REVIEW OF WATER DEMAND AND UTILIZATION STUDIES FOR THE PROVO RIVER DRAINAGE BASIN, AND REVIEW OF A STUDY OF THE EFFECTS OF THE PROPOSED JORDANELLE RESERVOIR ON SEEPAGE TO UNDERGROUND MINES, BONNEVILLE UNIT OF THE CENTRAL UTAH PROJECT

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EXECUTIVE SUMMARY

Background and Description of Central Utah Project

The Central Utah Project (CUP) was authorized by the Colorado River Storage Act of 1956. The project is being constructed by the U.S. Bureau of Reclamation (USBR) and will be operated by the Central Utah Water Conservancy District. The CUP consists of six units. Five of the units are in the Uinta Basin of the Colorado River drainage and the sixth unit, the Bonneville Unit includes parts of the Colorado River Basin and the Great Basin.

The Bonneville Unit is in central and eastern Utah. The Unit encompasses about 32,000 square miles and includes parts or all of the drainages of the Spanish Fork, Duchesne, Strawberry, Sevier, and Provo Rivers. Most of the water in the Bonneville Unit will be developed in the Uinta Basin of the Colorado River drainage basin and diverted to the Great Basin, with the goal of putting some of Utah's undeveloped water rights in the Colorado River Basin to beneficial use.

The Municipal and Industrial System is the largest and most complex part of the five major water collection and delivery systems in the Bonneville Unit of the CUP. The Municipal and Industrial System will provide municipal and industrial water to Salt Lake, Utah, and Wasatch Counties and some water for irrigation in Wasatch and Summit Counties. Water for the Municipal and Industrial System will be stored in Jordanelle Reservoir.

Because water in the Provo River is fully appropriated, about 90 percent of the water stored in Jordanelle Reservoir will consist of storable flow that must be exchanged with water in Utah Lake, either by the purchase of water rights or by diversion of water from the Uinta Basin. About ten percent of the water stored in the reservoir will consist of unappropriated high flows from the Provo River.

Problem

Questions have been raised concerning the adequacy of available water to fulfill the needs of storage, exchanges, diversions, and instream flows, pursuant to existing water rights in the Provo River drainage basin part of the Bonneville Unit. Also, concern has been expressed about the potential for seepage of water from Jordanelle Reservoir to underground mines. The Utah Congressional Delegation requested that the U.S. Geological Survey (USGS) review the results of analyses performed by and for the USBR.

Purpose and Scope

The purpose of this report is to present the results of the USGS review of (1) the hydrologic data, techniques, and model used by the USBR in their hydrologic analyses of the Provo River drainage basin and (2) the results of a study of the potential for seepage from the Jordanelle Reservoir to nearby underground mines.

The USGS reviewed USBR-supplied water demands, water utilization studies, and models of seepage from Jordanelle Reservoir. The USBR estimated that about 90 percent of the water supply for Jordanelle Reservoir will be water from Strawberry Reservoir exchanged for water from the Provo River stored in Utah Lake. If the Utah State Engineer allows the USBR to claim an estimated 19,700 acre-feet of return flows from the CUP, only about 77 percent of the supply would be derived from exchange of existing water rights in Utah Lake. The USGS assumed that planned importations of water from the Uinta Basin will be available and deliverable to fulfill the proposed exchanges.

Water rights and demands are important for determining water availability. The USGS did not conduct an independent review of water rights and demands. The USBR and Utah Division of Water Rights use different methods in some areas for determining stress on the system based on past records. The USBR used "historical observed diversions" and the Utah Division of Water Rights use "diversion entitlements", which may not be equal to the historical diversions. The USGS based its review upon water demands used by the USBR. The Utah Division of Water Rights has responsibility for granting and enforcing water rights, and the final decisions on how the rights will be adjudicated lies with the Utah Division of Water Rights and with the courts. The USGS review did not consider the draft water distribution plan for the Utah Lake drainage basin proposed by the Utah State Engineer (written commun., October 15, 1991). This plan, when finalized, may have an effect on water availability to the CUP.

Approach

The USGS reviewed the three principal water utilization studies done by the USBR—the Provo River Project Operation Study, the Provo River Surplus Flow Study, and the Jordanelle Reservoir Operation Study. The reviewers examined texts, water supply accounting tables, and water-accounting model programming found in various published and unpublished USBR documents. Data used in these studies were selectively reviewed and verified by comparing them with USGS streamflow records, water commissioner's reports, and unpublished data from the USBR. The USGS developed conceptual diagrams to facilitate its review of methods and logic used in models associated with the utilization studies.

Findings

The end result of the Provo River Project Operation Study is a water-accounting program developed to ensure that all water rights senior to CUP water rights are satisfied. The USGS concluded that the USBR, using this program, has adequately accounted for all water rights senior to the CUP and distributed the water without interfering with other rights.

The Provo River Surplus Flow Study was used to determine Provo River streamflows that are surplus to water rights above Utah Lake for the 1930-73 simulation period. The USGS concluded that the study correctly calculated surplus stream gains below Deer Creek Dam and surplus flow at Deer Creek Dam for a total surplus flow of 123,800 acre-feet. The surplus flow is the source of water for storage in the proposed Jordanelle Reservoir and on a space-available basis in Deer Creek Reservoir. However, the surplus flow used by the CUP must be replaced in Utah Lake by exchange or by purchase of Utah Lake water rights. The surplus flow of 123,800 acre-feet is available to the CUP for municipal, industrial, irrigation, and instream use contingent upon water rights purchases and the approval of these exchanges by the Utah State Engineer.

The USGS made four simulation runs using the Jordanelle Reservoir Operation Study model with the initial reservoir contents set at 0 and beginning at different times during the 1930-70 period. The simulations, which model the filling and operation of the dam after closure of the reservoir, indicated that the capability of the Jordanelle Reservoir and the Bonneville Unit of the CUP to deliver the proposed water supply depends on the streamflow conditions following closure. The model runs show that municipal and industrial water shortages occurred only during the initial years following closure. The maximum number of years shortages occurred following reservoir closure was 6 years, and in the other three simulation periods, shortages only occurred during the first 2 years. In actual operation, the USBR did not propose to meet the municipal and industrial demands from Jordanelle Reservoir until the water is stored and available in the reservoir, thereby eliminating reservoir filling as a cause of shortages in the system.

The Jordanelle Reservoir Operation Study is a hypothetical simulation of water management for a selected base period (1930-73). Management of the system in real time will depend on flow forecasts and other data containing possible uncertainty. Therefore, actual operation may be less efficient than the idealized operation demonstrated by the study, and the shortages of supply for the real-time operation could be larger than those computed by the model. The degree to which shortages resulting from system inefficiencies can be minimized will depend upon the degree of sophistication attained in managing the overall system.

The USGS review of the logic and organization of the Jordanelle Reservoir Operation Study model raised and addressed a number of questions and concerns. These concerns include the way the model accounts for irrigation-return flows, local water supply for the Heber area, shortages of instream flow for fisheries, the Provo City-USBR agreement, shortages of water for municipal, industrial, and irrigation use as a function of reservoir contents and hydrologic conditions, Utah Lake depletions, and differences in some values between the text of the Supplement to the Definite Plan Report (USBR, 1988f) and model input and output. The impact of these concerns would not affect the average annual storable flow of 123,800 acre-feet (which includes transbasin diversions and water-rights purchases) used in the Jordanelle Reservoir Operation Study model. However, if these concerns were addressed in the model, there could be changes in the distribution of monthly, or even annual, flows within the system.

The USGS reviewers concluded that the Jordanelle Reservoir Operation Study model demonstrates that the average annual storable flow of 123,800 acre-feet for the 1930-73 period would be sufficient to meet the demands of the CUP and to fill and to maintain storage in Jordanelle Reservoir. The water available to the CUP and Jordanelle Reservoir in the future will be dependent upon climatic conditions, water rights purchases, and the approval of water exchanges by the Utah State Engineer.

In ground-water models of seepage to underground mines from Jordanelle Reservoir, estimates for hydrologic properties are based on aquifer-test data whose validity is uncertain. Because of the fracturing, vertical flow of ground water through the geologic materials is highly likely, but aquifer-test analysis assumed only horizontal flow through porous media.

The estimates of seepage to a hypothetical new mine located close to the reservoir and the increased seepage to the existing mines caused by the reservoir are based on a model that oversimplifies a geologically complex system. The uncertainties in the validity of the model are due to inappropriate use of constant heads, lack of areal recharge, inadequate calibration, use of uniform values of hydrologic properties, and representation of the vertically complex system as a single layer. Without additional information and analysis, it cannot be determined if the seepage to the mines from the proposed reservoir, as projected in the investigation, is too small, too large, or accurate.

I INTRODUCTION

1.1 Background and description of the Central Utah Project

The Central Utah Project (CUP) was authorized by the Colorado River Storage Act of 1956 and is being constructed by the U.S. Bureau of Reclamation (USBR) and will be operated by the Central Utah Water Conservancy District. The CUP consists of six units. Five of the units are in the Uinta Basin of the Colorado River drainage basin and the sixth, the Bonneville Unit, includes parts of the Colorado River Basin and the Great Basin.

The Bonneville Unit in central and eastern Utah (fig. 1.1-1) encompasses about 32,000 square miles in 12 counties. The Unit includes parts or all of the drainages of the Spanish Fork, Duchesne, Strawberry, Sevier, and Provo Rivers. The Bonneville Unit consists of 10 reservoirs; 200 miles of aqueducts, tunnels, and canals; 162 miles of drains and channel improvements; 1 power plant; and 7 pumping plants.

The Bonneville Unit of the CUP will develop most of the project's water. Most of the water will be developed in the Uinta Basin of the Colorado River drainage basin and diverted to the Great Basin (fig. 1.1-2), with the goal of putting some of Utah's undeveloped water rights in the Colorado River drainage basin to beneficial use.

In the part of the Great Basin that includes the Bonneville Unit, the major streams include the Provo River and Spanish Fork, which flow from headwaters along the Colorado River-Great Basin divide into Utah Lake (fig. 1.1-1), the lowest part of Utah Valley. The Provo River flows into the lake from the northeast and has an average discharge of about 150,700 acre-feet per year at the Provo gaging station. Spanish Fork flows into the lake from the southeast and has an average discharge of about 66,000 acre-feet per year at Lake Shore.

Water from Utah Lake is used for irrigation in Utah Valley and for irrigation and other uses downstream in Salt Lake Valley. The Jordan River (fig. 1.1-1) flows from Utah Lake into Salt Lake Valley through Jordan Narrows, where the average annual discharge is about 310,000 acre-feet.

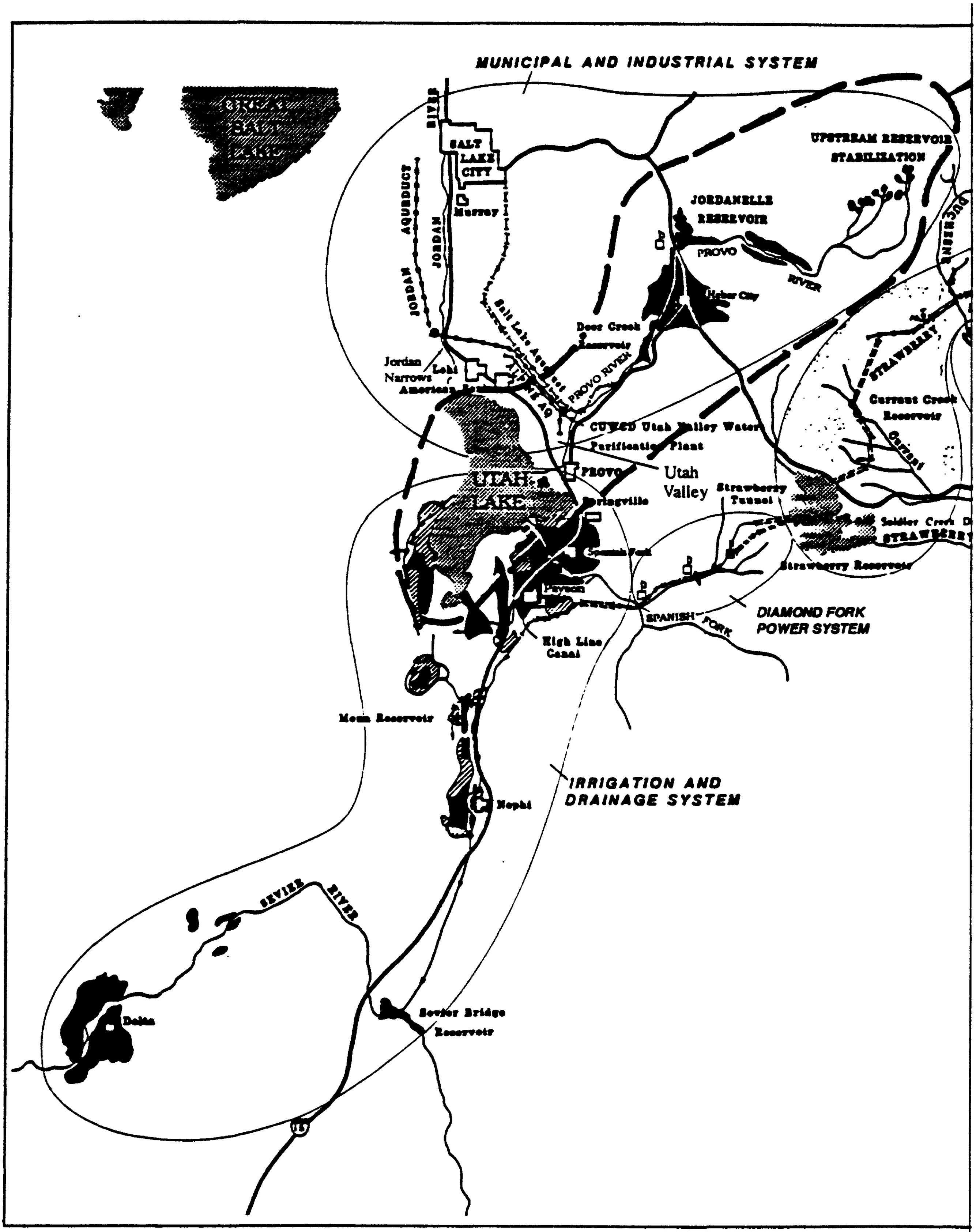


Figure modified from Central Utah Water Conservancy District
Construction Report, December 31, 1989.

Figure 1.1-1--Bonneville Unit of the Central Utah Project and Provo River drainage basin.

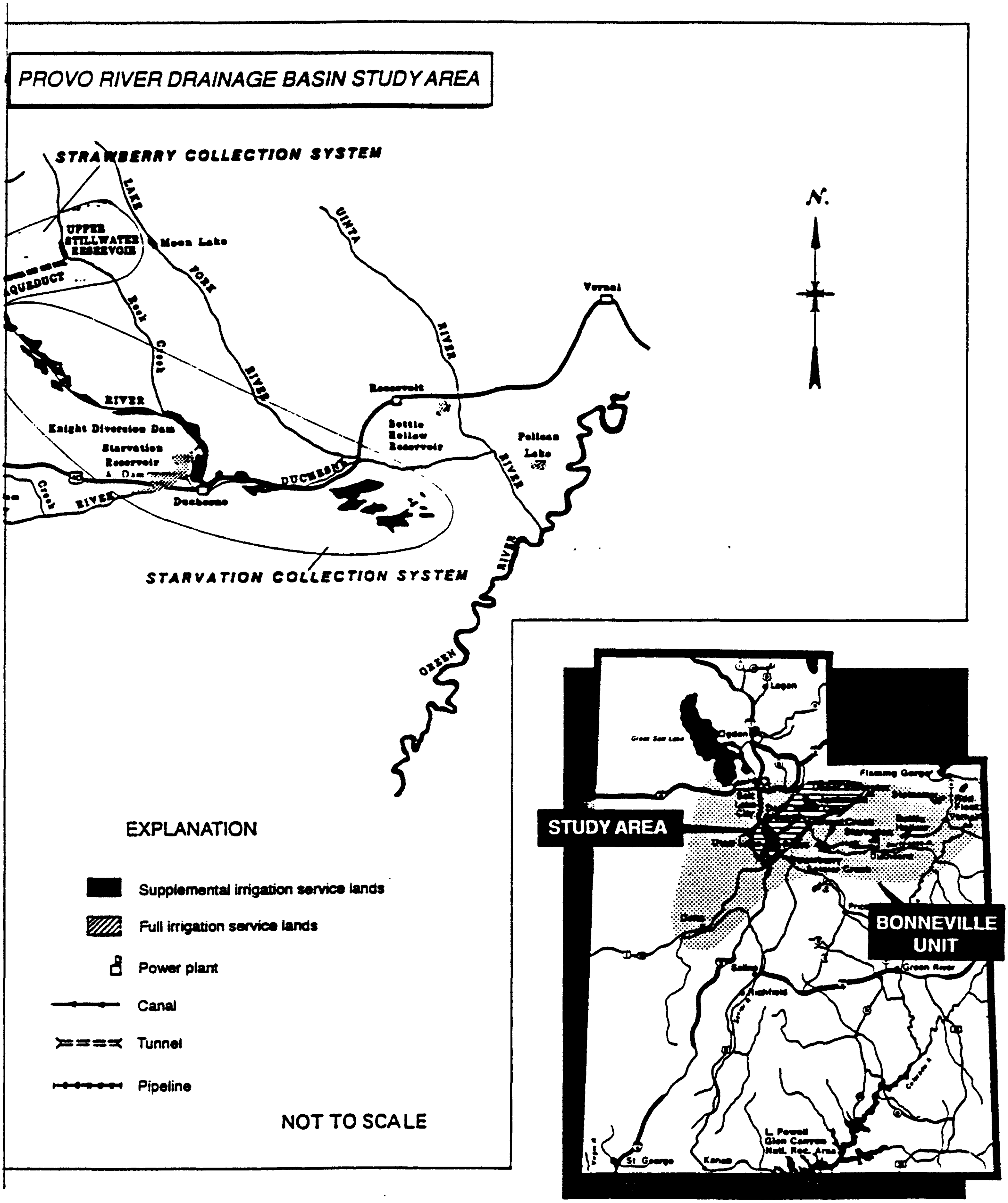


Figure 1.1-1--Bonneville Unit of the Central Utah Project and Provo River drainage basin--Continued.

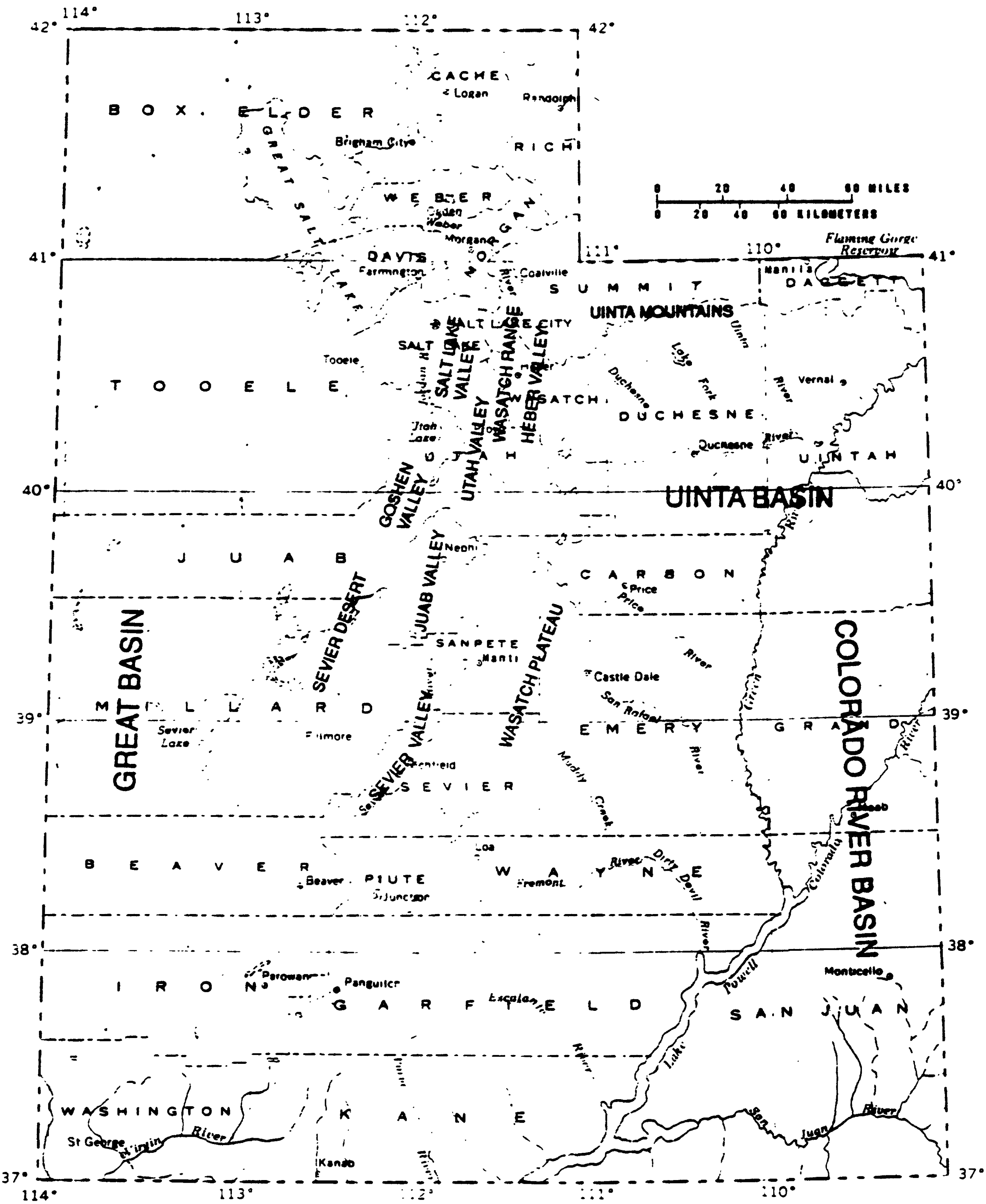


Figure 1.1-2--Location of geographic features associated with the Bonneville Unit.

The Bonneville Unit is subdivided into five major systems (fig. 1.1-1): (1) Starvation Collection System, (2) Strawberry Collection System, (3) Diamond Fork Power System, (4) Municipal and Industrial System, and (5) Irrigation and Drainage System. The Starvation and Strawberry Collection Systems have been completed. The Diamond Fork Power System is undergoing design changes. The Municipal and Industrial System is partly completed, and planning has started for the Irrigation and Drainage System.

The Municipal and Industrial System is the largest and most complex part of the Bonneville Unit. This system will provide municipal and industrial water to Salt Lake, Utah, and Wasatch Counties (Salt Lake, northern Utah, and Heber Valleys), and some water for irrigation in Wasatch (Heber Valley) and Summit Counties (fig. 1.1-2). The Municipal and Industrial System will develop 107,500 acre-feet of water per year, of which 90 percent will be derived from exchange of existing water rights in Utah Lake and 10 percent will be unappropriated high flow from the Provo River (based on savings of spills from Utah Lake). If the Utah State Engineer allows the USBR to claim an estimated 19,700 acre-feet of return flows from the CUP, only about 77 percent of the supply would be derived from exchange of existing water rights in Utah Lake. Because Provo River water is fully appropriated, water stored in the proposed Jordanelle Reservoir will consist of unappropriated high flow of the Provo River and appropriated water that must be replaced in Utah Lake by water rights purchase or exchange. Planned sources of water for replacement in Utah Lake includes project water diverted from the Uinta Basin, purchase of appropriated water in Utah Lake, unappropriated high flow of the Provo River directly to the lake, and project return flow.

Another feature of the system will be the stabilization of 12 of the 15 small reservoirs on the upper Provo River, upstream from Jordanelle Reservoir. The loss of storage from stabilization will be transferred to Jordanelle Reservoir.

Of the water released from Jordanelle Reservoir to the Provo River, 70,000 acre-feet will be diverted from the Provo River into the Jordan Aqueduct for transport to Salt Lake Valley, and 20,000 acre-feet will be diverted to the Alpine Aqueduct for transport to northern Utah Valley. Some water released from the reservoir, 17,500 acre-feet, will be used for municipal (2,400) and irrigation (12,100) purposes downstream in Heber Valley and 3,000 acre-feet for irrigation to the Francis area.

1.2 Problem

Questions have been raised concerning the adequacy of available water to fulfill the needs of storage, exchanges, diversions, and instream flows, pursuant to existing water rights in the Provo River drainage basin part of the Bonneville Unit. Concern also exists about the potential for seepage of water from Jordanelle Reservoir to underground mines. The Utah Congressional Delegation requested that the U.S. Geological Survey (USGS) review the work of the USBR to address these concerns.

1.3 Purpose and scope

The purpose of this report is to present results of the USGS review of hydrologic data, techniques, and models used by the USBR in their analyses of the Provo River drainage basin and of the results of a study of the potential for seepage from the Jordanelle Reservoir to nearby underground mines. The USGS review focused on the Provo River drainage basin and included Jordanelle and Deer Creek Reservoirs and Utah Lake (fig. 1.1-1).

The USBR estimated that about 77 to 90 percent of the water supply for Jordanelle Reservoir will be water from Strawberry Reservoir exchanged for water from the Provo River stored in Utah Lake. For this review, it was assumed that planned importations of water to the Provo River drainage basin and Utah Lake will be available and deliverable to fulfill the proposed exchanges.

Hydrologic data for the Provo River drainage basin were examined for selected years. Although selected data do not provide a quantitative assessment of water budgets or water availability for the 1930-73 base period used by the USBR for planning, review of these data provided insight into the reliability of water budgets and availability for selected years within the base period.

Water rights and demands are important for determining water availability. The USGS did not conduct an independent review of water rights and demands. Methods for determining water demand and the implications for water availability were discussed.

The Utah Division of Water Rights released a draft proposal (October 15, 1991, written commun.,) for managing the water rights and water distribution within the Utah Lake drainage basin, which includes the Provo River. The proposal includes adjudication and reclassification of some upper basin water rights and definition of Utah Lake rights. The Utah Division of Water Rights grants and enforces water rights, and the final decisions on how the rights will be adjudicated lies with the Utah Division of Water Rights and with the courts. These decisions could alter water rights in the Provo River drainage basin and affect the water availability and distribution.

