UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

WATER-RESOURCES ACTIVITIES IN UTAH

BY THE U.S. GEOLOGICAL SURVEY,

OCTOBER 1, 1988, TO SEPTEMBER 30, 1989

Compiled by Joseph S. Gates and Stefanie L. Dragos

U.S. GEOLOGICAL SURVEY

Open-File Report 90-589

Salt Lake City, Utah

1990

U.S. DEPARTMENT OF THE INTERIOR

MANUEL LUJAN, JR., Secretary

U.S. GEOLOGICAL SURVEY

Dallas L. Peck, Director

For additional information
write to:

District Chief
U.S. Geological Survey
Water Resources Division
Room 1016 Administration Building
1745 West 1700 South
Salt Lake City, Utah 84104

Copies of this report can be
purchased from:

U.S. Geological Survey
Books and Open-File Reports Section
Federal Center, Bldg. 810
Box 25425
Denver, Colorado 80225

CONTENTS

ILLUSTRATIONS

WATER-RESOURCES ACTIVITIES IN UTAH

BY THE U.S. GEOLOGICAL SURVEY,

OCTOBER 1, 1988, TO SEPTEMBER 30, 1989

Compiled by Joseph S. Gates and Stefanie L. Dragos

INTRODUCTION

This report contains summaries of the progress of water-resources studies in Utah by the U.S. Geological Survey, Water Resources Division, Utah District, from October 1, 1988, to September 30, 1989. The program in Utah during this period consisted of 21 projects; a discussion of each project is given in the main body of the report.

The following sections outline the basic mission and program of the Water Resources Division, the organizational structure of the Utah District, the distribution of District funding in terms of source of funds and type of activity funded, and the agencies with which the District cooperates. The last part of the introduction is a list of reports produced by the District from October 1988 to September 1989.

Basic Mission and Program of the Water Resources Division, U.S. Geological Survey

The U.S. Geological Survey, through its Water Resources Division, investigates the occurrence, quantity, distribution, and movement of the surface and ground water that comprise the Nation's water resources, and coordinates Federal water-data acquisition activities.

The mission of the Division is accomplished through programs supported by the U.S. Geological Survey independent of, or in cooperation with, other Federal and non-Federal agencies. These programs involve:

1. Collecting, on a systematic basis, data needed for the continuing determination and evaluation of the quantity, quality, and use of the Nation's water resources.

2. Conducting analytical and interpretive water-resource appraisals of the occurrence, availability, and the physical, chemical, and biological characteristics of surface and ground water.

3. Conducting basic problem-oriented research in hydrology to improve the scientific basis for investigations and measurement techniques, and to predict quantitatively the response of hydrologic systems to stress.

4. Disseminating water data and the results of investigations and research through reports, maps, computerized information services, and other forms of public releases.

5. Coordinating the activities of Federal agencies in the acquisition of water data for streams, lakes, reservoirs, estuaries, and ground water.

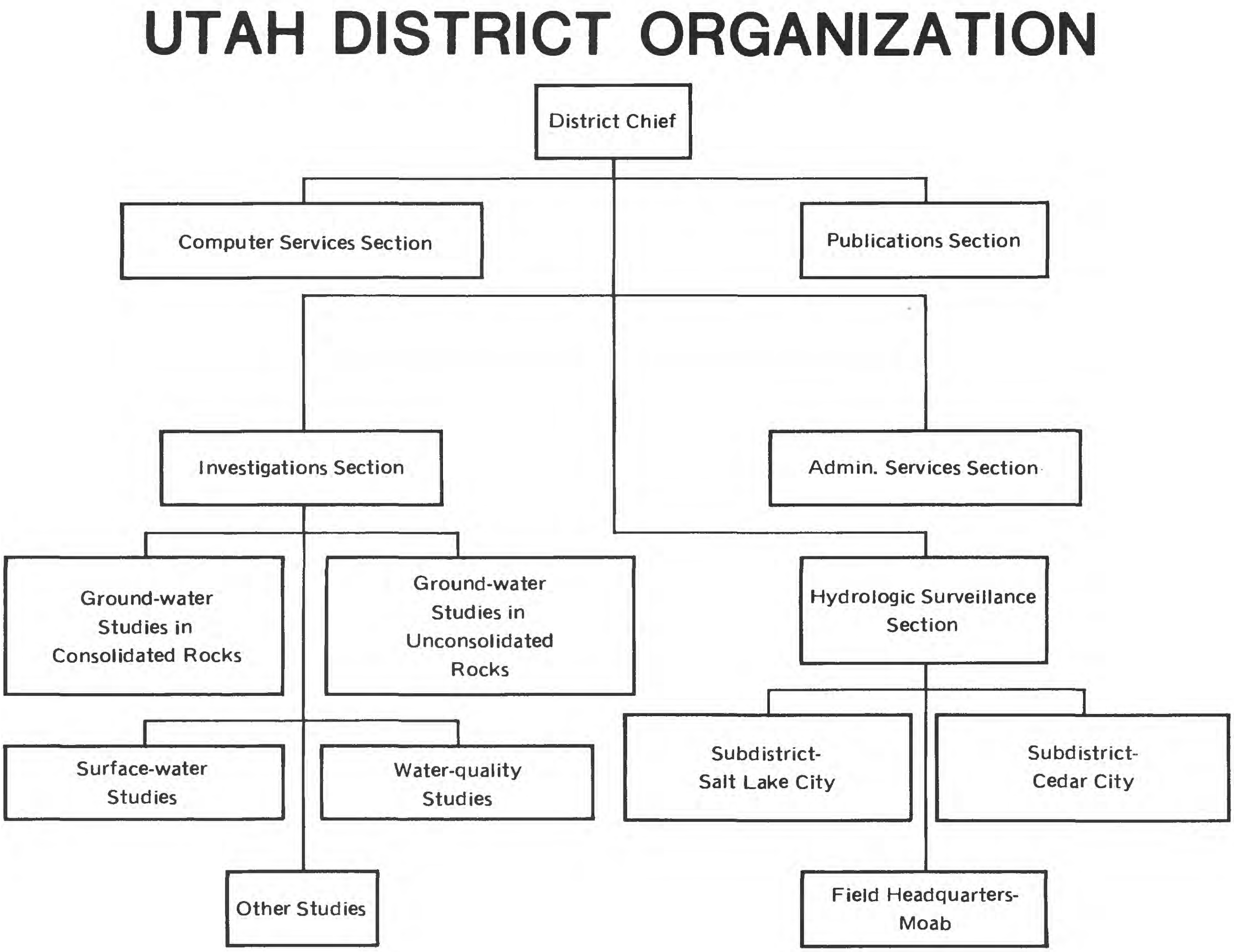
6. Providing scientific and technical assistance in hydrology to other Federal, State, and local agencies; to licensees of the Federal Power Commission; and to international agencies on behalf of the Department of State.

7. Administering the provisions of the Water Resources Research Act of 1984, which includes the State Water Resources Research Institute Program (Section 104) and the National Water Resources Research Grant Program (Section 105).

8. Acquiring information useful in predicting and delineating water-related natural hazards from flooding, volcanoes, mudflows, and land subsidence.

Utah District Organization

The Utah District of the Water Resources Division is organized into five operating sections under the District Chief (see organization chart). Water-resources projects are conducted by the Investigations Section (primarily interpretive studies) and Hydrologic-Surveillance Section (primarily collection of hydrologic data). Responsibility for each project is assigned to a project chief. Support for project work is supplied by the Publications Section, which processes and illustrates reports, and the Computer Services and Administrative Services Sections.



The Utah District consists of the District Office in Salt Lake City, Subdistrict Offices in Salt Lake City and Cedar City, and a Field Headquarters in Moab. The location of these offices and the areas of responsibility for Subdistrict Offices and Field Headquarters are shown in figure 1.

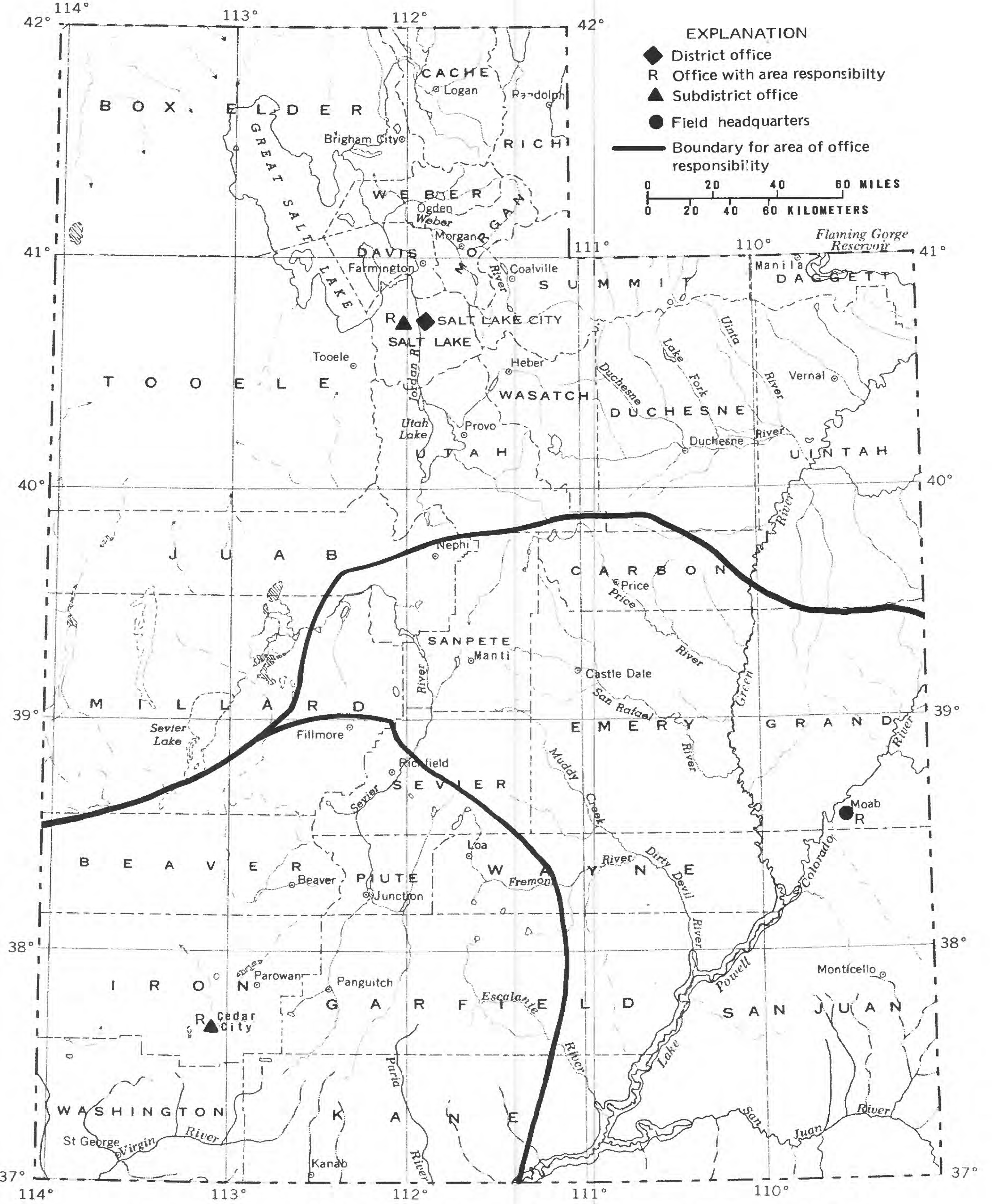
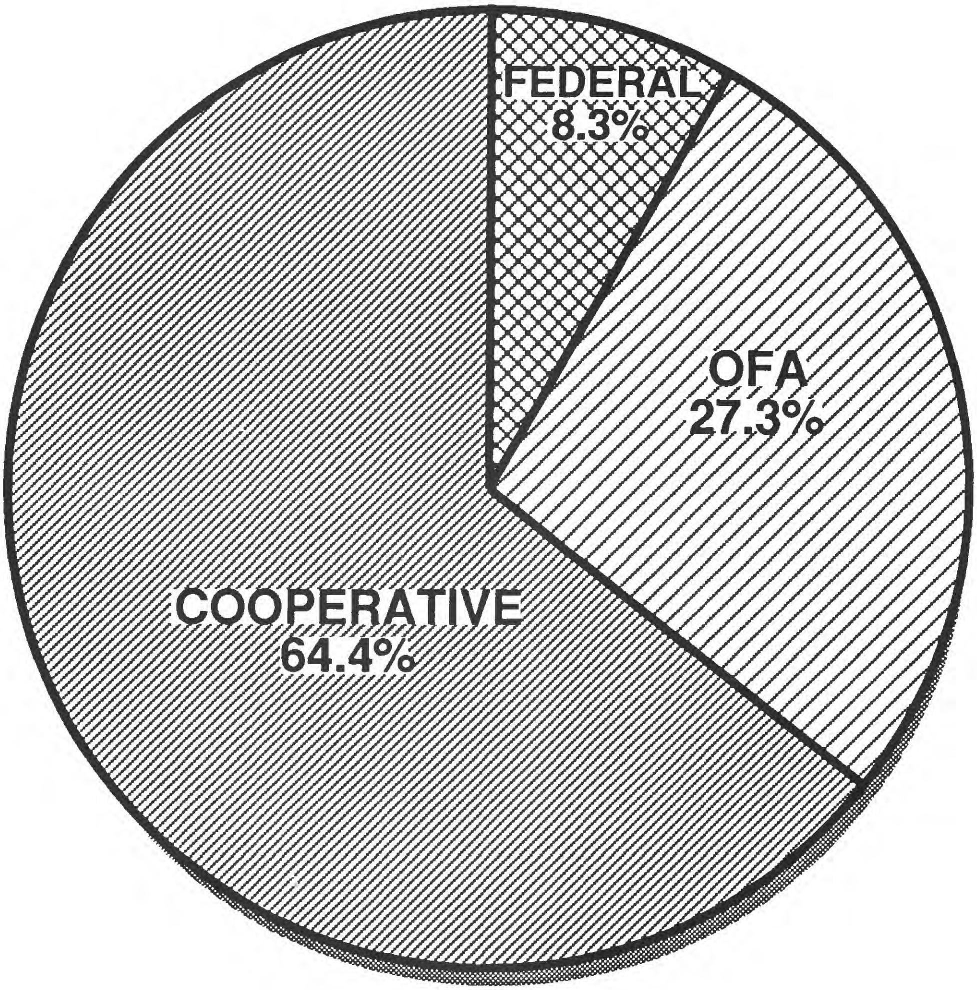


Figure 1.--Location of U.S. Geological Survey, Water Resources Division, offices and general areas of responsibility.

