STATE OF UTAH

JOSEPH M. TRACY, State Engineer

TECHNICAL PUBLICATION NO. 9

PROGRESS REPORT ON SELECTED GROUND-WATER BASINS IN UTAH

Prepared in cooperation with the

GEOLOGICAL SURVEY

W. E. WRATHER, *Director*

UNITED STATES DEPARTMENT OF THE INTERIOR

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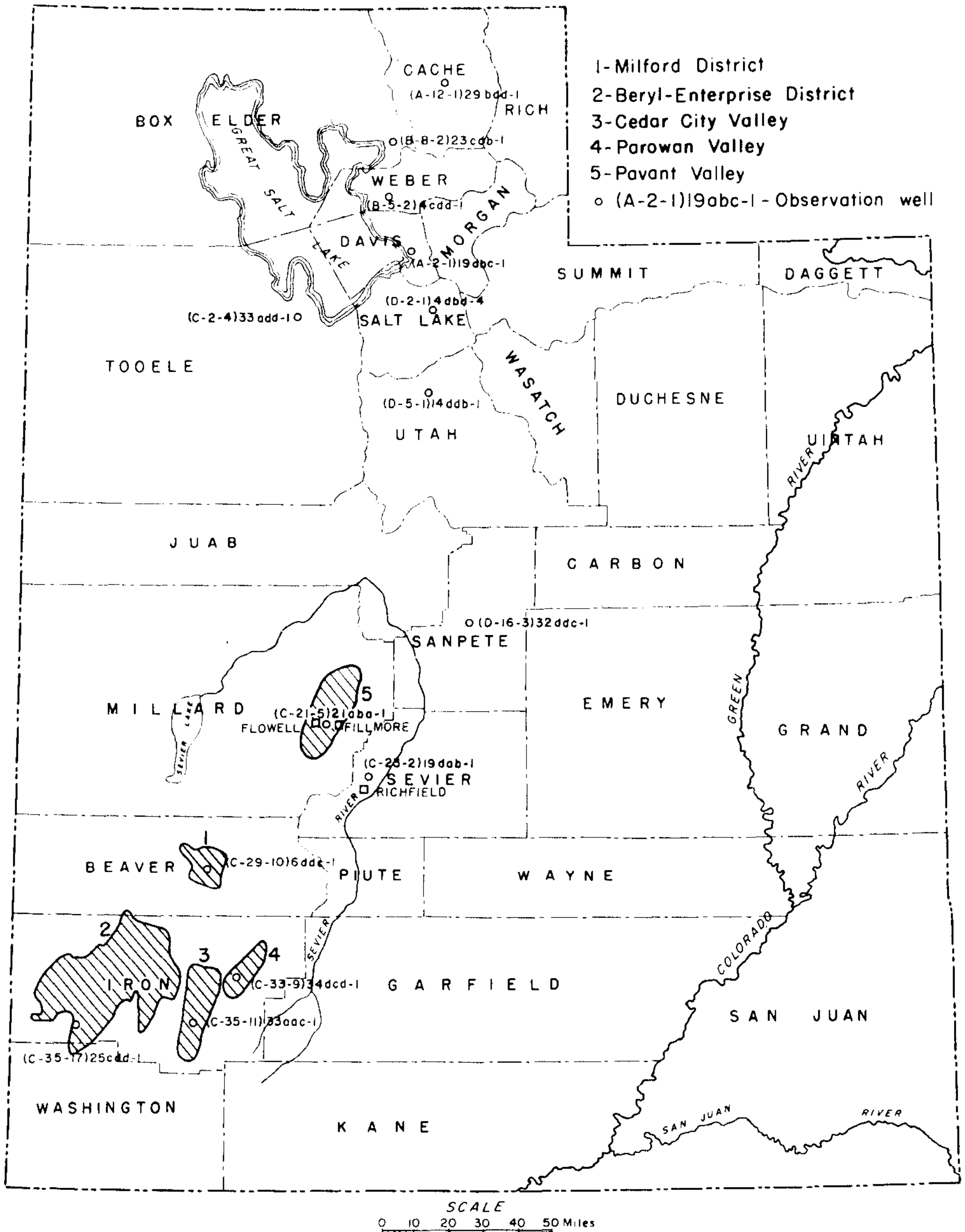

Figure 1. Index map of Utah showing location of 4 ground-water areas and 14 selected observation wells. (Frontispiece.)

STATE OF UTAH

JOSEPH M. TRACY, State Engineer

STATUS OF GROUND-WATER DEVELOPMENT IN FOUR IRRIGATION DISTRICTS IN SOUTHWESTERN UTAH

By
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By

H. A. Waite, W. B. Nelson, B. E. Lofgren,
R. L. Barnell, and R. G. Butler

PREFACE

This report was prepared as a part of the cooperative Statewide ground-water investigation, under the direction of A. Nelson Sayre, Chief of the Ground Water Branch of the United States Geological Survey, and Joseph M. Tracy, State Engineer of Utah. The authors wish to acknowledge their appreciation to John A. Ward of the State Engineer's Office, who review the report in detail, and to the individual well owners who cooperated in every way with the field engineers.

This technical publication consists essentially of the interpretation of data collected in connection with a detailed inventory of ground-water pumpage and water-level trends in four irrigation districts in southern Utah. Much of this information was assembled in a preliminary report entitled "Inventory of ground-water pumpage in three irrigation districts in southern Utah," by H. A. Waite and others, and was used by the State Engineer in a court hearing in Parowan in February 1954.

INTRODUCTION

Ground-water investigations in Utah by the Geological Survey, United States Department of the Interior, have been in progress since 1935, in cooperation with the Utah State Engineer. These cooperative studies have included (1) determinations of the fluctuations of water level in selected wells in most of the developed and some of the still undeveloped ground-water areas of the State, based upon measurements that are tabulated and published annually by the Geological Survey, and (2) detailed investigations of specific ground-water areas to determine the quantity and quality of the ground water and its source, movement, and disposal; and to show the relation of present development to the maximum development of which those areas are capable. Reports covering the detailed studies that have been completed to date appear in technical publications and biennial reports of the State Engineer, in water-supply papers of the Geological Survey, and in scientific journals; they are listed in the bibliography at the end of this report, and many are referred to in subsequent discussions of specific areas.

During 1953 a total of 2,696 measurements were made in 874 selected observation wells throughout the State. In addition, recording gages were maintained on 39 wells. The water-level records of 277 of these observation wells, including 27 with recording gages, are included in the annual water-level reports published in water-supply papers of the Geological Survey. The records of these and other observation wells may be examined at the U. S. Geological Survey, 503 Federal Building, Salt Lake City, Utah.

The 27th and 28th Biennial Reports of the State Engineer (1950 and 1952, respectively), have included technical publications on the ground water respectively in Escalante Valley in Beaver, Iron, and Washington Counties; and in 10 selected ground-water basins in Utah, with special reference to the status of their development. These and similar reports on other areas provide data necessary to the State Engineer in his control of ground-water development in those areas, in accordance with the State's ground-water law.

Early in 1953 the State Engineer pointed out the urgent need for a comprehensive field inventory of (1) the total pumpage from all irrigation wells and (2) the number of acres irrigated by each well, in each of the principal pumping districts in southwestern Utah. This technical publication summarizes the results of the field investigations that were carried on in these districts during the 1953 pumping season. It is intended that the pumpage and irrigated-acreage inventories will be continued on an annual basis and that the results of subsequent studies will be included in future technical publications of the State Engineer.

In some of these pumping districts studies were made many years ago, as in Cedar City Valley and Parowan Valley where detailed investigations were made in 1938 to 1940; for these areas the effects of natural factors and of development are summarized for subsequent years in the 28th Biennial Report of the State Engineer. The present report supplements earlier ground-water studies that have been made by the Geological Survey in each of the areas considered herein.

This technical publication is intended to be of value to users and applicants for rights to use of ground water, particularly in the areas for which summaries of pumpage and acres irrigated have been prepared. The field investigations were designed to furnish sufficient data to enable the State Engineer to evaluate the status of development in each of the heavily pumped districts. The results of the field inventories have been tabulated and summarized, and, on the basis of the information, the State Engineer can determine the average water requirement in acre-feet per acre for the wells in a given pumping district.

GROUND-WATER DEVELOPMENT

By H. A. Waite and others

Of the more than 31,000 operating wells in Utah, used for irrigation, industrial, or domestic use, approximately half are flowing artesian wells and the other half are pumped. Of the total, probably not more than 100 wells derive their supply from bedrock aquifers, and only about 15 of these bedrock wells yield water in significent quantities. In general, most of the flowing wells are in the narrow, densely populated belt west of the Wasatch Mountain front and north of the city of Nephi. For the most part these wells are of small diameter and low yield, but a few large-capacity flowing wells have been drilled in recent years, mostly in Utah County (Thomas, Hansen, and Lofgren, 1952) and Salt Lake, Davis, and Weber Counties (Thomas, and Nelson, 1948) and immediately west of the Wasatch Mountains. Nonflowing wells, on the other hand, are scattered throughout the State, although they too are more concentrated in the areas of heaviest population.

The relations of ground water to surface water and to precipitation are important elements in the analysis of the status of ground-water development in the principal pumping districts in southwestern Utah. The water in all streams in this part of the State has long been fully appropriated. Any new irrigation development must necessarily be supplied from ground-water sources. During the 9-year period, 1945-1953, the pumping of ground water for irrigation has more than doubled in the southwestern part of the State.

It has been estimated that about 70 percent of all ground water pumped in the State occurs in four principal pumping districts in southwestern Utah, namely, the Milford, Beryl-Enterprise, Cedar City, and Parowan districts. The locations of these districts are shown in figure 1. More than 118,000 acre-feet of water was pumped from the 425 irrigation wells operating in 1953 in these districts; pumping lifts ranged from 30 to 150 feet. The number of wells and the pumpage in acre-feet for these four districts are shown in the following table:

Estimated pumpage from wells for irrigation in four pumping districts in southwestern Utah, 1953

Irrigation district	Number of pumped irrigation wells	1953 pumpage (acre-feet)
Milford	136	41,300
Beryl-Enterprise	176	50,000
Cedar City	63	15,400
Parowan	50	11,400
Totals	425	118,100

WATER-LEVEL TRENDS

Several areas in Utah experienced ground-water shortages during 1953. These, however, have been due largely to inadequate pumping facilities or to lowered water levels in local congested areas. No critical shortage of ground water is noted in any major region of the State. Water levels in wells, especially in areas of heavy pumping, fluctuate considerably from one season to the next. As has been pointed out by Thomas (Thomas, Nelson, et al., 1952, p. 16-18):

> "Fluctuations of water levels are the chief elements used in the analyses of ground-water conditions in specific basins. These fluctuations may be traced to a variety of causes, some related to the storage and movement of ground water and the recharge to or discharge from the reservoir; others to changes in pressure upon confined water. . . . With respect to annual precipitation, there is good correlation in nearly all of Utah's ground-water basins between precipitation trends and water-level trends. Inasmuch as precipitation is recognized as the ultimate source of ground water as well as stream flow, this correlation is to be expected under natural conditions, whether the ground water is derived by direct penetration of precipitation or by seepage from streams.
>
> "The fact that water-level trends are upward in years of abundant precipitation indicates that in those years, at least, the draft from wells is not exceeding the replenishment to the ground-water reservoir. Such an area, however, will still be over-developed if the average draft exceeds the long-term average rate of replenishment, and close analysis of records is necessary to show whether this is the case."

In the same report, additional conclusions by Thomas (1952, p. 19) were as follows:

> ". . . In an area where ground water is used chiefly for irrigation, a pronounced seasonal lowering of water levels may be expected, even though the quantity pumped each year is fully replaced by recharge to the reservoir. If wells year after year draw more water from the reservoir than is replenished, the water levels in wells will show a progressive downward trend, a trend that is inevitable in overdeveloped basins. On the other hand, a progressive downward trend of water levels may occur in an area of incomplete but rapidly increasing development, because of the increasing rate of withdrawal. Thus a downward trend is not necessarily an indication of overdevelopment."

The hydrographs of 14 observation wells (fig. 2) have been selected as being representative of ground-water conditions that prevail throughout the State. The locations of these observation wells are shown in figure 1. Significant seasonal variations in water level have been measured in each of these wells, but only the year-end measurements have been used in plotting the hydrographs, because these indicate the annual changes in ground-water storage. In general, the southern part of the State has experienced an extended drought, and widespread pumping from wells for irrigation has caused a general downward trend in water levels during the last few years. In the northern part of the State, however, precipitation has been almost normal, and water levels have not shown similar downward trends.

As noted in each of the hydrographs selected to represent conditions in northern Utah (the upper 10 wells in fig. 2), water levels either remained relatively constant, or rose slightly, during the periods of record shown. Although there has been some increase in ground-water use in recent years, recharge from precipitation has been sufficient to offset this increase.

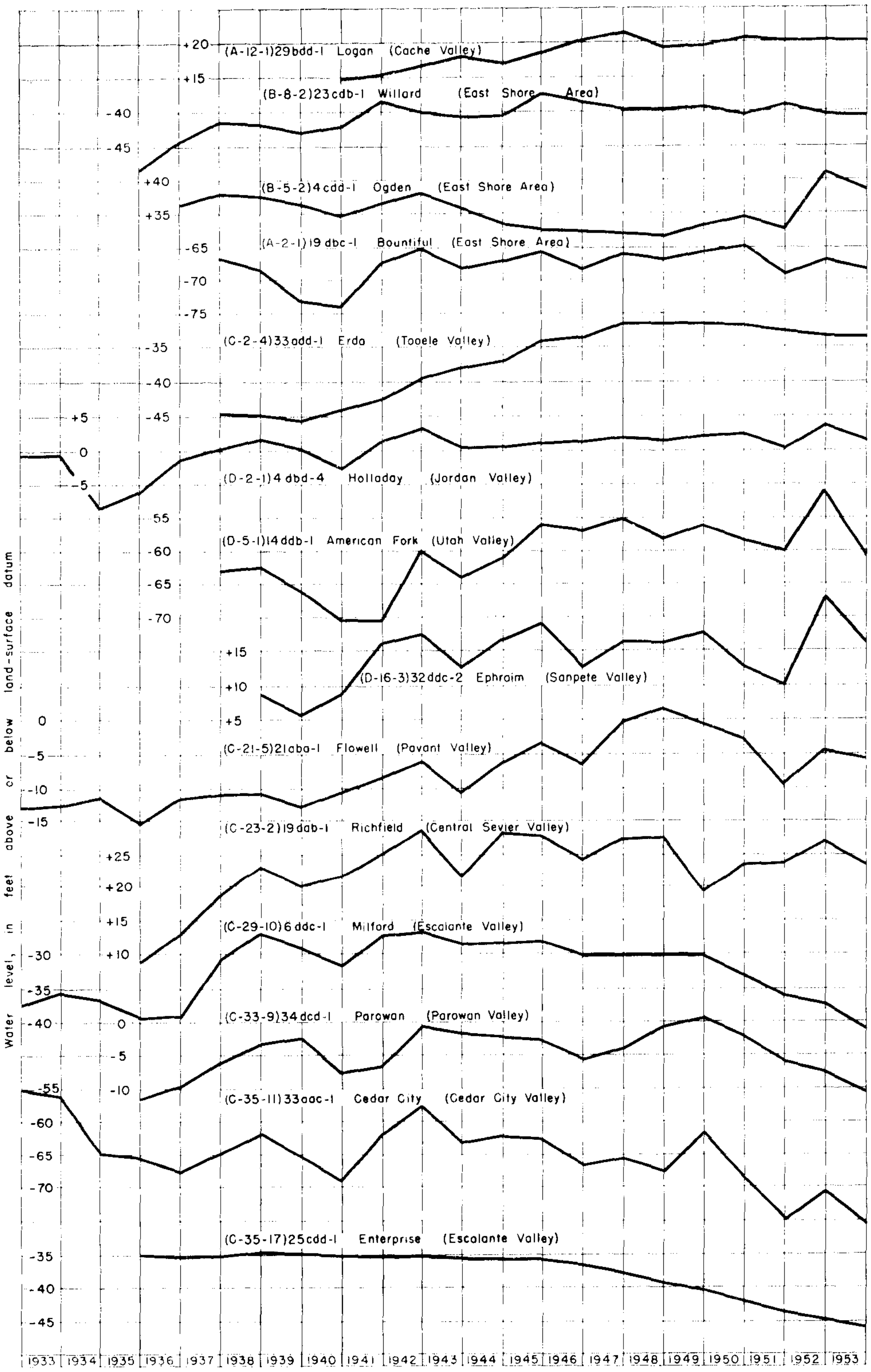


Figure 2. Annual water-level trends in 14 selected wells in Utah.

the drought that encompassed much of southern Utah in 1943-53. Although precipitation was deficient during the latter part of that period, it was well above normal in earlier years. The trend in water level in well (C-21-5)21aba-1 near Flowell generally follows the trend in precipitation (Thomas, Nelson, Lofgren, and Butler, 1952, p. 59, 60). During the 5-year period 1944-48 the water-year precipitation at Fillmore was above average in all but one year. As a result, the water level in well (C-21-5)21aba-1 reached its highest observed stage at the beginning of 1949. Since 1948, precipitation at Fillmore has been below average every year, and this has been largely responsible for the net decline of water level in well (C-21-5)21aba-1 during the period from the end of 1948 through the end of 1953.

During 18 years of record, the water level in well (C-23-2)19dab-1 near Richfield has had a maximum range in fluctation of about 20 feet, and, as pointed out earlier, the net rise in water level during the entire period amounted to about 15 feet. This well is in a relatively small, steeply inclined ground-water basin, and the water level responds to variations either in annual precipitation or in annual runoff of the Sevier River.

Well (C-29-10)6ddc-1 is in the heart of the Milford pumping district; its water level is affected by recharge from precipitation, the Beaver River, and surface-water irrigation; and it is influenced also by pumping up from irrigation wells in the district. In general, water-level trends in the Milford district have been downward since 1939 in response to abnormally low precipitation and accelerated pumping. At the end of 1953 the water levels in many wells were at the lowest stages of record.

The water levels in well (C-35-11)33aac-1 in Cedar City Valley and in well (C-35-17)25cdd-1 in the Beryl-Enterprise district (fig. 2) declined during their respective periods of record. The net decline in well (C-35-11)33aac-1 amounted to about 21 feet from January 1933 to December 1953, and the net decline in well (C-35-17)25cdd-1 amounted to about 11 feet from January 1936 to December 1953. The water levels in several other wells in both valleys also were reported to be at record-low stages in December 1953. The hydrograph of well (C-35-11)33aac-1 can be correlated with the runoff from Coal Creek. This stream is one of the principal sources of ground-water recharge to Cedar City Valley. Water levels in the Beryl-Enterprise district, on the other hand, reflect the gradual unwatering of an exceptionally large underground reservoir, that of Escalante Valley. The hydrograph of well (C-35-17)25cdd-1, situated in the center of this extensive district, shows only minor fluctuations from one year to the next, and indicates a general downward trend that has been in effect since pumping began.

In recent years water levels have trended downward also in Parowan Valley, as suggested by the hydrograph of well (C-33-9)34dcd-1.

CLIMATIC CONSIDERATIONS

Although no ground-water basins of the State have "gone dry," water levels in several areas have declined substantially, owing in part to a deficiency of precipitation and a lack of seasonal recharge and in part to a progressive increase in the amount of water pumped for irrigation. This is especially true in several districts of southern Utah which border on the extensive drought area of the southwestern United States and which have received below-normal runoff in 8 of the last 10 years. In these areas, declining water levels are of real concern. What the future water-level trend will be in these areas under the present pumping load, even with successive years of normal or above-normal precipitation, can only be determined from subsequent studies of water-level trends.