1.4 Approach

The data, hydrologic techniques, and models used by the USBR to assess the water availability for the Provo River drainage basin were reviewed. Included in the review were parts of the Definite Plan Report for the CUP (USBR, 1964) and Draft Supplements to the Definite Plan Report (USBR, 1988a–1988n) pertaining to the hydrology of the Provo River drainage basin. Three contractor's (Uintex Corp., 1982, 1984, 1987) reports were the primary documents used to review the effects of Jordanelle Reservoir on seepage to underground mines. Other reports and information in the literature were used to verify data or check methods used in the USBR reports.

1.5 Streamflow definitions

Because man-made developments have altered the streamflow characteristics in the Provo River drainage basin, the USBR provided definitions of terms used in their reports (USBR, 1988f, p. II-3,-4). The same definitions were used in this report and are provided below:

Historical flow--Historical flow is the flow actually experienced at a gaging station or point of measurement. It is the total runoff of a drainage area above the point of measurement as influenced by nature and the activities of man. It may be recorded or estimated.

Natural flow--Natural flow is that portion of the historical flow which originates within the drainage area tributary to the stream above the point of measurement.

Modified flow--Whenever the historical and/or natural flow is corrected for changes caused by man-made developments, it becomes modified flow. The conditions for which the modification was made should be specified. Following are three types of modified flow.

Past modified flow--is the historical and/or natural flow corrected to show for the period of study, the man-made developments as they existed at the beginning of the period of study. Also referred to as unmodified flow in Weber River Divertible Flow Study.

Present modified flow--is the historical and/or natural flow corrected to show the effect of the present man-made developments if they had existed over the period of study.

Future modified flow--is the flow expected at a point over the entire period of study with existing and contemplated future developments in operation.

Gross divertible flow--Gross divertible flow is the flow which could physically be diverted at a particular point, limited only by the capacity of the diversion works.

Net divertible flow--Net divertible flow is the gross divertible flow less bypasses required for downstream prior rights or other uses.

II REVIEW OF WATER DEMAND AND WATER UTILIZATION STUDIES

2.1 Literature review

A list of references pertaining to the Provo River drainage basin was compiled and sent to the USBR Central Utah Project office for their review. Specifically, the USBR was asked to review the reference list and to ensure that the USGS had access to all reports necessary to describe the data and methods used by the USBR to assess the hydrology of the Provo River drainage basin and the effects of the Jordanelle Reservoir on seepage to underground mines. Many of the USBR documents listed in the Selected References are unpublished reports or "draft reports".

The Definite Plan Report (USBR, 1964) and Draft Supplements (USBR, 1988a–1988n) do not describe many of the methods used by the USBR for estimating components of the water budgets and contain only final results. Further documentation of these methods was necessary for the review. The USBR was very cooperative and provided requested information and documents in a timely manner.

2.2 Water demand

Water in the Provo River drainage basin (fig. 2.2-1) is used for municipal and industrial purposes in Salt Lake, Utah, and Wasatch Counties and for irrigation water in Wasatch and Summit Counties. This review of municipal and industrial demand in the Provo River drainage basin focuses on demand from Salt Lake County which is the largest user of municipal and industrial water from the Provo River. Salt Lake County will receive 70,000 acre-feet of water annually from the Central Utah Project. Northern Utah Valley will receive 20,000 acre-feet of water annually, and the Heber area will receive 2,400 acre-feet of water annually. The review of irrigation demand focuses on the demand from the Heber area which will receive 12,100 acre-feet of water annually.

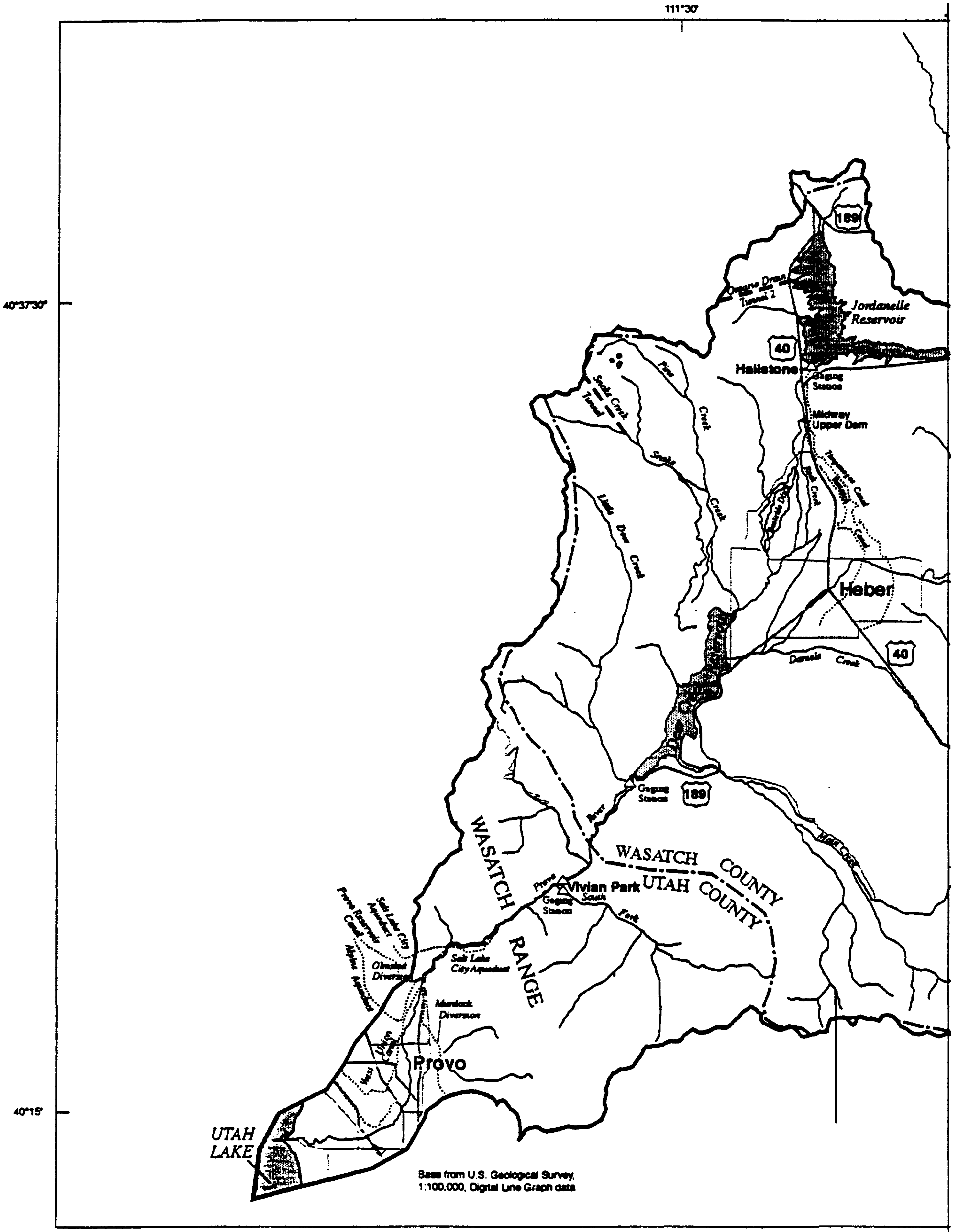


Figure 2.2-1-Provo River drainage basin.

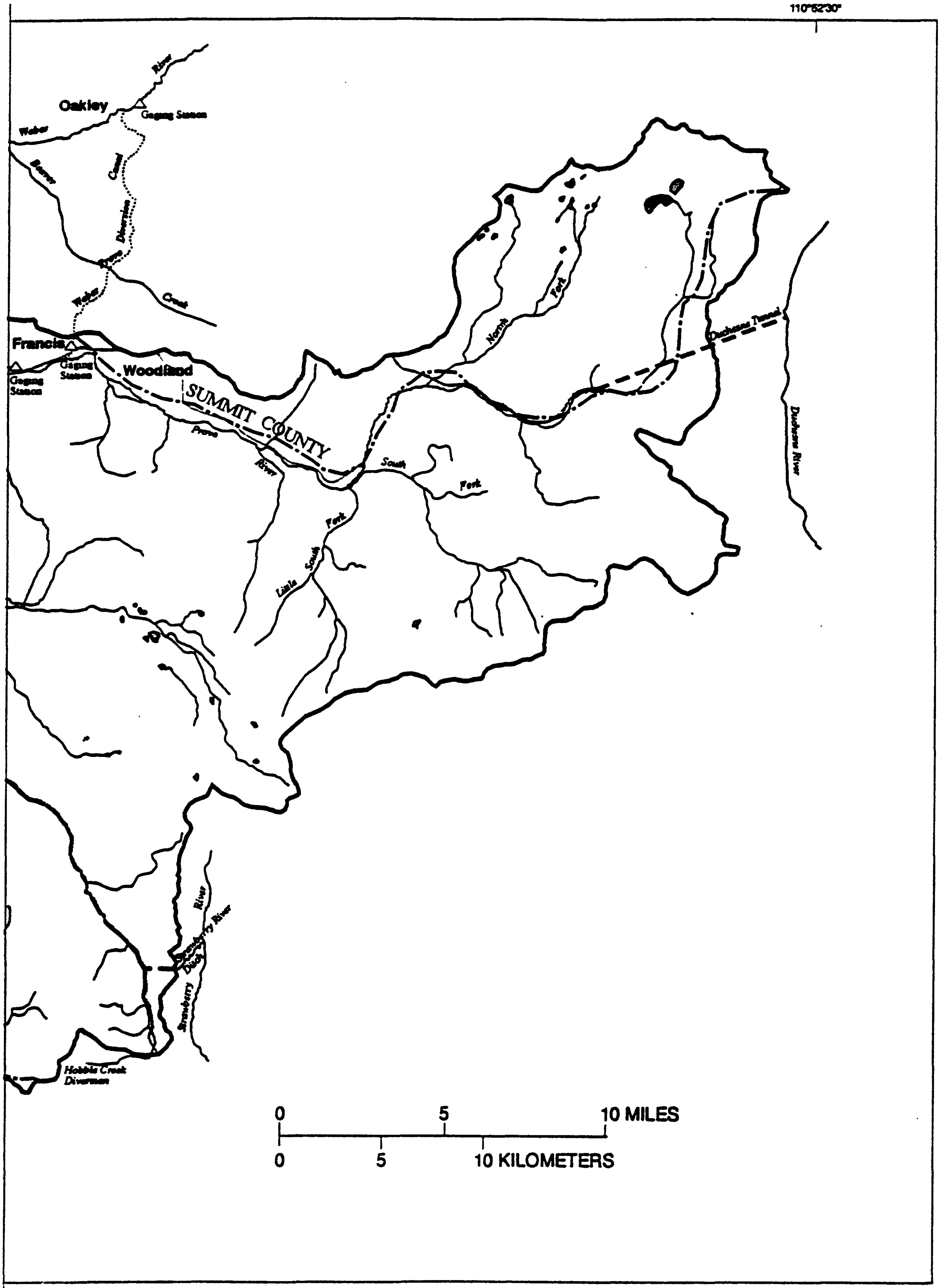


Figure 2.2-1-Provo River drainage basin--Continued.

2.2.1 Municipal and industrial demand

The USGS reviewed the USBR water demand calculations and checked the data and methods used. The USBR calculates municipal and industrial demands in the Definite Plan Report (DPR) (USBR, 1964, Appen. B, v. 2, p. 323) on the basis of "historical water use, an inventory of local resources, an analysis of local economic potentials, business and industrial growth, employment and population growth, and assuming adequate water would be available at reasonable costs". The USBR lists the municipal and industrial demands for years 1960-2020 (USBR, 1964, Appen. B., v. 2, table IV-44, p. 323), but per capita rates used to calculate the demands are not listed. The municipal and industrial demands for 1970-2020 in the Draft Supplement to the DPR (USBR, 1988f) are calculated on the basis of population projections and estimated water use per capita. This method is commonly used for estimating municipal and industrial demands. The estimates of the USBR are compared with other studies that used the same method for estimating water demands for Salt Lake County. These estimates are summarized in the following paragraphs.

The population projections used by the USBR were taken from "task force projections" (USBR, 1988f, p. III-1) and the Salt County 208 studies (USBR, 1988, p. III-2). Reports containing the results of the county studies were not cited in the Draft Supplement to the DPR (USBR, 1988f). The projected population estimates in Salt Lake County are based on an annual growth rate of about 2 percent (USBR, 1988f, p. III-1). The population projections in the Draft Supplement to the DPR (USBR, 1988f) for Salt Lake County are similar to the 1980 and 1990 census data and to population projections used in the Wasatch Front Total Water Management Study, Jordan River Basin (Utah Division of Water Resources and USBR, 1990) and Hansen and others (1979).

The major differences between studies that have estimated municipal and industrial water demand in Salt Lake County (USBR, 1964; USBR, 1988f; Utah Division of Water Resources and USBR, 1990; and Hansen and others, 1979) is the per capita water-use rates. Per capita water-use rates used in the DPR (USBR, 1964) for the water-demand calculations are not described; however, a simple division of the municipal and industrial demand by the estimated population indicates a constant per capita water-use rate of 0.50 acre-foot per year (USBR, 1964, table IV-44, p. 323). This water-use rate is much greater than the 0.25 to 0.33 acre-foot per capita use rates used in later publications (USBR, 1988f; Utah Division of Water Resources and USBR, 1990; Hansen and others, 1979).

The Draft Supplement to the DPR (USBR, 1988f, p. III-2) uses a variable water-use rate that increases from 0.28 to 0.33 acre-foot per capita (table 2.2.1-1). These values are based on the assumptions that no changes in historical water use occur and water conservation measures are not implemented. The average per capita water-use rate for Utah during 1974-76 was 0.29 acre-foot per capita (Hansen and others, 1979). Hansen and others (1979, p. 47) indicate that 0.29 acre-foot per capita is a useful figure for short-term water-use planning; however, this value would be expected to decrease over the long term. The decrease in per capita water-use rates will result from individual price-induced conservation, municipal system improvements, improved industrial plant efficiencies, and reduction of lot sizes with increased urbanization (Hansen and others, 1979, p. 47).

The Wasatch Front Total Water Management Study (Utah Division of Water Resources and USBR, 1990) uses a constant per capita water-use rate of 0.25 acre-foot per capita. This per capita water-use rate is based on the assumption that water management and conservation measures will reduce per capita use rates from 1980 rates. Water management options and conservation measures are discussed extensively (Utah Division of Water Resources and USBR, 1990).

As part of the Wasatch Front Total Water Management Study, a water demand and supply model was developed by Utah State University using a geographic information system. The model currently is being applied to Salt Lake County, and its use will be extended to Weber and Davis Counties. This model probably is the most up-to-date and sophisticated water-demand forecasting tool available.

Table 2.2.1-1 Salt Lake County municipal and industrial water demands

[Data from the Draft Supplement to the Definite Plan Report (DPR) (USBR, 1988f) and the Wasatch Front Total Water Management Study (WFTWMS) (Utah Division of Water Resources and USBR, 1990)]

Study	Year	Projected population	Per capita water-use rates (acre-foot)	Water demand (acre-feet)
DPR	1980	552,000	0.28	154,560
WFTWMS	1980	619,066	0.25	154,767
DPR[1]	1990	683,000	0.30	204,900
WFTWMS	1990	782,000	0.25	195,500
DPR	2000	814,000	0.32	260,480
WFTWMS	2000	893,000	0.25	223,250
DPR[1]	2010	1,005,750	0.33	331,897
WFTWMS	2010	1,090,000	0.25	272,500

[1]Data values interpolated from USBR (1988f, table II-1, III-2, p. III-1, III-2)

Comparison of the water-demand projections from the studies discussed in the previous paragraphs is complicated because these studies each use different population estimates and different per capita use rates. To compare the effects of different per capita water-use rates on water demand, the per capita water-use rates from the DPR (USBR, 1964), Draft Supplement to the DPR (USBR, 1988f) and Wasatch Front Total Water Management Study, Jordan River Basin, (Utah Division of Water Resources and USBR, 1990) were multiplied by the same population data set. The population data for 1960-90 (Bureau of Economic and Business Research, 1990) and projections for 2000 and 2010 from the 1990 Statistical Abstract of Utah (Bureau of Economic and Business Research, 1990, p. 15-16) were used to develop the municipal and industrial water-demand curves for Salt Lake County shown in figure 2.2.1-1. The difference between the projected water demands in 2010 based on the variable increasing per capita use rates from the Draft Supplement to the DPR (USBR, 1988f, p. III-2) and projected water demands based on a constant 0.25 acre-foot per capita use rate (Utah Division of Water Resources and USBR, 1990) is 85,000 acre-feet of water (fig. 2.2.1-1). The projected water demand from the Draft Supplement to the DPR, (USBR, 1988f, p. III-8) and from the Draft Wasatch Front Total Water Management Plan, Jordan River Basin, (USBR, 1990, p. V-2), which reflects the population and per capita use rate data used in these studies, also are shown for 1980-2010 in figure 2.2.1-1. The difference in project water demand in 2010 in these two studies is 59,400 acre-feet (fig. 2.2.1-1 and table 2.2.1-1)

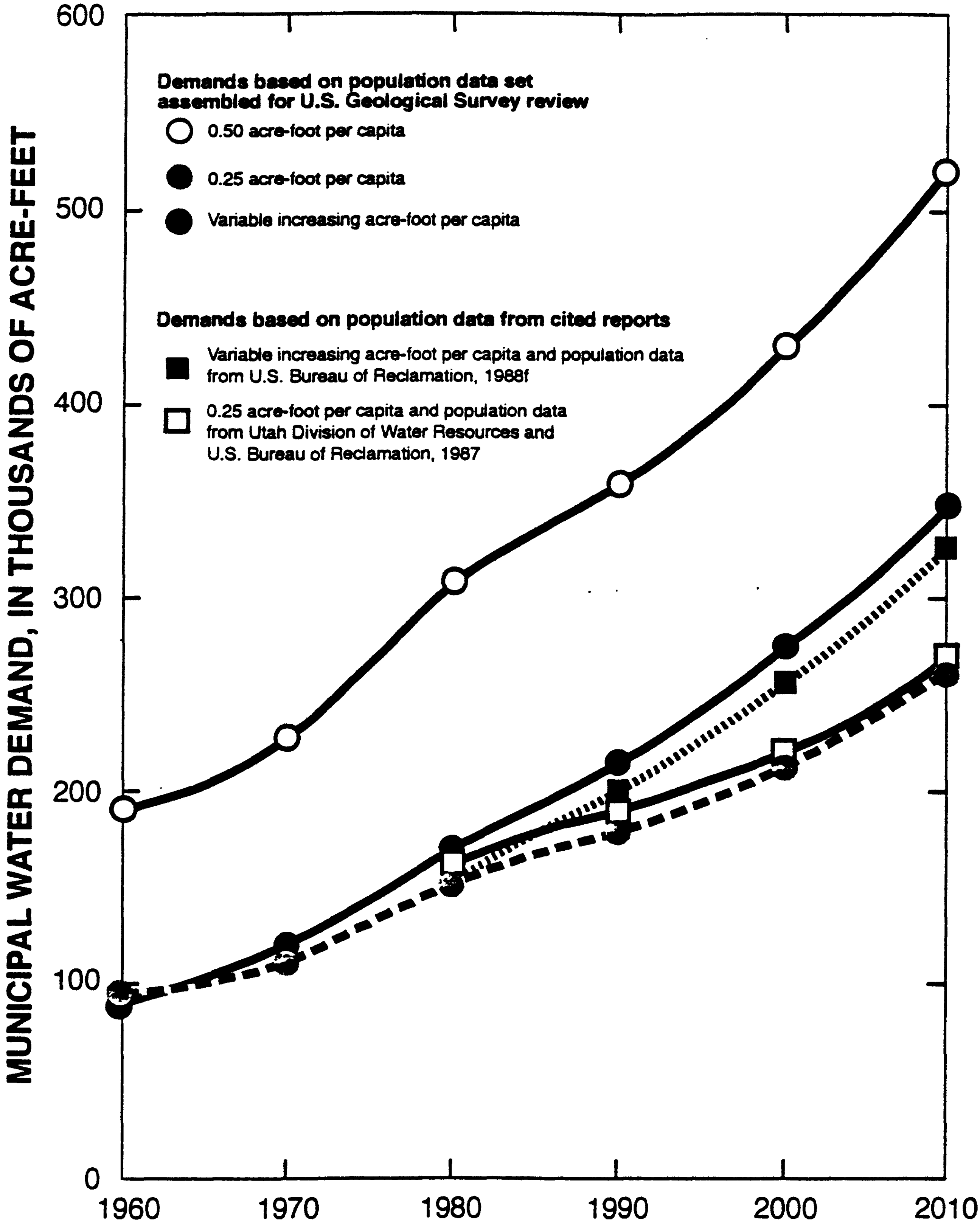


Figure 2.2.1-1--Projected municipal water demands for Salt Lake County under various per capita use rates.

The variable increasing per capita use rate used in the Draft Supplement to the DPR (USBR, 1988f) is a conservative approach to water demand. The 0.25 acre-foot per capita use rate used in the Draft Wasatch Front Total Water Management Study, Jordan River Basin, on the other hand, is based on the assumption that per capita use rates will decline from current levels, and with increased emphasis on conservation, the lower rates will be attainable (Utah Division of Water Resources and USBR, 1990).

The Draft Supplement to the DPR (USBR, 1988f) and the Draft Wasatch Front Total Water Management Plan, Jordan River Basin (Utah Division of Water Resources and USBR, 1987), were prepared at about the same time by the USBR, and the two reports take very different approaches to projecting water demands. In the Supplement to the DPR, water conservation was not assumed. The Wasatch Front Total Water Management Study was a cooperative effort between many of the Wasatch Front water management agencies and probably reflects a broader consensus on future water demands and per capita water-use rates than the Draft Supplement to the DPR (USBR, 1988f). If a per capita use rate of 0.25 acre-foot is attainable as assumed in the Wasatch Front Total Water Management Study (Utah Division of Water Resources and USBR, 1990), then water supplies could be sufficient to fulfill the demands of Salt Lake County beyond 2010.

In the Draft Supplement to the DPR (USBR, 1988f), the water-demand curve in figure III-2 was checked against population data and per capita water-use rates in tables III-1 and III-2. Using the data in these tables and following the approach described in the text, the USGS reviewers could not reproduce the water-demand curve in figure III-2. Multiplying the population projections by the per capita water-use rates in tables III-1 and III-2 results in water demands for 2010 that are about 55,000 acre-feet greater than the values in the water-demand curve in figure III-2. The results indicate that the curve in figure III-2 might have been created from different data sets than those listed in tables III-1 and III-2 or by different methods than those documented in the report.

2.2.2 Irrigation demand

The Municipal and Industrial System will develop an average of 15,100 acre-feet of water annually for supplemental irrigation of lands in the Francis and Heber areas. Heber Valley will receive 12,100 acre-feet of supplemental irrigation water. The supplemental irrigation water (3,000 acre-feet) delivered to the Francis area will replace rented water supplies or temporary water rights.

Irrigation demands are determined from consumptive-use studies, historical supplies, shortage criteria, and irrigated acreage. Supplemental irrigation demand for the Heber area was calculated by the USBR (1988f, p. III-21) on a basis of:

Crop requirements	1.41 acre-feet per acre
Farm efficiency	51 percent
Conveyance efficiency	77 percent
Diversion requirements	= crop requirements/farm efficiency/conveyance efficiency
	= 3.60 acre-feet per acre

The Utah Division of Water Resources (1986) also conducted an analysis of the irrigation systems in the Heber area and the irrigation demand or diversion requirements varied from 3.58 to 4.91 acre-feet per acre. These calculations were based on crop requirements of 1.72 acre-feet per acre and farm and conveyance efficiencies that varied with the individual irrigation companies (Utah Division of Water Resources, 1986, p. 41). The differences may be the result of the use of different estimates for crop requirements and for farm and conveyance efficiencies.

The Utah State Engineer recently released a draft water distribution plan for the Utah Lake drainage basin (Utah State Engineer, written commun., October 15, 1991). In this distribution plan the Utah State Engineer calculated irrigation demands for lands in Utah Valley using diversion entitlements or diversion requirements which are based on crop requirements, and farm and conveyance efficiencies (Michele Lemieux, oral commun., 1991). The USBR uses historical irrigation diversions for irrigation demands for these same lands in the Utah Valley. Historical irrigation diversions however, may be different from the diversion entitlements determined by the Utah State Engineer. The USGS review did not quantitatively evaluate the effects of the different approaches of the USBR and the Utah State Engineer on irrigation demand and on the water availability in the Provo River drainage basin.

2.3 Water Utilization Studies

The USBR evaluation of water utilization for the Provo River drainage basin was based primarily on three studies referred to as (USBR, p. IV-1):

1. Provo River Project Operation Study (reference 38b)
2. Provo River Surplus Flow Study (reference 38d)
3. Jordanelle Reservoir Operation Study (reference 38k)

The purpose of the studies was to determine the water distribution within existing water rights of the Provo River Project, determine the surplus or storable water available for use by the CUP, and demonstrate the adequacy of the planned project water supply to satisfy the CUP demands and existing water rights.

The USGS review of the USBR water utilization studies consisted of evaluating the methods and data used in each of the three studies. The review of the methods used in the studies was based primarily on the text and accounting tables of water supply and demand in the Draft Supplement to Definite Plan Report, Volume II, Part III, Chapter IV, (USBR, 1988f) and on unpublished model code, data, studies, and documentation of calculations provided by the USBR.

The data were reviewed and verified by comparing data used in the water utilization studies with USGS streamflow records, water commissioners' reports, and unpublished data from the USBR. The USBR water utilization studies used monthly time increments over the base period 1930-73. The monthly data were reviewed and verified for selected years, 1952 (high streamflow), 1961 (low streamflow), and 1971 (average streamflow).

2.3.1 Provo River Project Operation Study

The Provo River Project was authorized in 1935 and includes Deer Creek Reservoir and the Salt Lake Aqueduct Divisions (USBR, 1988f, p. IV-1). Most of the water supply for the project is water diverted to the Provo River drainage basin from the Weber River and Duchesne River basins. The Provo River Project and pre-Provo River Project water rights are senior to the water rights of the CUP.

The Provo River Project Operation Study is a water accounting program developed to insure that all water rights senior to CUP water rights are satisfied. The program consists of 36 columns that account for water demand and supply in monthly time increments for each year of the 1930-73 base period (USBR, 1988f, table IV-6). An explanation of the 36 columns is listed in table 6.0-1 in the Supplemental Information (Section VI). The column explanations are from the Draft Supplement to the DPR (USBR, 1988f, p. IV-17), and text in brackets in the explanation was added as part of this review.