Program Funding and Cooperating Agencies

Funds to support water-resources work by the Utah District are from three sources. Cooperative-Program funds and services are provided from State and local government agencies and generally are matched by Federal funds on a 50-50 basis. Funds transferred from other Federal agencies (OFA) are part of the OFA Program, and funds appropriated directly to the Geological Survey by the Congress are part of the Federal Program. In fiscal year 1989, the total financial support from these programs for the Utah District was about $3.8 million. The distribution of funds among the three sources is shown below:



In fiscal year 1989, the Utah District pursued two broad categories of studies: (1) hydrologic data collection, and (2) interpretive studies and areal appraisals. Approximately 49 percent of the program was for collection of hydrologic data and 51 percent for interpretive studies and appraisals. These studies provide water managers and planners with information about the availability and quality of Utah's water resources.

From October 1, 1988, to September 30, 1989, the State and local cooperators for District projects were:

Utah Department of Natural Resources
- Division of Water Rights
- Division of Water Resources
- Division of Wildlife Resources
- Division of Oil, Gas, and Mining
- Geological and Mineral Survey

Utah Department of Health, Division of Environmental Health
Bear River Commission
Salt Lake County Division of Flood Control and Water Quality
Central Utah Water Conservancy District
Utah Department of Agriculture
Utah Department of Transportation
Wasatch County
Weber Basin Water Conservancy District
Weber River Water Users Association
Wasatch County Water Users, Associated
Tooele County
City of Tooele
Ogden River Water Users Association

The Federal cooperators were:

U.S. Bureau of Land Management
U.S. Bureau of Reclamation
U.S. Air Force
U.S. Soil Conservation Service
Office of the Secretary, U.S. Department of the Interior
Federal Power Commission (Utah Power and Light Co.)
U.S. National Park Service

Reports Released or Published

Reports prepared by or in cooperation with the Utah District can be obtained at the following locations:

Utah District Office: Open-File Reports; Water-Resources Investigations Reports; Hydrologic-Data Reports; Water-Data Reports; and Utah Department of Natural Resources Technical Publications, Cooperative Investigations Reports, and Water Circulars.

U.S. Geological Survey Earth Science Information Center: (125 South State Street, Salt Lake City): U.S. Geological Survey Water-Supply Papers, Professional Papers, Circulars, and Hydrologic Investigations Atlases.

Utah Department of Natural Resources, Division of Water Rights: Technical Publications, Water Circulars, Hydrologic-Data Reports, Water-Use Reports.

Utah Department of Natural Resources, Division of Water Resources: Cooperative Investigations Reports.

The following report was released to the Open File:

Dragos, S.L., and Gates, J.S., Water-resources activities in Utah by the U.S. Geological Survey, July 1, 1987, to September 30, 1988: U.S. Geological Survey Open-File Report 89-240.

The following reports were published:

Blanchard, P.J., 1988, Hydrology of the Navajo Sandstone in southeastern and southern Utah: in Johnson, A.I., and McLean, J.S., eds., Regional aquifer systems of the United States--Aquifers of the western mountain area: American Water Resources Association Monograph Series No. 14, p. 101-119.

Burden, C.B., and others, Ground-water conditions in Utah, Spring of 1989: Utah Division of Water Resources Cooperative Investigations Report No. 29.

Freethey, G.W., 1989, Models, data available, and data requirements for estimating the effects of injecting saltwater into disposal wells in the Greater Altamont-Bluebell oil and gas fields, northern Uinta Basin, Utah, U.S. Geological Survey Open-File Report 88-475.

Freethey, G.W., 1988, Upper Colorado River Basin regional aquifer-systems analysis--Mesozoic rocks in Colorado, Utah, and Wyoming, Arizona, and New Mexico, in Johnson, A.I., and McLean, J.S., eds., Regional aquifer systems of the United States--Aquifers of the western mountain area: American Water Resources Association Monograph Series No. 14, p. 57-70.

Freethey, G.W., Lithologic and hydrologic properties of Mesozoic rocks in the Upper Colorado River Basin, in Johnson, A.I., and McLean, J.S., eds., Regional aquifer systems of the United States--Aquifers of the western mountain area: American Water Resources Association Monograph Series No. 14, p. 81-99.

Gates, J.S., and Freethey, G.W., 1989, The relation of geohydrologic setting to the potential for ground-water contamination in Utah, in Cordy, G.E., ed., Geology and hydrology of hazardous-waste, mining-waste, waste-water, and repository sites in Utah: Utah Geological Association Publication 17, p. 11-28.

Gates, J.S., and Bedinger, M.S., 1989, Ground-water flow systems of western Utah, in Johnson, A.I., and McLean, J.S., eds., Regional aquifer systems of the United States--Aquifers of the western mountain area: American Water Resources Association Monograph Series No. 14, p. 37-55.

Lambert, P.M., and West, J.C., 1989, Continuous seismic-reflection survey of the Great Salt Lake, Utah--East of Antelope and Fremont Islands: U.S. Geological Survey Water-Resources Investigations Report 88-4157.

Mason, J.L., 1989, Hydrology of the Prospector Square area, Summit County, Utah: U.S. Geological Survey Water-Resources Investigations Report 88-4156.

Mason, J.L., 1989, Geohydrology and water quality in the vicinity of the Silver Creek tailings, Summit County, Utah: in Cordy, G.E., ed., Geology and hydrology of hazardous-waste, mining-waste, waste-water, and repository sites in Utah: Utah Geological Association Publication 17, p. 135-148.

Stephens, D.W., and Waddell, B., 1989, Selenium contamination from irrigation drainage in the western United States with emphasis on Utah, in Cordy, G.E., ed., Geology and hydrology of hazardous-waste, mining-waste, waste-water, and repository sites in Utah: Utah Geological Association Publication 17, p. 165-181.

Thomas, B.E., Simulation analysis of the ground-water system in Mesozoic rocks in the Four Corners area, Utah, Colorado, Arizona, and New Mexico: U.S. Geological Survey Water-Resources Investigations Report 88-4086.

Weigel, Jay F., 1988, Sources of hydrologic data on Mesozoic formation in the Upper Colorado River Basin and comparison of data analysis methods in Johnson, A.I., and McLean, J.S., eds., Regional aquifer systems of the United States--Aquifers of the western mountain area: American Water Resources Association Monograph Series No. 14, p. 71-80.

Several reports on past projects are not yet released or published but are being completed. The status of these reports, listed by project number, is as follows:

UT-154
Freethey, G.W., and Cordy, G.E., Geohydrology of Mesozoic rocks in the Upper Colorado River Basin--excluding the San Juan Basin--in Arizona, Colorado, New Mexico, Utah, and Wyoming: U.S. Geological Survey Professional Paper 1411-C (in press).

UT-171
Howells, Lewis, The base of moderately saline ground water in San Juan County, Utah: Utah Department of Natural Resources Technical Publication No. 94 (in preparation).

UT-174
Arnow, Ted, and Stephens, D. W., The Great Salt Lake, Utah: 1847-1986: U.S. Geological Survey Water-Supply Paper 2332, (in press).

CURRENT PROJECTS BY NUMBER AND TITLE

COLLECTION OF HYDROLOGIC DATA

SURFACE-WATER DATA, INCLUDING SEEPAGE LOSSES FROM CANALS

Number: UT-00-001

Cooperating Agencies: U.S. Bureau of Reclamation; U.S. Bureau of Land Management; U.S. Soil Conservation Service; Utah Division of Water Rights; Utah Division of Water Resources; Utah Geological and Mineral Survey; Bear River Commission; Weber Basin Water Conservancy District; Salt Lake County Division of Flood Control and Water Quality; Weber River Water Users Association; Ogden River Water Users Association; Federal Power Commission (Utah Power and Light Co.)

Staff: L. R. Herbert, Hydrologic Technician, Project Chief (part time)
Other District personnel as assigned

Period of Project: Continuing

Objective: To obtain data on stream discharge, reservoir contents, and lake stage at selected sites throughout Utah (fig. 2).

Approach: Standard methods for the operation and maintenance of streamflow-gaging stations and for the computation, computer storage, and publication of the data were used.

Progress: Data collection and computation necessary for the publication of discharge records for 183 streamflow-gaging stations and contents and stage records for 18 reservoir and 4 lake-stage stations continued during the year. Figure 2 shows the locations of the stations and station numbers. Data collected at these stations, as well as larger-scale maps showing station locations, are given in the series of reports "Water resources data for Utah", U.S. Geological Survey Water-Data Reports. In addition, monthly flow measurements were made of water through the breach in the causeway across Great Salt Lake. The stations are classified as follows:

Discharge	
Current use	129
Hydrologic data for planning and design	43
Benchmark for long-term trends	11
Contents of reservoirs	19
Stage of Great Salt Lake and West Pond	3

Due to funding constraints, 1 gaging station was discontinued. This station was:

Rock Creek near Hanna

Gaging stations established were:

Diamond Fork at Monks Hollow
Rock Creek below Stillwater Dam
Weber River near Wanship
Weber River at Echo
Ogden River below Pineview Reservoir
Strawberry River below Starvation Reservoir
Settlement Canyon near Tooele
San Pitch River near Mt. Pleasant

Seepage-loss studies: A seepage study of Timpanogos, Wasatch, Sagebrush and Spring Creek, Upper Charleston, and Lower Charleston Canals, Wasatch County, was completed. The report is in preparation.

West Desert pumping project: Continued to monitor the stage of West Pond.

Plans for Next Year: Continue operation of network. Prepare 1989 water-year records for publication. Select canals for the next seepage-loss study, and begin flow measurements. Complete report on floods in the Great Basin during 1983-84, and flood report on Quail Creek Reservoir dike failure. Continue monitoring flow through breach in Great Salt Lake causeway. Complete report on floods near Lake Powell. Complete report on surface-water reconnaissance of the Sevier River Basin above Sevier Bridge Reservoir.

Reports:

Herbert, L.R., and Smith, G.J., 1988, Seepage study of the Southbend, Richfield, and Vermillion Canals, Sevier County, Utah: Utah Department of Natural Resources Technical Publication No. 97.

ReMillard, M.D., and others, 1989, Water resources data for Utah, water year 1988: U.S. Geological Survey Water-Data Report UT-88-1.

U.S. Geological Survey, 1990, National Water Summary 1987-88--Floods and Droughts: U.S. Geological Survey Water Supply Paper 2350.

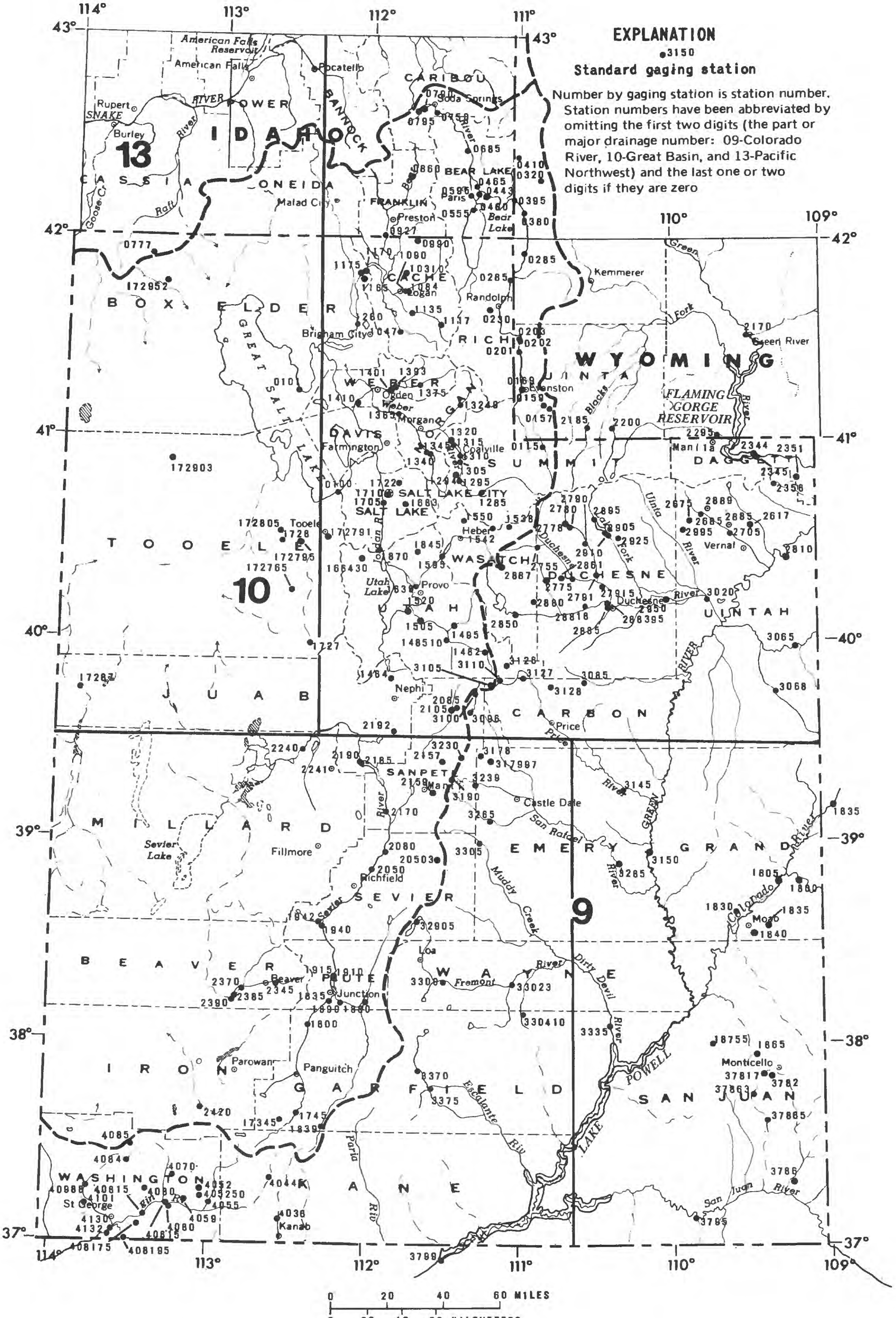


Figure 2.--Location of gaging stations, September 1989.