Climatic conditions in the southwestern part of the State have contributed to the lowering of water levels in wells, mainly by reducing the amount of water available for recharge. In Cedar City Valley many landowners use wells to supplement surface-water supplies diverted from Coal Creek; thus the amount of surface-water runoff available for irrigation affects the amount of water pumped from wells. In the Milford, Parowan, and Beryl-Enterprise districts, however, most wells pump throughout the growing season each year.

Within the broad area of deficient precipitation and runoff, farms that rely on ground water for their irrigation supply, or that have an irrigation well for supplemental water, have not suffered from drought conditions as seriously as have those farms that depend solely on surface streams. Thus, while mountain streams have diminished in flow and dry farms have "burned up," farms in the principal pumping districts have not suffered from a lack of water. In these districts, the lowering of water levels in many instances has forced farmers to install deeper pumping equipment and has increased the cost of pumping water, but wells have been permitted to pump without restriction.

Extended drought conditions are having a twofold effect on ground-water conditions in southern Utah. Not only are the quantities of water available for recharge to the ground-water reservoirs materially decreased by deficient runoff, but the quantity of water pumped by wells is notably increased. Thus, with increased demand for irrigated croplands during the hot, dry summer months, and with decreased supply from deficient rainfall and diminished surface flow, irrigation wells are pumped more heavily to provide the irrigation needs of the farms.

In most of the ground-water basins a close correlation exists between the cumulative departures from normal precipitation and the water-level trends. Thus, declining water levels in a basin are a measure of the quantity of water drawn from underground storage. The only way that this decline can be offset is for the inflow into the basin to exceed the discharge from the basin for an extended period of time. It is interesting to note that even the abnormally high runoff of 1952 had only a temporary effect in arresting the trend of declining water levels in southern Utah.

INVENTORY OF GROUND-WATER USE

Because of the accelerated development of ground water in southern Utah in recent years and the concurrent downward trend of water levels, the State Engineer has been faced with many serious problems in administering the State's ground-water resources. There are indications in several districts that ground-water pumpage is exceeding the natural recharge, and the declining trends are creating a general feeling of insecurity.

Within the congested central sections of each of the four principal pumping districts in southern Utah, namely, the Milford, Beryl-Enterprise, Parowan, and Cedar City districts, "closed areas" have been designated by the State Engineer to restrict development. Water-level trends are being watched very carefully in each of these districts. Although the number of wells in operation in each of the "closed areas" has not increased appreciably since the restricting regulations went into effect, the quantity of water pumped from many of the wells has increased. This has been accomplished by pumping existing wells for longer hours, by installing larger pumping equipment, or by drilling replacement wells that yield more water than the abandoned well.

Early in 1953 the State Engineer was faced with the problem of determining the quantity of ground water actually used for irrigation throughout the Milford and Beryl-Enterprise districts. This basic information was needed in working out a satisfactory adjudication of water rights in Escalante Valley. The State Engineer needed up-to-date information on the "acre-feet per acre" water requirement for land irrigated from each well. In order to obtain the necessary information, a comprehensive field inventory was conducted in each of the principal pumping districts to determine (1) the amount of water pumped from each irrigation well during the season and (2) the number of acres irrigated from each well. The intensive inventory of these two districts, and also the Parowan and Cedar City Valley districts, was begun in April 1953. This program was carried on during the 1953 irrigation season and was continued in 1954.

Scope of the Field Inventory

During the period April 1 to November 1, 1953, most of the pumping irrigation wells in the Milford, Beryl-Enterprise, Parowan, and Cedar City districts were measured periodically. For each well, 1 to 5 measurements of discharge, water level, and power consumption were made during the pumping season.

None of the wells in the four districts inventoried is equipped with a meter for measuring the quantity of water pumped. Most of the irrigation wells, however, are pumped with electric motors and are equipped with electric-power meters. Thus, a convenient and reliable method of relating quantities of water pumped to the rate of power consumption was employed to good advantage. For the irrigation wells not powered by electricity, estimates of the total hours of operation of the diesel or propane engines were obtained from well owners, but these provided a less reliable determination of total pumpage.

Relation of Water Pumped to Electrical Energy Used

A pump installation driven by an electric motor and with 100-percent overall efficiency would consume 1.024 kilowatt-hours of power to pump 1 acre-foot of water through a vertical lift of 1 foot. On this same basis it would take 10.24 kilowatt-hours of electrical power to lift 10 acre-feet of water 1 foot, or to lift 1 acre-foot of water a vertical distance of 10 feet. Thus, a theoretical relationship is readily available between the electrical energy supplied to a pump installation and the energy put out by that installation in the form of water pumped.

Several sets of measurements are required to determine the ratio of electrical power input to water output for each well. Thus, it was determined in the four districts that the number of kilowatt-hours required to lift an acre-foot of water 1 foot ranged from 1.47 to 3.22, indicating that the overall efficiency of the irrigation wells in the pumping districts of southern Utah ranges from 30 to more than 60 percent. When this relationship is satisfactorily established for a well, the estimate of pumpage for this well is computed from the records of power consumption as metered by the local power company and from a computed average of the pumping lifts measured during the period of pumping.

The watt-hour meter is an integral part of each electric-pump installation and provides a convenient means of measuring electrical power input. The watt-hour or disk constant of a watt-hour meter is the registration of one revolution of the rotating element expressed in watt-hours. This constant must be known by the field man who seeks to determine rate of energy input to an electrically driven pump. With a stop watch the average speed of the meter disk can be determined accurately, and from this the power consumption is expressed by the formula:

$$\text{Kilowatts} = \frac{3.6\ K \times M \times R}{t}$$

where K = disk constant found on the meter nameplate, and representing watt-hours per revolution.
M = transformer ratio (this usually equals 1).
R = total revolutions of watt-hour meter disk.
t = time for total revolutions of disk, in seconds.

By using this formula, the rate of power input can be determined for a pumping well in a few minutes. Then, by measuring the water discharge from the well (method described in a later section) and the pumping depth to water in the well, the more or less constant ratio of kilowatt-hours per acre-foot per foot of lift can be computed. The ratio of kilowatt-hours per acre-foot per foot of lift is determined twice in a pumping season, and, if this ratio varies only slightly, the amount of pumpage from wells can be determined for the entire season merely by metering the quantities of power consumed and by periodically measuring the pumping lifts in the wells.

As some wells in the area are equipped in such a manner that a tape cannot be lowered into them to measure the pumping depth to water, a somewhat modified procedure is employed. For these wells, the relation of power input (in kilowatts) to water output (in cubic feet per second) is determined, as suggested above, at frequent intervals during the pumping season. At the close of the season, the power-meter reading (in kilowatt-hours) can be converted readily into acre-feet of water by dividing the total kilowatt-hours consumed by the kilowatt-hours per acre-foot. The figure for kilowatt-hours per acre-foot is computed, of course, from observations made during the pumping season.

Field Methods

In order to determine for each irrigation well the quantity of water pumped during the 1953 season and the "acre-feet per acre" use of this water, a set procedure of data collection was adopted and carried out during the field season. At the time each pumping well was visited, the following field data were collected:

a. The rate of well discharge, in gallons per minute (gpm).
b. The total pumping lift, in feet.
c. The rate of power consumption for electrically driven pumps, or an estimation of the total time of operation for the engine-driven pumps.
d. The acreage irrigated from the well.

All measurements made during the field inventory were done in accordance with standard procedures accepted by the Geological Survey. Well-discharge measurements were made in most instances using the Cox flowmeter or the Hoff current meter, either of which is capable under ideal conditions of measuring the flow of water in a discharge pipe with a high degree of accuracy, the error ordinarily being less than 5 percent. Where the local conditions were such that the use of either of these meters was not feasible, one of the other standard techniques for measuring a discharging well was employed. Depth-to-water measurements during the periods of pumping were made with a two-conductor electric tape. Also, power-meter readings were made as outlined in the previous section.

The Cox flowmeter is used to determine the average discharge velocity in a pipe, which, when multiplied by the cross-sectional area of the pipe (in square feet), gives the discharge of the pipe in cubic feet per second. The Cox flowmeter, utilizing the Hall pitot tube, simplifies the task of measuring the velocity of water in discharge pipes. This meter consists essentially of four elements: (1) an inside-diameter caliper to measure the discharge pipe, (2) a modified Hall pitot tube, (3) two hose extensions, and (4) a water manometer. The water manometer is connected to the pitot tube by the rubber tubes. The manometer is direct reading and is calibrated in gpm per square inch. When the instrument is used in the field, the pitot tube is inserted into a threaded ¾-inch hole in the discharge pipe. The velocity of water flowing through the pipe is read directly on the calibrated rod that is part of the inverted "U"-tube assembly comprising the water manometer.

The Hoff current meter also is used for measuring yields of some of the wells, and it proved to be ideal for rapid measurements because it is quite adaptable to the different outlet conditions and to the variable discharges of some wells. The Hoff current meter is actuated by a rubber-bladed propeller. The instrument is inserted in the open end of a discharge pipe, and a sound indicating the revolutions of the rotating propellor is communicated to a set of headphones. The average velocity of the water flowing through the pipe is thus determined by comparing the revolutions of the meter blade in a given time with a rating table which relates revolutions to velocity.

Ground-Water Use in Acre-Feet Per Acre

In order to determine the ground-water use in acre-feet per acre, it was first necessary to obtain the acreage served by a particular well as well as the number of acre-feet pumped. The use of ground water in the four pumping districts ranged from less than 0.5 acre-foot to more than 8.0 acre-feet per acre, and the average use varied considerably from one district to the next. These variations are related in part to the different types of crops grown in the districts, and to the intensity of cultivation of the various crops. Other closely related factors which apparently determine the quantity of water required to irrigate a field adequately are: (1) nearness of the water table to the land surface, (2) type of soil, and (3) climatic factors of precipitation, temperature, and wind. No attempt has been made in this study to analyze the effect of each of these factors on the water-use requirements.

FOUR PUMPING DISTRICTS IN SOUTHWESTERN UTAH

As stated in a previous section of the report, an estimated 70 percent of all ground-water pumped in the State of Utah is withdrawn from four principal pumping districts in the southwestern part of the State, namely, the Milford, Beryl-Enterprise, Parowan, and Cedar City districts. More than 118,000 acre-feet of water was pumped from the 425 irrigation wells in these districts in 1953. Although the central area of each of the districts is "closed" to further new development, an adequate supply of ground water is currently available to all present irrigation wells. In several congested areas, espectially in parts of the Parowan and Milford districts, the mutual interference of nearby pumping wells

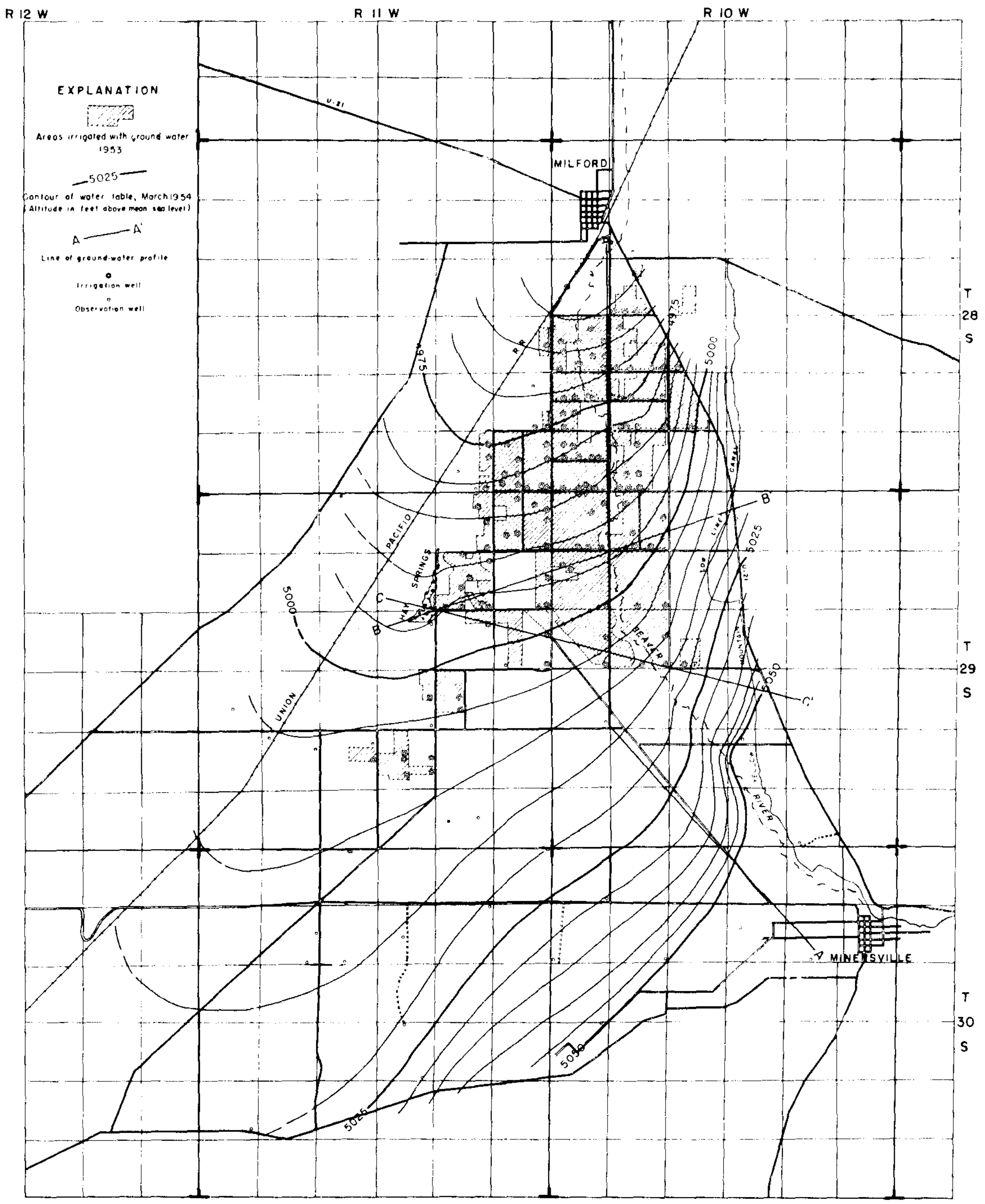


Figure 3. Map of Milford district showing irrigation wells, areas irrigated by wells in 1953, and water-table contours for March 1954.

causes undue seasonal drawdowns which materially increase the cost of pumping water in these areas. These conditions, however, are of only local extent.

The remainder of this report deals with the field and interpretive data collected and analyzed during the 1953 pumpage inventory in these four districts.

MILFORD PUMPING DISTRICT

By W. B. NELSON

Ground-Water Development

Ground-water development in the Milford pumping district has increased steadily since 1943. Records of the total pumpage and of the total acreage irrigated from wells in the Milford district are not available for many of the earlier years, but partial information is available for some years. From 1931 to 1953 the number of irrigation wells doubled, and the pumpage from these wells increased more than four times. In 1948 a total of 97 irrigation wells pumped 20,300 acre-feet of ground water, whereas in 1953 more than 41,300 acre-feet was pumped from the 136 wells then in operation. The number of acres irrigated from wells has also increased during the period 1942-53, the increase ranging from about 3,500 acres irrigated in 1942 to 9,426 acres in 1953. The change-over from surface-water irrigation to ground-water irrigation is largely responsible for the increase. Figure 3 is a map of the Milford district showing irrigation wells, the areas irrigated by wells in 1953, and water-table contours for March 1954.

Prior to 1945 most of the wells were less than 100 feet deep and equipped with small-yield centrifugal pumps. Many of these wells have since been replaced by larger, deeper wells, and only a few of the outmodeled centrifugal pumps are now in operation (Fix, Nelson, Lofgren, and Butler, 1950, p. 109-210). During this transition period the average discharge of individual wells increased from about 1 to 2 cfs, and many of the replacement wells now cover the established water rights of two or more older wells.

Because of the accelerated development of ground water in recent years and because of the concurrent downward trend of water levels in the heavily pumped area, the central part of the Milford district, as shown in figure 4, was closed to further appropriation of ground water for irrigation purposes by action of the State Engineer in December 1952.

In order to observe changes in ground-water conditions in an undeveloped area south of the district of heavy pumping, 16 observation wells were drilled by contract in the late fall of 1953. These wells are 4 inches in diameter and range in depth from 100 to 207 feet. This new network of observation wells will provide much-needed water-level information in strategic parts of the Milford district.

Discharge from Wells

In 1953 a total of 41,300 acre-feet of water was pumped to irrigate 9,426 acres of farmland in the Milford district. The rate of water use ranged from 0.6 acre-foot to 8.4 acre-feet per acre. This water was pumped from 136 irrigation wells. The yields of irrigation wells in the Milford district range from about 100 to 2,250 gpm. The upper histogram of fig. 5 shows the increase in ground-water use since 1933.

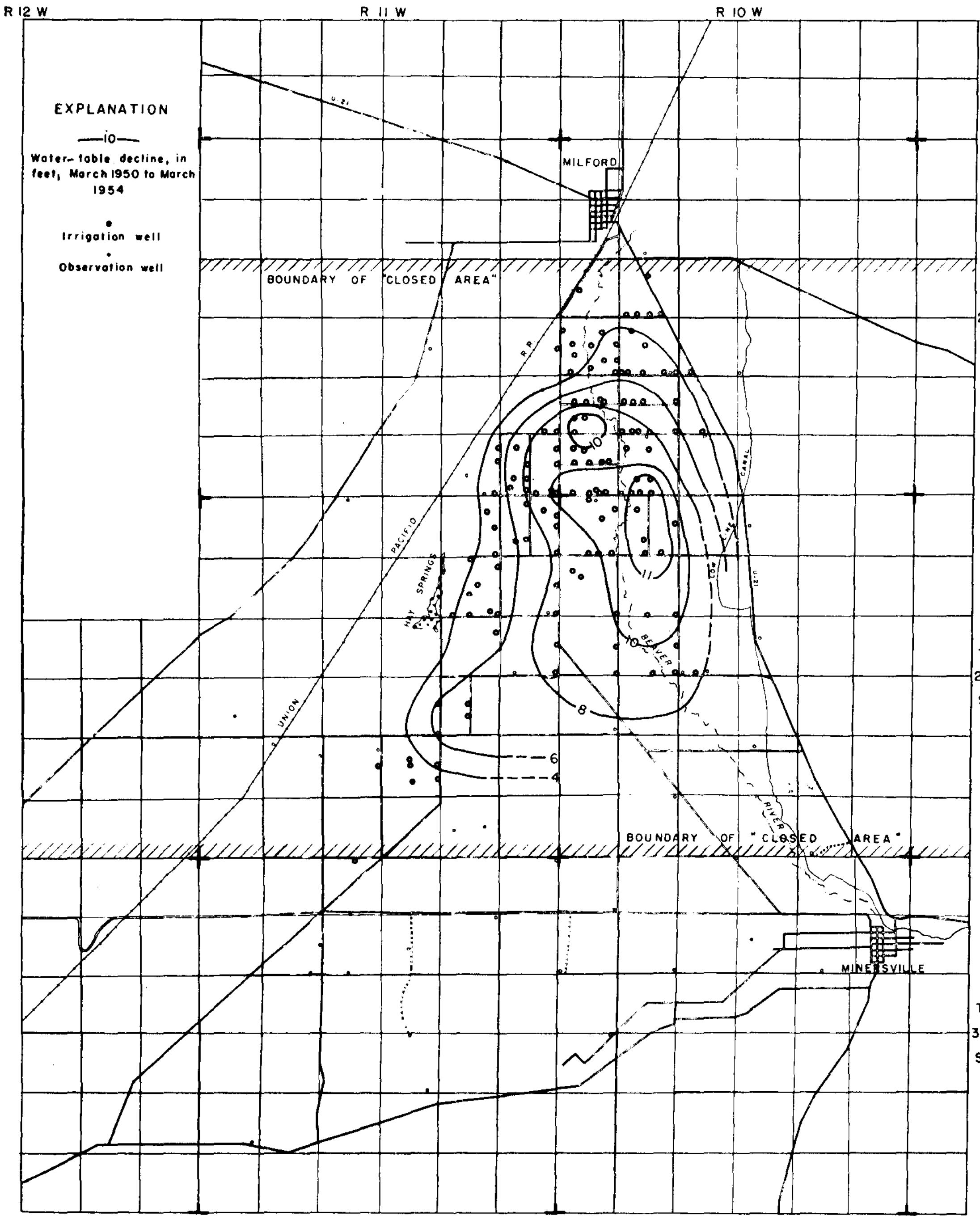


Figure 4. Map of Milford district showing areas of water-table decline, March 1950 to March 1954, and the "closed area."