A conceptual diagram of the Provo River Project Operation Study was developed to facilitate the review of the methods used in the model and is shown in figure 6.0-1. The numbers in figure 6.0-1 refer to the column descriptions in table 6.0-1.

The USGS examined the methods and logic used in the program and selectively checked and verified data in key columns in the program. The reviewers found that the Provo River Project Operation Study accounted for pre-Provo River Project and Provo River Project water rights and distributed the Provo River Project water without interfering with other rights.

The water supply for the Provo River Project is determined from the Weber River Divertible Flow Study and the Duchesne River Divertible Flow Study. The Weber River Divertible Flow Study was reviewed and is discussed in section 2.3.1.1. The USBR was unable to locate a copy of the Duchesne River Divertible Flow Study for review. Columns 10, 11, and 12 (fig. 6.0-1) in the Provo River Project Operation Study use data directly from the Duchesne Divertible Flow Study and could not be checked. However, the water supply from the Duchesne River has been used since 1952 and when combined with waters diverted from the Weber River has been able to supply Deer Creek Reservoir needs without utilizing all water rights belonging to the Provo River Project.

A discrepancy exists between estimated annual evaporation rates and the annual evaporation rate distribution for Deer Creek Reservoir in the Draft Supplement to the DPR on page II-47 and page IV-20 (USBR, 1988f). The accounting program for the Provo River Project Operation Study was checked and the correct values were used in the computations.

The estimated irrigation-return flow to Utah Lake is listed in column 32 (USBR, 1988f, p. IV-26). Applications by the USBR have been filed for these irrigation-return flows and will be approved by the Utah State Engineer (Robert Morgan, oral commun., 1991); however, the quantity of water that can be claimed as part of the Provo River Project water supply has not been decided by the Utah State Engineer. If the full application is approved, the water available to the project could be a maximum of 9,000 acre-feet annually (USBR, 1988f, p. IV-20).

Selected columns of data from the Provo River Project Operation Study were checked and verified. The column number, period reviewed, and the reference to data used in the review are listed in table 2.3.1-1. Data used in the water accounting program were found to be correct except for two or three instances. In these instances, the difference was not significant (less than 0.5 percent).

Table 2.3.1-1—Summary of data reviewed in the water utilization studies

[Column number: column number from the water accounting program of the indicated water utilization study. Columns are explained in Supplemental Information. Reference data used in review: Number refers to numbered reference in Selected References]

Column number	Period reviewed: Daily	Monthly	Annual	1952	1961	1971	Reference data used in review
Provo River Project Operation Study							
1	X	X	X	X	X	X	10A,10B,26,38a,39,40,41
2	X	X	X	X	X	X	10B,26,38a
3	X	X	X	X	X	X	10A,26,38a
4	X	X	X	X	X	X	10B,26,38a
5	X	X	X	X	X	X	26,38a
6		X		X	X	X	26
7		X		X	X	X	26
8		X		X	X	X	26
9		X		X	X	X	26
Weber River Divertible Flow Study							
1	X	X	X	X	X	X	38A, 40, 41
2	X	X	X	X	X	X	3, 5, 6, 26, 38a
3	X	X	X	X	X	X	26, 38a
4	X	X	X		X	X	3, 5, 6, 10C, 26, 38a
5	X	X	X		X	X	3, 5, 6, 10C, 26, 38a
6	X	X	X	X	X	X	10C, 26, 38a
7	X	X	X	X	X	X	26, 38a
8	X	X	X	X	X		26, 38a, 38A, 46, 47
9	X	X	X	X	X	X	26, 38a
10	X	X	X	X	X	X	10B, 26, 38a
11	X	X	X	X	X	X	10A, 26, 38a
12	X	X	X	X	X	X	10B, 26, 38a
13	X	X	X	X	X	X	10B, 26, 38a
14	X	X	X	X	X	X	10A, 26, 38a
15	X	X	X	X	X	X	26, 38a
16	X	X	X	X	X	X	10A, 26 38a
17	X	X	X	X	X	X	26, 38a
18	X	X	X	X	X	X	26, 38a
19	X	X	X	X	X	X	26, 38a
Provo River Surplus Flow Study							
1		X		X	X	X	4,39,38A,46,47
2		X			X	X	4,41,46
5		X		X	X	X	4,46,47
8		X			X	X	39,40,41,46,47

Table 2.3.1-1.—Summary of data reviewed in the water utilization studies—Continued

Column number	Daily	Monthly	Annual	1952	1961	1971	Reference data used in review
			Period reviewed				
Jordanelle Reservoir Operation Study							
10		X		X	X	X	26,38A,39,40,41
13 = 61			X	X	X	X	26,46,47
19			X	X	X	X	26,38d
21			X	X	X	X	26,38d
35 = 71			X	X	X	X	26
43 = 73			X	X	X	X	26
45 = 53			X	X	X	X	26
46 = 54			X	X	X	X	26
52			X	X	X	X	26,38b
55 = 68			X	X	X	X	26
57			X	X	X	X	4,26,38b,46,47
77			X	X	X	X	4,26,46,47

2.3.1.1 Weber River Divertible Flow Study

The Weber River Divertible Flow Study (USBR, 1975; reference 38a) determined the quantity of water that can be diverted from the Weber River to the Provo River Project through the Weber-Provo diversion canal (fig. 2.3.1.1-1). The quantity of water surplus to the requirements for the Weber River system (fig. 2.3.1.1-1) was calculated by the USBR using the sum of the historic diversions at selected locations on the Weber River plus the quantity of water for future development of lands or uses under existing rights. This sum was subtracted from the decreed rights. The difference was defined as a surplus to the system requirements at that location. The divertible flows calculated in the Weber River Divertible Flow Study are required as input to the Provo River Project Operation Study.

The Weber River Divertible Flow Study (USBR, 1975; reference 38a) is an unpublished 19-column accounting program for the Weber River system. The program uses daily data and accounts for instream flows, diversions, storage, losses, and exchanges for 1921–47. USBR updates to the program extended the period to include 1948–78. Documentation of column definitions, program logic, and program operation were not included with the accounting program, but were determined by USGS reviewers from other documents and through discussions with former and current employees of the USBR and the Weber River Water Commissioner. Column definitions developed by the USGS are presented in table 6.0-2.

The USGS review of the Weber River Divertible Flow Study consisted of verifying the logic and checking the data values and computations of program columns for the selected years of 1952, 1961, and 1971. A conceptual diagram (fig. 6.0-2) was developed to help verify the logic of the program.

The USGS review of the Weber River Divertible Flow Study determined that the water divertible to the Provo River Project Operation Study was calculated correctly with two minor exceptions. However, these exceptions will not affect the water available for diversion. The exceptions are:

1. In the determination of past modified flow (defined as unmodified flow in the Weber River Divertible Flow Study) of the Weber River at Gateway (USBR, 1975, column 5; reference 38a), Rockport Reservoir storage releases, water deliveries to Ogden Bay Wildlife Refuge, and changes in the content of East Canyon Reservoir were not accounted for correctly. The Rockport Reservoir storage releases are accounted twice—in the past modified flow of the Weber River at Echo Dam which is included in the computation of past modified flow of the Weber River at Gateway. The water deliveries to Ogden Bay Wildlife Refuge are demands that are downstream from the Gateway gaging station and therefore should not be part of the calculation. The change in content of East Canyon Reservoir was included in the calculation only for 1967-73. USGS reviewers believe the change in content also should have been used for 1930-66.

2. The past modified flow in the Provo River below Vivian Park is used to determine the quantity of flow in the Weber-Provo Diversion Canal that is diverted to the Provo River under the Contract of December 16, 1926, part 13(b). A discrepancy exists between the contract and the Draft Supplement to the DPR (USBR, 1988f) as to the location where the 510 cubic feet per second will be maintained. The Draft Supplement to DPR (USBR, 1988f) states that the 510 cubic feet per second of flow is to be maintained at the gage on the Provo River at Vivian Park, whereas the contract indicates that 510 cubic feet per second will be maintained below the confluence of the South Fork of the Provo River and the Provo River.

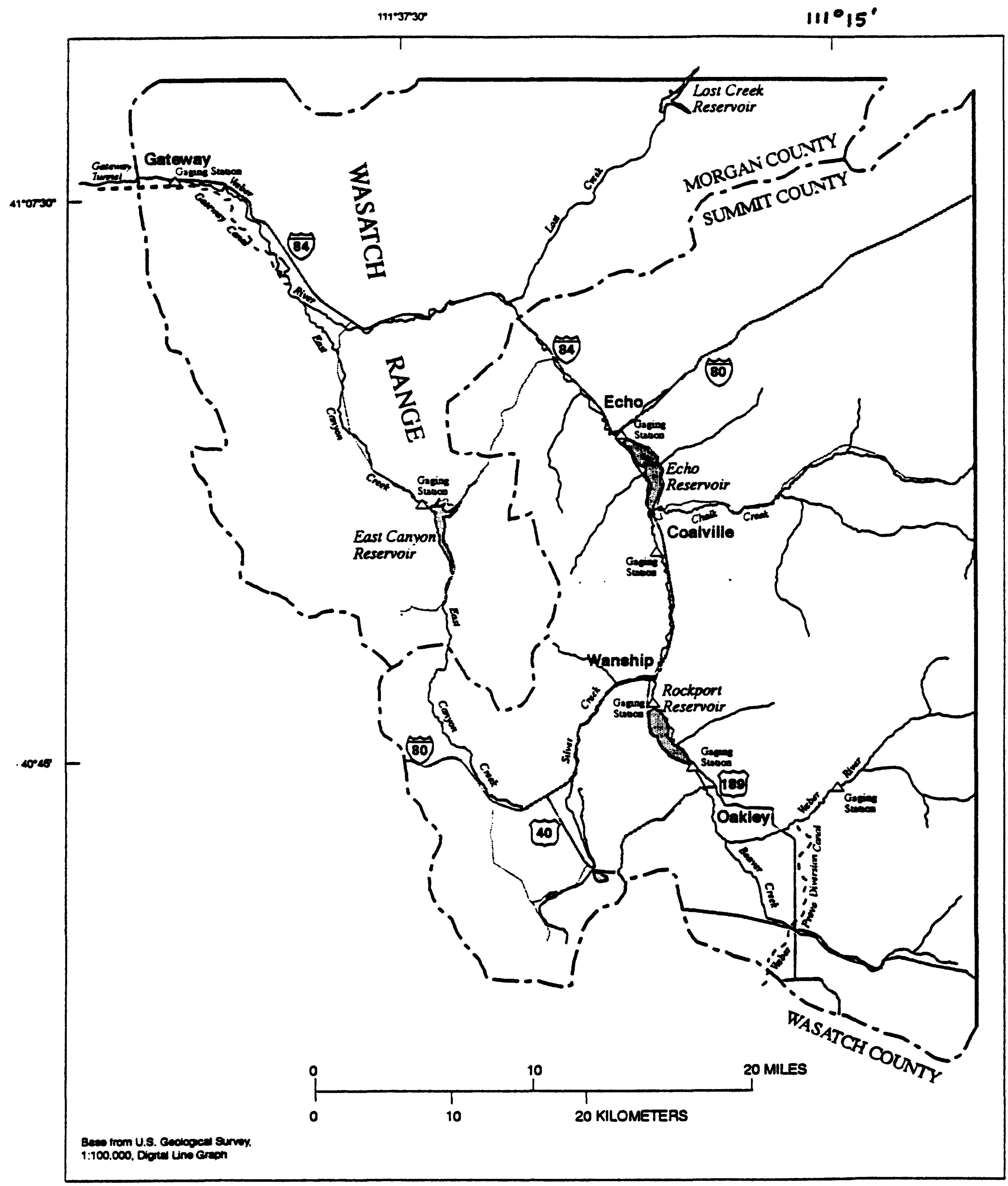


Figure 2.3.7.1-1- Central part of the Weber River drainage basin.

The daily, monthly, and annual data for each column of the Weber River Divertible Flow Study were verified for 1961 and 1971, and, where data were available, for 1952. The columns and time period for which data were verified and the reference data used in the review are listed in table 2.3.1-1. Generally, the data values were correct. Although discrepancies between the daily column data and the source data were identified during the review, most discrepancies were within the rounding error.

2.3.2 Provo River Surplus Flow Study

The Provo River Surplus Flow Study (USBR, 1976; reference 38d) determined the Provo River streamflows that are available for use by the CUP Project. The surplus flows are determined as the quantity of water that is in excess of rights above Utah Lake, measured at Olmsted Diversion Dam. The Provo River is fully appropriated and thus the "surplus flows" determined in this study are actually storable flows in the Provo River drainage basin that must be replaced in Utah Lake by exchange or by purchase of the Utah Lake water rights.

The Provo River Surplus Flow Study was made using a program consisting of 12 columns of input data. That program calculated surplus flow in monthly time increments for each year of the 1930-73 base period. To facilitate the review of the methods used in this study, a conceptual diagram was constructed that cross references the columns (where input data are entered or computations are made), to the appropriate point in the drainage system (fig. 6.0-3). The explanations of the column headings for table IV-9 (USBR, 1988f, p. IV-30, 31) are included in table 6.0-3 of this review.

The surplus flows are the source of water for storage in the proposed Jordanelle Reservoir (and on a space-available basis in Deer Creek Reservoir) and are available to the CUP for irrigation, municipal, industrial, and instream use. The surplus flows of the Provo River consist of streamflow gains in the reach below Deer Creek Dam and the surplus flows at Deer Creek Dam. For convenience, the USBR considered all surplus flow to be at Deer Creek Dam. During 1930-73, the surplus stream gain in the reach below Deer Creek dam ranged from 4,500 acre-feet in 1961 to 27,000 in 1952 and averaged 10,100 acre-feet. The surplus flows computed at the dam ranged from 38,900 in 1934 to 237,900 in 1952 and averaged 113,700 acre-feet. The total surplus flow averaged 123,800 acre-feet.

The review of the Provo River Surplus Flow Study consisted of: (1) Determining if the logic of the study was adequate for determining surplus flows including verification of streamflow modification and checking the addition and subtraction of the data columns, and (2) verifying streamflow and diversion data with the original sources.

The principal input data for the Provo River Surplus Flow Study are the past modified flows below Vivian Park and below Deer Creek Dam, columns 1 and 2 (table 6.0-3); historical canal diversions from the Provo River in Utah Valley, column 5; and the historical flow of the Provo River below Deer Creek Dam, column 8.

The methods used in the Provo River Surplus Flow Study were appropriate and calculations were correct. Another approximation of the average surplus flow of the Provo River at Deer Creek Dam was made by subtracting the 1930-73 average annual historical diversions from the past modified flow of the Provo River.

Past modified flow below Vivian Park	- Historical canal diversion to Utah Valley	= Approximate surplus flow
257,000 acre-feet (column 1)	- 150,200 acre-feet (column 5)	= 106,800 acre-feet

This calculation ignores all gains, diversions, evaporation, and conveyance losses. The approximate surplus flow, 106,800 acre-feet, is comparable to the surplus flow of 123,800 acre-feet, computed as the sum of columns 6 and 12 of the program (USBR, 1976; reference 38d). The Provo River Project has little affect on the surplus flow. Most of the water supply for the Provo River Project is from transbasin diversions from the Weber and Duchesne Rivers and demands are limited to the supply.

The monthly historical diversions from the Provo River to Utah Valley (table 6.0-3, column 5) were checked against the Provo River Commissioners' Reports (Wentz, 1952; Wayman, 1961). The data listed in column 5 agreed with the Commissioners' reports. The historical flow of the Provo River below Deer Creek Dam, column 8, was checked against USGS streamflow data for the 1961 water year (U.S. Geological Survey, 1970), and the data were correct.

The stream gaging station at Provo River below Deer Creek Dam was not operating in 1952. The USBR estimated the 1952 record by correlating records from gaging stations on the Provo River at Deer Creek Dam and Provo River at Wildwood. The documentation of these correlations could not be located for the USGS review.

Column 11 (USBR, 1988f, p. IV-32), which represents the changes to natural flow caused by the Provo River Project, was not verified. The USBR was unable to locate a copy of the South Fork of the Provo River Study, which is a separate operations study of the streamflows and exchanges on the South Fork of the Provo River. Calculations were verified for October through June, but the USGS could not check calculations for July, August, and September because of the missing South Fork of the Provo River Study.

The review of the procedures used in the detailed accounting in table 6.0-3 and the independent calculation of surplus flows and verification of data indicate that the surplus flow gains below Deer Creek Dam (column 6) and the Provo River surplus gains at Deer Creek Dam (column 12) are accurate for the 1930-73 base period. The USGS review did not consider the draft water distribution plan for the Utah lake drainage basin proposed by the Utah State Engineer (October 15, 1991). This plan, when finalized, may have a significant affect on water availability to the CUP.

2.3.3 Jordanelle Reservoir Operation Study

The Jordanelle Reservoir Operation Study (USBR, 1978; reference 38k) simulates the operation of the proposed Jordanelle Reservoir for the 1930-73 base period. The intended design of the study was to simulate operation of Jordanelle Reservoir to meet all existing water rights and to deliver an average annual water supply of 107,500 acre-feet. According to the USBR (1988f, p. IV-34), "The primary functions of Jordanelle Reservoir are: (1) to provide 92,400 acre-feet of water for municipal and industrial purposes in Salt Lake, northern Utah, and Wasatch Counties; (2) to provide 15,100 acre-feet of supplemental irrigation water to lands in the Heber-Francis area; (3) to provide replacement storage for water now stored in the upper Provo River reservoirs and delivered below Jordanelle Reservoir; (4) to provide water to maintain streamflow for fisheries of 125 cubic feet per second below Jordanelle to Deer Creek Reservoir, 100 cubic feet per second below Deer Creek Reservoir to the Olmsted Diversion Dam, and 25 cubic feet per second below the Olmsted Diversion Dam.

The Jordanelle Reservoir Operation Study (USBR, 1978; reference 38k) used an 83-column accounting model that produced monthly output for the 1930-73 base period. The output included an accounting of water distributed for municipal, industrial, irrigation, and instream use in the CUP system.

The USGS review of the Jordanelle Reservoir Operation Study examined the logic and organization of the model and selectively checked and verified key input data columns in the model. The sensitivity of the water availability to changes in selected data was also examined. To facilitate the review of the methods used in the operation study, a conceptual diagram was constructed that cross references the columns (where either input data are entered or computations are made) to the appropriate points in the drainage system (fig. 6.0-4 and table 6.0-4). Additional explanation and some corrections were added to the description of column headings in table 6.0-4. The columns of data that were verified with original sources are shown in table 2.3.1-1. All streamflow data and diversion records checked for the indicated years were accurate.

A thorough examination of the model was beyond the scope of this review. However, analysis of selected aspects of the model was made to address specific concerns raised during the review. The review was complicated by the difficulty in locating the most recent version of the model. The model described in the Draft Supplement to the DPR, (USBR, 1988f) had been superseded by later modifications that have not been documented. These modifications were recognized through discussions with USBR personnel and through inconsistencies with other data.

The Jordanelle Reservoir Operation Study is a hypothetical simulation for a selected base period (1930-73) for which historical streamflows and diversions were measured and recorded for much of the period. Actual or real-time operation will require concurrent, one-for-one exchanges of water between the Jordanelle Reservoir, Deer Creek Reservoir, and Utah Lake and will require timely decisions made with streamflow forecasts based on limited data. Thus, the real-time operation should be expected to be less efficient than the idealized operation demonstrated by the Jordanelle Reservoir Operation Study, and the shortages of supply for the real-time operation will be larger than those computed by the model.

The USGS review of the logic and organization of the Jordanelle Reservoir Operation Study model raised and addressed a number of questions and concerns. These concerns include the way the model accounts for irrigation-return flows, local water supply for the Heber area, shortages of instream flow for fisheries, the Provo City-USBR agreement, shortages of water for municipal, industrial, and irrigation use as a function of reservoir contents and hydrologic conditions, and Utah Lake depletions.

Supplemental irrigation water is supplied to the Francis and Heber areas by the Central Utah Project (columns 59 and 62, table 6.0-4). The Central Utah Project claims irrigation-return flows from this irrigation water as part of the project water supply (USBR, 1988f)(column 66, fig. 6.0-4 and table 6.0-4). In the Jordanelle Reservoir Operation Study, irrigation-return flows are accounted for only in the months when irrigation water is applied (June, July, August, and September) and are calculated as 36 percent of the water applied. Modeling of the ground-water system in Heber Valley indicates that about a 2-month delay exists between the application of irrigation water and irrigation-return flow to the stream channels as ground water (M. Roark, U. S. Geological Survey, oral commun., October 1991). As a result, irrigation-return flow is probably occurring in October and November after the irrigation season ends. The return flow after irrigation stops will not change the water availability on an annual basis but could change the accounting of the water supplies on a monthly basis.

The USBR (column 12, table 6.0-4) estimated the water supply available to project lands in the Heber area from springs and irrigation-return flow from Spring Creek and Sagebrush Creek and Sagebrush Canals to be 6,600 acre-feet per year. Roark and others (1991, p. 24) estimated an average annual water supply from springs and irrigation-return flow in the Heber Valley of 34,750 acre-feet.

The USBR also estimated stream gain available to project lands of 1,500 acre-feet per year in the reach of the Provo River below Midway Upper Dam and Deer Creek Reservoir (fig. 2.2-1); whereas Roark and others (1991, p. 24) measured gains of about 13, 040 acre-feet in a similar reach beginning about one mile below the Midway Upper Dam and extending to Deer Creek Reservoir. The USBR estimates of the local supply for the Heber area is for project lands only and will be part of the total water supply. The Heber area irrigation study used to determine the USBR estimates of local supply to the Heber area was not available for review. The USGS review was unable to evaluate the USBR estimates of the Heber area local supply.

Calculations of the proposed streamflows for the Provo River below Jordanelle Dam and below Deer Creek Dam in the Jordanelle Reservoir Operation Study model (USBR, 1988f, columns 81 and 82) were checked. It was verified that 125 cubic feet per second and 100 cubic feet per second, respectively, were maintained on a monthly basis throughout the 1930-73 base period to meet fishery requirements for instream flow. Although the USBR correctly set the instream fishery shortages to zero on the basis of consideration of the modified flows in the Provo River (for the model simulation), the model does not contain the flexibility to compute these shortages based on upstream water availability.

The Jordanelle Reservoir Operation Study in the Draft Supplement to the DPR (USBR, 1988f, p. IV-72 to 78) includes a section that discusses the effects of the USBR and Provo City agreement to allow Provo City to store 10,000 acre-feet of water annually in Jordanelle Reservoir. Several statements in this section are contradictory to the agreement between the USBR and Provo City (Jay Henerie, USBR, October 17, 1991, oral commun.). USBR personnel indicated that if a final version of the Draft Supplement to the DPR was produced, this section would be modified. The effects of this agreement would be most appropriately included in the Jordanelle Reservoir Operation Study model. Because Provo City is only allowed to store irrigation water from existing water rights, this change should not affect the water availability in the basin and would only affect the way water distribution for pre-CUP purposes is simulated by the model.

In the Jordanelle Reservoir Operation Study, the USBR assumed that the initial content of Jordanelle Reservoir was 269,500 acre-feet of water for the simulation of reservoir operation (USBR, 1988f, p. IV-55, column 78). As part of the USGS review, the model was run to determine the effects of an initial reservoir content of 0 acre-feet on shortages to the total municipal, and industrial, and irrigation water supply. Graphs of shortages for municipal, industrial, and irrigation water with the initial content of Jordanelle Reservoir set at 0 acre-feet and 269,500 acre-feet are shown in figure 2.3.3-1.

The initial shortages in municipal, industrial, and irrigation water will decrease during the initial filling of the reservoir if project demands are applied more gradually as will probably be the case when Jordanelle Reservoir actually begins operation. In actual operation, water will not be provided from Jordanelle Reservoir until the water is stored and available in the reservoir. In the model, shortages of municipal and industrial water occur when the initial contents of Jordanelle Reservoir is set at 0 acre-feet because the model operates with full project demands applied from the beginning of the simulated period while the reservoir is filling.

No municipal and industrial water shortages occurred in the base period (1930-73) when Jordanelle Reservoir was simulated with an initial content of 269,500 acre-feet in 1930. However, when the initial content was simulated as 0 acre-feet in 1930, considerable shortages of municipal and industrial water existed in the 1930's (fig. 2.3.3-1). Under actual reservoir operating conditions, shortages of irrigation water would also occur in years with municipal and industrial water shortages, but in this simulation they did not. Thus, the model does not compute shortages to irrigation as a function of reservoir contents. Under a more realistic approach, shortages in the 15,100 acre-feet of supplemental irrigation water to be supplied to the Heber and Francis areas would occur before any municipal and industrial water shortages occurred.