GROUND-WATER DATA AND GROUND-WATER CONDITIONS IN UTAH

Number: UT-00-002

Cooperating Agencies: Utah Division of Water Rights; Utah Division of Water Resources

Staff: L.R. Herbert, Hydrologic Technician, Project Chief (part time)
C.B. Burden, Hydrologic Technician and Editor of annual ground-water conditions report (part time)
J.S. Gates, Hydrologist (part time)
Other District personnel as assigned

Period of Project: Continuing

Objectives: To obtain long-term records of ground-water levels, to determine water-level changes for yearly or other periods, and to determine withdrawals from aquifers in the State. To make an annual evaluation of ground-water conditions in Utah.

Approach: Measure water levels annually or semiannually (normally February-March and September) and operate continuous water-level recorders on selected wells. Visit selected discharging irrigation wells, measure discharge, determine the ratio of water produced to energy consumed, and use the ratio along with energy-consumption data to compute total annual pumpage. Visit selected flowing wells and measure discharge. Obtain estimates of ground water withdrawn from wells for public supply and industrial use from the Utah Division of Water Rights. Obtain additional selected estimates of industrial use of water from wells by interviewing users, or by rating pumps and using the ratio of water produced to energy consumed with energy-consumption records. Determine the number and diameter of new wells drilled annually from well drillers' reports supplied by the Division of Water Rights. Prepare an annual report on ground-water conditions in Utah which includes data, graphs, and maps showing water-level changes; withdrawals from wells; number of wells drilled in defined ground-water basins or areas; and a discussion of ground-water conditions in each basin or area. Store water-level data in computer files and publish selected data in the annual report of water-resources data for Utah.

Progress: Water levels were measured in about 1,000 wells in February and March; in addition, water levels in 600 of these wells were measured in September, and water levels in 44 wells were measured monthly. Continuous water-level recorders were maintained on 31 wells. Locations of the water-level observation wells and recorder wells are shown in figure 3. During the irrigation season, about 500 discharging irrigation wells were visited; discharge was measured at those wells that were pumping, about one-half of the wells, and the ratio of water production to energy consumption was determined. Natural flow was measured for about 50 wells during the irrigation season. Number and diameters of new wells drilled were determined. The twenty-ninth in the series of annual reports on ground-water conditions in Utah was completed.

A draft of a report on how ground-water studies are done was prepared at the request of the office of Water-Data Coordination, U.S. Geological Survey.

Plans for Next Year: Continue collecting, recording, and publishing data on water levels, ground-water withdrawals, and wells drilled. The thirtieth in the series of annual ground-water reports will be compiled. A draft of the report on how ground-water studies are done will be completed. Continue measuring water levels in observation wells near dikes of West Pond.

Reports:

Burden, C.B. and others, 1989, Ground-water conditions in Utah, Spring of 1989: Utah Division of Water Resources Cooperative-Investigations Report 29.

ReMillard, M.D., and others, 1989, Water resources data for Utah, water year 1988: U.S. Geological Survey Water-Data Report UT-88-1.

Water-level-change maps, for the period February or March 1988-February or March 1989, of 15 areas in Utah--Issued April 1 as local press releases and distributed to agencies and interested individuals.

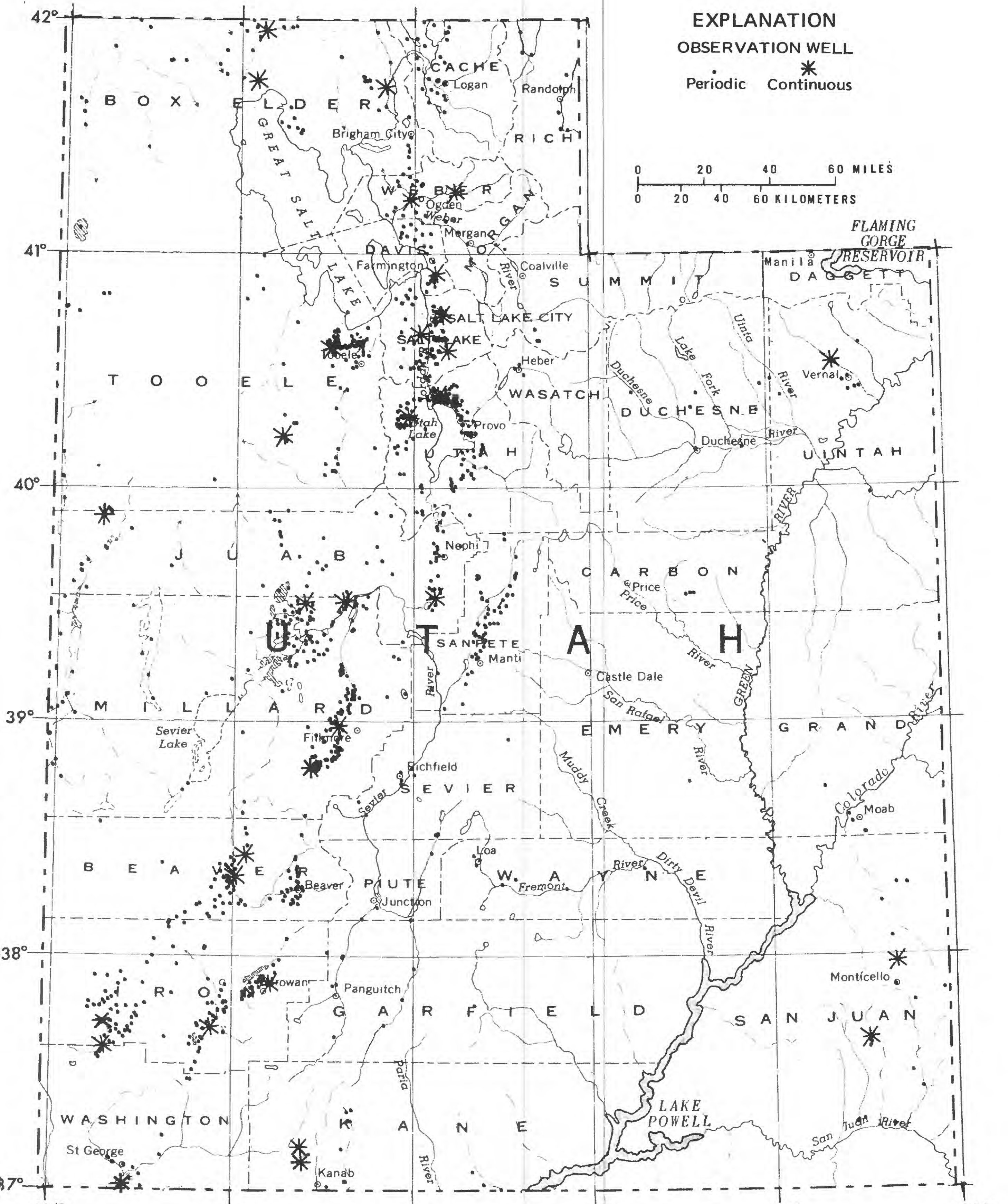


Figure 3.--Location of observation wells where ground-water levels were measured, September 1989

WATER-QUALITY AND FLUVIAL-SEDIMENT DATA

Number: UT-00-003; UT-00-004

Cooperating Agencies: Utah Department of Agriculture; Utah Division of Water Resources; Utah Division of Water Rights; Utah Geological and Mineral Survey; U.S. Bureau of Land Management; U.S. Bureau of Reclamation; U.S. Soil Conservation Service

Staff: L. R. Herbert, Hydrologic Technician, Project Chief (part time)
Other District personnel as assigned

Period of Project: Continuing

Objectives: To obtain records of the quality of water at selected stream sites (fig. 4), from wells (fig. 5), and of sediment (fig. 4) at selected sites throughout Utah and at sites on Great Salt Lake.

Approach: Standard methods for the collection and analysis of chemical-quality, fluvial-sediment, biological samples, and computer storage and publication of data were used.

Progress: Samples for chemical analysis were obtained periodically (about eight times per year) at 19 stream sites. In addition, temperature and specific-conductance data were obtained daily at five of these stream sites. Temperature and specific-conductance data also were obtained periodically at an additional 146 stream sites. Sediment data were obtained daily at five sites and periodically at an additional 12 sites. Samples for chemical analysis of ground water were obtained from about 88 wells. In addition, field values for temperature and specific conductance were collected at 105 wells. All water-quality data for streams and wells are listed in the annual water-resources data reports.

Physical and chemical data also were obtained for long-term sites on Great Salt Lake and West Pond of the West Desert pumping project. Temperature and density were measured at the sites at various depths, and selected samples were submitted for chemical and biological analyses. Seasonal and areal variations in water quality were defined by sampling three times a year at five sites in the north part of Great Salt Lake and three sites in the south part. Monthly measurements of temperature, density, and velocity of flow were made along several verticals through cross sections at both the upstream and downstream sides of the causeway at the breach between the south and north parts of the lake. In addition, monthly field measurements of temperature and specific gravity were made of water from 24 observation wells near the dikes of West Pond of the West Desert pumping project. Samples were taken quarterly from these wells for chemical analysis.

Plans for Next Year: Continue collecting and processing data and preparing records for publication. Continue monitoring Great Salt Lake and measure temperature and specific gravity at various depths. Continue monitoring water quality in observation wells near the dikes of West Pond of the West Desert pumping project.

Reports:

ReMillard, M.D., and others, 1989, Water resources data for Utah, water year 1988: U.S. Geological Survey Water-Data Report UT-88-1.

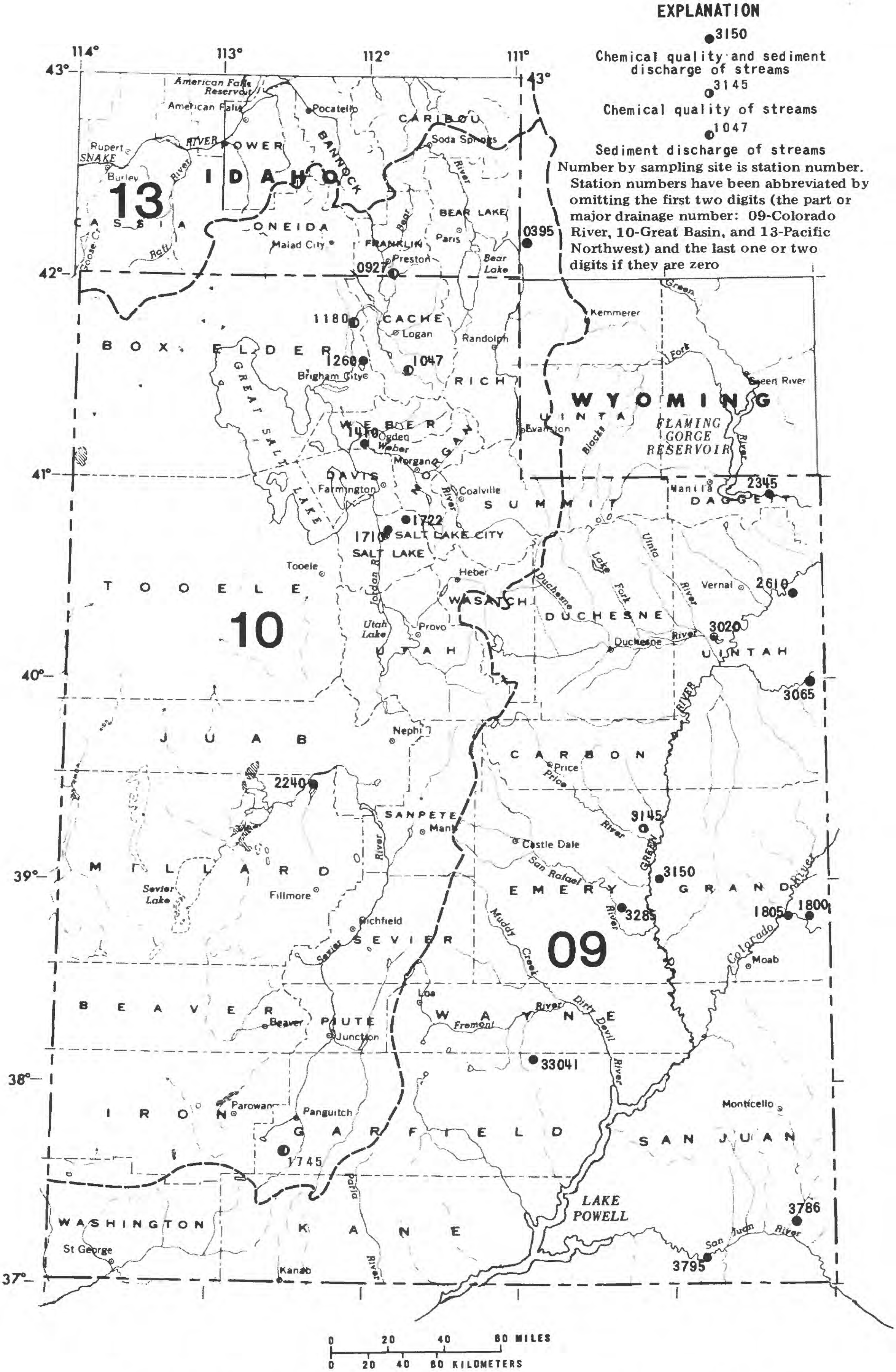


Figure 4.--Location of surface-water-quality stations, September 1989.