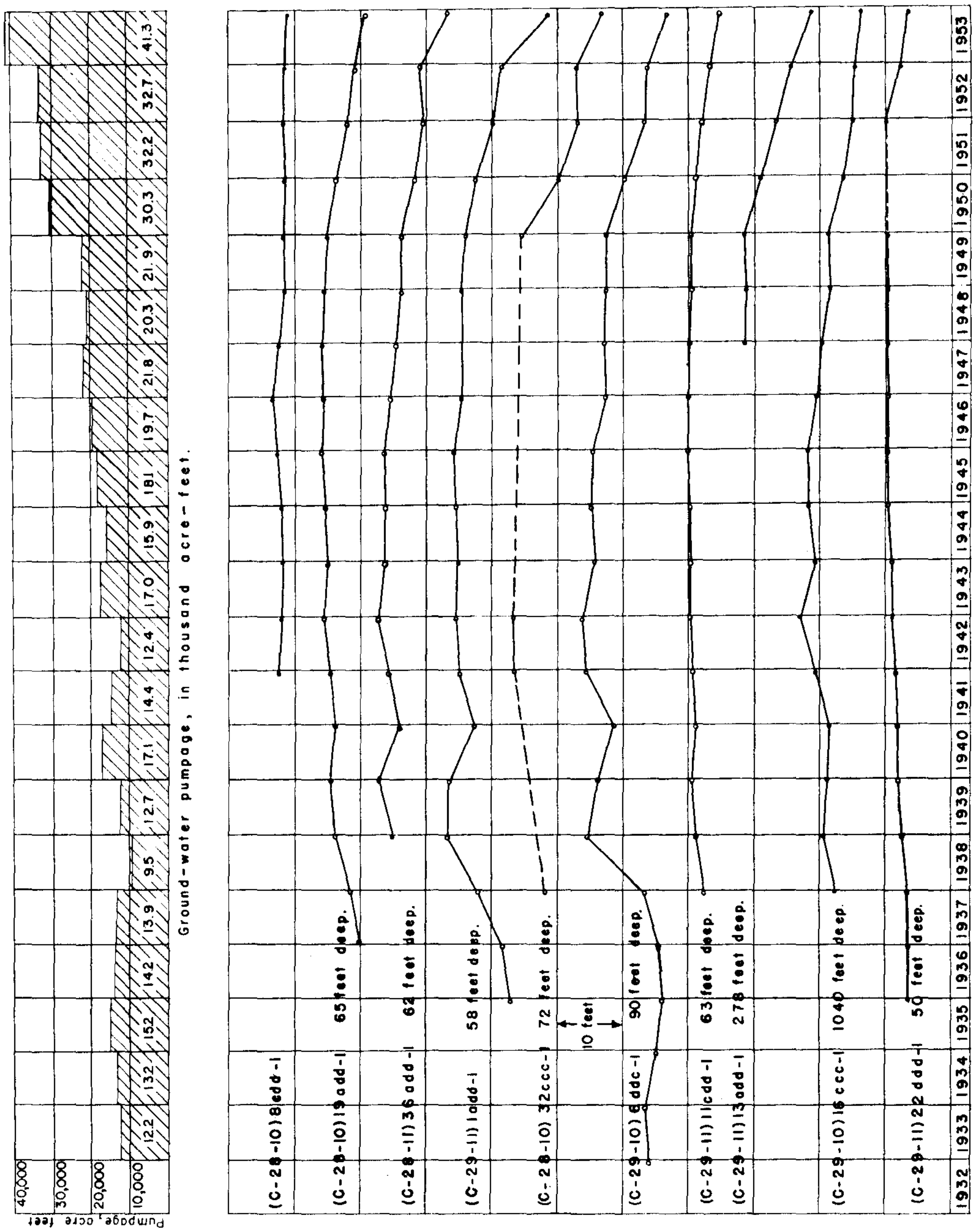


Figure 5. Annual pumpage and water-level trends, Milford district, Utah.

Table 1 lists the irrigation wells and the estimated annual pumpage in the Milford district, for several years during the period from 1931 to 1953. The estimated annual pumpage in the Milford district for every year of the period 1931-51, inclusive, was included in an earlier report published by the State Engineer (Thomas, Nelson, Lofgren, and Butler, 1952, opp. p. 54).

During the 1953 irrigation season 350 field visits were made to the 136 irrigation wells located in the district to determine the quantities of water being pumped and the acreage of land being irrigated. In addition, 305 measurements of nonpumping water levels were made in irrigation wells in the valley when they were idle. Table 2 lists the measurements of water level and well discharge for each of these wells. Table 3 includes for each well the computed ground-water pumpage, the approximate number of acres irrigated, and rate of ground-water use in acre-feet per acre. In several instances, as is indicated in the tables, the water from two or more wells was combined to irrigate a common plot of ground. In each instance, it has been impossible to separate the number of acres serviced by each well, and the two or more wells have been considered as a single pumping unit insofar as the water-use computations are concerned.

Two histograms (fig. 6) have been prepared to illustrate (1) the distribution of water use with respect to the total acres irrigated and (2) the distribution of water use in the district with repect to the number of pumping units. The upper histogram in fig. 6 A relates to the total number of acres irrigated in the district to the rate of water application in 1953. Thus, the average acre in the district received 4.4 acre-feet of water in 1953. The lower histogram, fig. 6 B, indicates the number of pumping units that fall within each category of water-use rate and shows that during the 1953 pumping season the median well in the district supplies water at the rate of 4.7 acre-feet per acre to the adjacent land which it irrigates. This diagram shows also a balanced distribution of wells falling in the categories from 2 to 7 acre-feet per acre. It is worthy of note that these two rates of ground-water use are in close agreement.

Recharge

The most important source of ground-water recharge in the Milford district, is the Beaver River. Direct precipitation on the contributing drainage area and infiltration from surface irrigation also are important sources of recharge (Fix, Nelson, Lofgren, and Butler, 1950, p. 184-194). Significant seepage losses from the Beaver River below Minersville have been measured on several occasions. The deeper aquifiers in the valley probably are recharged by water from the Beaver River in the upper reaches of the river, and the shallow aquifers probably are replenished by the stream in the lower reaches of the river. Thus, a close correlation has been observed between the fluctuations of water level in the shallow water-table wells near Beaver River in midvalley and the amount of water flowing down this stream channel.

The flow of the Beaver River at Minersville is divided into two main streams, one of which is diverted to irrigate land in the vicinity of Minersville and the other, via the Yellow Mountain Canal for use on land southeast of Milford. Water flows in the Beaver River channel below the Yellow Mountain Canal diversion only in years of unusually high water supply, when Rockyford Reservoir is filled to capacity and when enough water spills to exceed the early irrigation needs. This excess runoff can be expected about once in 10 years on the average. Excess runoff occurred in 1952 when the total runoff during the water year

Table 1. Irrigation wells and estimated annual pumpage in the Milford District, Escalante Valley, 1931-53.

Coordinate number	Application or claim	OWNER	Depth	ESTIMATED ANNUAL PUMPAGE, ACRE-FEET							
				1931	1935	1940	1945	1950	1951	1952	1953
(C-28-10)											
16cda-1		George Mayer									170
17bda-1	A 11764	Milton Poole						30	30	30	20
17ccc-1	A 11870	George C. Goodwin	92		130	160	190	240	290	130	160
17cdc-1	C 1087	George C. Goodwin			120		390	200	140	200	165
17cdd-1	A 14623	J. O. Singer	170					190	260	200	275
17dcd-1	C 20722	R. T. Slinkerd	156							130	120
18aca-1	C 1089	George C. Goodwin	75								
18acd-1	C 1090	George C. Goodwin	100		150	200	190	80	90	50	160
18cbc-1	A 17555	Carl Elmer	193						50	80	
19abd-1	C 3359	T. E. Walker	60				320	180	170	120	140
19acc-1	C 6563	Clauss Marshal	63	40	130	260	170	290	250	220	210
19add-1	C 6564	Clauss Marshal	65	150	140	310	190	320	280	200	130
19bbc-1	C 6352	Carl Elmer	72					130	110	60	180
19bcd-1	C 5340	Carl Elmer	58	200	210	290	240	180	190	80	185
19cbd-1	C 3994	Ivan McKnight	90		250	290		150	160	90	150
19ccc-1	C 3992	Ivan McKnight	87	110	200	180	260				
19ccd-4	C 3993	D. I. McKnight			110	100	260	290	210	110	215
19dac-1	C 1088	Lester Roberts	86		140	190	380	370	240	130	255
19dad-1	C 1086	Lester Roberts	72	110	160	170	160	210	150	250	210
19dcc-1	C 2042	H. L. Tolley		120	110	60	150	190	160	170	285
19ddd-1	C 2041	Floyd Wright	109				280	170	210	110	175
20bbd-1	C 5772	A. J. Kirk	90	20	220	270	290	190	190	180	210
20bdd-1	C 2043	R. W. Jones	85	30	220	320	260	440	430	270	245
20ccc-1	A 15157	R. W. Jones	90				180	190	160	90	65
20ccd-1	C 2044	R. W. Jones	84		140					360	355
20cdd-1	C 197	Floyd Wright		160	120	220	20	160	160	160	105
20dcd-1	C 10286	George Mayer	65						130	120	100
20ddd-1	A 18138	George Mayer	410						410	510	185

Table 1 (cont.). Irrigation wells and estimated annual pumpage in the Milford District, Escalante Valley, 1931-53.

Coordinate number	Application or claim	OWNER	Depth	ESTIMATED ANNUAL PUMPAGE, ACRE-FEET 1931	1935	1940	1945	1950	1951	1952	1953
(C-28-10)											
21cdd-1	A 18125	George Mayer	316					90	120	20	90
28cdd-1	A 18265	James Miner									355
29add-1	A 18265	James Miner									770
29bcc-1	C 13803	McCoy Williams	257				250	170	100		265
29bcd-1	C 13804	McCoy Williams							330	380	325
29bdd-1	C 2531	Duard Evans	60	200	210	280	200	260	210	150	160
29cad-1	C 2532	J. H. Lofthouse	78	180	140	280	250	260	170	140	175
29ccc-1	C 7801	John H. Weston	74	160	20	220	170	110	160	90	90
29ccd-1	C 7800	John H. Weston	83		390	330	320	220	360	270	535
29cdc-1	A 11742	John H. Weston	77		120			130	130	70	80
29dcc-1	C 2559	Boyd Evans	77	140	170	260	160	210	180	110	75
29ddd-1	A 18265	James Miner									365
30acd-1	C 15131	McCoy Williams			10			130	240	200	270
30adc-1	C 17791	McCoy Williams	101	20	160		450	250	270	230	260
30adc-2	C 17790	McCoy Williams	65								
30bdc-1	C 14102	Ira M. Fisher	131	220	220	240	240	240	240	60	285
30bdd-1	C 13813	Parley B. Fisher	148	120	230	340	270	210	260	250	285
30cac-1	A 19665	Morgan Griffiths	196						270	200	200
30cad-1	C 8900	Ivan McKnight	52	160	170	260	240	240	190	210	150
30ccc-1	C 4056	Morgan Griffiths	54	180	160	290	250	80	190	210	240
31acd-1	C 9911	Clair Gillins	79	110	160	200	220	150	140	180	110
31adc-1	C 7639	Guy Whitaker	136	130	140	340	370	330	210	400	535
31add-1	C 7640	Guy Whitaker	77	230	220	330	280	310	320		
31bac-2	C 1327	Delbert Schow	72		180	260		230	220	220	215
31bad-2	C 306	R. W. Jones	90	100	150	240		250	260	230	185
31bcd-1	C 2233	John T. May		190	160		190	220	200	170	90
31bdd-1	C 9912	Clair Gillins	89	60	160	270	220	200	210	160	265

31bdd-2	C 15171	William Naurse	100	70	230	180	170	60	230	240	270
31cad-1	C 10314	Clair Gillins	78	170	190	230	70	200	210	180	190
31cbd-1	C 11802	Ernest Myers	71				190	160	160	20	
31ccd-1	C 11801	Ernest Myers				310	310	210	230	370	460
31cdd-1	C 10315	Orin Puffer	78	250	240	260	210	250	200	200	155
31dcc-2	C 2815	Orin Puffer	138				180	310	420	160	190
31dcd-1	C 2816	Orin Puffer	72	120	260		150	220	180	380	365
31ddc-2	A 18181	Eugene Mayer	195					160	220	170	235
32aac-1	C 20597	J. H. Valine	94					70	110	90	20
32bda-1	C 8757	Walter Yardley	84						250	320	325
32bbc-1	C 8756	Walter Yardley	132	170	170	310	290	290	280	250	205
32cac-1	C 305	Don Alger	109	210	200		410	440	360	370	370
32ccc-1	C 2040	Jack Hadley	72	120	80						
32ccd-1	C 3837	Jack Hadley		120	120	200	320	150	150	180	190
32cdc-1	C 1421	C. Edwin Paice	85	150	200	360	40	400	210	300	190
32dbc-1	C 1423	C. Edwin Paice	84	110	400	340	280	300	150	190	165
32dcc-1	C 1422	C. Edwin Paice	68	180	250	330	310	250	140	290	240
(C-28-11)											
24daa-1	C 11221	Leo Mayer	204	210	200	330	290	190	290	120	255
25abd-1	C 9402	George Smith	77	80	310						
25dcd-1	A 19995	A. R. Backus	431					180		910	750
25ddd-1	C 3392	Kent Smith	73	190	220	260	240	240	230	160	160
35aad-1	C 4	W. D. Stewart	51					270	260	190	210
35add-1	C 3	Lewis Stewart	77					270	240	280	295
35ddd-1	C 3619	Mrs. W. M. Bond		200	140	170	150	320	290	190	265
36aad-1	C 7662	Gus Hooten	110					240	280	200	255
36add-1	C 20233	George Smith	62	160	160						60
36bac-1	C 5265	W. J. Stewart					280	270	320	370	295
36bad-1	C 6519	W. D. Stewart	85					170	10		
36bdd-1	C 2	W. D. Stewart	230	140	140	170	220	360	370	320	310
36bba-2	C 5267	W. D. Stewart	66	100	240						
36cad-2	C 19388	Lewis Stewart	170		30	170	200	280	270	300	350
36cbd-1	C 10149	Eugene Mayer	78					250	210	110	175
36cca-1	C 1	Eugene Mayer	84	70	60	180	170	230	200	190	235
36cdd-1	C 3691	John W. Stahl		140	200	270	410	550	380	470	470

Table 1 (cont.). Irrigation wells and estimated annual pumpage in the Milford District, Escalante Valley, 1931-53.

Coordinate number	Application or claim	OWNER	Depth	ESTIMATED ANNUAL PUMPAGE, ACRE-FEET							
				1931	1935	1940	1945	1950	1951	1952	1953
(C-28-11)											
36dcc-1	C 5143	Stanley B. Lewis		90	140	140	60	180	200	200	200
36dcd-1	C 5142	Stanley B. Lewis	71		190	250	200				
36ddd-1	C 5296	Dan Rollins	60		120	180	190	210	170	220	200
36ddd-2	C 5297	Dan Rollins	80	170	160	210	180	200	190	190	150
(C-29-10)											
5add-1	A 20049	Fowler & Pepple									530
5bac-1	C 6839	L.D.S. Church		250	210	290	290	270	210		110
5bbb-1	C 10318	Alvin Jones	58	80	80			50	30	10	
5cad-1	C 10285	Jack Hadley	84	290			240	30	250	240	280
5cdd-3	C 7638	Guy Whitaker	198		210	260		390	300	270	280
5dcd-1	A 19996	Otto Fowler	420								725
6aad-1	C 17295	Alvin Jones	95	230	150	160	60	250	150	80	170
6abb-1	a 2042	Gael Elmer						210	190	160	
6aca-1	C 5284	Gael Elmer	200	280	420			190	180	200	470
6baa-1	C 4494	Don Elmer		160	330	230	230	160	130	160	270
6bbd-1	C 13109	Don Elmer	130	120	200	110	120	140	150	110	
6cdd-1	A 17927	Rosheen Lavender	350					450	530	60	370
6dcd-1	A 11727	Lloyd Mayer	235					180	460	410	360
6ddc-1	C 13116	Willard Thompson						130	170	180	205
7bbd-1	C 15658	Arnold Lawson	80		230	250	230	200	240	180	170
7bda-1	C 13	Arnold Lawson	80	130	170	200	230	200	240	180	115
7ddd-1	A 13697	Russell Mayer	245					510	620	630	820
8cdd-1	A 19845	M. F. Persons								250}	
8ddd-1	A 18484	M. F. Persons								500}	1515
16cdc-2	A 18493	Eugene Myers	212								595
17add-1	A 18483	M. F. Persons	200					510	650	1130	1330
17cdd-1	A 18481	M. F. Persons	200					650	520	330	870
17ddd-1	A 18482	M. F. Persons	200					670	550	850	925
18add-1	A 18373	Russell Mayer	168					550	840	700	535
18ddd-1	A 18479	Russell Mayer	170					260	650	460	585

(C-29-11)											
1abd-1	C 6523	Basil Rollins	86	150		230	220	240	160	270	250
1ada-2	C 11579	M. K. Williams	58	140	150	130		260	250	170	125
1add-1	C 10290	Orin Williams	58	120		110		320	260	190	185
1bad-1	C 1166	Max K. Price	140	110	140	160	170	250	250	320	370
1cac-1	C 157	Doyle Sly	72	150	220	230		240	240	180	260
1cad-2	C 156	Doyle Sly	225					180	170	120	325
1ddd-1	A 18563	A. R. Backus						350		800	485
2aac-1	C 12797	Jimmy Sherwood	64	170	170	210	190	280	320	200	170
2add-1	C 2561	Lyle Applegate	52	120	130	170	170	160	190	190	160
2ddd-1	A 21160	Earl Limb		220	200		160	130	160	140	240
11aad-1	C 5768	Alvin Jones		130	110		160	140	50	110	545
11aba-1	C 5770	Alvin Jones	84			330	230	420	350	320	
11acd-1	C 5769	Alvin Jones	82		290	350	260	330	280	270	310
11baa-1	a 2356	Cook Brothers						180	200	240	170
11cad-1	C 7541	J. L. Shepherd	96					110	210	140	160
11ccd-1	C 7705	Russell Meyer	62	130	150	220	180	250	320	180	115
11cdd-1	C 7540	J. L. Shepherd						330	260	240	335
11ddc-1	C 1169	Cook Brothers	65					20	260	200	110
11ddd-1	C 1168	Cook Brothers	83			440	380	40	360	310	250
12add-1	A 17298	A. R. Backus	202					270			355
12ddd-1	A 18266	George Jessen						310	110		450
13add-1	A 18004	George Jessen	276							180	590
13ddd-1	A 17882	George Jessen	248					170		380	775
14aad-1	C 2814	Ben Lewis		210	220	290	300	440	360	450	485
22add-1	C 17158	M. F. Persons	65	290	340	390	380	220	200	280	435
23bdd-1	A 19840	Luther Tonn							500	650	960
23cad-1	C 13119	M. F. Persons		320	300	350	340	250	230	250	530
27add-2	C 2619	J. H. Hankins	118					320	340	440	
27bad-1	C 2618	J. H. Hankins	200						270	250	205
27bdd-1	C 2617	J. H. Hankins			140			170	120	160	130
27dad-1	A 18062	J. H. Hankins	300					580	730	840	620
27dcd-1	C 2620	J. H. Hankins	68	140	270	220		180	660	260	400
28aad-2	A 20102	Odell Leathers	203					220			
28add-2	C 10254	Otto Kesler						460	590	360	510
TOTAL NUMBER OF WELLS				68	83	71	78	124	126	130	135
TOTAL ACRE-FEET PUMPED				10,300	15,200	17,140	18,070	30,290	32,210	32,310	41,290

Table 2. Measurements of water level and discharge of irrigation wells in the Milford District, Escalante Valley, 1953.

