infiltration of precipitation where the Navajo Sandstone is overlain by unconsolidated deposits. Typically, the exposed surface of the Navajo Sandstone has small domes or knolls alternating with depressions, and the depressions are enclosed drainages (fig. 4). Precipitation runs off the domes or knolls and collects in the depressions, where it either evaporates or infiltrates into the Navajo Sandstone. The rate of recharge to the Navajo aquifer probably is much larger where the formation is fractured or jointed.

Recharge is enhanced where the depressions in the surface of the Navajo Sandstone contain thick, unconsolidated deposits. The deposits typically are erosional products of the formations of the Glen Canyon Group, are sandy, and are capable of holding water in storage for infiltration into the Navajo

Sandstone. Freeze and Cherry (1979, p. 152) estimated the porosity of nonindurated sands to be from 30 to 50 percent. Where water in the unconsolidated deposits is more than about 10 feet below the surface, evapotranspiration probably is insignificant, and most of the stored precipitation recharges the Navajo aquifer. The rate of evaporation of water from unconsolidated sand decreases rapidly below a depth of about 6 feet below the land surface to nearly zero at a depth of about 10 feet below the land surface (Ripple and others, 1972). Movement of water in the Navajo aquifer generally is from recharge areas to canyons that cut through the Navajo Sandstone. Discharge of water from the Navajo aquifer by springs is not concentrated in any part of the Grand County area, but may occur wherever canyons cut through part of the thickness of the Navajo Sandstone and the Navajo Sandstone is at the surface nearby.

Neck Spring [(D-27-19)22bbc-S1] in Canyonlands National Park, is an example of a large seep from the Navajo aquifer (fig. 12). At Neck Spring, there are two horizontal bands of discharge, each at the bottom of a crossbed set. The seepage face on the largest band (the lower band) is about 350 to 400 feet long, and about 6 feet wide. The spring is recessed in an alcove which faces generally north, and direct sunlight reaches it for only short periods on the longest days of the year. The sites of largest discharge are drips and, except for evaporation, discharge from the entire seepage face is probably less than 5 gal/min.

At many seeps, a large part of the discharge, and at some seeps, all of the discharge, is evaporated from the canyon wall, and there is little or no water on the wall. The only evidence of ground-water discharge is a white, scaly or powdery mineral residue, as near Buck Spring (fig. 13).

Sandy unconsolidated deposits can play a role in the use of discharge from the Navajo aquifer. An area of discharge from the Navajo aquifer at the head of a canyon at location (D-26-18)27abb is shown in figure 14. Originally, ground water discharged into thick, sandy unconsolidated deposits. A pipe had been installed in the unconsolidated deposits, and enough water collected to supply a nearby stock tank. In an attempt to increase production, the sandy unconsolidated material was removed, and explosives were set off to fracture the Navajo Sandstone. There presently are several drips from the vertical surface of the Navajo Sandstone, but because the sandy unconsolidated material is no longer present, most of the discharge evaporates and no water is supplied to the stock tank.

Water samples were collected and analyzed from two wells completed in the Navajo aquifer and five springs discharging from the Navajo aquifer. The dissolved-solids concentrations and major ion chemistry of the springs reflect the distance of the sites from recharge areas and the distance that water has traveled in the aquifer.

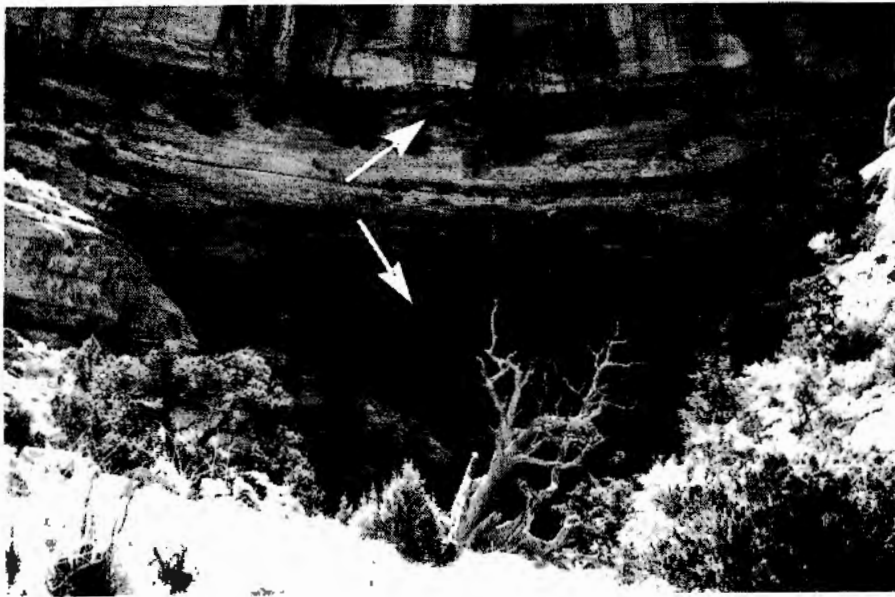


Figure 12.--Two seepage faces (arrows) above contacts between crossbed sets in the Navajo Sandstone at Neck Spring, (D-27-19) 22bbc-S1.



Figure 13.--White mineral residue as evidence of discharge from canyon wall near Buck Spring, at location (D-23-23) 12d.



Figure 14.--Seepage face (arrow) created by removal of unconsolidated material at head of canyon, at location (D-26-18)27abb. Water from Navajo aquifer no longer recharges unconsolidated material.

At Dripping Spring [(D-24-18)7aaa-S1] and Neck Spring, the dissolved-solids concentrations were 135 mg/L and 102 mg/L, the water types were calcium bicarbonate and calcium magnesium bicarbonate, and the water was moderately hard (table 4). The springs discharge from the Navajo aquifer near where the formation is recharged. The Navajo Sandstone is at the surface at both sites, and the springs discharge from canyon walls near the surface at contacts between crossbed sets.

At Deep Cut Spring [(D-26-22)14acc-S1], the concentration of dissolved solids was 171 mg/L, the water type was calcium magnesium bicarbonate, and the water was hard (table 4). The area where water is recharged to the Navajo aquifer may be several miles upgradient from Deep Cut Spring, but the recharge is from precipitation directly on the Navajo Sandstone or overlying sandy unconsolidated deposits. The water type is similar to Dripping Spring and Neck Spring, but the concentration of dissolved solids is larger and the water is harder because of the longer flow path through the Navajo aquifer.

At Buck Spring and at an unnamed spring [(D-23-23)11dbc-S1], dissolved-solids concentrations were 385 mg/L and 349 mg/L, the water types were calcium sodium magnesium bicarbonate and magnesium calcium sodium bicarbonate, and the water was very hard (table 4). The larger dissolved-solids concentration and the presence of sodium may be due to either contamination of surface water by movement across the nearby younger Summerville and Morrison Formations prior to recharging the Navajo aquifer, or by downward movement of water from those formations into the Navajo aquifer.

Two water samples from a well completed in the Navajo aquifer at location (D-24-18)12aca were collected and analyzed during 1982 and 1983 (J.L. Proffitt, written commun., 1983). Concentrations of dissolved solids in the two samples were 210 mg/L and 360 mg/L. The water types were magnesium sodium bicarbonate sulfate and magnesium sodium bicarbonate chloride sulfate.

Jobin (1962, figs. 20 and 21) estimated values of hydraulic conductivity and transmissivity for the Navajo aquifer in the Grand County area. Jobin's estimate of hydraulic conductivity ranged from less than 0.4 ft/d in the northeast to about 1 ft/d in the southwest, and his estimate of transmissivity ranged from nearly zero in the east where the formation pinches out to nearly 700 ft<sup>2</sup>/d in the southwest.

Specific capacities of two water-supply wells in Arches National Park completed in the Navajo aquifer were 1.7 (gal/min)/ft at well (D-25-21)20add-2 and 14.5 (gal/min)/ft at well (D-25-21)21bdc-1 (table 8). The specific capacity at well (D-24-18)25dba-1 was 0.25 (gal/min)/ft (table 8).

### The Wingate aquifer

The outcrop area of the Wingate Sandstone is small because the overlying, less permeable Kayenta Formation is generally resistant to erosion, and it caps the Wingate Sandstone in most places. The Wingate Sandstone generally crops out in canyon walls and floors, and in places as narrow benches at the tops of canyon walls. The Wingate Sandstone contains the Wingate aquifer. The outcrop area of the Wingate Sandstone is shown on plate 2.

Recharge to the Wingate aquifer generally occurs only where the Kayenta Formation is either sufficiently permeable or sufficiently fractured to allow downward movement of water through it from the land surface, from the Navajo aquifer, or from unconsolidated material. Movement of water in the Wingate aquifer is from areas of recharge toward canyons that cut through at least part of the Wingate Sandstone.

The principal area of discharge from the Wingate aquifer occurs near where Moab Valley meets the Colorado River. Discharge from springs ranges from less than 10 gal/min at Matrimony Spring [(D-25-21)26bdd-S1] to about 240 gal/min at Skakel Spring [(D-25-21)35aaa-S1]. One well completed in the Wingate aquifer, (D-23-21)27bcd-1, is used for water supply at Arches National Park.

Evidence of discharge from the Wingate aquifer in other areas includes alcoves formed in canyon walls, scaly or powdery mineral residue on canyon walls, or phreatophytes growing on the floor of canyons cut into the Wingate Sandstone. Discharge from the Wingate aquifer in Sevenmile Canyon at location (D-25-20)4d, as indicated by phreatophyte growth on the canyon floor, is shown in figure 15.

The concentration of dissolved solids in three water samples from springs discharging from the Wingate aquifer in the Moab Valley-Colorado River area ranged from 161 to 174 mg/L, the water type was calcium magnesium bicarbonate, and the water was moderately hard to hard (table 4). Recharge to the Wingate aquifer probably occurs nearby by downward movement from the





Figure 15.--Discharge from the Wingate aquifer into overlying unconsolidated material in Sevenmile Canyon, at location (D-25-20)4d. Discharge is evidenced by phreatophyte growth on canyon floor.

Navajo aquifer. The area is on a limb of the Moab Anticline (plate 2); the Navajo Sandstone is at the surface; and the Navajo Sandstone and the Wingate Sandstone, along with the intervening Kayenta Formation, are fractured and faulted. The small concentrations of dissolved solids and the water type indicate that recharge occurs nearby.

The concentration of dissolved solids in water from well (D-23-21)27bod-1, in Arches National Park, was 280 mg/L, the water type was magnesium sodium calcium bicarbonate, and the water was very hard (table 9). The top of the Wingate Sandstone is 765 feet below land surface at this site and the recharge area is uncertain, but the flow path appears to be longer than that in the Moab Valley-Colorado River area.

Four water samples from a well completed in the Wingate aquifer at location (D-24-18)13caa were collected and analyzed during 1982 and 1983 (J.L. Proffitt, private consultant, written commun., 1983). The well was converted to an observation well from a uranium-exploration hole that was drilled by the Tennessee Valley Authority. The median concentration of dissolved solids for the four samples was about 45,000 mg/L, and the water type was sodium chloride.

The large concentration of dissolved solids in water from the well located at (D-24-18)13caa is atypical for water in the upper ground-water system in this area. South of the outcrop area of rocks of younger age than the Entrada Sandstone, the concentration of dissolved solids in water samples collected from several formations that are part of the upper ground-water system ranged from 102 to 2,570 mg/L (fig. 7; tables 4 and 6). It is possible that the unusually large concentration of dissolved solids in water in the Wingate aquifer at location (D-24-18)13caa is caused by upward movement of water from the lower ground-water system or from the Paradox Member of the Hermosa Formation into the Wingate aquifer. Rush and others (1982; p. 12, fig. 5) indicate that the potential for upward leakage from the lower ground-water system to the upper ground-water system is present in this area, and Feltis (1966, p. 54-56) reported dissolved solids concentrations larger than 100,000 mg/L in water from the lower ground-water system and from the Paradox Member near location (D-24-18)13caa.

Extrapolation of potentiometric contours of the two ground-water systems as determined by Rush and others (1982; pl. 2, fig. 15) indicates that the potentiometric surface in the lower ground-water system is about 200 feet higher than that in the upper ground-water system at location (D-24-18)13caa (fig. 16). Feltis (1966, p. 54-56) reported dissolved-solids concentrations ranging from 160,000 to 230,000 mg/L in water from wells completed in the lower ground-water system about 10 miles northwest of location (D-24-18)13caa, and 300,000 mg/L in water from a well completed in the Paradox Member about 4 miles south of location (D-24-18)13caa.

Rush and others (1982, p. 12) indicated that movement of water from the lower ground-water system to the upper ground-water system could occur where salt beds of the Paradox Member have been removed by solution or plastic flow, or where faulting has caused the lower and upper ground-water systems to be juxtaposed, but these conditions are not known to exist near location (D-24-18)13caa. Poorly plugged petroleum-test or uranium-test holes that have been drilled through the upper ground-water system and into the Paradox Member or the lower ground-water system may provide pathways for movement of water from the lower ground-water system to the upper ground-water system.

J.L. Proffitt (private consultant, written commun., 1983) reported that seven uranium-test holes were drilled into the top of the Paradox Member in T. 24 S., R. 18 and 19 E. One of these wells is located 0.5 mile from (D-24-18)13caa, and another is located about 1.5 miles away from (D-24-18)13caa. Proffitt reported that all of the holes were plugged and abandoned; however, if plugging was not successful, these wells could provide a pathway for water containing large concentrations of dissolved solids to move upward from the Paradox Member into the Wingate aquifer and mix with water from the Wingate aquifer, resulting in water containing unusually large concentrations of dissolved solids in the Wingate aquifer.

Jobin (1962, figs. 14 and 15) estimated values of hydraulic conductivity and transmissivity for the Wingate aquifer in the Grand County area. Jobin's estimate of hydraulic conductivity ranged from about 0.1 ft/d in the north to more than 0.4 ft/d in the south, and his estimate of transmissivity ranged from about 40 ft<sup>2</sup>/d in the north to more than 150 ft<sup>2</sup>/d in the southwest.



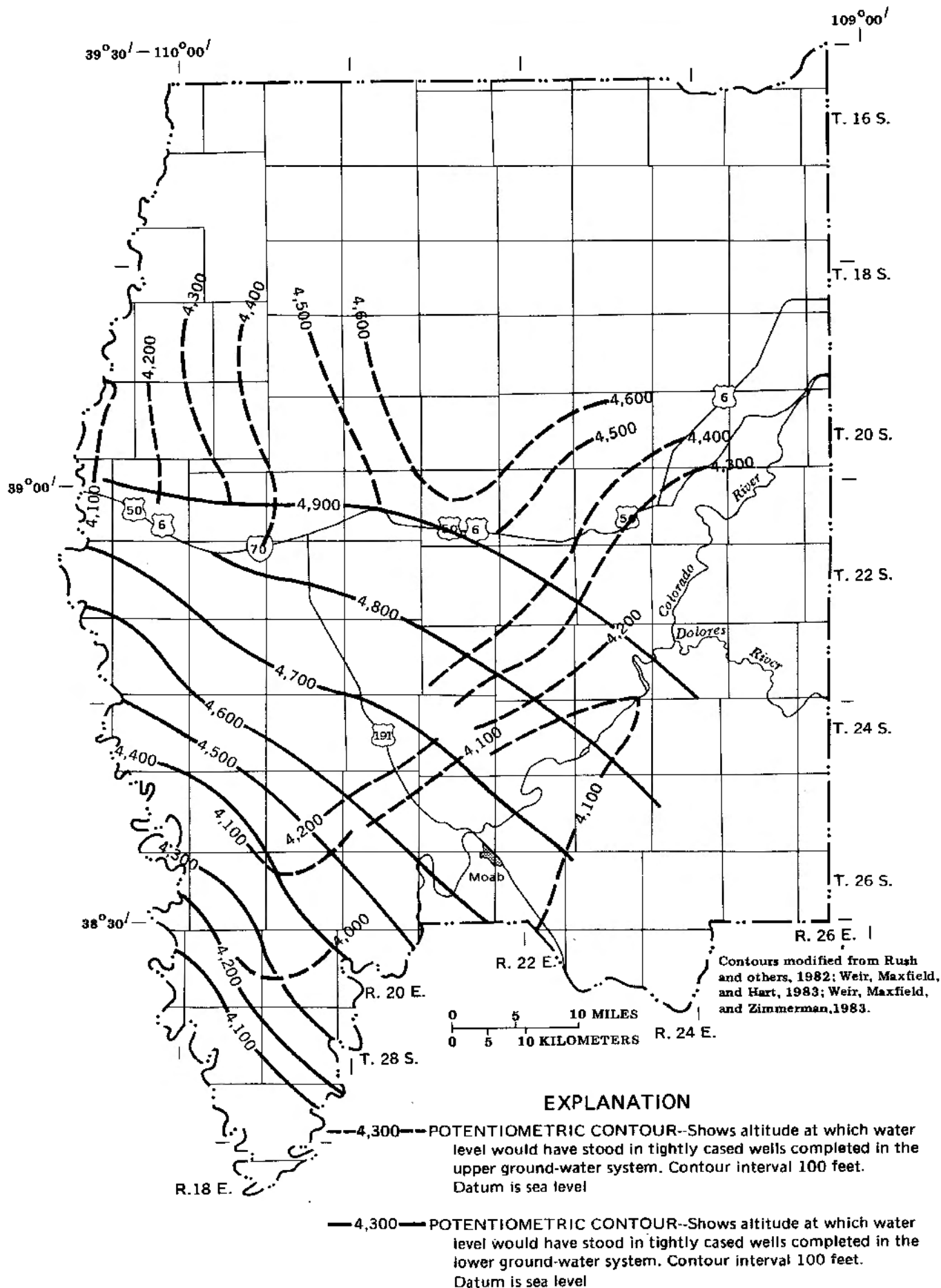


Figure 16.--Approximate potentiometric surface of water in the upper and lower ground-water systems.

GROUND-WATER CONDITIONS IN THE GLEN CANYON AQUIFER OF  
THE MILL CREEK-SPANISH VALLEY AREA

The Mill Creek-Spanish Valley area is located primarily in T. 26 and 27 S., R. 22 and 23 E. (fig. 17). The area includes about 37 square miles in the Mill Creek drainage and about 7 square miles in the Pack Creek drainage, southwest of the Mill Creek drainage. The Entrada Sandstone and the formations of the underlying Glen Canyon Group (the Navajo Sandstone, the Kayenta Formation, and the Wingate Sandstone) are exposed in most of the area (fig. 18). East of the Mill Creek-Spanish Valley area, the Summerville and the Morrison Formations are exposed.

In most of the Mill Creek drainage, the Entrada Sandstone and Glen Canyon Group dip to the west and southwest generally at less than 10 degrees (fig. 18). In the western part of the Mill Creek drainage and in the Pack Creek drainage, the geologic structure is more complex. Spanish Valley is in an eroded salt anticline (Weir, Maxfield, and Hart, 1983, p. 13); the area is faulted, and formations dip in various directions (fig. 18).

In the Mill Creek-Spanish Valley area, the Navajo and Wingate aquifers probably are in hydraulic connection because the intervening Kayenta Formation is mostly sandstone, and all three formations are jointed and fractured. The Navajo Sandstone, the Kayenta Formation, and the Wingate Sandstone form the Glen Canyon Group, and in this area contain one aquifer, designated the Glen Canyon aquifer. In the eastern part of the area, the Entrada aquifer also probably is in hydraulic connection with the underlying Glen Canyon aquifer. Areas of substantial discharge of ground water at the base of the Entrada aquifer were not observed; thus, suggesting that discharge is likely from the Entrada aquifer to the underlying Glen Canyon aquifer.

The Glen Canyon aquifer is the major consolidated-rock aquifer in the Grand County area. Most of the water supplied by the City of Moab is from wells and springs discharging from the Glen Canyon aquifer, and the principal culinary water-supply well for the Grand County Water Conservancy District is completed in the Glen Canyon aquifer.

Average annual precipitation in the Mill Creek-Spanish Valley area ranges from about 9 inches in the western part of the area near the mouth of North Fork of Mill Creek, to about 16 inches in the eastern part of the area near the eastern edge of the outcrop of the Entrada Sandstone (fig. 17). May-September precipitation ranges from less than 4 inches in the western part of the area to more than 6 inches in the eastern part. Precipitation increases with the altitude of the land surface: The altitude of the land surface increases from about 4,400 feet above sea level in the western part of the area to about 7,000 feet above sea level in the eastern part.

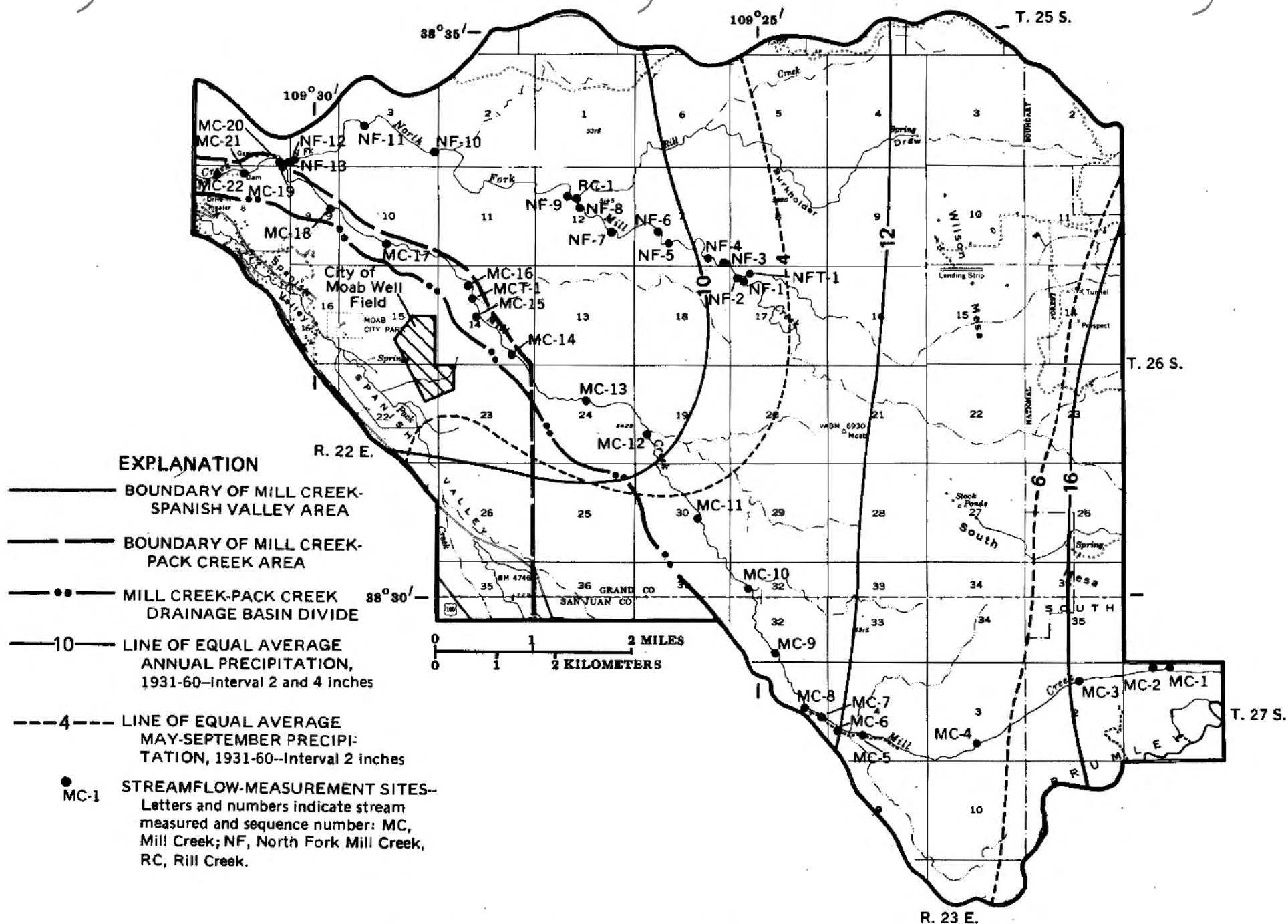


Figure 17.--Selected hydrologic data in the Mill Creek-Spanish Valley area.

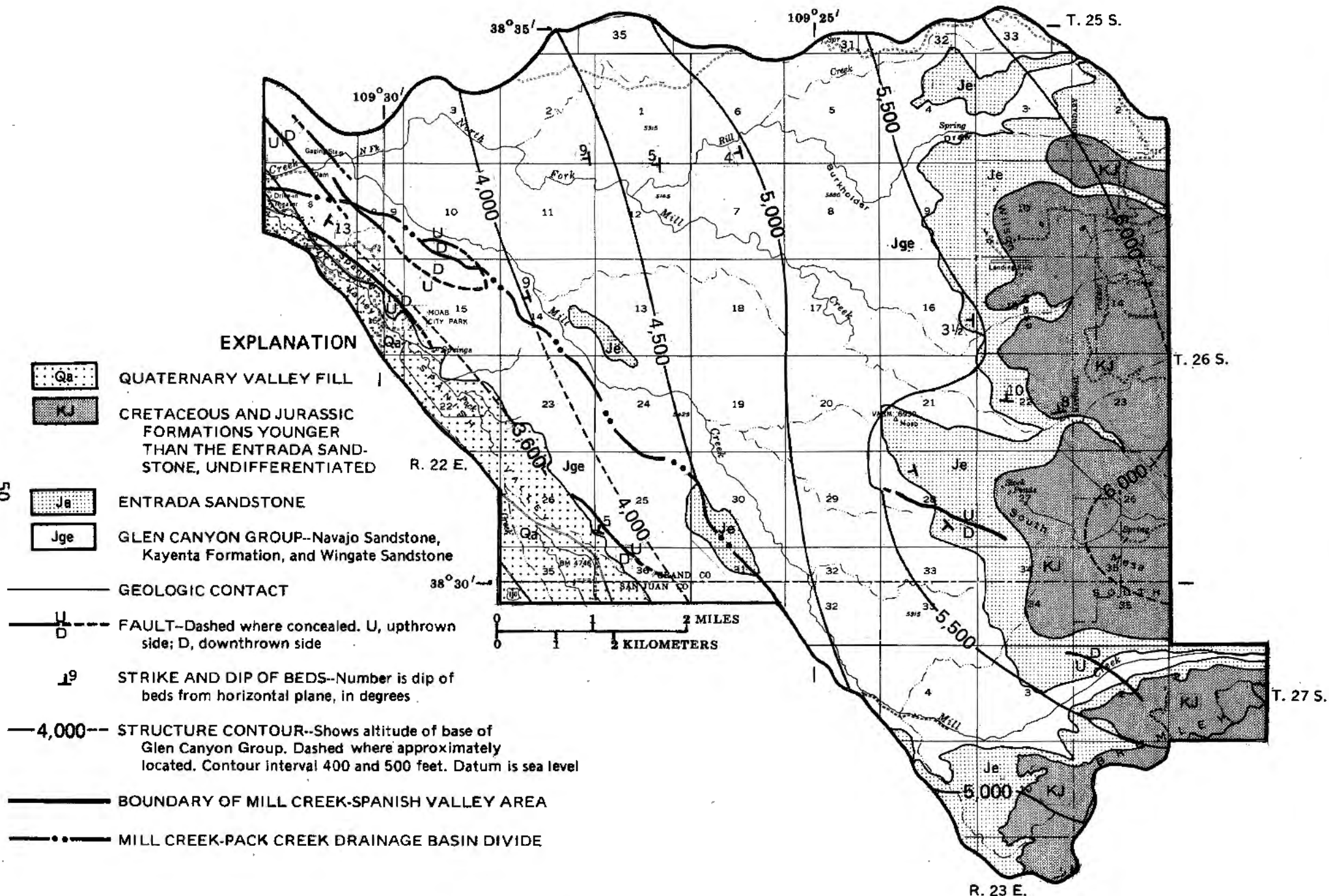


Figure 18.--Geology of the Mill Creek-Spanish Valley area.

### Recharge, Movement, and Discharge

Most of the outcrop areas of formations in the Glen Canyon Group probably receive some recharge. The surface of the outcrop generally has small domes and knolls alternating with enclosed depressions, and the depressions typically contain loose sand that has eroded from the outcrops. Precipitation that falls on the knolls runs off into the depressions and is retained there along with the precipitation that falls directly on the depressions. Where the loose sand in the depressions is more than about 6 feet thick, it aids in retention of precipitation by reducing the evaporation rate (Ripple and others, 1972). Additional recharge to the Glen Canyon aquifer occurs by streamflow loss along some reaches of Mill Creek.

In the Mill Creek-Spanish Valley area, the direction of movement of water in the upper ground-water system is generally to the west and west-northwest (fig. 9). The Glen Canyon aquifer is part of the upper ground-water system. Ground water moves downdip and westward from all parts of the outcrop area where recharge occurs, to some reaches of Mill Creek and the North Fork of Mill Creek and to Spanish Valley, where discharge occurs from seepage, springs, and wells.

In the Mill Creek-Pack Creek area, which is located in T. 26 S., R. 22 E. and is defined in figure 17, the direction of ground-water movement in the Glen Canyon aquifer generally is to the west and southwest, in places subperpendicular to the northeast canyon wall of Spanish Valley (fig. 19). The direction of movement of water in the Glen Canyon aquifer is oblique and in some places nearly perpendicular to that of water in the unconsolidated deposits of Spanish Valley, as shown by Sumsion (1971, pl. 2).

In the Mill Creek-Pack Creek area, discharge from the Glen Canyon aquifer occurs from wells and springs. Most of the discharge occurs along the northeast canyon wall of Spanish Valley in parts of sections 15, 22, and 23, and is from wells and springs owned by the City of Moab and the Grand County Water Conservancy District. From 1978 to 1986, average annual discharge from wells and springs owned by the two municipal water suppliers was about 2,000 acre-feet per year (fig. 20). In addition, about 200 acre-feet is discharged from privately owned domestic wells and springs. The total discharge from municipal wells and springs increased by about 40 percent from 1983 through 1986 as shown in figure 20. Spring discharge increased by about 200 percent, and well discharge decreased about 20 percent.

Streamflow gain-loss studies were conducted on Mill Creek and on the North Fork of Mill Creek during October 1985, to determine areas and approximate quantities of recharge and discharge along the streams (fig. 17; tables 9 and 10). In the following analysis, the streams were at or near base flow, and the values of instantaneous streamflow, in cubic feet per second, were converted to annual discharge, in acre-feet per year, by multiplying the instantaneous streamflow by 723.97. Gains and losses are reported in terms of streamflow; therefore, an increase in streamflow is equal to ground-water discharge, or loss of water from the Glen Canyon aquifer. Conversely, a decrease in streamflow is equal to ground-water recharge, or gain of water to the Glen Canyon aquifer.

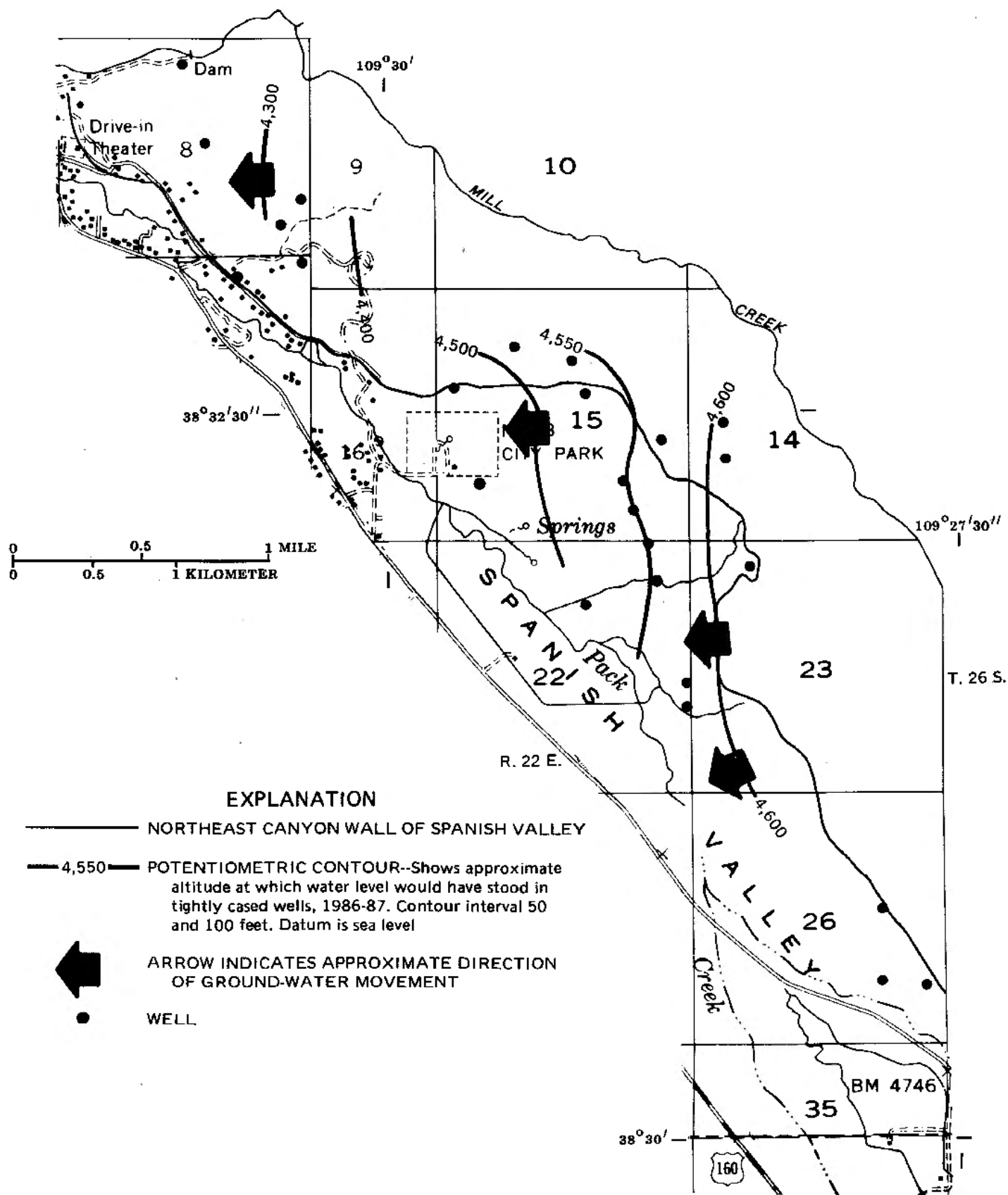


Figure 19.--Approximate potentiometric surface and direction of movement of water in the Glen Canyon aquifer in the Mill Creek-Pack Creek area, 1986-87.