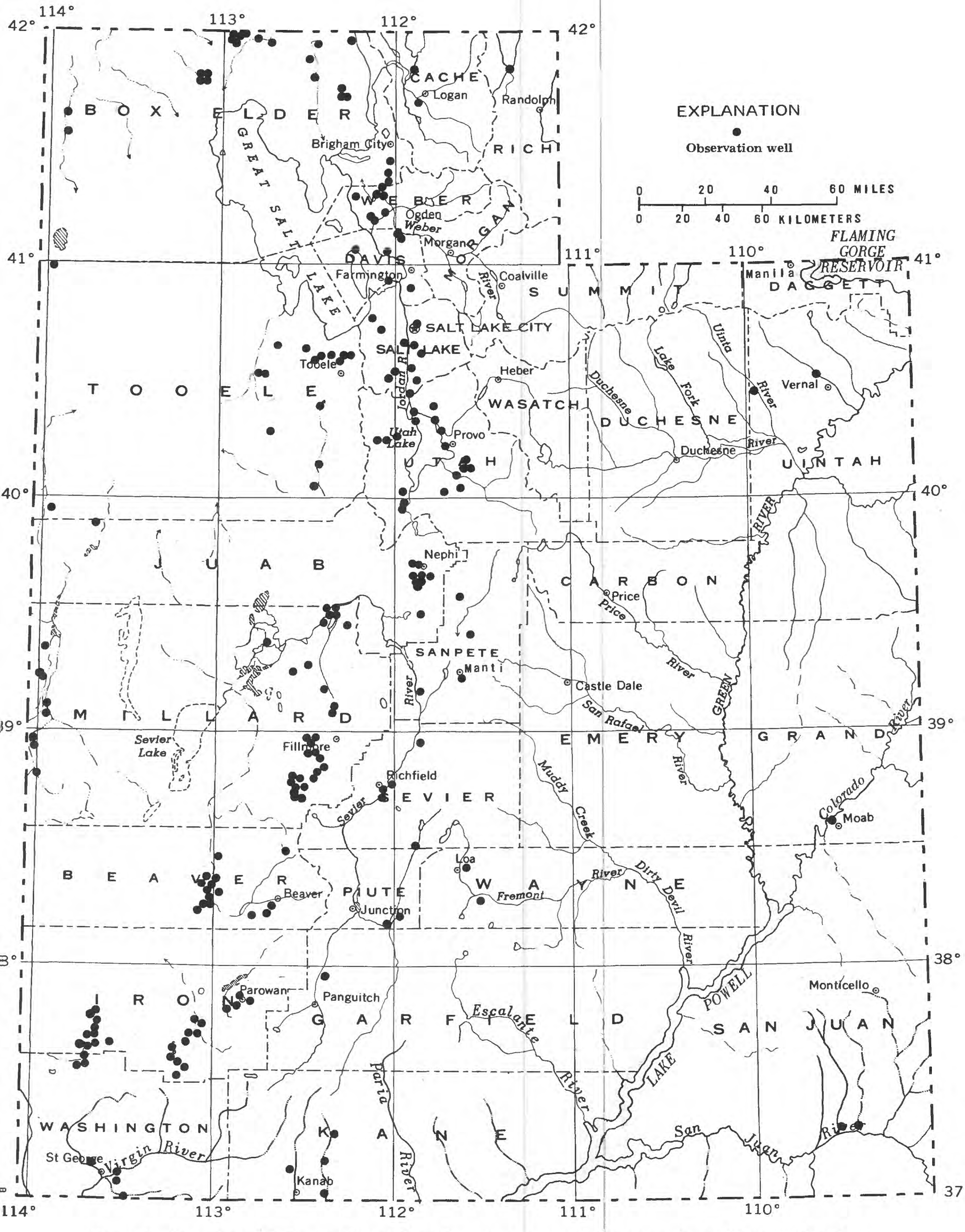


Figure 5.--Location of observation wells where water samples were collected for monitoring ground-water quality, September 1989.

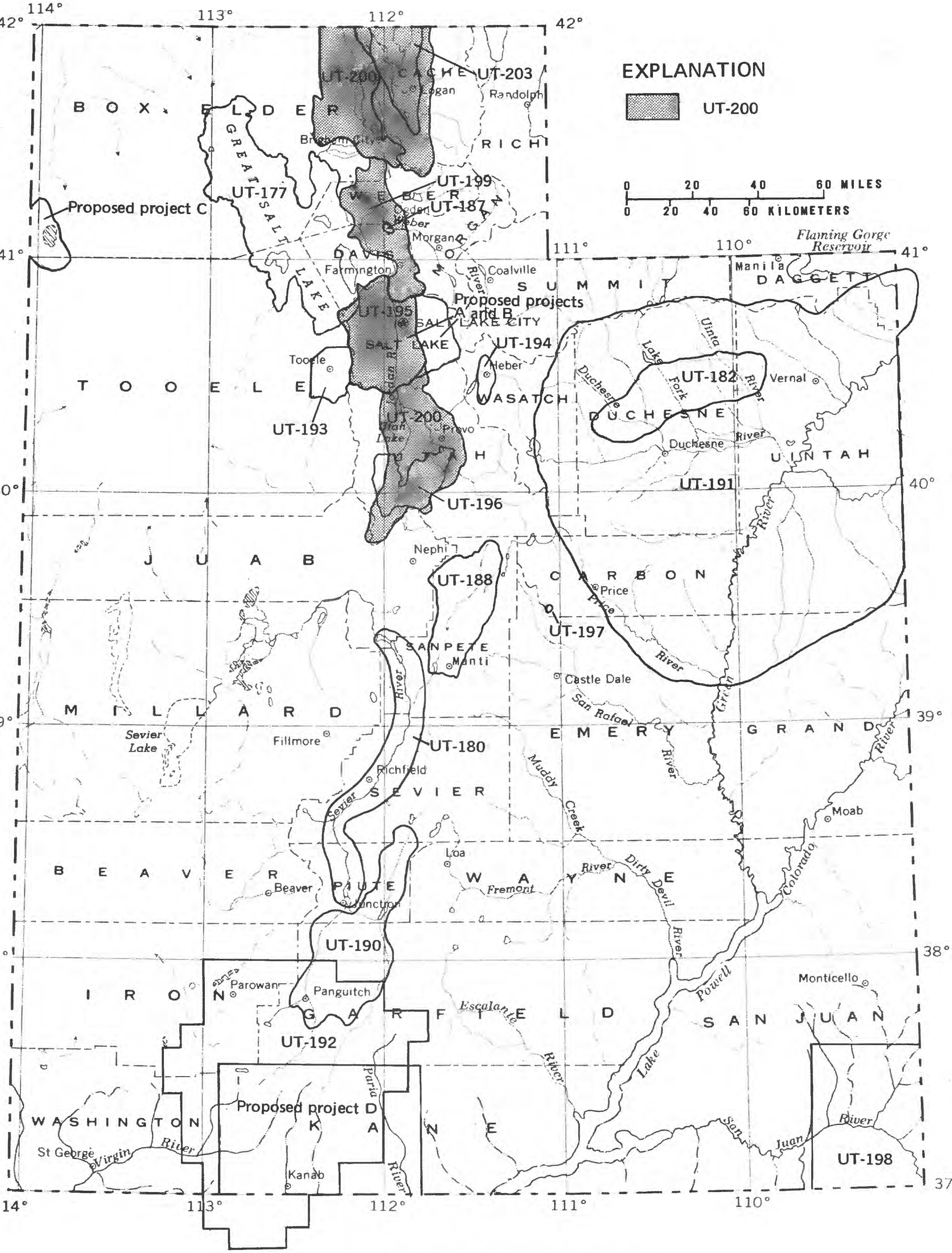


Figure 6.--Location of interpretive studies.

INTERPRETIVE STUDIES

STATEWIDE WATER USE

Number: UT-00-007

Cooperating Agencies: Utah Division of Water Rights; Utah Division of Water Resources

Staff: G.E. Pyper, Hydrologist, Project Chief
Brent Johnson, Engineer, Utah Division of Water Rights
Other State and District personnel as assigned

Period of Project: Began July 1977, continuing

Objective: To obtain information about withdrawals and return flows of water for various uses and consumptive use of water in connection with each type of withdrawal.

Approach: Total water diversions and consumptive use will be determined by verification of user measurements and records and, where possible, by field inventory and measurement of surface-water diversions and selected types of ground-water diversions. Acreage and crop surveys will be used to aid in estimating consumptive use by irrigation. State personnel are collecting data on public-supply and industrial use; U.S. Geological Survey personnel are collecting data on irrigation use.

Progress: Mail surveys were made by the Division of Water Rights to determine water use by about 390 public water-suppliers and about 110 major self-supplied and public-supplied industries. No visits were made during the year to verify data from the public suppliers. The report on water use during 1986 and 1987 by public water-suppliers and industry was reviewed and approved for publication. Field verification of irrigated land during 1989 was made in hydrologic units 16030006, 16030007, and 16030008 in the Great Basin. Data on water use by agriculture (other than irrigation) and power generation were compiled for the years 1986, 1987, and 1988.

Plans for Next Year: Collection and verification of public-supply and industrial water-use data by the Division of Water Rights will continue. Collection of irrigation water-use data will continue by river basin, and irrigation water-use in the Bear River basin above Cutler Reservoir will be determined during FY 1990. In addition to irrigation water use, other water uses in Cache Valley will be determined. A report will be written on irrigation water-use data sources for Utah, and a selected alternative approach for estimation of irrigation water use where published data are not available.

MODEL FOR PREDICTING THE WATER AND SALT BALANCE OF GREAT SALT LAKE FOR SELECTED LAKE LEVELS

Number: UT-87-177

Cooperating Agency: Utah Division of State Lands and Forestry

Staff: K.M. Waddell, Hydrologist, Project Chief (part time)
S.R. Wold, Hydrologist

Period of Project: January 1986 to December 1987

Objectives: To update the existing model (constructed in 1972) of the water and salt balance for Great Salt Lake so that it can be used to predict the water and salt balance between the north and south parts of the lake for variable amounts of freshwater inflow. The existing model is out-of-date in terms of currently higher water levels and modification of the causeway between the north and south parts of the lake since 1972. Variations in stratification in the south part of the lake will be incorporated in the model, if possible. The location of the study area is shown in figure 6.

Approach: Equations used for flow through the causeway breach will be taken from Holley and Waddell (1976) and new equations for stratified flows through the submerged culverts will be developed. The causeway-fill flows are being updated using the two-constituent solute-transport model of Sanford and Konikow (1985). The fill-flow model will be calibrated by indirectly estimating flow through the causeway fill as the unknown variable, and calculating the fill-flow values using equations that describe the water and salt balance for the north and south parts of the lake.

Data collected by the Utah Geological and Mineral Survey indicate the deep stratified layer in the south part of the lake remained relatively stable during 1962-83 but began to change when the causeway was breached in 1984. The effects of different variables on stratification patterns will be determined by plotting time trends of density for each sampling section and then contrasting the trends for other parameters, such as surface inflow and breach width, that affect the water and salt balance of the lake.

Progress: Due to funding constraints, little progress has been made on this study.

Plans for Next Year: Complete calibration of overall model, determine effects of various parameters on stratification, and continue writing report. A report on the model for predicting the water and salt balance of Great Salt Lake, Utah, for selected lake levels, will be written.

HYDROLOGY OF THE CENTRAL SEVIER VALLEY, CENTRAL UTAH, WITH EMPHASIS ON THE SEVIER-SIGURD BASIN

Number: UT-86-180

Cooperating Agency: Utah Division of Water Rights

Staff: J.L. Mason, Project Chief
P.M. Lambert, Hydrologist
R.W. Puchta, Hydrologist
T.P. Ryan, Hydrologic Technician (part time)
J.D. Olson, Hydrologic Technician (part time)

Period of Project: July 1986 to June 1990

Objectives: To assess the current state of the hydrologic system of the Central Sevier Valley, in terms of surface-water flow, ground-water levels, and water quality. To quantify the hydrologic system in terms of surface-water runoff and ground-water recharge, movement and discharge, and to determine the relations between surface and ground water. To determine the factors that result in an increase in dissolved solids in surface and ground water along the valley. To estimate the effects of continued and increased ground-water withdrawals on the hydrologic system, including water quality. The location of the study area is shown in figure 6.

Approach: Update data on streamflow, ground-water levels, and surface- and ground-water quality. Refine previous estimates of ground-water recharge and discharge, especially recharge from irrigation and discharge by seepage to the Sevier River. Sample ground and surface water to define in detail the changes that occur in water quality. Construct a digital model (or models) of the valley's ground- and surface-water system (or a representative part of the system) to define surface-water/ground-water interaction. Install a series of shallow wells near selected river reaches to determine quality of ground-water seepage to the river and to obtain the gradient from the aquifer to the stream. Conduct seepage studies during low flow combined with sampling to better define quality and quantity of inflow to the river. Analyze ground water for isotopes to help determine sources of recharge, and to differentiate recharge by irrigation, precipitation, and inflow from adjacent areas. Apply geochemical models (such as salt-routing models) in an attempt to quantitatively characterize changes in water quality. A solute-transport model of a representative part or cross-section of the valley also might be used to study changes in ground-water quality. Use the analytical techniques to further estimate the effects of continued and increased ground-water withdrawals on the hydrologic system, including water quality.

Progress: Mass measurements of water levels in observation wells were completed in March and September 1989. Monthly water-level measurements were continued on the majority of the observation wells in the Sevier-Sigurd area through September 1989. Six shallow observation wells were completed in three different areas. These wells were used to determine hydraulic gradient of the unconfined aquifer and to collect water for chemical analysis. The ground-water flow model for the Sevier-Sigurd area has been calibrated to steady-state conditions for 1957. Transient calibration involved matching ground-water levels on a monthly basis for 1958 and 1959 and on a yearly basis for 1957-88. Ground-water sampling for water quality was completed with more than 50 samples collected. Most of the samples were collected in the Sevier-Sigurd area. Geochemical interpretations will be compared to ground-water flow paths determined from model simulations. Other samples were collected throughout the study area with emphasis on collecting samples from wells that were sampled in the previous study.

Plans for Next Year: Complete compilation of collected data for final report. Complete final simulations for ground-water flow model to determine ground- and surface-water relationships in the Sevier-Sigurd area. Interpret water-quality data to determine possible ground-water flow paths and ground- and surface-water relations. Complete final report on the hydrology of the Central Sevier Valley, central Utah, with emphasis on the Sevier-Sigurd Basin.

PLAN TO DETERMINE EFFECTS OF INJECTING BRINE, UINTA BASIN

Number: UT-87-182

Cooperating Agency: Utah Division of Oil, Gas, and Mining

Staff: G. W. Freethey, Hydrologist, Project Chief (part time)

Period of Project: October 1986 to September 1989

Objectives: To determine the best method of estimating the effects of injecting brines produced by oil and gas wells on the ground-water system in the Uinta Basin. If digital modeling is determined to be part of the method, define the type of data needed and the availability of that data for developing a model to simulate the hydraulic and chemical effects of injecting the brines. The location of the study area is shown in figure 6.

Approach: (1) Evaluate methods for estimating the effects of brine injection, especially the use of various digital models, (2) determine data requirements for modeling, (3) determine availability, sources, reliability, and distribution of these data, (4) design a data-collection program to obtain these data if they are not available, and (5) begin model development if data are available and time allows.

Progress: The report, outlining model requirements, was distributed to the cooperator and other interested agencies. Geophysical logs were purchased for the prototype area within the Altamont-Bluebell oil field, and 5 geologic sections have been prepared on the basis of these logs. The sections include a 1,500-foot interval from 3,500 feet to 2,000 feet above sea level. This interval is where injection of oilfield production water is taking place and constitutes the most likely source of contamination to any overlying freshwater aquifers. Individual sand layers cannot be traced from well to well without a means of more specific identification, but a trend in the number of lenses that form the injection zone indicates a likely decrease in effective horizontal conductivity of the zone to the south.