Coordinate number	Depth (feet)	Type of pump & power[1]	Static measurements: Date	Static measurements: Depth to water[2] (feet)	Pumping measurements: Date	Pumping measurements: Depth to water[2] (feet)	Discharge (gpm)
(C-28-10)							
16cda-1	170	T D	3/16	37.36	7/13	122.0	810
			4/7	37.20	8/27	156.1	970
			10/8	40.92			
			12/9	35.58			
17ccc-1	92	T E	3/17	5.25	5/8	21.5	550
			10/8	9.92	7/14	23.0	485
			12/9	9.19	8/20	24.7	460
17cdc-2		T E			5/8	29.0	605
17cdd-1	170	T E			5/4	24.8	570
					7/14	28.5	505
					8/20	29.9	485
17dcd-1	156	T E	3/17	17.33	6/9	39.7	445
			10/8	22.94	7/13	41.0	410
			12/9	20.31			
18acd-1	100	C E			8/26		*a*390
19abd-1	60	C E			8/26		*a*245
19acc-1	63	T E			5/6	33.0	480
					7/13	36.0	380
					8/28	33.5	320
19add-1	65	C E	3/17	7.03	5/6	25.7	370
			10/8	13.00	7/13	28.0	
			12/9	10.57	8/26	26.5	315
19bbc-1	72	T E			7/14	22.0	340
					8/27	22.5	325
19bcc-1	58	T E			7/14	29.5	340
					8/27	30.2	320
19cdb-1	90	C E			6/13		340
					8/27		325
19ccd-4		T E	3/17	7.97	5/6	44.0	400
			10/14	17.18	7/14	47.5	350
			12/9	11.93	8/26	50.0	340

19dac-1	86	T E			7/14		380
					8/28		340
19dad-1	72	T E			5/4	29.7	430
					6/16	32.1	
					7/13	41.0	295
					8/28	*a*38.1	235
19dcc-1		T E			5/6	25.3	
					6/10	29.4	485
					7/14	29.7	455
					8/28	30.1	375
19ddd-1	109	C E	3/17	8.83	5/4	30.7	405
			10/8	17.12	7/14	36.0	260
			12/9	14.01	8/28	35.7	230
20bbd-1	90	T E			5/5	25.0	
					7/14	27.5	480
20bdd-1	85	T E			5/5	37.6	690
					7/20		620
20ccc-1	90	C E			7/14	35.8	160
					8/27	34.9	155
20ccd-1		T E			6/16	46.3	
					7/14	49.0	550
					5/4	44.5	625
					8/28	49.8	545
20cdd-1		T E	3/17	12.19	7/13	46.2	430
			10/8	19.63	8/28	45.5	425
			12/9	16.73			
20dcd-1	65	T E			6/10		390
20ddd-1	410	T E			6/10	52.8	585
					7/14	58.0	510
					8/28	59.0	475
21ccd-1	316	T E	3/17	22.68	6/17	73.5	
			10/8	30.55	8/27	80.3	210
			12/9	26.19			
28cdd-1		T E	3/17	18.06	5/8	98.4	610
			10/8	25.34			
			12/9	21.39			
29add-1		T E	3/17	13.76	6/12		*a*1350
			10/8	25.38			
			12/9	18.00			

Table 2 (cont.). Measurements of water level and discharge of irrigation wells in the Milford District, Escalante Valley, 1953.

Coordinate number	Depth (feet)	Type of pump & power[1]	Static measurements Date	Static measurements Depth to water[2] (feet)	Pumping measurements Date	Pumping measurements Depth to water[2] (feet)	Discharge (gpm)
(C-28-10) cont.							
29bcc-1		T E			5/12	24.7	635
					6/16	28.4	525
					7/13	29.4	460
					8/28	31.8	360
29bcd-2		T E			5/6		590
					7/13		380
					8/28		365
29bdd-1	60	C E	3/18	12.72	5/6	28.6	460
			10/8	22.70	7/13	31.0	230
			12/9	18.56	8/28	33.4	160
29cad-1	78	C E			7/14	30.3	265
					8/31	31.5	240
29ccc-1	74	C E	3/17	12.84	6/16		*a*100
			10/8	20.00	7/14	29.0	165
			12/9	16.66			
29ccd-1	83	T E			5/6	26.8	500
					6/16	30.5	460
					7/14	32.5	430
					8/31	33.5	420
29cdc-1	77	C E			5/6		320
					6/17		150
29dcc-1	77	C E	3/17	11.46	8/26		190
			10/8	19.85			
			12/9	17.09			
29ddd-1		T E	10/8	26.26	6/12		885
			12/11	20.38			
30acd-2		T E			5/12	39.6	500
					6/16	40.4	460
					7/13	43.0	420
30adc-1		T E	3/17	11.62	5/6	31.4	455
			10/8	20.40	7/13	37.5	365
			12/9	17.53	8/28	38.8	345

30bdc-1	131	T E			5/6		550
					6/16	30.4	550
					7/13	34.0	440
					8/31	35.7	380
30bdd-2	148	T E			5/6	38.5	670
					6/16	39.8	610
					7/13	42.0	510
					8/31	43.0	430
30cac-1	196	T E			5/7	36.0	600
					7/15	42.0	520
						44.7	510
30cad-1	52	C E			6/13		285
					8/26		145
30cdc-1	54	T E	3/17	14.56	5/7	34.9	445
			10/14	27.41	6/16	37.0	330
			12/9	21.57	7/15	37.5	225
					8/31	37.0	*a*270
31acd-1	79	C E			5/7	32.0	240
31adc-1		T E			5/7	47.8	1050
					6/17	52.8	
					7/16	54.4	925
					9/1	56.5	850
31bac-2		C E			5/7		390
					7/15	38.0	
					8/31	39.8	270
31bad-2	90	T E			5/7	36.7	480
					7/15	40.0	*a*190
					8/31	41.0	*a*160
31bcd-1		T E			5/7	35.2	240
					7/16	42.1	105
31bdd-1	89	T R	3/17	18.31	5/7	40.0	575
			10/8	29.25	7/16	47.6	440
			12/9	24.62	9/1	51.3	400
31bdd-2	100	T E			5/7	48.2	650
					6/17	49.0	
					7/16	55.2	490
					9/1		450
31cad-1	78	T E			5/12	40.8	515
					9/1	51.5	310

Table 2 (cont.). Measurements of water level and discharge of irrigation wells in the Milford District, Escalante Valley, 1953.

Coordinate number	Depth (feet)	Type of pump & power[1]	Static measurements: Date	Static measurements: Depth to water[2] (feet)	Pumping measurements: Date	Pumping measurements: Depth to water[2] (feet)	Discharge (gpm)
(C-28-10) cont.							
31ccd-1		T E			6/10	41.0	870
					7/15	43.4	780
					8/31	56.1	800
31cdd-1	78	C E			6/10		230
					7/15		195
					8/31	51.5	195
31dcd-1		T E			6/10	45.9	200
					7/16		430
					8/31		345
31dcc-2	138	T E			6/10	52.8	665
					7/16	59.9	585
					8/31	64.8	525
31ddc-2	195	T E			7/16		490
32aac-1	94	C E			6/17	24.0	
					8/26		510
32bda-1	84	T E			5/12	28.4	
					7/17	35.6	500
32bbc-1	132	T E			8/26	44.8	460
32cac-1	109	T E			5/12	31.6	590
					7/17	37.8	545
					8/31	42.8	510
32ccd-1		T E			6/13	43.7	485
					7/17	45.2	445
					8/31	47.2	380
32cdc-1	85	T E			5/6	34.1	505
					6/17	39.0	460
					7/17	41.0	385
32dbc-1	84	C E			5/6	34.0	460
					7/17	36.9	340
					8/31	37.4	260
32dcc-1	68	C E			5/6		555
					7/17		410
					8/31		370

(C-28-11)							
24daa-1	204	C E	3/17	7.47	7/14	21.3	410
			10/23	11.30	8/27	22.0	395
			12/9	9.25			
25dcd-1	431	T D	3/17	9.21	6/9		1800
			10/23	17.19	8/20		1700
			12/9	14.20			
25ddd-1	73	T E			7/15	38.2	235
					8/31	43.8	170
35aad-1	51	C E			5/11		410
					8/27		300
35add-1	77	T E	3/17	12.62	5/11	21.8	615
			10/14	21.56	9/1	30.2	415
			12/9	15.65			
35ddd-2		T E			6/11	39.2	380
					7/13	41.0	345
					9/1	41.7	335
36aad-1	110	T E			6/10	41.0	510
					7/15	44.0	450
					8/27	49.3	310
36add-1	62	C E	3/18	12.98	6/9	30.5	330
			10/8	25.74	7/15	32.5	190
			12/8	19.67	9/1	34.4	130
36bac-1		T E			5/8	25.5	660
					6/15	26.5	625
					7/15	28.5	520
36bdd-1	230	T E			9/1	28.0	435
					5/8	30.0	590
					6/15	35.2	550
					7/15	44.4	490
36cad-2	170	T E			9/1	44.2	475
			3/18	15.45	5/8	33.9	640
			12/9	20.50	6/15	38.6	585
					7/15	44.0	530
36cbd-1	78	T E			9/1	46.7	500
					6/11	29.0	390
					7/15	30.2	365
36cca-1	84	T E			9/1	35.2	340
					6/11	32.7	480
					7/15	35.8	440
					9/1	36.7	405

Table 2 (cont.). Measurements of water level and discharge of irrigation wells in the Milford District, Escalante Valley, 1953.

Coordinate number	Depth (feet)	Type of pump & power[1]	Static measurements Date	Static measurements Depth to water[2] (feet)	Pumping measurements Date	Pumping measurements Depth to water[2] (feet)	Discharge (gpm)
(C-28-11) cont.							
36cdd-2		T E			5/8	49.9	905
					7/15	54.0	685
					9/1	55.1	665
36dcc-1		T E			5/11	37.7	510
					7/13	45.5	315
					9/1	46.3	280
36ddd-1	60	C E	3/18	16.49	5/7	33.5	450
			10/8	27.00	6/15	33.5	
			12/9	23.21	7/13		260
					8/27		170
36ddd-2	80	C E			5/7		295
		T E			8/27	51.2	250
(C-29-10)							
5add-1		T E	4/7	36.42	6/9		1380
			10/9	44.38	7/17	100.0	1300
			12/9	40.28			
5bac-2		T E			7/23	*a*55.0	395
					9/2	50.2	355
5cad-1	84	T E			5/10	42.6	600
					7/17	51.9	495
					9/2	54.7	295
5cdd-3	198	T E	3/17	41.02	5/8	48.0	770
			10/9	48.00	6/16	54.6	
			12/9	44.15	7/17	63.7	515
					8/26	64.0	*a*470
					9/2	62.1	560
5dcd-1	420	T E			6/13	93.8	2000
					7/17	99.0	
6aad-1	95	C E			6/13	47.6	480
					7/23	*a*47.0	165

6aca-1	200	T E			5/5	59.5	1090
					6/17	63.3	910
					7/18	63.9	880
					9/1	64.6	770
6baa-2		T E			6/10	54.0	705
					6/17	56.8	
					7/15	58.6	660
					8/28	61.8	610
6cdd	350	T E			5/6	75.6	1550
					7/20	77.0	1330
					9/1	77.9	1200
6dcd-1	235	T E			7/20	67.5	680
					9/2	70.0	610
6ddc-1		T E	3/16	34.10	6/12	50.5	500
			10/9	44.58	7/18	51.0	470
			12/9	40.53			
7bbd-1	80	T E			6/12		305
					7/18	48.5	280
					9/2	*a*48.2	235
7bda-1	80	C E			6/12	47.7	265
					7/18	48.8	170
7ddd-1	245	T D			6/12		1520
					7/20		1370
					9/2		1350
8cdd-1		T P			7/22		1580
					9/2		990
8ddd-1		T P			7/22	*a*97.0	1870
					9/2	*a*96.0	1670
16cdc-1	212	T E			6/12		1360
					7/22		1240
					9/2		1190
17add-1	200	T E	3/10	64.05	5/8	83.7	2120
			10/9	77.80	6/16	91.0	2040
			12/9	70.47	7/22	94.7	1930
					8/19	96.5	1880
17cdd-1	200	T E			6/12	93.0	2250
					7/20	96.5	2220
					9/2	97.0	2200

Table 2 (cont.). Measurements of water level and discharge of irrigation wells in the Milford District, Escalante Valley, 1953.

Coordinate number	Depth (feet)	Type of pump & power[1]	Static measurements Date	Depth to water[2] (feet)	Pumping measurements Date	Depth to water[2] (feet)	Discharge (gpm)
(C-29-10) cont.							
17ddd-1	200	T E	3/17	74.28	5/8	94.0	
			10/23	84.60	6/12		1610
			12/9	80.40	7/22		1610
					8/14		1500
18add-1	168	T D	3/17	53.79	6/12		1330
			10/23	61.85	7/20		1020
			12/9	60.00	9/2		960
18ddd-1	170	T D			6/12		1460
					7/20	*a*78.0	1340
					9/2	*a*65.0	1310
(C-29-11)							
1ada-2	86	T E			5/11		460
					7/20		310
					9/1		235
1abd-1	86	T E			5/11	32.1	
					7/20	39.9	340
					9/1	43.5	345
1add-1	58	T E	3/17	24.02	5/7	40.4	400
			10/14	32.85	7/18		340
			12/8	29.50	9/1		350
1bad-1	140	T E			5/11	42.2	705
					6/15	47.6	
					7/18	49.9	610
					9/1	51.5	590
1cac-1	72	T E			6/11	33.7	400
					9/1	35.0	370
1cad-2	225	T E			6/3	41.0	625
					9/1	42.8	600
1ddd-1		T D			6/9		1780
					7/18		1540
					9/1		915

2aac-1	64	T E			5/11	36.2	
					6/15	37.0	
					8/27	38.3	205
2add-1	52	C E	12/9	18.44	5/11	31.7	
					7/13	32.0	255
2ddd-1		C E			5/11	31.3	
					7/13	35.0	260
					9/1		230
11aad-1		T E	3/17	19.15	6/11	52.4	1060
			10/20	23.47	7/20	59.5	1080
			12/9	22.20	8/20	60.7	1060
11acd-1	82	C E			6/15	31.5	610
		T E			7/18	41.3	555
					9/2	40.8	500
11baa-1		T E	3/17	8.73	7/13	25.5	325
			10/13	13.18	9/1	26.7	310
			12/9	11.67			
11cad-1	96	T E			6/11	37.9	680
					7/18	43.2	750
					9/2	42.8	680
11ccd-1	62	T E			7/20		420
					9/2		405
11cdd-2		T E	3/17	20.26	6/11	36.9	640
			10/13	22.79	7/18	38.2	620
			12/9	22.35	9/2	39.2	585
11ddc-1	65	T E			7/18	35.0	265
					9/2	40.3	255
11ddd-1	83	C E			5/11		640
					9/2		630
12add-1	202	T D	3/17	32.00	7/23	38.0	1070
			10/9	38.50	9/2	38.7	1250
12ddd-1		T D			8/27	*a*78.0	1710
					9/2	*a*78.0	1730
13add-1	276	T E	3/17	39.26	6/12	68.0	1380
			10/9	45.54	7/23	67.6	1310
			12/8	43.80	9/2	67.5	1305
13ddd-1	248	T E	3/17	47.48	5/7	62.0	1480
			10/9	53.22	7/23	64.1	1350
			12/8	51.52	9/2	65.5	1300

Table 2 (cont.). Measurements of water level and discharge of irrigation wells in the Milford District, Escalante Valley, 1953.

Coordinate number	Depth (feet)	Type of pump & power[1]	Static measurements Date	Static measurements Depth to water[2] (feet)	Pumping measurements Date	Pumping measurements Depth to water[2] (feet)	Discharge (gpm)
(C-29-11) cont.							
14aad-2		T E	3/17	22.95	5/11	31.9	880
			10/13	26.52	7/22	33.5	645
			12/9	26.55	9/2	35.4	710
22add-1	65	T E	3/17	22.63	7/20	38.7	685
			12/9	23.85			
23bdd-1		T D			8/27	60.3	*a*1910
23cad-1		T E			7/20	58.0	1690
					9/2	55.3	1720
27bad-1	200	T E			7/23		865
					9/2		810
27bdd-1		T E			7/20		535
27dad-1	300	T E	3/17	35.24	6/11	55.3	1250
			10/8	37.13	7/22	55.9	1230
			12/9	36.48	9/2	57.0	1215
27dcb-1		T E			6/11		750
					7/20		750
					9/2		745
28add-2		T E			6/11	46.0	935
					7/20	45.5	970
					9/2	45.4	975

[1] Pumps: T, turbine; C, centrifugal. Power: E, electric motor; D, diesel engine; P, propane engine.
[2] Below land surface.
a Accuracy questionable.

Table 3. Pumpage inventory, Milford District, Escalante Valley, 1953.