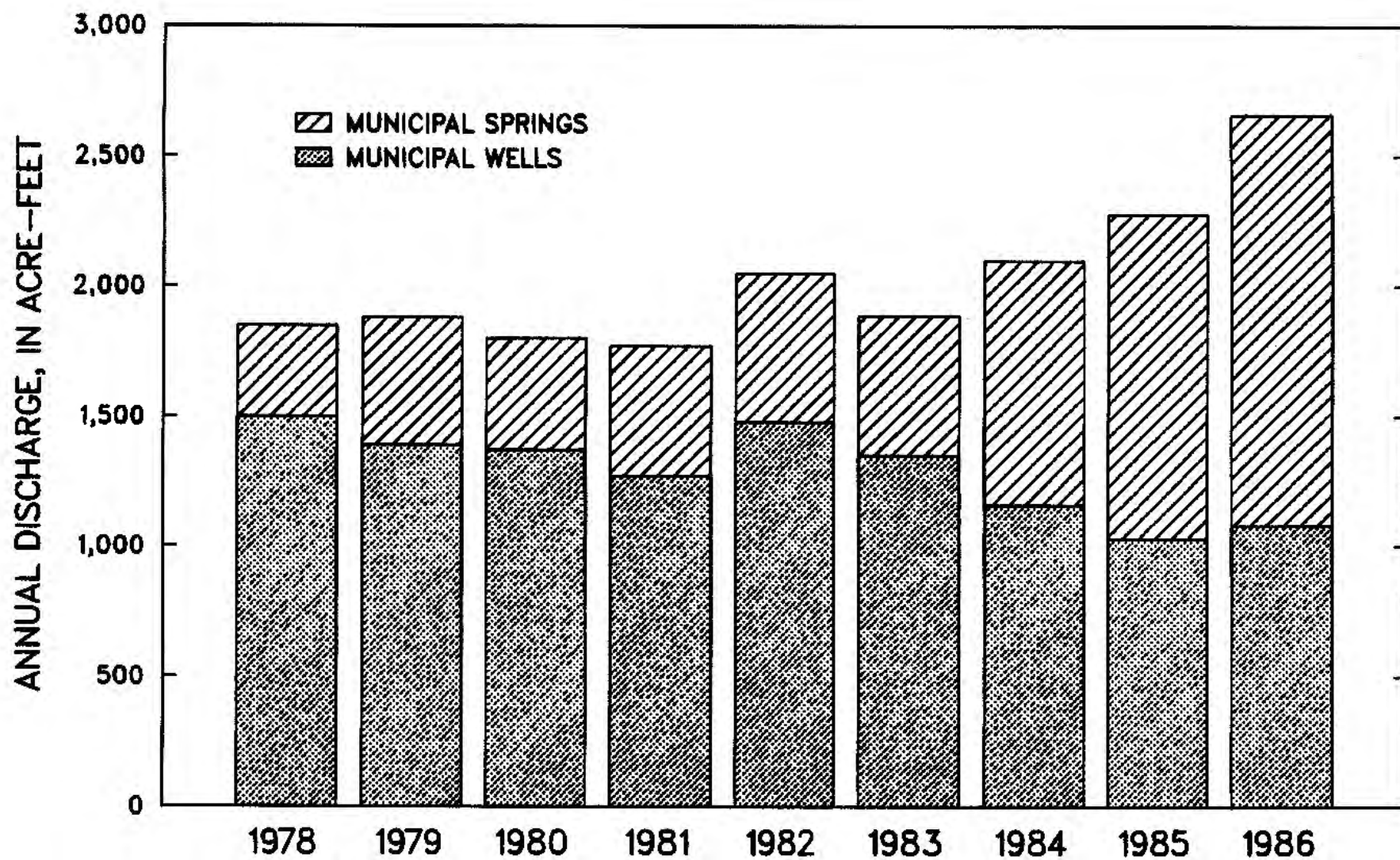


Figure 20.--Municipal well and spring discharge in the Mill Creek-Spanish Valley area, 1978-86.



Table 9.—*Miscellaneous streamflow measurements in Mill Creek  
and at points of tributary inflow*

[Abbreviations used in headings: ft<sup>3</sup>/s, cubic feet per second;  
acre-ft/yr, acre-feet per year]

| Measure-<br>ment site<br>(fig. 17) | Miles<br>downstream<br>from MC- 1 | Date     | Discharge            |              |
|------------------------------------|-----------------------------------|----------|----------------------|--------------|
|                                    |                                   |          | (ft <sup>3</sup> /s) | (acre-ft/yr) |
| MC- 1                              | —                                 | 10-21-85 | 10.20                | 7,384        |
| MC- 2                              | 0.2                               | do.      | 10.55                | 7,638        |
| MC- 5                              | 3.4                               | do.      | 13.14                | 9,513        |
| MC- 6                              | 3.7                               | do.      | 13.46                | 9,745        |
| MC- 7                              | 3.9                               | do.      | 12.66                | 9,165        |
| MC- 8                              | 4.1                               | do.      | 3.99                 | 2,889        |
| MC- 9                              | 4.8                               | do.      | 3.44                 | 2,490        |
| MC-10                              | 5.5                               | do.      | 3.53                 | 2,556        |
| MC-11                              | 6.4                               | do.      | 3.44                 | 2,490        |
| MC-12                              | 7.5                               | do.      | 3.52                 | 2,548        |
| MC-13                              | 8.4                               | do.      | 3.85                 | 2,787        |
| MC-14                              | 9.4                               | do.      | 3.47                 | 2,512        |
| MC-15                              | 9.9                               | do.      | 3.21                 | 2,324        |
| MCT-1                              | —                                 | do.      | 0.32                 | 232          |
| MC-16                              | 10.2                              | do.      | 3.58                 | 2,592        |
| MC-17                              | 11.2                              | do.      | 3.45                 | 2,498        |
| MC-18                              | 11.9                              | do.      | 3.33                 | 2,411        |
| MC-19                              | 12.7                              | do.      | 3.09                 | 2,237        |
| NF-13                              | —                                 | do.      | 3.73                 | 2,700        |
| MC-20                              | 12.8                              | do.      | 6.90                 | 4,995        |
| MC-21                              | 13.1                              | do.      | 7.18                 | 5,198        |
| MC- 5                              | 3.4                               | 10-23-85 | 13.03                | 9,433        |
| MC- 6                              | 3.7                               | do.      | 12.80                | 9,267        |
| MC- 7                              | 3.9                               | do.      | 11.90                | 8,615        |
| MC- 1                              | —                                 | 10-24-85 | 9.27                 | 6,711        |
| MC- 3                              | 1.0                               | do.      | 8.97                 | 6,494        |
| MC- 4                              | 2.2                               | do.      | 9.90                 | 7,167        |
| MC- 5                              | 3.4                               | do.      | 10.42                | 7,544        |
| MC-21                              | 13.1                              | 10-14-86 | 6.74                 | 4,880        |
| MC-22                              | 13.4                              | do.      | 6.41                 | 4,641        |

Table 10.—*Miscellaneous streamflow measurements in the North Fork of Mill Creek and at points of tributary inflow*

[Abbreviations used in headings: ft<sup>3</sup>/s, cubic feet per second; acre-ft/yr, acre-feet per year]

| Measure-<br>ment site<br>(fig. 17) | Miles<br>downstream<br>from NF- 1 | Date     | Discharge            |              |
|------------------------------------|-----------------------------------|----------|----------------------|--------------|
|                                    |                                   |          | (ft <sup>3</sup> /s) | (acre-ft/yr) |
| NF- 1                              | —                                 | 10-24-85 | 0.42                 | 304          |
| NFT-1                              | —                                 | do.      | .34                  | 246          |
| NF- 2                              | 0.1                               | do.      | .76                  | 550          |
| NF- 3                              | .3                                | 10-22-85 | 1.01                 | 731          |
| NF- 4                              | .5                                | do.      | 1.17                 | 847          |
| NF- 5                              | 1.1                               | 10-23-85 | 1.32                 | 956          |
| NF- 6                              | 1.4                               | do.      | 2.18                 | 1,578        |
| NF- 7                              | 2.0                               | do.      | 3.03                 | 2,194        |
| NF- 8                              | 2.5                               | do.      | 2.66                 | 1,926        |
|                                    |                                   | 10-22-85 | 2.76                 | 1,998        |
| RC- 1                              | —                                 | do.      | .13                  | 94           |
| NF- 9                              | 2.6                               | do.      | 2.80                 | 2,027        |
| NF-10                              | 4.7                               | do.      | 3.19                 | 2,309        |
| NF-11                              | 5.6                               | do.      | 3.21                 | 2,324        |
| NF-12                              | 6.5                               | do.      | 3.28                 | 2,375        |
| NF-13                              | 6.6                               | 10-21-85 | 3.73                 | 2,700        |

Water discharges from consolidated rock to Mill Creek in the eastern part of the Mill Creek-Spanish Valley area. In the 3.4 stream miles between sites MC-1 and MC-5 (fig. 17; table 9), streamflow in Mill Creek increased by about 2,100 acre-ft/yr on October 21, 1985, and about 800 acre-ft/yr on October 24, 1985. In the next 0.5 stream mile, between sites MC-5 and MC-7, the flow in Mill Creek decreased by about 350 acre-ft/yr on October 21, 1985, and decreased by about 800 acre-ft/yr on October 23, 1985. The net discharge from bedrock between sites MC-1 and MC-7 ranged from 0 to 1,750 acre-ft/yr.

The streamflow in Mill Creek is affected by the Sheley diversion between sites MC-7 and MC-8. The decrease in streamflow between these two sites primarily is a result of the diversion of streamflow and not the loss of streamflow to the ground-water system. Some streamflow may be gained from or lost to the ground-water system between MC-7 and MC-8, but the amount is unknown. Downstream from the Sheley diversion, in the 8.6-mile reach between sites MC-8 and MC-19, streamflow in Mill Creek decreased by about 650 acre-ft/yr (table 9). Water from Mill Creek recharges the ground-water system in this reach.

Ground water discharges to the North Fork of Mill Creek throughout most of its reach, and most of the discharge occurs in the upper reaches of the North Fork. In the 2.4 stream miles between sites NF-2 and NF-8, streamflow

increased by about 1,400 acre-ft/yr (table 10). In the next 4 stream miles, between sites NF-9 and NF-12, streamflow increased about 350 acre-ft/yr. The total streamflow in the North Fork is about 2,700 acre-ft/yr, and this amount is equal to discharge from the Glen Canyon aquifer.

The total increase in streamflow, or ground-water discharge, in the Mill Creek drainage ranged from about 2,050 to about 3,800 acre-ft/yr--from about -650 to about 1,100 acre-ft/yr in Mill Creek and about 2,700 acre-ft/yr in North Fork. The combined annual discharge to streams in the Mill Creek drainage and discharge from springs and wells in the Mill Creek-Pack Creek area, then, is 4,200 to 6,000 acre-ft.

#### Aquifer Characteristics

The City of Moab well field is located on the limb of the salt anticline in which Spanish Valley is located. Near the well field, the Glen Canyon aquifer is faulted (fig. 18), and the fractures in the Glen Canyon aquifer were observed in the field. Springs discharge from the Glen Canyon aquifer in the well field. These geologic and hydrologic conditions could result in anisotropic conditions caused by fractures, impermeable boundary conditions caused by faults, or recharge boundaries caused by springs.

In order to determine which of these conditions are present in the Glen Canyon aquifer, and in order to estimate which conditions might dominate, an 8-day aquifer test was conducted in the City of Moab well field. One discharging well and seven observation wells were used in the test. The discharging well was City of Moab well number 6, (D-26-22)15dca-1.

Plots of the drawdown data from each well did not fit standard drawdown curves. Plots of data from the discharging well and four observation wells showed excess drawdown at late time, indicating the presence of impermeable boundaries. Plots of water-level data from two observation wells showed no drawdown, also indicating impermeable boundaries.

Specific-capacity values were reported for 14 wells completed in the Glen Canyon aquifer and inventoried in the Mill Creek-Spanish Valley area. The values ranged from 0.25 to 167 (gal/min)/ft (fig. 21; table 8), and the median value was 12.5 (gal/min)/ft. The wide range of values also suggests that impermeable boundaries are present in the Glen Canyon aquifer.

At well (D-26-22)26dbd-1, the specific capacity was 167 (gal/min)/ft, more than twice as much as at any of the other 14 wells. At this well, the saturated Glen Canyon aquifer is overlain by 36 feet of saturated valley fill. The valley fill may be hydraulically connected to the Glen Canyon aquifer, and may contribute to the relatively large specific capacity of the well.

The above evidence indicates that in the City of Moab well-field area, the Glen Canyon Group is structurally complex, and that aquifer characteristics of the Glen Canyon aquifer vary considerably in short distances. The value of aquifer characteristics of the Glen Canyon aquifer at any given location can be accurately estimated only by site-specific investigation.

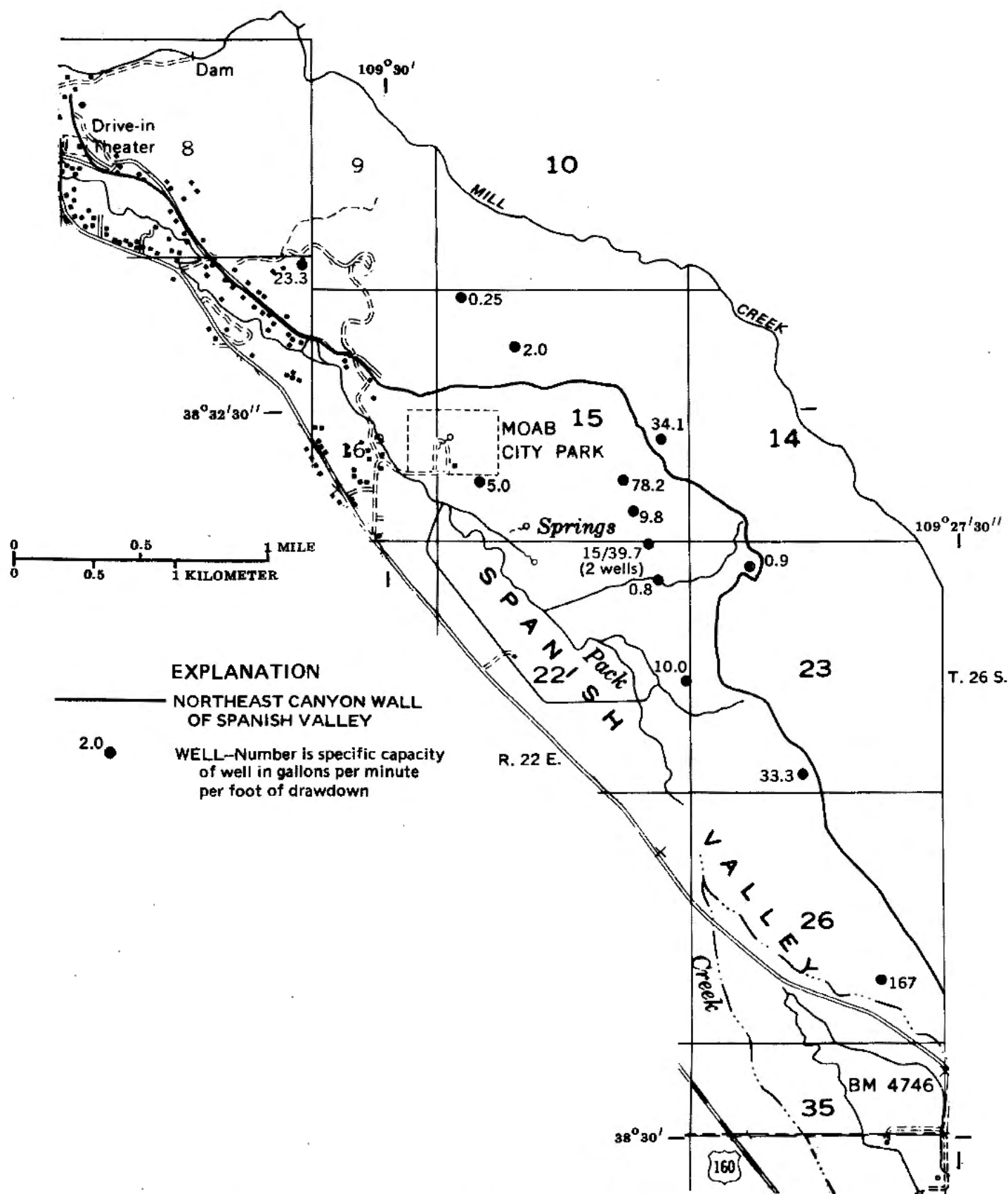


Figure 21.—Specific capacity of wells completed in the Glen Canyon aquifer in the Mill Creek-Pack Creek area.

### Storage and Water Levels

The total quantity of water stored in the Glen Canyon aquifer in the Mill Creek-Spanish Valley area is unknown because water levels are only available in the Mill Creek-Pack Creek area, and the thickness of the aquifer is not well known in any part of the area. Available water levels, however, indicate substantial variations in storage with time in the City of Moab well field. Observations about variations in storage with time include: (1) Water levels were lower in 1987 than in 1961 and 1962, (2) water levels declined from the early 1960's to about 1979, and then rose through 1987, (3) there is a correlation between precipitation and water levels, and (4) there is substantial drawdown during the summer pumping season and subsequent recovery during the fall and winter. Water levels for selected wells in the City of Moab well field are shown in table 11, and hydrographs for these wells are shown in figure 22.

Data from City of Moab well numbers 4 and 5 indicate that 1987 water levels were lower than those of 1961 and 1962. The January 1987 water level was about 11.6 feet lower in well number 4 and 1.4 feet lower in well number 5 (table 11). Data from well numbers 5, 7, and 10 indicate that water levels declined between the early 1960's and about 1979, and rose from about 1979 to the present (1987). In well number 5, the water level declined between 1962 and 1979; in well number 7, the water level declined between 1972 and 1979; and in well number 10, the water level declined between 1976 and 1979. The decline in water level in well number 10 between 1976 and 1979 indicates that the lowest water level occurred after 1976, but there are no water-level data available between 1976 and 1979 or between 1979 and 1985 to determine in what year water-level declines ceased, and water levels began rising.

Water levels in wells 5, 7, and 10 rose about 15, 37, and 35 feet, respectively, between January 1979 and January 1986, and the water level in well 9 rose about 24 feet between October 1978 and January 1986. The large rises between 1978 or 1979 and 1986 suggest that water levels began rising considerably before 1985, and possibly as early as about 1979. Between January 1986 and January 1987, the rise in water levels in wells 4, 5, 7, and 10 ranged from about 1.4 to 3.0 feet, and between March 1986 and March 1987, the rise in the water level in well 9 was about 3.5 feet, indicating that the trend in rising water levels continued from 1986 to 1987.

Precipitation at the Moab Airport was larger than normal in every year between 1977 and 1986 except 1982 and 1985, and it was several inches above normal in 1978, 1980-81, 1983-84, and 1986 (fig. 6). The period of rise in water levels roughly correlates to the period of larger-than-normal precipitation, and the time correlation suggests that ground-water levels in the area respond fairly rapidly to changes in annual precipitation.

Water-level recovery from seasonal pumping in the City of Moab well field has been documented for three seasons: 1978-79, 1985-86, and 1986-87 (fig. 22; table 11). Water-level increases in wells 5, 7, and 10 ranged from 5 to 18 feet between October 1978 and January 1979. Water-level increases in wells 4, 5, 7, and 10 ranged from about 1.6 to 6.9 feet between September 1985 and January 1986; and from about 2.9 to 7.3 feet between August 1986 and January 1987. The water-level recovery period normally extends into April when seasonal pumping begins, but the previously-discussed aquifer test was

Table 11.—Water levels in selected observation wells

Well number: See "Numbering system for hydrogeologic-data sites", p. 5 and figure 2.

Altitude of well: Altitude of land surface, in feet above sea level; altitudes interpolated from U.S. Geological Survey topographic maps.

Water level: Measured water level, in feet below land surface.

(D-26-22)15daa- 2  
City of Moab well number 10  
Altitude of well: 4,640 feet

| Date     | Water level | Date     | Water level | Date     | Water level | Date     | Water level |
|----------|-------------|----------|-------------|----------|-------------|----------|-------------|
| 07/15/76 | 146.00      | 10/01/78 | 174.00      | 01/01/79 | 160.00      | 08/15/85 | 132.66      |
| 09/27/85 | 131.16      | 10/29/85 | 129.14      | 11/27/85 | 127.40      | 12/28/85 | 125.95      |
| 01/16/86 | 125.29      | 01/24/86 | 125.02      | 01/28/86 | 124.70      | 02/14/86 | 127.46      |
| 03/26/86 | 127.14      | 04/29/86 | 125.61      | 05/31/86 | 126.34      | 06/22/86 | 127.47      |
| 07/27/86 | 128.41      | 08/31/86 | 128.47      | 09/30/86 | 127.31      | 11/04/86 | 125.64      |
| 01/10/87 | 122.31      |          |             |          |             |          |             |

(D-26-22)15ddc- 1  
City of Moab well number 7  
Altitude of well: 4,600 feet

| Date     | Water level | Date     | Water level | Date     | Water level | Date     | Water level |
|----------|-------------|----------|-------------|----------|-------------|----------|-------------|
| 10/27/72 | 68.00       | 10/01/78 | 88.00       | 01/01/79 | 70.00       | 08/15/85 | 41.64       |
| 09/26/85 | 40.32       | 10/28/85 | 37.20       | 11/27/85 | 35.43       | 12/28/85 | 34.00       |
| 01/16/86 | 33.40       | 01/24/86 | 33.11       | 01/28/86 | 32.83       | 02/14/86 | 35.69       |
| 03/26/86 | 36.84       | 04/29/86 | 34.32       | 07/27/86 | 38.74       | 08/31/86 | 37.79       |
| 09/30/86 | 35.52       | 11/04/86 | 33.94       | 01/10/87 | 30.50       |          |             |

(D-26-22)22aab- 1  
City of Moab well number 4  
Altitude of well: 4,580 feet

| Date     | Water level | Date     | Water level | Date     | Water level | Date     | Water level |
|----------|-------------|----------|-------------|----------|-------------|----------|-------------|
| 05/18/61 | 16.00       | 03/01/69 | 31.00       | 09/26/85 | 35.33       | 10/28/85 | 32.92       |
| 11/27/85 | 31.17       | 12/28/85 | 29.79       | 01/16/86 | 30.11       | 01/23/86 | 29.62       |
| 01/28/86 | 28.66       | 01/31/86 | 31.64       | 02/05/86 | 34.52       | 02/10/86 | 32.03       |
| 02/15/86 | 31.38       | 02/20/86 | 30.73       | 02/25/86 | 30.29       | 02/28/86 | 30.46       |
| 03/05/86 | 30.46       | 03/10/86 | 30.84       | 03/15/86 | 30.39       | 03/20/86 | 30.68       |
| 03/25/86 | 31.36       | 03/26/86 | 31.88       | 03/31/86 | 31.28       | 04/05/86 | 30.34       |
| 04/10/86 | 30.51       | 04/15/86 | 30.48       | 04/20/86 | 30.31       | 04/25/86 | 31.56       |
| 04/30/86 | 29.77       | 05/05/86 | 30.30       | 05/10/86 | 30.12       | 05/15/86 | 31.70       |
| 05/20/86 | 30.46       | 05/25/86 | 30.42       | 05/31/86 | 33.99       | 06/05/86 | 34.25       |
| 06/10/86 | 32.66       | 06/15/86 | 32.27       | 06/20/86 | 32.20       | 06/25/86 | 32.45       |
| 06/30/86 | 33.32       | 07/05/86 | 36.52       | 07/10/86 | 33.63       | 07/15/86 | 33.09       |
| 07/20/86 | 34.47       | 07/25/86 | 33.11       | 07/31/86 | 33.56       | 08/05/86 | 34.43       |
| 08/10/86 | 33.86       | 08/15/86 | 33.49       | 08/20/86 | 33.87       | 08/25/86 | 34.32       |
| 08/31/86 | 33.50       | 09/05/86 | 32.96       | 09/10/86 | 32.46       | 09/15/86 | 32.74       |
| 09/20/86 | 36.16       | 09/25/86 | 32.38       | 09/30/86 | 31.34       | 10/15/86 | 30.52       |
| 10/20/86 | 30.05       | 10/25/86 | 31.94       | 10/31/86 | 30.43       | 11/04/86 | 29.65       |
| 01/06/87 | 27.63       | 01/07/87 | 27.63       | 01/08/87 | 27.54       | 01/09/87 | 27.57       |
| 01/10/87 | 27.63       | 03/11/87 | 26.94       |          |             |          |             |

(D-26-22)22aac- 1  
City of Moab well number 5  
Altitude of well: 4,580 feet

| Date     | Water level | Date     | Water level | Date     | Water level | Date     | Water level |
|----------|-------------|----------|-------------|----------|-------------|----------|-------------|
| 08/20/62 | 1.00        | 10/01/78 | 24.00       | 01/01/79 | 19.00       | 08/16/85 | 6.39        |
| 09/26/85 | 6.87        | 10/28/85 | 5.23        | 11/27/85 | 4.53        | 12/28/85 | 4.05        |
| 01/16/86 | 3.82        | 01/24/86 | 3.72        | 01/28/86 | 3.65        | 02/14/86 | 3.79        |
| 03/26/86 | 3.99        | 04/29/86 | 3.84        | 05/31/86 | 5.59        | 06/22/86 | 5.49        |
| 07/27/86 | 5.16        | 08/31/86 | 5.29        | 09/30/86 | 4.40        | 11/04/86 | 3.24        |
| 01/10/87 | 2.41        |          |             |          |             |          |             |

Table 11.—Water levels in selected observation wells—Continued

(D-26-22)23bba-1  
City of Moab well number 9  
Altitude of well: 4,720 feet

| Date     | Water level | Date     | Water level | Date     | Water level | Date     | Water level |
|----------|-------------|----------|-------------|----------|-------------|----------|-------------|
| 04/07/75 | 32.00       | 10/01/78 | 40.00       | 09/26/85 | 17.91       | 10/28/85 | 17.31       |
| 11/27/85 | 16.97       | 12/28/85 | 16.54       | 01/16/86 | 16.32       | 01/25/86 | 18.83       |
| 01/28/86 | 16.12       | 01/31/86 | 15.99       | 02/05/86 | 15.90       | 02/10/86 | 15.96       |
| 02/15/86 | 15.81       | 02/20/86 | 15.80       | 02/25/86 | 15.89       | 02/28/86 | 15.80       |
| 03/05/86 | 15.74       | 03/10/86 | 15.52       | 03/15/86 | 15.57       | 03/20/86 | 15.84       |
| 03/25/86 | 15.49       | 03/31/86 | 15.44       | 04/05/86 | 15.45       | 04/10/86 | 15.29       |
| 04/15/86 | 15.24       | 04/20/86 | 15.33       | 04/25/86 | 14.99       | 04/30/86 | 15.16       |
| 05/05/86 | 14.96       | 05/10/86 | 15.00       | 05/15/86 | 15.03       | 05/20/86 | 14.86       |
| 05/25/86 | 14.96       | 05/31/86 | 14.78       | 06/05/86 | 14.76       | 06/10/86 | 15.00       |
| 06/15/86 | 14.77       | 06/20/86 | 14.77       | 06/25/86 | 14.80       | 06/30/86 | 14.74       |
| 07/05/86 | 14.71       | 07/10/86 | 14.69       | 07/15/86 | 14.70       | 07/20/86 | 14.68       |
| 07/25/86 | 14.62       | 07/31/86 | 14.54       | 08/05/86 | 14.50       | 08/10/86 | 14.51       |
| 08/15/86 | 14.43       | 08/20/86 | 14.49       | 08/25/86 | 14.38       | 08/31/86 | 14.28       |
| 09/05/86 | 14.26       | 09/10/86 | 14.17       | 09/15/86 | 14.09       | 09/20/86 | 14.06       |
| 09/25/86 | 13.94       | 09/30/86 | 13.91       | 03/11/87 | 12.10       |          |             |

conducted in January and February 1986, and pumping during the test disrupted the normal recovery of water levels during that period. Drawdown of water levels due to pumping in wells 4, 5, 7, and 10 ranged from about 1.5 to 4.4 feet between January 16, 1986, when the aquifer test began, and August 31, 1986, which was about the end of the pumping season.

#### Chemical Quality

Water samples from 15 wells and 4 springs were analyzed to determine water-quality characteristics of the Glen Canyon aquifer in the Mill Creek-Pack Creek area (table 4). The concentration of dissolved solids ranged from 150 to 674 mg/L. The cation type in all of the samples was calcium magnesium, but the anion type varied from bicarbonate to bicarbonate sulfate to sulfate bicarbonate, and the ratio of milliequivalents of bicarbonate to sulfate ranged from 12.9:1 to 0.5:1. The shift in anion type from bicarbonate to sulfate bicarbonate, the increase in concentration of dissolved solids, and the decrease in the ratio of bicarbonate to sulfate all occurred from the north and east to the south and west (figs. 23 and 24).

In T. 26 S., R. 22 E., section 26, the chemistry of water is representative of the Glen Canyon aquifer where it is overlain by saturated valley fill. In the Glen Canyon aquifer, the water type is calcium magnesium sulfate bicarbonate, the dissolved-solids concentration of the water is larger than 400 mg/L, and the bicarbonate-to-sulfate ratio is less than one. Water in several wells completed in the valley fill has similar chemical characteristics (figs. 23 and 24; table 4). These observations suggest that the valley fill and the underlying Glen Canyon aquifer are hydraulically connected.



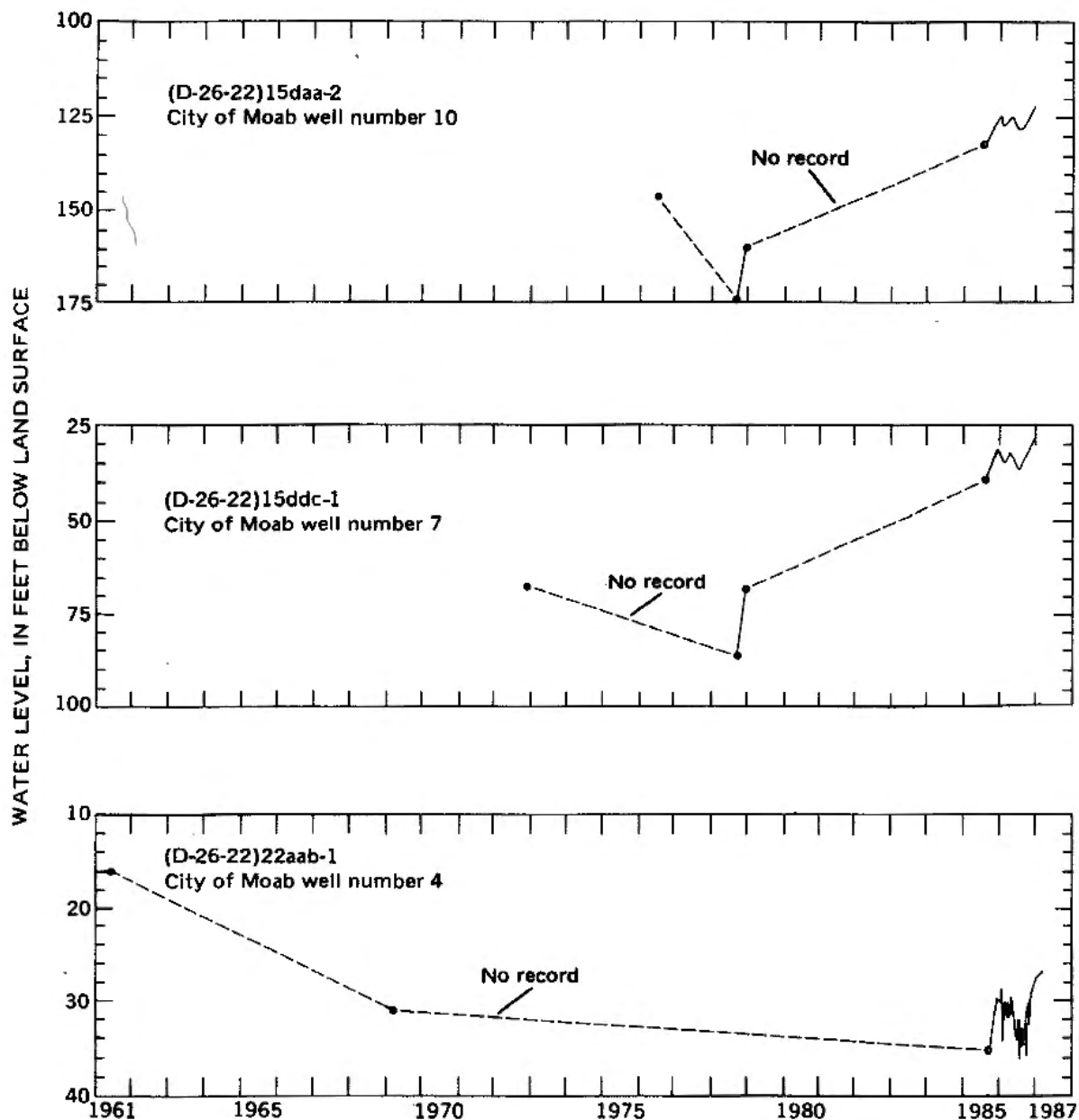


Figure 22.--Hydrographs of wells in the City of Moab well field.