The project has been suspended because preliminary results have indicated that a much greater effort will be needed to obtain data necessary to adequately simulate the effects of injection in the area, and funding is not available at this time to undertake such a project.

Plans for Next Year: An Open-File map report is planned. A map of the prototype area and 12 geologic sections based on geophysical and stratigraphic logs will show lithologic and hydrologic trends for the 1,500-foot zone where the shallowest injection is occurring. The map will show structure contours at the base of the Duchesne River Formation and general hydrologic trends noted in the geophysical logs. The sections will provide a third dimension to understanding these trends.

Reports:

Freethey, G.W., 1989, Models, data available, and data requirements for estimating the effects of injecting saltwater into disposal wells in the Greater Altamont-Bluebell oil and gas fields, northern Uinta Basin, Utah, U.S. Geological Survey Open-File Report 88-475.

GROUND-WATER CONTAMINATION AT HILL AIR FORCE BASE LANDFILLS 1 AND 2

Number: UT-88-187

Cooperating Agency: U.S. Air Force

Staff: K.M. Waddell, Hydrologist, Project Chief
K.A. Kariya, Hydrologist
L.J. Gerner, Hydrologist
C.B. Slaughter, Hydrologist (part time)
T.J. Burbey, Hydrologist, Nevada District (part time)
Other District and Regional personnel as assigned

Period of Project: October 1987 to September 1992

Objectives: To conduct a remedial investigation/feasibility study at landfills 1 and 2, Hill Air Force Base, to identify the existence of hazardous waste and to evaluate the source, extent, and degree of contamination of ground water. To assess the risk to human health and the environment. To define and assess alternative actions that will control or eliminate the risk. The location of the study area is shown in figure 6.

Approach: Determine the hazard level of the site so that the proper safety equipment will be used. Define the source, extent, and degree of contamination by sampling and analyzing soil gas, by drilling and logging test holes and completing them as monitoring wells, analyzing borehole-geophysical logs, and sampling and analyzing cuttings and water. Conduct surface-geophysical surveys and use data from test holes to characterize the local hydrogeologic system. Measure water levels in monitoring wells to determine directions of ground-water movement. The data collected at the site will be used to prepare a risk assessment. The U.S. Bureau of Reclamation, as a contractor, will design and evaluate alternatives for controlling or removing the contaminant source and the contaminated ground water.

Progress: Completed aquifer tests, soil-gas investigations, water-use inventory, and water sampling and analysis on existing monitoring wells. Drilled 21 monitoring wells. A plume of trichloroethylene was defined for study area. A three-dimensional digital model of ground-water flow and transport at the site was designed and construction of the model was begun.

Plans for next year: Complete the last 9 monitoring wells and conduct all logging, testing, and sampling of these wells. Collect one more set of water samples from monitoring wells. Complete the digital ground-water flow and transport model and the Remedial Investigation Report. A site-characterization report will be written.

GROUND-WATER HYDROLOGY OF SANPETE VALLEY AND THE SAN PITCH RIVER DRAINAGE BASIN, UTAH

Number: UT-88-188

Cooperating Agency: Utah Division of Water Rights

Staff: D.E. Wilberg, Hydrologist, Project Chief
G. Herbold, Hydrologist (part time)
V.M. Heilweil, Hydrologist (part time)

Period of Project: July 1987 to June 1990

Objectives: (1) To assess current hydrologic conditions in terms of ground-water occurrence, recharge, movement, and discharge; ground-water levels and quality; surface-water flow and quality; and ground- and surface-water interrelations. (2) To improve understanding of the hydrologic system and how it functions, especially the ground-water component. (3) To estimate the effects on the hydrologic system caused by potential redistribution or changes in the quantities and locations of ground-water withdrawals, importation of surface water, and modification of irrigation methods. (4) To determine causes for downstream deterioration in quality of surface water, the lesser deterioration in quality of ground water, and local variations in ground-water quality. (5) To define the relationship between the consolidated-rock aquifer(s), the valley-fill aquifer, and surface water. (6) To locate the ground-water divide between the San Pitch and Spanish Fork surface-water drainage basins and to assess basic ground-water conditions in the Indianola area. The location of the study area is shown in figure 6.

Approach: (1) Compile data on ground water and surface water that have been collected since the last study in the area during 1964-67. (2) Measure or estimate ground-water discharge from wells, springs, drains, to streams, and by evapotranspiration; and estimate recharge from streams, irrigation, and seepage from consolidated rock. Conduct low-flow discharge measurements on the San Pitch River to delineate losing and gaining reaches and to estimate ground-water recharge and discharge, including irrigation return flow. Measure seepage losses on representative tributaries to determine the quantity of runoff that contributes to ground-water recharge. (3) Measure water levels in wells to monitor spatial and temporal variations, to define directions of ground-water movement, and to determine ground-water divides. (4) Conduct aquifer tests to obtain hydraulic characteristics of the valley fill. (5) Construct a digital model of the valley-fill aquifer to simulate the three-dimensional ground-water system and to provide a means of estimating the effects of changes in the hydrologic system. (6) Install temporary surface-water gages on major tributaries of the San Pitch River in order to better define surface-water runoff prior to importation of surface water. (7) Sample and analyze water from wells, springs, streams, and drains to define variations in ground- and surface-water quality and provide information to use in estimating causes of these variations. Sample selected ground- and surface-water sources that have had previous chemical analyses to determine if any water-quality deterioration has occurred; and correlate available analyses with geologic cross-sections and drillers' logs to determine possible causes of water-quality variation. (8) Compile drill-stem-test data from the few oil-test wells drilled in the area to help determine the hydrologic connection between the consolidated-rock aquifer and the valley-fill aquifer.

Progress: Water levels in 50 wells and one reservoir were measured regularly at 6-week intervals to estimate changes in storage. Water levels in 160 wells were measured at 6-month intervals, in May and November, for comparison with other hydrologic data such as precipitation and surface-water runoff at gaged sites, and to estimate the potentiometric surface and ground-water storage changes. This information, along with discharge data collected from pumping wells, flowing wells, springs, and river seepage studies, will be used to calibrate a three-layer digital computer model that is actively being developed to simulate ground-water conditions in the Sanpete Valley. Water-quality data, such as temperature, electrical conductance, and pH, were gathered from both surface- and ground-water sources throughout the valley to determine if any deterioration has occurred. Computer-generated coverages of the model grid, land use, cultural networks, and drainages have been created to enhance the interpretation and presentation of data.

Plans for Next Year: Field work will be completed with the semi-annual water-level measurements in November. Computer entry of field data will soon be completed to expedite data access for both analysis and generation of tables for publication. Laboratory analyses of water samples will be compared with previous analyses to determine if the water quality has changed and possible reasons for the change. Interpretation of water levels, seepage loss-gain data, precipitation-runoff relations, and other pertinent hydrologic data that relate to ground-water occurrence, recharge, movement, discharge, and surface-water interaction will be summarized in a report. Upon completion of both steady-state and transient calibrations of the digital-computer model, the modeling results also will be summarized in a report on the hydrology of the Sanpete Valley.

GROUND-WATER HYDROLOGY OF THE UPPER SEVIER RIVER BASIN, SOUTH-CENTRAL UTAH, AND SIMULATION OF THE GROUND-WATER SYSTEM IN PANGUITCH VALLEY

Number: UT-88-190

Cooperating Agency: Utah Division of Water Rights

Staff: S.A. Thiros, Hydrologist, Project Chief
W.C. Brothers, Hydrologist
J.D. Olson, Hydrologic Technician

Period of Project: July 1987 to June 1990

Objectives: (1) To define the hydrology of the Upper Sevier River drainage basin and the current state of the hydrogeologic system, including the hydrologic budget and ground-water/surface-water relations, and to improve the existing characterization of the ground-water system. (2) To define the chemical quality of ground and surface water and to describe the mechanisms for quality changes in the downstream direction. (3) To estimate the hydrologic effects of increased ground-water development, changes in irrigation practices, and impoundment of surface water on ground-water levels, streamflow, spring discharge, and evapotranspiration. The location of the study area is shown in figure 6.

Approach: (1) Compile all data on ground water, surface water, and chemical quality of water collected since the last study in the area in 1961-64. (2) Conduct seepage runs and/or install short-term gaging stations along the major streams to define ground-water seepage to or from streams and gaining and losing reaches. Select observation wells to better define periods of ground-water seepage to or from streams. Conduct aquifer tests on suitable wells. (3) Estimate ground-water recharge from streams and irrigation, ground-water inflow from adjacent basins, and discharge by wells, springs, seepage to streams, and evapotranspiration. (4) Sample and analyze water from wells, springs, drains, and streams to define quality of ground and surface water, and use analyses to determine causes of downstream changes in water quality. (5) Construct analytical and/or digital models for simulating flow in parts of the basin to help estimate hydrologic effects of increased ground-water development, changes in irrigation practices, or surface-water impoundment.

Progress: All water-level, well-discharge, water-quality, and surface-water data, and well drillers' logs available for the area have been compiled. A base map of the area has been constructed using ARC/INFO. Most wells and springs in the area have been inventoried and the data entered into the Ground-Water-Site Inventory (GWSI) database. Water levels in selected observation wells have been measured on a monthly basis through October 1989.

Soil-moisture access tubes and water-level observation wells were installed on two test plots in Panguitch Valley, one irrigated by flooding and the other by sprinklers, in order to quantify and determine the rate of recharge from irrigation. The soil-moisture access tubes were monitored by the Soil Conservation Service using a neutron probe. The observation wells were equipped with pressure-transducer recorders.

A three-dimensional finite-difference ground-water flow model was constructed and used to simulated ground-water conditions in Panguitch Valley.

Plans for Next Year: Interpret the available data and generate related illustrations. A report on ground-water hydrology of the upper Sevier River basin, south-central Utah, and simulation of the ground-water system in Panguitch Valley will be written.

DETAILED ASSESSMENT OF EFFECTS OF IRRIGATION DRAINAGE ON WATER QUALITY IN THE MIDDLE GREEN RIVER BASIN, UTAH

Number: UT-88-191

Cooperating Agency: Office of the Secretary, U.S. Department of the Interior

Staff: D.W. Stephens, Hydrologist, Project Chief
L.A. Peltz-Lewis, Hydrologic Technician

Period of Project: October 1988 to September 1990

Objectives: (1) To define the extent and severity of existing irrigation-induced water-quality problems or the potential for future problems, and (2) to provide the scientific understanding needed for development of alternatives to mitigate or resolve identified problems. The areas that will receive detailed study are: Stewart Lake and associated Marsh 4720, lower Ashley Creek, and Ouray National Wildlife Refuge. Reconnaissance will be extended at Pariette Wetlands to include upstream agricultural areas in Pleasant Valley. The location of the study area is shown in figure 6.

Approach: The relative contribution of each of the drains to chemical loading will be determined by sampling drain water. Once major contributing reaches are identified, soil cores will be collected and analyzed, and sequential extractions will be used to determine the potential for continued release of selenium if irrigation is continued. Analyses to determine selenium speciation in the drain water will be done and compared to selenium speciation in shallow ground-water samples collected from wells. Shallow ground water in the Jensen area will be investigated by determining vertical and horizontal gradients, direction of flow, and concentration of dissolved constituents in the water at existing and new wells. Shallow wells will be augered north of Stewart Lake and cased to provide piezometers, which will be monitored periodically for water levels and sampled for chemical analysis to determine the concentrations of selenium in the ground water.

The degree to which the water has been concentrated by evaporation will be determined using hydrogen and oxygen isotopes as described by Deveral and Fujii (1988). As the shallow ground water probably is less than 30 years old, age dating will be done using tritium. Water samples will be collected at several locations for analysis of oxygen-18/oxygen-16 ratios, deuterium/protium ratios, and tritium. Processes involved in precipitation of selenium, incorporation by sediments, and uptake by plants will be identified and quantified by transect sampling and analysis of water, sediments, and plants.

Synoptic sampling will be done on Ashley Creek from Vernal to its confluence with the Green River. Samples will be collected from all inflowing water and from existing wells and analyzed to determine quantities of selenium and total salts entering Ashley Creek.

Reconnaissance will be continued on water supplied to Marsh 4720 to determine if seasonal patterns exist in selenium content of the irrigation-drainage water. The relation of water delivery in the Ruppe drain, Naples drain, and the oilfield canal to selenium entering the marsh will be determined.

The outflow from Pelican Lake and Ouray Park Irrigation Company drainage, which provide inflow to the Ouray National Wildlife Refuge, will be sampled at the refuge three times during the summer and analyzed for selenium and major ions. A more complete search of well records will be made prior to test-well drilling to determine if existing wells could be used for monitoring. Synoptic sampling will be done to identify stream reaches where the selenium input in ground water is greatest. The distribution of selenium will be determined in the sediments in the Roadside ponds and in Sheppard Pond S5.

Progress: Monitoring of water quality has been completed at Stewart Lake, Ouray National Wildlife Refuge, and Ashley Creek. Water from shallow wells at Ouray have contained as much as 9,300 micrograms per liter of selenium. Tributary inflows into Ashley Creek have contained as much as 16,000 micrograms per liter of selenium. Shallow ground water is the source of the contamination as it leaches selenium from the surficial formations. Deformed waterfowl have been found at Stewart Lake and Ouray. Field work has been completed and preparation of the final report has begun. Several presentations have been made before technical and professional groups and two proceedings papers have been published.

Plans for Next Year: Complete interpretive report and submit for approval. Project will terminate in FY 1990.

Reports:

Stephens, D.W., and Waddell, Bruce, 1989, Selenium contamination from irrigation drainage in the western United States with emphasis on Utah, in Cordy, G.E., ed., Geology and hydrology of hazardous-waste, mining-waste, waste-water, and repository sites in Utah, Utah Geological Association Publication 17, 1989, p. 165-181.

Stephens, D.W., Selenium and wildlife areas in Utah, 1989, in Proceedings of the Second National Symposium on Water Quality, Orlando, Florida, November 12-17, 1989.

Stephens, D.W., Waddell, Bruce, and Miller, J.B., 1989, Irrigation drainage: Green River Basin, Utah, in Planning Now for Irrigation and Drainage: Proceedings, American Society of Civil Engineers, Lincoln, Nebraska, July 18-21, 1988.