Coordinate number	Application or claim	OWNER	Pumpage (ac. ft.)	Acres irrigated	Acre-feet / acres
(C-28-10)					
16cda-1		George Mayer	170	66	2.6
17bda	A 11764	Milton Poole	20	14	1.4
17ccc-1	A 11870	G. C. Goodwin	160		
17cdc-1	C 1087	G. C. Goodwin	165	54	6.0
17cdd-1	A 14623	Dr. Kohler	275	53	5.2
17dcd-1	C 20722	R. T. Slinkard	120	30	4.0
18acd-1	C 1090	G. C. Goodwin	160	40	4.0
19abd-1	C 3359	T. E. Walker	140	40	3.5
19acc-1	C 6563	Clauss Marshall	210		
19add-1	C 6564	Clauss Marshall	130	105	3.2
19bbc-1	C 6352	Carl Elmer	180		
19bcb-1	C 5340	Carl Elmer	185	133	2.7
19cbd-1	C 3994	Ivan McKnight	150		
19ccd-4	C 3992	Jess McKnight	215	77	4.7
19dac-1	C 1088	Lester Roberts	255		
19dad-1	C 1086	Lester Roberts	210	85	5.5
19dcc-1	C 2042	H. L. Tolley	285	49	5.8
19ddd-1	A 21799	Floyd Wright	175	36	4.9
20bbd-1	C 5772	J. A. Kirk	210	39	5.4
20bdd-1	C 2043	R. W. Jones	245		
20ccc-1	A 15157	R. W. Jones	65	150	4.4
20ccd-1	C 2044	R. W. Jones	355		
20cdd-1	C 197	Floyd Wright	105	38	2.8
20dcd-1	C 10286	Mayer Brothers	100		
20ddd-1	A 18138	George Mayer	185	142	2.0
21cdd-1	A 18125	Mayer Brothers	90	46	2.0
28cdd-1	A 18265	James Miner	355	*a*580	2.6
29add-1	A 18265	James Miner	770	*a*	
29bcc-1	C 13803	McCoy Williams	265	*b*166	6.7
29bcb-1	C 13804	McCoy Williams	325	*b*	
29bdd-1	C 2531	Duard Evans	160	55	2.9
29cad-1	C 2532	J. H. Lofthouse	175	37	4.7
29ccc-1	C 7801	Waldo Yardley	90		
29ccd-1	C 7800	Waldo Yardley	535	114	6.2
29cdc-1	A 11742	Waldo Yardley	80		
29dcc-1	C 2559	Boyd Evans	75	47	1.6
29ddd-1	A 18265	James Miner	365	*a*	
30acd-1	C 15131	McCoy Williams	270	*b*	
30adc-1	C 17791	McCoy Williams	260	*b*	
30bdc-1	C 14102	Ira Fisher	285	59	4.8
30bdd-2	C 13813	Parley Fisher	285	69	4.1
30cac-1	A 19665	Morgan Griffith	200	*c*98	4.5
30cad-1	C 8900	Ivan McKnight	150	38	4.0
30cdc-1	C 4056	Morgan Griffith	240	*c*	
31acd-1	C 9911	Clair Gillins	110	*d*	8.0
31adc-1	C 7639	Guy Whitaker	535	64	8.4
31bac-2	C 1327	Delbert Schow	215	37	5.8
31bad-2	C 306	R. W. Jones	185	31	6.0
31bcd-1	C 2233	J. T. Nay	90	38	2.4
31bdd-1	C 9912	Clair Gillins	265	*d*	
31bdd-2	C 15171	William Naurse	270	39	6.9
31cad-1	C 10314	Clair Gillins	190	*d*	
31ccd-2	C 11802	Ernest Mayer	460	76	6.1
31cdd-1	C 10315	O. T. Puffer	155		
31dcd-2	C 2815	O. T. Puffer	190	118	6.0
31dcd-1	C 2816	O. T. Puffer	365		
31ddc-2	A 18181	Mayer Brothers	235	76	3.1
32aac-1	C 20597	J. H. Valine	20	36	0.6
32bda-1	C 8757	Walter Yardley	325		
32bbc-1	C 8756	Walter Yardley	205	88	6.1
32cac-1	C 305	Don Alger	370	63	5.9
32ccd-1	C 3837	Gus Hooten	190	38	5.0

Table 3 (cont.). Pumpage inventory, Milford District, Escalante Valley, 1953.

Coordinate number	Application or claim	OWNER	Pumpage (ac. ft.)	Acres irrigated	Acre-feet / acres
(C-28-10)					
32cdc-1	C 1421	C. E. Paice	190		
32dbc-1	C 1423	C. E. Paice	165	148	4.1
32dcc-1	C 1422	C. E. Paice	240		
(C-28-11)					
24daa-1	C 11221	Leo Mayer	255	57	4.5
25dcd-1	A 19995	A. R. Backus	750	238	3.2
25ddd-1	C 3392	Kent Smith	160	43	3.7
35aad-1	C 4	W. D. Stewart	210	27	7.8
35add-1	C 3	Lewis Stewart	295	42	7.0
35ddd-1	C 3619	Mrs. W. M. Bond	265	49	5.4
36aad-1	C 7662	Gus Hooten	255	78	3.3
36add-1	C 20233	Leo Mayer	60	35	1.7
36bac-1	C 5265	W. J. Stewart	295		
36bdd-1	C 2	W. D. Stewart	310	157	6.1
36cad-3	A 19388	Lewis Stewart	350		
36cbd-2	C 10149	Eugene Mayer	175		
36cca-1	C 1	Eugene Mayer	235	114	3.6
36cdd-2	C 3690	H. S. Thompson	470	71	6.6
36dcc-1	C 5143	S. B. Lewis	200	41	4.9
36ddd-1	C 5296	Dan Rollins	200		
36ddd-2	C 5297	Dan Rollins	150	79	4.4
(C-29-10)					
5add-1	A 20049	Fowler & Pepple	530	*e*314	4.0
5bac-2	C 6839	L. D. S. Church	110	33	3.3
5cad-1	C 10285	Alden Hadley	280	76	3.7
5cdd-3	C 7638	Guy Whitaker	280	75	3.7
5dcd-1	A 19996	Fowler & Pepple	725	*e*	
6aad-1	C 17295	Alvin Jones	170	38	4.5
6aca-1	C 5284	Gael Elmer	470		
6baa-2	C 13109	Don Elmer	270	128	5.8
6cdd-1	A 17927	Mayer Brothers	370	207	1.8
6dcd-1	A 11727	Mayer Brothers	360	79	4.6
6ddc-1	C 13116	H. S. Thompson	205	75	2.7
7bbd-1	C 15658	Arnold Lawsen	170		
7bda-1	C 13	Arnold Lawsen	115	91	3.1
7ddd-1	A 13697	Russell Mayer	820	*f*550	3.5
8cdd-1	A 19845	M. F. Persons	1515	*g*1122	4.1
8ddd-1	A 18484	M. F. Persons		*g*	
16cdc-2	A 18493	Eugene Myers	595	120	5.0
17add-1	A 18483	M. F. Persons	1330	*g*	
17cdd-1	A 18481	M. F. Persons	870	*g*	
17ddd-1	A 18482	M. F. Persons	925	*g*	
18add-1	A 18373	Russell Mayer	535	*f*	
18ddd-1	A 18479	Russell Mayer	585	*f*	
(C-29-11)					
1abd-1	C 6523	Basil Rollins	250	35	7.2
1ada-2	C 11579	Mayer Brothers	125	50	2.5
1add-1	C 10290	Orin Williams	185	41	4.5
1bad-1	C 1166	Max K. Price	370	73	5.1
1cac-1	C 157	Doyle Sly	260		
1cad-1	C 156	Doyle Sly	325	119	4.9
1ddd-1	A 18563	A. R. Backus	485	235	2.1
2aac-1	C 12797	Jimmy Sherwood	170	50	3.4
2add-1	C 2561	Lyle Applegate	160	31	5.2
2dcd-1	A 21160	Earl Limb	240	56	4.3
11aad-2	C 5768	Alvin Jones	545		
11acd-2	C 5769	Alvin Jones	310	108	7.9
11baa-1	C 7643	R. E. Connally	170	38	4.5
11cad-1	C 7541	J. L. Shepherd	160	*h*78	6.4
11ccd-1	C 7705	Russell Mayer	115	28	4.1
11cdd-2	C 7540	J. L. Shepherd	335	*h*	

Table 3 (cont.). Pumpage inventory, Milford District, Escalante Valley, 1953.

Coordinate number	Application or claim	OWNER	Pumpage (ac. ft.)	Acres irrigated	Acre-feet acres
(C-29-11)					
11ddc-1	C 1169	R. E. Connally	110		
11ddd-1	C 1168	R. E. Connally	250	74	4.9
12add-1	A 17298	A. R. Backus	355		
12ddd-1	A 18266	A. R. Backus	450	157	5.1
13add-1	A 18004	George Jesser	590		
13ddd-1	A 17882	George Jesser	775	267	5.1
14aad-1	C 2814	Ben Lewis	485	72	6.7
28add-1	C 17158	M. F. Persons	435	70	6.2
23bdd-1	A 19840	Luther Tonn	960	157	6.1
23cad-1	C 13119	M. F. Persons	530	77	6.9
27bad-1	C 2618	J. H. Hankins	205		
27bdd-1	C 2617	J. H. Hankins	130		
27dad-1	A 18062	J. H. Hankins	620	234	5.8
27dcb-1	C 2620	J. H. Hankins	400		
28add-2	C 10254	Otto Kesler	510	68	7.5
TOTAL			41,290	9,440	Avg. 4.4

a Water from 3 wells commingled to irrigate 580 acres.
b Water from 4 wells commingled to irrigate 166 acres.
c Water from 2 wells commingled to irrigate 98 acres.
d Water from 3 wells commingled to irrigate 71 acres.
e Water from 2 wells commingled to irrigate 314 acres.
f Water from 3 wells commingled to irrigate 550 acres.
g Water from 5 wells commingled to irrigate 1122 acres.
h Water from 2 wells commingled to irrigate 78 acres.

(October 1, 1951, to September 30, 1952) was 49,970 acre-feet measured at the gaging station at Minersville. Of this quantity, an estimated 19,450 acre-feet was used during the year in the Minersville area and about 17,720 acre-feet was diverted into the Yellow Mountain Canal. There was a runoff of 11,570 acre-feet from the area as measured at the gaging station on Beaver River 3 miles north of Milford. Of this total of 11,570 acre-feet, an estimated 2,770 acre-feet occurred as spring snow melt from the flat valley floor. Thus, as much as 4,000 acre-feet of water was lost from the stream channel and much of this water served to recharge the underground reservoir.

Recharge to the ground-water reservoir occurs also in areas where considerable amounts of water are lost by seepage from canals and irrigated lands. Records of water-level fluctuations in wells show that this deep percolation results in substantial recharge to the ground-water reservoir.

Shift in Area Irrigated from Beaver River

Beginning in about 1952 a general shift in surface-water use in the Milford district began, and this change should have a significant effect on future ground-water conditions in the valley. It has been brought about primarily by the intensive farming practices that have been adopted in the farming area south of Milford, and by the conversion of the principal water supply from surface streams diverted from Beaver River to large irrigation wells. Thus, surface water that formerly was spread for irrigation on the broad, flat bottom lands south of Milford and thereby recharged the shallow water body in that area is now being diverted for use in other parts of the valley, notably in the vicinity of Minersville. As yet no marked effects of this shift in the area of ground-water recharge have been noted; however, it could add to the complexity of the ground-water problems in the next few years.

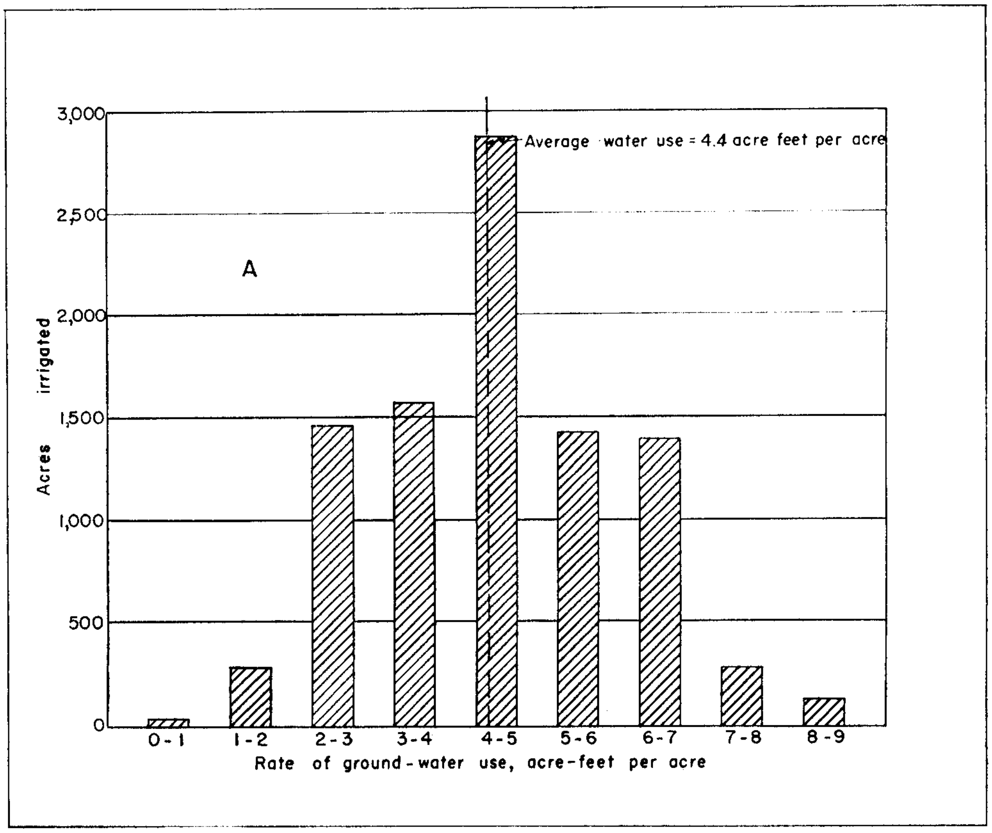
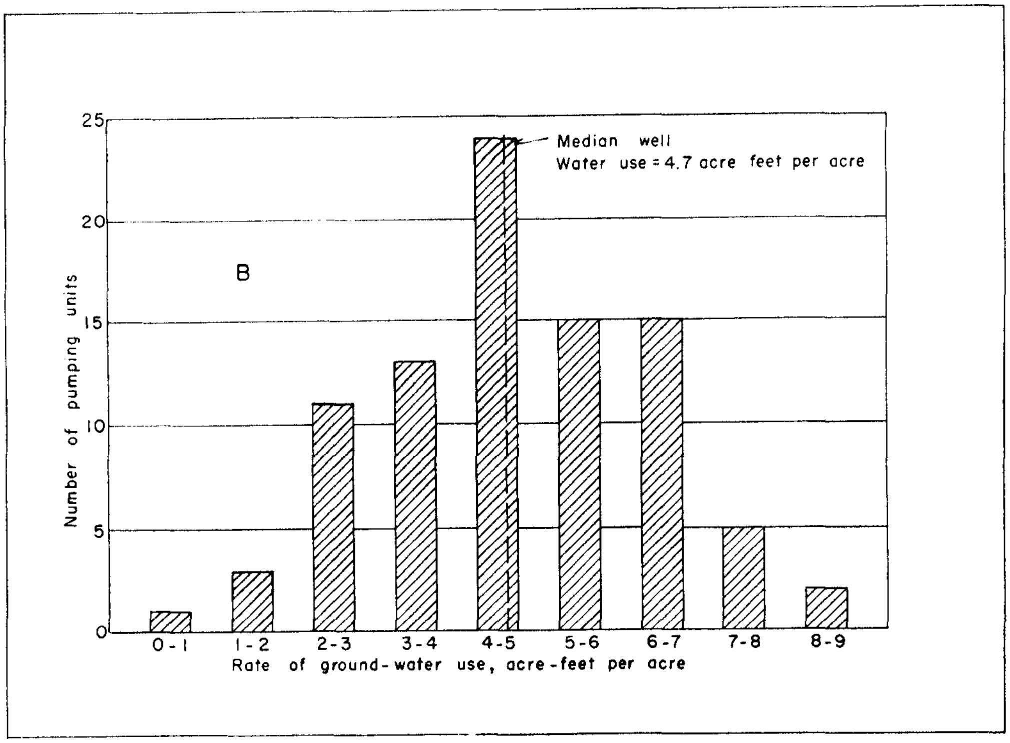


Figure 6. Distribution of pumpage in the Milford district in 1953 showing (A) rate of ground-water use with respect to acres irrigated, and (B) (opposite page) rate of ground-water use with respect to number of pumping units.

As pointed out earlier, 16 new observation wells were drilled in 1953 in the Minersville-Thermo vicinity to keep track of water-level changes in this part of the valley. Many of the new observation wells were installed in and near the recently opened irrigation area west of Minersville and in bordering areas of the valley where points of observation were needed. It is believed that the water-level records from these wells will become increasingly valuable as development in the southeastern part of the valley continues, and the effects of the shift in the area irrigated from the Beaver River become significant.

It is interesting to note that in 1952 during the period of high spring runoff only a small marginal area east of the Milford pumping district received surface-water irrigation, with the bulk of the runoff being permitted to flow through and leave the areas of the valley recharge via Beaver River. In former years of high runoff, excess stream flow was used to irrigate extensive areas on the valley floor with the result that most of the floodwater percolated into the ground to recharge the underground reservoir. The effects of these shifts in ground-water recharge and the effects of more intensive use of ground water in the valley are being studied carefully.



Water-Level Trends

The modified hydrographs of 10 selected observation wells in the Milford district are shown in figure 5. These show only the year-end water levels in wells located within the district of heavy pumping, and the close correlation between water-level trends in each of these wells and the record of ground-water pumpage is noteworthy. Wells outside the zone of influence of these pumped irrigation wells have shown little change over the period of record. Thus, water levels in these outlying wells were about the same at the end of 1953 as they were at the end of 1935. The end of 1953 marked a 6-year period of increased pumping, however, whereas an extended drought was terminated in 1935.

Water levels in the pumping district reflect somewhat the trend of runoff of the Beaver River. Thus in 1952, a year of exceptionally high runoff, a slight arresting of the downward water-level trends was noted in many of the wells, even though much of this floodwater passed the areas of ground-water recharge rather than being spread over them. Similarly, the trend of water levels during 1938 (fig. 5) showed a marked rise in response to the exceedingly high runoff of the Beaver River that year and to the large amount of surface spreading of this floodwater for cropland irrigation. In this year, little or no water passed Milford in the Beaver River, and the quantity of ground water pumped during this year (fig. 5) was greatly decreased. In 1952, only a few wells on the eastern margin of the pumping district showed marked water-level rises, this being the only area in which extensive water spreading took place.