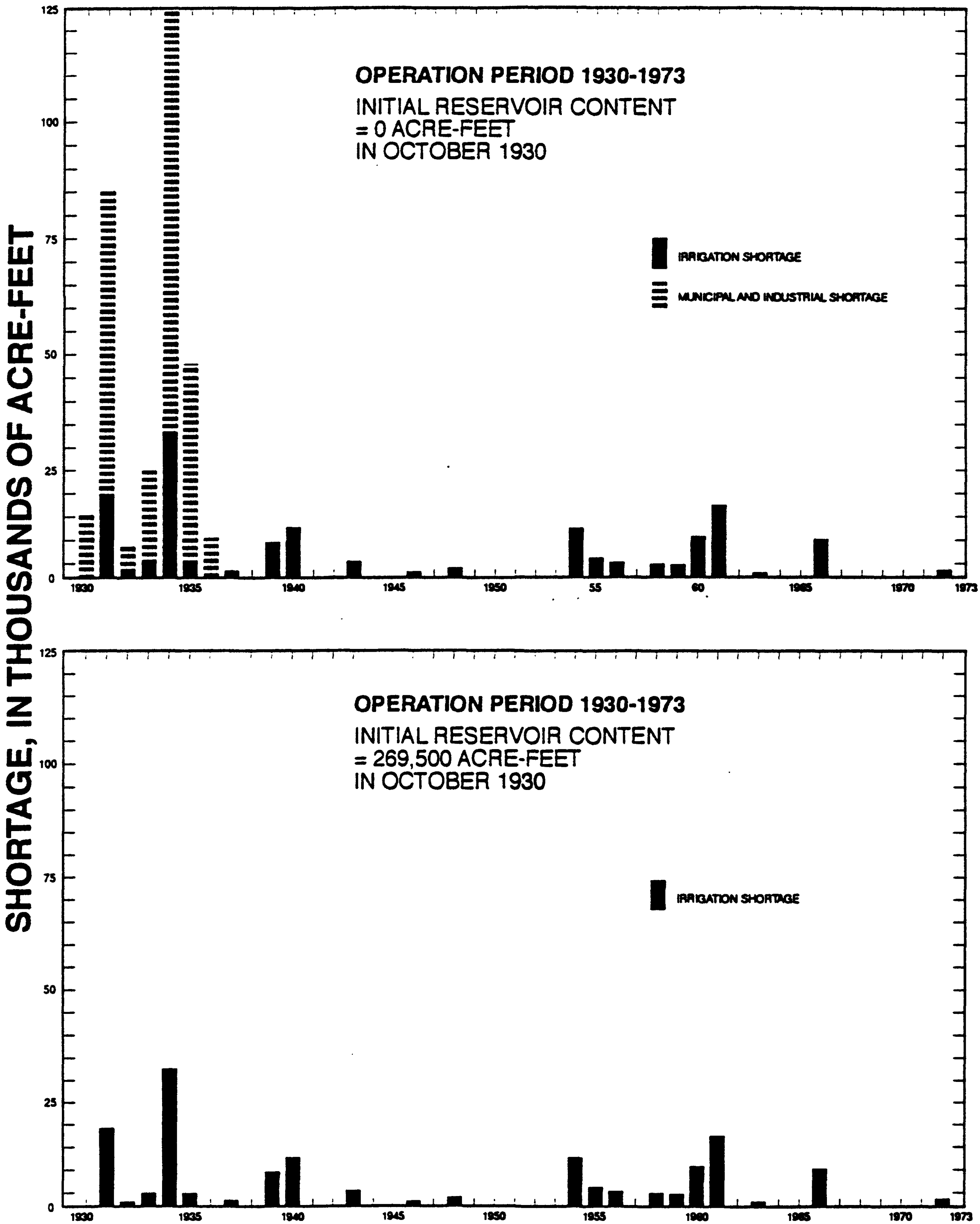


Figure 2.3.3-1--Calculated shortage of water for simulated operation of Jordanelle Reservoir assuming initial content is 0 and 269,500 acre-feet for operation period 1930-73.

Irrigation shortages to the Heber area (column 63, fig. 6.0-4) are computed in an operation study and are entered directly into the model. This operation study was not available for the USGS review. Apparently, the USBR examined the past modified flows at Hailstone as part of this operation study and prorated the irrigation shortages to the Heber area for the 1930-73 simulation based on the streamflow at Hailstone. The response of the Jordanelle Reservoir Operation Study model was evaluated for a change (plus or minus 10 percent) in the past modified flow at Hailstone (column 37, fig. 6.0-4), and it was determined that the shortages to the Heber area (column 63, figure 6.0-4) varied as a function of the change in flow at Hailstone (fig. 2.3.3-2).

Four model runs were made with the initial reservoir contents set at 0 at the beginning of each of the four simulation periods, 1930-73, 1941-73, 1952-73, and 1963-73. The shortages to municipal, industrial, and irrigation supply are shown in figures 2.3.3-1 and 2.3.3-3. As previously stated, the model is not programmed to vary shortages to irrigation as a function of reservoir contents, so irrigation shortages do not respond to changes in reservoir content and are not considered in the following discussion.

The 1930's were a drought period with less-than-average streamflows. For the 1930-73 simulation, municipal and industrial shortages were indicated during 1930-36 while Jordanelle Reservoir was slowly filled (fig. 2.3.3-1). For the 1941-73 simulation period (fig. 2.3.3-3), 1941 was a relatively dry year with less-than-average streamflows followed by greater-than-average streamflows during 1942-46; shortages to municipal and industrial supply occurred only during 1941-42. The 1952 water year was the wettest year of the 1930-73 base period, and only a minor shortage of municipal and industrial water occurred during the first year (1952) of the 1952-73 simulation period (fig. 2.3.3-3). The 1963 water year was relatively dry, and large shortages occurred during the first 2 years (1963-64) of the 1963-73 simulation period.

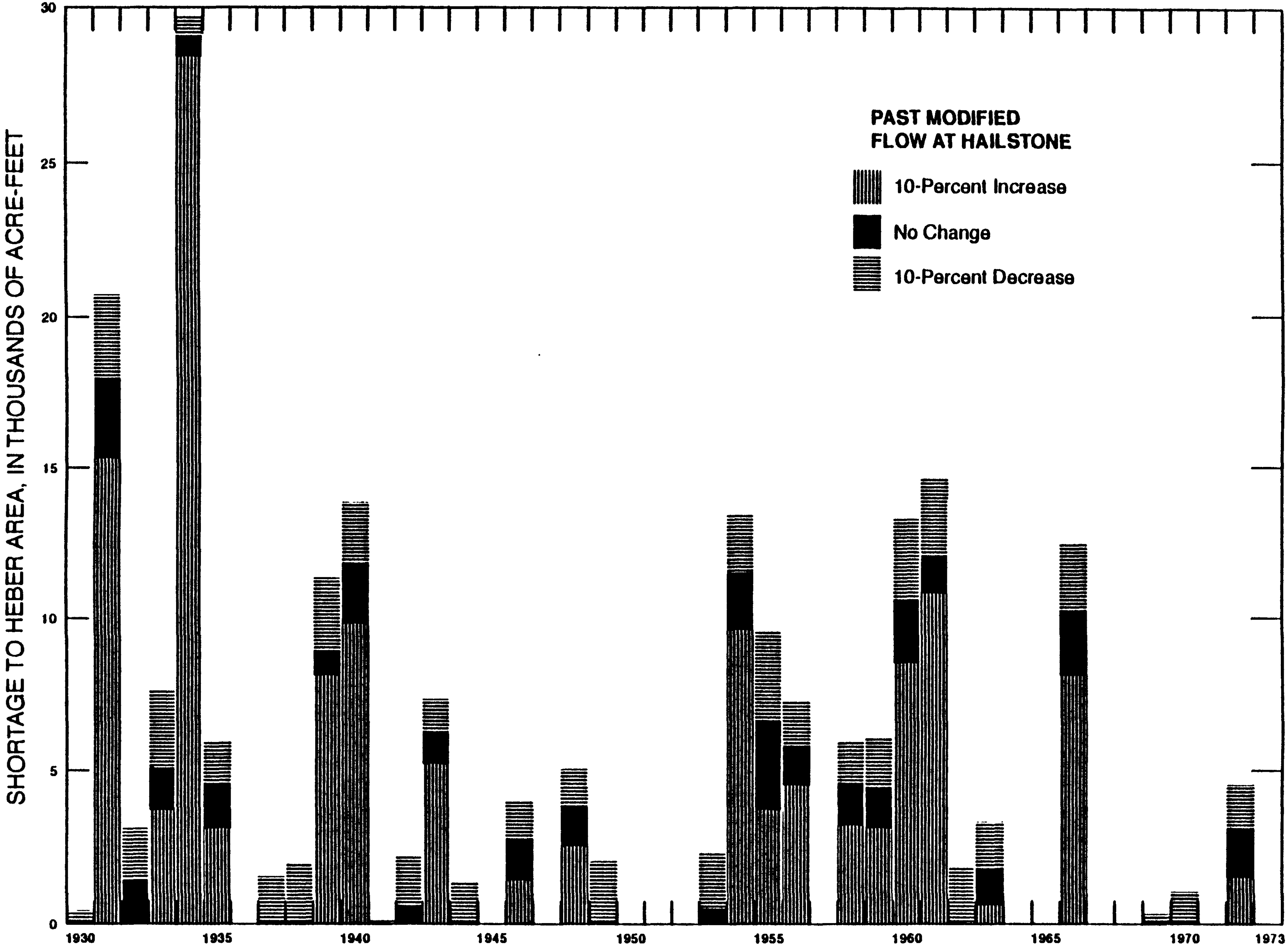


Fig 2.3.3-2--Effects of reducing or increasing past modified flow at Hailstone on shortage of supply to Heber area.

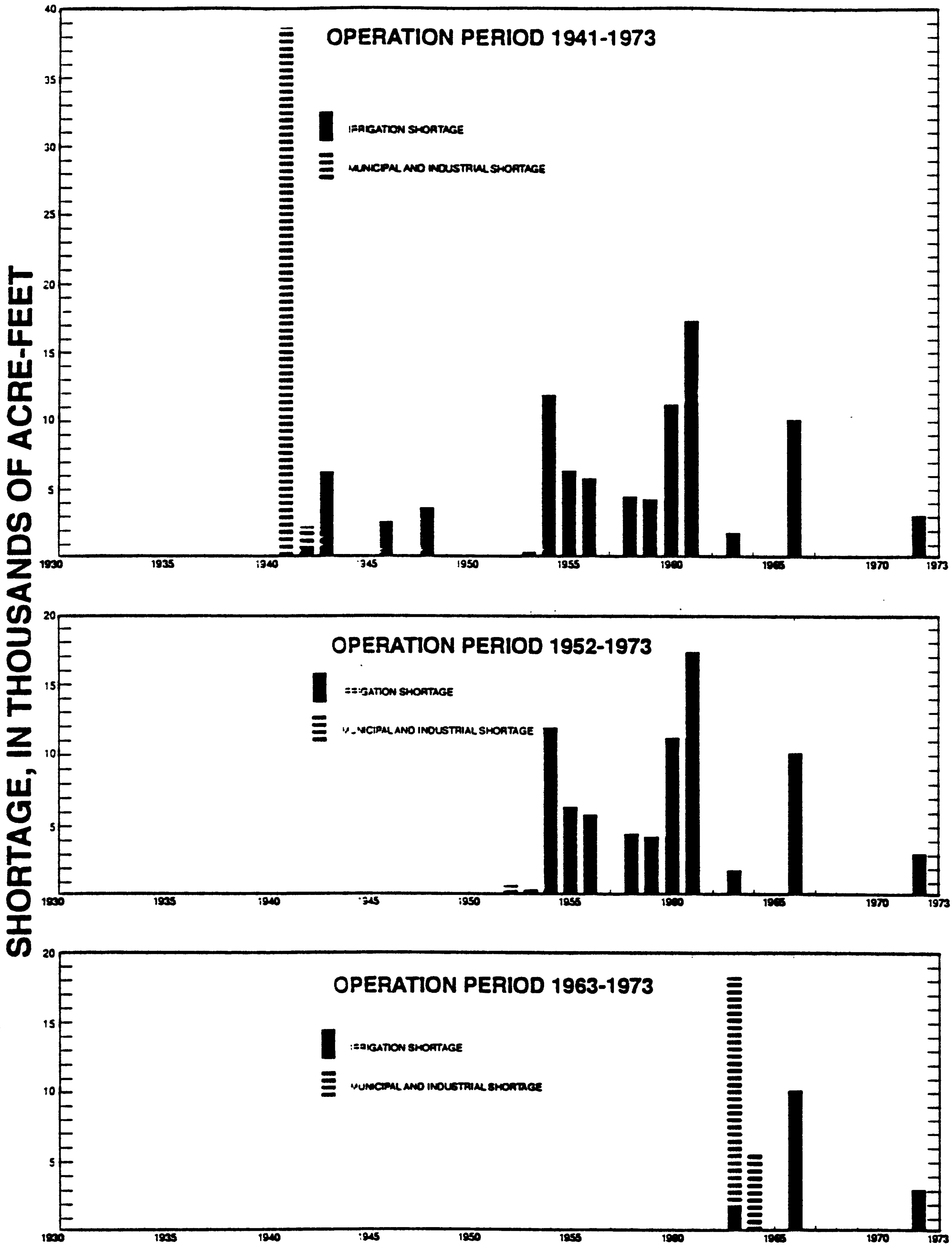


Figure 2.3.3-3--Calculated shortage of water for simulated operation of Jordanelle Reservoir assuming initial content is zero for operation periods 1941-73, 1952-73, and 1963-73.

The simulations for the four periods indicate that the capability of the Jordanelle Reservoir and Bonneville Unit of the CUP to deliver the proposed water supply will depend directly on the streamflow conditions following the closure of the reservoir. Municipal and industrial shortages occurred only during the initial years following closure. The maximum time during which shortages occurred following reservoir closure was 6 years, and in the other three simulation periods, shortages only occurred during the first 2 years.

The response of the model to changes in surplus flow at Deer Creek Dam was evaluated (plus or minus 10 percent) (column 19, fig 6.0-4). The response function for the change in surplus flow was the end-of-year contents in Jordanelle Reservoir (column 78, fig. 6.0-4). The contents of Jordanelle Reservoir should respond to changes in the surplus flow even though Deer Creek Reservoir is downstream from Jordanelle Reservoir. As can be seen in figure 2.3.3-4, the end-of-year contents of Jordanelle Reservoir did respond and increased by a maximum of about 15,000 acre-feet when the surplus flow at Deer Creek Dam was increased by 10 percent.

Some values are fixed or constant in the model, and the model does not respond dynamically to some changes of input values. Because many of the values were fixed as constants in the model, only a partial sensitivity analysis could be conducted as part of this review. Also, the combined effects of the small errors or inconsistencies pointed out in this review could not be quantitatively evaluated because the model does not react dynamically.

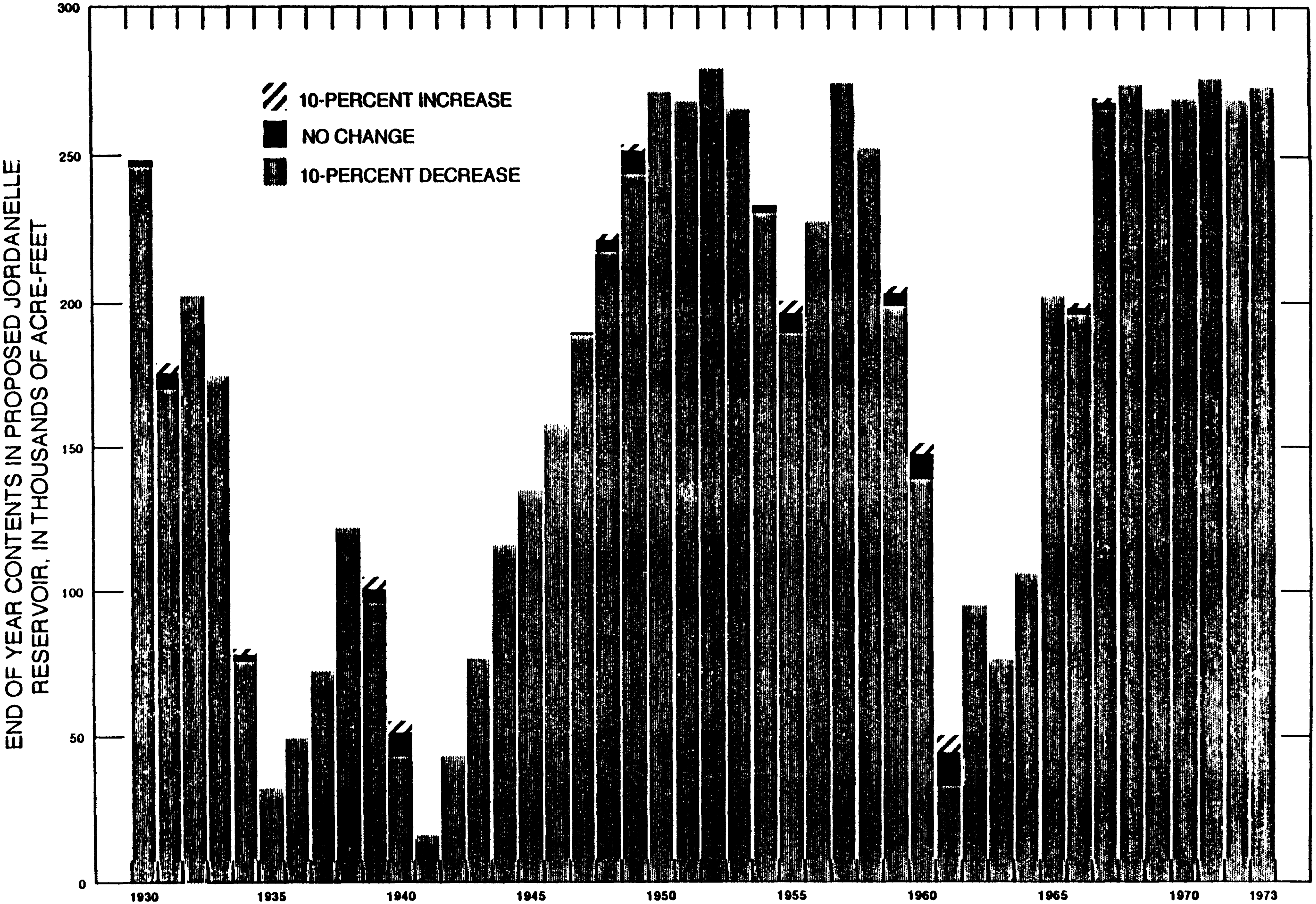


Figure 2.3.3-4--Effects of reducing or increasing surplus flow of Provo River at Deer Creek Dam on end-of-year contents in proposed Jordanelle Reservoir.

A balance of the average annual water supply, water use, and Utah Lake depletion were computed by the USBR using the model results for the 1930-73 simulation of Jordanelle Reservoir (USBR, 1988f, table IV–26). Because some changes to the computer model were made subsequent to completion of the Draft Supplement to the DPR (USBR, 1988f, p. IV-69); a similar balance of water supply, water use, and Utah Lake depletion was made by the USGS using the results of the updated computer code. In table 2.3.3-1, the balance computed with the updated computer code and the balance in table IV-26 in the Draft Supplement to the DPR (USBR, 1988f) are presented.

The major change to water supply resulting from the updated model code (table 2.3.3-1) was in the irrigation-return flows from the Heber area, which decreased by 600 acre-feet per year. This occurred because the updated model included a change in the criteria used to distribute CUP irrigation water to the Heber area, which, in turn, affected the quantity of return flow.

The major change in water use resulting from the updated model code was in supplemental irrigation water. This value decreased by 1,400 acre-feet per year.

The only other change in the water balances occurred in hypothetical spills from the proposed Jordanelle Reservoir. The spills from Jordanelle Reservoir increased by 800 acre-feet per year because of the change in criteria used to distribute irrigation water to the Heber area. However, the model code did not account for the discrepancies in local supply from the Heber area pointed out in previous discussions of this section.

The changes in water supply and water use resulted in a net decrease of 700 acre-feet per year in depletion to Utah Lake (table 2.3.3-1). In table IV-26 (USBR, 1988f), the change in reservoir contents was incorrectly added to the Utah Lake depletion. The error is 100 acre-feet per year and is not a significant part of the average annual depletion for 1930-73 (85,600 acre-feet per year).

The depletion to Utah Lake was calculated by subtracting CUP water that reaches Utah Lake from the total water use (table 2.3.3-1) and by assuming that all water used by the CUP from the Provo River must be replaced in Utah Lake. This approach is conservative because full replacement of the Utah Lake depletion will not always be required. The quantity of replacement is dependent upon the level of Utah Lake, which has not been determined by the Utah State Engineer.

Table 2.3.3-1 Comparison of water balances compiled from results of Jordanelle Reservoir Operation Study (Modified from USBR, 1988f, table IV-26)

	Average annual quantity of water for 1930-73, in thousands of acre-feet		
	From table IV-26, USBR (1988f)	From updated USBR model code	Net difference
	WATER SUPPLY		
Surplus flow	115.0	114.9	0.1
Surplus gains	10.1	10.1	0.0
Indian Ford exchange	8.6	8.6	0.0
Heber area return flows	4.7	4.1	0.6
Provo River power water	1.1	1.2	-0.1
TOTAL	139.5	138.9	0.6
ROUNDING	-0.1	0.1	-0.2
	139.4	139.0	0.4
	WATER USE		
Municipal and industrial	90.0	90.1	-0.1
Supplemental irrigation	16.5	15.1	1.4
Upstream stabilization	5.7	5.7	0.0
Stream fishery	7.9	7.9	0.0
Evaporation	5.9	6.0	-0.1
Spills	13.3	14.1	-0.8
Change in reservoir content	0.1	0.1	0.0
TOTAL	139.4	139.0	0.4
	UTAH LAKE DEPLETION		
Total water use	139.4	139.0	0.4
Municipal & industrial-return flow	-13.0	-13.0	0.0
Irrigation-return flow	-4.7	-4.1	-0.6
Fishery flows	-7.9	-7.9	0.0
Upstream reservoir stabilization	-5.7	-5.7	0.0
Spills	-13.3	-14.1	0.8
Indian Ford exchange	-8.6	-8.6	0.0
Change in reservoir content	0.1	--	0.1
TOTAL	86.3	85.6	0.7

The water supply, water use, and Utah Lake depletion were also computed on an annual basis to check the annual balance between water supply and use and to determine the annual average variation of the depletion of Utah Lake. Comparison of water supply and use in figure 2.3.3-5 shows that the annual average water supply does not balance every year. The year-to-year discrepancies are minor and may reflect computational inaccuracies of the model that are probably larger for year-to-year accounting than for the 1930-73 average. The USGS reviewers did not determine the causes of these differences.

The annual average depletion to Utah Lake ranged from 17,800 acre-feet to 156,200 acre-feet and averaged 85,600 acre-feet for the simulation for 1930-73 using the updated model code. The years when depletions were larger than average (85,600 acre-feet per year) are important for consideration because of the year-to-year variability required for importation of water from Strawberry Reservoir. Figure 2.3.3-5 shows that in 15 of the 44 years, the depletion will be 100,000 acre-feet per year or larger and deliveries from Strawberry Reservoir would have to meet the variable depletions to prevent project shortages.

It was assumed in this review that water was available from Strawberry Reservoir to replace the water depleted from Utah Lake. The quantity of water that must be replaced also is dependent upon the level of Utah Lake. If Utah Lake is full, then no water must be replaced. The Utah State Engineer has proposed a new management plan for water distribution focusing on Utah Lake. The plan integrates Utah Lake water levels with the Central Utah Project.

The model for the Jordanelle Reservoir Operation Study is not a dynamic model that can be used to simulate operation of Jordanelle Reservoir on a real-time basis. A number of data columns are read into the model and fixed for the 1930-73 period. The model was designed to distribute water in the Provo River drainage basin under set project conditions that are valid only for the 1930-73 base period. For any other base period, these constants would have to be revised manually. For example, if the streamflow in the Provo River at Hailstone were changed, the downstream reservoirs and gaging stations would not reflect the change of flow at Hailstone.

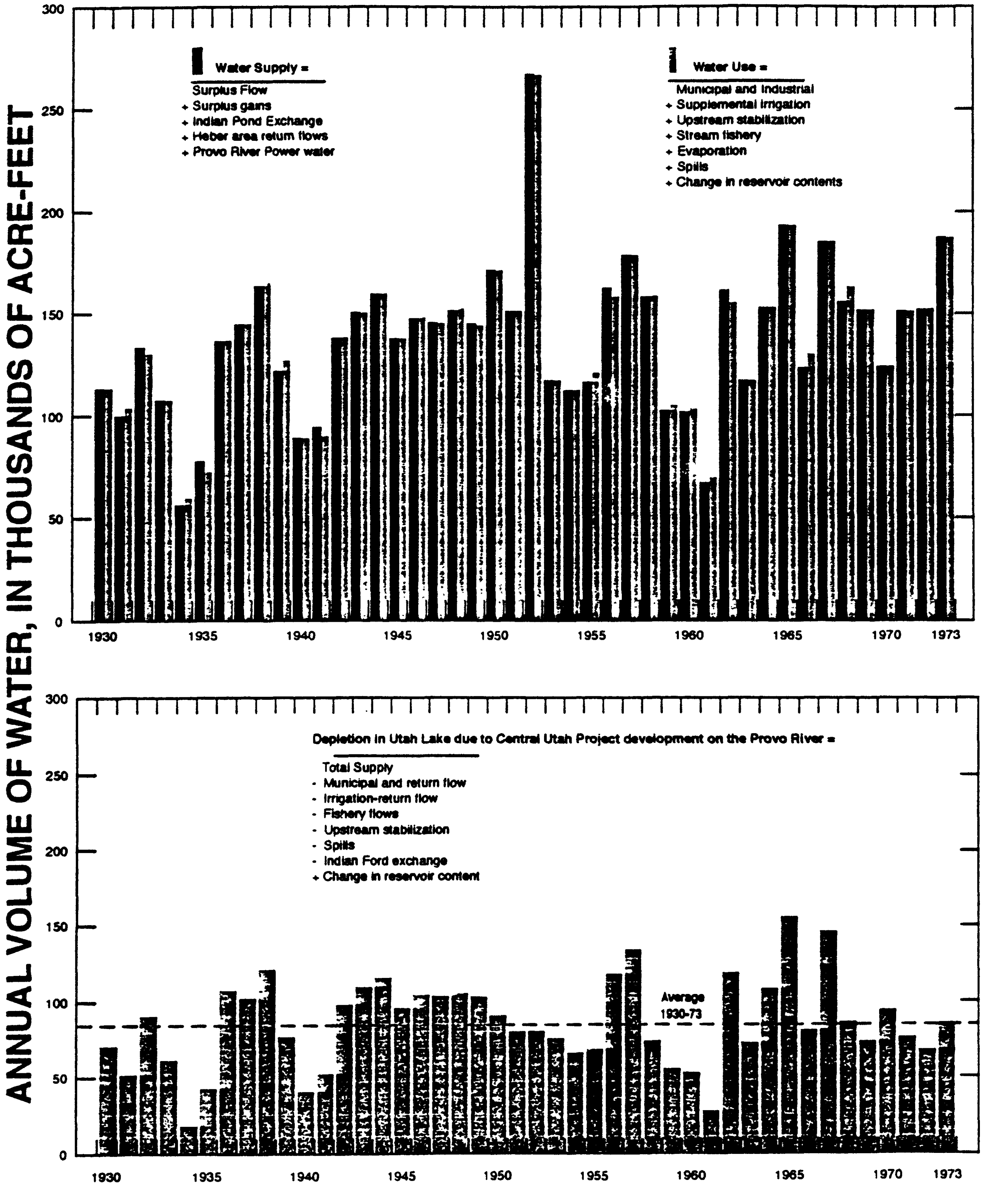


Figure 2.3.3-5–Summary of annual water supply, water use, and depletion in Utah Lake.

The concerns addressed within this section should not effect the overall conclusions pertaining to the storable water supply computed as part of the Provo River Surplus Flow Study and used as input to the Jordanelle Reservoir Operation Study model. The model could be modified to address the concerns so that the distribution of water for the intended uses at various points in the system can be accurately portrayed by the USBR for the simulated period.