EXAMINATION OF THE GROUND-WATER HYDROLOGY OF SOUTHWESTERN UTAH AND NORTHWESTERN ARIZONA USING COMPUTER SIMULATION TO ESTIMATE EFFECTS OF PUMPING FROM THE NAVAJO SANDSTONE

Number: UT-88-192

Cooperating Agency: U.S. National Park Service

Staff: G. W. Freethey, Hydrologist, Project Chief (part time)
V. M. Heilweil, Hydrologist

Period of Project: May 1988 to September 1989

Objectives: The objective of the study is to improve understanding of the hydrologic system of the Navajo Sandstone without the collection of additional extensive and costly field data. This involves using computer simulation to test various alternative concepts of the system or system parameters, and to determine the range of possible effects if pumping of ground water from wells in the Navajo Sandstone increases. The location of the study area is shown in figure 6.

Approach: The first step will be to compile all data that can be used to describe the ground-water budget of the area. These data will include estimates of recharge from infiltrating precipitation, underflow from adjacent areas, and stream losses; estimates of discharge from springs, wells, and evapotranspiration; and seepage to streams. The second step will be to describe the direction and rate of ground-water flow on the basis of water-level measurements in wells and the altitudes of springs that are part of the regional ground-water-flow system in the Navajo Sandstone, and on the basis of hydrologic properties of the Navajo aquifer. The third step will be to define hydrologic boundaries of the system that are not affected by any projected development of ground-water supplies. The fourth step will be to develop and test several of the most plausible hydrologic conceptualizations in a numerical model to determine if they are mathematically plausible. The final step will be to use several of the most plausible steady-state simulations to determine the effects of pumping from wells in the Navajo Sandstone on the direction and rate of flow in the aquifer, and subsequently on the rate of flow from springs in Zion National Park and Pipe Spring National Monument.

Progress: The three-dimensional ground-water-flow model developed for the project was used to test three different steady-state alternatives to the flow system in the Navajo Sandstone. Testing indicated that the most likely concept of the flow system is one that incorporates some flow across major fault planes where the two opposing blocks are not completely offset, and no flow across faults where the opposing blocks are completely offset. Testing the proposed pumping from the Navajo Sandstone (for water supplies for mining and transporting coal by slurry pipeline) showed that small decreases in water levels could occur in the Zion Park area under the worst-case hydrologic conditions.

Plans for next year: Complete and publish a report on the hydrologic investigation and three-dimensional finite-difference computer simulation of ground-water flow in the Navajo Sandstone of southwestern Utah and northwestern Arizona.

HYDROLOGY AND WATER AVAILABILITY IN SOUTHEASTERN TOOELE VALLEY, NORTHEASTERN RUSH VALLEY, AND ADJACENT AREAS IN THE OQUIRRH MOUNTAINS, TOOELE COUNTY, UTAH

Number: UT-88-193

Cooperating Agencies: Tooele County; City of Tooele

Staff: B. J. Stolp, Hydrologist, Project Chief
W. F. Holmes, Hydrologist (part time)

Period of Project: May 1988 to August 1990

Objectives: (1) To determine the saturated thickness and hydraulic characteristics of the basin fill in southeastern Tooele Valley. (2) To determine the quantity of water moving out of the Oquirrh Mountains via underflow in the channel alluvium of Soldier, Settlement, and Middle Canyons. (3) To determine the occurrence of ground water in and hydraulic properties of the consolidated rock of the Oquirrh Mountains. (4) To determine the average annual streamflow in Soldier, Settlement, and Middle Canyons. The location of the study area is shown in figure 6.

Approach: Inventory and measure water levels of wells located in southeastern Tooele Valley. Determine the depth to consolidated rock from drillers' logs and seismic surveys. Monitor water levels in and determine quality of water from selected wells. Perform aquifer tests to determine hydraulic parameters.

Obtain all water-level data, pumping records, and drillers' logs for municipal wells located at the mouths of Settlement and Middle Canyons, and continuously monitor water levels in selected wells. Inventory all wells and monitor water levels of selected wells at the mouth of Soldier Canyon. Perform aquifer tests on wells at canyon mouths to determine hydraulic properties of alluvium. If possible, conduct an aquifer test on two wells above the mouth of Middle Canyon. Collect water samples at selected sites for chemical analysis.

Determine the locations of all water sources (springs and tunnels) in the mountain areas, and monitor discharge at selected sites. Identify several candidate sites along the mountain front for possible test drilling into the consolidated rock. If test drilling is feasible and water is found in a test hole, conduct a slug or aquifer test to estimate hydraulic properties. Collect water samples from selected mountain sites for chemical analysis.

Based on studies in adjacent areas, historical records, and streamflow monitoring during this study, estimate average annual streamflow for Soldier, Settlement, and Middle Canyons.

Progress: A list of the water rights filed for the water sources located in the study area was compiled for the City of Tooele. Streamflows were monitored at Middle and Soldier Canyon Creeks. A streamflow-gaging station was installed on Settlement Creek above Settlement Reservoir. Two deep test holes were drilled in the study area, one at the mouth of Spring Canyon and one at Angel Grove. A monitoring network of 42 wells and springs was developed; 11 of the sites are monitored monthly, and 31 sites are monitored four times a year. The inventory of springs in the Oquirrh Mountains has been completed with an additional 35 sites visited. Two short-term aquifer tests were conducted, one near the Tooele airport and one at the mouth of Settlement Canyon. The relative elevations and distances between wells were surveyed at four well clusters. A field-data logger (datapod) for recording and storing water-level data was installed on a well at the mouth of Settlement Canyon. The final draft of the base map has been completed.

Plans for Next Year: Several aquifer tests on existing wells are planned for the fall of 1989. Monitoring of wells, springs, and surface-water sites in the network will be continued through December 1989. Water sources in the Carr Fork area will be inventoried in the fall of 1989. Compilation and interpretation of data, completion of the written report, and report review will be finished by August 1990.

HYDROLOGY OF HEBER AND ROUND VALLEYS, WASATCH COUNTY, UTAH, WITH EMPHASIS ON GROUND WATER

Number: UT-88-194

Cooperating Agencies: Utah Division of Water Resources; Utah Division of Water Rights; Wasatch County; Central Utah Water Conservancy District; Wasatch County Water Users, Associated

Staff: W. F. Holmes, Hydrologist, Project Chief
D. M. Roark, Hydrologist
H. K. Schatmeier, Hydrologic Technician (part time)

Period of Project: May 1988 to June 1990

Objectives: (1) Define and quantify recharge, movement, and discharge of the ground-water systems of Heber and Round Valleys. (2) Define ground-water quality in the two valleys and its spatial and temporal variations. (3) Provide a method for assessing the effects on the hydrologic system of changes in surface-water flows, irrigation methods, and ground-water recharge in Heber Valley, and increased ground-water withdrawals in Round Valley. (4) In a written report, discuss the hydrologic systems of Heber and Round Valleys and how the components of each system interact. The location of the study area is shown in figure 6.

Approach: (1) Update the hydrologic data base. (2) Inventory all large-diameter wells drilled since 1968 and all wells in areas where data were lacking in the previous study, and drill observation wells where needed. (3) Assess the quality of ground water by collecting samples for laboratory analysis. (4) Conduct seepage studies, check diversion and streamflow records, and estimate recharge from irrigated fields and direct precipitation. (5) Estimate discharge from wells, springs, evapotranspiration, and seepage to Deer Creek Reservoir. (6) Compile water budgets for Heber and Round Valleys. (7) Construct a three-dimensional ground-water flow model of Heber Valley to improve understanding of the hydrologic system and estimate water-level changes and changes in natural discharge related to potential changes in surface-water flows and irrigation practices.

Progress: Most culinary and large-diameter wells were inventoried. Monthly water-level measurements on 34 wells, which included six observation wells that were drilled and completed by the project, were ended. Water-quality analyses were done on samples from about 35 springs and wells in both Heber and Round Valleys. All other field work was completed in August 1989, and all data collected were put in computer storage. The model for Heber Valley was calibrated for steady-state conditions.

Plans for Next Year: Calibrate the model of Heber Valley for transient-state conditions. Complete the report on hydrology of Heber and Round Valleys, Wasatch County, Utah, with emphasis on ground water, and submit it for review.

SELECTED FACTORS RELATED TO THE POTENTIAL FOR CONTAMINATION OF THE PRINCIPAL AQUIFER, SALT LAKE VALLEY, UTAH

Number: UT-88-195

Cooperating Agency: Utah Division of Environmental Health

Staff: R.L. Baskin, Project Chief (part time)
K.M. Waddell, Hydrologist, (part time)
J.S. Gates, Hydrologist, (part time)
P.D. Fikstad, Computer Programmer (part time)
Other District personnel as assigned

Period of Project: February 1988 to January 1989

Objectives: (1) To define the natural and potential recharge areas of the principal aquifer of Salt Lake Valley, including areas where water can readily infiltrate directly to the deep unconfined part of the principal aquifer. (2) To determine areas where additional development of ground water from the confined part of the principal aquifer may cause a reversal of hydraulic gradient and allow percolation of contaminated water from the shallow unconfined aquifer into the principal aquifer. (3) To identify other factors related to movement of contaminants to the principal aquifer, to spread of contaminants, and to sources of contamination. The location of the study area is shown in figure 6.

Approach: (1) Using information from prior USGS studies, select the approximate boundaries of natural and potential recharge areas. For these areas, develop a data base from existing data. (2) Many wells in the Salt Lake Valley have been logged by drillers, and some have borehole-geophysical logs. If time permits, these logs will be used to assist in evaluating the lithology and hydraulic properties of the subsurface both in the saturated and unsaturated zones of the recharge areas. (3) Obtain Digital Line Graph (DLG) data on transportation and hydrography in the Salt Lake Valley from U.S. Geological Survey, National Mapping Division, for inclusion in the base map. (4) Obtain digitized political boundaries and reference information from the State of Utah, Automated Geographic Reference (AGR) group for inclusion in the base map. (5) Place DLG, AGR, recharge-area maps, and model-generated data into geographic-information-system data bases. (6) Simulate hydraulic gradients resulting from potential future ground-water withdrawals using the digital model of the Salt Lake Valley's ground-water flow system described in Waddell and others (1987). (7) Show areas where hydraulic gradients may be reversed or changed due to pumping by comparing current and future gradients derived from the model. (8) Obtain and place into a geographic-information-system coverage general land-use data for the Salt Lake Valley from the University of Utah, Center for Remote Sensing and Cartography. Define land uses in the categories of residential, rural, and commercial/industrial. (9) Obtain locations of hazardous-waste sites and public-supply wells from the Utah Division of Environmental Health and U.S. Geological Survey files and place into a geographical-information-system coverage. (10) Identify areas of potential contamination by assessing vertical hydraulic gradient and conductivity, quality of ground water, and extent of shallow-unconfined and principal aquifers.

Progress: Report has been written, technical reviews have been completed, and report has been forwarded for approval.

Plans for Next Year: The report on recharge areas and contamination potential of the principal aquifer, Salt Lake Valley, Utah, will be completed and published.

GROUND WATER IN SOUTHERN UTAH AND GOSHEN VALLEYS, UTAH COUNTY

Number: UT-88-196

Cooperating Agency: Utah Division of Water Rights

Staff: L.E. Brooks, Hydrologist, Project Chief
H.K. Schatmeier, Hydrologic Technician, (part time)
C.E. Hansen, Hydrologic Technician (part time)

Period of Project: October 1988 to September 1991

Objectives: (1) To assess current hydrologic conditions in terms of recharge, movement, and discharge of ground water, water levels, ground-water quality, and volumes of ground water in storage. (2) To better define the ground-water system and how its components interact. (3) To estimate the effects of additional ground-water withdrawals on water levels, water quality, and surface water; and the effects of importation of additional surface water on the ground-water system. The location of the study area is shown in figure 6.

Approach: (1) Compile data on wells, springs, water levels, ground-water quality, and surface-water flow. (2) Inventory ground-water discharge by wells and springs to drains and streams, by evapotranspiration, and by seepage to Utah Lake. (3) Estimate recharge, where feasible, from streams, irrigation, precipitation, and subsurface flow from consolidated rock. (4) Conduct aquifer tests to improve knowledge of hydraulic characteristics of the basin fill. (5) Construct a three-dimensional digital model of the ground-water system to simulate and better understand ground-water flow, and predict effects of proposed changes in water use on the system. (6) Prepare a basic-data report and an interpretive report of the study for publication by the Utah Department of Natural Resources.

Progress: An inventory of wells drilled since 1967 that are eight inches in diameter or larger has been completed, as has an inventory of flowing wells with reported discharges greater than 30 gallons per minutes. For all sites with water-level or discharge measurements, new Ground-Water Site Inventory (GWSI) schedules were filled out. Sites already in GWSI were updated, and sites not already in GWSI were added. A study of drillers' logs is ongoing to try to delineate the aquifer system, and to help assign high-production wells to model layers. A monthly water-level monitoring network was designed and approximately 35 wells are measured on a monthly basis. Discharge of flowing wells in the network is also being measured monthly.

Plans for Next Year: The funding level for this project is uncertain at the current time, but plans for next year include a canal-seepage study, examining diversion records to determine where water is applied, and measurements of spring discharge. If development of a model is funded, it will begin, and will possibly stretch the project from three years to four years at current funding levels.

HYDROLOGIC RESPONSE TO LAND SUBSIDENCE CAUSED BY UNDERGROUND COAL MINING, MILLER CREEK DRAINAGE, CARBON COUNTY, CENTRAL UTAH

Number: UT-89-197

Cooperating Agency: Utah Division of Oil, Gas, and Mining

Staff: C.B. Slaughter, Hydrologist, Project Chief
G.W. Freethey, Hydrologist (part time)

Period of Project: October 1988 to September 1993

Objectives: The objectives of the proposed study are: (1) to determine the effect of longwall mining of coal on overlying ground water and surface water in an area where the thickness of overburden is less than 500 feet, and (2) to develop methods of determining the hydrologic effects of mining-related land subsidence. The location of the study area is shown in figure 6.

Approach: The approach will consist of (1) an initial monitoring-well installation, data-collection, and data-analysis phase (first year), (2) a less-intense monitoring phase after removal of the Wattis coal seam in the Cyprus Plateau Mine (second year), (3) a more intense monitoring and data-collection phase as the "Third" coal seam is being mined, and (4) a final monitoring phase to observe how the hydrologic systems recover from the impact of mining, and whether they attain a new state of equilibrium. The effects of certain geologic properties will be included in the study. These properties include the variable thickness, strength, stratigraphy, and lithologic character of overlying rocks, the orientation and density of pre-existing joints, and the proximity and principal strike direction of faults. Documenting the impact on specific hydrologic features such as perched water levels, water-level gradients in regional aquifers, chemical quality of ground water in these aquifers, streamflow quantity and quality, and spring discharge quantity and quality, also will be included in the study.