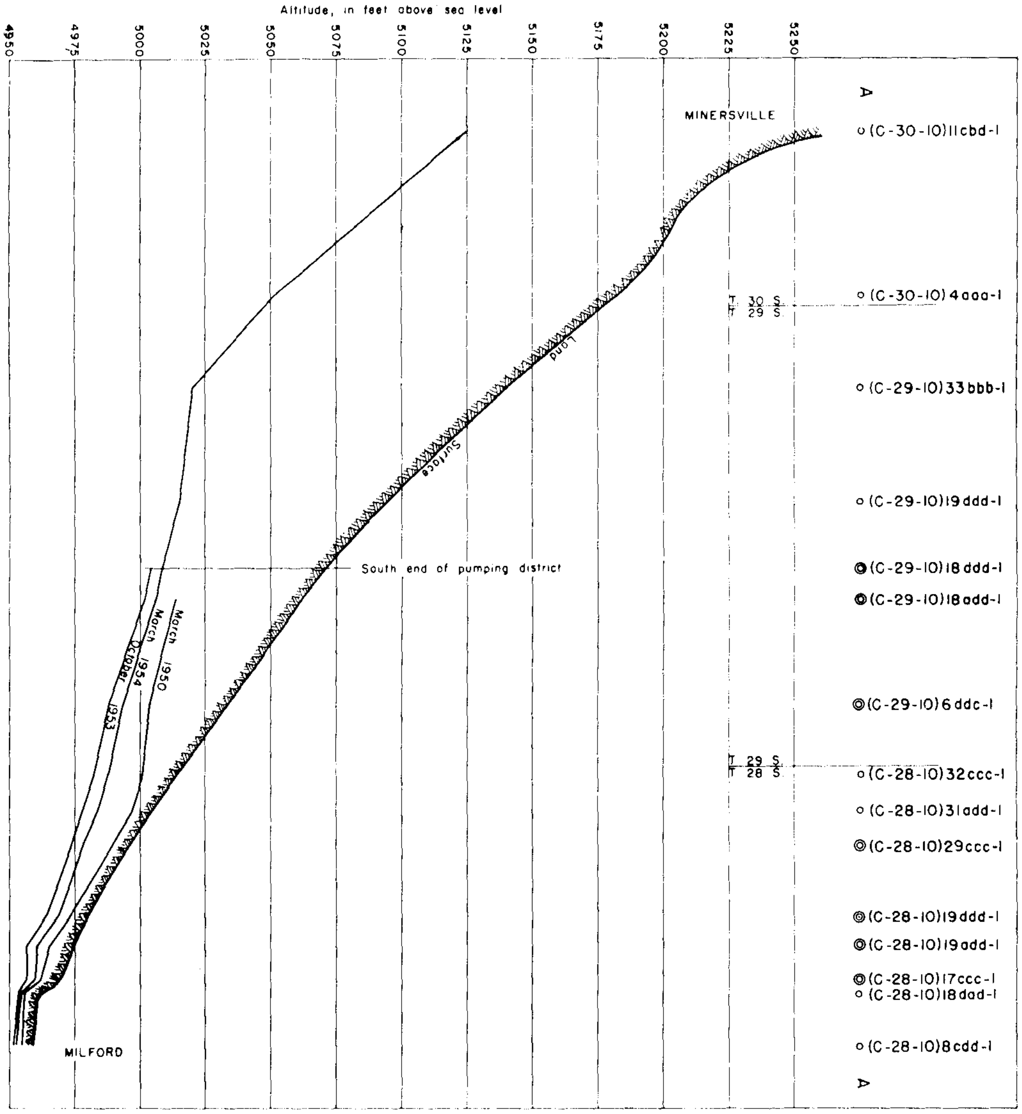


Figure 7. Profile A-A′ of the Milford district showing positions of water table.

Water levels in most of the wells in the pumping district have declined every year since 1948. The greatest declines have occurred in the past 4 years, during which the annual pumpage from the district has exceeded 30,000 acre-feet each year. Thus, heavy pumping has lowered the year-end water levels as much as 12 feet during the past 4 years, and has steepened the water-table gradient toward the center of pumping. Three cross sections have been drawn to show the effect that sustained ground-water pumping is having on the water table. In each of these are profiles based on water-level records of March 1950, October 1953, and March 1954. Thus, profile A-A′ (fig. 7) shows the position of

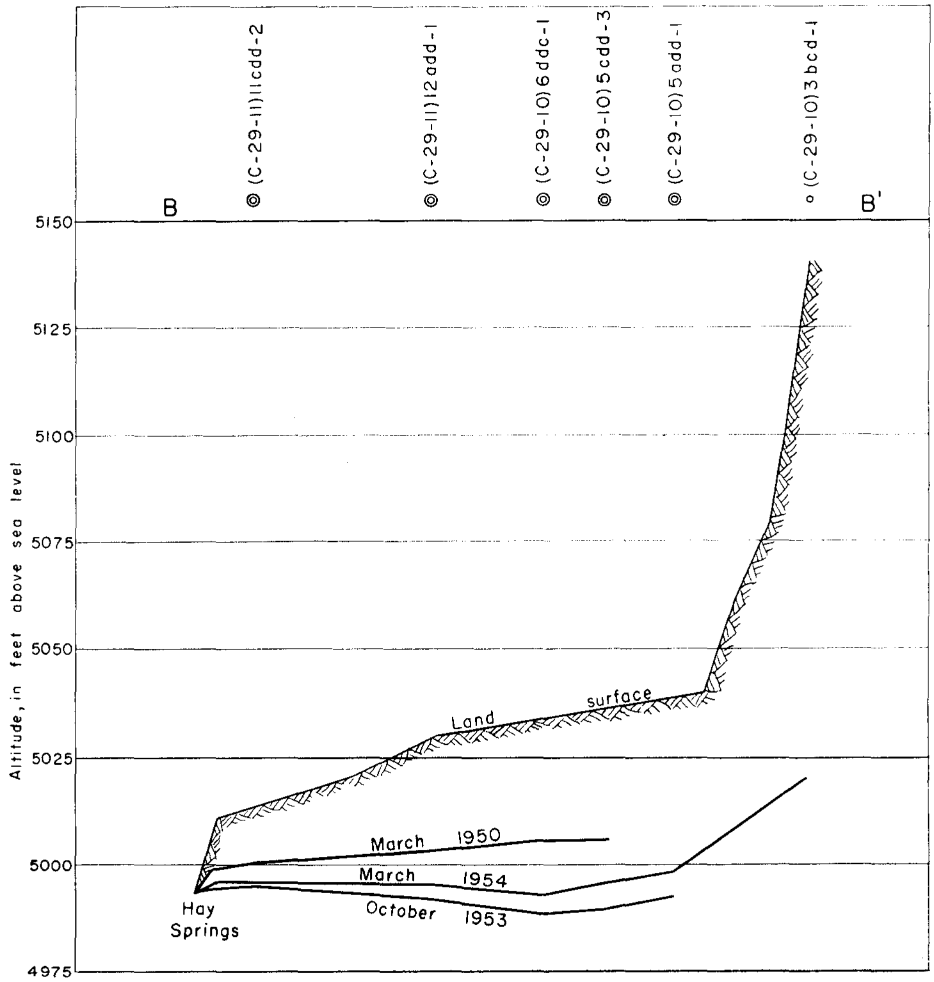


Figure 8a. Profile B-B′ of the Milford district showing positions of water table.

the water table along a "dog-leg" line of observation wells trending south, and then southeast from Milford toward Minersville. The other two profiles of the water table in the Milford district are shown in fig. 8. Profile B-B′ extends northeastward from the Hay Springs vicinity and profile C-C′ extends southeastward from Hay Springs. These two profiles do not cross the water-table contours at right angles, but they give some idea of the position of the water table in these directions. The locations of profiles A-A′, B-B′, and C-C′ are shown in figure 3.

It is assumed that ground-water pumping within the "closed area" of the Milford district is rapidly approaching its maximum. Any new developments in the district are expected to be located outside of the area of heavy pumping, and it is believed that any such new developments will not seriously change the existing conditions in the valley. With continued pumping at the 1953 rate, however, water levels can be expected to decline until a hydrologic balance is reached between the recharge to the ground-water basin and natural and artificial discharge.

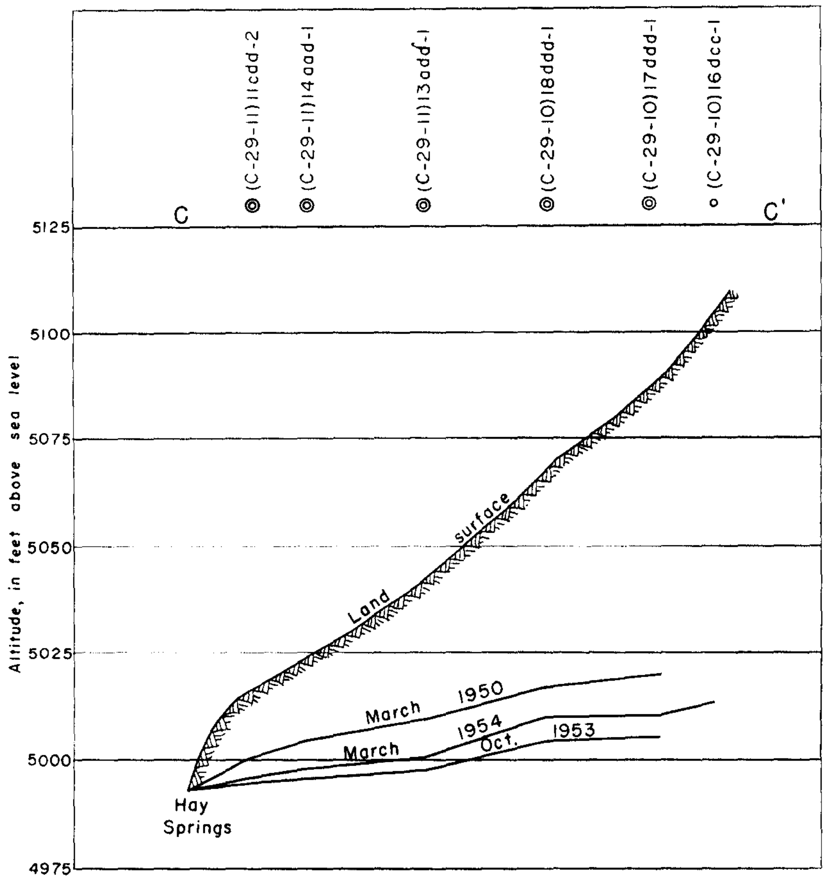


Figure 8b. Profile C-C′ of the Milford district showing positions of water table.

BERYL-ENTERPRISE PUMPING DISTRICT

By B. E. LOFGREN

The Beryl-Enterprise pumping district in southern Escalante Valley is the largest pumping district in the State. In 1953 more than 50,000 acre-feet of ground water was pumped from wells for irrigation. Except in three small areas at the mouth of Shoal, Pinto, and Mountain Meadow Creeks, respectively, all water for irrigation, stock watering, and domestic uses is necessarily obtained from wells. The surface streams serve only a small portion of the district, chiefly in the vicinity of Enterprise and Newcastle, and even in these areas stream supplies have been supplemented by water pumped from wells. Any increase in agricultural acreage or population in the future will be dependent upon the continued availability of ground-water supplies.

The ground-water reservoir that supplies water to wells in the valley has a surface area of more than a quarter of a million acres, and an average saturated thickness of at least several hundred feet. Thus, the total volume of water in storage in the valley alluvium must exceed several million acre-feet. As has been pointed out in earlier studies (Fix, Nelson, Lofgren, and Butler, 1950, p. 146-180; Thomas, Nelson, Lofgren, and Butler, 1952, p. 40-48), the annual discharge of ground water from the basin greatly exceeds the natural recharge, and the water developed by wells is drawn largely from underground storage.

In other words, it has been mined from the ground-water reservoir. As a consequence, water levels in the heavily developed areas of the valley have declined progressively as pumping has continued. Because the overall size of the ground-water reservoir is exceptionally large as compared with the amount of water pumped each year, water levels have not declined seriously except in the central area of heavy pumping. As pointed out in the progress report cited above (1950, p. 175-179):

"However, there is no likelihood of early or sudden exhaustion of the ground-water reservoir unless the rate of pumping is increased markedly above that in 1950 (50,000 acre-feet). The quantity of water in that reservoir is not yet known, but present information shows that there is probably at least several million acre-feet, and each million acre-feet would be enough for about 2 decades of pumping at 1950 rates. Further, the water table in the pumping district is declining at a rate of less than 2 feet a year, so that the energy requirement for lifting the water is increasing only rather slowly. If the reservoir extends to sufficient depth, the economic factor of pumping cost, rather than the hydrologic factor of reservoir exhaustion, may set the date for reduction or cessation of pumping."

Ground-Water Development

In 1953 there were 161 pumped irrigation wells in operation in the Beryl-Enterprise district, of which 24 used internal-combustion engines for power. In addition, 59 irrigation wells remained idle during the year, making a total of 220 units in the valley. During the year, a computed 50,045 acre-feet of water was pumped for the irrigation of 15,347 acres of cropland. Figure 9 is a map of the Beryl-Enterprise district showing the location of irrigation wells, areas irrigated by wells, and water-table contours for December 1953.

Because of the accelerated exploitation of the ground-water resources in Escalante Valley after World War II, all of Escalante Valley in Washington and Iron Counties, together with its tributary drainage basin, and including the entire Beryl-Enterprise district, was closed to further appropriation of water (except for domestic and stock-watering purposes) by proclamation of the Governor in April 1946 (Tracy, 1950, p. 22). In February 1953 the northern part of this "closed area" was reopened to permit further drilling of water wells. This reopened part, however, was considerably northeast of the pumping district shown in figure 9, and beyond the range of interference of pumping wells in the Beryl-Enterprise district. During 1952-53 only a few large-diameter wells were drilled within the "closed area," bringing nearly to an end the list of undrilled applications for irrigation wells that had been approved prior to the closing of the area.

During the 5-year period from 1945 to 1950 the number of acres irrigated by wells jumped from less than 5,000 to more than 16,000 acres, and the quantity of ground water pumped for irrigation increased in about the same proportion. Since the peak year of 1950, little change in ground-water use has taken place. Most of the speculative development of the postwar years has run its course, and the farms now in operation are for the most part permanent installations. Thus, the number of acres irrigated by wells is about the same each year. Table 4 lists the irrigation wells in the Beryl-Enterprise district and includes the estimated annual pumpage for several years during the period 1937-53. The estimated annual pumpage for all years during the period 1937-51 has been published in an earlier report of the State Engineer (Thomas, Nelson, Lofgren, and Butler, 1952, opp. p. 42).

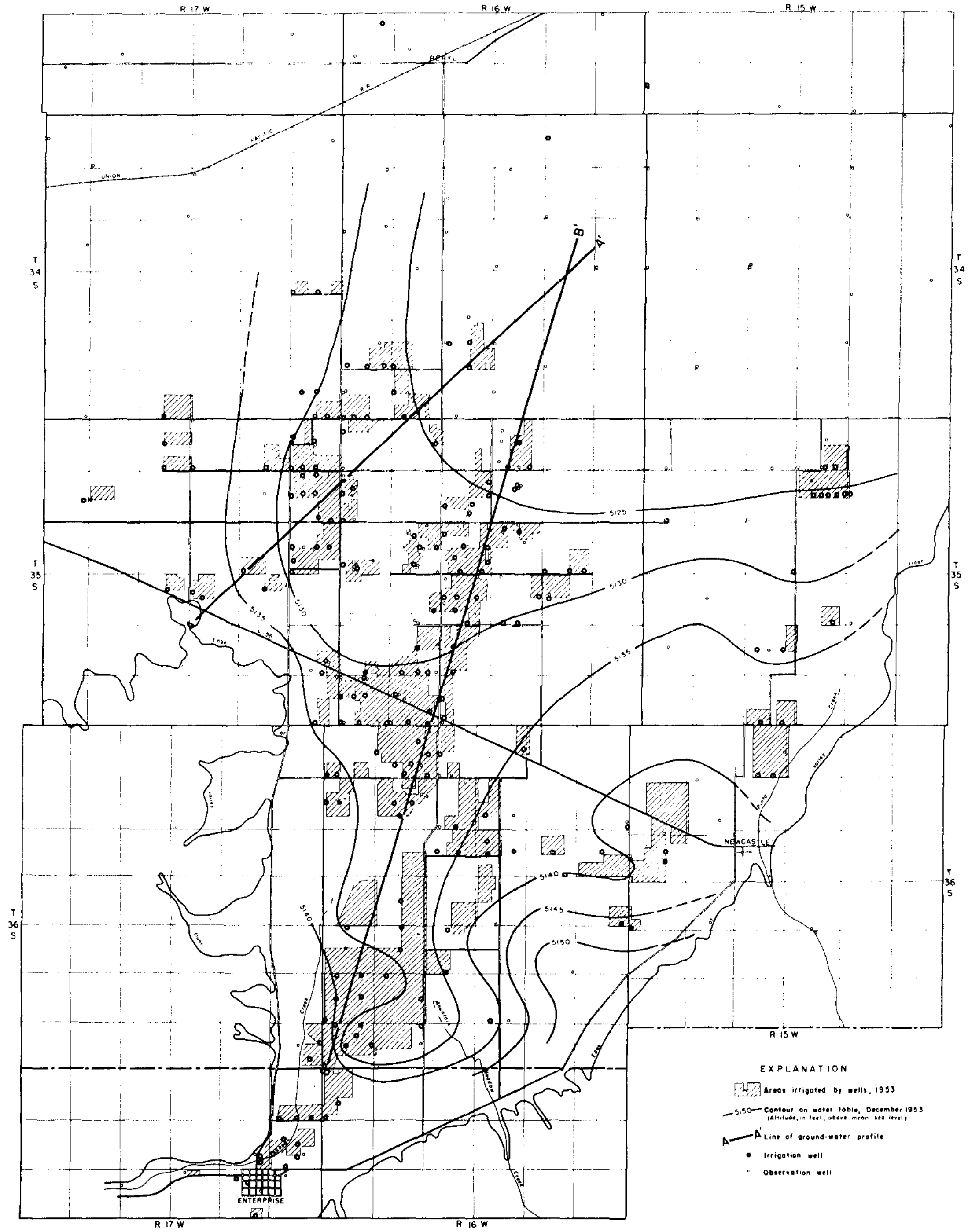


Figure 9. Map of Beryl-Enterprise district showing the location of irrigation wells, areas irrigated by wells, and water-table contours for December 1953.

Table 4. Irrigation wells and estimated annual pumpage in the Beryl-Enterprise District, 1937-53.

Coordinate number	Application or claim	OWNER	Diameter (inches)	Depth (feet)	Estimated annual pumpage, acre-feet						
					1937	1940	1945	1950	1951	1952	1953
(C-33-14)											
6acb-1	A 14501	J. H. Johnson	12	230				[1]220			
(C-33-15)											
31bcc-1	A 16458	George C. Dodson	12	275							
(C-33-16)											
23abb-1	A 17162	William H. Wood	16	203				[1]400	[1]400	[1]400	[1]400
30aac-1	A 15878	Joseph Del Vecchio	14	154				[1]200			
(C-34-16)											
2bcc-1	A 16236	C. R. Burns	16	240				[1]170	175		
28acc-2	A 16178	Donald Horsley	12	130	70	90	[1]150	240		230	230
28bcc-2	C 20672	I. Matson	12	67	20						
28bcc-3	C 20672R	I. Matson	16						20	100	
28dcc-2	C 10426	Loren Reber	12	84				550	540	650	460
29ccc-1	A 16524	Monte Miller	14	203					430	400	275
30adc-2	C 17699	D. F. Shelley	12	90							
30ccc-1		D. F. Shelley	12	250							
30dcc-1	A 15615	D. F. Shelley	12	250				620	490	670	285
30ddc-2	C 11721	D. F. Shelley	12	100				10			90
31bcc-3	C 923	S. B. Endicott		22	80	30					
31ccc-1	A 15664	Deward Hall	12	160				850	450	560	275
31cdc-1		Deward Hall								50	
31dcc-1	A 17011	John Jordan	16	248					100		
32bcc-1	A 15770	R. A. Gardner	16	199				[1]60	120	450	65
32cdc-1	A 14829	R. A. Gardner	16	200				520	470	550	370
(C-34-17)											
24acc-2	C 16680	H. L. Austin	12	105				200	220	250	295
24bcc-2	C 16679	H. L. Austin	12	120				310	240	260	165
33dcc-1	A 17269	Wallace MacFarlane	14	224						150	75
36acc-1	A 17080	Jack Rall	16	184					210	300	90
36bdc-1	A 17081		16	200							
36dcc-1	A 17071	Carl Anderson	14	232						60	
36ddc-1	A 17070	Albert Schwartz	14	150				220	330	250	260

Table 4 (cont.). Irrigation wells and estimated annual pumpage in the Beryl-Enterprise District, 1937-53.