III REVIEW OF A STUDY OF THE POTENTIAL EFFECTS OF JORDANELLE RESERVOIR ON SEEPAGE TO UNDERGROUND MINES OF THE PARK CITY MINING DISTRICT, UTAH

3.1 Background

Mining in the area (fig. 3.1-1) for silver and other metals began in the late 1860's and, partly because of changing ore prices, fluctuated in intensity during the next 100 years. As mining progressed, shafts and mine tunnels were placed at greater depths. Shaft No. 3 in the Ontario mine was excavated to an elevation of about 5,650 feet above sea level and Ontario No. 6 shaft to about 5,500 feet. Before the Mayflower Mine was closed in 1971, its workings extended to about 5,300 feet above sea level and the Mayflower shaft was completed at about 4,350 feet above sea level. Projected maximum water level of the Jordanelle Reservoir is 6,170 feet above sea level, which would be from 900 to 1,800 feet above the elevation of these existing mines. It is possible that renewed mining may extend toward the proposed Jordanelle Reservoir.

The dam and reservoir are to be located in an area where rocks are structurally deformed. Faults of numerous geologic ages have been identified. The rocks in the area of the reservoir and the mined area to the west are mainly Tertiary age igneous rocks, but include some Paleozoic and Mesozoic sedimentary rocks (quartzite, shale, sandstone, siltstone, and limestone). In a large part of the reservoir area, alluvium overlies the consolidated formations. The consolidated formations are fractured, and ground water probably moves through these fractures; however, determining the rate and direction of ground-water movement is difficult, especially where the alluvial cover exists.

In order to confirm its own findings, the U.S. Bureau of Reclamation contracted the Uintex Corporation to study the potential for seepage from the reservoir to existing mines and hypothetical new mines. The U.S. Geological Survey was asked to review the studies related to potential seepage from the reservoir to underground mines.

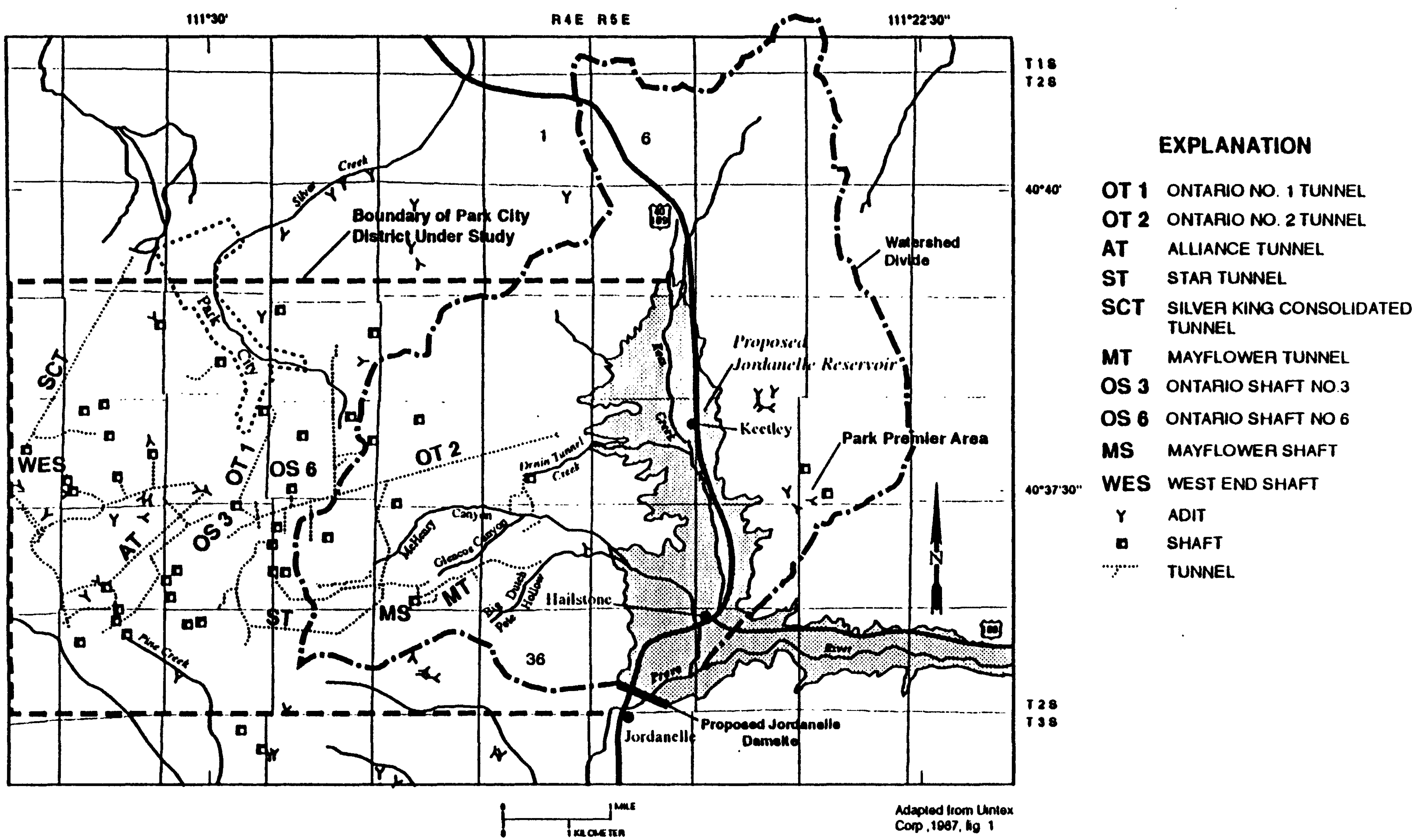


Figure 3.1-1--Location of the Jordanelle Damsite and Reservoir and the mining areas to the west and east.

This review is limited to information contained in three reports produced by Uintex Corporation under contract with the USBR (Contract No. 2-07-40-S3080) from May 1982 through February 1987, and selected available supporting literature. The three reports are an original draft report and two successive updates over the 5-year period of the investigation. The last report is assumed to contain the information upon which final conclusions were based and is the primary focus of this review. The reports were obtained from the USBR in Salt Lake City, Utah.

Parts of the original material were missing from copies of the first two reports that were examined, "An Evaluation of Hydrogeology of the Proposed Jordanelle Reservoir - Draft Report", December 31, 1982, and "A Hydrogeologic Evaluation of the Proposed Jordanelle Reservoir - Final Report", July 1, 1984. The last report, "A Hydrogeologic Evaluation of the Proposed Jordanelle Reservoir, Utah", February 9, 1987 was complete with figures and appendix. The USBR contractor, Uintex Corporation, no longer exists; thus, a review of supporting information and data was not possible. In this review, the three reports will be referred to as Uintex Corp., 1982, 1984, and 1987.

The conclusions of the USBR contractor concerning the potential for seepage from the proposed Jordanelle Reservoir into nearby mine workings were based on values of hydrologic properties determined from field investigations and on results from a computer model of ground-water flow in aquifers underlying the proposed reservoir and mined area. Neither the input data for the model nor any of the computer simulations run by the contractor were available for review. In particular, only general information about the model is described in the final report. The values for transmissivity, horizontal hydraulic conductivity, vertical hydraulic conductivity, hydraulic heads and/or flux assigned to boundaries, and evapotranspiration rates are known only on an area-wide basis. Because the model is described as having only one layer, the reason for specifying values for vertical hydraulic conductivity in the model are unknown to the USGS reviewers.

The conclusions drawn in the first two reports (Uintex Corp., 1982 and 1984) were founded on less information and data than the conclusions in the final report (Uintex Corp., 1987); thus, their conclusions differed somewhat from the conclusions in the final report. Conclusions from the third and final report (Uintex Corp., 1987) are:

1. Near land surface, the hydraulic conductivity of the Weber Quartzite and the Keetley Volcanics is less than 2.7 feet per day; values are much smaller at depth.

2. Average hydraulic conductivity of the Ross Creek Alluvium is less than 0.22 foot per day.

3. Hydraulic conductivity of the Silver Fissure and the Provo River Valley Alluvium is greater than 27 feet per day. The aquifers in the mined area have an estimated hydraulic conductivity of 2.1 feet per day.

4. There is no evidence that flow through fissures between the mined areas and the area of the reservoir either exists or does not exist.

5. The proposed reservoir may increase seepage of ground water into the Mayflower Mine by about 50 gallons per minute after it is filled, but seepage to the mine will be less during filling of the reservoir.

6. Mines that are developed closer to the reservoir will require less pumping to dewater than the mines that now exist because they are farther from the ground-water reservoir to the west and because the reservoir will decrease the average slope of the potentiometric surface.

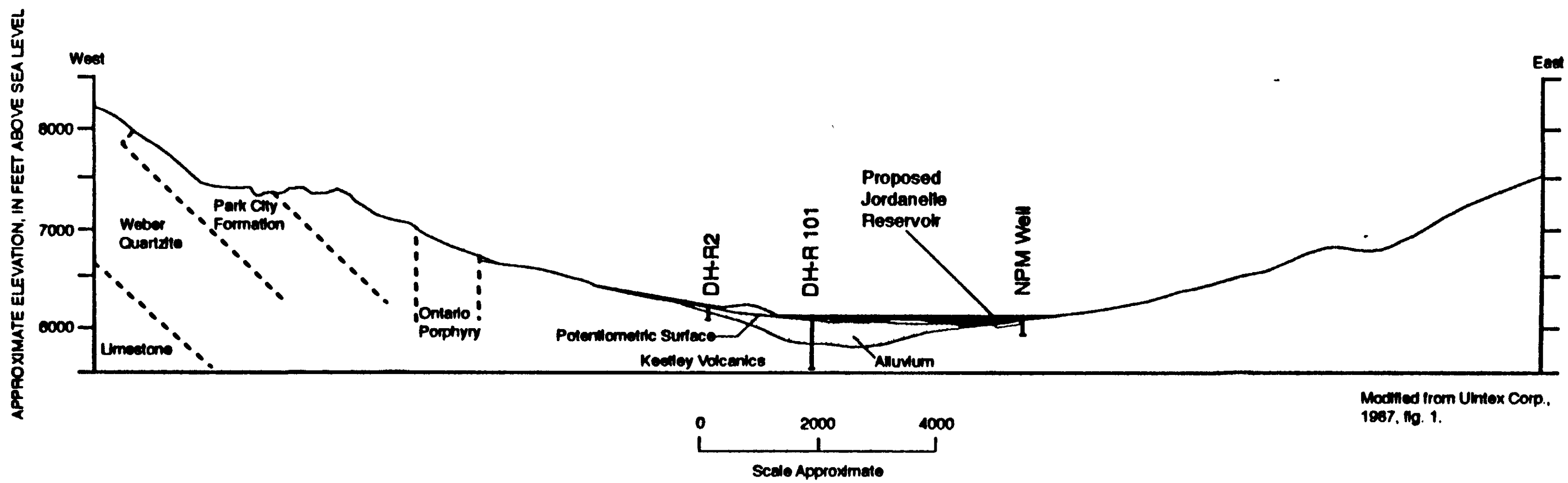
7. The mines in the Park Premier area east of the reservoir will be inundated because the surface opening to the mines lies below the reservoir-full elevation of 6,170 feet above sea level.

3.2 Assessment Of Conclusions

To assess the accuracy of the conclusions reached by the USBR contractor, four processes will be evaluated: (1) How the hydrologic system was conceptualized, (2) the origin of the hydrologic property values used to conceptualize and ultimately simulate the hydrologic system, (3) how the model was developed and calibrated, and (4) how the model was used to simulate the reservoir and its effect on seepage into mines. The evaluation will be organized in the same way that the contractor's last report was presented. A brief summary of each aspect of the contractor's report will be followed by an assessment of the technical accuracy of the conclusions related to that aspect.

3.2.1 Summary and review of aquifer geometry

The USBR contractor conceptualized the ground-water-flow regime areally as six different, but hydraulically connected, hydrogeologic systems. Beneath the reservoir area, geometry of the aquifers is complex and is poorly understood (fig. 3.2.1-1). Development of mine tunnels has allowed a slightly better understanding of subsurface geology and structure west of the proposed reservoir. West of the proposed reservoir, two hydrogeologic systems were depicted as having the same areal extent as the two principal geologic formations, the Weber Quartzite and the Mayflower-Ontario Porphyry that exist at the level of Ontario Drain Tunnel No. 2 at 6,300 feet above sea level. Both hydrogeologic systems include smaller amounts of other formations (Park City Formation, Round Valley Limestone, and Valeo Porphyry). A third hydrogeologic system, the mine system, was delineated in the area where mining had previously taken place west of the reservoir area. This system, mostly consisting of the same rocks that are in the Weber Quartzite and Mayflower-Ontario systems, and other formations (Doughnut Formation, Humbug Formation, and Deseret Limestone), was assumed by the contractor to be hydrologically different from the other two systems to the west of the reservoir because of the extensive tunneling. The three remaining systems are near and underlie the proposed reservoir and were depicted as having the same areal distribution as the Ross Creek Alluvium, the Provo River Valley Alluvium, and the Keetley Volcanics as they are mapped at land surface.



Modified from Uintex Corp., 1987, fig. 1.

Figure 3.2.1-1--Generalized section from west to east across study area.

The delineation of different systems on the basis of geology is valid especially if hydrologic properties differ substantially between formations, and ground-water flow within and between systems must be represented differently in a computer simulation of these systems. On the basis of the contractor's description of the complex geologic structure and the presence of igneous intrusions within a faulted and dipping sedimentary sequence (Uintex Corp., 1987, p. 7-8), the division of the hydrologic system into six units that do not vary vertically is not sufficient. Faulting and associated fractures and variations in lithologic character of the rocks both laterally and vertically indicate that the geometry of the aquifers needs to be conceptualized in three dimensions rather than two, in order to adequately represent the system in a computer simulation.

3.2.2 Summary and review of aquifer properties

This section discusses the number of permeability and aquifer tests obtained in each hydrogeologic system, location of the test sites, and the methods used to derive the values. The contractor presented results of field permeability tests performed in 52 boreholes, results from 2 aquifer tests for which wells were drilled and pumped, and 3 aquifer tests using recovery data in mine shafts. Boreholes used for permeability tests are in the reservoir area and the hillsides close to the reservoir area. The pumped wells used for aquifer testing were on the west shore of the proposed reservoir approximately 1,000 feet apart. After pumping to dewater mines ceased, water levels were monitored in the West End Shaft and Ontario No. 3 Shaft, located about 20,000 and 10,000 feet west of the Mayflower Shaft, respectively. Analyses for the aquifer tests were done using curve matching with the Theis curve (Lohman, 1972, p. 15-19).

3.2.2.1 Weber Quartzite system

The Weber Quartzite system consists of the Weber Quartzite, the Park City Formation, the Round Valley Limestone, and igneous stocks that contain interconnected fracture zones. The USBR contractor determined typical horizontal hydraulic-conductivity values either by field testing or by estimation. The value for horizontal hydraulic conductivity of the Weber Quartzite system was based on results from one aquifer test using one pumped well and one observation well in the Weber Quartzite (Uintex Corp., 1987, Appendix A). On the basis of an aquifer thickness of 233 feet, matching the Theis curve with drawdown data in the observation well collected from 800 to 2,000 minutes into the test resulted in a hydraulic conductivity of 1.5 feet per day. Drawdown data from 7,000 to 40,000 minutes into the aquifer test plotted above the Theis curve, and this deviation was thought to be caused by the existence of an impermeable boundary about 1,000 to 1,300 feet away from the pumping well. Vertical hydraulic conductivity was assumed to be the same as horizontal hydraulic conductivity. Independent results from borehole permeability tests in holes DH-R5, DH-R6, and DH-R118 indicated that the horizontal hydraulic conductivity of the Weber Quartzite-Mayflower Stock ranged from 0.01 to 1 foot per day.

Depicting the Weber Quartzite system as a hydrologic unit with uniform horizontal and vertical properties is not appropriate. The "unit" consists of several formations with different lithologic character. In the unit, the Weber Quartzite is the most highly fractured. The lithologic character and degree of fracturing varies laterally and with depth; thus it is likely that values for hydrologic properties vary in the same way. From the description given in the third report (Uintex Corp., 1987, p. 12), most ground water probably moves through the fractures in this system; thus the validity of the assumption that a continuum exists depends on how uniformly distributed the fractures are and how well they are interconnected.

The validity of the data collected for the aquifer tests is uncertain. During the pumping and recovery periods of the test, observation wells completed in the Weber Quartzite, the Keetley Volcanics, and the overlying alluvium were monitored. Rises and declines of water levels in all wells except one were erratic and seem unrelated to the pumping. Water levels in the one observation well that was used for the analysis fluctuated during the recovery period and rose about 2.5 feet higher than the prepumping trend right before pumping started. Reasons for these fluctuations are unknown.

The aquifer-test analysis is probably not appropriate. On the basis of the water-level changes shown in hydrographs (Uintex Corp., 1987, Appendix F) from wells that are open to both the shallow alluvium and deeper bedrock, the use of analysis methods for leaky-artesian aquifers would have been better suited than the method that was used for obtaining aquifer properties. Water levels in the alluvial material rose soon after precipitation. Water levels in bedrock aquifers also rose in response to precipitation after a time delay of as long as one month. This indicates either slower vertical movement of water in the bedrock or a poor connection between bedrock and alluvium. Using methods of analysis for nonleaky aquifers, as the contractor did, may yield order-of-magnitude errors in transmissivity and storage-coefficient values (Lohman, 1972, p. 34).

The deviation from the Theis curve for the plot of drawdown versus time in the observation well was thought by the contractor to be the result of an impermeable boundary. This is one possibility; however, the deviation could also be caused by a change from radial flow to the pumped well to linear flow along a fracture zone. This possibility needs to be considered. If the aquifer-test results indicate fracture flow, the hydraulic-conductivity values for distinct fracture zones calculated from test results could be much different from values reported by the contractor, thus substantially changing the calculated quantity of seepage to mines.

The hydraulic-conductivity value used to represent about 5 square miles of the Weber Quartzite system was determined from one aquifer test located near the east edge of the system. It is unknown if a value derived from one point in the aquifer is representative of the entire Weber Quartzite system, parts of which are about 4 miles from the test location.

3.2.2.2 Mayflower-Ontario system

The Mayflower-Ontario system consists of the Mayflower, Ontario, and Valeo Porphyrys and the Weber Quartzite. No aquifer tests for this system were performed. A study by Villas (1975), which yielded values as large as 27.5 feet per day for hydraulic conductivity from laboratory fracture analyses, was not used. The contractor judged that laboratory values were larger than field values because fractures on a larger scale do not connect and transmit water. The value for horizontal hydraulic conductivity in the Mayflower-Ontario system was assumed to be identical to that of the Weber Quartzite system, 1.5 feet per day. Values for hydraulic conductivity obtained by Villas (1975) are real, but their applicability for aquifers in this case is unknown. Values need to be obtained from aquifer tests using wells completed in this system.

3.2.2.3 Mine system

Formations included in the area defined as the mine system include all of the same formations that are part of the Weber Quartzite system, the Mayflower-Ontario Porphyry system, and other units such as the Doughnut Formation, the Humbug Formation, and the Deseret Limestone. The hydrologic properties of the rocks that have been mined since 1868 were assumed by the contractor to differ from the properties of rocks that have not been mined. Transmissivity of the Weber Quartzite in the mined area was estimated to be 990 feet squared per day, and the hydraulic conductivity was estimated to be 2.1 feet per day on the basis of a Theis-curve analysis of the water-level recovery in mine shafts after pumping ceased in June 1949 and April 1950. Transmissivity of the Doughnut Formation, the Humbug Formation, and the Deseret Limestone was estimated to be 130 feet squared per day, the hydraulic conductivity was 0.14 foot per day, and the storage coefficient was 0.013 (Uintex Corp., 1987, fig. B-3, Appendix B), on the basis of a Theis-curve analysis of water-level recovery in mine shafts after pumping ceased in April 1982.

On the basis of the analysis of recovery data, the hydraulic conductivity of the Doughnut Formation, the Humbug Formation, and the Deseret Limestone is more than one order of magnitude smaller than that of the Weber Quartzite. This difference and the known diversity in the type of rock present indicate that the mine system is not uniform either laterally or vertically; thus, the system cannot be considered a single hydrologic unit having uniform hydrologic properties.

The analysis of the recovery data from the mine shafts was based on the Theis curve-matching method for a nonleaky aquifer. Using methods based on curves for leaky aquifers would have been more appropriate. Using a less appropriate method of analysis may result in a larger margin of error for transmissivity and hydraulic-conductivity values. The value for storage coefficient shown on Figure B-3 in Appendix B (Uintex Corp., 1987) is 0.013. Recalculation indicates that this value should have been 0.0019 on the basis of the information shown.

Although two aquifer tests cannot provide a comprehensive lateral or vertical distribution of hydrologic properties for the mine system, they do give an example of the difference in values one can expect between different formations. This points out that it was not appropriate to delineate an area that includes many different formations into a single hydrogeologic unit represented by uniform values for hydrologic properties.

3.2.2.4 Ross Creek alluvial system

The Ross Creek alluvial system includes the Ross Creek Alluvium and, according to borehole logs, is underlain by Keetley Volcanics. The Ross Creek Alluvium includes alluvial and colluvial materials ranging in size from clay to gravel. Borehole logs show no distinguishable stratigraphic correlation. Horizontal hydraulic conductivity of the Ross Creek alluvial system was reported to be 0.2 foot per day and vertical hydraulic conductivity was reported to be 0.04 foot per day (Uintex Corp., 1987, Table 3.4). Hydraulic conductivity of the Ross Creek Alluvium was an average of values from field-permeability tests performed by the USBR in 25 boreholes, distributed over the area where the alluvium exists (Uintex Corp., 1987). Standard USBR test methods were used (USBR Groundwater Manual, 1985, p. 247-248), and may have included pressure tests, constant-head gravity tests, or falling-head gravity tests. All of the methods are considered by USBR to yield semi-quantitative values for permeability. It was not stated by the contractor which of the three test methods were used to obtain the values reported.

As a unit, the Ross Creek alluvial system lacks areal uniformity, and thus would be difficult to represent with a single uniform value for hydraulic conductivity. A single value for hydraulic conductivity also is inappropriate to represent the aquifer in the vertical direction because the Ross Creek Alluvium is underlain by the Keetley Volcanics and both are part of the aquifer in the area of the Ross Creek alluvial system. From the test results shown in graphs in Appendix B of the third report (Uintex Corp., 1987), horizontal hydraulic conductivity of the Ross Creek Alluvium ranges from 0 to 7 feet per day. Thickness-weighted values (Uintex Corp., 1987, table 3.2) for the same holes that are shown in Appendix B range from 0 to 2.8 feet per day. Thickness-weighted values for 9 additional holes, not shown in Appendix B, range from 0 to 3.2 feet per day. The thickness-weighted value for hydraulic conductivity for each borehole was calculated as the sum of the hydraulic conductivity of each layer times the tested thickness divided by the total tested thickness of the borehole. Mean vertical hydraulic conductivity of a borehole was calculated as the sum of the reciprocal of horizontal hydraulic conductivity of each layer times the thickness of the layer divided by the total tested thickness of the borehole. The physical basis for calculating vertical hydraulic conductivity is not clear, and therefore, the accuracy of values derived by this method is unknown.

The locations of the boreholes are such that an adequate sampling of the Ross Creek alluvial system was obtained. The values obtained from the field tests should give a good picture of the variability that can be expected in the alluvial material even though the actual values are semi-quantitative.

3.2.2.5 Provo River Valley system

The Provo River Valley system includes the Provo River Valley Alluvium and, according to borehole logs, is underlain by consolidated rock. The Provo River Valley Alluvium includes clay- to gravel-size material. Horizontal hydraulic conductivity of the Provo River Valley Alluvium was reported to be 41.9 feet per day, and vertical hydraulic conductivity was reported to be 27.7 feet per day (Uintex Corp., 1987, table 3.3). These values were derived from field-permeability tests in 16 boreholes drilled by the USBR. A value for each borehole was obtained from a thickness-weighted average of all test values for the borehole. Thickness-weighted average hydraulic conductivity for the boreholes shown in table 3.3 of the third report (Uintex Corp., 1987) range from 0 to 132.9 feet per day (horizontal) and 0 to 114.8 feet per day (vertical).

The 16 boreholes used for estimating hydraulic conductivity are in one part of the river valley, near the damsite, rather than distributed throughout the length of the river valley where the Provo River Valley Alluvium exists. If there is any areal lithologic variability in the alluvium, it will not be represented accurately by the average values obtained from the damsite boreholes.

Generally, sediments deposited by alluvial processes have a horizontal hydraulic conductivity that is many times larger than the vertical hydraulic conductivity. For the Provo River Valley Alluvium, the vertical hydraulic conductivity of less than one half the horizontal hydraulic conductivity appears to be inconsistent with this concept. Because vertical hydraulic conductivity is important to describing seepage from the reservoir, this value needs to be more accurately defined using aquifer tests designed for this purpose.

3.2.2.6 Keetley Volcanics system

The Keetley Volcanics system consists of the Keetley Volcanics, which contain fractures. Hydraulic conductivity of the Keetley Volcanics system is variable. Field permeability tests in 49 boreholes in the reservoir area yielded thickness-weighted values ranging from 0 to 2.6 feet per day (Uintex Corp., 1987, table 3.2 and 3.3). From these tests, the contractor concluded that the mean horizontal hydraulic conductivity of the Keetley Volcanics near the damsite was 0.85 foot per day; on the hillsides adjacent to the damsite mean hydraulic conductivity was 0.71 foot per day; and in the Ross Creek drainage mean hydraulic conductivity was 1.2 feet per day. Results from 1 aquifer test, located near the west edge of the reservoir area, yielded a horizontal hydraulic-conductivity value of 0.4 foot per day, based on the Theis curve-matching method and an aquifer thickness of 180 feet.

The drawdown data from the aquifer test deviate above the Theis curve after about 2 hours of pumping, and after about 8 hours these data form a straight line on the log-log plot that has a graphic slope of approximately one half. This could be caused by an impermeable boundary somewhere near the test site, but this pattern is also indicative of fracture-flow systems. The possibility of fracture flow needs to be examined to determine if the hydraulic-conductivity value of 0.4 foot per day is reasonable for the entire area. In addition, values derived assuming a nonleaky aquifer (Theis curve-matching procedure) could be in error by an order of magnitude because the system appears to fit the criteria for a leaky artesian aquifer more closely.

The distribution of boreholes is adequate for defining the areal variability of hydrologic properties in the Keetley Volcanics, but the accuracy of the individual values obtained is unknown.