Progress: Two wells were drilled, one from the surface and one up from inside the mine to monitor water levels and water quality in zones above the mine where the water table is perched. The monitor well drilled from the surface (Wattis well 1, altitude of 8,801) and the monitor well drilled up from inside the mine (Wattis well 2, altitude of 8,660) are along the North Fork of the Right Fork Miller Creek (NFRFMC). Next to each monitor well, a hole was drilled in which cable for a Time Domain Reflectometer (TDR) was cemented. The TDR unit was used to measure progression of caving and bed separation above the mine in an area which has less than 500 feet of overburden. Prisms for surveying were set up to use in monitoring both horizontal and vertical surface-ground movement caused by the underground coal mining.

In early October, a reconnaissance of the NFRFMC was conducted to become familiar with the Miller Creek drainage before longwall mining began below the stream. Natural fractures in the creek bed were measured and photographed. Surface fractures induced by the longwall mining to the north of NFRFMC were mapped on October 19.

A battery-operated field-data logger (datapod) was installed at a weir located on the NFRFMC on November 5 to monitor the discharge of the stream. Datapods were installed on November 22 to record water-level changes in the two monitor wells in the perched aquifer above the mine. An attempt to obtain a water sample from Wattis well 1 was unsuccessful because of a bend in the plastic casing approximately 15 feet below the surface, which prevented the bailer from reaching the water surface in the well. Water samples were taken from the Wattis well 2 on December 19, 1988, and from the NFRFMC at the weir on December 20.

In January, datapods in the canyon were serviced. Rock cores were prepared from Wattis well 1 (well drilled from the surface) to be sent to Utah Division of Oil, Gas, and Mining to have various hydrologic tests performed.

More-than-normal quantities of water began flowing through the gob (waste rock material displaced by mining) from several areas in the mine on February 10. Water samples of the initial flows were taken, and discharge measurements were made. The water volume coming from the gob was monitored periodically while the flows were accessible. On February 27, fluorescein dye was placed in the northeast portion of NFRFMC to determine if the stream was providing water to the mine. Water samples from the Wattis well 2 (well drilled up from inside the mine) and from the flows from the gob were taken and analyzed.

A field reconnaissance to map fractures was conducted on August 2, 1989. Numerous cracks were mapped with varying widths and depths ranging from several inches wide and several inches deep to 4.5 feet wide and over 100 feet in depth on the north slope of the study area. The lateral extent of the fractures is unknown.

On August 3, a vertical 2-inch exploratory hole was drilled from Main west, inside the Cyprus Plateau mine, to locate the sandstone aquifer above the Third coal seam. The sandstone aquifer, 20 feet thick, was encountered 100 feet above the Third coal seam.

A 90 degree weir was installed on September 27 to better monitor the low streamflow during the winter months on the lower reach of the NFRFMC.

Plans for Next Year: The second phase will be a low-level monitoring and data-synthesis phase. A preliminary report outlining short-term impacts of mining-induced subsidence on ground-water and surface-water systems will be written and published.

INVESTIGATION OF SALINITY OF WATER IN THE NAVAJO SANDSTONE AQUIFER IN THE ANETH AREA, SAN JUAN COUNTY, UTAH

Number: UT-89-198

Cooperating Agencies: Utah Division of Oil, Gas, and Mining

Staff: L.E. Spangler, Hydrologist, Project Chief
R.S. Black, Hydrologic Technician (part time)

Period of Project: October 1988 to September 1993

Objectives: The objectives of the proposed study are to determine the following: (1) The extent of the area affected, (2) the cause of the salinity, (3) the direction and rate of movement of the salinity, and (4) the character of the source of salinity (single point, multiple points, or a uniformly distributed source). The location of the study area is shown in figure 6.

Approach: Considerably more geochemical, hydrochemical, geological, and hydrological information will be needed to determine the source of the saline water, its direction and rate of movement, and its areal extent. An investigation of the problem will be pursued in four phases: (1) Collection of new and compilation of existing geological, geochemical, and hydrological information. (2) Collection and compilation of hydrochemical data. (3) Analysis of all data and preliminary development of a variable-density model to calculate possible flow directions for variably-saline fluids. (4) Development and testing of final variable-density-flow and solute-transport models.

Progress: During the 1989 fiscal year, plans were made to carry out an extensive reconnaissance survey of existing wells on the Navajo Indian Reservation in the vicinity of Aneth-Montezuma Creek. Previous field work in the early 1980's indicated the presence of numerous flowing wells and windmills in this area, many of which yielded water that was moderately saline with respect to dissolved solids. In addition to locating all but a few of these wells, a number of additional wells with no record in the U.S. Geological Survey data base were located. After initial field location of wells, sampling of wells producing mostly from the Navajo Sandstone began. For each site, 7 samples were taken and analyzed for common ions, trace elements, selected isotopes, and field parameters. In all, samples from 18 sites have been collected, including 2 samples of production-water brine that is injected in the subsurface for disposal.

A number of preliminary maps were also completed, including the base map for an introductory figure, a contour map showing salinity of water from the Navajo aquifer, structure and thickness maps of the Navajo Sandstone, and a potentiometric map of water levels in the Navajo aquifer.

Plans for Next Year: During the next fiscal year, several additional trips to the Aneth area will be planned in order to finish locating any other wells that have not been located previously and would be useful to this study. Water from a number of other wells will also be sampled, including water from the Entrada and Bluff Sandstones, which appear to contain water with relatively large dissolved-solids concentrations. For any new wells that are documented, log information will have to be obtained in order to establish the zones of freshwater production, especially in flowing wells. More work will be undertaken with regard to isotopic fingerprinting and use of various isotopic and elemental ratios to help determine the best criteria for characterizing ground water from each horizon. If time and funding allow, more effort will be put into utilizing techniques of geophysical prospecting in order to help delineate areas of saline-water migration. Finally, if adequate information is available, additional maps will be constructed displaying parameters such as density of water, porosity, hydraulic conductivity, and transmissivity within the Navajo and other aquifers.

DEFINITION OF RECHARGE AREAS, AQUIFERS, AND CONFINING BEDS, AND CLASSIFICATION OF AQUIFERS BASED ON WATER QUALITY IN THE EAST SHORE AREA OF GREAT SALT LAKE; BOX ELDER, WEBER, AND DAVIS COUNTIES, UTAH

Number: UT-88-199

Cooperating Agency: Utah Department of Health, Division of Environmental Health

Staff: K.R. Thompson, Hydrologist, Project Chief
S.R. Wold, Hydrologist
R. L. Baskin, Hydrologist (part time)
T. Dardon, Hydrologic Technician (part time)
P.B. Anderson, Consultant (part time)
J.W. Hood, Consultant (part time)

Period of Project: October 1988 to December 1989

Objectives: (1) Define areas in which recharge occurs to the principal water-yielding aquifers of the East Shore area. (2) Define areas in which recharge could occur if land-use practices resulted in infiltration of water. (3) Define areas in which downward migration of water from the shallow-unconfined aquifer potentially could occur if increased withdrawals of ground water from the confined principal aquifer resulted in a downward hydraulic gradient. These are areas in which the hydraulic gradient currently is upward and, thus, there currently is little potential for contamination. (4) Estimate ground-water velocities in recharge areas to define subareas where potential contamination could spread rapidly. (5) Compile available data on the thickness, lateral extent, and other relevant characteristics of aquifers and confining beds in the East Shore area. (6) Improve knowledge of ground-water quality and define areas of the principal aquifers in terms of the State's aquifer-classification system, in which aquifers are classified on the basis of water quality. The location of the study area is shown in figure 6.

Approach: (1) Compile all drillers', formation, and geophysical logs from likely recharge areas to identify where confining layers are absent (primary recharge area). (2) Use log and water-level data to identify areas where confining layers exist, and the vertical hydraulic gradient is downward (secondary recharge area). (3) Compile information on horizontal hydraulic conductivity values used to construct the digital-computer models and values generated by calibration of models of the East Shore area. Use these data, as well as hydraulic gradients, to estimate ground-water-flow velocities. (4) Use the digital-computer model to identify areas where withdrawals of water might cause a downward hydraulic gradient and result in movement of water from the shallow-unconfined aquifer to the principal artesian aquifer. (5) Use geographic-information-system techniques to define various aquifer and recharge-area characteristics and how they overlap, coincide, or relate to each other. (6) Select wells in various areas of the valley in order to obtain representative data from recharge areas near mountain fronts (both near and distant from losing reaches of streams) including areas where confining beds exist but the vertical gradient is downward, areas where water is confined and the gradient is upward, and areas of major ground-water discharge. These wells will be used for sampling and analysis of selected major constituents, trace metals, organic chemicals (including pesticides), and radionuclides. Most sampling sites will be wells in the principal artesian-aquifer system, as few wells are completed in the shallow-unconfined aquifer. (7) Compile existing data on ground-water quality, and prepare contour maps of dissolved-solids concentrations in water of the principal artesian-aquifer system at concentrations of 500, 1,000, 3,000, and 10,000 milligrams per liter. (8) Identify areas where ground-water-quality standards are exceeded (data on trace metals, organic chemicals, and radionuclides are limited, so data may be mostly that collected for this project). (9) Prepare a report consisting of a map or series of maps, in hydrologic-atlas format, delineating the recharge areas, extent of confining beds and aquifers, if possible, and water quality.

Progress: All field work has been completed. Base maps, maps of dissolved-solids concentrations in ground water, maps of direction of ground-water flow, and preliminary recharge-area maps are completed. All water-quality samples have been submitted to the laboratory. Major sections of a draft of the final report are completed.

Plans for Next Year: Complete recharge-area maps, summarize aquifer and confining-bed data, and summarize water-quality analyses. Complete report.

DEFINITION OF AQUIFERS AND CONFINING BEDS AND CLASSIFICATION OF AQUIFERS IN TERMS OF WATER QUALITY--WASATCH FRONT, CACHE VALLEY, AND LOWER BEAR RIVER VALLEY IN CACHE, BOX ELDER, SALT LAKE, AND UTAH COUNTIES, UTAH

Number: UT-88-200

Cooperating Agency: Utah Department of Health, Division of Environmental Health

Staff: K.R. Thompson, Hydrologist, Project Chief
S.R. Wold, Hydrologist
R. L. Baskin, Hydrologist (part time)
T. Dardon, Hydrologic Technician (part time)
P.B. Anderson, Consultant (part time)
J.W. Hood, Consultant (part time)

Period of Project: October 1988 to December 1989

Objectives: (1) Define areas in which recharge occurs to the principal water-yielding aquifers in the basins along the Wasatch Front, Cache Valley, and the lower Bear River Valley. This work would supplement existing studies of the recharge areas in Salt Lake Valley in cooperation with the Utah Division of Environmental Health and a study of ground water in southern Utah Valley in cooperation with the Utah Division of Water Rights. (2) Define areas in which recharge could occur if land-use practices resulted in infiltration of water. (3) Compile available data on the thickness, lateral extent, and other relevant characteristics of aquifers and confining beds in the basins along the Wasatch Front, Cache Valley, and the lower Bear River Valley. (4) Improve knowledge of ground-water quality in these areas by sampling water from selected wells and springs for analysis of constituents listed in the State's ground-water quality standards. (5) Define areas of the principal aquifers in terms of the State's aquifer-classification system, in which aquifers are classified on the basis of water quality. The location of the study area is shown in figure 6.

Approach: (1) Compile all drillers', formation, and borehole-geophysical logs from likely recharge areas to identify where confining layers are absent (primary recharge area). (2) Use log and water-level data to identify areas where confining layers exist, and the vertical hydraulic gradient is downward (secondary recharge area). (3) Select wells in various areas of each valley in order to obtain representative data from recharge areas near mountain fronts (both near and distant from losing reaches of streams) including areas where confining beds exist but the vertical gradient is downward, areas where water is confined and the gradient is upward, and areas of major ground-water discharge. These wells will be used for sampling and analysis of selected major constituents, trace metals, organic chemicals (including pesticides), and radionuclides. Most sampling sites will be wells in the principal artesian-aquifer system, as few wells are completed in the shallow-unconfined aquifer. (4) Compile existing data on ground-water quality for each valley and prepare contour maps of dissolved-solids concentrations in water for the principal artesian-aquifer system at concentrations of 500, 1,000, 3,000, and

10,000 milligrams per liter. Identify areas where ground-water-quality standards are exceeded (data on trace metals, organic chemicals, and radionuclides are limited, so data may be largely that collected for this project). (5) Prepare a report that will consist of a map or series of maps, possibly in hydrologic-atlas format, delineating the recharge areas and the extent of the aquifer(s) and confining bed(s), if possible, and water quality in all areas.

Progress: All field work has been completed. Base maps, maps of dissolved-solids concentrations in ground water, maps of direction of ground-water flow, and preliminary recharge-area maps are nearing completion. All water-quality samples have been forwarded to the laboratory. Major sections of a draft of the final report are completed.

Plans for Next Year: Complete recharge-area maps, summarize aquifer and confining-bed data, and summarize water-quality analyses. Complete report on recharge areas, aquifers, and ground-water quality of the Wasatch Front, Cache Valley and Lower Bear River areas, Northern Utah.

PROJECT BEGINNING BETWEEN JULY 1 AND SEPTEMBER 30, 1989

GROUND WATER AND GROUND-WATER/SURFACE-WATER RELATIONS IN CACHE VALLEY, CACHE COUNTY, UTAH, AND ADJACENT PARTS OF IDAHO

Number: UT-89-203

Cooperating Agency: Utah Division of Water Resources

Staff: K.A. Kariya, Hydrologist, Project Chief
G.E. Pyper, Hydrologist (part time)
M. Drumiler, Hydrologic Technician (part time)

Period of Project: September 1989 to September 1992

Problem: The State of Utah would like to know the potential for increased ground-water development in Cache Valley, and the possible hydrologic effects of such development, especially on surface water and springs.

Objectives: To assess current ground-water conditions especially in terms of water levels, well and spring discharge, ground-water quality, and volumes of water in storage, and to document changes in conditions since the last study in 1967-69. To better define the components of the ground-water system in terms of recharge, movement, and discharge, with emphasis on ground-water/surface-water relations. To determine how the components of the system interact, and to estimate the effects of additional ground-water withdrawals in various geographic patterns, on water levels, streamflow, spring discharge, and evapotranspiration. The location of the study area is shown in figure 6.