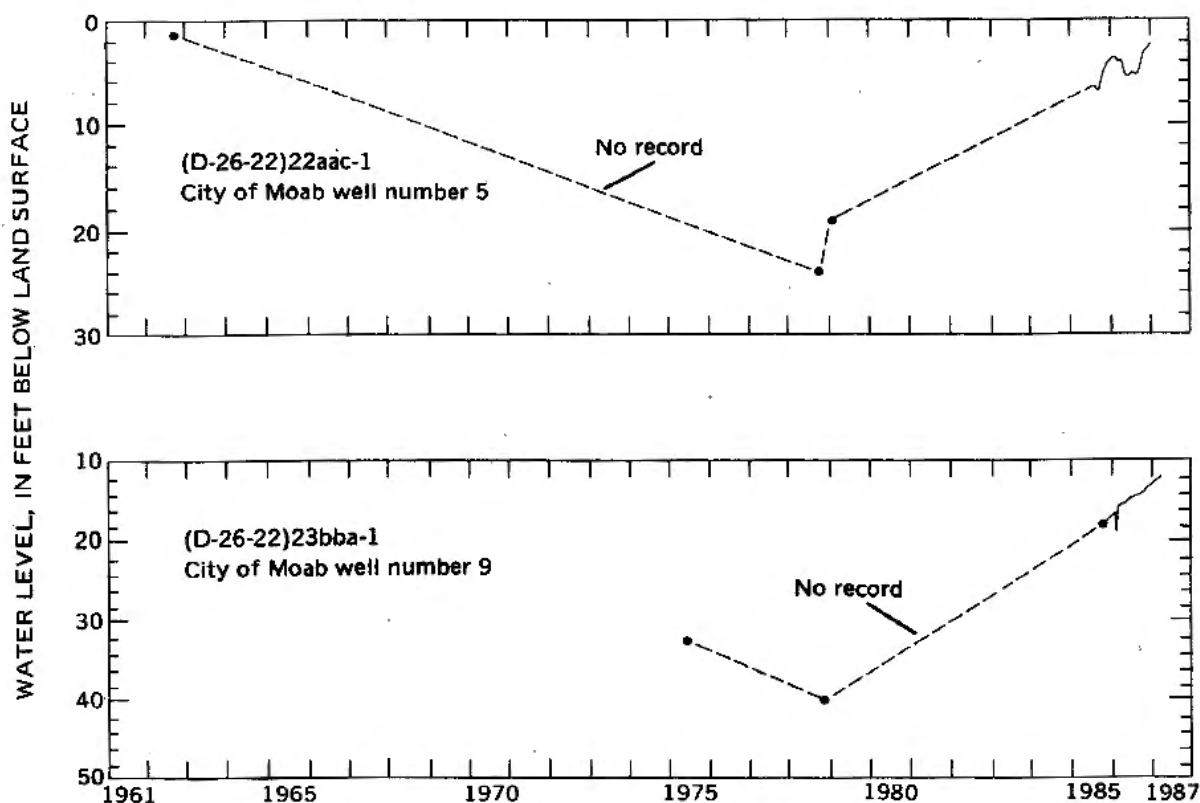


Figure 22.--Hydrographs of wells in the City of Moab well field--Continued.

In sections 8, 9, 14, and the northern part of 15, north of the northeast canyon wall of Spanish Valley, the chemistry of water from the Glen Canyon aquifer where it is not overlain by valley fill is similar to that of water in the Glen Canyon aquifer near the recharge area to the east. The water type is calcium magnesium bicarbonate, the dissolved-solids concentration of the water is about 150 mg/L [about 200 mg/L at well (D-26-22)8bad-1], and the bicarbonate-to-sulfate ratio is more than about three. These characteristics are typical of ground water in recharge areas (Freeze and Cherry, 1979, p. 241-244).

The spatial variation in the water-quality characteristics in the Glen Canyon aquifer probably results from mixing of ground water from the valley fill in Spanish Valley with water from the Glen Canyon aquifer. Sumsion (1971, pl. 2) indicated that water in the valley fill in Spanish Valley generally moves down-valley from southeast to northwest, in a direction nearly parallel to the canyon walls on the sides of Spanish Valley (the deviations from this direction in T. 26 S., R. 22 E., sections 15 and 22, are because the water-level contours in that area are based in part on water levels in the Glen Canyon aquifer, rather than solely on water levels in the valley fill). Water in the Glen Canyon aquifer moves west and, in some areas, southwest as shown in figure 19. Water from the two sources converges and mixes along the northeast canyon wall of Spanish Valley and west of the canyon wall.

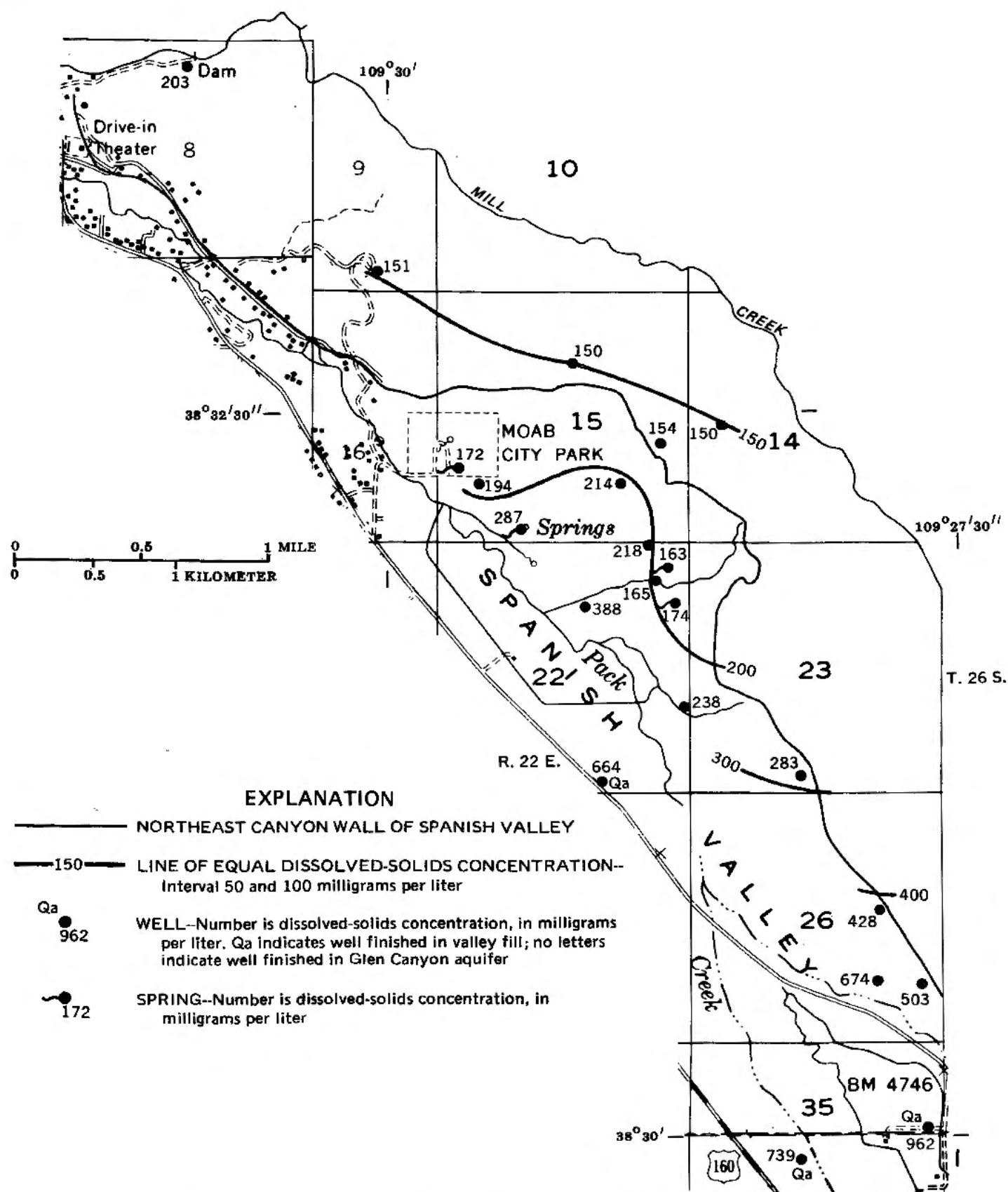


Figure 23.--Concentration of dissolved solids in water from the Glen Canyon aquifer and from overlying valley fill in the Mill Creek-Pack Creek area.

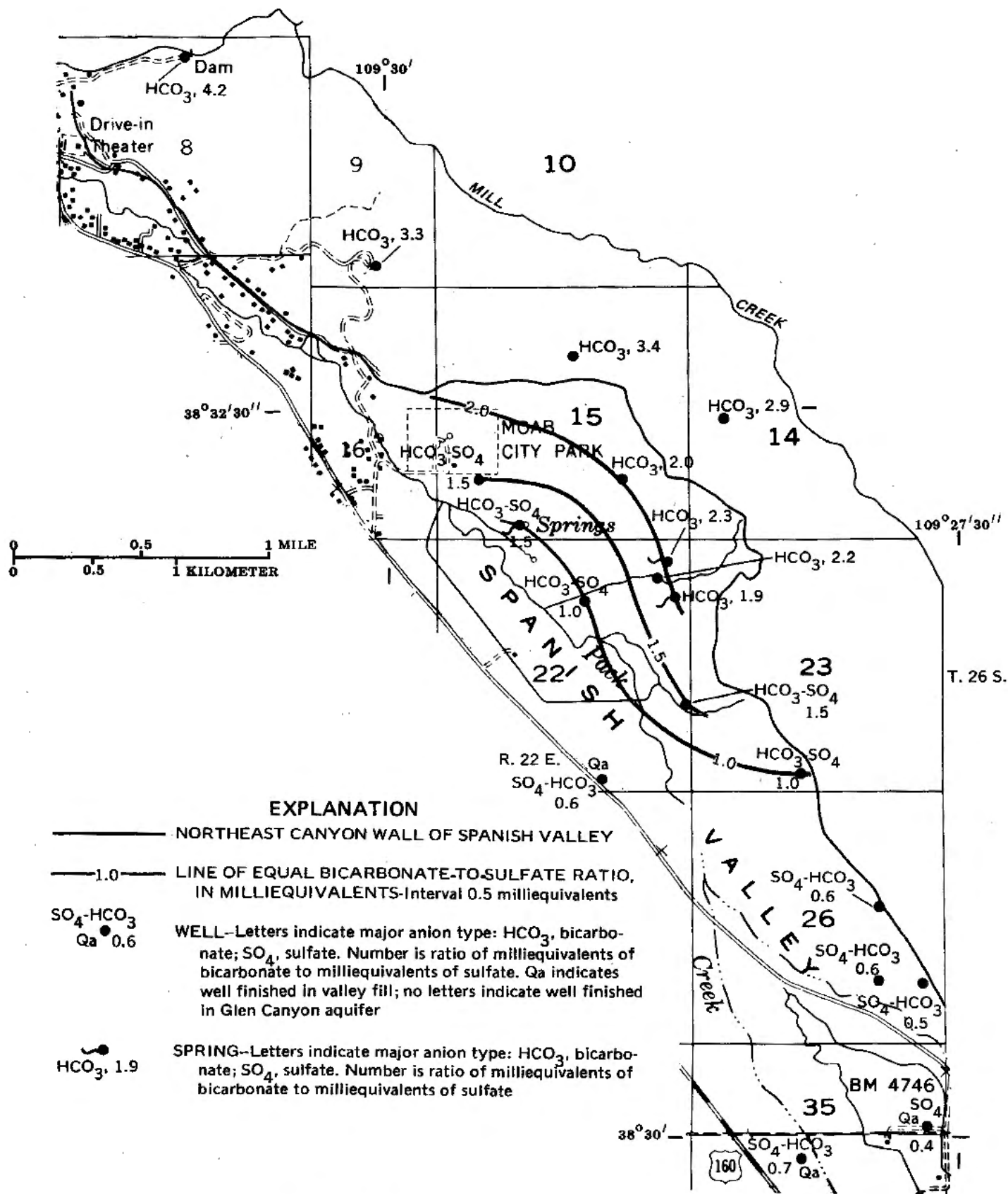


Figure 24--Anion chemistry of water from the Glen Canyon aquifer and from overlying valley fill in the Mill Creek-Pack Creek area.

The proportion of water from the two sources dictates the water-quality characteristics of water being pumped in sections 15 and 22, in the eastern part of Spanish Valley. Water withdrawn in the north half of section 15 has water-quality characteristics similar to those of water in the Glen Canyon aquifer to the east. Water withdrawn in section 22, just to the south of section 15, has water-quality characteristics similar to water from the valley fill aquifer to the southeast (fig. 23). The gradual decrease in the bicarbonate-to-sulfate ratio from 3.0 or greater in sections 8, 9, 14, and the northern half of 15, to less than 1.0 in sections 26, 35, and the western half of 22 (fig. 24) also show this gradual mixing of the two different water types.

A change in water quality with time was observed at City of Moab well number 6. From 1978 to 1986, average annual discharge from the well was about 500 acre-ft/yr. Specific conductance was 268  $\mu\text{S}/\text{cm}$  (microsiemens per centimeter at 25 degrees Celsius) in March 1969 and 360  $\mu\text{S}/\text{cm}$  in August 1985 (table 4); however, specific conductance decreased from 360 to 290  $\mu\text{S}/\text{cm}$  from August 1985 to January 1986.

Specific conductance was measured in well number 6 during January and February 1986 when the well was being pumped as part of an aquifer test. During the aquifer test, specific conductance was 290  $\mu\text{S}/\text{cm}$  after 20 minutes of pumping at about 1,670 gal/min, and increased to 345  $\mu\text{S}/\text{cm}$  after about 2 1/2 days of pumping at about the same rate. This increase is about 60 percent of the increase observed between March 1969 and August 1985.

The small difference in specific conductance between March 1969 (268  $\mu\text{S}/\text{cm}$ ) and January 1986 (290  $\mu\text{S}/\text{cm}$ ) indicates that long-term changes in water quality at the well site are minimal. The March 1969 sample was collected at the beginning of or possibly prior to the pumping season, and the August 1985 sample was collected during the pumping season. The differences between 1969 and 1985 samples are probably attributable to seasonal pumping. Seasonal pumping may change the proportion of water entering the well from the Glen Canyon aquifer and from ground water moving down Spanish Valley.

#### SUMMARY AND CONCLUSIONS

The Grand County area is located in southeastern Utah, and includes about 3,980 square miles in Grand County, the Mill Creek and Pack Creek drainages in San Juan County, and the area between the Colorado and Green Rivers in San Juan County. The principal consolidated-rock aquifers in the Grand County area are the Entrada, Navajo, and Wingate aquifers in the Entrada Sandstone, the Navajo Sandstone, and the Wingate Sandstone. The Glen Canyon aquifer in the Glen Canyon Group is the principal consolidated-rock aquifer in the Mill Creek-Spanish Valley area. The Glen Canyon Group is comprised of the Navajo Sandstone, the Kayenta Formation, and the Wingate Sandstone. The Glen Canyon aquifer is used only in the Mill Creek-Spanish Valley area. Elsewhere in the study area, the separate Navajo and Wingate aquifers are used. Other consolidated-rock units known to yield water in the Grand County area are the Parachute Creek Member of the Green River Formation, the Wasatch Formation, the Cedar Mountain Formation, the Brushy Basin Shale and Salt Wash Sandstone Members of the Morrison Formation, the White Rim Sandstone Member of the Cutler Formation, and the undifferentiated Cutler Formation.

Springs discharge from the Parachute Creek Member of the Green River Formation and from the Wasatch Formation in outcrop areas north of the Book Cliffs, in the northern part of the Grand County area. The springs discharge at rates ranging from less than 1 to about 20 gal/min, and the water is fresh; concentrations of dissolved solids are about 600 mg/L or less.

Water from springs and flowing wells discharges from the Cedar Mountain Formation and the Brushy Basin Shale and Salt Wash Sandstone Members of the Morrison Formation in an outcrop band south of the Book Cliffs, and water from one spring discharges from the Salt Wash Member of the Morrison Formation on the lower flanks of the La Sal Mountains. Discharge rates typically are less than 1 gal/min. The water is slightly saline; concentrations of dissolved solids range from about 1,000 to 1,500 mg/L.

Wells are completed in and springs and seeps discharge from the White Rim Sandstone Member of the Cutler Formation in and north of Canyonlands National Park. Water from wells typically is slightly saline, and water from springs and seeps is fresh.

About 30 wells are completed in the undifferentiated Cutler Formation along the west side of Castle Valley. Measured specific capacity of the wells ranged from less than 0.01 to 4.0 (gal/min)/ft of drawdown. Five wells produced from 20 to 40 gal/min for 2 hours without measurable drawdown. Water in three sampled wells was slightly saline to saline; concentrations of dissolved solids ranged from 1,420 to 3,450 mg/L. Water from the wells also had concentrations of selenium that exceeded the State of Utah primary drinking-water standard of 10 µg/L.

The Entrada Sandstone, the Navajo Sandstone, and the Wingate Sandstone crop out extensively in the southern one-third of the Grand County area; however, few wells have been completed in these aquifers. Characteristics typical of springs in the Entrada, Navajo, and Wingate aquifers are: (1) Discharge is less than 5 gal/min, (2) concentrations of dissolved solids in the water are less than 200 mg/L, (3) the water type is calcium bicarbonate or calcium magnesium bicarbonate, and (4) the water is moderately hard to hard. Springs with larger discharge rates are present near the intersection of the Colorado River and Moab Valley.

In the Mill Creek-Spanish Valley area, the Navajo Sandstone, the Wingate Sandstone, and the intervening Kayenta Formation, which comprise the Glen Canyon Group, combine to form the Glen Canyon aquifer. Most of the recharge to the Glen Canyon aquifer in the area occurs in the outcrop area of the Glen Canyon Group east of Spanish Valley. Movement of ground water generally is westward and southwestward toward Spanish Valley, and much of the water moves toward the City of Moab well field.

The principal area of discharge from the Glen Canyon aquifer in the Mill Creek-Spanish Valley area occurs in and near the City of Moab well field, along the northeast canyon wall of Spanish Valley. Near the well field, average annual discharge from municipal wells and springs between 1978 and 1986 was about 2,000 acre-ft/yr. Several wells in the area have discharge rates that exceed 1,000 gal/min, and two springs in the area have discharge rates that exceed 300 gal/min.

Water levels in the Mill Creek-Pack Creek area declined between the early 1960's and about 1979, and then rose as much as 39.5 feet from 1979 through 1987. Precipitation was consistently above normal from 1977 through 1986, and it appears that the larger-than-normal quantity of precipitation is a contributing factor to the rise in water levels. Water levels fluctuate seasonally in response to pumping in the City of Moab well field. Between August 1986 and January 1987, recovery from seasonal pumping ranged from about 2.9 to 7.3 feet.

Water-quality characteristics typical of water in the Glen Canyon aquifer are: (1) Concentrations of dissolved solids are between 150 and 220 mg/L, (2) the water type is calcium magnesium bicarbonate, and (3) the water is hard. West and south of the City of Moab well field, concentrations of dissolved solids and sulfate increase because an increasingly larger proportion of the ground water is derived from valley-fill deposits to the southeast, in Spanish Valley, and a smaller proportion is derived from the Glen Canyon aquifer.



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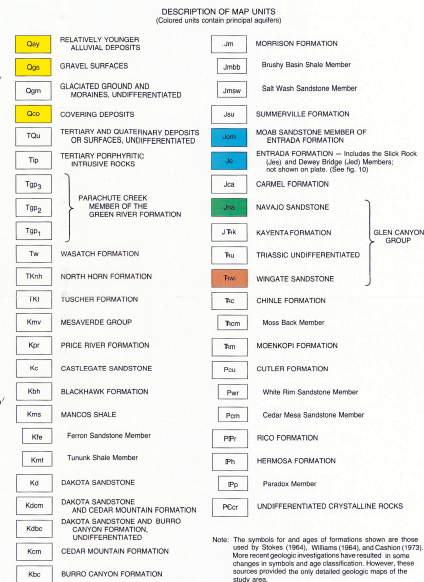
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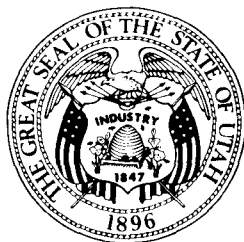
# MAP SHOWING GENERAL GEOLOGY OF THE GRAND COUNTY AREA, UTAH





**STATE OF UTAH  
DEPARTMENT OF NATURAL RESOURCES**

**Technical Publication No. 32**



**GEOLOGY AND WATER RESOURCES OF THE SPANISH VALLEY  
AREA, GRAND AND SAN JUAN COUNTIES, UTAH**

**by**

**C. T. Sumsion, Hydrologist  
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**Prepared by the U.S. Geological Survey  
in cooperation with  
the Utah Department of Natural Resources  
Division of Water Rights**

**1971**





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# **GEOLOGY AND WATER RESOURCES OF THE SPANISH VALLEY AREA, GRAND AND SAN JUAN COUNTIES, UTAH**

by

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## **ABSTRACT**

The Spanish Valley area covers about 144 square miles on the western slopes of the La Sal Mountains in southeastern Utah; within it, Spanish Valley comprises about 18 square miles. Altitudes of land surface within the area range from about 3,950 feet at the Colorado River near Moab to 12,646 feet at Mount Mellenthin in the La Sal Mountains. Principal streams in the area are Mill and Pack Creeks; they join near Moab, and Mill Creek enters the Colorado River.

The climate ranges from arid and semiarid in the canyons and valleys at lower altitudes to generally humid and cool in the higher parts of the La Sal Mountains. The precipitation at Moab is fairly evenly distributed throughout the year, but slightly more falls during the winter than during the summer. Mean annual precipitation is about 8 inches at the city of Moab in Spanish Valley, and the weighted normal annual precipitation on the entire Spanish Valley area is about 15 inches.

Sedimentary formations exposed in the area range in age from Middle Pennsylvanian to Holocene, attaining a total maximum exposed thickness of nearly 6,400 feet. They are intruded by igneous stocks, laccoliths, sills, and dikes of Tertiary age which form the La Sal Mountains. The unconsolidated valley fill of Pleistocene and Holocene age in Spanish Valley attains a maximum thickness of more than 360 feet.

Little of the precipitation on Spanish Valley enters the ground-water system. Snowfall in the upland areas melts slowly and contributes most of the ground-water recharge by movement through sandstones of the Glen Canyon Group to the valley fill of Spanish Valley. Ground water occurs under water-table conditions in the valley fill, which consists generally of gravelly sand. The long-term specific yield of the valley fill is estimated to be about 0.25, and total ground-water storage about 200,000 acre-feet. Aquifer characteristics vary throughout the valley. Well yields may be as much as 1,000 gallons per minute with but 35 feet of drawdown in the valley fill. Where sandstones of the Glen Canyon Group are intensely fractured northeast of Spanish Valley, they yield large quantities of ground water to springs and wells.

Inflow to the Spanish Valley area is about 115,000 acre-feet annually from precipitation; of this, about 28,000 acre-feet is discharged annually from Spanish Valley by surface streams and from the ground-water reservoir, and the remainder is discharged by evapotranspiration in the Spanish Valley area.

Annual recharge to and discharge from the ground-water basin in Spanish Valley are estimated to be 14,000 acre-feet. Only 3,300 acre-feet is used for beneficial purposes in the valley. Of the remainder, ground-water outflow to the Colorado River is estimated to be 8,000 acre-feet, and about 3,000 acre-feet is consumed in an area of phreatophytes and hydrophytes.



Predictions of the effects of water levels that would be caused by continuation of withdrawals at nearly the 1969 rate or by a threefold increase in rate of withdrawal were made by means of an electric analog model of Spanish Valley. The predictions indicate that existing water levels in the valley would be least affected if any additional withdrawal of ground water were at the northwest end of the valley. The additional amount of ground water which could be diverted for beneficial use from present consumptive use in the area of phreatophytes and hydrophytes is estimated to be 190 acre-feet per year.

The chemical quality of water in the Spanish Valley area is generally good. Mill Creek contains water of better chemical quality than does Pack Creek, but both are used as a source of water for irrigation. Ground water in the valley fill in the southeast part of Spanish Valley contains the greatest concentration of dissolved solids in the area and is not suitable for public supply. Ground water entering Spanish Valley from the northeast through sandstones of the Glen Canyon Group is of suitable chemical quality for public supply. Natural mixing of the two types of water results in a progressive northwestward decrease in the concentration of dissolved solids in the ground water in the valley fill.

## **INTRODUCTION**

### **Location and extent of the area**

The Spanish Valley area covers about 144 square miles on the western slopes of the La Sal Mountains in southeastern Utah; within it, Spanish Valley comprises about 18 square miles. Altitudes of land surface within the area range from about 3,950 feet at the Colorado River near Moab to 12,646 feet at Mount Mellenthin in the La Sal Mountains. Principal streams in the area are Mill and Pack Creeks; they join near Moab, and Mill Creek enters the Colorado River.

The Mill Creek-Pack Creek drainage basin extends from southeast to northwest between a drainage divide along the lofty crests of the La Sal Mountains and a base level at the meanders of the turbid Colorado River. The drainage basin covers about 144 square miles in southeastern Utah (pl.1).

At the west edge of the drainage basin, the elongate, crag-walled trough that forms Spanish and Moab Valleys covers about 18 square miles. The northwestern, topographically lower, part of the trough in the vicinity of the city of Moab is known as Moab Valley, and the southeastern part of the trough is known as Spanish Valley. Spanish and Moab Valleys are not topographically or geologically separable; they are in this report referred to as Spanish Valley, and the entire Mill Creek-Pack Creek drainage basin, for purposes of this report, is referred to as the "Spanish Valley area."

The area is within Tps. 25-28 S., Rs. 21-24 E., Salt Lake Base Line and Meridian. It is covered by the following U.S. Geological Survey 15-minute topographic quadrangle maps: Moab, Utah; Castle Valley, Utah; Polar Mesa, Utah-Colo.; La Sal Junction, Utah; and La Sal, Utah-Colo. (p. 1).

U.S. Highway 160 traverses Spanish Valley and passes through the city of Moab. Many secondary and unpaved roads provide access to nearly all parts of the Spanish Valley area. About 245 miles of major State and Federal highways link the area with Salt Lake City.

### **Purpose and scope**

This water-resources investigation was initiated in order to provide an estimate of the average annual water yield of the Mill Creek-Pack Creek drainage basin, the parts of that total yield available as surface water and ground water, the amount of ground water that might be recovered for beneficial use, and the effect of this use on the usable ground-water storage within the valley fill in Spanish and Moab Valleys. Detailed information has been sought which is basic to the establishment of sound policies for the development and management of water resources. The investigation was carried out as part of water-resources investigations in Utah with the Utah Division of Water Rights, Department of Natural Resources. Fieldwork was done during the period July 1967-November 1969.

### **Previous investigations**

A general description of the geology and possibilities of oil occurrence in part of the Spanish Valley area, including some references to water, is given by Baker (1933).

The structural and igneous geology of the La Sal Mountains is described in detail by Hunt (1958).

Quaternary stratigraphy and the Pleistocene-Holocene physiographic development of the La Sal Mountains area, including Spanish Valley, is given a detailed analytical description by Richmond (1962).

A regional study of the Upper Colorado River Basin by Iorns, Hembree, and Oakland (1965) supplies basic data and summarizes the quantitative and qualitative hydrology of a region in which Spanish Valley is centrally located.

A reconnaissance survey of regional ground-water data by Feltis (1966) describes the occurrence and quality of water in bedrock aquifers of eastern Utah, including the Spanish Valley area.

#### **Acknowledgments**

Cooperation and assistance by H.D. Donaldson, H.E. Staker, and others in the Utah Division of Water Rights is gratefully acknowledged. Appreciation is due many residents of Moab and Spanish Valley for their gracious contributions of information and other assistance.

#### **Well- and spring-numbering system**

The system of numbering wells and springs in Utah is based on the cadastral land-survey system of the Federal Government, and the number describes the location of the well or spring within the land net. By this system, the State is divided into four quadrants by the Salt Lake Base Line and Meridian. The quadrants are designated A, B, C, and D; indicating the northeast, northwest, southwest, and southeast quadrants, respectively. The quadrant letter is followed by numbers indicating the township and range (in that order); the quadrant letter, township, and range are separated by dashes and enclosed in parentheses. A number following the parentheses designates the section, and is followed by three letters indicating the quarter section (generally 160 acres), quarter-quarter section (40 acres), and quarter-quarter-quarter section (10 acres) in which the well or spring is located. A number following the section subdivisions is the serial number of the particular well or spring in the given 10-acre tract; springs are designated by the letter S preceding the serial number. If a well or spring cannot be located to the nearest 10 acres, the serial number is omitted; but the S designating a spring is retained at the end of the number. Thus well number (D-26-21)1bda-1 is the first well constructed or visited in the NE $\frac{1}{4}$ SE $\frac{1}{4}$ NW $\frac{1}{4}$  sec. 1, T. 26 S., R. 21 E. The well- and spring-numbering system is illustrated in figure 1.

#### **Use of metric units**

In this report, concentrations of dissolved solids and individual ions determined by chemical analysis and the temperatures of air and water are given in metric units. This change from reporting in English units has been made as a part of a gradual change to the metric system that is underway within the scientific community. The change is intended to promote greater uniformity in reporting of data. Chemical data for concentrations are reported in milligrams per liter (mg/l) rather than in parts per million (ppm), the units used in earlier reports in this series. For concentrations less than 7,000 mg/l, the number reported is about the same as for concentrations in parts per million.