3.2.3 Summary and review of fracture-flow analysis

The USBR contractor evaluated the concept of flow through a discrete zone of fracturing, termed fissures by the contractor (with a large hydraulic-conductivity value), rather than through an area-wide porous medium. Hydrologic properties for a hypothetical fracture zone connecting the Mayflower Shaft with the reservoir area were based on values derived from analysis of a known fracture zone in the mined area. The contractor determined that the increase in flow through a hypothetical fracture zone after the reservoir was filled would be no more than 55 gallons per minute.

Fracture flow as hypothesized by the USBR contractor could be larger or smaller. The entire analysis is based on measurements of one fissure and the assumption that the same attributes apply to other hypothetical fractures. Reliable estimates cannot be made without knowing the geometry and hydraulic properties of specific fractures. Further, the maximum increase of 55 gallons per minute was based on a distance of 12,000 feet between Ross Creek and the Mayflower Shaft and an identical distance of 12,000 feet between the reservoir and the Mayflower Shaft. The areal extent of the reservoir will be substantially greater than that of Ross Creek. In places the shore of the reservoir could be 4,000 to 5,000 feet nearer the shaft than is Ross Creek. If the difference in flow to the shaft is recalculated on the basis of a fracture length of 8,000 feet instead of 12,000 feet, then the increase in flow to the shaft may be as large as 220 gallons per minute per fracture.

3.2.4 Summary of system conceptualization and model development and calibration

In order to develop a representative model of a ground-water-flow system, a concept of how that system functions must first be formulated. The conceptualization needs to include identification and definition of the aquifer properties, hydrologic boundaries, and a definition of the direction and rate of ground-water movement through that system. Boundaries that are most easily represented in a mathematical model would include flow lines; ground-water divides where transverse flow is zero; streams, drains, or canals where a nonvarying hydraulic head or flow rate can be determined; or a water-table surface. The distribution of areal recharge at the water-table surface also needs to be defined.

The water-level contour map constructed by the USBR contractor (Uintex Corp., 1987, fig. 14) indicates that ground water moves from the areas of highest elevation on the margins of the drainage basin toward the valleys formed by the Provo River, Ross Creek, and various tributaries. The main source of recharge to the ground-water system is precipitation that primarily infiltrates high in the surrounding mountains. Some recharge probably occurs from precipitation at lower elevations and from streamflow losses. No estimate was made of the quantity of recharge or how recharge is areally distributed over the study area. Local recharge along parts of streams is suspected because streamflow losses were observed during field investigations by the contractor, and not all the losses were thought to be a result of evapotranspiration. Water levels in wells in the study area fluctuate seasonally in response to recharge. Water levels in alluvial wells respond more rapidly and with greater magnitude than water levels in bedrock wells. Water levels in near-stream wells change when streamflow changes. Water levels in hillside wells change in response to snowmelt.

Natural discharge from the ground-water system was identified as evapotranspiration in areas of phreatophyte cover, discharge of springs and seeps, and seepage to gaining reaches along Ross Creek. Discharge, from seeps just upstream from the damsite, is estimated by the contractor to exceed 1,000 gallons per minute. Additional discharge occurred intermittently because of pumping for the purpose of dewatering mines. Since mining ceased and pumping from Ontario Shaft No. 6 was stopped in 1982, the only discharge from the mines is natural drainage from Ontario Drain Tunnel No. 2 with a portal elevation of about 6,300 feet above sea level. In September and October of 1983, the USGS measured discharge at the tunnel portal. Measurements were 9,560 and 9,610 gallons per minute. More recent measurements were not mentioned in the report.

The model developed to simulate this ground-water-flow system was based on the model code developed and documented by Prickett and Lonnquist (1971). The model conceptualized by the USBR contractor consists of one layer having a rectangular area about 5.8 miles east to west and 3.2 miles north to south (fig. 3.2.4-1). The area includes a large part of the area to be inundated by the proposed Jordanelle Reservoir. The model area extends beyond the drainage divide to the west and south, but the model area does not extend beyond the drainage divide on the north and east.

For modeling, head values for the proposed reservoir area were assigned on the basis of the water-level contour map for the area and the elevation of the reservoir when filled (Uintex Corp., 1987, fig. 14). Head values for the area west of the proposed reservoir were assigned elevations equal to the elevation of Ontario Drain Tunnel No. 2 (6,300 feet). All perimeter boundaries of the modeled area were designated constant heads (Uintex Corp., 1987, Appendix G). Constant heads made up about one-fifth of all nodes in the model. In a model, constant-head nodes allow inflow or outflow to take place based on the difference in the head in adjacent nodes and the constant-head nodes. Constant heads also were assigned to nodes representing drain tunnels, rivers, and the area where the Provo River Valley Alluvium exists.

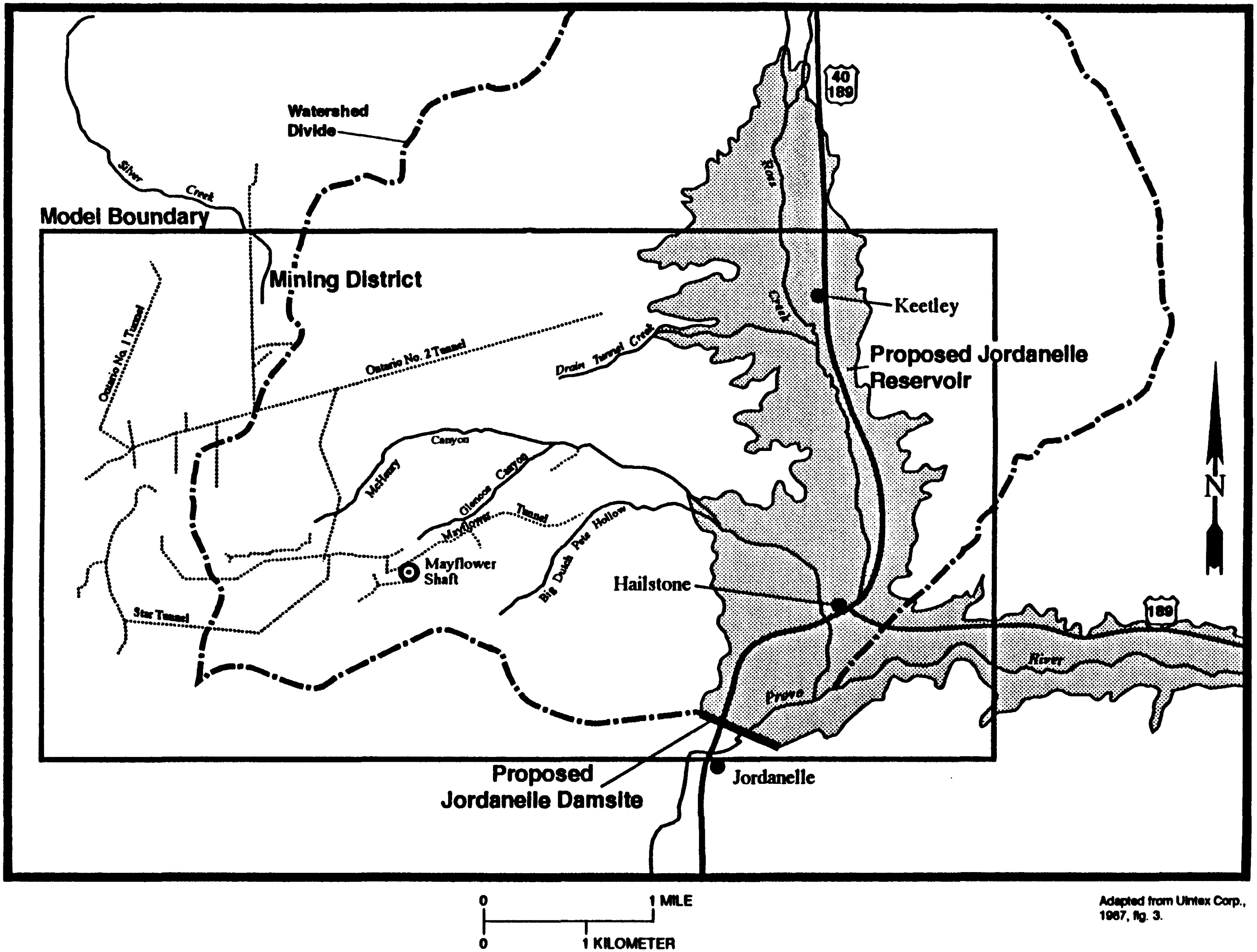


Figure 3.2.4-1--Boundary of the ground-water-flow model used to determine seepage to mines.

The model was run only in steady-state mode; thus, transient response and storage effects were not considered. The model was "calibrated" by adjusting hydraulic-conductivity values until a model node representing the Mayflower Shaft at a constant head of 4,400 feet allowed discharge approximately equal to the average pumping rate that had been required to dewater the shaft to a level of 4,400 feet during mining operations. The model was run first using hydraulic-conductivity values derived from field tests and best estimates; second using hydraulic-conductivity values one order of magnitude smaller than field tests and best estimates; and third using a uniform value of 0.15 feet per day for hydraulic conductivity.

Based on the three alternative hydraulic-conductivity arrays used to simulate constant-head flow to the node representing the Mayflower Shaft, the USBR contractor concluded that using a smaller uniform value for hydraulic conductivity resulted in constant-head flow to the shaft node that most closely approximated estimated pumping from the Mayflower Shaft (3,000 gallons per minute), and that using values of hydraulic conductivity derived from field investigations resulted in simulated flow that was much larger than actual pumping from the shaft. If the shaft were closer to the reservoir, at its east edge, the rate of pumping needed would be less than the rate used at the Mayflower Shaft.

3.2.5 Review of system conceptualization and model development and calibration

Because the criteria for calibration only involved balancing the outflow from one node that represented pumping, the contractor failed to consider other equally important natural components of the hydrologic system, which are essential for model calibration and confidence in model results. These components are areal recharge, subsurface underflow from areas outside the model boundary, and discharge to streams, springs, and seeps, and to phreatophyte areas.

Identification and definition of the hydrologic boundaries of the ground-water-flow system are incomplete. The upper boundary, the surface representing the transition from unsaturated to saturated material, is typically defined by a water-table contour map or the structure contour map of the top of the geologic layer that contains the ground water. The water-level map provided includes only the area near the reservoir. The lower boundary was arbitrarily assumed to be a no-flow boundary at a level of 4,200 ft. The great vertical variation in lithologic character and fracturing and the presence of water at greater depths in mines indicates that this assumption may be incorrect. Most importantly, the perimeter of the model, rivers, drain tunnel, and the Provo River Valley Alluvium are arbitrarily defined to be constant-head boundaries.

The constant-head boundaries prevent heads from responding appropriately to stresses. Mine dewatering could cause actual heads to fluctuate significantly in the areas where constant heads are specified. Likewise, the filling of the reservoir would likely change heads in regions that are modeled as constant heads. The use of constant-head nodes to simulate the Ontario Drain Tunnel No. 2 is a major concern because of its proximity to the Mayflower Mine. The dewatering at the mine causes a very steep head gradient between the drain and the mine in the model. Because of the constant head, the cone of depression cannot extend beyond the drain.

The inappropriate use of constant heads can also cause incorrect flows in the model. The drawdown in the mine would cause a considerable quantity of water to be induced from the constant-head drain and parts of the model perimeter. No mention was made of checks to see if the quantity of leakage from the drain and increased flow across the perimeter were reasonable. Such checks are important to ensure that the constant-head boundary does not supply more water than is actually available in the physical system.

The constant-head boundary at the model perimeter is substituting for areal recharge, which is the natural source for most of the water flowing through the system. Instead of simulating the recharge that infiltrates in upland areas and alluvial material, the constant-head boundaries are supplying the water that flows through the modeled system. Recharge depends primarily on the quantity of precipitation whereas flow from constant-head nodes depends on hydraulic conductivity and head gradient; therefore, it is impossible for the constant-head boundaries to supply the correct quantity of recharge under all the conditions being simulated.

Further, even under natural conditions, the model was not calibrated on the basis of total flow through the system. Calibration was based entirely on seepage to the mines, which is a small fraction of total flow through the modeled region. It is possible, especially considering the large number of constant-head nodes, to have a model that produces correct heads without having the correct flows. If flows as a whole are incorrect, then hydraulic-conductivity values are also incorrect. As a result, any predictions based on the model would be meaningless.

The one-layer model does not consider vertical flow. Because the consolidated rocks are highly fractured, because water-level hydrographs show different response times to areal recharge, and because the formations vary with depth, especially under the reservoir area, an understanding of vertical flow in this hydrologic system is critical to determining the quantity of seepage into existing and hypothetical new mines. A model simulating only one layer cannot adequately represent this complex system.

3.2.6 Summary and review of computer simulations

The way in which the model was conceptualized and developed causes all subsequent computer simulations to be an unsuitable foundation on which to draw conclusions about seepage to mines. For example, the conclusion that flow to a hypothetical shaft placed at the east edge of the reservoir would be less than flow to the Mayflower Shaft, several thousand feet from the reservoir, is a manifestation of the way in which the boundaries of the model were represented. The computer simulations are based on a set of assumptions, hydrologic-property values, and flow conditions that are not representative of actual ground-water conditions in the studied area. The potentially significant flaws include:

1. Areal recharge to the ground-water system is not simulated.
2. Constant heads are used inappropriately.
3. Calibration is inadequate.
4. Hydrologic properties of all formations are simulated as being identical.
5. Vertical ground-water flow is not simulated.

Model parameters were also entered and run in another modeling program, MODFLOW (McDonald and Harbaugh, 1984) to see how results from the two modeling programs compared. When the same set of model input data were run in the second ground-water modeling program, differences in predicted head occurred. The contractor attributed these differences to a breakdown of the prediction equation for a single well. There are probably some variations in how the data are assembled and put into each of the models, but a difference of "less than 15 percent" in predicted heads is a significant difference. The reasons for the difference need to be determined in order to be able to have confidence in the results from either model.

3.3 Summary Of Model Uncertainties

There are uncertainties inherent in all the conclusions related to uncertainties in general hydrogeology, fracture flows, and seepage flows. These uncertainties are summarized as follows.

A. The estimates for hydraulic-conductivity values for the aquifers are uncertain for the following reasons:

   1. Vertical flow between units is highly likely, but the aquifer tests were analyzed using the assumption that flow is horizontal with no vertical leakage.

   2. When analyzing aquifer tests, it is assumed that fractures in the consolidated materials are evenly distributed.

   3. The aquifer-test data presented contain many anomalies and complexities that were not addressed.

   4. The calculated values of hydraulic conductivity are not consistent with the values that gave good results in the model. Model values are at least an order of magnitude smaller than the values calculated from aquifer tests. The inconsistencies may be the result of uncertainties in the model that are described below, or the inconsistencies may be the result of the difficulties of analyzing data in the complex geologic environment.

B. Estimates of flow through fractures are uncertain because the estimates are based on measurements at one location. The distribution and characteristics of fractures probably vary significantly from location to location.

C. The estimates of seepage to a new mine located close to the reservoir and the increased seepage to the existing mines caused by the reservoir are based on a model that is oversimplified; thus, these estimates and all the resulting conclusions probably are not valid. The major uncertainties introduced by this oversimplification include:

   1. The one-layer model does not account for vertical flow in the geologically complex system. Vertical flow is likely to be an important factor in determining mine seepage, especially for mines near the reservoir.

2. The model boundary does not coincide with natural hydrologic boundaries, and a constant head is specified along all of the model boundary. The constant head along the boundary overly constrains heads throughout the model.
3. The constant-head boundary is used to supply recharge to the simulated area instead of directly simulating areal recharge or constant flow from the mountainous area to the west.
4. The model is calibrated only on seepage to the mines. There is no assessment of overall flow through the system.
5. Although the base of the system is assumed to be flat, and arbitrarily located, the lithologic units have substantial slopes. The units extend to much greater depths than simulated by the model.
6. The model was tested by constructing a second model using the same data but using a different model program. Although the two model programs might be expected to produce similar results, there were significant differences.

IV SUMMARY

Questions have been raised concerning the adequacy of water supplies to fulfill the needs of storage, exchanges, diversions, and instream flows, pursuant to existing water rights in the Provo River drainage basin part of the Bonneville Unit of the Central Utah Project (CUP). Concern also has been expressed about the potential for seepage of water from Jordanelle Reservoir to underground mines. The Utah Congressional Delegation requested that the USGS review the work of the USBR to address these concerns. The scope of the USGS review focused on water demands, water utilization studies, and models of seepage from Jordanelle Reservoir.

USBR municipal and industrial water-demand calculations for Salt Lake County were checked against other water demand studies for Salt Lake County. The USBR used increasing per capita water use rates of 0.28-0.33 acre-feet per capita in their calculations. This approach is a conservative one and probably maximizes water use. Other studies are based on a use rate of 0.25 acre-feet per capita and have assumed implementation of water conservation measures. These studies result in smaller projections of water demand. If the lower per capita use rates are achieved the municipal and industrial water supply from the CUP will be able to meet demands farther into the future.

Approximately 12,100 acre-feet of supplemental-irrigation water will be supplied annually to the Heber area by the CUP. Supplemental-irrigation demands are calculated on the basis of consumptive-use studies, historical supplies, shortage criteria, and irrigated acreage. The USBR calculates irrigation demands of 3.60 acre-feet per acre and the Utah Division of Natural Resources calculates demands of 3.58-4.91 acre-feet per acre. The differences in irrigation demands calculated by the two studies are the result of different crop requirements and efficiencies.

The USGS reviewed three principal USBR water utilization studies: the Provo River Project Operations Study, the Provo River Surplus Flow Study, and Jordanelle Reservoir Operation Study. The purposes of the studies were to model the water distribution within existing water rights of the Provo River Project, to determine the surplus or storable water available for use by the CUP, and to demonstrate the adequacy of the planned project water supply to satisfy the CUP demands and existing water rights.

The Provo River Project Operations Study is a 36 column water accounting program developed to insure all water rights senior to the CUP water rights are satisfied. The Weber River Divertible Flow Study and Duchesne River Divertible Flow Study determine the quantity of water that can be diverted from the Weber and Duchesne Rivers to the Provo River. This study is the major input for the Provo River Project Operation Study. The unmodified flow of the Weber River at Gateway was incorrectly computed in the Weber River Divertible Flow Study. The data in the columns checked in the Weber River Divertible Flow Study were correct within the rounding errors. The Duchesne River Divertible Flow Study was unavailable for this review. The review determined that the Provo River Project Operation Study accounted for all water rights senior to the CUP and realistically distributed the water with several minor exceptions.

The Provo River Surplus Flow Study (USBR, 1976; reference 38d) determined the Provo River streamflows that are available for use by the CUP Project. The surplus flows are determined as the quantity of water that is in excess of rights above Utah Lake, measured at Olmsted Diversion Dam. The review checked the accounting in the program and the data and determined that the surplus stream gains below Deer Creek Dam and surplus flows at Deer Creek Dam were calculated correctly. These flows will be the primary source of water for Jordanelle Reservoir. The USGS review did not consider the draft water distribution plan for the Utah lake drainage basin proposed by the Utah State Engineer (written commun., October 15, 1991). This plan, when finalized, may have an affect on water availability to the CUP.

The Jordanelle Reservoir Operation Study simulates the operation of the proposed Jordanelle Reservoir for the 1930-73 base period. The intended design of the study was to operate Jordanelle Reservoir to meet all existing water rights and to provide (1) an average annual water supply of 92,400 acre-feet of water for municipal and industrial purposes in Salt Lake, northern Utah, and Wasatch Counties; (2) 15,100 acre-feet of supplemental irrigation water to lands in the Heber-Francis area; (3) replacement storage for water now stored in the upper Provo River reservoirs and delivered below Jordanelle Reservoir; and (4) water to maintain streamflows of 125 cubic feet per second below Jordanelle to Deer Creek Reservoir, 100 cubic feet per second below Deer Creek Reservoir to the Olmsted Diversion Dam, and 25 cubic feet per second below the Olmsted Diversion Dam. The USGS review of the Jordanelle Reservoir Operation Study examined the logic and organization of the model and selectively checked and verified key data columns in the model.

Irrigation-return flows from the Heber–Francis area are accounted for only in the months when irrigation water is applied rather than when the irrigation-return flows actually arrive in the stream. This accounting could affect the water availability on a monthly basis.

The Jordanelle Reservoir Operation Study in the Supplement to the Definite Plan Report includes a section that discusses the effects of the USBR and Provo City agreement to allow Provo City to store 10,000 acre-feet of water annually in Jordanelle Reservoir. Several assumptions in this section are contradictory to the agreement between the USBR and Provo City. The reviewers suggest this section be revised to accurately reflect the agreement and that additional modeling be done to demonstrate the effect of the USBR-Provo City agreement on water available to the CUP.

Shortages to municipal and industrial water are a function of Jordanelle Reservoir contents and occur when Jordanelle Reservoir is initially filling. As would be expected, the quantity and duration of the shortages to municipal and industrial water are dependent upon climatic conditions when the reservoir is initially filling. Simulations were made for four selected periods with initial reservoir contents of 0 to demonstrate that the capability of the Jordanelle Reservoir and Bonneville Unit of the CUP to deliver the proposed water supply. Municipal and industrial shortages occurred only during the initial years following closure of the reservoir. The maximum time during simulation that shortages occurred following reservoir closure was 6 years, and in the other three simulation periods, shortages only occurred during the first 2 years. In actual operation, water will not be provided from Jordanelle Reservoir until the water is stored and available in the reservoir, thereby minimizing shortages when the reservoir is filling.

The average-annual simulated depletion to Utah Lake ranged from 17,800 to 156,200 acre-feet and averaged 85,600 acre-feet. The years when depletions are greater than average are important because of the large volumes of water that must be replaced in Utah Lake. In 15 of the 44 years simulated, the depletions exceeded about 100,000 acre-feet per year.

The USGS reviewers concerns about the Jordanelle Reservoir Operation study should not effect the overall conclusions pertaining to the storable water supply computed as part of the Provo River Surplus Flow Study and used as input to the Jordanelle Reservoir Operation Study model. The model could be modified to address the concerns so that the distribution of water for the intended uses at various points in the system can be accurately portrayed by the USBR for the simulated period.

In the review of the potential for seepage to underground mines, the USGS examined reports prepared by the Uintex Corporation. Uncertainties exist in the conclusions in these reports relating to general hydrogeology, fracture flows, and seepage flows. These uncertainties are summarized as follows.

Estimates for hydrologic properties are based on aquifer-test data whose validity is uncertain. Vertical flow of ground water through the geologic materials is highly likely, because of the fracturing, but aquifer-test analysis assumed only horizontal flow through porous media.

The estimates of seepage to a hypothetical new mine located close to the reservoir and the increased seepage to the existing mines caused by the reservoir are based on a model that oversimplifies a geologically complex system. The uncertainties in the validity of the model are due to inappropriate use of constant heads, lack of areal recharge, inadequate calibration, use of uniform values of hydrologic properties, and representation of the vertically complex system as a single layer. Without additional information and analysis, it cannot be determined if the seepage to the mines from the proposed reservoir, as projected in the investigation, is too small, too large, or accurate.

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38b	Provo River Project operation	July 1971 and 1975	1930-1973
38c	Provo River Project power replacement	July 1971 and 1975	1930-1973
38d	Provo River surplus flow	March 10, 1976	1930-1973
38e	Jacob-Welby irrigation exchange	March 17, 1976	1930-1973
38f	Salt Lake County municipal and industrial	August 1978	1930-1973
38g	North Utah County municipal and industrial	August 1978	1930-1973
38h	Heber and Francis area consumptive use	February 1969	---
38i	Francis area irrigation	November 12, 1975	1930-1973
38j	Upper Provo River Reservoir stabilization	November 2, 1977	1930-1973
38k	Jordanelle Reservoir operation	December 6, 1978	1930-1973
38l	Provo River fishery flow	March 13, 1979	1930-1973

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VI SUPPLEMENTAL INFORMATION

Table 6.0-1 Column descriptions for the Provo River Project Operation Study

[Column descriptions are from USBR, 1988f, Comments by USGS are shown in enclosed brackets]

Column 1--Weber River water divertible to the Provo River for storage and use under the Provo River Project. This column shows the total divertible flow to the Provo River Project as determined in the Weber River divertible flow study--Columns 11 + 13 + 15 + 18. [Column 1 flow is limited to flow available at the gaging station 10-128500 Weber River near Oakley, Utah.]

Column 2--Weber River winter power water stored in Echo Reservoir under the Weber River Project, Application No. 9568, pursuant to the provisions of the Power Contract, Provo River Project, Utah, dated December 20, 1938. The data for this column was determined in the Weber River divertible flow study--Column 12.

Column 3--Weber River winter power water diverted directly to Provo River at the Weber-Provo Diversion Dam pursuant to the provisions of the Power Contract, Provo River Project, Utah, dated December 20, 1938. Data determined in the Weber River divertible flow study--Column 11. [Same as column 1 until 50 percent of total power water has been delivered or until Echo Reservoir is full, whichever comes first.]

Column 4--Weber River water diverted to the Provo River by exchange to make a 50-50 division of all winter power rates accruing at and above Echo Reservoir. The balance is made by diverting to the Provo River, water surplus to prior rights that would normally be stored in Echo Reservoir—Column 13 of the Weber River divertible flow study. [Column 4 flow balances the Power Water account of the Contract of December 16, 1926.]

Column 5--Surplus water diverted to Provo River from Weber river at Oakley. This water is surplus to prior rights on the Weber River, or in the case of the Echo storage right, it is water that may be diverted when it is assured the Echo Reservoir will fill. Column 15 + 18 of the Weber River divertible flow studies, if it is all diverted. This water has fourth (last) priority to be diverted to the Provo River project.

Column 6--Total Weber River water diverted to the Provo River Project under Application No. 9569, equals the sum of columns 3, 4, and 5.

Column 7--Weber River water diverted to the Provo River under Application No. 12141. This water diverted to the Provo River for storage in Utah Lake when there is little or no capacity available in Deer Creek Reservoir. Diversions under this application were limited to the amount that would allow 30,000 acre-feet to be recovered from Utah Lake the following year after making reductions for conveyance and evaporation losses. [Delivered to Utah Lake in column 31.]

Column 8--Total water diverted from the Weber River, sum of Columns 6 and 7. [Column 8 flow does not include water diverted as shown in columns 9 and 16 of the Weber River Divertible Flow Study, that water is non-project water used in the Provo River drainage concurrently with its diversion from the Weber River.]

Column 9--Weber River divertible flows in excess of Provo River Project diversions, Column 1 minus Column 8.