Approach: Compile available data on wells, springs, water levels, ground-water quality, and streamflow, focusing on post-1969 data, and collect data on wells drilled since the last study in 1967-69. Inventory ground-water discharge by wells and springs, to drains and streams, and by evapotranspiration. Estimate recharge from streams; irrigation, including that from canals; precipitation; and subsurface flow from consolidated rock. Conduct seepage runs on streams, if possible, to define ground-water/surface water relations, and estimate recharge from and discharge to streams. Prepare maps of the potentiometric surface and distribution of water quality, and if possible, prepare maps showing aquifer thickness. Conduct aquifer tests to improve knowledge of hydraulic characteristics of the basin fill. If funds are available, conduct surface-geophysical surveys to better define the thickness and characteristics of the basin fill and quality of ground water. Construct a three-dimensional digital model to help understand how the components of the system interact and how increased development of ground water in various parts of the valley would affect water levels, spring discharge, streamflow, and evapotranspiration. Prepare a basic-data report and an interpretive report for publication by the Utah Department of Natural Resources.

Plans for Next Year: Compile water-level, well-discharge, and water-quality data, well-drillers' logs, and surface-water data available for the area. Construct a base map for the area. Inventory wells and springs to be monitored for study, and ensure that data is entered into the Ground-Water Site Inventory (GWSI) database. Measure water levels and discharge on a bimonthly basis in wells and springs selected for observation.

PROPOSED PROJECTS

A. INNOVATIVE TECHNIQUES OF MAPPING ATTRIBUTES IN SUPPORT OF WELLHEAD-PROTECTION AREA DELINEATION, SALT LAKE COUNTY, UTAH

Cooperating Agency: U.S. Environmental Protection Agency

Staff: G. W. Freethey, Hydrologist, Project Chief (part time)

Period of Project: October 1989 to September 1990

Problem: The U.S. Environmental Protection Agency would like to develop an uncomplicated and inexpensive method of delineating the area around public-supply wells that needs to be protected from surface contaminants. The method developed should use data that are readily available to water suppliers. Interpretation of these data, to derive values for properties needed to calculate ground-water flow velocity, should also be easily understood and easily implemented by persons who may not be familiar with analytical techniques in hydrology.

Objectives: The objectives are to (1) map the areal distribution of hydraulic conductivity using existing hydrogeologic data from reports, well logs, aquifer tests, and geophysical logs; (2) measure water levels and develop up-to-date potentiometric-surface configurations for the principal and shallow-unconfined aquifers; (3) assign values of effective porosity to the aquifers based on lithologic character and probable depositional environment; (4) develop an areal distribution of average linear velocity based on distribution maps developed in the first two objectives; and (5) demonstrate how time-of-travel along flow paths to wells can be calculated from the distribution map of average linear velocity. The location of the study area is shown in figure 6.

Approach: The steps involved will be as follows: (1) Choose an appropriate study area along the Wasatch Front that includes a typical number of public-supply wells. (2) Compile drillers' logs, aquifer tests, geophysical logs, and water-level information for the area. (3) Extract pertinent information from these sources to derive values for hydraulic conductivity, effective porosity, and head gradients. (4) Develop a flow net for the area for the confined and unconfined aquifers, and identify the flow lines leading to public-supply wells. (5) Calculate average linear velocity along these flow lines from the areal distributions of hydraulic conductivity, effective porosity, and hydraulic head gradients. (6) Determine time-of-travel along these flow lines, mark points of predetermined times (250-day, 15-year, etc.), and show how lines connecting these points could define various protection areas.

Plans for Next Year: Project will be completed and a report written by September 1990.

B. GROUND-WATER FLOW AND SOLUTE MIGRATION IN THE SALT LAKE VALLEY, UTAH

Cooperating Agencies: Utah Division of Water Rights; Utah Division of Environmental Health; and local agencies

Staff: G.W. Freethey and W.F. Holmes, Project Supervisors, (part time)
Hydrologist, Vacant (part-time)
Hydrologist/Geologist, Vacant (full-time)

Period of Project: March 1990 through August 1994

Problem: The Salt Lake Valley in Utah is the main population and industrial center in the State of Utah. An adequate supply of water of usable quality is one of the most important factors in sustaining the current population and industrial activity and in allowing for continued economic growth. The location of the study area is shown in figure 6.

The Utah Divisions of Water Rights and Environmental Health are facing water-development dilemmas. Water rights already allocated likely exceed the total annual inflow of acceptable-quality ground water to the basin-fill sediments of the Salt Lake Valley. The Division of Water Rights needs to know the effects on the hydrologic system of further development of ground water. Both Divisions also need to be able to determine the source area for water withdrawn from proposed wells at various locations within the valley in order to anticipate and prevent migration of contaminated water or water with large dissolved-solids concentrations to points of withdrawal, and thus to better manage development of the principal aquifer. Certain areas have a greater potential for yielding water with dissolved-solids concentrations that exceed State drinking-water standards. Defining the pumping rate that minimizes saline-water encroachment in these areas is critical to continued prosperity of Utah's largest metropolitan area.

Objectives: The objectives of the study are (1) to better define the quality of water in the shallow-unconfined aquifer and the confining unit in Salt Lake Valley; (2) to determine the hydrologic properties of the shallow-unconfined aquifer and the underlying confining unit; (3) To better define the ground-water/hydrochemical flow system, including three-dimensional variation of hydrologic properties and ground-water quality; and (4) to provide the Utah Divisions of Water Rights and Environmental Health with a means of determining the quantity of water that can be withdrawn from different areas in the Salt Lake Valley without causing undesirable water-level declines and without inducing water with large concentrations of dissolved solids or contaminants to migrate toward wells used for municipal and industrial water supply.

Approach: The approach to achieving the objectives will involve several components of field investigation and information interpretation. These components are integrated and each is necessary for accomplishing the objectives stated. In general these components consist of: (1) drilling, field testing, and laboratory testing to determine aquifer and confining-unit properties, mineralogic composition of aquifer material, and chemical composition of the water; (2) determining the extent of the effects of variable-density fluid movement; (3) updating and refining the existing ground-water flow model; (4) conducting a particle-tracking investigation to increase knowledge about source and movement of water of various degrees of salinity in specific parts of the system; (5) developing multiple solute-transport simulations to better understand the hydrochemical system in the valley; and (6) synthesis of collected information and report writing.

Plans for Next Year: Drill and complete about 50 observation/monitoring wells in the shallow-unconfined aquifer and confining unit. Obtain water samples from wells and analyze for major inorganic ions and selected metals and organic chemicals. Conduct slug tests on wells. Begin variable- and constant-density modeling.

C. EFFECTS OF BRINE WITHDRAWALS ON THE HYDROLOGIC SYSTEM OF THE BONNEVILLE SALT FLATS AREA, UTAH

Cooperating Agency: U.S. Bureau of Land Management (BLM)

Staff: Hydrologist, Project Chief, (Vacant)
Hydrologist, Vacant, National Research Program, Denver, Colorado (part time)

Period of Project: January 1990 to December 1992

Problem: The U.S. Bureau of Land Management needs scientific information in order to determine the potential effects of development of mineral resources, primarily brine withdrawals, in the vicinity of the Bonneville Salt Flats. In the past 10 years, substantial climatic variations have imposed measurable stresses on the hydrologic system. One inferred impact of the climatic variations and development has been a measured reduction in salt thickness in the area which includes Bonneville Salt Flats State Park and Bonneville Speedway. There is a need to evaluate the source, timing, magnitude, and extent of climatic stresses, as well as the stresses of continuing withdrawal of brine; apply new technology where appropriate; and update previous hydrologic studies in the area. The location of the study area is shown in figure 6.

Objectives: (1) Document changes in the hydrologic system since Lines (1979). (2) Establish a network to monitor future changes in water levels, water chemistry, and salt thickness in the Bonneville Salt Flats. (3) Assess the potential for removal of salts from the salt flats area via wind-driven ponds. (4) Assess the impacts of current and projected brine withdrawals, other man-induced variations, and climatic changes on the hydrologic system. This includes impacts on ground-water chemistry, water levels, and salt deposits in the Bonneville Salt Flats. The location of the study area is shown in figure 6.

Approach: (1) Prepare a detailed plan of study and review entire plan with BLM and other entities selected by BLM. (2) Define formation and movement of ponds using LANDSAT and other available aerial photography of the salt-flats area. (3) Develop preliminary three-dimensional solute-transport model. (4) Gather data collected or available since Lines (1979) conducted his study, including brine-withdrawal, water-level, chemical-analysis, meteorological, soil-moisture, and other pertinent data. (5) Locate observation wells drilled during and prior to the Lines study. (6) Establish observation-well network for monthly water levels and collection of samples of brine for density analysis. (7) Drill new observation wells on and adjacent to the Salt Flats. Cores will be collected and analyzed for mineralogical content. Salt thickness and water levels will be measured, samples of brine will be collected and analyzed, and the wells will be added to the observation-well network. Nested wells (or adjacent wells completed at different depths) will be part of the drilling plan in order to determine vertical variation in water level and water density/chemistry. One or more productions wells (8 inches or larger) and several observation wells near each production well will be drilled for use in an aquifer test or tests. (8) Conduct and analyze aquifer tests on wells and ditches. (9) Assess raceway surface/salt to describe the technical (physical, geologic, hydrologic, geomorphic, sedimentary) factors contributing to an acceptable raceway surface. At least five soil-moisture holes will be augered and properly completed and instrumented to collect data on temporal variations. (10) Conduct geochemical studies to estimate the geochemical flow paths and reactions along these paths to describe processes that may increase or decrease the salt thickness and area. (11) Design and construct a transport model to simulate the flow rates, flow paths, and chemical concentrations and migration of selected constituents. The model will be used to simulate future water levels and ground-water chemistry using alternatives supplied by Reilly Industries and BLM. (12) Prepare reports documenting the results of the study.

Plans for Next Year: Prepare project plan. Assemble all available post-1979 data. Locate satellite imagery and begin to define movement of surface-brine ponds. Locate monitoring wells still existing and plan for drilling new wells. Develop preliminary solute-transport model.

D. DEFINITION OF RECHARGE AREAS, PHYSICAL EXTENT, AND WATER QUALITY IN THE PRINCIPAL AQUIFERS IN WESTERN KANE COUNTY, UTAH

Cooperating Agencies: Utah Division of Environmental Health and Kane County; City of Kanab; and the Kanab Area Water Association, Inc., through the Five County Association of Governments.

Staff: G.W. Freethey, Hydrologist, Project Chief (part time)

Period of Project: March 1990 through February 1991

Problem: The residents of Kane County, Utah, and the Utah Division of Environmental Health would like to define and classify major aquifers in western Kane County and to identify the recharge areas for these aquifers so that future plans for development in the County could provide for the protection of its ground-water resources. Kane County contains large reserves of coal whose development might substantially impact the area's ground-water resources by changing the quality and quantity of the water that recharges the aquifers, or by physically changing aquifer geometry by mining practices.

The State and County, as part of their ground-water protection strategy, would like to identify the principal aquifers, their recharge areas, and their confining boundaries so that future development, be it mining, agriculture, stock grazing, or residential, could be planned in such a way that ground-water contamination or aquifer alterations are minimized. The information will be used to design a plan for reviewing development so as to minimize detrimental effects to aquifers and their recharge areas.

Objectives: (1) Define and describe the physical boundaries of the principal aquifers in western Kane County. This would include the variability in thickness and the upper, lower, and lateral extents. (2) Identify the recharge areas for the aquifers and the relative quantity of recharge provided by each of these areas. (3) Provide the maps necessary for classification of the ground water in these aquifers using the State's aquifer-classification system (based on chemical character). The location of the study area is shown in figure 6.

Approach: Because of limited funding, field work will be restricted to collection of six to eight water samples. Remaining information necessary to complete the project will be obtained from available reports and data in the files of the U.S. Geological Survey and State agencies. The basic approach will be as follows: (1) Compile and review geologic reports to identify lateral and vertical extent and lithologic character of formations. This will lead to a preliminary categorization of aquifers and confining layers within 2,000 feet of land surface. (2) Compile drillers' and geophysical logs and water-quality information from the files of the U.S. Geological Survey, the Utah Division of Water Rights, and Petroleum Information, Inc., to identify aquifers and their dimensions and to initially determine depth to water and relative quality of ground water. (3) Use information from existing digital models and from available aquifer-test data, specific-capacity data, water-level data, and drill-stem-test data to estimate ground-water flow velocities between recharge and discharge areas. (4) Use geographic-information-system techniques to define and characterize aquifers, confining layers, and recharge areas, and to determine how they spatially relate to each other. (5) Prepare maps showing: (a) Lateral extent of principal aquifers that occur within 2,000 feet of land surface; (b) thickness of principal aquifers; (c) location of recharge areas for the principal aquifers; and (d) summary of chemical quality of water in the principal aquifers from previously collected water-quality data. (6) Select and sample six to eight wells tapping the area's principal aquifer (the Navajo Sandstone) and analyze for major chemical constituents, trace metals, organic chemicals, and radionuclides. These will serve as baseline data for comparison with future samples collected during development.

Plans for Next Year: Compilation of geologic and hydrologic information, collection and analysis of water samples, preparation of maps, and report writing will be completed by August 1991.

REFERENCES CITED

Deveral, S.J., and Fujii, R., 1988, Processes affecting the distribution of selenium in shallow ground water of agricultural areas, San Joaquin Valley, California: Water Resources Research 24, no. 4, p. 516-524.

Holley, E.R., and Waddell, K.M., 1976, Stratified flow in Great Salt Lake culvert: Journal of the Hydraulics Division, American Society of Civil Engineers, v. 102, no. HY7, Proceedings Paper 12250, July 1976, p. 969-985.

Lines, G.C., 1979, Hydrology and surface morphology of the Bonneville Salt Flats and Pilot Valley Playa, Utah: U.S. Geological Survey Water Supply Paper 2057, 107 p.

Sanford, W.E., and Konikow, L.F., 1985, A two-constituent solute-transport model for ground-water having variable density: U.S. Geological Survey Water-Resources Investigations Report 85-4279, 88 p.

Waddell, K.M., Seiler, R.L., Santini, M., Solomon, D.K., 1987, Ground-water conditions in Salt Lake Valley, 1969-83, and predicted effects of increased withdrawals from wells: Utah Department of Natural Resources Technical Publication No. 87.