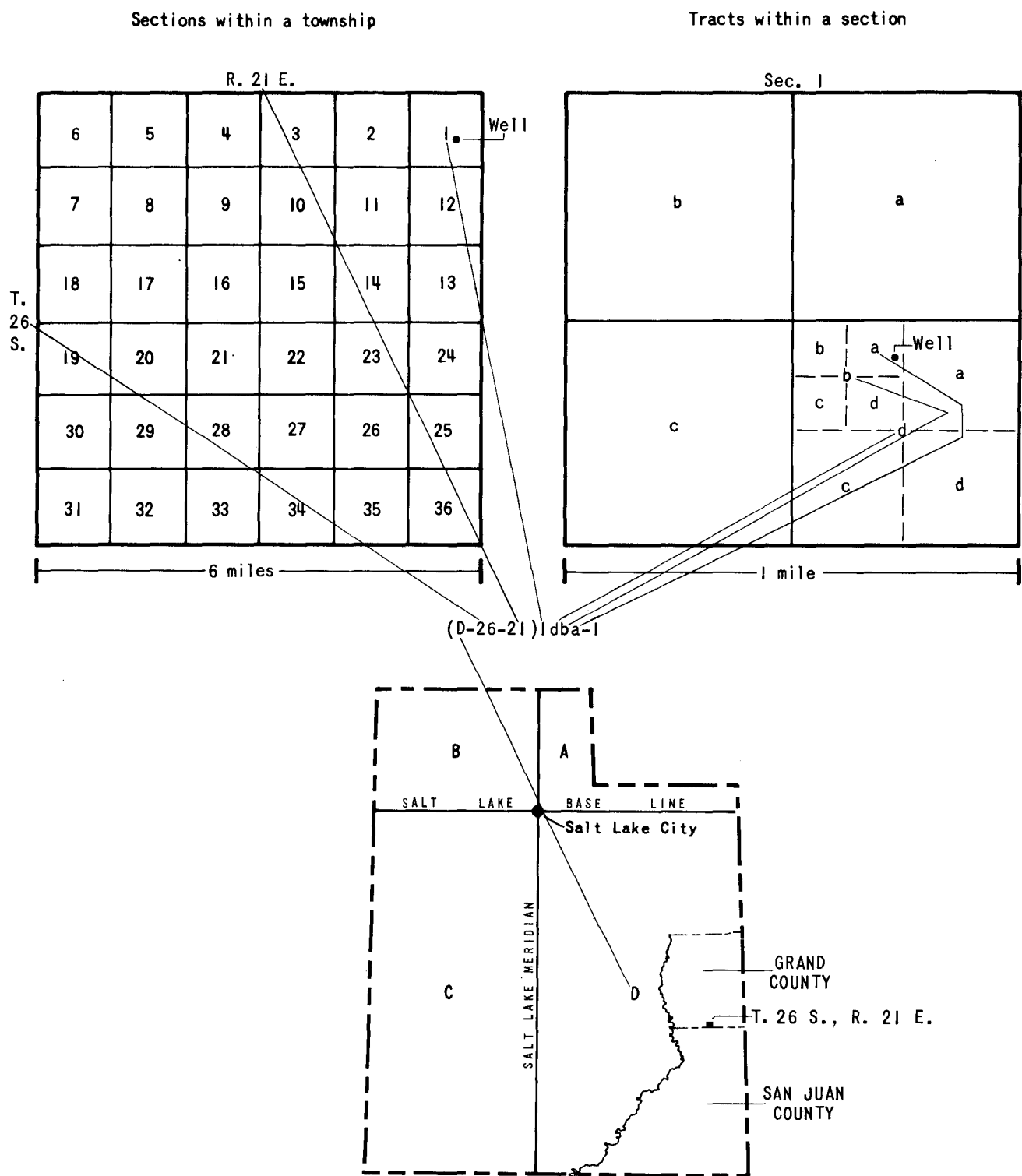


Figure 1.—Well- and spring-numbering system used in Utah

Water temperature is reported in degrees Celsius ( $^{\circ}\text{C}$ ), but the customary English unit of degrees Fahrenheit ( $^{\circ}\text{F}$ ) follows in parentheses in the text. Air temperature is reported in  $^{\circ}\text{F}$ , but the equivalent temperature in  $^{\circ}\text{C}$  follows in parentheses in the text for easier comparison with water temperature in tables. The reporting of temperatures in both metric and English units is done to assist those readers who are not familiar with the Celsius temperature scale. The following conversion table will also help to clarify the relation between degrees Fahrenheit and degrees Celsius:

#### TEMPERATURE-CONVERSION TABLE

Temperatures in  $^{\circ}\text{C}$  are rounded to nearest 0.5 degree. Underscored temperatures are exact equivalents. To convert from  $^{\circ}\text{F}$  to  $^{\circ}\text{C}$  where two lines have the same value for  $^{\circ}\text{F}$ , use the line marked with an asterisk (\*) to obtain equivalent  $^{\circ}\text{C}$ .

| $^{\circ}\text{C}$ | $^{\circ}\text{F}$ | $^{\circ}\text{C}$ | $^{\circ}\text{F}$ | $^{\circ}\text{C}$ | $^{\circ}\text{F}$ | $^{\circ}\text{C}$ | $^{\circ}\text{F}$ | $^{\circ}\text{C}$ | $^{\circ}\text{F}$ | $^{\circ}\text{C}$ | $^{\circ}\text{F}$ | $^{\circ}\text{C}$ | $^{\circ}\text{F}$ |
|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|
| <u>-20.0</u>       | <u>-4</u>          | <u>-10.0</u>       | <u>14</u>          | <u>0.0</u>         | <u>32</u>          | <u>10.0</u>        | <u>50</u>          | <u>20.0</u>        | <u>68</u>          | <u>30.0</u>        | <u>86</u>          | <u>40.0</u>        | <u>104</u>         |
| -19.5              | -3                 | -9.5               | 15                 | +0.5               | 33                 | 10.5               | 51                 | 20.5               | 69                 | 30.5               | 87                 | 40.5               | 105                |
| -19.0              | -2                 | -9.0               | 16                 | 1.0                | 34                 | 11.0               | 52                 | 21.0               | 70                 | 31.0               | 88                 | 41.0               | 106                |
| -18.5              | -1                 | -8.5               | 17                 | 1.5                | 35                 | 11.5               | 53                 | 21.5               | 71                 | 31.5               | 89                 | 41.5               | 107                |
| -18.0              | * 0                | -8.0               | * 18               | 2.0                | * 36               | 12.0               | * 54               | 22.0               | * 72               | 32.0               | * 90               | 42.0               | * 108              |
| -17.5              | 0                  | -7.5               | 18                 | 2.5                | 36                 | 12.5               | 54                 | 22.5               | 72                 | 32.5               | 90                 | 42.5               | 108                |
| -17.0              | 1                  | -7.0               | 19                 | 3.0                | 37                 | 13.0               | 55                 | 23.0               | 73                 | 33.0               | 91                 | 43.0               | 109                |
| -16.5              | 2                  | -6.5               | 20                 | 3.5                | 38                 | 13.5               | 56                 | 23.5               | 74                 | 33.5               | 92                 | 43.5               | 110                |
| -16.0              | 3                  | -6.0               | 21                 | 4.0                | 39                 | 14.0               | 57                 | 24.0               | 75                 | 34.0               | 93                 | 44.0               | 111                |
| -15.5              | 4                  | -5.5               | 22                 | 4.5                | 40                 | 14.5               | 58                 | 24.5               | 76                 | 34.5               | 94                 | 44.5               | 112                |
| <u>-15.0</u>       | <u>5</u>           | <u>-5.0</u>        | <u>23</u>          | <u>5.0</u>         | <u>41</u>          | <u>15.0</u>        | <u>59</u>          | <u>25.0</u>        | <u>77</u>          | <u>35.0</u>        | <u>95</u>          | <u>45.0</u>        | <u>113</u>         |
| -14.5              | 6                  | -4.5               | 24                 | 5.5                | 42                 | 15.5               | 60                 | 25.5               | 78                 | 35.5               | 96                 | 45.5               | 114                |
| -14.0              | 7                  | -4.0               | 25                 | 6.0                | 43                 | 16.0               | 61                 | 26.0               | 79                 | 36.0               | 97                 | 46.0               | 115                |
| -13.5              | 8                  | -3.5               | 26                 | 6.5                | 44                 | 16.5               | 62                 | 26.5               | 80                 | 36.5               | 98                 | 46.5               | 116                |
| -13.0              | 9                  | -3.0               | 27                 | 7.0                | 45                 | 17.0               | 63                 | 27.0               | 81                 | 37.0               | 99                 | 47.0               | 117                |
| -12.5              | 10                 | -2.5               | 28                 | 7.5                | 46                 | 17.5               | 64                 | 27.5               | 82                 | 37.5               | 100                | 47.5               | 118                |
| -12.0              | * 10               | -2.0               | * 28               | 8.0                | * 46               | 18.0               | * 64               | 28.0               | * 82               | 38.0               | * 100              | 48.0               | * 118              |
| -11.5              | 11                 | -1.5               | 29                 | 8.5                | 47                 | 18.5               | 65                 | 28.5               | 83                 | 38.5               | 101                | 48.5               | 119                |
| -11.0              | 12                 | -1.0               | 30                 | 9.0                | 48                 | 19.0               | 66                 | 29.0               | 84                 | 39.0               | 102                | 49.0               | 120                |
| -10.5              | 13                 | -0.5               | 31                 | 9.5                | 49                 | 19.5               | 67                 | 29.5               | 85                 | 39.5               | 103                | 49.5               | 121                |

For temperature conversions beyond the limits of the table, use the equation  $C = 0.5556 (F - 32)$  and  $F = (1.8 (^{\circ}\text{C}) + 32)$ . The formulae say, in effect, that from the freezing point of water ( $0^{\circ}\text{C}$ ,  $32^{\circ}\text{F}$ ) the temperature in  $^{\circ}\text{C}$  rises (or falls)  $5^{\circ}$  for every rise (or fall) of  $9^{\circ}\text{F}$ .

## **GEOGRAPHY**

### **Physiography and drainage**

The Spanish Valley area is centrally located in the Canyon Lands section of the Colorado Plateaus physiographic province, as delineated by Fenneman and Johnson (1946). Marked contrasts in landforms and colors characterize the area, from the summits and slopes of the La Sal Mountains to the steep-walled canyons and the floor of Spanish Valley. Richmond (1962, p. 6) finds the area to have six physiographic subdivisions: (1) igneous mountains, (2) hogbacks, (3) plateaus, (4) cuervas, (5) pediments, and (6) canyons.

The high, eastern divide of the area is at or near the crest of the laccolithic La Sal Mountain group. The highest peak on the drainage divide is Mount Mellenthin, which reaches an altitude of 12,646 feet. Glaciation during Pleistocene and Holocene times has eroded cirques near the summits and deposited thin moraines on the higher slopes of the mountains.

The dioritic-intrusive stocks of Tertiary age exposed in the mountain groups are rimmed by hogbacks of Triassic and Jurassic sandstone formations. The hogbacks generally are covered by colluvium except at their ridge tops and where they are breached by transverse streams and canyons.

West of the mountains, the hogbacks give way to gently sloping cuervas and pediments, which are dissected by steep-walled sandstone canyons. Some of the west-trending canyons, such as the North Fork of Mill Creek, cross the generally northwest-trending structure of the area obliquely, suggesting superposition of the canyon streams on the sandstone strata from an earlier alluvial cover. The dissected cuervas and pediments yield to sandstone mesas adjacent to Spanish Valley.

Spanish Valley resembles a structural trough, but it has a more complex geologic history (Baker, 1933, p. 63-67). It contrasts in origin and in all dimensions with the deep meandering canyons that dissect the higher terrain. The rectilinear, northwest-trending valley is about 13½ miles in length and averages about 1½ miles in width. Its surface has an average slope of about 120 feet per mile.

Stream patterns are dendritic in the upper reaches of the Spanish Valley area. In lower parts of the area they assume a roughly parallel pattern, with the exceptions noted above, which appear to be related to regional structure. The lowest altitude is about 3,950 feet, at the Colorado River.

### **Climate**

#### **Topographic influence**

The region about the La Sal Mountains is endowed with a broad range of climate. Differences in altitude and the influence of mountains on the movement of air masses and storms have more effect on the climate than does the small range of geographic latitude. Pacific air masses and storms dominate the regional weather during October-April; warm, moisture-laden air masses from the Gulf of Mexico may traverse the region in the summer. Summer weather produces less frequent but more intense storms.



The higher parts of the La Sal Mountains are comparatively wet and cool; their slopes and adjacent plateaus are drier and subject to wide variations in temperature diurnally and seasonally. The semiarid and arid canyons and valleys at lower altitudes, also subject to wide variations of diurnal and seasonal temperatures, endure hot, dry summers and cold winters which are almost equally dry.

#### Precipitation

The U.S. Environmental Science Services Administration<sup>1</sup> maintains a weather station about 4 miles northwest of Moab (Moab 4 NW) to record daily temperatures and precipitation. Mean annual precipitation at Moab 4 NW for the period 1900-68 is 8.18 inches (fig. 2). Precipitation figures for higher parts of the Spanish Valley area are interpolated from isohyetal maps prepared by the U.S. Weather Bureau (1963). Average precipitation over the drainage basin is given in table 1.

Table 1.—Average annual precipitation and potential evapotranspiration

| Altitude, in thousands of feet | Percent of area | Average precipitation (in.) | Weighted average precipitation (in.) | Average potential evapotranspiration <sup>1</sup> (in.) | Weighted average potential evapotranspiration (in.) |
|--------------------------------|-----------------|-----------------------------|--------------------------------------|---------------------------------------------------------|-----------------------------------------------------|
| 11-12.6                        | 2.7             | 32.0                        | 0.9                                  | 24.0                                                    | 0.7                                                 |
| 10-11                          | 6.5             | 28.7                        | 1.9                                  | 26.4                                                    | 1.7                                                 |
| 9-10                           | 7.1             | 24.2                        | 1.7                                  | 28.6                                                    | 2.0                                                 |
| 8-9                            | 9.6             | 20.1                        | 1.9                                  | 31.0                                                    | 3.0                                                 |
| 7-8                            | 16.0            | 16.2                        | 2.6                                  | 33.6                                                    | 5.4                                                 |
| 6-7                            | 11.6            | 12.8                        | 1.5                                  | 36.5                                                    | 4.2                                                 |
| 5-6                            | 26.8            | 10.3                        | 2.8                                  | 43.1                                                    | 11.5                                                |
| 3.9-5                          | 19.7            | 8.6                         | 1.7                                  | 53.6                                                    | 10.6                                                |
| Weighted mean                  |                 |                             | 15.0                                 |                                                         | 39.1                                                |

<sup>1</sup>Equivalent lake evaporation (Blaney and Criddle, 1962).

From May through September, average precipitation ranges from less than 4 inches near Moab to more than 10 inches in the La Sal Mountains; it falls mainly as locally occurring thunderstorms, which may produce flash floods in some small streams. Much of the winter precipitation falls as snow, particularly at higher altitudes in the La Sal Mountains. From October through April, average precipitation ranges from less than 6 inches near Moab to more than 20 inches at higher altitudes. The weighted mean annual precipitation in the Spanish Valley area is about 15 inches.

The greatest total annual precipitation recorded near Moab is 15.96 inches in 1918 and again in 1927; the least total annual precipitation recorded is 3.02 inches in 1956. Mean annual precipitation near Moab for 69 years of record (1900-1968) is 8.18 inches; mean monthly precipitation near Moab is shown in figure 2.

<sup>1</sup>Prior to July 1965, the U.S. Weather Bureau.

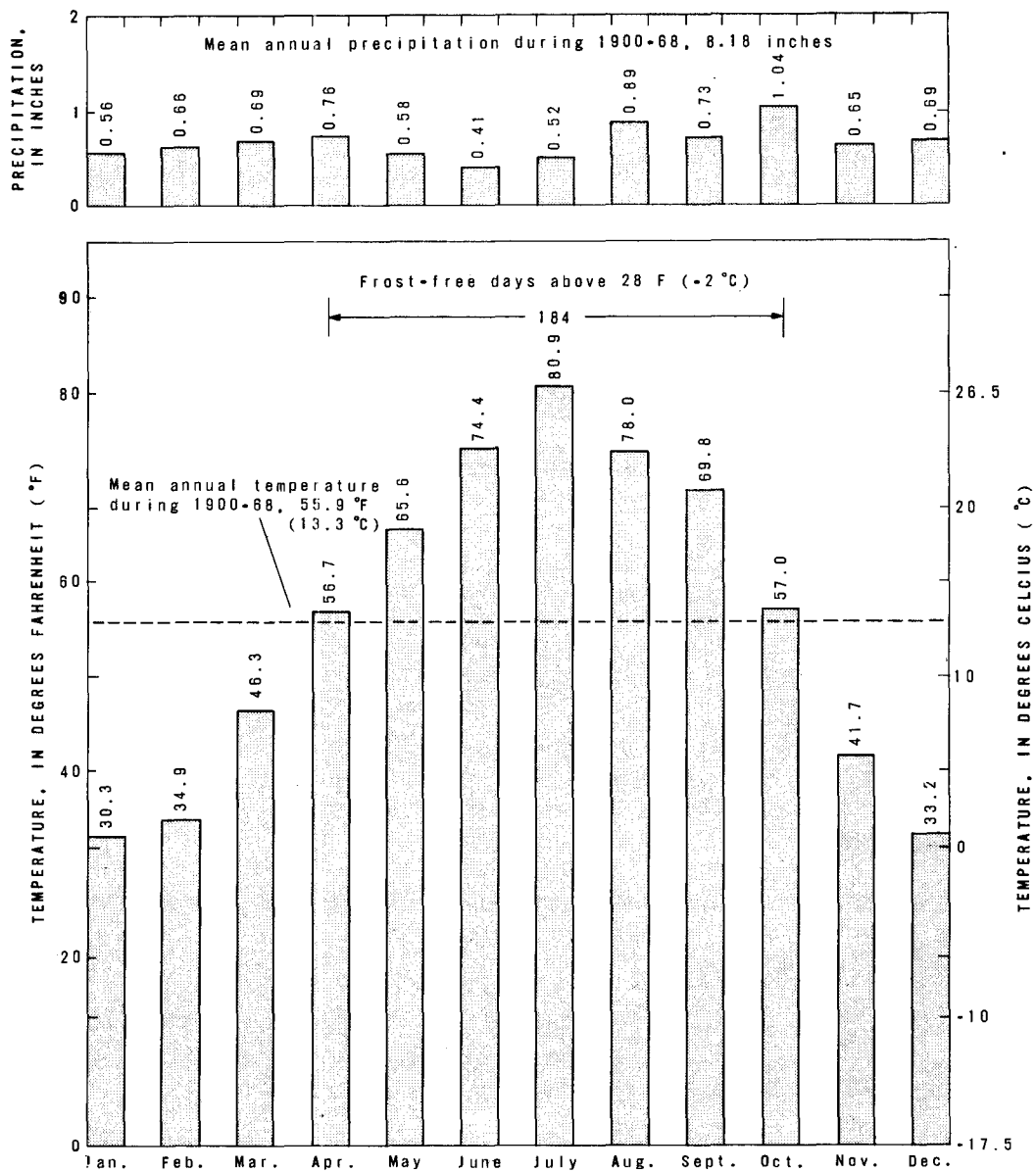


Figure 2.—Mean monthly and annual precipitation, temperature, and frost-free season at Moab (alt. 3,965 ft).

### Temperature

Diurnal temperature changes near Moab are about 20°F (11°C) in winter and usually about 40°F (22°C) but may be as much as 50°F (28°C) during the summer. Daytime temperatures during the winter may be as high as 70°F (21°C), but often the temperature may not rise above freezing for as long as a week or more at a time. The lowest temperature recorded near Moab is -24°F (-31°C). During the summer, daytime temperatures may reach or exceed 100°F (38°C); the maximum recorded near Moab is 113°F (45°C). The mean annual temperature near Moab is 55.9°F (13.3°C); mean monthly temperatures near Moab are shown in figure 2.

### Evapotranspiration

In the hydrologic regimen of a drainage basin, evapotranspiration constitutes the bulk of consumptive use (water loss). It includes water loss through transpiration by all types of vegetation and evaporation from land, vegetation, and water surfaces. Potential evapotranspiration is defined by Thornthwaite (1948, p. 55-94) as the water loss that will occur if there is no deficiency of soil water. Determination of potential evapotranspiration for the Spanish Valley area follows the method developed by Blaney and Criddle (1962).

Weighted mean annual potential evapotranspiration for the Spanish Valley area is about 39 inches (table 1). Potential evapotranspiration ranges from about 54 inches near Moab (below 5,000 ft) to about 24 inches near the summits of the La Sal Mountains (above 11,000 ft). These values for potential water loss are, of course, much greater than actual water loss, about 87,000 acre-feet per year, as there is a nearly continuous deficiency of soil water in this arid environment.

### Vegetation

The differences in climate provided by nearly 8,700 feet of relief in the Spanish Valley area give rise to irregularly overlapping zones of vegetation related to prevailing temperatures and precipitation, and hence to altitude. On north-facing slopes the zones are lower and on south-facing slopes higher.

The lowermost zone, a sagebrush-grass association, ranges in altitude from less than 4,000 feet to about 7,000 feet. Phreatophytes are present along the Colorado River and the lower reaches of Mill Creek within this zone.

A mountain-brush zone ranging in altitude from about 5,500 to 9,500 feet consists of shrub types transitional between the sagebrush-grass association and coniferous forest. It includes a scrub oak-mountain mahogany climax and a pinyon-juniper climax.

From altitudes of about 8,000 to 11,500 feet are ill-defined zonations of montane and subalpine forest. These may be grouped as subalpine forest and consist mainly of an aspen-meadow climax and a spruce-fir climax.

Timberline ranges in altitude from about 11,000 to 11,500 feet. Above timberline to the mountain summits, an alpine-meadow or alpine-tundra zone prevails.

Vegetation species and associations typical of these zones are described in more detail by F.A. Branson (*in* Iorns and others, 1965, p. 80-81).

### **Population and economy**

The first settlement of Spanish Valley was attempted in 1855 near the present site of Moab by 41 Mormon pioneers; their works included construction of an irrigation canal. Shortly after its inception, this settlement was abandoned for about 20 years, after which time the farming and grazing community was re-established. By 1879 two irrigation canals had been constructed to divert water from Mill Creek.

In 1950 the population of Moab was 1,274. Its economy stimulated by the nearly explosive growth of the mining industry, Moab attained a population of approximately 5,000 by 1956. By 1960 the population had decreased to 4,682. At the time of this water-resources investigation (1970), the population is reported to be about 6,500; and it is increasing due to a resurgence of mining activity, tourism, and other favorable economic factors.

### **GENERAL GEOLOGY**

Throughout the Spanish Valley area geologic controls on all aspects of drainage-basin hydrology are readily apparent. Landforms affect the pattern and amount of precipitation. Relief and land-surface materials regulate runoff, infiltration, and evapotranspiration. Geologic structural and stratigraphic characteristics control the recharge and subsequent movement of ground water.

The sedimentary formations exposed in the area attain a maximum total thickness of nearly 6,400 feet. The oldest rocks exposed (near Moab) are contorted evaporites and shales in the Paradox Member of the Hermosa Formation of Middle and Upper Pennsylvanian age. The pliable Paradox rocks are not in proper stratigraphic position in this locality; they appear to have been extruded upward through fault zones at the northeast and southwest margins of Spanish Valley. Formations overlying the Paradox are in proper stratigraphic sequence and span geologic ages from Middle Pennsylvanian through Cretaceous. The La Sal Mountains represent igneous stocks, including laccoliths, sills, and dikes of Tertiary age injected through and into the stratigraphic sequence. Extensive surficial deposits of Quaternary age overlie the higher parts of the area as an irregular, discontinuous veneer. Quaternary deposits in Spanish Valley attain considerable thickness, over 360 feet in some places. The geologic formations are summarized in table 2.

This report deals with those geologic features most directly related to stream discharge and ground-water occurrence. More comprehensive geologic information, upon which many hydrologic interpretations in this report are based, is available in publications by Baker (1933), Hunt (1958), Richmond (1962), and Iorns and others (1965). A generalized geologic map of the Spanish Valley area is shown on plate 1.

#### **Geologic structure**

The La Sal Mountains are igneous structural domes; exposed at their summits are the stocks from which laccoliths, sills, and dikes originated. Sedimentary formations dip away from hogbacks that skirt the exposed stocks; their dips decrease with increased distance from the hogbacks, and the formations become nearly horizontal at some of the mesas adjacent to Spanish Valley.

Table 2.--Generalized geologic section for the Spanish Valley area

[Adapted from Hunt (1958), Richmond (1962), and Stokes (1964)]

| System     | Series              | Group                                                                                                                                | Formation                                       | Member                     | Thickness (ft) | Lithology and water-bearing characteristics                                                                                                                                                                                                                                                                                                                                                                                                                             |
|------------|---------------------|--------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------|----------------------------|----------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Quaternary | Holocene            |                                                                                                                                      | Gold Basin Formation                            |                            | 0-360+         | Eolian and fluvial silt and sand; rounded to subrounded gravel, cobbles, and boulders in a clean sandy matrix; poorly sorted angular to subangular alluvial-fan debris in a clayey, silty, and sandy matrix; terrace deposits; sandy colluvium; and glacial deposits in the high plateaus and mountain areas. In Spanish Valley, eolian and alluvial deposits or formations (undifferentiated) compose the principal water-bearing material and source of ground water. |
|            |                     |                                                                                                                                      | Unconformity                                    |                            |                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
|            | Pleistocene         |                                                                                                                                      | Beaver Basin Formation                          |                            |                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
|            |                     |                                                                                                                                      | Unconformity                                    |                            |                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
|            |                     |                                                                                                                                      | Placer Creek Formation                          |                            |                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| Tertiary   |                     |                                                                                                                                      | Igneous intrusive rocks of the La Sal Mountains |                            |                | Igneous rocks; mostly diorite, monzonite, and syenite porphyry that intrude older sedimentary formations as dikes, sills, stocks, and laccoliths. Precipitation may enter these rocks where they are intensely fractured and subsequently recharge adjacent permeable sedimentary rocks.                                                                                                                                                                                |
|            |                     |                                                                                                                                      | Unconformity                                    |                            |                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| Cretaceous | Upper Cretaceous    |                                                                                                                                      | Mancos Shale                                    | Unnamed upper shale member | 410-800+       | Dark-gray and gray-brown marine shale with discontinuous thin beds of gray sandstone; relatively impermeable; does not yield water in this area.                                                                                                                                                                                                                                                                                                                        |
|            |                     |                                                                                                                                      |                                                 | Ferron Sandstone Member    |                | Tan and gray thin-bedded fine-grained sandstone and sandy shale, about 160 ft thick; permeable, but not known to yield water in this area.                                                                                                                                                                                                                                                                                                                              |
|            |                     |                                                                                                                                      |                                                 | Unnamed lower shale member |                | Dark-gray and gray-brown marine shale with discontinuous thin beds of gray sandstone; relatively impermeable; does not yield water in this area.                                                                                                                                                                                                                                                                                                                        |
|            | Lower Cretaceous    |                                                                                                                                      | Dakota Sandstone                                |                            | 50-120         | Rust-brown and yellowish-brown carbonaceous sandstone with interbeds of dark-gray siltstone and lenticular tan conglomeratic sandstone; permeable, but not known to yield water in this area.                                                                                                                                                                                                                                                                           |
|            |                     |                                                                                                                                      | Unconformity                                    |                            |                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
|            |                     |                                                                                                                                      | Burro Canyon Formation                          |                            | 50-250         | Light-gray silicified sandstone; lenticular conglomeratic brownish-gray crossbedded sandstone with thin interbeds of green mudstone; and thin sparse beds of gray limestone; has a low intrinsic hydraulic conductivity, but yields water to springs where the beds are intensely fractured.                                                                                                                                                                            |
| Jurassic   | Upper Jurassic      | San Rafael Group                                                                                                                     | Morrison Formation                              | Brushy Basin Shale Member  | 250-450        | Variegated red, green, and purple mudstone with sandy clay; and greenish-gray bentonite with interbeds of conglomeratic sandstone; has a low intrinsic hydraulic conductivity and is not known to yield water in this area.                                                                                                                                                                                                                                             |
|            |                     |                                                                                                                                      |                                                 | Salt Wash Sandstone Member | 60-220         | Tan to gray well-sorted fluvial cross-bedded sandstone with interbeds of red and gray mudstone; permeable in part, but not known to yield water in this area.                                                                                                                                                                                                                                                                                                           |
|            |                     |                                                                                                                                      | Unconformity                                    |                            |                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
|            |                     |                                                                                                                                      | Summerville Formation                           |                            | 0-50           | Red thin-bedded sandstone; red sandy mudstone; red shale; and thin gray limestone layers with some large gray-white to red chert concretions; has a low intrinsic hydraulic conductivity, and is not known to yield water in this area.                                                                                                                                                                                                                                 |
|            |                     |                                                                                                                                      | Entrada Sandstone                               | Moab Member                | 300-550        | Pale-tan to grayish-white massively cross-bedded medium-grained sandstone; permeable, but not known to yield water in this area.                                                                                                                                                                                                                                                                                                                                        |
|            |                     |                                                                                                                                      |                                                 | Slick Rock Member          |                | Light-tan to red eolian sandstone; permeable, but not known to yield water in this area.                                                                                                                                                                                                                                                                                                                                                                                |
|            | Dewey Bridge Member | Light-red aqueous siltstone and fine-grained sandstone, contorted beds common; permeable, but not known to yield water in this area. |                                                 |                            |                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
|            | Lower Jurassic      | Glen Canyon Group                                                                                                                    | Unconformity                                    |                            |                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
|            |                     |                                                                                                                                      | Navajo Sandstone                                |                            | 300-400        | Pale yellowish-orange to pale reddish-brown fine- to medium-grained sandstone with eolian cross beds, and sparse thin lenticular beds of gray sandy limestone; intrinsic hydraulic conductivity not great, but yields water to wells and springs where intensely fractured.                                                                                                                                                                                             |
|            | Triassic(?)         | Upper Triassic(?)                                                                                                                    |                                                 | Kayenta Formation          |                | 230-270                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |

Table 2.--Generalized geologic section for the Spanish Valley area - Continued

| System        | Series                         | Group             | Formation          | Member                 | Thickness (ft) | Lithology and water-bearing characteristics                                                                                                                                                                                                                                                                                                                                    |
|---------------|--------------------------------|-------------------|--------------------|------------------------|----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Triassic      | Upper Triassic                 | Glen Canyon Group | Wingate Sandstone  |                        | 275-350        | Medium-reddish-orange fine-grained sandstone in tabular sets of massive eolian cross strata; permeability not great, but where intensely fractured yields water to springs; has potential for moderate yields of water to wells.                                                                                                                                               |
|               |                                |                   | Chinle Formation   | Church Rock Member     | 170-270        | Reddish-brown and variegated gray-brown siltstone; reddish-gray sandstone; gray-green conglomeratic sandstone; lenticular conglomerate; sparse intrastratal laminae of gypsum; low intrinsic hydraulic conductivity, not known to yield water in this area.                                                                                                                    |
|               |                                |                   |                    | Moss Back Member       | 30-80          | Gray to greenish-gray thinly to thickly cross-bedded fine-grained sandstone; layers of siltstone, calcareous sandstone, and conglomerate; lignitic debris, pyrite, and other metallic deposits common; permeable, but not known to yield water in this area.                                                                                                                   |
|               | Middle(?) and Lower Triassic   |                   | Unconformity       |                        |                |                                                                                                                                                                                                                                                                                                                                                                                |
|               |                                |                   | Moenkopi Formation |                        | 470-530        | Mostly reddish-brown laminated to thin-bedded siltstone and gray fine-grained micaceous sandstone; sparse thin lenses of white cherty limestone; sparse thin layers of quartz-granule conglomerate; current-ripple marks, mud cracks, intrastratal laminae of gypsum, and gypsum veinlets common; low intrinsic hydraulic conductivity; not known to yield water in this area. |
|               |                                |                   | Unconformity       |                        |                |                                                                                                                                                                                                                                                                                                                                                                                |
| Permian       |                                |                   | Cutler Formation   | Unnamed arkosic member | 250-700+       | Red, brown, and dark-red fluvial arkose and arkosic conglomerate; red arkosic sandstone with massive crossbedding; and tabular-bedded red-brown siltstone and sandstone with sparse thin layers of lacustrine limestone; yields water to a few wells for domestic use in Spanish Valley, but is not an important aquifer in this area.                                         |
|               |                                |                   | Rico Formation     |                        | 200-450+       | Reddish-brown and greenish-gray fine- to medium-grained cross-bedded fluvial sandstone; gray thin- to thick-bedded cherty marine limestone; and reddish-gray micaceous siltstone; the sandstones are permeable but the formation has a generally low intrinsic hydraulic conductivity, and is not known to yield water in this area.                                           |
| Pennsylvanian | Upper Pennsylvanian            |                   |                    |                        |                |                                                                                                                                                                                                                                                                                                                                                                                |
|               | Upper and Middle Pennsylvanian |                   | Hermosa Formation  | Unnamed upper member   | 800+(?)        | Bluish-gray marine limestone and dolomite containing gray and red chert; gray fine-grained micaceous cross-bedded sandstone and siltstone; reddish-gray sandy shale and sandstone; and gray arkosic conglomerate; not known to yield water in this area.                                                                                                                       |
|               |                                |                   |                    | Paradox Member         | 2,000+(?)      | Light-colored salt, gypsum, anhydrite, and other evaporites; black shale, dark-gray sandy shale, gray sandstone, and gray dolomitic marine limestone; not known to yield water in this area.                                                                                                                                                                                   |
|               |                                |                   | Unconformity       |                        |                |                                                                                                                                                                                                                                                                                                                                                                                |
| Precambrian   |                                |                   |                    |                        |                | Metamorphic complex of gneisses, schists, and similar rock types with associated intrusive rocks; not known to yield water in this area.                                                                                                                                                                                                                                       |

Spanish Valley outwardly resembles a structural trough, although its configuration and origin are more complex. The valley is superimposed on the Moab anticline and the Spanish Valley-Pack Creek syncline described by Baker (1933, p. 64-67). The northwest-trending axes of these contiguous structures are roughly aligned with the trend of laccoliths of the southern group of La Sal Mountains. The Moab anticline is most perceptible at the northwest end of Spanish Valley. Fault zones parallel to the anticline have displaced its limbs. The anticlinal crest, which is nearly coincident with the axis of the valley basin, has been removed by erosion. The Spanish Valley-Pack Creek syncline becomes perceptible near the central part of the valley and southeastward. It lies along a faulted monocline which plunges rather steeply beneath the alluvium of Spanish Valley from the northeast. Displacement along this fault zone is as much as 1,500 feet; it decreases southeastward.

Spanish Valley has an irregular bedrock floor in which probable faulting is concealed by alluvium. The greatest thickness of alluvium in the valley penetrated by wells is slightly more than 360 feet.

#### Principal aquifers

Although many of the rocks in the Spanish Valley area are capable of transmitting and yielding small quantities of water, only the Wingate and Navajo Sandstones of the Glen Canyon



Group and the unconsolidated Quaternary deposits within Spanish Valley are sufficiently important as aquifers in the area to warrant further description.

#### **Wingate Sandstone**

The Wingate Sandstone of Late Triassic age consists of uniform medium-reddish-orange fine-grained sandstone occurring in the tabular sets of massive eolian cross-strata. In the Spanish Valley area, the Wingate ranges in thickness from about 275 to 350 feet. On the southwest side of the valley, it forms abrupt, high, desert-varnished cliffs that display large conchoidal fracture surfaces. The Wingate is also present on the northeast side of the valley and is exposed at the fault zone east of Moab and in the deeply incised upper reaches of the Mill Creek drainage. Intrinsic permeability of the Wingate is not great because of the fineness of its constituent sands. It is a competent formation, however, and where intensely fractured it yields moderate quantities of water to springs and has an equally great potential for yields to wells. The chemical quality of spring water from the Wingate is excellent.