Column 10--Duchesne River flows in excess of prior downstream rights, divertible to the Provo River Project under Application No. 12230. The maximum rate of diversion is 575 second-feet limited to 49,500 acre-feet per year. Data determined in the Duchesne River divertible flow study.

Column 11--Duchesne River flows diverted to the Provo River under Application No., 12230. Duchesne River flow is third in priority to be diverted to the Provo River.

Column 12--Duchesne River divertible flows in excess of the amount diverted, Column 10 minus Column 11.

Column 13--Total Weber River and Duchesne River diversion to the Provo River for storage in Deer Creek Reservoir, columns 6 and 11.

Column 14--Weber River and Duchesne River imported for storage in Deer Creek Reservoir that reaches the reservoir after making allowance for conveyance losses, Column 13 times 96 percent.

Column 15--Natural flow of Provo River at Deer Creek Dam--1921 to 1939 by correlation with natural flow of Provo River at Vivian Park plus flow of South Fork of Provo River at Vivian Park--1940 to 1949 is Provo River at Wildwood corrected for Weber-Provo Canal diversions, Deer Creek flow, and Deer Creek Reservoir operations--1950 to May 1953 by correlation with the natural flow of Provo River at Vivian Park--May 1953 to 1973 by adjusting the flow of Provo River below Deer Creek Dam for Weber-Provo Canal, Duchesne Tunnel, and Deer Creek Reservoir operations.

Column 16--Provo River flows surplus to rights above Utah Lake. These flows are storable in Deer Creek Reservoir by exchange if there is sufficient project water in Utah Lake to allow the exchange. The exchange is accomplished by water right Application Nos. 12151 [corrected 12141] and 12144. The water is second in priority to be diverted and used in the Provo River Project.

Column 17--Provo River flows surplus to all prior rights including Utah Lake that is storable in Deer Creek Reservoir under Application No. 16642. This has first priority.

Column 18--Provo River water surplus to all prior rights (Column 17) stored in Deer Creek Reservoir under Application No. 16642.

Column 19--Provo River decreed water stored in Deer Creek Reservoir under Change Applications, Nos. a-1902 and a-1903. These rights combined cover 9.33 second-feet for the April 15 to October 15 period not to exceed a total of 3,400 acre-feet.

Column 20--Provo River winter power water stored in Deer Creek Reservoir in exchange for project water held in Utah Lake under Application Nos. 12141 and 12144. The withholding of winter power water on the Provo River cannot exceed 10,000 acre-feet per year and in 10 progressive years 50,000 acre-feet as pursuant to the provisions of the Power Contract, Provo River Project, Utah, dated December 20, 1938. [The CUP has purchased the Olmsted Power Plant and accompanying water rights, therefore, the 1938 Power Contract is no longer applicable.]

Column 21--Provo River water surplus to prior rights above Utah Lake (Column 16) that is stored in Deer Creek Reservoir in exchange for project water held in Utah Lake under Application Nos. 12141 and 12144.

Column 22--Total Provo River Water stored in Deer Creek Reservoir, equals the sum of Columns 18, 19, 20, and 21.

Column 23--Total Provo River water stored in Deer Creek Reservoir, equals Column 15 minus Column 21 [corrected, 22]. [This flow is not stored but passes through Deer Creek Reservoir for downstream water rights.]

Column 24--Total Deer Creek Reservoir supply. equals the sum of Columns 14 and 22.

Column 25--Provo River project demand based on a project demand [of] 100,000 acre-feet annually distributed to reflect a future demand pattern involving greater municipal use than at present.

Column 26--Storage water released from Deer Creek Reservoir to satisfy the demands to the extent possible shown in Column 25.

Column 27--Project shortage or the demand on storage that could not be supplied, equals column 25 minus Column 26.

Column 28--Total evaporation loss from Deer Creek Reservoir based on an annual loss rate of 2.81 [2.66] feet [per acre] distributed as follows: October 0.19[0.18] feet, November 0.09 [0.07]feet, December 0.05 [0.03] feet, January 0.0 [0.02] feet, February 0.05 [0.03] feet, March 0.14 [0.13] feet, April 0.29 [0.27] feet, May 0.41 [0.39] feet, June 0.45 [0.44] feet, July 0.43 feet, August 0.38 feet, and September 0.29 feet. [The total evaporation loss and monthly distribution shown here is for Jordanelle Reservoir. The correct values were used in the Provo River Project Operation program.]

Column 29--Storage water released from Deer Creek Reservoir through the Deer Creek and Olmsted Power Plants necessary for the replacement of power losses on the Weber River resulting from the diversion of winter power water to the Provo River and the storage of winter power water in Echo Reservoir. Data determined in the Power Replacement Operation Study—Column 6. [The Olmsted Power Plant and water rights were purchased by the CUP; therefore, part of this storage water is now owned by the CUP.]

Column 30--Deer Creek Reservoir content at the end of the month, equal previous months Column 30, plus Column 24, minus Column 26, minus Column 28, minus Column 29.

Column 31--Weber River water diverted under Application No. 12141 storable in Utah Lake, equals Column 7 times 96 percent to allow for conveyance losses.

Column 32--Project return flows from project water used in Utah County that would flow into Utah Lake and be stored under Application No. 12144. The return flow is estimated as follows:

(1) Conveyance losses of water delivered through the Provo Reservoir Canal to Salt Lake County lands.

12 percent X 19,000 acre-feet = 2,280 [acre-feet]

(2) Conveyance losses of water used in Utah County.

12 percent X 31,475 acre-feet = 3,780 [acre-feet]

(3) Farm and municipal loss and waste of water in Utah County.

45 percent (31,475 acre-feet - 3,780 acre-feet) = 12,450 [12,460] [acre-feet]

Total losses to lake drainage = 18,610 [18,520][acre-feet]

Nonreproducible consumptive use - 51.6 percent= 9,610 [9,560][acre-feet]

Return flow to lake (annual acre-feet) = 9,000 [8,960]

Column 33--Total project inflow to Utah Lake, equals sum of Columns 29, 31, and 32.

Column 34--Total Provo River Project water recovered from Utah Lake, equals sum of Columns 20 and 21.

Column 35--Balance of Provo River Project water in Utah Lake, equals previous months balance plus Column 33 minus Column 34. Evaporation loss from project water that is stored in Utah Lake was computed at the end of September for each year by reducing the balance shown by 25 percent.

Column 36--Project water in Utah Lake lost to the Provo River Project is water would have caused the balance of project water in Utah Lake to exceed 30,000 acre-feet after making the reduction for evaporation at the end of September. [Water that exceeds project storage in Utah Lake.]

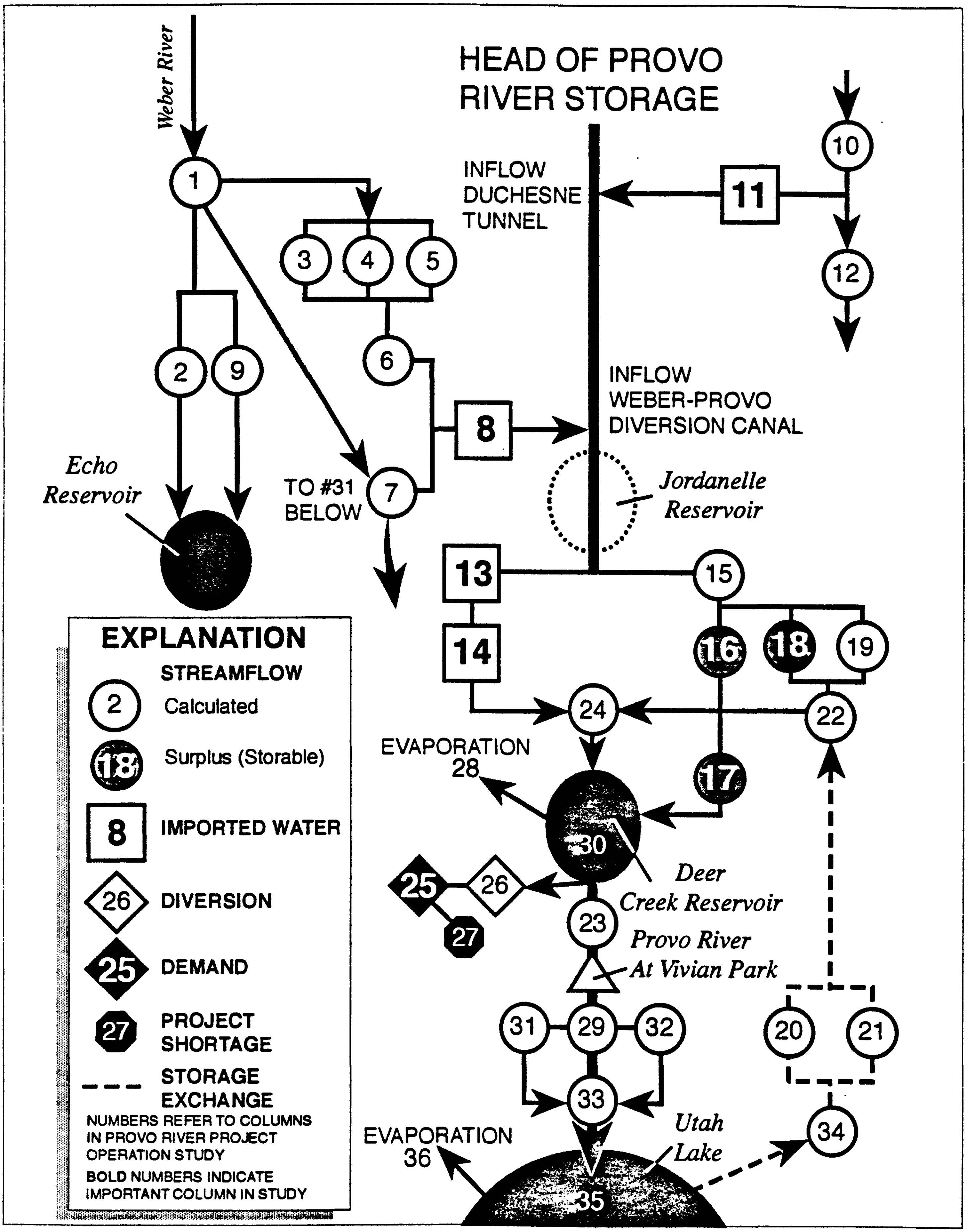

Figure 6.0-1--Conceptual diagram of Provo River Project Operation Study.

Table 6.0-2 Column Descriptions for the Weber River Divertible Flow Study

[Column headings are from USBR, 1988f, page II-16 and II-17. Column descriptions by USGS, developed from references cited. Added explanation by USGS shown in brackets.)

Column 1--Weber River [near] at Oakley. The historical record given in the Geological Survey water supply papers is continuous from October 1904, to the present. The flow is affected by several very small diversions upstream and is slightly regulated by several small lakes on the headwaters. Total capacity of all reservoirs is about 3,400 acre feet. The record is good, except for a few periods of ice effect.

Column 2--Demands between Oakley gage and Beaver Creek. Requirement between gage near Oakley and confluence of the Weber River with Beaver Creek. Basis for evaluating the water supply available for development: decreed rights were limited to historic diversions plus an allowance for future development of lands that conceivably might be supplied under the rights. The requirement value and the time applied are:

86 cubic feet per second starting May 1, increased by 2.5 cubic feet per second per day to 166 cubic feet per second	May 1 to May 30
166 cubic feet per second	June 1 to June 30
115 cubic feet per second	July 1 to October 31
0 cubic feet per second	November 1 to April 30

This requirement amounts to 45,660 acre-feet per year.

Column 3--Surplus [flow] at Oakley. Computed as column 1 minus column 2 of the accounting program.

Column 4--Unmodified flow [same as past modified flow] of Weber River at Echo. Unmodified flow defined: Since historical streamflow records have been influenced by progressive storage and trans-basin development, these records do not reflect the true water resource situation. For this reason an artificial group of streamflow records have been developed called "unmodified" flows. Unmodified flows represent the runoff that would have occurred if Echo and Rockport Reservoirs and the Weber-Provo Diversion Canal had not been constructed. Adjustments for in-basin direct streamflow diversions were not made, since the diversions and resulting return flows have been relatively constant since 1920 in the upper valleys.

Prior to May 18, 1930, when Echo Reservoir commenced storage of runoff, the unmodified flow of Weber River at Echo equalled the recorded flow of Weber River at Echo. Subsequent to this date it was equivalent to the recorded flow of the Weber River at Coalville plus the recorded flow of Chalk Creek at Coalville plus the unmeasured inflow between the Coalville gage and the Echo gage plus past Weber-Provo Diversion Canal diversions. Based on available records of Echo Reservoir fluctuations and the recorded flow above and below the reservoir, the unmeasured inflow is estimated as 20 cubic feet per second from March 1 to June 30, and 10 cubic feet per second from July 1 to February 28. The two records above Echo Reservoir were utilized instead of the gage below the reservoir and the change in contents because of inaccuracies in the daily content readings.

Column 5--Unmodified flow of Weber River at Gateway. This unmodified flow equals the unmodified flow downstream of Echo and East Canyon Dams plus the river gains from the dams to the Gateway gaging station. The Gateway gaging station is the key measuring station on the main stem of the Weber River, recording flow from 1610 square miles of drainage. The gaging station is immediately above most of the irrigation and power diversions and thus is used as the controlling point for the water supply study. Diversions for irrigation are made in valleys upstream from the gage. Most of the return flow from these areas filter back into the river and is reflected in the gage record. The flow is regulated by Rockport, Echo, Lost Creek, and East Canyon Reservoirs and is further affected by Weber-Provo trans-basin diversions. The determination of the unmodified flows for Weber River at Gateway consists of a daily accounting program where:

Unmodified flow at Gateway = + recorded flow at Gateway
- recorded flow at Echo
+ unmodified flow at Echo
+ Gateway tunnel flow
- Deliveries to Ogden Bay Refuge
- Rockport Reservoir storage releases
+/- Change in contents of East Canyon Reservoir, 1967-73
+/- Change in content of Lost Creek Reservoir, 1967-73

Column 6--[Equivalent] rights below Gateway. The "equivalent right" is an estimated compromise between decreed and contracted rights and beneficial use as determined by the mean past diversions. As a basis for evaluating the water supply available for development, decreed rights were limited to historic diversions plus an allowance for future development of lands that conceivably might be supplied under the right. The equivalent rights below Gateway as used in the accounting program are:

January 1 to April 15	365 cubic feet per second - power right
April 16 to May 15	378 cubic feet per second on April 16, increased by 13 cubic feet per second per day up to 760 cubic feet per second.
May 16 to August 31	760 cubic feet per second
Sept 1 to October 31	570 cubic feet per second
Nov 1 to Dec 31	365 cubic feet per second - power right.

This amounts to 385,815 acre-feet per year.

Column 7--Surplus at Gateway. Unmodified flow at Gateway in excess of that required to supply the equivalent right below Gateway. Column 5 minus column 6. Occurrence generally only during part of March, April, May, and June.

Column 8--Unmodified [flow] Provo River below Vivian Park. The recorded flow of Provo River at Vivian Park adjusted for man made imports and storage plus the unmodified flow of the South Fork Provo River at Vivian Park. The unmodified flow Provo River below Vivian Park is used to determine the portion of flow in the Weber-Provo Diversion Canal that is diverted to the Provo River under the Contract of December 16, 1926, part 13(b). Part 13 (b): Capacity in the said Weber-Provo Diversion Canal up to but not to exceed 210 second-feet, together with the right to divert surplus water from the natural flow of the Weber River from May 1st to August 1st of each year in such amount not exceeding 210 second-feet as is sufficient, (when beneficially used for irrigation purposes through existing canals diverting water from the Provo River above its confluence with the South Fork of the Provo River near Vivian Park at a duty not lower than 1 second-foot for 60 acres of land), to maintain the flow of the Provo River just below its confluence with the South Fork of the Provo River near Vivian Park, Utah, up to but not exceeding 510 second-feet after which said Echo Reservoir shall be filled once each and every yearly period from November 1st to the following October 31st as against the right to divert through said Weber-Provo Diversion Canal the difference between what is actually required to maintain said flow in the Provo River near Vivian Park, Utah, at 510 second-feet as aforesaid and said 210 second-feet and also as against the right to divert an additional 790 second-feet from the Weber River to the Provo River which may be required for developments which may be provided by the United States in the future in connection with the Salt Lake Basin Project. [The Provo River Project.]

Column 9--Divertible water to Provo River under application 9580 LT [less than] 3 or 7 LE [limited to] 210. Definition is stated under column 8 above. The daily accounting program value is less than column 3 or column 7 and is limited to a maximum of 210 second-feet.

Column 10--Winter power water at Echo. Winter "power water" available for storage at Echo Reservoir under application 9568 by agreement with Utah Power and Light Company dated December 20, 1938. Annually during the "winter" period, Utah Power and Light Company (UP&L) will permit the United States or the Weber/Provo Associations to divert to the Provo River and/or impound in the Echo Reservoir all or part of the Weber River power water originating above Echo dam, such water being that part of the natural flow, designated "power water", which UP&L is entitled to divert and use under its appropriations and applications in and from the Weber River in making up its power rights of 365 second-feet. Determination is column 4 minus column 7. Same as Column 2 of the Provo River Project Operation Study.

Column 11--Winter power water diverted to Provo River. The winter "power water" available to storage minus the winter "power water" actually stored in Echo Reservoir by agreement with Utah Power and Light Company under application 9568 dated December 20, 1938. Value is less than column 3 or column 10.

Column 12--Winter power water stored at Echo. The winter power water available to storage minus the winter "power water" diverted to the Provo River by agreement with Utah Power and Light Company under application 9568 dated December 20, 1938. Determination is column 10 minus column 11.

Column 13--[Winter] power water diverted to Provo River by exchange. To accomplish a 50-50 balance of "power water" between the Weber River and Provo River Associations, water is diverted in the early spring. The determination is column 3 minus the sum of columns 9 and 10.

Column 14--Irrigation water stored at Echo Reservoir. Water in excess of irrigation demands below Echo Reservoir and stored in Echo Reservoir under application 9568. Determination is column 7 minus column 11 of the daily accounting program.

Column 15--Diversions to Provo River under application 9569. Water in excess of all prior Weber River decreed rights and when Echo Reservoir is spilling. Water diverted for storage in Deer Creek Reservoir. Determination is column 3 minus column 9 of the daily accounting program.

Column 16--Diversions to Provo River under application 9568. Echo Reservoir storage belonging to Weber River Project stockholders on the Provo River. Limited to 5,400 acre-feet per year of the surplus Weber River water near Oakley (column 3 of the accounting program).

Column 17--Water available for storage at Echo [Reservoir] to replace water diverted [to Provo River Project if needed.].

Column 18--Surplus [Weber River water near] at Oakley for Echo [Reservoir] but diverted. High spring flow decreed for storage in Echo Reservoir but diverted to the Provo River when subsequent filling of Echo Reservoir is assured.

Column 19--Total [Weber River] water divertible. Total of columns 9 + 11 + 13 + 15 + 16 + 18.

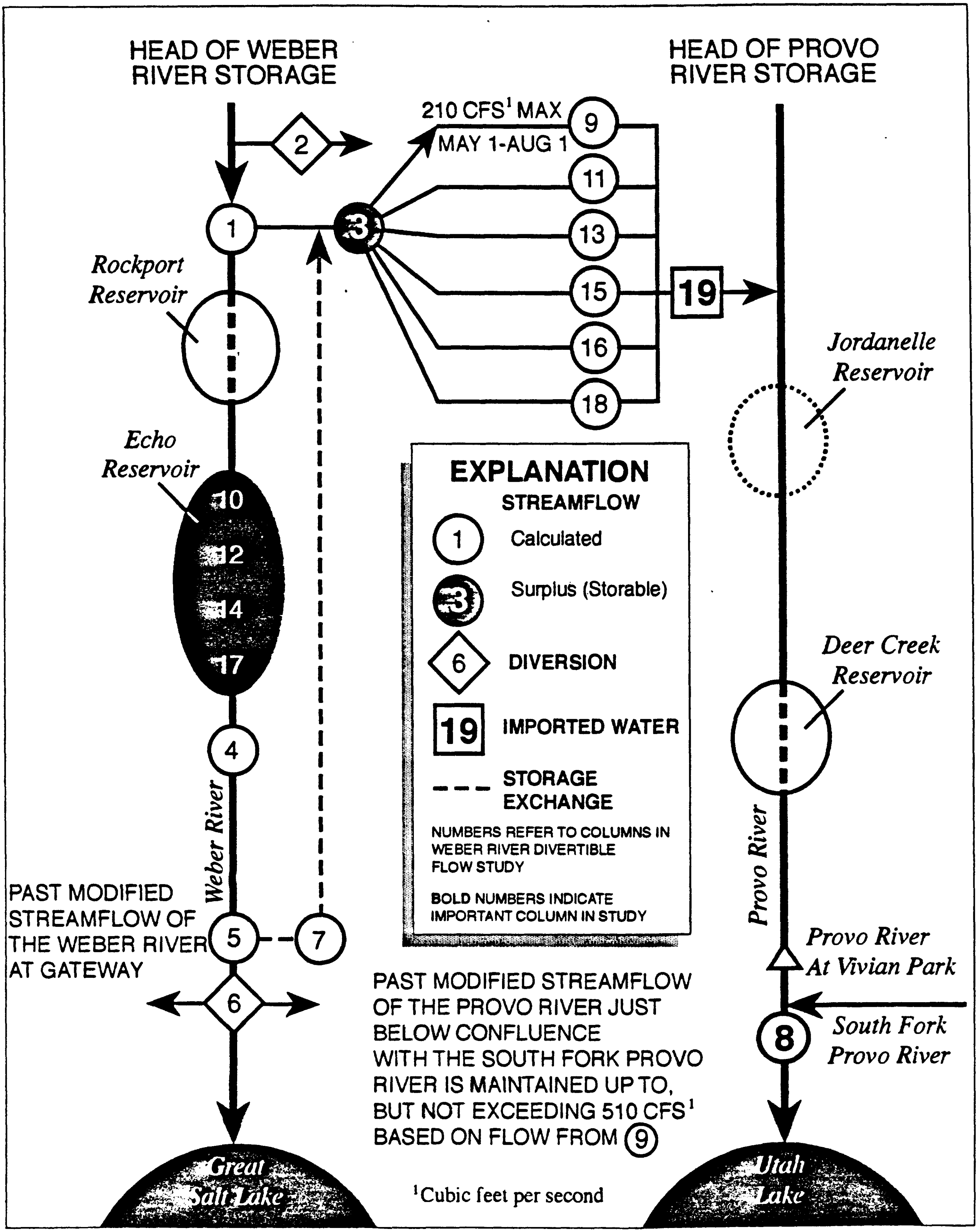

Figure 6.0-2--Conceptual diagram of Weber River Divertible Flow Study.

Table 6.0-3 Column Descriptions for the Provo River Surplus Flow Study

[Column descriptions are from USBR, 1988f. Comments by USGS are shown in enclosed brackets]

Column 1--Past Modified Flow of the Provo River below Vivian Park without Deer Creek Dam in place and operating and no transbasin diversions. [Modifications include: Provo River water stored in Deer Creek Reservoir, Weber River inflow, Duchesne River inflow, Salt Lake aqueduct flow, South Fork of the Provo River, and evaporation from Deer Creek Reservoir.]

Column 2--Past Modified Flow of the Provo River below Deer Creek Dam, which is the flow of the Provo River below Deer Creek Dam without Deer Creek Dam in place and operating and no transbasin diversions. [Modifications include: Provo River water stored in Deer Creek, Weber River inflow, Duchesne River inflow, Salt Lake aqueduct flow, and evaporation from Deer Creek Reservoir.]

Column 3--Past Modified Stream Gains--Column 1 minus Column 2 greater than zero. [Streamflow gains in the reach between Deer Creek Dam and the gaging station Provo River at Vivian Park plus the flows of the South Fork of the Provo River.]

Column 4--Future anticipated M&I Diversions to Cities--those future M&I needs which cannot be met by presently existing water rights [mostly to Provo City].

Column 4 of the Provo River Surplus Flow Study describes a future M&I demand for mainly Provo City. The demand pattern is set at the following levels: November through March equal to 20 ft^3/s [cubic feet per second] average, April and October equal to 23 ft^3/s, May equals 28 ft^3/s, June and September equal to 30 ft^3/s, August equals 33 ft^3/s, and July equals to 34 ft^3/s.

Column 5--Historical Canal Diversions from Provo River in Utah Valley; those Utah Valley canal diversions which have been historically diverted except for the Provo Reservoir Canal.

Column 6--Surplus Stream Gain--Column 3 minus Column 4 minus Column 5 greater than zero.

Column 7--Remaining Historical Canal Diversions--Column 5 minus Column 3 plus Column 4 greater than zero. [Historical canal diversions that have not been met from stream gains.]

Column 8--Historical flow of the Provo River below Deer Creek Dam, which are the flows of the Provo River below Deer Creek Dam with Deer Creek Dam historically in place and operating and two historically transbasin diversions operating.

Column 9--Future Provo City Use of Deer Creek Reservoir Water--that storage water in the reservoir for use by Provo City by water right exchange with the South Fork of the Provo River. [Provo City has water rights in the South Fork of the Provo River that are exchanged upstream for storage in Deer Creek Reservoir.]

Column 10--Provo River Water Stored in Deer Creek Reservoir--water stored in the reservoir under the Provo River Project operation. [Natural flow of the Provo River is stored in Deer Creek Reservoir.]

Column 11--Provo River Project Changes in Natural Flow--for October through March (Column 8 minus Column 2). [For October through March column shows the storage and releases from Deer Creek Reservoir. In the April through September period the diversions, gains and evaporation are accounted for. This insures that surplus flows will not be overestimated. In the summer irrigation months there are no surplus flows.]

--for April through September--

South Fork of the Provo River at Vivian Park (+), Weber-Provo River Diversion at Woodland (-), Duchesne Tunnel Diversion near Kamas (-), Regulation and Evaporation of Deer Creek Reservoir (+), Olmsted Diversion Rights (-), Provo Reservoir Canal Diversion Rights (-), Salt Lake Aqueduct Diversion Rights (+), South Fork Exchange with Deer Creek Reservoir (-), Provo City Demand from South Fork (-). [This paragraph was shown under column 12 of USBR, 1988f pg. IV-29.],

Column 12--Surplus flow of the Provo River at Deer Creek Dam--Column 8 minus Column 7 plus Column 9 minus Columns 10 and 11 greater than zero. [The water that is storable in Jordanelle Reservoir is computed in this column. The demands on the Provo River below Deer Creek Dam are subtracted from the historical flows of the Provo River at Deer Creek Dam. Note again that this water is not surplus. It is necessary to fulfill Utah Lake water rights and is only available for storage if the water is replaced or the water rights purchased.]