Coordinate number	Application or claim	OWNER	Diameter (inches)	Depth (feet)	Estimated annual pumpage, acre-feet						
					1937	1940	1945	1950	1951	1952	1953
(C-35-15)											
3dcc-2	C 3788	E. J. Graff	16	350	20			340	190	430	275
3ddc-1	C 3789	E. J. Graff	16	350	220		[1]200			100	320
7cdd-1		Erwin Schmidt									
10acc-1	C 3784	E. J. Graff	16	334	460			[1]300	300	300	130
10acd-1	C 3785	E. J. Graff	16	280			700	[1]300	300	250	375
10adc-1	C 3786	E. J. Graff	16	400				330	440	490	170
10add-1	C 3787	E. J. Graff	16	350				150	80	250	300
10bdc-1	A 12134	Walter Martin	16	271		350	[1]350	890	780	750	645
11bcc-1	A 16934	E. J. Graff	16	310							95
16ddd-1	A 12838	E. F. Stark	16	300							
22dcd-1	A 16703	Kumen Gardner	14	257				40	80	110	135
28acc-2	A 12095	Robert Reeve	12	163				340			
28adc-1	A 15021	Robert Reve	14	200				280	260	280	220
28bdc-1		Deward Spendlove						280	140	30	
33cdc-1		Melvin Hewlet									390
33dcd-1	a 2448	Mike Torres	14	254				190	120	150	270
(C-35-16)											
3bdd-1	A 17350	R. J. Kaltenborn								50	10
3cdc-1	A 17350	R. J. Kaltenborn								410	320
3dcc-2	A 15616	R. J. Kaltenborn								80	290
5add-1	A 12758	Norval Bracken	16	40		50		250	240	170	125
6bbc-2	C 19503	W. W. Staheli						470	190	300	415
6ccc-1	C 9748	N. E. Jones	12	80	2						
7bbb-1	C 13661	H. L. Austin	16	95	70	20					
7bcc-1	C 13660	H. L. Austin	12	65	60	120		280	310	200	240
7bdb-1	C 14227	Parley Moyle	12	75	40	130	[1]200	170	280	160	
7ccc-1	C 17796	Arnold Barlocker	12	104	80	50	[1]100	210	50	90	245
9aad-1	A 15777	H. J. Beecher	16	150				[1]300	300		300
9add-1	A 15945	George Clove	16	150				270	190	310	320
9cbc-1	A 15707	Normand Laub	12	126						230	390
9dac-1	A 16011	Clark & Monroe						320	170		
10acb-1	C 10338	Edmond Thomas	12	103	75	10		490	620	300	

10bda-1	A 13760	H. B. McReynolds	14	117	60	30		[1]240			
14ccc-1	A 16535	Hunter Brothers	14	192				120	90	120	30
14dcc-1	A 16223	P. M. Smith	14	167							
14ddc-1	A 15946	John McGarry	14	100					10	70	50
15abc-1		M. F. Dewey	12	120	185				120	140	110
15bba-1	C 20262	Dee Burgess	12	133				340	310	310	340
16add-1	A 17436	Neal Bracken	14	116				40	80	80	170
16bbc-1	A 16835	Marion Beckstrom	14	174				110	190	270	250
16bdd-1	A 16834	L. M. Thomas	14	163				100	200	130	
16cac-1	A 16537	G. T. Wertz	12	122				130	140	130	160
16cdd-1	A 14347	Ray Hunt	12	125				340	260	380	385
16dda-1	A 15948	Calvin Lewis	12	125				110	130	190	250
16ddc-1	A 15947	Niels Nielson	14	152				190	190	220	245
17acc-2	A 13523	Ray Hunt	20	70		40	[1]200	360	380	430	210
17add-2	A 13459	Marion Beckstrom	13	103		50		490	420	370	170
17bad-1	C 2230	M. Vicerra	12	120	130	150	[1]80	130	110	180	140
17cda-2	C 16463	Roy Pectol	12	70	50	100		300	180	50	260
17ddd-1	C 17282	James Dell	12	25		30					
18ccb-1	A 15980	J. C. Bosshardt	14	160				300	370	370	335
18cdc-1	C 20391	J. C. Bosshardt	14	95				370	320	300	300
20dad-1	A 16018	James Wagner	12	200				150	80	120	95
21acd-1	A 17208	Milford Barnum	12	105				280	270	200	335
21bcc-1	A 15313	A. D. Moyle	14	120				440	370	370	620
21bdc-1	A 14471	A. D. Moyle	16	178							
21cac-1	A 15786	A. V. Piper	14	155				310	200	240	210
21dcc-1	A 14471	A. D. Moyle	16	204				590	570	490	625
21ddc-1	A 15787	D. L. Love	14	156						40	
22add-1	C 10337	Dewey Goddard	12	147	130	130	[1]200	340	270	300	305
22ccd-1	A 16931	Lyman Sevy	14	206						170	
22dcc-1	A 16930	Lyman Sevy	12	130							
23bcd-1	A 15644	A. L. Graff	12	160				240	470	340	545
28bdc-1	A 15771	Bruno Biasi	18	200				460	600	500	590
28cdc-1	A 16866	C. T. Holland	18	185				[1]350	160	260	435
29acc-1	A 15788	F. O. Barker	16	194				690	270	630	865
29ccd-1	A 16863	Floyd Ence	16	194				210	340	330	510
29dcc-1	A 14570	C. A. Thomas	12	140				230	180	170	
29ddc-1	A 14569	C. A. Thomas	14	200				160	60	40	
30dcc-1	A 17490	C. E. Mitchell	16	155				160	170	140	110
31abc-1	A 16800	C. E. Mitchell	16					320	310	300	410

Table 4 (cont.). Irrigation wells and estimated annual pumpage in the Beryl-Enterprise District, 1937-53.

Coordinate number	Application or claim	OWNER	Diameter (inches)	Depth (feet)	Estimated annual pumpage, acre-feet						
					1937	1940	1945	1950	1951	1952	1953
(C-35-16)											
31acc-2	A 17490	C. E. Mitchell	14	147				530	350	370	300
31bdc-1	A 16654	L. V. Robinson	12	155				170	170	180	175
31cbb-1	A 16872	Chester Whitelaw	16	195				270	300	400	405
31ccc-1	A 15906	Marvin Miller	12	209				250	110	140	
31cdc-1	A 15907	Dan Murphy	16						170	180	125
31ddd-1	A 15905	F. B. Dalton	14	160				360	380	480	590
32acc-1	A 16829	Tony Alberto	16	167				340	260	210	230
32bcb-1	A 16830	Adams & Pedersen	16	173				510	550	480	680
32ccc-1	A 16621	Sullivan Brothers	14	176				360	460	470	625
32cdc-1	A 16621	Sullivan Brothers	14	176				180	270	260	205
32dcd-1	A 16831	John C. McGarry	16	452				90	100	100	265
33bcc-1	A 16662	Cliff Quinn	12	140				390	70	170	70
33ccb-1	A 16662	Cliff Quinn	12	130				330	160	140	10
(C-35-17)											
1acc-2	C 17961	H. L. Bennett	16	265				190			
1bcc-1	A 15654	John C. McGarry	16	130					20		
1bcc-2		John C. McGarry									90
1cdc-1	A 22953	Dean Forsyth	12	114				630	410	300	300
1dcc-1	A 17073	Jack Reber	16	260				200	320	270	395
1ccc-1	A 16928	W. W. Price	16	207						90	90
2dcc-1	A 17121	Vern Frailey	16	160				260	230	240	230
3ccc-1	A 17133	G. M. Sevy	12	240							
4acc-1	A 17268	H. E. Christensen	14	176				280	320	360	135
4dcc-1	A 17286	MacFarlane Bros.	14	240				320	190	200	190
7daa-1	A 17290	W. W. Adams	12	200				170	230	200	140
12abb-1	A 14523	J. B. Moyle	12	90						350	120
12acc-1	A 14229	J. B. Moyle						210	140	150	175
12bcc-1	A 14024	F. S. Price	14	161				130	190	240	465
12bdc-1	A 12677	A. L. Daniel	12	86	10			90	10	120	220
12dcd-1	A 11564	Albert Feldsted	14	202						40	25
12ddc-1	A 14714	Arnold Barlocker	16	200				320	400	350	400
13acc-1	A 13014	J. E. Moyle	18	101		180	[1]300	590	460	520	210

13adc-1	A 13996	J. E. Moyle	13	182			[1]200	400	300	350	225
13bcc-1	A 13990	A. D. Moyle	13	183			[1]200	250		300	35
13bdc-1	C 14228	A. D. Moyle	16	95	70	130					
13cbc-1	C 12346	H. G. Moyle	14	150	60	160	[1]200	330	330	330	225
13ccc-1	A 12346	H. G. Moyle	16	200				220	170	250	140
14ccc-1	A 16833	C. H. Frailey	16	300				[1]240		370	395
21bda-1	C 16438	G. J. Busher								20	180
22bcc-1	A 16526	P. L. Morris	16	163				[1]120	50	50	210
22bdc-1	A 16525	Joe Green	12	200				260	250	100	60
23acb-1	A 14749	H. G. Moyle	12	125				310	100	310	400
25dca-2	C 10296	Charles Bosshardt	12	110	10	10	[1]150	380	340	390	415
25dcd-1	A 16205	Charles Bosshardt						[1]40	50	50	20
36dcc-1	A 16425	M. H. Crosier	16	200				540	20	200	190
(C-36-15)											
4cdd-1	A 15828	W. Leo Knell	16	245							750
4dcd-1	A 14051	W. Leo Knell	14	235				[1]670	650	600	
7dba-1		Sterling Tullis									95
7dcc-1		Vern Pickerell									140
18bda-1	A 16398	Vern Pickerell	16	400				270	320	300	200
18caa-1	A 16395	Vern Pickerell	16	233					120	350	200
19ccc-1	A 14057	A. C. Christensen	16	217				310	310	210	210
22cdd-1	A 15590	New Castle	12	75				[1]150	250	50	[1]150
27abb-1	A 16434	Reclamation	16	66				[1]150	300	120	[1]200
(C-36-16)											
1ddd-1	A 16852	Vern Pickerell	16	200						50	
3a-1	A 14709	G. E. Smith	12	115				30	80	150	110
3c-2	A 16860	Vern Pickerell	20	196				[1]300	200	240	245
4a-2	A 16699	Vern Frailey	16	207				[1]240	150	200	120
4b-3	C 1396	Willard Randall	12	144		290	160	410	390	440	410
4b-4	A 16218	G. S. Holt	16	250				240	220	180	290
4b	A 12422	Wayne Holt								100	210
4d	A 12282	Heber Sevy	16	220						120	280
5a-1	C 16592	W. T. Hunt	12	112		250		330	330	320	350
5a-8	A 15124	George Crawford	12	180			260	290	410	410	345
5a-9	A 15774	Leonal Gardner	12	200			90	320	290	370	555
5a-12	A 19947	Bryant Beacham					250	290	300	250	305
5b-1	A 15147	Gordon Clark	12	150				340	280	350	315
5b-2	A 15384	Heber Sevy	12	156			320	390	350	360	585
5b-3	A 16700	Heber Sevy	16				320	440	390	420	580
5c-1	A 15772	Leonal Gardner	12	160				250	310	210	315

Table 4 (cont.). Irrigation wells and estimated annual pumpage in the Beryl-Enterprise District, 1937-53.

Coordinate number	Application or claim	OWNER	Diameter (inches)	Depth (feet)	Estimated annual pumpage, acre-feet 1937	1940	1945	1950	1951	1952	1953
(C-36-16)											
6b-3	A 12859	Escalante Farm	16	270					120	230	150
6b-4		Escalante Farm									120
6c-2	A 17121	Escalante Farm	16	290						130	200
6c-3	A 17121	Escalante Farm	16	200					150	300	200
9acd-1	A 16244	Joseph Judd	14	214				360	430	350	635
9bcd-1	A 16253	Wilson Scott	14	272			40	350	510	600	830
10		Vern Pickerell									
10bbd-1	A 16042	N. J. Barlow	14	290				240	70	240	295
10bdc-1	A 16043	N. J. Barlow	14	340				290	330	240	105
11caa-1	A 16857	Vern Pickerell	16	210							270
11dcd-1	A 16856	Vern Pickerell	16	206							250
12bdd	A 16854	Vern Pickerell	16	230							245
13ddc	A 15150	Vern Pickerell	16	207					330	200	235
15cdd-1	C 13998	A. C. Christensen	5	200				[1]40	40	30	30
17dbb-1	A 14642	Weyl Zuckerman	16	404				610	300	160	
19abb-1	A 15511	T. W. Jones	16	352				260	510	420	580
20abb-1	A 16418	Weyl Zuckerman	16	400				540	445	360	500
20dbb-1	A 14642	Weyl Zuckerman						530	470	330	310
21abc-1	A 16342	T. W. Jones	16	351			70	520	410	290	715
(C-37-17)											
12acc-1	A 16231	Grant Clove	16	320				240	270	340	290
12bdc-1	A 14183	Charles Side	14	170				180	170	240	175
12cbd-1	A 15585	Charles Side	14	150			210	210	180	240	110
12cdd-2	A 16183	Arthur Thomas	16	132			10	190	100	120	95
14acb-1	C 17896	Enterprise Town	10	185			250	260	300	250	250
14bac-1	A 16090	Jacob Busher	14	100			20	220	230	220	100
14dcd-1	A 14213	Roland Bowler	12	152			130	100	60	120	65
15bab-3	C 7157	Nelson Thomas	10	125				90	40	20	10
TOTAL NUMBER OF WELLS PUMPED					22	24	37	163	165	178	176
TOTAL NUMBER OF ACRE-FEET PUMPED					2,942	257	5,830	51,320	45,020	46,990	50,045

[1] Estimated.

Table 5. Measurements of water level and discharge of irrigation wells in the Beryl-Enterprise District, 1953.

Coordinate number	Depth (feet)	Type of pump & power[1]	Static measurements: Date	Static measurements: Depth to water[2] (feet)	Pumping measurements: Date	Pumping measurements: Depth to water[2] (feet)	Pumping measurements: Discharge (gpm)
(C-34-16)							
28acc-2	130	T E			7/10	22.5	650
					8/20	29.0	550
29dcc-2	84	T E			7/10		710
					8/20		665
29ccc-1	203	T E	3/19	11.59	7/10	56.0	980
			12/5	12.88	8/20	62.1	980
30dcc-1	250	T E			7/10	60.0	725
					8/20	68.9	680
30ddc-2	100	T D			7/10	58.0	990
31ccc-1	160	T E			7/10		730
					8/20		770
32cdc-1	200	T E			7/10		900
(C-34-17)							
24acc-2	105	C E			7/9	23.2	510
					8/20	23.8	490
24bcc-2	120	C E			7/9	39.8	520
					8/20	38.8	540
33dcc-1	224	T E			8/20		770
36acc-1		T E			8/20	64.3	690
36ddc-1	150	T E			8/20		690
(C-35-15)							
3dcc-2	350	T E	3/19	13.45	7/10	43.3	1220
			12/6	15.06			
3ddc-1	350	T D			7/10	39.8	1200
10acc-1	334	T D			7/10	49.3	990
10acd-1	280	T E			7/10		1250
10adc-1	400	T E			7/10		600
10add-1	350	T E	12/6	16.82	7/10	50.2	1070
10bdc-1	271	T E	3/18	14.12	7/10	46.4	1080
			12/6	15.90	8/25	47.8	1480

Table 5 (cont.). Measurements of water level and discharge of irrigation wells in the Beryl-Enterprise District, 1953.

Coordinate number	Depth (feet)	Type of pump & power[1]	Static measurements: Date	Static measurements: Depth to water[2] (feet)	Pumping measurements: Date	Pumping measurements: Depth to water[2] (feet)	Discharge (gpm)
(C-35-15)							
22dcd-1	257	T E	12/6	35.50	7/10	79.0	640
					8/25	72.2	730
28adc-1	163	T E			8/25		430
33ddc-1		T E			7/10	115.2	620
(C-35-16)							
3cdc-1		T D			8/25		1910
3dcd-1		T D			8/20	43.0	1720
4dcc-1		T D			8/25	50.1	930
5add-1	40	C E			8/20		700
6bbc-2		T E	12/5	23.62	7/10		835
					8/19		850
7bcc-1	65	T E			7/10		530
7ccc-1	104	T E			7/10		650
9aad-1	150	T E			7/9		945
					8/21		840
9add-1	150	T E	12/6	24.04	7/8	33.5	710
					8/21	35.8	660
9cbc-1		T E			7/8	39.5	665
15abc-1	120	T E			8/21		820
15bba-1	133	T E			8/21	37.2	655
16add-1	116	T E			8/21		760
16bbc-1	174	T E	3/19	24.72	8/21		540
			12/6	26.60			
16cac-1	122	T E			7/8	45.0	600
16cdd-1	125	T E			7/9		650
					8/21		630
16dda-1	125	T E			7/9	48.5	610
					8/21	49.8	605
16ddc-1	152	T E			7/9	45.0	725
					8/21	45.5	700
17acc-2	70	C E			7/9		*a*400
17add-2	103	C E			7/8		660

17bad-1	120	C E	12/5	24.61
17cda-2	70	T E		
18ccb-1	160	T E	12/5	32.30
18cdc-1	95	T E		
20dad-1	200	T E		
21bcc-1	120	T E		
21dcc-1	204	T E		
22add-1	147	C E		
23bcd-1	160	T E		
28bdc-1	200	T E	3/19	33.47
			10/7	37.58
			12/5	36.45
28cdc-1	185	T E		
29acc-1		T E		
29ccd-1	194	T E	12/5	42.70
30dcc-1		T E		
31abc-1	150	T E	3/19	42.40
			10/7	47.67
			12/6	45.32
31acc-2	147	T E		
31bdc-1	155	T E		
31cbb-1	195	T E		
31cdc-1		T E		
31ddd-1	160	T E		
32acc-1	167	T E		
32bcd-1	173	T E		
32ccc-1	176	T E	10/7	53.15
			12/6	50.72
32cdc-1	176	T E		

8/18		540
8/18	38.0	1060
8/19	43.2	600
8/19	60.0	550
7/9	40.5	
8/21	41.4	725
6/21		1280
6/21	52.3	1080
7/9		830
8/18	40.2	730
7/9	47.0	845
8/18	46.0	870
7/9	49.0	1960
8/18	49.0	1850
7/2		1140
8/18	50.7	1040
8/18	53.5	1700
7/8	56.5	1180
9/28	57.8	1310
7/9	51.0	965
8/17	51.5	910
6/22	58.7	
8/17	60.4	1240
8/17	61.1	955
8/13	66.3	550
6/30	75.0	1030
8/13	73.1	980
6/30	73.5	580
8/13	69.3	585
6/30	62.5	980
8/13	63.4	950
6/22	55.7	1570
8/18	56.7	1460
7/8		1670
6/30	59.5	1170
8/13	60.7	1150
8/13		440

Table 5 (cont.). Measurements of water level and discharge of irrigation wells in the Beryl-Enterprise District, 1953.