#### **Navajo Sandstone**

The Navajo Sandstone of Jurassic and Triassic (?) age is predominantly pale yellowish-orange to pale reddish-brown, fine- to medium-grained eolian sandstone. Weakly bonded by calcium carbonate, it weathers to gracefully rounded landforms, which display conspicuous eolian cross-strata. The Navajo contains sparse thin lenticular beds of gray, sandy limestone. The lower formational contact of the Navajo is gradational, and it also intertongues with the underlying Kayenta Formation of Late Triassic (?) age. The Navajo lies unconformably beneath the Entrada Sandstone. The Navajo caps the abrupt cliffs on the southwest side of Spanish Valley and is also present over a large area northeast of the valley where it forms bluffs and underlies mesas. Along the northeast side of the valley it plunges beneath the alluvial surface in a monoclinal fold. The Navajo ranges in thickness from about 300 to 400 feet in the Spanish Valley area. The intrinsic permeability of the Navajo is not great because of the fineness of its constituent sands. It is a competent formation, however, and where intensely fractured, yields water to springs and wells. The chemical quality of water from the Navajo is excellent in this area.

#### **Quaternary deposits**

The Quaternary deposits of the Spanish Valley area consist of unconsolidated sediments of diverse origin and manner of deposition. Richmond (1962) divides these deposits into four geologic formations. In ascending order they are the Harpole Mesa and Placer Creek Formations of Pleistocene age, the Beaver Basin Formation of Pleistocene and Holocene age, and the Gold Basin Formation of Holocene age (table 2). Separated by unconformities, the formations are further divided into members and facies (Richmond, 1962, p. 17-84).

The water-bearing characteristics of the unconsolidated deposits in Spanish Valley cannot be directly related to specific formations, members, or facies. For the purpose of this investigation, therefore, the Pleistocene and Holocene formations are considered as a single undivided unit. With few exceptions, wells in the valley withdraw ground water from these unconsolidated Quaternary deposits. The thickness of saturated deposits in the valley is about 360 feet in a few places; average thickness of the saturated deposits is about 70 feet.

## WATER RESOURCES

Precipitation, which falls mostly as rain in Spanish Valley and the lower canyons and as rain and snow in the upland areas, is the source of all water in the Spanish Valley area. In the higher areas, some of the snowmelt and rain from low-intensity storms infiltrates the ground and enters the ground-water system. Infiltration and stream runoff account for a small part of the annual precipitation; evapotranspiration consumes the greater part. A summary of the hydrologic balances for the ground-water basin in Spanish Valley and for the entire Spanish Valley area is given in table 3.

**Table 3.—Summary of the hydrologic balance for the ground-water basin  
in Spanish Valley and for the Spanish Valley area**

| <b>Ground-water basin in Spanish Valley:</b>                       |            | <b>Acre-feet per year</b> |
|--------------------------------------------------------------------|------------|---------------------------|
| Recharge                                                           |            | 14,000 <sup>1</sup>       |
| Discharge                                                          |            |                           |
| Ground-water outflow                                               |            | 8,000                     |
| Net ground-water withdrawal use                                    |            | 6,300                     |
| Total discharge (rounded)                                          |            | 14,000                    |
| <b>Spanish Valley area:</b>                                        |            |                           |
| Inflow                                                             |            |                           |
| Weighted mean precipitation (15 in.)                               |            | 115,000                   |
| Outflow                                                            |            |                           |
| Water yield                                                        |            |                           |
| Surface runoff                                                     |            | 14,000 <sup>2</sup>       |
| Ground-water discharge from Spanish Valley<br>(includes base flow) |            | 14,000                    |
| Subtotal                                                           | (3.6 in.)  | 28,000                    |
| Water loss                                                         |            |                           |
| Consumptive use                                                    | (11.4 in.) | 87,000 <sup>3</sup>       |
| Total                                                              | (15 in.)   | 115,000                   |

<sup>1</sup> Assumed to equal the total discharge.

<sup>2</sup> Average discharge of Mill Creek and Pack Creek plus gain of Mill Creek from the gaging sites to the confluence of Mill Creek with the Colorado River.

<sup>3</sup> Assumed to equal difference between inflow and outflow.

### Volume of precipitation

Average annual precipitation on the entire Spanish Valley area is estimated to be about 115,000 acre-feet. Of this, about 15,000 acre-feet falls on and near the floor of Spanish Valley (below about 5,500 ft altitude) mostly as rain. On the mesas, plateaus, and mountains (above about 5,500 ft altitude) approximately 100,000 acre-feet of precipitation falls annually, much of it as snow. Weighted mean annual precipitation on the drainage basin, about 15 inches, was determined from data compiled by the U.S. Weather Bureau (1963). Isohyets of normal annual precipitation (1931-60) are shown on plate 2.

## Surface water

Continuous records of stream discharge are available for Mill Creek near Moab for the water years 1950-68 and for Mill Creek at Sheley Tunnel, Pack Creek near Moab, and Pack Creek at the M4 Ranch for water years 1954-59 (table 4). Stream discharge was measured intermittently during the investigation at the irrigation diversion site of upper Pack Creek, the Pack Creek diversion ditch near the irrigated area northwest of the old county airport in the SW¼SE¼SW¼ sec. 36, T. 26 S., R. 23 E., lower Pack Creek near its confluence with Mill Creek, and Mill Creek near its confluence with the Colorado River.

The combined average annual discharge of Mill Creek near Moab and Pack Creek near Moab is about 13,000 acre-feet (table 4). Stream-discharge measurements of Mill Creek near its confluence with the Colorado River indicate a gain of about 1,400 acre-feet downstream from the gaging sites of table 4. The annual stream discharge from the Spanish Valley area is thus about 14,000 acre-feet (table 3).

**Table 4.—Stream discharge at gaged sites in the Spanish Valley area.**

**Station No. 1835. Mill Creek at Sheley Tunnel, near Moab, Utah**

**Location.**—Lat 38°29'00", long 109°24'25", in NW¼NE¼SE¼ sec. 5, T. 27 S., R. 23 E., on left bank 9 miles southeast of Moab.

**Drainage area.**—27.4 sq mi upstream from gage site.

**Records available.**—October 1954 to September 1959.

**Gage.**—Water-stage recorder. Altitude of gage is 5,400 ft (from topographic map).

**Average discharge.**—5 years (1954-59), 8,280 acre-ft per year (11.43 cfs).

**Extremes.**—1954-59: Maximum discharge, 405 acre-ft per day (204 cfs) Aug. 30, 1957, gage height 3.97 ft (from rating curve extended above 96 cfs on basis of logarithmic plotting); minimum recorded, 4.2 acre-ft per day (2.1 cfs) Apr. 5, 1955.

**Remarks.**—Small diversion near headwaters for irrigation.

Monthly and yearly mean discharge (1954-59), in acre-feet and cubic feet per second

| Oct. | Nov. | Dec. | Jan. | Feb. | Mar. | Apr.  | May   | June  | July  | Aug.  | Sept. | The year      |
|------|------|------|------|------|------|-------|-------|-------|-------|-------|-------|---------------|
| 465  | 349  | 367  | 352  | 304  | 344  | 621   | 1,689 | 1,795 | 866   | 615   | 491   | 8,280 acre-ft |
| 7.56 | 5.87 | 5.97 | 5.72 | 5.43 | 5.59 | 10.44 | 27.47 | 30.17 | 14.41 | 10.00 | 8.25  | 11.43 cfs     |

#### Station No.1840. Mill Creek near Moab, Utah

**Location.**—Lat  $38^{\circ}33'40''$ , long  $109^{\circ}30'50''$ , in NW¼NW¼NE¼ sec. 8, T. 26 S., R. 22 E., on right bank 0.5 mile downstream from North Fork, 1.5 miles southeast of Moab, and 3.5 miles upstream from mouth.

**Drainage area.**—74.9 sq mi upstream from gage.

**Records available.**—October 1914 (fragmentary), November 1914, February to September 1915, October to November 1915, February to March 1916, June 1916 to June 1917, April to July 1918 (fragmentary), April to July 1919, July 1949 to September 1968.

**Gage.**—Water-stage recorder and sharp-crested weir. Altitude of gage is 4,240 ft (from topographic map). Prior to Apr. 28, 1918, staff gage; from Apr. 28, 1918 to Aug. 2, 1919, and July 1949 to Mar. 15, 1962, water-stage recorder; 0.4 mile upstream at various datum sites.

**Average discharge.**—19 years (1949-68), 10,140 acre-ft per year (14.00 cfs).

**Extremes.**—1949-68: Maximum recorded discharge, about 10,140 acre-ft per day (5,110 cfs) Aug. 21, 1953 (gage height 10.74 ft from flood mark, site and datum then in use); maximum gage height 11.6 ft Aug. 26, 1961, site and datum then in use; minimum discharge recorded, 0.4 acre-ft per day (0.2 cfs) Feb. 15, 1964.

**Remarks.**—Records good except for those for period of no gage-height record which are poor. Small diversions near headwaters for irrigation.

Monthly and yearly mean discharge (1949-68), in acre-feet and cubic feet per second

| Oct.  | Nov. | Dec. | Jan. | Feb. | Mar. | Apr.  | May   | June  | July  | Aug.  | Sept. | The year       |
|-------|------|------|------|------|------|-------|-------|-------|-------|-------|-------|----------------|
| 662   | 567  | 558  | 527  | 526  | 583  | 957   | 1,693 | 1,522 | 866   | 953   | 723   | 10,140 acre-ft |
| 10.77 | 9.53 | 9.08 | 8.57 | 9.39 | 9.48 | 16.08 | 27.53 | 25.58 | 14.08 | 15.60 | 12.15 | 14.00 cfs      |

#### Station No. 1845. Pack Creek at M4 Ranch, near Moab, Utah

**Location.**—Lat  $38^{\circ}26'10''$ , long  $109^{\circ}21'15''$ , in SE¼NW¼SE¼ sec. 23, T. 27 S., R. 23 E., on left bank half a mile upstream from M4 Ranch and 14 miles southeast of Moab.

**Drainage area.**—15.8 sq mi upstream from gage.

**Records available.**—October 1954 to September 1959.

**Gage.**—Water-stage recorder and concrete control. Altitude of gage is 6,140 ft (from topographic map).

**Average discharge.**—5 years (1954-59), 1,840 acre-ft per year (2.54 cfs).

**Extremes.**—1954-59: Maximum discharge, 2,390 acre-ft per day (1,200 cfs) July 26, 1955, gage height 9.02 ft (from rating curve extended above 80 cfs on basis of slope-area measurement of peak flow); minimum, 0.6 acre-ft per day (0.3 cfs) Sept. 2, 4, 1956.

**Remarks.**—During periods of average or less than average streamflow, the entire discharge is diverted to irrigation about 2 miles downstream from the gage.

Monthly and yearly mean discharge (1954-59), in acre-feet and cubic feet per second

| Oct. | Nov. | Dec. | Jan. | Feb. | Mar. | Apr. | May  | June  | July | Aug. | Sept. | The year      |
|------|------|------|------|------|------|------|------|-------|------|------|-------|---------------|
| 55   | 51   | 47   | 44   | 46   | 54   | 82   | 476  | 664   | 187  | 79   | 54    | 1,840 acre-ft |
| 0.89 | 0.86 | 0.76 | 0.72 | 0.82 | 0.88 | 1.38 | 7.74 | 11.16 | 3.04 | 1.28 | 0.91  | 2.54 cfs      |

**Station No. 1850. Pack Creek near Moab, Utah**

**Location.**—Lat 38°32'25", long 109°30'00", in NE¼NE¼SW¼ sec. 16, T. 26 S., R. 22 E., on left bank 3.5 miles southeast of Moab.

**Drainage area.**—57.4 sq mi upstream from gage.

**Records available.**—October 1954 to September 1959.

**Gage.**—Water-stage recorder and concrete control. Altitude of gage is 4,390 ft (from topographic map).

**Average discharge.**—5 years (1954-59), 2,910 acre-ft per year (4.02 cfs).

**Extremes.**—1954-59: Maximum discharge, 1,012 acre-ft per day (510 cfs) Oct. 8, 1954, gage height 4.05 ft (from rating curve extended above 60 cfs on basis of slope-area measurement of peak flow); minimum, 1.39 acre-ft per day (0.7 cfs) Aug. 27, 1956.

**Remarks.**—In this lower part of Pack Creek, perennial flow rises about 1.5 miles upstream from the gage.

Monthly and yearly mean discharge (1954-59), in acre-feet and cubic feet per second

| Oct. | Nov. | Dec. | Jan. | Feb. | Mar. | Apr. | May  | June | July | Aug. | Sept. | The year      |
|------|------|------|------|------|------|------|------|------|------|------|-------|---------------|
| 201  | 206  | 231  | 240  | 244  | 258  | 224  | 426  | 513  | 129  | 126  | 114   | 2,910 acre-ft |
| 3.27 | 3.46 | 3.76 | 3.90 | 4.35 | 4.20 | 3.67 | 6.93 | 8.62 | 2.10 | 2.05 | 1.92  | 4.02 cfs      |

**Mill Creek**

The Mill Creek drainage basin occupies about 80 square miles of the northern part of the Spanish Valley area. The length of the main channel of Mill Creek is about 24 miles, and the average gradient is about 270 feet per mile; in Spanish Valley, however, the gradient is about 64 feet per mile. The stream gage at Mill Creek near Moab is about 3.5 miles upstream from the mouth of the creek; it records stream discharge from about 75 square miles of drainage basin. The gaging site on Mill Creek at Sheley Tunnel was about 9 miles upstream from the gage near Moab.

Throughout its length, Mill Creek is a gaining stream. Records for water years 1950-67 indicate that for about 80 percent of the time the average daily discharge at Mill Creek near Moab equaled or exceeded 8 cfs (cubic feet per second) (about 5,800 acre-ft per yr). The latter figure is probably a good approximation of the base flow of Mill Creek near Moab. The base flow of the creek is derived mainly from sandstone strata of the Glen Canyon Group. Average monthly and yearly discharge of Mill Creek near Moab and at Sheley Tunnel is given in table 4.

#### **Pack Creek**

The Pack Creek drainage basin occupies about 64 square miles of the southern part of the Spanish Valley area. The main channel of Pack Creek is about 23 miles long, and it has an average gradient of about 480 feet per mile in Spanish Valley, however, the gradient is about 120 feet per mile. The inactive stream gage on Pack Creek near Moab is about 4.3 miles above the mouth; it recorded stream discharge from about 57 square miles of drainage basin. The inactive gaging site at the M4 Ranch is at the southeast end of Spanish Valley, about half a mile upstream from the ranchhouse.

The upper part of Pack Creek, from its origin at Barber and Pack Creek Springs, (D-27-24)30bbc-S1 and 24dcc-S1, is a gaining stream to within a short distance of the site of its diversion for irrigation. The entire discharge of upper Pack Creek is diverted by ditch to the irrigated area northwest of the old county airport in secs. 35 and 36, T. 26 S., R. 22 E., where the water infiltrates the permeable alluvium or is discharged by evapotranspiration; there is no surface return flow from irrigation. Thus Pack Creek channel is dry between the diversion site and the springs near Moab City Park in secs. 15 and 22, T. 26 S., R. 22 E., except during infrequent and brief occurrences of heavy runoff. Lower Pack Creek, from its perennial source at the springs near Moab City Park to its confluence with Mill Creek, is a gaining stream. Average monthly and yearly discharge figures of the gaging stations on Pack Creek for the period 1955-59 are given in table 4.

#### **Colorado River**

The Colorado River is base level for the Spanish Valley area. The nearest gaging station on the Colorado River is near Cisco, Utah, about 30 miles upstream from Spanish Valley. For 57 years of record (1911-68), the average discharge of the Colorado River near Cisco is about 7,725 cfs. The average discharge of the Colorado River at Spanish Valley is estimated to be less than 1 percent more than the average discharge near Cisco; the river has only a few small perennial tributaries between these localities. Where it passes the northeast end of Spanish Valley, the Colorado River receives the discharge of Mill Creek and ground-water outflow from Spanish Valley. This combined discharge increases the average flow of the Colorado River by less than one-half of 1 percent.

#### **Ground water**

Essentially all ground-water use in the Spanish Valley area is in Spanish Valley. The principal source of the ground water used in the valley is the gravelly sand that constitutes the valley fill. A secondary source of ground water is from the relatively small area of intensely fractured sandstones of the Glen Canyon Group adjacent to Spanish Valley on the northeast, northeast of the Moab City Park. Ground water occurs in other places but is available in such relatively small amounts as to be nonutilitarian. Records of 232 selected wells are given in table 9 and records of selected springs in table 10.

### Recharge

In upland parts of the Spanish Valley area, water from snowmelt and from low-intensity rainfall infiltrates the surface cover of soils, eolian sand, glacial moraine, and colluvium. Such water descends as ground-water recharge into a ground-water system in the sandstones of the Glen Canyon Group. The ground water seeps through fractures or pore spaces in the sandstones in a general southwestward direction toward Spanish Valley. Some of the ground water reappears at the land surface as base flow in either Mill or Pack Creeks or as spring discharge on the northeast side of Spanish Valley and some enters the fill in Spanish Valley by subsurface flow. After entering the valley fill, the ground water flows generally northwestward as indicated by arrows in the ground-water contours on plate 2, finally discharging as outflow to the Colorado River.

The total recharge on the upland areas is not directly measurable. It may be assumed equal to the sum of (1) the base flow of Mill Creek (5,800 acre-ft per yr or about 8 cfs), (2) total discharge of the springs at the northeast side of the valley (2,200 acre-ft per yr or about 3 cfs), and (3) recharge to the ground-water basin in Spanish Valley by underflow (assumed to be equal to discharge), mostly from the Glen Canyon Group (14,000 acre-ft per yr or about 19 cfs). Total recharge on upland areas is thus 22,000 acre-feet per year or about 30 cfs.

The recharge to the ground-water basin in Spanish Valley is assumed to be approximately the same as the discharge from the basin. This is the sum of ground-water outflow to the Colorado River and the ground water discharged by consumptive use. Recharge to the basin thus computed is about 14,000 acre-feet per year or 19 cfs.

### Water levels

Ground-water levels are nearer the land surface at the northwest end of Spanish Valley than they are elsewhere in the valley. The water table in the valley rises southeastward, but water levels become progressively deeper because the land surface rises more rapidly in the same direction. Altitudes of water levels are shown by contours on plate 2, where the depth to water may be obtained by subtracting water-level altitudes from land-surface altitudes. Irregularities in spacing of the water-level contours (differences in hydraulic gradient) are reflections of diversities in hydraulic conductivity and rates of subsurface recharge to the valley. The comparatively low hydraulic gradient in the vicinity of the old county airport and the Grand County-San Juan County boundary may indicate an area of increased recharge to the valley basin, or it may be due to a local concentration of more uniformly coarse aquifer materials.

Water-level contours, where projected into the area underlain by the Glen Canyon Group northeast of the valley, trend generally northeastward. The contours suggest that the direction of ground-water movement in the Glen Canyon Group is from the La Sal Mountains toward the northwest, paralleling the movement of water in the fill in Spanish Valley. Water-level contours are not extended far beyond the valley on plate 2 because of sparse water-level data in the uplands area.

Water-level changes in selected observation wells in Spanish Valley are shown in figure 3. The maximum seasonal water-level change observed was a rise of 5.8 feet in well (D-26-22)17dbc-1, and the maximum yearly water-level change observed was a rise of 6.7 feet in well (D-26-22)22dcd-1. The length of record available is not sufficient to indicate any upward or downward trend of water levels in the valley.



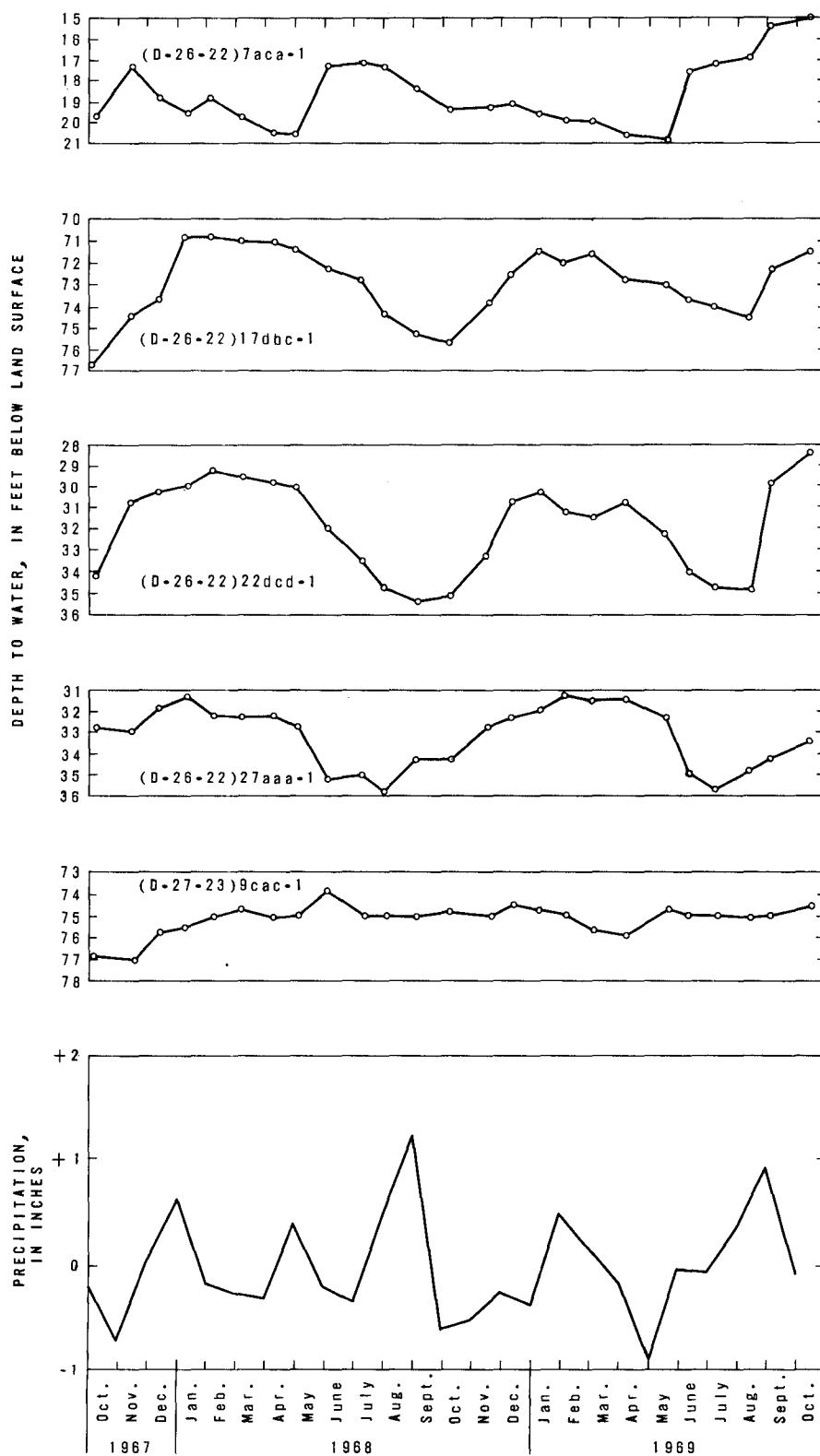


Figure 3.—Monthly changes in water levels in selected wells and departures from the 1931-60 normal monthly precipitation at Moab, October 1967-September 1969.

#### Storage

The fill in Spanish Valley underlies about 11,500 acres. Wells and test holes that fully penetrate the fill indicate that it has a maximum thickness of about 360 feet, and that ground water in the fill occurs under water-table conditions. The average saturated thickness of the fill is about 70 feet; thus the approximate total volume of saturated fill is about 800,000 acre-feet.

The fill may be described generally as a gravelly sand. An analysis of 202 well logs, mostly from drillers' records, indicates that the fill has approximately the following textural composition:

- 7 percent clay
- 4 percent silt
- 50 percent sand
- 23 percent fine-to-medium gravel
- 16 percent coarse gravel

Selected drillers' logs of seventeen wells are given in table 8. Based on the preceding characteristics, it is estimated that the apparent specific yield of the fill (Ferris and others, 1962, p. 77-78) ranges from 0.10 to 0.15. In other areas of similar deposits, however, specific yield has been observed to increase during an extended period of pumping (Lugn and Wenzel, 1938, p. 89-96; Williams and Lohman, 1949, p. 213, 220). The long-term specific yield of the saturated gravelly sand in Spanish Valley, therefore, is believed to be about 0.25 (Johnson, 1967, p. 4, 68-71). Thus, the total volume of ground water theoretically recoverable from storage is estimated to be about 200,000 acre-feet. Assuming a long-term practicable withdrawal of about one-third of the total ground water in storage, the volume recoverable from storage in the fill in Spanish Valley is about 70,000 acre-feet.

#### Well and aquifer characteristics

Wells are concentrated at the central and northwest part of Spanish Valley where requirements for municipal and domestic use and irrigation by ground water are greatest. Well yields from the valley fill are as much as 1,000 gpm (gallons per minute) with but 35 feet of water-level drawdown [(D-26-22)35abd-1] and as little as 8 gpm with 110 feet of drawdown [(D-26-22)16cab-1]. Most of the wells in Spanish Valley supply water for domestic use. The average yield of 170 of the domestic wells listed in table 8 is about 24 gpm; they range in yields from 6 to 150 gpm. Relatively few wells are used solely for irrigation in Spanish Valley. The average yield of 14 of the irrigation wells listed in table 8 is about 220 gpm; they range in yields from 100 to 1,000 gpm. The average yield of five public-supply wells listed in table 9 is about 800 gpm; they range in yields from 100 to 2,445 gpm. The well yielding 2,445 gpm is in fractured Navajo Sandstone of the Glen Canyon Group.

Aquifer characteristics of the fill in Spanish Valley determined on the basis of bailing 16 wells and pumping two wells are given in table 5. From the results it may be inferred that the transmissivity of the valley fill is variable. The average transmissivity determined from the 18 wells is about 6,000 cubic feet per day per foot. The transmissivity values in table 5 were determined on the basis of specific capacities observed in the wells tested. Such tests involve head

**Table 5.—Aquifer characteristics of the valley fill**

[Transmissivity estimated from specific capacity according to the method of Theis (1963, p. 332-336). Hydraulic conductivity is assumed equal to transmissivity divided by saturated thickness.]

| Well number        | Specific capacity<br>(gpm/ft of drawdown) | Transmissivity<br>(cubic ft per day per ft) | Saturated thickness<br>(ft) | Hydraulic conductivity<br>(cubic ft per day per square ft) |
|--------------------|-------------------------------------------|---------------------------------------------|-----------------------------|------------------------------------------------------------|
| (D-25-21)36cda-1   | 41                                        | 8,000                                       | 225                         | 36                                                         |
| (D-26-22)6cbb-1    | 36                                        | 7,000                                       | 140                         | 49                                                         |
| 6cbb-2             | 20                                        | 3,700                                       | 125                         | 29                                                         |
| 7bac-1             | 25                                        | 4,300                                       | 125                         | 35                                                         |
| 8cba-1             | 20                                        | 3,700                                       | 40                          | 94                                                         |
| 8dcb-1             | 30                                        | 5,700                                       | 50                          | 115                                                        |
| 16cdd-1            | 36                                        | 7,000                                       | 65                          | 107                                                        |
| 17aac-1            | 48                                        | 8,700                                       | 50                          | 174                                                        |
| 17aad-1            | 18                                        | 3,100                                       | 70                          | 44                                                         |
| 17ada-2            | 10                                        | 1,600                                       | 50                          | 32                                                         |
| 17cab-1            | 20                                        | 3,700                                       | 50                          | 75                                                         |
| 20acd-1            | 20                                        | 3,700                                       | 30                          | 124                                                        |
| 21bdd-1            | 20                                        | 3,600                                       | 50                          | 72                                                         |
| 22cbb-1            | 32                                        | 5,700                                       | 75                          | 76                                                         |
| 22cbd-1            | 60                                        | 11,600                                      | 100                         | 116                                                        |
| 22dcb-1            | 90                                        | 13,900                                      | 105                         | 132                                                        |
| 35abd-1            | 30                                        | 4,700                                       | 120                         | 39                                                         |
| 35bdd-2            | 30                                        | 5,700                                       | 160                         | 36                                                         |
| Averages (rounded) | 30                                        | 6,000                                       | 90                          | 80                                                         |

losses as the water moves through perforations in the well casing; thus the real transmissivity of the aquifer is undoubtedly considerably higher than indicated. Based on a comparison of similar well determinations with aquifer data obtained from pumping tests in basin fill elsewhere in Utah (R.W. Mower, oral commun., 1970), it is believed that a more realistic average value for the transmissivity of the fill in Spanish Valley is about 10,000 cubic feet per day per foot.

Several public-supply wells and domestic wells withdraw water from the Navajo Sandstone northeast of the Moab City Park in secs. 15 and 22, T. 26 S., R. 22 E. The Navajo in this area is shattered by faulting and jointing, and it has an estimated transmissivity of about 6,000 cubic feet per day per foot. The transmissivity of the less-disturbed Navajo in the uplands northeast of the locally shattered area is relatively slight, however, and it is estimated to be about 1,200-1,500 cubic feet per day per foot.

#### Discharge

Ground water is discharged from Spanish Valley by evapotranspiration from areas of water-loving plants (phreatophytes and hydrophytes); outflow to the Colorado River; consumptive use of water withdrawn for irrigation, public supply, and domestic use, and sewage discharge from municipal and domestic water systems to the Colorado River. Total ground-water discharge from the valley is estimated to be about 14,000 acre-feet per year.

Phreatophytes and hydrophytes flourish in a meadowland of about 1,280 acres at the northwest end of the valley adjacent to the Colorado River (pl. 2). Phreatophytes predominate in this area; the most common types are willow (*Salix* sp.), saltcedar or tamarisk (*Tamarix gallica*), cottonwood (*Populus* sp.), and giant reed grass (*Phragmites communis*). Hydrophytes are represented mostly by horsetail (*Equisetum* sp.), meadowgrass (*Glyceria* sp.), and cattail (*Typha latifolia*). Areas of open water occur in lower parts of the meadowland, mainly during the dormant season. Annual use of ground water by phreatophytes and hydrophytes is estimated to be about 3,000 acre-feet (about 2.4 acre-ft per acre).

The discharge of ground water by outflow to the Colorado River was estimated by using an adaptation of Darcy's law (Darcy, 1856),

$Q = 0.0084 T / W$ , in which

$Q$  = discharge in acre-feet per year;

0.0084 is a conversion factor of cubic feet per day to acre-feet per year;

$T$  = 16,000 cubic feet per day per foot, the estimated average transmissivity of the fill in Spanish Valley where the average thickness of the saturated fill is about 140 feet (at the middle of line A - A' on pl. 2);

$I$  = 71 feet per mile, the gradient of the water table between the water-level contours at altitudes of 3,950 and 4,050 feet (the measured line of gradient is 1.4 miles, shown as A - A' on pl. 2); and

$W$  = 1.2 miles, the average width of the valley throughout the length of the line of gradient A - A'; thus

$Q = 0.0084 \times 16,000 \times 71 \times 1.2 = 11,000$  acre-feet per year.

Thus the outflow to the Colorado River is 11,000 acre-feet per year minus the 3,000 acre-feet per year consumed in the area of phreatophytes and hydrophytes in the northwest end of the valley, or about 8,000 acre-feet per year.

Ground water is withdrawn from wells for domestic use mostly throughout the northwestern part of Spanish Valley, whereas the irrigation and public-supply wells, which withdraw the greatest volumes of water, are in the central part of the valley (table 9). Withdrawals are greatest during the growing season from April to October when irrigation wells are pumped, domestic pumping is increased, and public-supply wells are pumped to supplement supplies from springs.

The total annual ground-water withdrawal for domestic and public supply and irrigation is about 5,200 acre-feet per year. Of this, about 3,800 acre-feet is withdrawn for irrigation, about 1,200 acre-feet for public supply, and about 200 acre-feet for domestic use.

Ground water withdrawn for irrigation in Spanish Valley is applied to two large areas totaling about 740 acres—an area of about 290 acres south of Moab City Park and an area of about 450 acres northwest of the abandoned county airport (pl. 2). The principal crop is alfalfa. Smaller areas irrigated with ground water are scattered throughout the northwestern part of Spanish Valley, but the total area in the valley irrigated with ground water does not exceed 1,000 acres. The amount of irrigated land in the valley does not change significantly from year to year. The soil of Spanish Valley is generally coarse, and infiltration loss during irrigation is estimated to be about 50 percent. The volume of ground water withdrawn for irrigation is estimated to be about 3,800 acre-feet per year. Thus, the consumptive use of ground water for irrigation is about 1,900 acre-feet annually, and the remaining 1,900 acre-feet is returned to the aquifer by infiltration.

The public-supply system of Moab obtains water from two wells, (D-27-22)22aad-1 and (D-26-22)15dca-1, and five springs, (D-25-21)35aaa-S1, (D-26-22)15cbb-S1, (D-26-22)15cdc-S1, and (D-26-22)22aaa-S1 and S2. The wells are used mainly during the summer months to supplement water supplies from the springs. The system has been metered since February 1968, and withdrawals of ground water, in acre-feet, during 1968-69 are tabulated as follows:

|         | 1968 (incomplete) | 1969  |
|---------|-------------------|-------|
| Wells   | 281               | 535   |
| Springs | 603               | 665   |
| Total   | 884               | 1,200 |

The 1,200 acre-feet metered during 1969 is assumed to be a representative figure for annual withdrawal for public supply.