Two columns of the Provo River Surplus Flow Study are used in the Jordanelle Reservoir Operation Study. These columns are Column 6, Surplus Stream Gains; and Column 12, Surplus Flow of Provo River at Deer Creek Dam. These two columns are Columns 19 and 21 [respectively] in the Jordanelle Reservoir Operation Study.

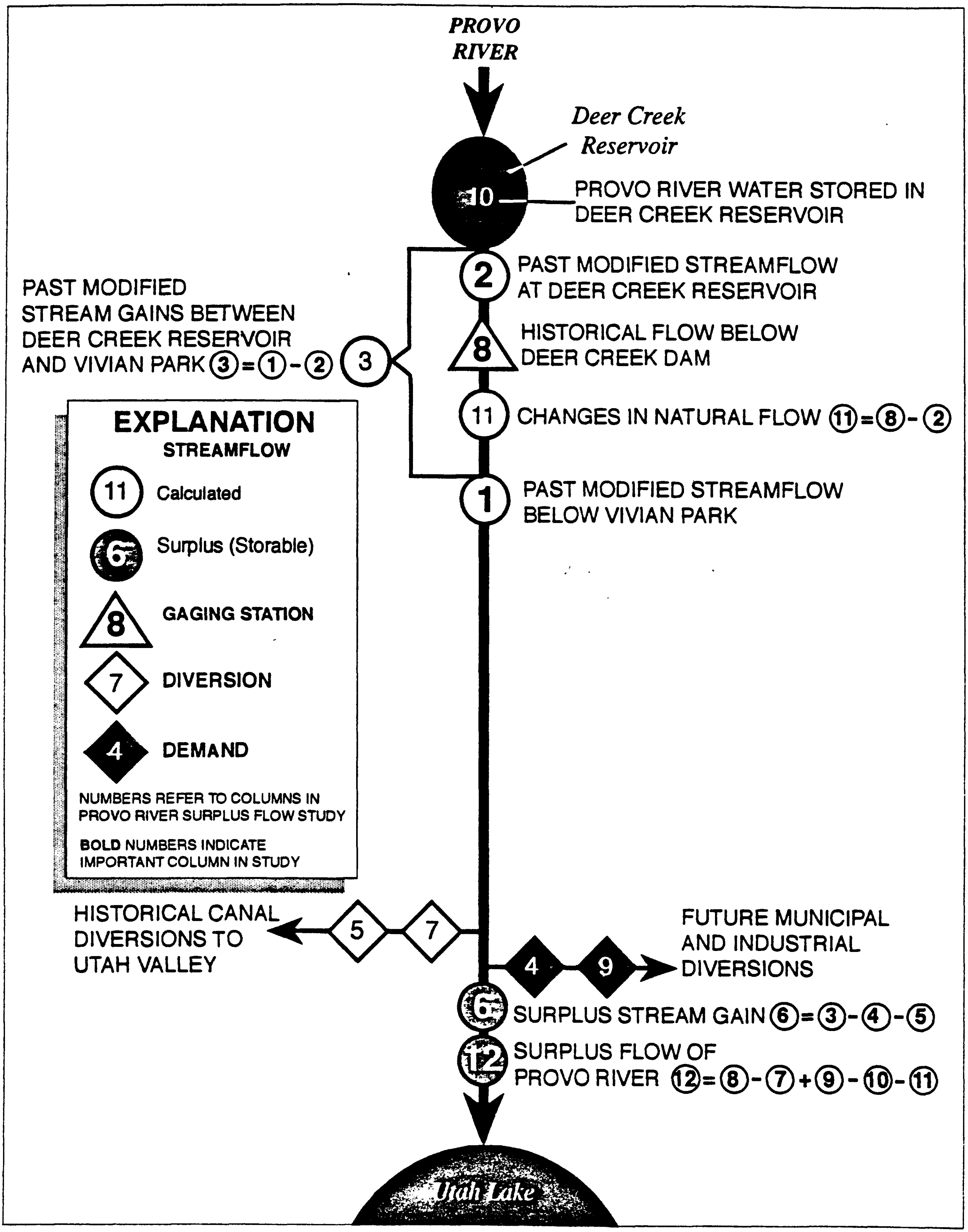

Figure 6.0-3-- Conceptual diagram of Provo River Surplus Flow Study.

Table 6.0-4 Column Descriptions for the Jordanelle Reservoir Operation Study

[Column descriptions are from USBR, 1988f. Columns 1 to 9 are directly entered into model from Francis Area Irrigation Study. Comments by USGS are shown in enclosed brackets.]

Column 1--Total irrigation demands. The three canals in the Francis area needing supplemental irrigation water are the Washington-South Kamas, the Sunrise, and the Larson-Cutler Canals, with total demands (including 6W lands) respectively of 10.0, 1.8, and 1.6 thousands of acre-feet per year.

Column 2--Historical direct flow diversions within ideal demand. Each of the three canals is taken separately, limiting historical direct flow diversions to ideal demand and then summing the three to get to total.

Column 3--Historical storage delivery. The storage historically delivered to the Francis area from the head of the Provo River storage (HPRS). Essentially, all of this storage went to the Washington and South Kamas Canals.

Column 4--Remaining demand. The demand remaining after using present supplies--column 1 minus columns 2 and 3.

Column 5--Project demand. The demand to project lands after deducting all nonproject lands, computed as 90 percent of column 4.

Column 6--Other demands. The Washington-South Kamas area has historically rented a right of 900 acre-feet per year flow from the Beaver-Shingle Creek Irrigation Company. Three hundred acre-feet per year will also be needed to continue deliveries to nonproject lands which presently use HPRS water. The other demands include that historically delivered from the Beaver-Shingle Creek and the 300 acre-feet per year needed for nonproject lands.

Column 7--Total direct flow diversions with project. This is the amount of direct flow water delivered to the three canal areas under project conditions. It is assumed the Washington and South Kamas Canals have available to it all the adjusted, past-modified flow of the Provo River near Woodland. The additional flow thus taken will be exchanged at Jordanelle. The other two canals direct flows will be the same as their historical flows within the ideal demand. The sum of the three is the total direct flow diversions with project [includes pre-project and project water].

Column 8--Total storage delivered with project. The Washington and South Kamas demand will be satisfied within tolerable shortages by direct flows only from the Provo River. However, storage water will be required to replace their temporary supply from the Beaver-Shingle Creek. Storage will also be required in the Sunrise and Larson-Cutler Canal area. An additional 300 acre-feet per year will also be needed to continue deliveries to nonproject lands which presently use HPRS water. The sum of these four demands make up the total storage delivered with project [includes pre-project and project water].

Column 9--Shortages to project lands. Tolerable shortage criteria of 100 percent [of annual demand] in 10 years; 75 percent in 2 years, and 50 percent in a single years was applied to each of three canals to get their individual shortages. These were than summed to give the total shortage to project canals.

Column 10--Past-modified flow of the Provo River at Hailstone. The historical flow of the Provo River at Hailstone minus the historical flows at the Weber-Provo Diversion Canal near Woodland and the Duchesne Tunnel near Kamas.

Column 11--Head of Provo River storage releases below Hailstone. The total historical releases to all users below Hailstone.

Column 12--The water supply available to the Heber area from local sources is mostly from springs an drains and is relatively a constant supply, though ungaged. Based on fragmentary records and spot measurements, the present supply is estimated as follows:

(a) 6,600 acre-feet annually from springs and return flow irrigation supplied through the Spring Creek and Sagebrush Canal.

(b) 2,700 acre-feet annually from Ontario Drain Tunnel, a constant source.

(c) 1,500 acre-feet annually from Provo River gains below Midway Upper Dam.

(d) 200 acre-feet annually from Provo River supplied through the Lower Charleston Canal.

There is always more than enough water in the river to supply the latter right. The total local supply is estimated to be 11,000 acre-feet annually.

Column 13--Supply from Head of Provo River storage to Heber area. The historical release for the Heber area which has averaged about 4,200 acre-feet per year. Column 61 shows the release from Jordanelle Reservoir necessary to replace this water.

Column 14--The total present supply to the Heber area computed as column 10 minus column 11 plus columns 12 and 13.

Column 15--The irrigation demand for 14,680 acres (at 3.60 acre-feet per acre) in the Heber area served by canals diverting from the Provo River plus high spring runoff historically diverted by the irrigators. The total demand is 77,300 acre-feet annually of irrigation plus a 2,400 acre-foot M&I demand.

Column 16--The demand remaining after Provo River, local sources, and Head of Provo River storage have been used. It comprises the demand for all lands to be served from Provo River including nonproject land. Column 15 minus 14.

Column 17--Project demand. The demand to project lands after deducting all nonproject lands, computed as 95.3 percent of column 16.

Column 18--Supply from flow of Provo River at Hailstone. The past modified flow of Provo River used in the Heber area. Computed as column 15 minus columns 12, 13, and 16.

Column 19--Surplus Provo River gains below Deer Creek Dam. The surplus gains below Deer Creek [Dam] were determined in the Provo [River] Surplus Flow Operation Study, column 6. Same as Table IV-9.

Column 20--Provo Reservoir Canal exchange water. A pump would be installed at the outlet of Utah lake to supply 13,500 acre-feet per year irrigation water to the Jacob-Welby area. This same amount would be used [from the Provo River] concurrently to help satisfy the M&I demand. The 13,500 acre-feet would be pumped during July, August, and September (4,500 acre-feet per month) each year that Jordanelle does not fill. When Jordanelle is filled by June, the exchange does not take place.

Column 21--Surplus flow of Provo River at Deer Creek Dam as determined in the Provo River surplus Flow Operation Study, column 12. Surplus flow of Provo River at Deer Creek Dam in excess of rights above Utah Lake is the historical flow of the river, minus historical canal diversion and Provo River water stored in Deer Creek Reservoir under ultimate development of the Provo River Project. The project demand at Murdock Dam would at all times exceed the river gains below Deer Creek Dam, thereby requiring either a bypass of surplus flow or release from storage to supplement the surplus river gains in order to supply the demands. For convenience of operations, therefore, all surplus water and demands are considered to be at Deer Creek Dam. This column also includes 1,300 acre-feet of return flow from Heber Valley M&I. Same as Table IV-10.

Column 22--Salt Lake County M&I demand. The demand for Salt Lake County as determined in the Salt Lake County M&I Water Supply Operation Study.

Column 23--Utah County M&I demand. This was determined in a separate computerized operation study--alternative M-2.

Column 24--Total M&I demand. The sum of columns 22 and 23.

Column 25--Demand met from surplus Provo River gains below Deer Creek Dam. The M&I demand is first met by the surplus Provo River gains below Deer Creek [Dam] - column 19.

Column 26--Demand met from Provo Reservoir Canal exchange water. The remaining M&I demand is then met by the Provo Reservoir Canal exchange water - column 20.

Column 27--Demand met from surplus flow of the Provo River at Deer Creek Dam. The M&I demand is then met as far as possible from the surplus flow of the Provo River at Deer Creek Dam - column 21.

Column 28--Remaining M&I demand. The remaining demand after using Provo River gains, Provo Reservoir Canal exchange water, and the Provo River surplus flows. Computed as column 24 minus columns 25, 26, and 27.

Column 29--Demand for stream fishery below Deer Creek Reservoir. The total demand for stream fishery below Deer Creek [Dam] is 100 cfs, but historically, Little Deer Creek inflow has averaged approximately 10 cfs, leaving a remaining demand for stream fishery of 90 cfs or 65,100 acre-feet per year.

Column 30--Remaining demand after joint use of M&I demands met from surplus flow of Provo River. The stream fishery demand is first met from that portion of the surplus flow of the Provo River which was released to meet M&I demands - column 27. The remaining demand after said joint use is computed as column 29 minus column 27.

Column 31--Demand met by the net historical canal diversions. The demand is then met by the net historical canal diversion from Provo River to Utah County - column 5 of the Provo River Surplus Flow study.

Column 32--Demand met from surplus flow of Provo River at Deer Creek Dam. The amount released from the surplus flow of the Provo River to meet the fishery demand - column 21.

Column 33--Demand met by CUP M&I deliveries through Jordan Aqueduct. CUP M&I water could be delivered through Olmsted Aqueduct during winter months to meet fishery demand if the demand could not be met from PRP M&I deliveries through the aqueduct.

Column 34--Demand met by PRP M&I deliveries through Olmsted Aqueduct. Provo River Project M&I water released during winter months for joint fishery use below Deer Creek Dam. That released to meet demands, limited by PRP deliveries in Provo River Project Operation Study minus Bonneville Unit M&I water delivered to north Utah County which must go through Salt Lake Aqueduct - column 23.

Column 35--Demand on storage. The remaining demand after using all available sources. Computed as column 30 minus columns 31, 32, 33, and 34, plus that required to provide 25 cfs fishery below Olmsted Diversion Dam from column 83.

Column 36--Remaining surplus flow of Provo River at Deer Creek Dam. The surplus flow of the Provo River remaining after releases from M&I use and stream fishery have been made. Computed as column 21 minus columns 27 and 32.

Column 37--Remaining flow of Provo River at the Hailstone gage. The remaining flow at Hailstone is the past-modified flow at Hailstone (the historical subtracting out the Weber-Provo diversion and the Duchesne Tunnel) adjusted for the stabilization of the upstream reservoirs minus the additional water diverted to the Francis area under project conditions plus the additional water saved by limiting deliveries to ideal demand, plus the additional net return flow water from the Francis area. This is computed in a separate operation study entitled, Flow at Hailstone Gage Under Project Conditions. Note: This flow does not include imported water through Weber-Provo Diversion and Duchesne Tunnel.

Column 38--Remaining flow of Provo River after direct flow releases to Heber area. The flow of the Provo River (without import water) after adjustments for the effects of the Francis area irrigation and direct flow releases to Heber area have been made. Computed as column 37 minus columns 18 > 0.

Column 39--Imported water at the Hailstone gage. The total Weber River and Duchesne River water imported to the Provo River was taken from the Provo River Project Operation Study, column 14. Importations were discontinued when Deer Creek [Reservoir] was full and Provo River Project water stored in Utah Lake has reached a total of 36,000 acre-feet or when Utah Lake was spilling.

Column 40--Stream fishery demand below Jordanelle Reservoir not met by Drain Tunnel Creek flows. The total fishery demand is 125 cfs. This is met first from Drain Tunnel Creek water which flows through Jordanelle Reservoir and the water released (column 35) for fishery below Deer Creek Reservoir. The remaining is met by releases from Jordanelle Reservoir. Computed as 125 cfs minus column 65 minus column 35.

Column 41--Imported water bypassed for fish. Imported water is first released to meet the fishery demand - column 39.

Column 42--Provo River water bypassed for fish. Flow from the Provo River at Hailstone is next released as needed to meet the fishery demand - column 38.

Column 43--Demand on storage. The remaining stream fishery demand after using imported water and Provo River water. Computed as column 40 minus columns 41 and 42.

Column 44--Storable surplus flow of Provo River at Deer Creek [Dam]. The surplus flows of the Provo River at Deer Creek Dam are storable in Jordanelle [Reservoir] as long as there is sufficient flow at Hailstone. All remaining flow at Hailstone is storable limited by the remaining surplus flows of the Provo River at Deer Creek Dam or column 38 minus column 42 not be greater than column 36.

Columns 45--Storable natural flow of Provo River at Hailstone. The remaining flow of the Provo River at Hailstone minus the remaining surplus flow of the Provo River at Deer Creek [Dam]. Column 38 minus column 36 minus [column] 42 > 0.

Column 46--Imported flow from Weber and Duchesne Rivers that was not bypassed for fish is storable in Jordanelle [Reservoir], as long as it can be exchanged with Deer Creek Reservoir the same year. Column 39 minus column 41 until the end-of-month content of project water stored in Deer Creek Reservoir (column 56) goes to zero.

Column 47--Total water storable in Jordanelle Reservoir. Columns 44 plus columns 45 and 46.

Column 48--Imported water bypassed to Deer Creek Reservoir. The remaining imported water after stream fishery bypass and the Jordanelle Reservoir - Deer Creek Reservoir exchange have been satisfied. Column 39 minus columns 41 and 46.

Column 49--Surplus flow of Provo River at Deer Creek [Dam] stored in Deer Creek Reservoir. The remaining surplus flow at Deer Creek Dam not stored in Jordanelle [Reservoir]. Column 36 minus column 44.

Column 50--Remaining surplus Provo River gains below Deer Creek Dam after released for M&I use, is storable in Deer Creek [Reservoir] to be exchanged with Jordanelle [Reservoir]. Computed as column 19 minus column 25.

Column 51--Fishery releases from Jordanelle Reservoir not used jointly for M&I are storable in Deer Creek [Reservoir]. Computed as column 43 plus column 66 minus column 28 > 0.

Column 52--Water released from Provo River Project power capacity replacement. With the Olmsted Powerplant not in operation, the water released for power capacity replacement under the Provo River Project would be storable in Deer Creek [Reservoir]. Column 29 of Provo River Project Operation Study.

Column 53--Surplus flow of Provo River at Deer Creek [Dam] released in exchange for natural flow water stored in Jordanelle Reservoir. Same as column 45.

Column 54--Surplus flow of Provo River at Deer Creek [Dam] released in exchange for imported water stored in Jordanelle Reservoir. Same as column 46.

Column 55--Water released from Deer Creek Reservoir to meet M&I demands. This release is made in June to release all remaining Bonneville Unit water from Deer Creek Reservoir, thus avoiding carry over water in Deer Creek [Reservoir]. The water is used to meet M&I demands - column 68. [Same as Column 68.]

Column 56--End-of-month content of project water stored in Deer Creek Reservoir. Computed as column 56 (previous month) plus columns 49, 50, 51, and 52, minus [columns] 53, 54, and 55. This cannot exceed the capacity available in Deer Creek Reservoir.

Column 57--End-of-month content of Deer Creek Reservoir without Bonneville Unit water. Taken from column 30 of the Provo River Project Operation Study.

Column 58--Spills of project water stored in Deer Creek Reservoir. The amount of project water storable in Deer Creek Reservoir which exceed the capacity available in Deer Creek [Reservoir].

Column 59--Demand supplied to Francis area. The demand supplied is the difference in the amount they would receive under project conditions (direct flow and storage) minus that amount historically delivered. Columns 7 plus 8 minus columns 2 and 3.

Column 60--Supplied from project storage. The flow necessary to replace that part of the direct flow taken in the Francis area that as a result is no longer available at Hailstone to meet Heber demands. Computed as column 18 minus column 37 > 0.

Column 61--Head of Provo River storage releases to Heber area. Same as historical - column 13.

Column 62--Project storage releases. The project releases to the Heber area are limited to 16,600 acre-feet in any one year. This gives Heber area no greater than a 100 percent shortage in any 10-year period, 75 percent shortage in any 2-year period, or 50 percent shortage in a single year. Column 17 limited to 13,200 acre-feet per year.

Column 63--Irrigation shortage to Heber area. Column 17 minus column 62.

Column 64--Head of Provo River storage releases to users below Deer Creek [Dam]. Releases made from Jordanelle Reservoir to replace water presently supplied to users below Deer Creek Dam from Head of Provo River storage.

Column 65--Historical inflow from Drain Tunnel Creek. This water will flow through Jordanelle Reservoir to downstream users and is used to help meet fishery flow demands below Jordanelle Reservoir during the winter.

Column 66--M&I water supplied from Heber area return flow. Part of the water supplied to the Heber area will return to the Provo River and be used to meet M & I demands. Thirty-six percent of column 62 plus return flow of the 2,400 M&I demand in Heber Valley supplied by project.

Column 67--M&I water supplied from joint use of fishery releases. Provo River surplus flows at Deer Creek Reservoir which were used to meet fishery demands will also be used to help meet M&I demands when needed - smaller of column 43 minus column 51 and column 28 minus columns 66 and 68.

Column 68--M&I water supplied from project water stored in Deer Creek Reservoir same as column 55. [Column 28 - column 66 - column 67, always = 0.]

Column 69--M&I water supplied from project storage. The remaining M&I demand to be supplied by project storage. Column 28 minus columns 66, 67, and 68.

Column 70--Shortage to M&I water. Column 28 minus columns 66, 67, 68, and 69. [Always = 0]

Column 71--Stream fishery below Deer Creek [Dam] supplied from storage - column 35.

Column 72--Shortage to stream fishery below Deer Creek [Dam] - column 35 minus column 71. [Always = 0]

Column 73--Stream fishery from Jordanelle [Dam] to Deer Creek [Reservoir] supplied from storage - column 43. [Column 73 equal column 43]

Column 74--Shortage to stream fishery from Jordanelle [Reservoir] to Deer Creek [Reservoir] - column 43 minus column 73. [Always = 0]

Column 75--Release to Utah Lake - project water released to Utah Lake. There were no released made during period of study.

Column 76--Total storage release - column 59 plus columns 60, 61, 62, 64, 69, 71, 73, and 75.

Column 77--Evaporation based on a rate of 2.81 feet per year. The evaporation was computed as the rate times the previous end-of-month surface area.

Column 78--End-of-month content of Jordanelle Reservoir. Column 78 (previous month) plus column 47 minus columns 76 and 77, limited to 320,000 acre-feet.

Column 79--Spills - that amount in column 78 that exceeds 320,000 acre-feet.

Column 80--Utah Lake depletion. Total depletion to Utah Lake due to Bonneville Unit development on the Provo River. Column 24 minus 65 percent of column 23 plus columns 59, 60, and 62 minus column 66 plus column 77 plus/minus change in content (column 78) minus column 26.

Column 81--Provo River flow below Jordanelle Reservoir. This is the total flow out of Jordanelle Reservoir including spills and irrigation water to Timpanogos Canal. Computed as column 37 + 39 - 47 + 65 + 76 + 79.

Column 82--Provo River flow below Deer Creek Reservoir. This is the total flow below Deer Creek Reservoir with operation of Jordanelle Reservoir. Computed as the present modified

flow below Deer Creek [Dam] plus column 34 - 44 - 49 - 50- 52+ 53+ 54+ 58 + 66 + 67 + 68 + 69 + 71 + 75 + 79.

Column 83--Provo River flow below Olmsted Diversion Dam. The total flow in the Provo River remaining after diverting all the M&I water at the Olmsted Diversion Dam. Computed as column 82 plus natural stream gains minus column 24 - column 34. If flow is less than 25 cfs, additional water is released from Jordanelle Reservoir (columns 35 and 71) to guarantee a 25 cfs minimum year-round fishery flow.

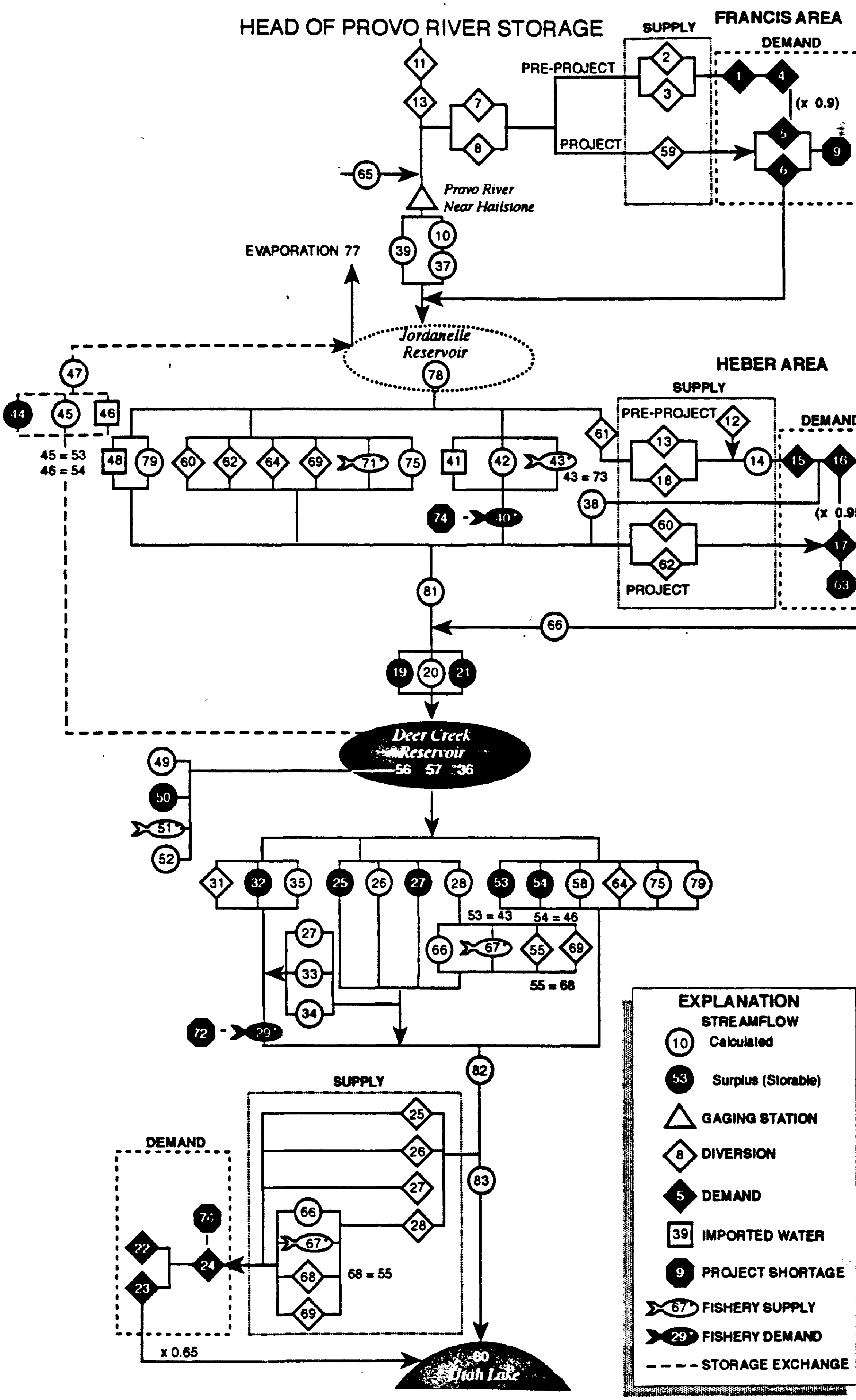

Fig 6.0-4--Conceptual diagram of Jordanelle Reservoir Operation Study.