Withdrawal of ground water from privately owned wells, mainly for domestic use, is estimated to be about 200 acre-feet per year in Spanish Valley.

The consumptive use of water used for public and domestic supplies is assumed to be about 25 percent of the water withdrawn. Thus, of the 1,400 acre-feet of water withdrawn annually, about 350 acre-feet is consumed. Almost all the remainder, however, is discharged as treated sewage to the Colorado River.

In summary, the annual discharge of ground water from Spanish Valley is estimated to be:

- 8,000 acre-feet by outflow to the Colorado River
- 3,000 acre-feet by evapotranspiration in area of phreatophytes and hydrophytes
- 1,900 acre-feet by consumptive use in irrigation
- 1,400 acre-feet withdrawn for public and domestic supplies and either consumed or discharged as treated sewage to the Colorado River
- 14,000 acre-feet total (rounded)

#### **Additional development**

Additional ground water could be withdrawn in Spanish Valley by diverting part of the outflow to the Colorado River, by diverting part of the water consumed by evapotranspiration in the northwestern end of the valley, or by withdrawing water from storage in the valley fill throughout the valley. Any of these actions would affect water levels in the valley. Predictions of the effects on water levels that would be caused by continuation of withdrawals at essentially the 1969 rate or increasing the withdrawals threefold were made by means of an electric analog model of the valley.

The analog model was designed and constructed during the early stages of the investigation, and in addition to use for predictive purposes it was used to verify or reject hydrologic interpretations while the investigation was in progress. Flow of ground water is simulated by flow of electrical current through conductors in the analog model. The time ratio of ground-water change to analog-model change is in years to seconds. Analogies exist between the volume rate of flow and electrical current, hydraulic potential and electrical potential, transmissivity and electrical conductance, ground-water storage and electrical capacitance, and in the length of an aquifer segment represented by a conductance element. When valid data are supplied, the analog model may be used to simulate ground-water withdrawals under varying conditions of recharge and discharge (Wykoff and Reed, 1935, and Skibitzke, 1960).

Of seven data-processing runs on the analog model, runs 6 and 7 gave results that most closely represented hydrologic conditions in Spanish Valley. Results of the two runs are given as simulated water-level changes on plate 3. The simulated pumping locations were arrayed as nodes to represent average values for different areas rather than for specific wells (table 6). This was done in order to simulate the effects of large numbers of domestic wells in some areas and to simulate the effects of irrigation and public supply wells where they would have the greatest influence on water levels.

Run 7 on plate 3 shows the change in water levels that is predicted after 10 years of simulated ground-water withdrawals at the rate of 3,810 acre-feet per year. This rate is about 15 percent greater than the net rate of withdrawal during 1969 (1,400 acre-feet for domestic and public supply and 1,900 acre-feet for irrigation). Run 6 shows the change in water levels that is predicted after 10 years of simulated ground-water withdrawal at the rate of 9,440 acre-feet per year, about three times the net withdrawals during 1969.

As shown by both runs on plate 3, the greatest predicted changes in water levels are in the central part of Spanish Valley; and little or none of the simulated source of the water withdrawn is from outflow to the Colorado River or water consumed by evapotranspiration in the northwestern end of the valley. It is apparent, therefore, that if some of the outflow to the Colorado River or some of the water consumed by evapotranspiration is to be diverted by means

Table 6.—Simulated discharge and assumed transmissivity at nodes representing simulated pumping in the analog model.

| Node No.         | Analog discharge, in millions of gallons per day |       | Assumed average transmissivity, in cubic feet per day per foot |
|------------------|--------------------------------------------------|-------|----------------------------------------------------------------|
|                  | Run 6                                            | Run 7 |                                                                |
| 1                | 0.016                                            | 0.007 | 5,000                                                          |
| 2                | .063                                             | .025  |                                                                |
| 3                | .063                                             | .025  |                                                                |
| 4                | .063                                             | .025  |                                                                |
| 5                | .016                                             | .007  |                                                                |
| 6                | .063                                             | .025  |                                                                |
| 7                | .063                                             | .025  |                                                                |
| 8                | .063                                             | .025  |                                                                |
| 9                | .016                                             | .007  |                                                                |
| 10               | .063                                             | .025  |                                                                |
| 11               | .063                                             | .025  |                                                                |
| 12               | .016                                             | .007  |                                                                |
| 13               | .063                                             | .025  |                                                                |
| 14               | .063                                             | .025  |                                                                |
| 15               | .016                                             | .007  |                                                                |
| 16               | .005                                             | .002  | 7,600                                                          |
| 17               | .019                                             | .008  |                                                                |
| 18               | .019                                             | .008  |                                                                |
| 19               | .016                                             | .369  |                                                                |
| 20               | .005                                             | .002  |                                                                |
| 21               | .104                                             | .042  |                                                                |
| 22               | .005                                             | .002  |                                                                |
| 23               | .019                                             | .008  |                                                                |
| 24               | .019                                             | .008  |                                                                |
| 25               | .019                                             | .008  |                                                                |
| 26               | .916                                             | .369  |                                                                |
| 27               | .019                                             | .008  |                                                                |
| 28               | .019                                             | .008  |                                                                |
| 29               | .104                                             | .042  |                                                                |
| 30               | .916                                             | .369  | 5,200                                                          |
| 31               | .104                                             | .042  |                                                                |
| 32               | .005                                             | .002  |                                                                |
| 33               | .019                                             | .008  |                                                                |
| 34               | .019                                             | .008  |                                                                |
| 35               | .005                                             | .202  |                                                                |
| 36               | .117                                             | .047  |                                                                |
| 37               | .500                                             | .202  |                                                                |
| 38               | .500                                             | .202  |                                                                |
| 39               | .117                                             | .047  |                                                                |
| 40               | .500                                             | .202  |                                                                |
| 41               | .500                                             | .202  |                                                                |
| 42               | .117                                             | .047  |                                                                |
| 43               | .500                                             | .202  |                                                                |
| 44               | .500                                             | .202  |                                                                |
| 45               | .500                                             | .202  |                                                                |
| 46               | .117                                             | .047  |                                                                |
| Totals (rounded) | 8.43                                             | 3.40  |                                                                |



of withdrawals from additional wells, these wells should be in the northwestern part of the valley where simulated water-level changes on plate 3 are less than 5 feet. Thus by dispersing some of the ground-water withdrawals from the central part of Spanish Valley to the northwestern part, water will be salvaged for beneficial use in the valley, water-level declines in the central part of the valley will be lessened, and lowering of future pumping levels in the valley generally will be kept to a minimum.

The maximum amount of ground water that could be diverted annually in the Spanish Valley area is about 11,000 acre-feet—3,000 acre-feet now being consumed in the area of phreatophytes and hydrophytes and 8,000 acre-feet now being discharged from the lower end of Spanish Valley by outflow to the Colorado River. Some of the 11,000 acre-feet could be recovered for beneficial use in Spanish Valley by additional pumping in the northwestern part of the valley in or near the area of phreatophytes and hydrophytes (pl. 2). The amount of ground water that could thus be diverted from consumptive use by the phreatophytes and hydrophytes to beneficial use is estimated to be a maximum of about 190 acre-feet per year (pl. 3).

### Quality of Water

#### Surface Water

A summary of the chemical classification of surface waters for irrigation in Spanish Valley is given in figure 4 and table 7. The U.S. Salinity Laboratory Staff (1954) used the sodium-adsorption ratio (SAR) as a method of predicting the sodium (or alkali) hazard in the use of water for irrigation. SAR is calculated by dividing the sodium concentration by the square root of one-half the calcium and magnesium concentration (all concentrations are in milliequivalents per liter). The interpretation of the low-, medium-, and high-salinity hazards and the low-sodium hazard indicated by figure 4 are defined by the U.S. Salinity Laboratory Staff as follows:

Low-salinity water can be used for irrigation with most crops on most soils with little likelihood that soil salinity will develop. Some leaching is required, but this occurs under normal irrigation practices except in soils of extremely low permeability.

Medium-salinity water can be used if a moderate amount of leaching occurs. Plants with moderate salt tolerance can be grown in most cases without special practices for salinity control.

High-salinity water cannot be used on soils with restricted drainage. Even with adequate drainage, special management for salinity control may be required and plants with good salt tolerance should be selected.

Low-sodium water can be used for irrigation on almost all soils with little danger of the development of harmful levels of exchangeable sodium. However, sodium-sensitive crops such as stone-fruit trees may accumulate injurious concentrations of sodium.

The specific conductances of surface waters at selected sites in the Spanish Valley area are shown on plate 2. Specific conductance is a convenient rapid determination for estimating the concentration of dissolved solids in water, the concentration of dissolved solids (in milligrams per liter) generally being about 65 percent of the specific conductance (in micromhos per centimeter at 25°C).

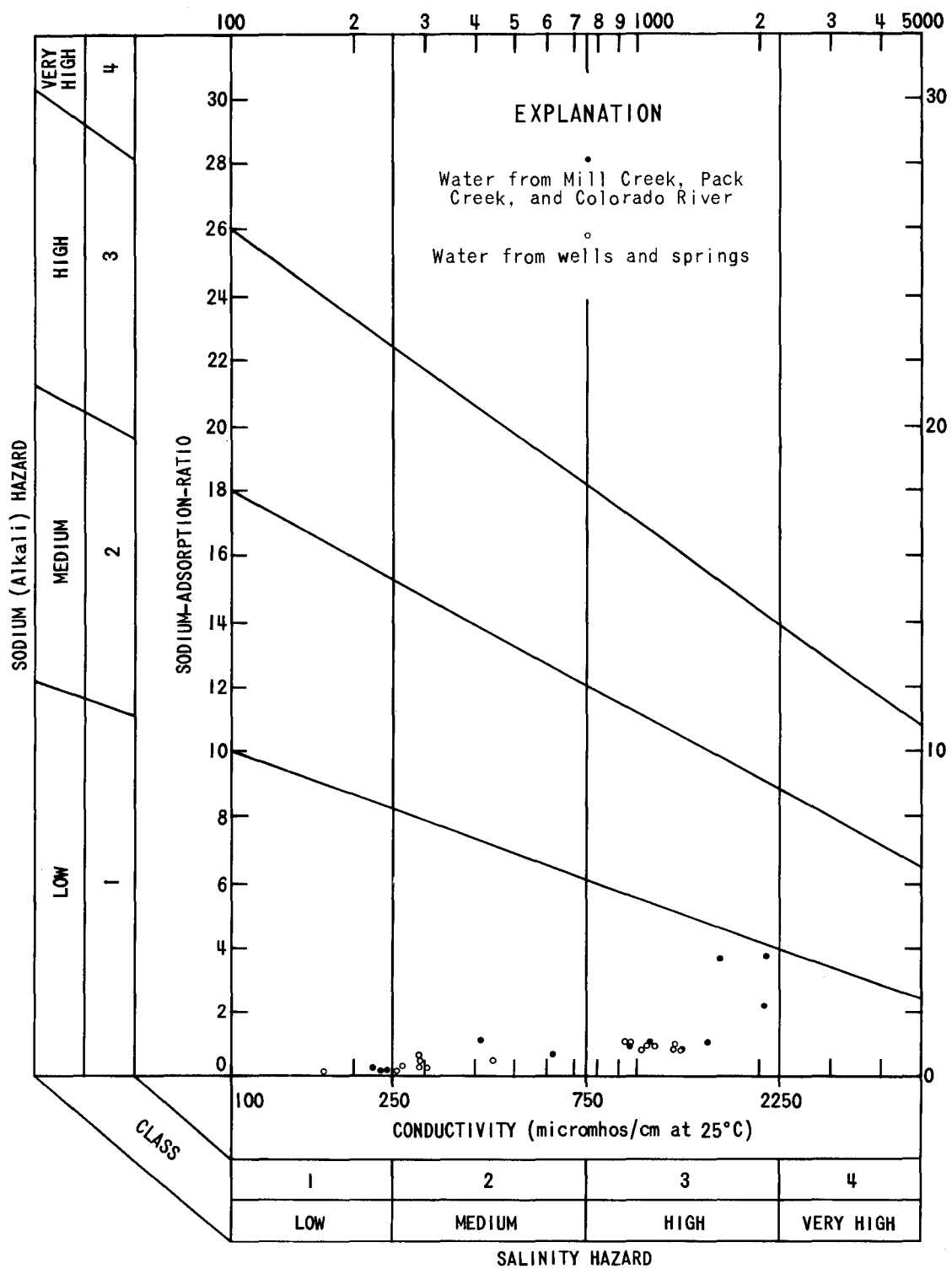


Figure 4.—Chemical classification of water for irrigation.

Table 7—Suitability of surface waters for irrigation

Adapted from Iorns and others (1965, p. 176)

| Source                                           | Date                        | Water discharge       |                | Specific conductance (micro-mhos per cm at 25° C) | Percent sodium | Sodium adsorption ratio | Classification After U.S. Salinity Laboratory Staff (1954) |
|--------------------------------------------------|-----------------------------|-----------------------|----------------|---------------------------------------------------|----------------|-------------------------|------------------------------------------------------------|
|                                                  |                             | Cubic feet per second | Classification |                                                   |                |                         |                                                            |
| Colorado River above Mill Creek, near Moab, Utah | 7-2-49                      | 22,900 <sup>1</sup>   | High           | 410                                               | 31             | 1.1                     | C2-S1<br>C3-S1                                             |
|                                                  | 9-1-49                      | 1,920 <sup>1</sup>    | Low            | 2,100                                             | 31             | 2.3                     |                                                            |
|                                                  | Jan. 16-18, 21-24, 26, 1952 | 3,300 <sup>1</sup>    | Medium         | 1,590                                             | 46             | 3.7                     |                                                            |
|                                                  |                             |                       |                |                                                   |                |                         |                                                            |
| Mill Creek at Sheley Tunnel near Moab, Utah      | 9-1-49                      | 6.0 <sup>1</sup>      | Low            | 230                                               | 7              | .2                      | C1-S1                                                      |
| Mill Creek near Moab, Utah                       | 8-22-56                     | 6.8                   | Low            | 247                                               | 6              | .1                      |                                                            |
|                                                  | 10-26-57                    | 13 <sup>2</sup>       | Medium         | 238                                               | 6              | .1                      |                                                            |
|                                                  | 5-9-58                      | 63 <sup>2</sup>       | High           | 200                                               | ---            | ---                     |                                                            |
| Pack Creek at M4 Ranch, near Moab, Utah          | 8-6-58                      | 1.4 <sup>2</sup>      | ---            | 963                                               | 17             | .9                      | C3-S1<br>C2-S1                                             |
| Pack Creek near Moab, Utah                       | 7-2-49                      | .5 <sup>1</sup>       | Low            | 1,530                                             | 17             | 1.0                     |                                                            |
|                                                  | 5-8-58                      | 8.8 <sup>2</sup>      | ---            | 612                                               | 15             | .6                      |                                                            |
|                                                  | 8-6-58                      | 1.5 <sup>2</sup>      | ---            | 1,080                                             | 18             | 1.0                     |                                                            |
| Mill Creek at mouth, near Moab, Utah             | 9-28-48                     | 2.5                   | Low            | 1,290                                             | 14             | .8                      | C3-S1                                                      |
| Colorado River below Mill Creek, near Moab, Utah | 9-28-48                     | 2,400 <sup>1</sup>    | Low            | 2,100                                             | 42             | 3.8                     |                                                            |

<sup>1</sup> Estimated.<sup>2</sup> From gage height or measurement at time of sampling.

The specific conductances of surface waters in the Spanish Valley area were measured during February 1969, a time of year when discharge of the streams is generally low (table 4) and the concentrations of dissolved solids in the streams as indicated by specific conductance, is most nearly representative of base flow (Hem, 1959, p. 42). During the period of measurement, the specific conductance of water in Mill Creek near its source at Warner Lake was 170 micromhos per centimeter (pl. 2). The specific conductance of the water increased with increasing distance from its source, mainly due to ground-water inflow, and it was 245 micromhos per centimeter before flowing into Spanish Valley. From that point to the confluence of Mill Creek with the Colorado River, the specific conductance of water in the creek increased to 760 micromhos per centimeter. This increase was caused by ground-water inflow in Spanish Valley and from lower Pack Creek, both of which contain considerably more dissolved solids than does the water in Mill Creek. Before it enters Spanish Valley, the water in Mill Creek has a low-salinity hazard and low-sodium hazard for irrigation. By the time it discharges into the Colorado River, the creek water has a high-salinity hazard (table 7).

The specific conductance of water in upper Pack Creek near its source at Pack Creek Spring in February 1969 was 1,220 micromhos per centimeter, and it showed little change as far as the irrigated area near the old county airport. The conductance increases somewhat downstream from the airport due to return flow from irrigation, and throughout its course Pack Creek has a high-salinity hazard and low-sodium hazard for irrigation (table 7).

Water is not diverted from the Colorado River for any use in Spanish Valley; near Moab it has a medium-to-high salinity hazard and a low-sodium hazard for irrigation (table 7).

#### Ground water

Ground water from selected sources in the Spanish Valley area contains concentrations of dissolved solids ranging from 101 to 1,040 milligrams per liter (table 11). The principal dissolved constituents in the water are calcium, magnesium, sodium, bicarbonate, sulfate, and chloride. The concentrations (in milliequivalents per liter) of these constituents in selected samples are shown by modified Stiff diagrams on plate 2 (Stiff, 1951, p. 15-17).

Ground water in and near the southeastern part of Spanish Valley contains relatively high concentrations of calcium and sulfate, as indicated by Stiff diagrams of water samples from well (D-27-23)23cab-1 and Pack Creek Spring, (D-27-23)24dcc-S1 (pl. 2) and analyses in table 11. Ground water of this chemical quality has a high-salinity hazard and a low-sodium hazard for irrigation and contains more than twice the concentrations of sulfate and dissolved solids that are recommended for drinking-water supplies by the U.S. Public Health Service (1962). The source of the ground water in and near the southeastern part of Spanish Valley probably is recharge from permeable units of the Morrison Formation of Late Jurassic age and formations of Cretaceous age (pl. 1).

Selected ground-water samples from the Navajo and Wingate Sandstones that were collected in the upland areas northeast of Spanish Valley contain lower concentrations of dissolved solids than does ground water at the southeastern part of Spanish Valley. Stiff diagrams of water samples from public-supply wells (D-26-22)15dca-1 and (D-26-22)22aad-1 and from spring (D-26-22)14acc-S1, and chemical analysis of a sample from spring (D-26-22)15cbb-S1 indicate that the principal dissolved constituents of water from the sandstones are calcium and

bicarbonate (pl. 2 and table 11). Ground water from these wells and springs is satisfactory for public supply and has a medium-salinity hazard and low-sodium hazard for irrigation (fig. 4 and table 11). As water from the sandstone aquifers enters the valley fill, it mixes with and dilutes the ground water in the valley fill. Mixing of the two types of water is irregular but becomes progressively more apparent northwestward through Spanish Valley as indicated by Stiff diagrams of water samples from wells (D-26-22)21baa-2, (D-26-22)7bad-1, and (D-26-21)1dcc-1 (pl. 2). Analyses of water samples of these wells in table 11 show a decrease in the concentration of dissolved solids between the southeastern well and the northwestern well.

Although Spanish Valley is underlain at depth by evaporite deposits of the Paradox Member of the Hermosa Formation, no saline water or brine has been observed in the valley fill. The valley fill is separated from the underlying Paradox by relatively impervious shale and anhydrite as shown in the driller's log of well (D-25-21)26dcc-2 (table 8). The black shale directly underlying the valley fill contains some thin anhydrite layers, but the principal evaporite deposits of the Paradox are about 435 to 540 feet beneath the base of the fill near Moab.

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## **BASIC DATA**

Table 8.--Selected drillers' logs of wells in Spanish Valley

Altitudes are in feet above sea level for land surface at well.

Thickness in feet.

Depth in feet below land surface.

| Material                                                         | Thickness | Depth | Material                                                            | Thickness | Depth | Material                                                         | Thickness | Depth |
|------------------------------------------------------------------|-----------|-------|---------------------------------------------------------------------|-----------|-------|------------------------------------------------------------------|-----------|-------|
| <u>(D-25-21)26dcc-2.</u> Log by E. J. Mayhew.<br>Alt. 3,970 ft.  |           |       | <u>(D-26-22)7bdc-2.</u> Log by C. E.<br>Harrison. Alt. 4,125 ft.    |           |       | <u>(D-26-22)22ddc-1 - Continued</u>                              |           |       |
| Mud, sand, and gravel. . . . .                                   | 42        | 42    | Soil . . . . .                                                      | 5         | 5     | Sand and gravel; water bearing . . . . .                         | 85        | 120   |
| Gravel; water bearing . . . . .                                  | 84        | 126   | Sand . . . . .                                                      | 23        | 28    | Clay . . . . .                                                   | 5         | 125   |
| Clay and gravel. . . . .                                         | 58        | 184   | Clay, yellow. . . . .                                               | 4         | 32    | <u>(D-26-22)35acd-1.</u> Log by J.<br>Zimmerman. Alt. 4,760 ft.  |           |       |
| Gravel; water bearing . . . . .                                  | 142       | 326   | Cobbles; water bearing . . . . .                                    | 19        | 51    | Gravel and boulders. . . . .                                     | 145       | 145   |
| Sand; water bearing; base of fresh-<br>water zones . . . . .     | 39        | 365   | Sand; water bearing . . . . .                                       | 2         | 53    | Gravel; water bearing . . . . .                                  | 10        | 155   |
| Sandstone and black shale . . . . .                              | 35        | 400   | <u>(D-26-22)7ddb-1.</u> Log by E. L.<br>Christensen. Alt. 4,210 ft. |           |       | Clay . . . . .                                                   | 5         | 160   |
| Gypsum and black shale . . . . .                                 | 103       | 503   | Sandy soil . . . . .                                                | 50        | 50    | Gravel; water bearing . . . . .                                  | 50        | 210   |
| Shale, black . . . . .                                           | 4         | 507   | Quicksand; water bearing. . . . .                                   | 35        | 85    | <u>(D-26-22)35bab-2.</u> Log by H. E.<br>Beeman. Alt. 4,700 ft.  |           |       |
| Anhydrite and black shale . . . . .                              | 80        | 587   | Gravel; water bearing . . . . .                                     | 6         | 91    | Cobbles. . . . .                                                 | 140       | 140   |
| Anhydrite, black shale, and sandstone. . . . .                   | 148       | 735   | <u>(D-26-22)16ccb-1.</u> Log by H. E.<br>Beeman. Alt. 4,430 ft.     |           |       | Dark sand and gravel . . . . .                                   | 61        | 201   |
| Anhydrite and black shale. . . . .                               | 54        | 789   | Sand, red . . . . .                                                 | 45        | 45    | <u>(D-27-22)1bbb-1.</u> Log by C. M. Conway.<br>Alt. 4,820 ft.   |           |       |
| Anhydrite . . . . .                                              | 93        | 882   | Gravel, coarse. . . . .                                             | 15        | 60    | Soil . . . . .                                                   | 5         | 5     |
| Salt . . . . .                                                   | 54        | 936   | Sand, red . . . . .                                                 | 25        | 85    | Sand, gravel, and cobbles. . . . .                               | 195       | 200   |
| Anhydrite and shale. . . . .                                     | 107       | 1,043 | Gravel; water bearing . . . . .                                     | 19        | 104   | Gravel . . . . .                                                 | 30        | 230   |
| Salt . . . . .                                                   | 777       | 1,820 | <u>(D-26-22)17acb-1.</u> Log by J.<br>Zimmerman. Alt. 4,370 ft.     |           |       | Sand . . . . .                                                   | 5         | 235   |
| Salt, anhydrite, and carbonaceous<br>shale . . . . .             | 15        | 1,835 | Soil and red sand . . . . .                                         | 16        | 16    | Sand; water bearing. . . . .                                     | 45        | 280   |
| Salt . . . . .                                                   | 1,365     | 3,200 | Clay . . . . .                                                      | 53        | 79    | Sand, hard . . . . .                                             | 70        | 350   |
| <u>(D-25-21)35dca-1.</u> Log by H. E. Beeman.<br>Alt. 3,965 ft.  |           |       | Quicksand . . . . .                                                 | 9         | 88    | <u>(D-27-22)1bda-1.</u> Log by J.<br>Zimmerman. Alt. 4,880 ft.   |           |       |
| Sand, red . . . . .                                              | 38        | 38    | Clay . . . . .                                                      | 47        | 135   | Boulders . . . . .                                               | 15        | 15    |
| Gravel . . . . .                                                 | 7         | 48    | Quicksand; water bearing . . . . .                                  | 10        | 145   | Sand, gravel, and boulders . . . . .                             | 130       | 145   |
| <u>(D-26-21)1bac-1.</u> Log by H. E.<br>Harrison. Alt. 3,990 ft. |           |       | Gravel; water bearing . . . . .                                     | 9         | 154   | Clay . . . . .                                                   | 6         | 151   |
| Soil . . . . .                                                   | 5         | 5     | <u>(D-26-22)21bad-1.</u> Log by J.<br>Zimmerman. Alt. 4,500 ft.     |           |       | Shale . . . . .                                                  | 13        | 164   |
| Sand; water bearing . . . . .                                    | 34        | 39    | Sand . . . . .                                                      | 8         | 8     | Shale, white . . . . .                                           | 8         | 172   |
| Sand and gravel; water bearing . . . . .                         | 5         | 44    | Clay, sand, and gravel . . . . .                                    | 22        | 30    | Shale, red . . . . .                                             | 9         | 181   |
| <u>(D-26-21)1ddb-1.</u> Log by W. Tuy.<br>Alt. 4,060 ft.         |           |       | Sand; water bearing . . . . .                                       | 10        | 40    | Sand, white, hard; water bearing . . . . .                       | 8         | 189   |
| Sand . . . . .                                                   | 5         | 5     | Gravel and sand; water bearing. . . . .                             | 16        | 56    | Boulders . . . . .                                               | 3         | 192   |
| Clay . . . . .                                                   | 3         | 8     | Gravel; water bearing . . . . .                                     | 6         | 62    | <u>(D-27-22)1cdd-1.</u> Log by C. E.<br>Harrison. Alt. 4,920 ft. |           |       |
| Sand, gravel, and cobbles; water<br>bearing . . . . .            | 22        | 30    | <u>(D-26-22)22cba-1.</u> Log by H. E.<br>Beeman. Alt. 4,550 ft.     |           |       | Soil . . . . .                                                   | 8         | 8     |
| <u>(D-26-21)1ddc-1.</u> Log by T. White.<br>Alt. 4,075 ft.       |           |       | Soil and sand . . . . .                                             | 40        | 40    | Gravel . . . . .                                                 | 97        | 105   |
| Sand . . . . .                                                   | 20        | 20    | Conglomerate; water bearing . . . . .                               | 41        | 81    | Shale, hard . . . . .                                            | 18        | 115   |
| Gravel; water bearing . . . . .                                  | 15        | 35    | <u>(D-26-22)22ddc-1.</u> Log by H. E.<br>Beeman. Alt. 4,600 ft.     |           |       | Gravel and boulders. . . . .                                     | 30        | 145   |
| Cobbles; water bearing . . . . .                                 | 18        | 53    | Sand, red . . . . .                                                 | 35        | 35    | Sandstone, red, broken; water bearing. . . . .                   | 155       | 300   |
| Gravel; water bearing . . . . .                                  | 27        | 80    |                                                                     |           |       | Sand; water bearing. . . . .                                     | 10        | 310   |

Table 9.--Records of selected wells in the Spanish Valley area

Location: See text for well-numbering system.

Aquifer: Qvf, valley fill; JTrn, Navajo Sandstone; Trw, Wingate Sandstone; Pc, Cutler Formation.

Water use: C, commercial; H, domestic; I, irrigation; N, industrial; P, public supply T, institution; U, unused; Z, mining.

Other data available: C, chemical analysis in table 11; D, driller's log of well available from files of Utah Department of Natural Resources, Division of Water Rights, or the U.S. Geological Survey; L, driller's log of well in table 8.

| Location  | Owner or name                       | Year drilled | Depth of well | Casing            |              | Aquifer | Altitude above sea level (feet) | Water level (in feet below land surface) | Date of measurement | Yield      |                  | Use of water | Other data available |
|-----------|-------------------------------------|--------------|---------------|-------------------|--------------|---------|---------------------------------|------------------------------------------|---------------------|------------|------------------|--------------|----------------------|
|           |                                     |              |               | Diameter (inches) | Depth (feet) |         |                                 |                                          |                     | Rate (gpm) | Draw-down (feet) |              |                      |
| (D-25-21) |                                     |              |               |                   |              |         |                                 |                                          |                     |            |                  |              |                      |
| 26dcc-1   | Suburban Gas Co.                    | 1962         | 55            | 7                 | 45           | Qvf     | 3,990                           | -                                        | -                   | 25         | 0                | H            | C,D                  |
| 26dcc-2   | do                                  | 1960         | 3,200         | 9                 | 1,260        | Qvf     | 3,970                           | -                                        | -                   | -          | -                | U            | D,L                  |
| 27dda-1   | Bureau of Reclamation               | 1957         | 10            | 3                 | 1            | Qvf     | 3,950                           | 4                                        | June 1957           | -          | -                | U            | D                    |
| 28adb-1   | Atomic Energy Commission            | 1954         | 114           | 6                 | -            | Qvf     | 4,060                           | 24                                       | May 1954            | 11         | 2                | N            | D                    |
| 28add-1   | Bureau of Land Management Park well | 1940         | 67            | 8                 | 53           | Qvf     | 3,990                           | 42                                       | Jan. 1940           | 20         | -                | U            | D                    |
| 28dab-1   | Morrison-Knudsen Co.                | 1961         | 130           | 8                 | 118          | Qvf     | 4,080                           | 89                                       | Oct. 1967           | 18         | 11               | Z            | D                    |
| 34bbd-1   | Embar Oil No. 1                     | 1928         | 5,345         | 12                | -            | Qvf     | 3,965                           | 85                                       | Oct. 1967           | -          | -                | U            | D                    |
| 35bbb-1   | Bureau of Reclamation               | 1957         | 10            | 3                 | 1            | Qvf     | 3,955                           | 2                                        | June 1957           | -          | -                | U            | D                    |
| 35bdd-1   | GLC Oil Test                        | 1942         | 1,700         | 10                | 408          | Qvf     | 3,955                           | -                                        | -                   | -          | -                | U            | D                    |
| 35daa-1   | E. Thompson                         | 1956         | 57            | 7                 | 45           | Qvf     | 3,980                           | 9                                        | July 1956           | 20         | 13               | H            | D                    |
| 35dac-1   | Utex Explor. Co.                    | 1959         | 45            | 6                 | 10           | Qvf     | 3,960                           | 0                                        | Oct. 1967           | -          | -                | H            | D                    |
| 35dca-1   | V. McElbany                         | 1956         | 48            | 6                 | 40           | Qvf     | 3,965                           | -                                        | -                   | 20         | -                | H            | D,L                  |
| 35dca-2   | J. W. Estes                         | 1964         | 45            | 6                 | 45           | Qvf     | 3,965                           | -                                        | -                   | 20         | 0                | H            | D                    |
| 36cac-1   | Utex Explor. Co.                    | 1961         | 90            | 6                 | 24           | Qvf     | 3,995                           | 17                                       | Oct. 1967           | 70         | -                | H            | D                    |
| 36cad-1   | C. A. Steen                         | 1955         | 200           | 6                 | 140          | Qvf     | 4,080                           | -                                        | -                   | -          | -                | H            | D                    |
| 36cbd-1   | J. Hudson                           | 1968         | 85            | 6                 | 82           | Qvf     | 3,985                           | 12                                       | Aug. 1968           | 45         | 8                | H            | D                    |
| 36ccd-1   | L. L. Taylor                        | 1956         | 65            | 10                | 53           | Qvf     | 3,980                           | -                                        | -                   | 30         | -                | I            | D                    |
| 36cda-1   | Utex Explor. Co.                    | 1959         | 84            | 6                 | -            | Qvf     | 4,000                           | 14                                       | Oct. 1967           | 82         | 2                | H            | D                    |
| 36cdb-1   | W. K. Alexander                     | 1963         | 60            | 6                 | 54           | Qvf     | 3,985                           | -                                        | -                   | 15         | 0                | H            | D                    |
| 36cdc-1   | Grand County                        | 1956         | 89            | 7                 | 69           | Qvf     | 3,990                           | 20                                       | Oct. 1967           | -          | 40               | P            | D                    |
| 36dcc-1   | A. Day                              | -            | 60            | 6                 | 48           | Qvf     | 4,035                           | 42                                       | Oct. 1967           | 25         | 3                | H            | D                    |
| (D-26-21) |                                     |              |               |                   |              |         |                                 |                                          |                     |            |                  |              |                      |
| 1abc-1    | R. Miller                           | 1964         | 80            | 6                 | 58           | Qvf     | 4,030                           | -                                        | -                   | 50         | 0                | I            | D                    |
| 1abd-1    | C. H. Berhardt                      | 1954         | 47            | 6                 | 40           | Qvf     | 4,030                           | 16                                       | June 1954           | 20         | 9                | H            | D                    |
| 1aca-1    | Grand County                        | 1954         | 60            | 6                 | 50           | Qvf     | 4,030                           | 20                                       | June 1954           | 36         | 10               | T            | D                    |
| 1ada-1    | L. E. Baldwin                       | 1954         | 43            | 6                 | 40           | Qvf     | 4,070                           | 7                                        | May 1954            | 10         | -                | H            | D                    |
| 1bab-1    | J. E. Kirby                         | 1954         | 48            | 6                 | 42           | Qvf     | 3,990                           | 15                                       | June 1954           | 15         | -                | H            | D                    |
| 1bac-1    | V. C. Johnson                       | 1956         | 44            | 6                 | 38           | Qvf     | 3,990                           | 8                                        | Nov. 1956           | 20         | 10               | H            | D,L                  |
| 1bad-1    | V. L. Carroll                       | 1956         | 51            | 7                 | 44           | Qvf     | 3,995                           | 7                                        | June 1956           | 20         | 13               | H            | D                    |
| 1bbb-1    | H. M. Knight                        | 1954         | 48            | 6                 | 42           | Qvf     | 3,980                           | 12                                       | Oct. 1964           | 12         | 9                | H            | D                    |
| 1bbb-2    | J. L. Rauer                         | 1950         | 40            | 7                 | -            | Qvf     | 3,980                           | 7                                        | June 1950           | 10         | 1                | H            | D                    |
| 1bda-1    | J. Turner                           | 1954         | 45            | 5                 | 40           | Qvf     | 4,060                           | -                                        | -                   | 15         | -                | H            | D                    |
| 1bda-2    | L. Scrup                            | 1955         | 60            | 6                 | -            | Qvf     | 4,005                           | 20                                       | Oct. 1967           | 36         | 10               | H            | D                    |
| 1caa-1    | S. Sears                            | 1968         | 85            | 10                | -            | Qvf     | 4,000                           | 6                                        | July 1968           | 110        | 18               | H            | D                    |
| 1cbb-1    | D. Borwick                          | 1955         | 62            | 6                 | 22           | Qvf     | 4,020                           | 26                                       | Oct. 1967           | 50         | -                | H            | D                    |
| 1cbc-1    | M. Bullick                          | 1955         | 50            | 6                 | 40           | Qvf     | 4,035                           | 35                                       | Oct. 1967           | 36         | 10               | H            | D                    |
| 1dah-1    | J. C. Burgess                       | 1954         | 59            | 6                 | -            | Qvf     | 3,990                           | 16                                       | May 1954            | 14         | -                | H            | D                    |
| 1dah-2    | do                                  | 1955         | 42            | 6                 | -            | Qvf     | 3,990                           | 10                                       | Oct. 1967           | 36         | 5                | H            | D                    |
| 1dac-1    | L. Dull                             | 1964         | 36            | 6                 | -            | Qvf     | 4,060                           | -                                        | -                   | 25         | 0                | H            | D                    |
| 1dba-1    | J. C. Burgess                       | 1957         | 40            | 6                 | 30           | Qvf     | 3,990                           | 6                                        | Mar. 1957           | 36         | 0                | H            | D                    |
| 1dba-2    | W. R. McConkie                      | 1954         | 41            | 6                 | 30           | Qvf     | 4,030                           | 12                                       | -                   | 11         | -                | H            | D                    |
| 1dba-3    | A. Georgedes                        | 1962         | 87            | 7                 | -            | Qvf     | 4,050                           | 12                                       | May 1962            | 36         | 14               | H            | D                    |
| 1dbb-1    | E. E. Provonsha                     | 1954         | 37            | 7                 | -            | Qvf     | 4,035                           | 7                                        | July 1954           | 15         | 8                | H            | D                    |
| 1dbb-2    | V. Grow                             | 1956         | 28            | 6                 | 20           | Qvf     | 4,000                           | 12                                       | Oct. 1967           | 24         | 0                | H            | D                    |
| 1dcc-1    | Desert Lodge                        | 1961         | 50            | 7                 | 43           | Qvf     | 4,045                           | 18                                       | Oct. 1961           | 21         | 0                | C            | C,D                  |
| 1dcc-2    | G. A. Larsen                        | 1964         | 60            | 6                 | 40           | Qvf     | 4,045                           | 28                                       | Dec. 1964           | -          | -                | I            | D                    |
| 1ddb-1    | E. Anderson                         | 1964         | 30            | 5                 | 23           | Qvf     | 4,060                           | 25                                       | Oct. 1967           | -          | -                | I            | D,L                  |
| 1ddc-1    | Grand County                        | 1966         | 80            | 9                 | 60           | Qvf     | 4,075                           | 18                                       | May 1966            | -          | -                | T            | D,L                  |
| (D-26-22) |                                     |              |               |                   |              |         |                                 |                                          |                     |            |                  |              |                      |
| 6bbb-1    | J. E. Riley                         | 1954         | 51            | 6                 | -            | Qvf     | 4,320                           | 12                                       | Sept. 1954          | 15         | -                | H            | D                    |
| 6cba-1    | J. Youvan                           | 1955         | 128           | 6                 | 120          | Qvf     | 4,090                           | 20                                       | Sept. 1955          | 36         | 50               | H            | D                    |
| 6cba-2    | G. E. Lile                          | 1955         | 59            | 6                 | 53           | Qvf     | 4,110                           | 12                                       | Sept. 1955          | 20         | 8                | H            | D                    |
| 6cbb-1    | M. Bentley                          | 1955         | 30            | 6                 | 25           | Qvf     | 4,080                           | 20                                       | July 1955           | 36         | 0                | H            | D                    |
| 6cbb-2    | D. O'Laurie                         | 1956         | 30            | 6                 | 22           | Qvf     | 4,090                           | 20                                       | June 1956           | 20         | 0                | H            | D                    |
| 6cbb-3    | L. A. McCormick                     | 1955         | 93            | 6                 | 73           | Qvf     | 4,100                           | 80                                       | Nov. 1955           | 8          | 0                | H            | D                    |
| 6cbc-1    | H. E. Provonsha                     | 1955         | 46            | 6                 | -            | Qvf     | 4,080                           | 4                                        | July 1955           | 36         | 26               | H            | D                    |
| 6cbc-2    | D. Provonsha                        | 1956         | 85            | 9                 | 70           | Qvf     | 4,075                           | 10                                       | Apr. 1956           | 15         | 5                | H            | D                    |
| 7aca-1    | City of Moab                        | 1956         | 222           | 12                | -            | Qvf     | 4,160                           | 22                                       | Apr. 1956           | 100        | 108              | P            | D                    |
| 7aca-2    | do                                  | 1956         | 245           | 12                | 24           | Qvf     | 4,160                           | 20                                       | Oct. 1967           | 250        | 80               | P            | D                    |
| 7bac-1    | Helca Subdivision                   | 1964         | 108           | 8                 | -            | Qvf     | 4,125                           | -                                        | -                   | 25         | 0                | H            | C,D                  |
| 7bad-1    | Hecla Mine Co.                      | 1955         | 80            | 6                 | 70           | Qvf     | 4,125                           | 10                                       | May 1955            | 36         | 10               | H            | D                    |
| 7bbd-1    | D. Young                            | 1956         | 59            | 7                 | 50           | Qvf     | 4,110                           | 20                                       | July 1956           | 20         | 3                | H            | D                    |
| 7bcb-1    | M. L. Walston                       | 1964         | 46            | 8                 | -            | Qvf     | 4,100                           | -                                        | -                   | 15         | 0                | H            | D                    |
| 7bcc-1    | B. E. Kinney                        | 1955         | 50            | 6                 | 40           | Qvf     | 4,130                           | 30                                       | Oct. 1967           | 36         | 10               | H            | D                    |
| 7bdc-1    | J. W. Taylor                        | 1959         | 47            | 6                 | 41           | Qvf     | 4,140                           | 15                                       | Mar. 1959           | 6          | 20               | H            | D                    |
| 7bdc-2    | P. C. Steinke                       | 1956         | 53            | 7                 | 51           | Qvf     | 4,125                           | 20                                       | May 1956            | 20         | 5                | H            | D,L                  |
| 7cab-1    | Moab Lanes                          | 1960         | 50            | 7                 | 44           | Qvf     | 4,160                           | 15                                       | Oct. 1967           | 15         | 10               | C            | D                    |
| 7cab-2    | R. L. Dalton                        | 1959         | 47            | 6                 | -            | Qvf     | 4,160                           | 25                                       | Aug. 1959           | 10         | 5                | H            | D                    |
| 7cad-1    | K. Westwood                         | 1954         | 42            | 6                 | -            | Qvf     | 4,215                           | 35                                       | Sept. 1954          | 10         | 0                | H            | D                    |
| 7cad-2    | M. Smith                            | 1954         | 31            | 6                 | -            | Qvf     | 4,200                           | 19                                       | Sept. 1954          | 10         | 0                | H            | D                    |
| 7cbe-1    | R. Starbuck                         | 1954         | 70            | 6                 | -            | Qvf     | 4,180                           | 10                                       | May 1954            | 10         | -                | H            | D                    |
| 7cbd-1    | First Assembly of God Church        | 1963         | 83            | 6                 | 75           | Qvf     | 4,205                           | -                                        | -                   | 303        | 3                | T            | D                    |

Table 9.--Records of selected wells in the Spanish Valley area - Continued

| Location  | Owner or name             | Year drilled | Depth of well | Casing            |              | Aquifer | Altitude above sea level (feet) | Water level (in feet below land surface) | Date of measurement | Yield      |                  | Use of water | Other data available |
|-----------|---------------------------|--------------|---------------|-------------------|--------------|---------|---------------------------------|------------------------------------------|---------------------|------------|------------------|--------------|----------------------|
|           |                           |              |               | Diameter (inches) | Depth (feet) |         |                                 |                                          |                     | Rate (gpm) | Draw-down (feet) |              |                      |
| (D-26-22) |                           |              |               |                   |              |         |                                 |                                          |                     |            |                  |              |                      |
| 7dbc-1    | T. Anderson               | 1961         | 50            | 7                 | 40           | Qvf     | 4,175                           | 15                                       | June 1961           | 14         | 22               | H            | D                    |
| 7dbc-2    | D. Gordon                 | 1961         | 47            | 7                 | 39           | Qvf     | 4,175                           | 18                                       | June 1961           | 28         | 15               | H            | D                    |
| 7dbc-3    | Basin Indust. Co.         | 1961         | 57            | 7                 | 51           | Qvf     | 4,200                           | 23                                       | Feb. 1961           | 5          | 20               | C            | D                    |
| 7dbc-4    | J. A. Fullmer             | 1961         | 65            | 6                 | 55           | Qvf     | 4,200                           | 35                                       | July 1961           | 10         | 55               | H            | D                    |
| 7dbd-1    | V. Lehr                   | 1961         | 45            | 9                 | 39           | Qvf     | 4,200                           | 13                                       | June 1961           | 4          | 30               | H            | D                    |
| 7dbd-2    | W. Irish                  | 1959         | 120           | 7                 | -            | Qvf     | 4,195                           | 26                                       | Aug. 1959           | 3          | 19               | H            | D                    |
| 7dcd-1    | G. Holyoak                | 1961         | 45            | 7                 | 39           | Qvf     | 4,275                           | 12                                       | Feb. 1961           | 10         | 8                | H            | D                    |
| 7dda-1    | D. J. Barnes              | 1954         | 80            | 7                 | 55           | Qvf     | 4,230                           | 35                                       | Sept. 1954          | 20         | 15               | H            | D                    |
| 7ddb-1    | W. F. Sanders             | 1954         | 91            | 6                 | 85           | Qvf     | 4,210                           | 50                                       | Oct. 1954           | 25         | 10               | H            | D, L                 |
| 7ddb-2    | N. Dull                   | 1964         | 60            | 6                 | 55           | Qvf     | 4,230                           | -                                        | -                   | 10         | 20               | H            | D                    |
| 7ddd-1    | A. Holyoak                | 1955         | 70            | 8                 | 53           | Qvf     | 4,140                           | 0                                        | Sept. 1955          | 15         | 20               | I            | D                    |
| 8caa-1    | R. Phillips               | 1969         | 180           | 6                 | 40           | JTrn    | 4,330                           | -                                        | -                   | 35         | -                | H            | D                    |
| 8cba-1    | O. Murphy                 | 1948         | 50            | 6                 | 35           | Qvf     | 4,240                           | 26                                       | Oct. 1948           | 20         | 1                | H            | D                    |
| 8cba-2    | do                        | 1954         | 75            | 6                 | -            | Qvf     | 4,240                           | 65                                       | Oct. 1967           | 25         | 0                | H            | D                    |
| 8cbc-1    | Moab Uranium Co.          | 1954         | 34            | 6                 | -            | Qvf     | 4,210                           | 22                                       | Nov. 1954           | 10         | 2                | C            | D                    |
| 8cbc-2    | H. Jeffries               | 1954         | 58            | 6                 | -            | Qvf     | 4,210                           | 18                                       | Oct. 1967           | 15         | -                | H            | D                    |
| 8cbc-3    | C. Hayes                  | 1963         | 101           | 7                 | -            | Qvf     | 4,210                           | 26                                       | Dec. 1963           | 30         | 35               | H            | D                    |
| 8cca-1    | K. Cooper                 | 1961         | 31            | 6                 | 25           | Qvf     | 4,220                           | 12                                       | Mar. 1961           | 14         | 3                | H            | D                    |
| 8ccd-1    | W. L. Coalson             | 1960         | 54            | 7                 | 48           | Qvf     | 4,240                           | 18                                       | Apr. 1960           | 8          | 33               | H            | D                    |
| 8cdc-1    | M. Dalley                 | 1958         | 38            | 6                 | 34           | Qvf     | 4,250                           | 15                                       | Aug. 1958           | 6          | 19               | -            | D                    |
| 8cdc-2    | C. Kimball                | 1963         | 168           | 6                 | 165          | Qvf     | 4,260                           | -                                        | -                   | 20         | 30               | H            | D                    |
| 8cdc-3    | S. A. Swink               | 1964         | 42            | 6                 | -            | Qvf     | 4,260                           | 20                                       | -                   | 20         | 0                | H            | D                    |
| 8cdd-1    | W. F. Coalson             | 1958         | 51            | 6                 | 35           | Qvf     | 4,270                           | 20                                       | Oct. 1967           | 7          | 25               | H            | D                    |
| 8cdd-2    | J. A. King                | 1957         | 115           | 6                 | 65           | Qvf     | 4,260                           | 2                                        | Oct. 1967           | 10         | 68               | H            | D                    |
| 8cdb-1    | V. J. Murphy              | 1953         | 105           | 6                 | 80           | Qvf     | 4,280                           | 60                                       | Dec. 1953           | 30         | 0                | H            | D                    |
| 8dcc-1    | J. E. Graham              | 1966         | 52            | 6                 | -            | Qvf     | 4,280                           | -                                        | -                   | 10         | 0                | H            | D                    |
| 15bcc-1   | A. N. Ray                 | 1960         | 60            | 5                 | -            | Qvf     | 4,520                           | 28                                       | Sept. 1960          | 15         | 7                | H            | D                    |
| 15bdb-1   | L. Kisida                 | 1964         | 160           | 8                 | -            | JTrn    | 4,610                           | -                                        | -                   | 10         | -                | H            | D                    |
| 15dab-1   | Texas Gulf Sulphur Co.    | 1964         | 187           | 6                 | 147          | JTrn    | 4,680                           | 125                                      | Mar. 1969           | 25         | 0                | H            | D                    |
| 15dca-1   | City of Moab              | 1969         | 185           | 14                | 98           | JTrn    | 4,600                           | 54                                       | Mar. 1969           | 2,445      | 36               | P            | C, D                 |
| 16acc-1   | W. G. Harrison            | 1956         | 75            | 6                 | -            | Trw     | 4,400                           | 30                                       | Feb. 1956           | 30         | 25               | H            | D                    |
| 16acd-1   | M. D. Anderson            | 1964         | 100           | 6                 | 10           | Trw     | 4,450                           | 60                                       | Oct. 1967           | -          | -                | H            | D                    |
| 16ada-1   | W. S. Christensen         | 1955         | 26            | 5                 | 19           | JTrn    | 4,500                           | 15                                       | Mar. 1955           | 36         | 0                | H            | D                    |
| 16adc-1   | J. I. Winder              | 1966         | 85            | -                 | -            | JTrn    | 4,460                           | -                                        | -                   | 15         | 0                | H            | D, L                 |
| 16add-1   | P. Shumway                | 1959         | 50            | -                 | 30           | Qvf     | 4,500                           | 6                                        | Dec. 1959           | 30         | 0                | H            | D                    |
| 16bdb-1   | A. R. Shumway             | 1956         | 75            | 6                 | -            | Trw     | 4,360                           | 32                                       | Feb. 1956           | 36         | 23               | H            | D                    |
| 16cab-1   | D. G. Farnsworth          | 1965         | 120           | 6                 | 60           | Trw     | 4,380                           | -                                        | -                   | 8          | 110              | H            | D                    |
| 16cad-1   | L. D. Shumway             | 1965         | 46            | 6                 | 40           | Qvf     | 4,400                           | -                                        | -                   | 10         | 20               | H            | D                    |
| 16ccb-1   | R. Beeman                 | 1967         | 104           | 6                 | 90           | Qvf     | 4,430                           | -                                        | -                   | 20         | 0                | H            | D                    |
| 16ccb-2   | C. Kretzer                | 1962         | 51            | 6                 | 45           | Qvf     | 4,450                           | 40                                       | Oct. 1967           | -          | -                | H            | D                    |
| 16ccc-1   | J. Dowd                   | 1959         | 78            | 9                 | -            | Qvf     | 4,450                           | 35                                       | Oct. 1968           | 25         | 15               | I            | D                    |
| 16ccd-1   | L. G. Shumway             | 1955         | 40            | 6                 | 30           | Qvf     | 4,460                           | 15                                       | June 1955           | 36         | 0                | H            | D                    |
| 16ced-2   | M. Randall                | 1963         | 54            | 6                 | -            | Qvf     | 4,460                           | -                                        | -                   | 30         | 10               | H            | D                    |
| 16cdb-1   | J. E. Purchell            | 1960         | 40            | 6                 | 30           | Qvf     | 4,450                           | 25                                       | Dec. 1960           | 30         | 0                | H            | D                    |
| 16cdc-1   | L. H. Cole                | 1954         | 65            | 5                 | -            | Qvf     | 4,470                           | 20                                       | Nov. 1954           | -          | -                | H            | D                    |
| 16dab-1   | D. O'Laurie               | 1955         | 110           | 8                 | -            | Trw     | 4,440                           | 70                                       | Feb. 1955           | 24         | 0                | H            | D                    |
| 16dca-1   | F. Kerby                  | 1962         | 69            | 8                 | -            | Qvf     | 4,440                           | 26                                       | Mar. 1962           | 24         | 2                | I            | D                    |
| 16dcd-1   | E. Brown                  | 1962         | 57            | 7                 | 50           | Qvf     | 4,470                           | -                                        | -                   | 20         | 7                | H            | D                    |
| 16ddc-1   | R. Randall                | 1963         | 53            | 6                 | 48           | Qvf     | 4,460                           | -                                        | -                   | 25         | 0                | H            | D                    |
| 16ddd-1   | J. L. Winbourne           | 1962         | 254           | 8                 | -            | Qvf     | 4,470                           | 16                                       | Mar. 1962           | 32         | 4                | H            | D                    |
| 16ddd-2   | Ace Turner                | 1962         | 60            | 6                 | 52           | Qvf     | 4,470                           | -                                        | -                   | 60         | 10               | H            | D                    |
| 17aab-1   | L. F. Newman              | 1963         | 140           | 6                 | -            | JTrn    | 4,400                           | 115                                      | Sept. 1963          | 15         | 0                | H            | D                    |
| 17aac-1   | P. H. Stocks              | 1954         | 42            | 6                 | 32           | Qvf     | 4,420                           | 10                                       | Dec. 1954           | 48         | 0                | H            | D                    |
| 17aac-2   | W. R. Enright             | 1961         | 45            | 6                 | 20           | Qvf     | 4,310                           | 20                                       | July 1961           | 30         | 0                | H            | D                    |
| 17aac-3   | J. Patrick                | 1960         | 33            | 7                 | 27           | Qvf     | 4,310                           | 12                                       | Oct. 1967           | 12         | 8                | H            | D                    |
| 17aac-4   | M. J. Ambrose             | 1957         | 42            | 6                 | 32           | Qvf     | 4,340                           | 12                                       | Feb. 1957           | 20         | -                | H            | D                    |
| 17aad-1   | D. E. Johnson             | 1956         | 40            | 6                 | -            | Trw     | 4,340                           | 26                                       | Mar. 1956           | 36         | 2                | H            | D                    |
| 17aba-1   | H. Sargeant               | 1957         | 120           | 8                 | -            | Trw     | 4,320                           | 54                                       | Apr. 1957           | 20         | 41               | -            | D                    |
| 17aba-2   | H. Oliver                 | 1961         | 58            | 7                 | 50           | Qvf     | 4,300                           | 13                                       | Feb. 1961           | 7          | 41               | H            | D                    |
| 17aba-3   | do                        | 1962         | 100           | 7                 | 89           | Trw     | 4,310                           | 51                                       | Oct. 1962           | 32         | 0                | H            | D                    |
| 17abb-1   | J. R. Nicol               | 1956         | 42            | 6                 | 37           | Qvf     | 4,290                           | 14                                       | Dec. 1956           | 16         | 8                | H            | D                    |
| 17acb-1   | D. J. Tanner              | 1961         | 154           | 7                 | -            | Qvf     | 4,370                           | 126                                      | Dec. 1961           | 7          | 25               | H            | D, L                 |
| 17acc-1   | C. S. Thompson            | 1961         | 206           | 6                 | -            | Qvf     | 4,380                           | 80                                       | Oct. 1967           | 7          | 0                | H            | D                    |
| 17acd-1   | W. Coalson                | 1960         | 108           | 6                 | 79           | Qvf     | 4,380                           | 23                                       | Apr. 1960           | 6          | 62               | H            | D                    |
| 17ada-1   | D. Wimmer                 | 1964         | 201           | 7                 | -            | Qvf     | 4,340                           | 88                                       | May 1964            | 12         | 60               | H            | D                    |
| 17ada-2   | J. L. Starbuck            | 1957         | 42            | 6                 | 37           | Qvf     | 4,310                           | 16                                       | Mar. 1957           | 20         | 2                | H            | D                    |
| 17ada-3   | J. D. Romero              | 1957         | 42            | 6                 | 37           | Qvf     | 4,310                           | 15                                       | Apr. 1957           | 20         | 3                | H            | D                    |
| 17adb-1   | R. L. Christensen         | 1955         | 42            | 7                 | 30           | Qvf     | 4,320                           | 8                                        | Nov. 1955           | 20         | -                | H            | D                    |
| 17adc-1   | M. Beeson                 | 1957         | 36            | 6                 | 26           | Qvf     | 4,380                           | 20                                       | July 1957           | 30         | 4                | H            | D                    |
| 17adc-2   | E. Tomsic                 | 1956         | 69            | 6                 | 59           | Qvf     | 4,380                           | 12                                       | Sept. 1956          | 8          | 40               | H            | D                    |
| 17bdd-1   | O. E. Boulder             | 1955         | 83            | 9                 | 75           | Qvf     | 4,390                           | 40                                       | Sept. 1955          | 15         | 20               | H            | D                    |
| 17cab-1   | I. Stewart                | 1959         | 170           | 6                 | 160          | Qvf     | 4,420                           | 150                                      | Dec. 1959           | 20         | 0                | H            | D                    |
| 17dba-1   | C. L. Relitz              | 1969         | 197           | 6                 | -            | Qvf     | 4,400                           | 70                                       | Feb. 1969           | 16         | 0                | H            | D                    |
| 17dbb-1   | H. Cleveland              | 1963         | 211           | 6                 | -            | Qvf     | 4,400                           | -                                        | -                   | 15         | 35               | H            | D                    |
| 17dbc-1   | Garrett Freight Lines Co. | 1954         | 153           | 6                 | 123          | Qvf     | 4,450                           | 77                                       | Oct. 1967           | 14         | 25               | H            | C, D                 |
| 18abd-1   | I. W. Allen               | 1949         | 280           | 6                 | 90           | Pc      | 4,400                           | 78                                       | June 1949           | 15         | 6                | H            | D                    |
| 20aac-1   | M. C. Tangreen            | 1963         | 120           | 7                 | 117          | Qvf     | 4,510                           | -                                        | -                   | 15         | 0                | H            | D                    |
| 20acd-1   | R. L. Robson              | 1959         | 133           | 6                 | -            | Pc      | 4,580                           | 118                                      | Oct. 1967           | 20         | 0                | H            | D                    |
| 20ada-1   | M. A. Coalson             | 1958         | 113           | 6                 | 107          | Qvf     | 4,550                           | 110                                      | Nov. 1958           | 7          | 0                | H            | D                    |
| 20adb-1   | D. Carlin                 | 1962         | 150           | 6                 | 140          | Pc      | 4,550                           | -                                        | -                   | -          | -                | -            | D                    |

Table 9.--Records of selected wells in the Spanish Valley Area - Continued

| Location  | Owner or name             | Year drilled | Depth of well | Casing            |              | Aquifer | Altitude above sea level (feet) | Water level (in feet below land surface) | Date of measurement | Yield      |                  | Use of water | Other data available |
|-----------|---------------------------|--------------|---------------|-------------------|--------------|---------|---------------------------------|------------------------------------------|---------------------|------------|------------------|--------------|----------------------|
|           |                           |              |               | Diameter (inches) | Depth (feet) |         |                                 |                                          |                     | Rate (gpm) | Draw-down (feet) |              |                      |
| (D-26-22) |                           |              |               |                   |              |         |                                 |                                          |                     |            |                  |              |                      |
| 21aac-1   | K. Allred                 | 1964         | 65            | 6                 | -            | Qvf     | 4,500                           | -                                        | -                   | 35         | 0                | H            | D                    |
| 21abd-1   | V. L. Davis               | 1964         | 64            | 8                 | 56           | Qvf     | 4,500                           | -                                        | -                   | 28         | 0                | H            | D                    |
| 21aca-1   | L. W. Scorup              | 1959         | 63            | 6                 | 53           | Qvf     | 4,510                           | 35                                       | Aug. 1959           | 20         | 15               | H            | D                    |
| 21aca-2   | L. C. Davis               | 1960         | 63            | 7                 | 57           | Qvf     | 4,500                           | 29                                       | Dec. 1960           | 12         | 21               | H            | D                    |
| 21acb-1   | R. Coalson                | 1958         | 65            | 6                 | 57           | Qvf     | 4,530                           | 19                                       | Nov. 1958           | 10         | 16               | H            | D                    |
| 21acd-1   | W. F. Coalson             | 1958         | 60            | 6                 | 53           | Qvf     | 4,540                           | 21                                       | Nov. 1958           | 10         | 19               | H            | D                    |
| 21adb-1   | J. O. Rossiter            | 1958         | 56            | 6                 | 51           | Qvf     | 4,510                           | 18                                       | Nov. 1958           | 10         | 12               | H            | D                    |
| 21adb-2   | G. Gordon                 | 1960         | 65            | 7                 | 59           | Qvf     | 4,510                           | 32                                       | Mar. 1960           | 14         | 22               | H            | D                    |
| 21baa-1   | R. J. Oviatt              | 1961         | 55            | 7                 | -            | Qvf     | 4,480                           | 28                                       | Apr. 1961           | 20         | 11               | H            | D                    |
| 21baa-2   | W. J. Jones               | 1966         | 66            | 10                | 54           | Qvf     | 4,480                           | -                                        | -                   | 70         | 10               | I            | C, D                 |
| 21bab-1   | R. E. McCormick           | 1960         | 54            | 6                 | -            | Qvf     | 4,490                           | 33                                       | Oct. 1960           | -          | -                | -            | D                    |
| 21bad-1   | D. Oliver                 | 1961         | 62            | 7                 | 56           | Qvf     | 4,500                           | 31                                       | June 1961           | 20         | 5                | H            | D, L                 |
| 21bbb-1   | J. M. Adkinson            | 1961         | 32            | 6                 | 26           | Qvf     | 4,470                           | 21                                       | Mar. 1961           | 12         | 0                | -            | D                    |
| 21bbc-1   | P. Rockwell               | 1961         | 71            | 6                 | -            | Qvf     | 4,500                           | 60                                       | Feb. 1961           | 10         | 5                | H            | D                    |
| 21bdd-1   | C. Story                  | 1962         | 87            | 7                 | 77           | Qvf     | 4,550                           | -                                        | -                   | 20         | 5                | H            | D                    |
| 21bdd-2   | O. Sheets, Jr.            | 1966         | 67            | 6                 | -            | Qvf     | 4,540                           | -                                        | -                   | 15         | 0                | H            | D                    |
| 21daa-1   | K. L. Young               | 1960         | 57            | 7                 | 51           | Qvf     | 4,580                           | 29                                       | Mar. 1960           | 11         | 7                | H            | D                    |
| 21daa-2   | V. P. Welch               | 1961         | 72            | 9                 | 64           | Qvf     | 4,560                           | 27                                       | Apr. 1961           | 30         | 10               | H            | D                    |
| 21daa-3   | K. L. Young               | 1962         | 57            | 7                 | 51           | Qvf     | 4,580                           | 31                                       | Dec. 1962           | 16         | 10               | H            | D                    |
| 21dad-1   | C. R. Wildersen           | 1967         | 95            | 6                 | 89           | Qvf     | 4,600                           | -                                        | -                   | 20         | 0                | H            | D                    |
| 21dba-1   | T. E. Ferron              | 1961         | 65            | 11                | 55           | Qvf     | 4,570                           | 24                                       | Feb. 1961           | 16         | 10               | I            | D                    |
| 21dba-2   | do                        | 1965         | 75            | 6                 | 65           | Qvf     | 4,570                           | 25                                       | Dec. 1965           | 15         | 0                | H            | D                    |
| 22aab-1   | City of Moab              | 1961         | 106           | 12                | 20           | JTrn    | 4,590                           | 31                                       | Mar. 1969           | 1,000      | 40               | P            | C, D                 |
| 22aad-1   | do                        | 1962         | 238           | 13                | 114          | JTrn    | 4,590                           | 1                                        | Aug. 1962           | 250        | 129              | P            | C, D                 |
| 22add-1   | E. R. Carter              | 1964         | 105           | 9                 | 64           | JTrn    | 4,610                           | -                                        | -                   | 50         | 0                | H            | D                    |
| 22add-2   | E. L. Schumaker           | 1964         | 112           | 8                 | -            | JTrn    | 4,610                           | -                                        | -                   | 150        | 30               | H            | D                    |
| 22bcc-1   | R. W. Musselman           | 1965         | 65            | 6                 | -            | Qvf     | 4,540                           | -                                        | -                   | 25         | 0                | H            | D                    |
| 22bcc-2   | K. Slany                  | 1962         | 75            | 6                 | -            | Qvf     | 4,490                           | 37                                       | Dec. 1962           | 14         | 2                | H            | D                    |
| 22bcc-3   | D. Provonsna              | 1964         | 60            | 6                 | -            | Qvf     | 4,540                           | -                                        | -                   | 15         | 15               | H            | D                    |
| 22bda-1   | R. Ritchie                | 1965         | 80            | 6                 | -            | Trw     | 4,480                           | -                                        | -                   | 25         | 0                | H            | D                    |
| 22cac-1   | G. M. White               | 1963         | 100           | 6                 | 95           | Qvf     | 4,550                           | -                                        | -                   | 30         | 0                | H            | D                    |
| 22cad-1   | J. Halverson              | 1961         | 69            | 9                 | 59           | Qvf     | 4,570                           | 31                                       | Apr. 1961           | 60         | 8                | H            | D                    |
| 22cba-1   | D. Tangreen               | 1966         | 81            | 6                 | 69           | Qvf     | 4,550                           | -                                        | -                   | 20         | 0                | H            | D, L                 |
| 22cba-2   | L. Spencer                | 1961         | 72            | 7                 | 60           | Qvf     | 4,510                           | 23                                       | Oct. 1967           | 50         | 6                | H            | D                    |
| 22cbb-1   | E. Scharf                 | 1962         | 87            | 9                 | 80           | Qvf     | 4,560                           | 36                                       | Dec. 1962           | 32         | 0                | H            | D                    |
| 22cbb-2   | T. R. Pogue, Jr.          | 1967         | 82            | 6                 | -            | Qvf     | 4,550                           | -                                        | -                   | -          | -                | H            | D                    |
| 22cbc-1   | R. A. Kyle                | 1967         | 87            | 8                 | 87           | Qvf     | 4,580                           | -                                        | -                   | 25         | 0                | H            | D                    |
| 22cbd-1   | H. E. Beeman              | 1961         | 72            | 7                 | 60           | Qvf     | 4,570                           | 26                                       | Mar. 1961           | 60         | 1                | H            | D                    |
| 22cbd-2   | J. Krist                  | 1969         | 119           | 8                 | -            | Qvf     | 4,555                           | 24                                       | Mar. 1969           | 25         | 0                | H            | D                    |
| 22cda-1   | H. E. Thomas              | 1965         | 65            | 6                 | -            | Qvf     | 4,580                           | -                                        | -                   | 20         | 0                | H            | D                    |
| 22cdd-1   | C. E. Hunton              | 1963         | 100           | 6                 | 94           | Qvf     | 4,580                           | -                                        | -                   | 25         | 4                | H            | D                    |
| 22daa-1   | B. A. Broughton           | 1969         | 200           | 12                | 77           | JTrn    | 4,475                           | 28                                       | Mar. 1969           | 200        | 20               | I            | D                    |
| 22dbd-1   | G. M. White               | 1961         | 126           | 16                | -            | Qvf     | 4,570                           | 32                                       | Aug. 1961           | 300        | 39               | I            | D                    |
| 22dcb-1   | do                        | 1961         | 130           | 16                | 21           | Qvf     | 4,580                           | 21                                       | Oct. 1967           | 90         | 0                | I            | D                    |
| 22dcc-1   | H. E. Beeman              | 1962         | 84            | 8                 | 75           | Qvf     | 4,590                           | -                                        | -                   | 30         | 0                | H            | D                    |
| 22dcc-2   | C. Duren                  | 1962         | 75            | 6                 | 65           | Qvf     | 4,580                           | -                                        | -                   | 25         | 0                | H            | D                    |
| 22dcc-3   | M. Schermerhorn           | 1963         | 77            | 6                 | 66           | Qvf     | 4,590                           | -                                        | -                   | 25         | 0                | H            | D                    |
| 22dcc-4   | H. E. Beeman              | 1967         | 80            | 8                 | -            | Qvf     | 4,590                           | -                                        | -                   | 30         | 0                | H            | D                    |
| 22dcd-1   | G. M. White               | 1959         | 70            | 16                | -            | Qvf     | 4,580                           | 34                                       | Oct. 1967           | 100        | 51               | I            | C, D                 |
| 22dcd-2   | do                        | 1968         | 125           | 12                | 70           | Qvf     | 4,600                           | 31                                       | Mar. 1968           | -          | -                | I            | D, L                 |
| 23ccb-1   | J. E. Kerby               | 1962         | 110           | 7                 | 75           | Qvf     | 4,620                           | -                                        | -                   | 25         | 0                | H            | D                    |
| 23ccc-1   | J. Payne                  | 1961         | 104           | 8                 | 45           | Qvf     | 4,610                           | 2                                        | Oct. 1967           | 450        | 58               | I            | D                    |
| 26ccc-1   | J. Doud                   | 1955         | 120           | 9                 | -            | Qvf     | 4,700                           | 40                                       | -                   | 20         | 20               | H            | D                    |
| 27aaa-1   | C. J. Maador              | 1960         | 60            | 7                 | 47           | Qvf     | 4,610                           | 33                                       | Oct. 1967           | -          | -                | H            | D                    |
| 35abd-1   | R. L. Holyoke             | 1961         | 205           | 16                | 165          | Qvf     | 4,730                           | 135                                      | Oct. 1961           | 1,000      | 35               | I            | D                    |
| 35abd-2   | do                        | 1959         | 182           | 9                 | 140          | Qvf     | 4,730                           | 125                                      | Feb. 1959           | 55         | 30               | H            | D                    |
| 35acd-1   | N. Murphy                 | 1961         | 210           | 16                | -            | Qvf     | 4,760                           | 140                                      | Oct. 1961           | 700        | 50               | I            | D, L                 |
| 35acd-2   | do                        | 1956         | 185           | 7                 | 160          | Qvf     | 4,760                           | 140                                      | Jan. 1956           | 20         | 10               | H            | D                    |
| 35ada-1   | L. W. Bull                | 1962         | 185           | 6                 | -            | Qvf     | 4,740                           | 154                                      | Feb. 1962           | 7          | 0                | H            | C, D                 |
| 35adc-1   | S. Sommerville            | 1963         | 173           | 7                 | 171          | Qvf     | 4,760                           | 160                                      | Oct. 1967           | 15         | 0                | H            | D                    |
| 35bab-1   | J. W. Vancil              | 1962         | 288           | 7                 | -            | Qvf     | 4,710                           | 110                                      | Nov. 1962           | 20         | 0                | H            | D                    |
| 35bab-2   | C. E. McClellon           | 1964         | 201           | 7                 | -            | Qvf     | 4,700                           | -                                        | -                   | 35         | 0                | H            | D, L                 |
| 35bad-1   | R. R. Rutt                | 1967         | 261           | 8                 | 157          | Qvf     | 4,730                           | -                                        | -                   | -          | -                | H            | D                    |
| 35bdb-1   | W. W. Williams            | 1964         | 295           | 7                 | -            | Qvf     | 4,740                           | 138                                      | July 1964           | 15         | 22               | H            | D                    |
| 35bdd-1   | R. C. Pogue               | 1959         | 140           | 5                 | 130          | Qvf     | 4,750                           | 128                                      | July 1959           | 20         | 0                | H            | D                    |
| 35bdd-2   | J. Callor                 | 1963         | 247           | 6                 | 230          | Qvf     | 4,740                           | -                                        | -                   | 30         | 0                | H            | C, D                 |
| 35bdd-3   | M. J. Eldredge            | 1962         | 250           | 7                 | -            | Qvf     | 4,740                           | 124                                      | July 1962           | 21         | 0                | H            | D                    |
| 35daa-1   | S. Sommerville            | 1964         | 173           | 7                 | -            | Qvf     | 4,780                           | -                                        | -                   | 15         | 0                | H            | D                    |
| 35daa-2   | do                        | 1956         | 170           | 6                 | 156          | Qvf     | 4,780                           | 158                                      | Sept. 1956          | 7          | 4                | H            | D                    |
| 35dbb-1   | D. L. Hammer              | 1962         | 186           | 7                 | -            | Qvf     | 4,760                           | 118                                      | Oct. 1967           | 20         | 0                | H            | D                    |
| (D-26-23) |                           |              |               |                   |              |         |                                 |                                          |                     |            |                  |              |                      |
| 10ccb-1   | F. Shields                | 1953         | 445           | 6                 | -            | JTrn    | 6,880                           | 410                                      | Aug. 1953           | .5         | -                | I            | D                    |
| 12aba-1   | J. W. Corbin              | 1953         | 450           | 6                 | -            | JTrn    | 7,690                           | 395                                      | Sept. 1953          | 2          | -                | I            | D                    |
| 12cca-1   | do                        | 1966         | 1,100         | 19                | -            | Qvf     | 7,460                           | 850                                      | Jan. 1966           | -          | -                | I            | D                    |
| (D-27-22) |                           |              |               |                   |              |         |                                 |                                          |                     |            |                  |              |                      |
| 1abb-1    | Bureau of Land Management | 1936         | 315           | 4                 | 298          | Qvf     | 4,860                           | 245                                      | Dec. 1936           | 3          | 5                | U            | D                    |
| 1bbb-1    | do                        | 1941         | 350           | 6                 | -            | Qvf     | 4,820                           | 200                                      | May 1941            | 18         | 0                | U            | D, L                 |
| 1bda-1    | Moab Airport              | 1956         | 192           | 7                 | 155          | Qvf     | 4,880                           | 181                                      | Oct. 1967           | 7          | 0                | U            | D, L                 |
| 1edd-1    | W. D. Moore               | 1951         | 310           | 6                 | -            | Pe      | 4,920                           | 165                                      | Sept. 1951          | 20         | -                | U            | D, L                 |
| 2abd-1    | Bureau of Land Management | 1938         | 315           | 6                 | 275          | Qvf     | 4,940                           | 284                                      | Nov. 1938           | 9          | -                | U            | D                    |
| (D-27-23) |                           |              |               |                   |              |         |                                 |                                          |                     |            |                  |              |                      |
| 6dad-1    | do                        | 1941         | 455           | 6                 | -            | Qvf     | 5,060                           | 390                                      | Nov. 1941           | 15         | -                | U            | D                    |
| 9cac-1    | -                         | -            | 96            | 8                 | 96           | JTrn    | 5,280                           | 77                                       | Nov. 1967           | -          | -                | U            | D                    |
| 9cdb-1    | N. S. Christensen         | 1953         | 298           | 8                 | -            | JTrn    | 5,360                           | -                                        | -                   | -          | -                | U            | D                    |
| 23cab-1   | D. H. Brownell            | 1963         | 84            | 9                 | 65           | Qvf     | 6,040                           | 29                                       | Oct. 1967           | 100        | 34               | H            | C, D                 |

Table 10.--Records of selected springs in the Spanish Valley area

Location: See text for spring-numbering system.

Aquifer: Qvf, valley fill; Kbc, Burro Canyon Formation; JTrn, Navajo Sandstone; Trw, Wingate Sandstone.

Discharge: Measured unless indicated by e, estimated.

Water use: I, irrigation; P, public supply; R, recreation; S, stock; U, unused.

Other data available: C, chemical analysis in table 11.

| Location          | Name                     | Altitude<br>(feet) | Aquifer | Discharge<br>(gpm) | Date<br>measured | Temperature<br>(°C) | Water<br>use | Other data<br>available |
|-------------------|--------------------------|--------------------|---------|--------------------|------------------|---------------------|--------------|-------------------------|
| GRAND COUNTY      |                          |                    |         |                    |                  |                     |              |                         |
| (D-25-21)26bdc-S1 | Lions Club Spring        | 4,160              | Trw     | 7                  | Jan. 1968        | 17                  | R            | C                       |
| 35aaa-S1          | Skakel Spring            | 4,000              | Trw     | 240e               | Oct. 1967        | 14                  | P            | C                       |
| (D-26-22)7cca-S1  | Jackson Reservoir Spring | 4,240              | Trw     | 24                 | Mar. 1968        | 16                  | I            | C                       |
| 14acc-S1          | Deep Cut Spring          | 4,640              | JTrn    | 90                 | Nov. 1968        | 16                  | U            | C                       |
| 15cbb-S1          | Birch Spring             | 4,480              | Trw     | 90e                | Oct. 1967        | 14                  | P            | C                       |
| 15dbc-S1          | 1/Moab Spring No. 1      | 4,480              | JTrn    | 50                 | Mar. 1969        | 14                  | P            |                         |
| 22aaa-S1          | 1/Moab Spring No. 2      | 4,600              | JTrn    | 300                | Mar. 1969        | 14                  | P            |                         |
| 22aaa-S2          | 1/Moab Spring No. 3      | 4,600              | JTrn    | 333                | Mar. 1969        | 14                  | P            |                         |
| (D-26-24)28aba-S1 | Warner Lake Spring       | 9,370              | Kbc     | 200e               | July 1967        | 7                   | R            | C                       |
| SAN JUAN COUNTY   |                          |                    |         |                    |                  |                     |              |                         |
| (D-26-23)3ccc-S1  | Sand Pot Spring          | 5,600              | JTrn    | 12e                | Nov. 1968        | 16                  | U            |                         |
| (D-27-23)24dcc-S1 | Pack Creek Spring        | 6,400              | Qvf     | 200e               | Apr. 1968        | 16                  | I            | C                       |
| (D-27-24)30bbc-S1 | Barber Spring            | 6,700              | Qvf     | 30e                | Apr. 1968        | 14                  | S            | C                       |

1/ Also known as Sommerville or White Springs.

Table 11.--Chemical analyses of water from selected wells and springs

Location: See text for well- and spring-numbering system.

Aquifer: Qvf, valley fill; Kbc, Burro Canyon Formation; JTrn, Navajo Sandstone; Trw, Wingate Sandstone.

Sodium: Where no value is shown for potassium, sodium and potassium are calculated and reported as sodium.

|                       |         |                    | Milligrams per liter |                            |           |              |                |             |               |                                 |                              |                            |               |              |                            |           |                                         |                                               | Specific conductance<br>(micromhos per cm at 25°C) |                 | Sodium-adsorption ratio | pH  |                  |
|-----------------------|---------|--------------------|----------------------|----------------------------|-----------|--------------|----------------|-------------|---------------|---------------------------------|------------------------------|----------------------------|---------------|--------------|----------------------------|-----------|-----------------------------------------|-----------------------------------------------|----------------------------------------------------|-----------------|-------------------------|-----|------------------|
| Location              | Aquifer | Date of collection | Temperature (°C)     | Silica (SiO <sub>2</sub> ) | Iron (Fe) | Calcium (Ca) | Magnesium (Mg) | Sodium (Na) | Potassium (K) | Bicarbonate (HCO <sub>3</sub> ) | Carbonate (CO <sub>3</sub> ) | Sulfate (SO <sub>4</sub> ) | Chloride (Cl) | Fluoride (F) | Nitrate (NO <sub>3</sub> ) | Boron (B) | Ca, Mg<br>Hardness as CaCO <sub>3</sub> | Noncarbonate hardness<br>as CaCO <sub>3</sub> |                                                    |                 |                         |     | Dissolved solids |
|                       |         |                    |                      |                            |           |              |                |             |               |                                 |                              |                            |               |              |                            |           |                                         |                                               | Deter-<br>mined                                    | Calcu-<br>lated |                         |     |                  |
|                       |         |                    |                      |                            |           |              |                |             |               |                                 |                              |                            |               |              |                            |           |                                         |                                               | WELLS                                              |                 |                         |     |                  |
| (D-25-21)<br>26dce-1  | Qvf     | 9- 5-68            | 16                   | 14                         | 0.04      | 46           | 23             | 13          | 2.3           | 220                             | 0                            | 38                         | 14            | 0.5          | 1.3                        | 0.04      | 212                                     | 32                                            | 256                                                | 260             | 440                     | 0.4 | 8.0              |
| (D-26-21)<br>1dce-1   | Qvf     | 7- 8-69            | 15                   | 9.1                        | .21       | 29           | 16             | 6.8         | 1.1           | 127                             | 0                            | 38                         | 3.2           | .3           | 1.0                        | .07       | 136                                     | 32                                            | 169                                                | 167             | 286                     | .3  | 7.9              |
| (D-26-22)<br>7bad-1   | Qvf     | 9- 5-68            | 16                   | 19                         | .00       | 112          | 57             | 41          | 2.4           | 312                             | 0                            | 300                        | 20            | .8           | 9.0                        | .07       | 516                                     | 260                                           | 749                                                | 714             | 1,020                   | .8  | 7.8              |
| 15dca-1               | JTrn    | 3- 6-69            | 15                   | 7.7                        | .57       | 30           | 16             | 5.4         | 1.2           | 121                             | 0                            | 48                         | 2.4           | .4           | .9                         | .06       | 140                                     | 41                                            | 154                                                | 173             | 268                     | .2  | 8.0              |
| 17dbc-1               | Qvf     | 7- 9-68            | 16                   | 10                         | 1.3       | 98           | 51             | 44          | 2.1           | 168                             | 0                            | 370                        | 17            | .6           | 2.8                        | .00       | 454                                     | 316                                           | 701                                                | 680             | 961                     | .9  | 7.5              |
| 21baa-2               | Qvf     | 7- 8-69            | 10                   | 14                         | .15       | 120          | 45             | 46          | 2.2           | 198                             | 0                            | 352                        | 30            | .5           | 13                         | .03       | 486                                     | 324                                           | 772                                                | 720             | 1,040                   | .9  | 7.9              |
| 22aab-1               | JTrn    | 11-19-68           | 13                   | 9.5                        | .09       | 30           | 13             | 6.5         | 1.0           | 124                             | 0                            | 38                         | 2.7           | .3           | 1.3                        | .04       | 128                                     | 26                                            | 218                                                | 163             | 273                     | .3  | 7.6              |
| 22aad-1               | JTrn    | 11-19-68           | 15                   | 11                         | .17       | 32           | 14             | 7.6         | 1.0           | 128                             | 0                            | 39                         | 2.9           | .4           | .1                         | .03       | 136                                     | 31                                            | 166                                                | 171             | 286                     | .3  | 7.4              |
| 22dcd-1               | Qvf     | 7- 9-68            | 16                   | 14                         | .02       | 107          | 38             | 48          | 2.2           | 218                             | 0                            | 303                        | 16            | .5           | 12                         | .00       | 422                                     | 243                                           | 664                                                | 648             | 930                     | 1.0 | 7.6              |
| 35ada-1               | Qvf     | 7- 8-69            | 14                   | 17                         | .10       | 180          | 38             | 54          | 2.1           | 243                             | 0                            | 450                        | 30            | .5           | 26                         | .11       | 608                                     | 409                                           | 962                                                | 917             | 1,230                   | 1.0 | 7.6              |
| 35bdd-2               | Qvf     | 9- 5-68            | 10                   | 14                         | -         | 144          | 28             | 43          | 2.1           | 264                             | 0                            | 305                        | 11            | .9           | 11                         | .06       | 476                                     | 260                                           | 739                                                | 689             | 984                     | .9  | 7.7              |
| (D-27-23)<br>23cab-1  | Qvf     | 4-30-68            | 13                   | 9.2                        | .00       | 190          | 42             | 50          | 1.8           | 226                             | 0                            | 545                        | 16            | 1.2          | .5                         | .07       | 648                                     | 463                                           | 1,020                                              | 967             | 1,240                   | .9  | 7.6              |
| SPRINGS               |         |                    |                      |                            |           |              |                |             |               |                                 |                              |                            |               |              |                            |           |                                         |                                               |                                                    |                 |                         |     |                  |
| (D-25-21)<br>26bdc-S1 | Trw     | 10- 8-58           | 17                   | 14                         |           | 33           | 10             | 18          | -             | 132                             | 0                            | 36                         | 12            | -            | 0.8                        | -         | 124                                     | 16                                            | -                                                  | 186             | 298                     | 0.7 | 8.1              |
| 35aaa-S1              | Trw     | 10-19-67           | 14                   | 11                         | 0.00      | 32           | 12             | 13          | 0.6           | 128                             | 0                            | 31                         | 14            | 0.3          | .7                         | 0.01      | 128                                     | 23                                            | 168                                                | 178             | 296                     | .5  | 7.5              |
| (D-26-22)<br>7cca-S1  | Trw     | 3- 7-68            | 16                   | 11                         | .03       | 102          | 47             | 46          | 2.1           | 168                             | 0                            | 370                        | 18            | .7           | 4.6                        | .03       | 448                                     | 310                                           | 717                                                | 684             | 954                     | .9  | 7.9              |
| 14acc-S1              | JTrn    | 11-19-68           | 16                   | 8.9                        | -         | 35           | 16             | 5.3         | 1.2           | 184                             | 0                            | 11                         | 2.7           | .1           | .4                         | .04       | 152                                     | 1                                             | 171                                                | 171             | 306                     | .2  | 7.6              |
| 15cbb-S1              | Trw     | 10-19-67           | 14                   | 8.9                        | .00       | 35           | 12             | 8.2         | .5            | 132                             | 0                            | 39                         | 4.3           | .3           | .5                         | .00       | 136                                     | 28                                            | 172                                                | 174             | 295                     | .3  | 7.6              |
| (D-26-24)<br>28aba-S1 | Kbc     | 7- 8-69            | 7                    | 8.0                        | .08       | 21           | 8.3            | 1.9         | .6            | 94                              | 0                            | 10                         | 1.2           | .5           | .6                         | .06       | 86                                      | 9                                             | 101                                                | 98              | 170                     | .1  | 7.7              |
| (D-27-23)<br>24dcc-S1 | Qvf     | 4-30-68            | 13                   | 17                         | .00       | 189          | 37             | 49          | 2.7           | 200                             | 0                            | 561                        | 16            | 1.4          | 1.1                        | .05       | 624                                     | 460                                           | 995                                                | 972             | 1,220                   | .9  | 7.8              |
| (D-27-24)<br>30bbc-S1 | Qvf     | 4-30-68            | 14                   | 19                         | .00       | 194          | 38             | 54          | 2.0           | 136                             | 0                            | 610                        | 16            | 1.9          | 1.3                        | .04       | 640                                     | 528                                           | 1,040                                              | 1,000           | 1,240                   | .9  | 7.5              |

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- No. 1. Underground leakage from artesian wells in the Flowell area, near Fillmore, Utah, by Penn Livingston and G. B. Maxey, U. S. Geological Survey, 1944.
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- \*No. 4. Ground water in Tooele Valley, Tooele County, Utah, by H. E. Thomas, U. S. Geological Survey, in Utah State Eng. 25th Bienn. Rept., p. 91-238, pls. 1-6, 1946.
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- No. 7. Status of development of selected ground-water basins in Utah, by H. E. Thomas, W. B. Nelson, B. E. Lofgren, and R. G. Butler, U. S. Geological Survey, 1952.
- \*No. 8. Consumptive use of water and irrigation requirements of crops in Utah, by C. O. Roskelly and Wayne D. Criddle, 1952.
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- \*No. 14. Water-resources appraisal of the Snake Valley area, Utah and Nevada, by J. W. Hood and F. E. Rush, U. S. Geological Survey, 1966.
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- \*No. 3. Ground water data, central Sevier Valley, parts of Sanpete, Sevier, and Piute Counties, Utah, by C. H. Carpenter and R. A. Young, U. S. Geological Survey, 1963.
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- No. 7. Selected hydrologic data, Tooele Valley, Tooele County, Utah, by J. S. Gates, U. S. Geological Survey, 1963.
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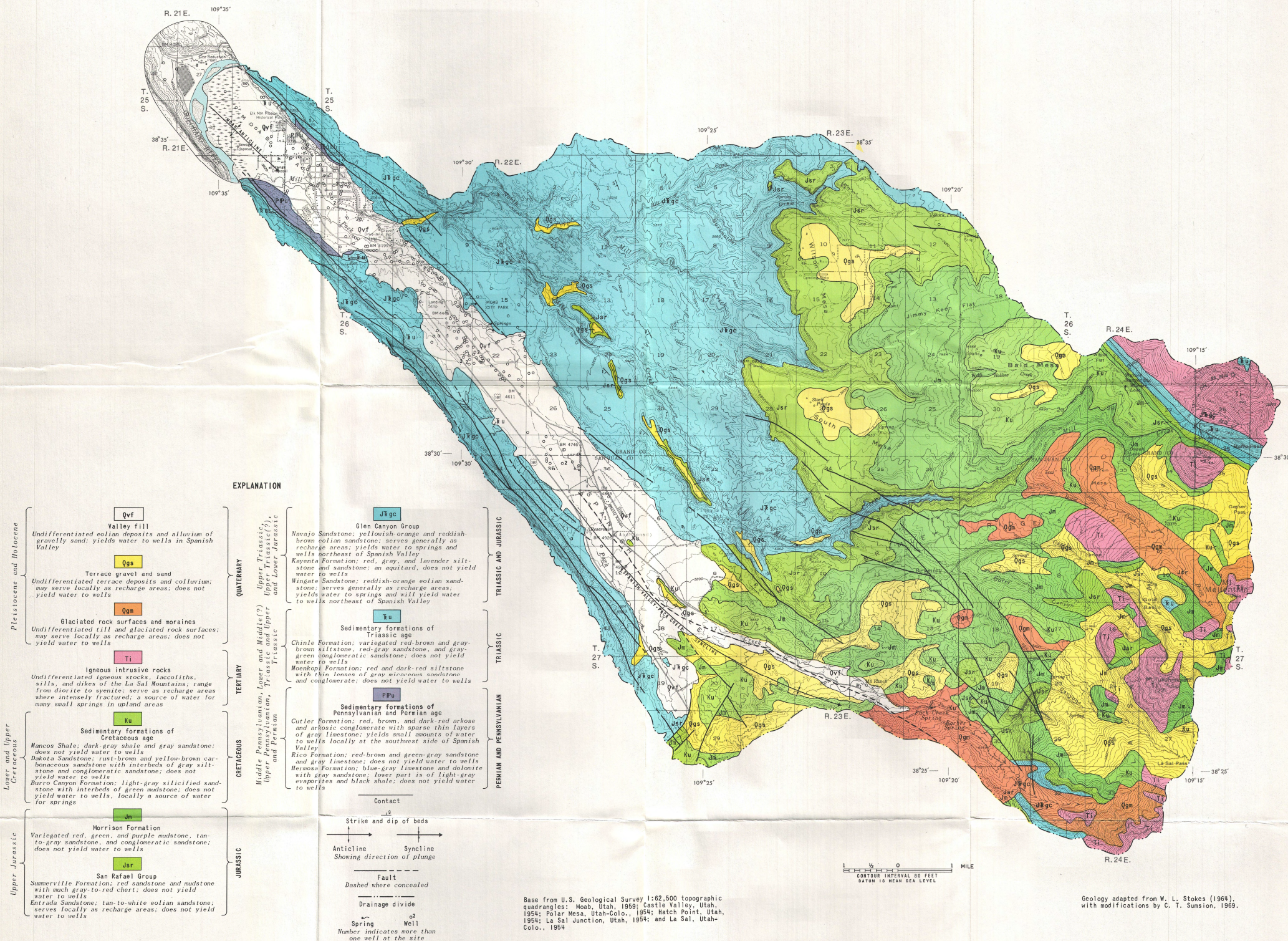
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- \*No. 2. Water production from oil wells in Utah, by Jerry Tuttle, Utah State Engineer's Office, 1960.
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- \*No. 6. Work outline and report outline for Sevier River basin survey, (Sec. 6, P.L. 566), U. S. Department of Agriculture, 1961.
- No. 7. Relation of the deep and shallow artesian aquifers near Lynndyl, Utah, by R. W. Mower, U. S. Geological Survey, 1961.

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- No. 9. Projected 1975 municipal water-use requirements, Weber County, Utah, by Utah State Engineer's Office, 1962.
- \*No. 10. Effects on the shallow artesian aquifer of withdrawing water from the deep artesian aquifer near Sugarville, Millard County, Utah, by R. W. Mower, U. S. Geological Survey, 1963.
- No. 11. Amendments to plan of work and work outline for the Sevier River basin (Sec. 6, P.L. 566), U. S. Department of Agriculture, 1964.
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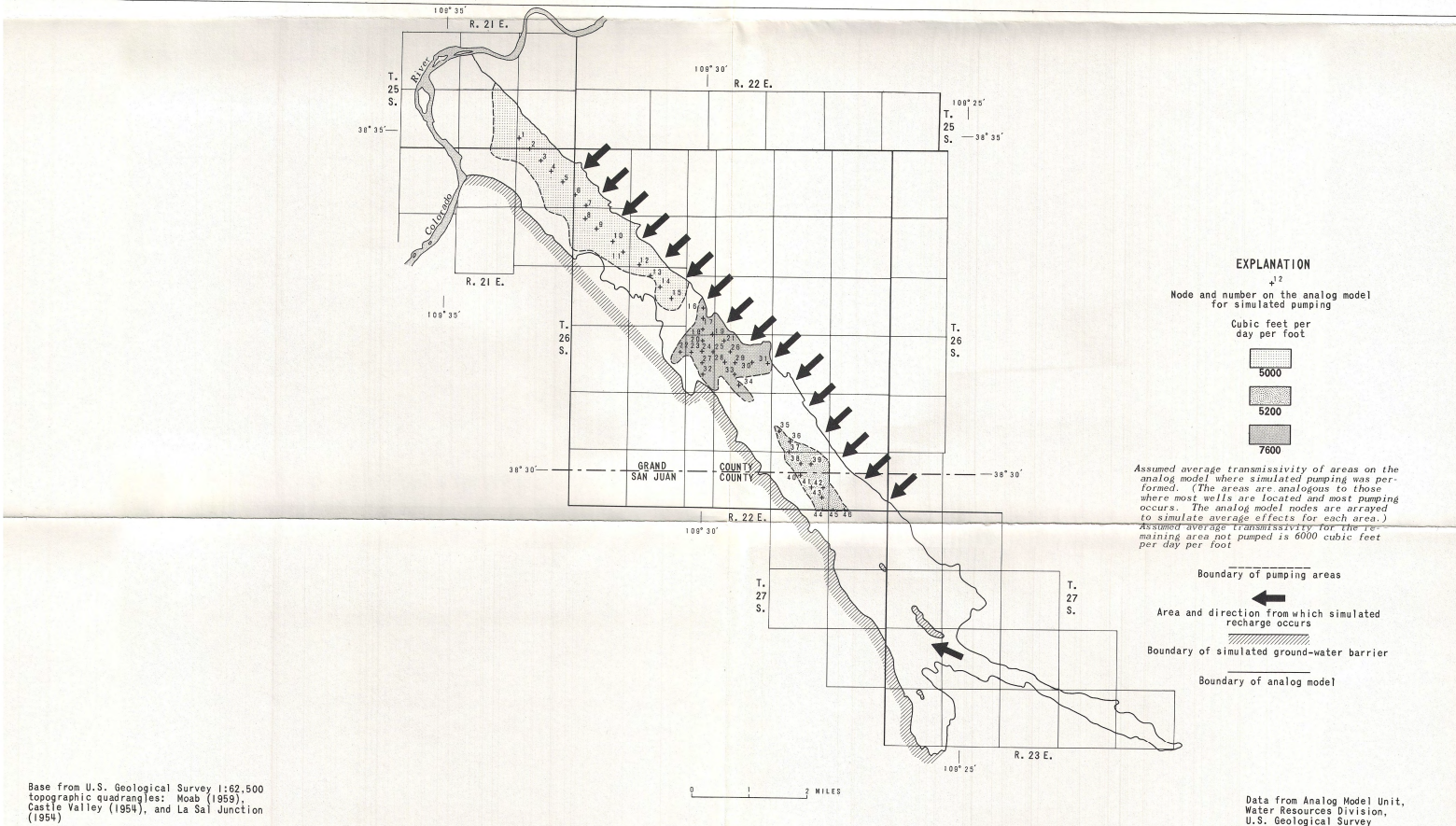
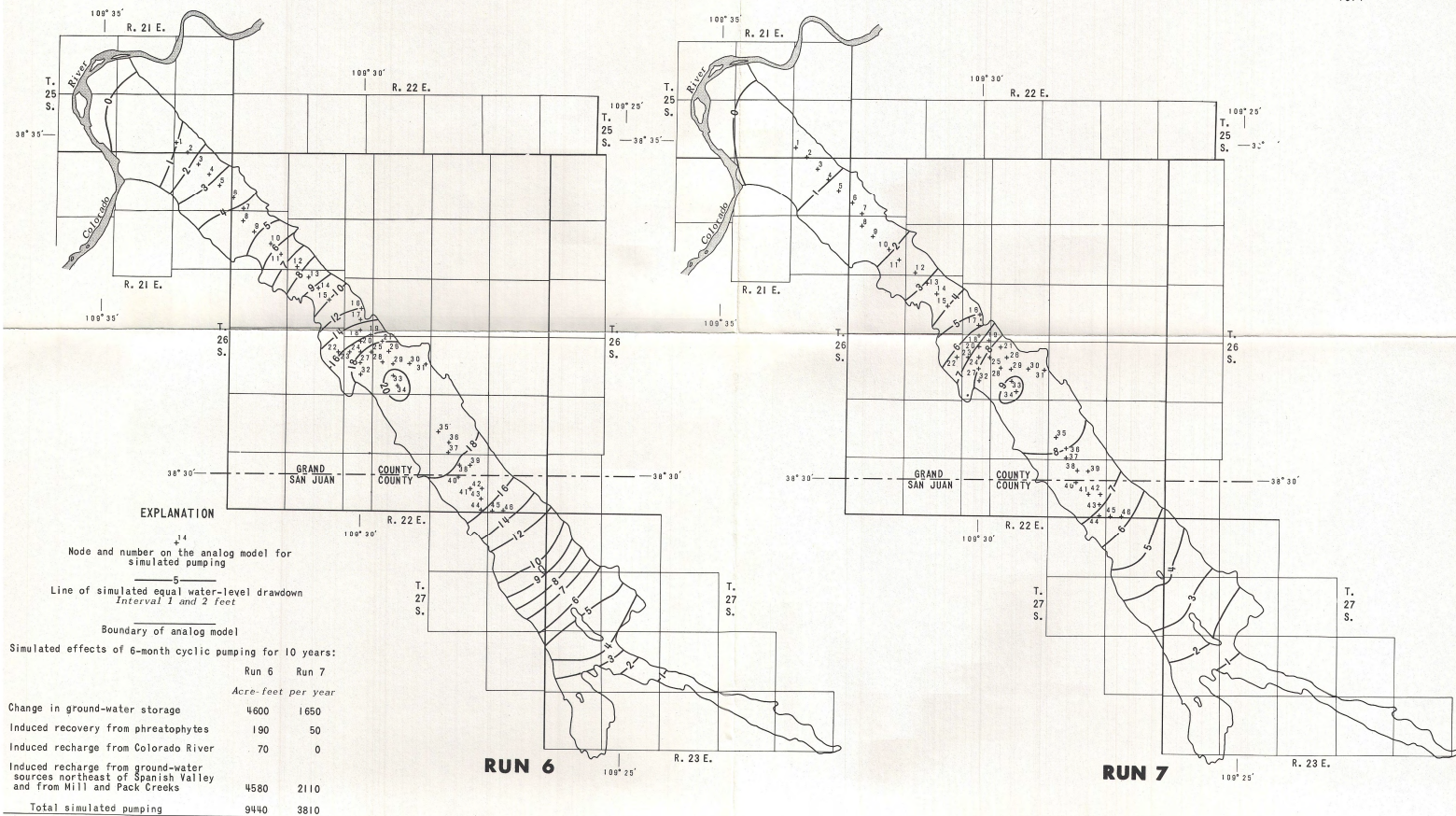
MAP OF THE SPANISH VALLEY AREA, GRAND AND SAN JUAN COUNTIES, UTAH, SHOWING GENERALIZED GEOLOGY AND LOCATIONS OF SELECTED WELLS AND SPRINGS





HYDROLOGIC MAP OF THE SPANISH VALLEY AREA, GRAND AND SAN JUAN COUNTIES, UTAH





MAP OF SPANISH VALLEY, GRAND AND SAN JUAN COUNTIES, UTAH, SHOWING SIMULATED WATER-LEVEL CHANGES