Coordinate number	Depth (feet)	Type of pump & power[1]	Static measurements: Date	Static measurements: Depth to water[2] (feet)	Pumping measurements: Date	Pumping measurements: Depth to water[2] (feet)	Discharge (gpm)
(C-35-16)							
32dcd-1	452	T E	10/7	48.01	6/29		1180
			12/6	46.14	8/18	57.2	1150
33ccb-1	130	T G			7/9		435
(C-35-17)							
1bcc-2		T E			7/9	92.5	1050
1ccc-1		T E			7/9	71.8	720
1cdc-1	114	T E			7/9	86.0	655
					8/19	73.2	705
1dcc-1	260	T E			7/9	57.6	840
					8/19	58.0	850
2dcc-1	160	T E	3/19	36.73	7/9	83.0	725
			10/7	41.74	8/19	84.1	670
			12/5	39.38			
4acc-1	176	T E			8/20	69.0	800
4dcc-1	240	T E			8/20	66.6	680
12abb-1		T E			7/9		615
					8/19		655
12acc-1	90	T E			7/9		635
12bcc-1	161	T E	10/7	42.95	7/8	63.8	1080
			12/5	38.74			
12bdc-1		T D			7/9		700
12dcd-1		T E			7/9	62.0	580
					8/19	61.1	565
12ddc-1		T E	12/5	32.72	7/9	54.1	
					8/19	53.2	630
13acc-1	101	T E			7/9		*a*670
13adc-1	182	T E			7/9		680
					8/18		660
13bcc-1	183	T E			8/19		*a*670
13cbc-1	150	T E			7/8	60.5	720
					8/19	60.5	650

13ccc-1	200	T E	10/7	41.58	7/8	68.0	850
			12/5	39.95			
14ccc-1	300	T E			7/8	72.3	1430
21acb-1	125	T D			7/8		1360
					8/19		950
22bcc-2	163	T E	3/19	56.65	7/8	69.0	1010
			10/7	57.92	8/19	66.5	580
			12/5	57.90			
22bdc-1	200	T E			7/8		620
23acb-1		T E			8/19	58.9	1000
25dca-12	110	T E			7/8	67.5	840
					8/17	66.0	845
25dcd-1		T D	10/7	50.72	7/1	80.4	760
			12/6	49.61			
36dcc-1	200	T E	3/19	55.64	6/30	77.3	750
			10/7	59.06	8/17	78.8	745
			12/6	58.29			
(C-36-15)							
4dcd-1	235	T D			7/10		1010
7dba-1		T D	12/11	112.88	8/25	128.7	1240
7dcc-1		T D			6/29	103.5	1880
18bda-1	400	T D	10/7	83.7	6/29	107.3	1120
			12/6	83.37	8/12	*a*122.5	990
18caa-1	233	T D			6/29	94.0	1300
					8/12	94.3	900
19ccc-1	217	T E	3/19	84.84	7/10	159.0	425
			12/6	87.76	8/25	160.5	330
(C-36-16)							
3a-1	115	T E	3/19	41.00	6/29	76.7	630
			10/7	43.70	8/25	77.6	670
			12/5	43.20			
3c-2	196	T D			6/29	74.5	2340
					9/4	65.7	1550
4a-2	207	T D	3/19	54.69	7/1	70.3	780
			12/6	57.56	8/12	70.8	760
4b-1		T E	6/22	52.13	8/12	62.1	780
4b-3	144	T E			6/30		1040
					8/12		1020
4b-4	250	T E	3/19	49.54	6/29	62.5	880
			12/6	53.58	8/12	63.7	840

Table 5 (cont.). Measurements of water level and discharge of irrigation wells in the Beryl-Enterprise District, 1953.

Coordinate number	Depth (feet)	Type of pump & power[1]	Static measurements: Date	Static measurements: Depth to water[2] (feet)	Pumping measurements: Date	Pumping measurements: Depth to water[2] (feet)	Discharge (gpm)
(C-36-16)							
4d-1		T E			7/1		1100
					8/12		1110
5a-1	112	T E			6/30	63.0	540
5a-8	180	T E			7/2		870
					8/12		850
5a-9	200	T E			8/13	57.0	780
5a-12		T E			6/30		445
					8/13		560
5b-1	150	T E	12/7	63.82	6/30	76.0	820
					8/13	78.5	750
5b-2	156	T E	12/6	55.22	6/30	67.0	860
5b-3		T E	12/6	57.88	6/30	71.6	1000
					8/13	71.7	940
5c-1	160	T E			8/13		680
6b-3		T D	12/6	67.28	7/1	71.3	1140
6b		T G			8/12	80.6	1110
6c-3		T G	12/6	76.35	7/1	82.0	940
					8/12	82.1	730
6c-2		T D			7/1	79.0	630
9acd-1	214	T E			6/29	76.0	845
					8/12	76.1	770
9bcd-1	272	T E	10/7	68.97	6/29	73.0	1150
			12/6	64.14	8/12	74.2	1160
10bbd-1	290	T E	12/6	57.73	7/2		715
					8/12		705
10bdc-1	340	T E			6/29		645
					8/12		630
11caa-1	210	T D	12/6	52.20	8/12		*a*900
12bdd-1	230	T D	12/6	60.74	6/29		615
13ddc-1	207	T E			7/8		410
					8/25		330

19abb-1	352	T E	3/20	87.72	7/7	102.2	925
			12/6	91.52			
20abb-1	400	T E	3/20	79.52	7/7	102.0	2120
			10/7	101.60	8/17	104.0	2640
			12/6	82.22			
20dbb-1		T E			7/7	96.5	1430
					8/17	97.9	1380
21abc-1	351	T E			7/8		1160
					8/13		1000
21cdd-1	254	T E			7/1		820
					8/13		820
29bab-1	401	T E			7/7	106.0	1720
					8/17	108.8	1770
29daa-1	381	T E	3/20	96.58	7/7	138.2	965
			12/6	100.28			
30acb-1	402	T E	3/20	93.71	8/17	111.4	1900
			12/6	97.57			
30bab-1	401	T E			7/7	115.0	1860
					8/17	115.3	1840
30cab-1	381	T E			7/7	128.0	1480
30ccc-1	400	T E			8/25		430
30dab-1	381	T E			7/7	129.0	1880
31aba-1	349	T E			7/7	127.5	1270
					8/14		1250
31aca-1	407	T E			7/7	129.6	2210
31add-1	381	T E	3/20	104.57	7/7	125.0	1140
			12/6	111.12	8/13		955
31bab-1	419	T E			7/7	129.0	1400
					8/17		1420
31bdd-1	398	T E	3/20	113.20	7/7		1450
			12/6	125.65	8/13		1190
31cdc-1	393	T D			7/7	123.0	600
31ccc-1	222	T E	3/20	121.14	6/22	143.9	
			12/6	126.68	7/1	144.8	510
					8/13	146.6	480
32aaa-1	401	T E			7/7	169.5	510
(C-36-17)							
36add-1	202	T E	12/6	121.93	7/1	164.2	730
					8/13	165.4	760
36ddb-1	382	T E			8/13	160.4	470

Table 5 (cont.). Measurements of water level and discharge of irrigation wells in the Beryl-Enterprise District, 1953.

Coordinate number	Depth (feet)	Type of pump & power[1]	Static measurements: Date	Static measurements: Depth to water[2] (feet)	Pumping measurements: Date	Pumping measurements: Depth to water[2] (feet)	Discharge (gpm)
(C-37-16)							
6cac-1	304	T E			7/2	133.0	820
6ccc-1	200	T E	3/20	86.52	6/22	114.0	
			10/7	102.70	7/1	116.2	520
			12/6	100.45	8/14	125.2	575
(C-37-17)							
1ccd-1	438	T E	3/20	49.86	6/22	109.4	
			12/6	62.65	7/2	109.7	380
1dcd-1	250	T E	6/22		7/2	99.0	510
			10/7	76.99	8/14	101.2	530
			12/6	71.44			
1ddc-1	205	T E	12/6	74.41	7/2	100.0	415
					8/14	101.1	380
11dad-1	86	T E			8/14		265
11ddb-1	223	T E			8/14		*a*180
12acc-1	318	T E	12/6	43.09	7/2	100.0	450
					8/14	105.7	445
12bdc-1	170	T E	12/6	34.16	7/2	49.0	
					8/14	52.0	*a*345
12cbd-1	150	T E			8/14	67.2	240
12cdd-2	132	T E					
14bac-1	100	T E	10/7	32.01	7/9	78.0	710
			12/6	31.63	8/14	78.4	630
14dcd-1	152	T E			7/9	91.0	140
15bab-3	125	T E			8/14	63.5	150

[1] Pumps: T, turbine; C, centrifugal.
Power: E, electric motor; D, diesel engine; G, gasoline engine.
[2] Below land surface.
a Accuracy questionable.

Table 6. Pumpage inventory, Beryl-Enterprise District, 1953.

Coordinate number	Application or claim	OWNER	Pumpage (ac. ft.)	Acres irrigated	Acre-feet / acres
(C-33-16)					
23abb-1	A 17162	William H. Wood	*a*400	*a*200	
(C-34-16)					
28acc-2	A 16178	Donald Horsley	230	60	3.8
28dcc-2	C 10426	Lorin Reber	460	130	3.5
29ccc-1	A 16524	E. R. Miller	275	95	2.9
30dcc-1	A 15615	D. F. Shelley	285		
30ddc-2	C 11721	D. F. Shelley	90	155	2.4
31ccc-1	A 15664	D. L. Hall	275	160	1.7
32bcc-1	A 15770	R. A. Gardner	65		
32cdc-1	A 14829	R. A. Gardner	370	255	1.7
(C-34-17)					
24acc-2	C 16680	H. L. Austin	295	40	7.4
24bcc-2	C 16679	H. L. Austin	165	39	4.2
33dcc-1	A 17269	Wallace MacFarlane	75	55	1.4
36acc-1	A 17080	Carl Anderson	90	59	1.5
36ddc-1	A 17070	Albert Schwartz	260	58	4.5
(C-35-15)					
3dcc-2	C 3788	E. J. Graff	275		
3ddc-1	C 3789	E. J. Graff	320		
10acc-1	C 3784	E. J. Graff	130		
10acd-1	C 3785	E. J. Graff	375	320	5.2
10adc-1	C 3786	E. J. Graff	170		
10add-1	C 3787	E. J. Graff	300		
11bcc-1	A 16934	E. J. Graff	95		
10bdc-1	A 12134	Paul Martin	645	160	4.0
22dcd-1	A 16703	Kumen Gardner	135	90	1.5
28adc-1	A 15021	R. J. Reeve	220	60	3.7
33cdc-1		Melvin Hulet	390	80	
33dcd-1	a 2448	Jerome Tullis	270	127	2.1
(C-35-16)					
3bdd-1	A 17350	R. J. Kaltenborn	*a*10		
3cdc-1	A 17350	R. J. Kaltenborn	*a*320	206	
3dcc-2	A 15616	R. J. Kaltenborn	*a*290		
5add-1	A 12758	Neal Bracken	125	40	3.1
6bbc-1	C 19503	W. W. Staheli	415	97	4.3
7bcc-1	C 13660	H. L. Austin	240	39	6.2
7ccc-1	C 17796	Arnold Barlocker	245	54	4.5
9aad-1	A 15777	Leon Bowler	300	68	4.4
9add-1	A 15945	George Clove	320	75	4.3
9cbc-1	A 15707	Normand Laub	390	80	4.9
14ccc-1	A 16535	Hunter Bros.	30	20	
14ddc-1	A 15946	John C. McGarry	50	*a*30	
15abc-1		M. F. Dewey	110	80	1.4
15bba-1	C 20262	Dee Burgess	340	85	4.0
16add-1	A 17436	Neal Bracken	170	75	2.3
16bbc-1	A 16835	Marion Beckstrom	250	70	3.6
16cac-1	A 16537	G. T. Wertz	160	74	2.2
16cdd-1	A 14347	Ray Hunt	385	70	5.5
16dda-1	A 15948	Max Cannon	250	70	3.6
16ddc-1	A 15947	Niels Nielsen	245	80	3.1
17acc-2	A 13523	Ray Hunt	210	40	5.2
17add-2	A 13459	Marion Beckstrom	170	89	1.9
17bad-1	C 2230	M. Vicerra	140	32	4.4
17cda-2	C 16463	D. L. Sargent	260	39	6.7
18ccb-1	A 15980	John Bosshardt	335		
18cdc-1	C 20391	John Bosshardt	300	136	4.7
20dad-1	A 16018	Order of Aaron	95	49	1.9
21acd-1	A 17208	Milford Barnum	335	84	4.0
21bcc-1	A 15313	A. D. Moyle	620	152	4.1

Table 6 (cont.). Pumpage inventory, Beryl-Enterprise District, 1953.

Coordinate number	Application or claim	OWNER	Pumpage (ac. ft.)	Acres irrigated	Acre-feet / acres
(C-35-16)					
21cac-1	A 15786	A. V. Piper	210	75	2.8
21dcc-1	A 14471	A. D. Moyle	625	159	3.9
22add-1	C 10337	Dewey Goddard	305	100	3.1
23bcd-1	A 15644	A. L. Graff	545	140	3.9
28bdc-1	A 15771	Bruno Biasi	590	193	3.1
28cdc-1	A 16866	C. T. Holland	435	141	3.1
29acc-1	A 15788	R. W. Smith	865	157	5.5
29ccd-1	A 16863	Floyd Ence	510	149	3.4
30dcc-1	A 17490	C. E. Mitchell	110	56	2.0
31abc-1	A 16800	C. E. Mitchell	410	103	4.0
31acc-2	A 17490	C. E. Mitchell	300	56	5.4
31bdc-1	A 16654	L. V. Robinson	175	54	3.2
31cbb-1	A 16872	C. W. Whitelaw	405	126	3.2
31cdc-1	A 15907	Dan Murphy	125	55	2.3
31ddd-1	A 15905	F. B. Dalton	590	145	4.1
32acc-1	A 16829	T. C. Alberto	230	95	2.4
32bcd-1	A 16830	Adams & Pedersen	680	151	4.5
32ccc-1	A 16621	Sullivan Brothers	625		
32cdc-1	A 16621	Sullivan Brothers	205	185	4.5
32dcd-1	A 16831	John McGarry	265	60	4.4
33bcc-1	A 16662	Cliff Quinn	*a*70	63	
33ccb-1	A 16662	Cliff Quinn	*a*10	31	
(C-35-17)					
1bcc-2	A 15654	John C. McGarry	90	80	1.1
1ccc-1	A 16928	W. W. Price	90	79	1.1
1cdc-1	A 22953	Dean Forsyth	300	77	3.9
1dcc-1	A 17073	Jack Reber	395	79	5.0
2dcc-1	C 17127	Vern Frailey	230	118	2.0
4acc-1	A 17268	Hale Christensen	135	80	1.7
4dcc-1	A 17286	MacFarlane Brothers	190	80	2.4
7daa-1	A 17290	W. W. Adams	140	80	1.8
12abb-1	A 14523	J. B. Moyle	120		
12acc-1	C 14229	J. B. Moyle	175	139	2.1
12bcc-1	A 14024	F. S. Price	465	78	6.0
12bdc-1	A 12677	W. W. Mathews	*a*220	77	
12dcd-1	C 11564	Albert Feldsted	25	48	0.5
12ddd-1	A 14714	Arnold Barlocker	400	78	5.1
13acc-1	A 13614	J. E. Moyle	210		
13adc-1	A 13996	J. E. Moyle	225	220	2.0
13bcc-1	A 13990	A. D. Moyle	35		
13cbc-1	C 12346	H. G. Moyle	225	71	3.6
13ccc-1	A 12346	H. G. Moyle	140	70	2.0
14ccc-1	A 16833	C. H. Frailey	395	96	4.1
21bda-1	C 16438	Jacob Busher	*a*180	60	
22bcc-1	A 16526	Harry Randall	*a*210	66	
22bdc-1	A 16525	Joe Green	60	76	0.8
23acb-1	A 14749	H. G. Moyle	400	64	6.3
25dca-2	C 10296	Charles Bosshardt	415	83	5.0
25dcd-1	A 16205	Charles Bosshardt	20	17	1.2
36dcc-1	A 16425	Calvin G. Mettler	190	63	3.0
(C-36-15)					
4dcd-1	A 15828	Leo Knell	750	412	3.6
7dba-1		Sterling Tullis	95	*b*	*b*
7dcc-1	A 16825	Vern Pickerell	140	40	3.5
18bda-1	A 16398	Vern Pickerell	*a*200	60	
18caa-1	A 16395	Vern Pickerell	*a*200	200	
19ccc-1	A 14057	A. C. Christensen	210	*c*140	3.2
22cdd-1	A 15590	Newcastle Reclamation Co.	150	*b*	*b*
27abb-1	A 16434	Newcastle Reclamation Co.	200	*b*	*b*

Table 6 (cont.). Pumpage inventory, Beryl-Enterprise District, 1953.

Coordinate number	Application or claim	OWNER	Pumpage (ac. ft.)	Acres irrigated	Acre-feet / acres
(C-36-16)					
3a-1	A 14709	C. E. Smith	110	58	1.9
3c-2	A 16860	Vern Pickerell	*a*245	148	
4a-2	A 16699	Vern Frailey	*a*120	40	
4b-2	A 12422	H. W. Holt	210	78	2.7
4b-3	C 1396	Willard Randall	410	113	3.6
4b-4	A 16218	G. S. Holt	290	76	3.8
4d-1	A 12282	Heber Sevy	280	110	2.4
5a-1	C 16592	W. T. Hunt	350	75	4.7
5a-8	A 15124	George Crawford	345	80	4.3
5a-9	A 15774	Edward Gardner	555	153	3.6
5a-12	A 19947	Bryant Beacham	305	72	4.2
5b-1	A 15147	Gordon Clark	315	68	4.6
5b-2	A 15384	Heber Sevy	585	158	3.7
5b-3	A 16700	Heber Sevy	580	133	4.4
5c-1	A 15772	Leonal Gardner	315	149	2.1
6b-3	A 12859	Escalante Farm	*a*150	80	
6b-4		Escalante Farm	*a*120	40	
6c-2	A 17121	Escalante Farm	*a*200	80	
6c-3	A 17121	Escalante Farm	*a*200	64	
9acd-1	A 16244	Joseph Judd	635	148	4.3
9bcd-1	A 16253	Wilson Scott	830	115	7.2
10bbd-1	A 16042	N. B. Barlow	295		
10bdc-1	A 16043	N. B. Barlow	105	160	2.0
11caa-1	A 16857	Vern Pickerell	*a*270	120	
11dcd-1	A 16856	Vern Pickerell	*a*250	104	
12bdd-1	A 16854	Vern Pickerell	*a*245	160	
13ddc-1	A 15150	A. C. Christensen	235	*c*	
15cdd-1	C 13998	A. C. Christensen	30	10	
19abb-1	A 15511	T. W. Jones	580	300	1.9
20abb-1	A 16418	Weyl-Zuckerman	500	*d*2200	3.0
20dbb-1	A 14642	Weyl-Zuckerman	310	*d*	
21abc-1	A 16342	T. W. Jones	715	203	3.5
21cdd-1	A 16317	Arthur Barlocker	220	160	1.4
29bab-1	A 16415	Weyl-Zuckerman	590	*d*	
29daa-1	A 16189	Weyl-Zuckerman	455	*d*	
30aab-1	A 16414	Weyl-Zuckerman	365	*d*	
30bab-1	A 16413	Weyl-Zuckerman	720	*d*	
30cab-1	A 16189	Weyl-Zuckerman	535	*d*	
30ccc-1	A 15833	Raymond Staheli	210	74	2.8
30dab-1	A 16189	Weyl-Zuckerman	550	*d*	
31aba-1	A 14642	Weyl-Zuckerman	325	*d*	
31aca-1	A 14786	Weyl-Zuckerman	720	*d*	
31add-1	A 14197	Weyl-Zuckerman	425	*d*	
31bab-1	A 14197	Weyl-Zuckerman	410	*d*	
31bdd-1	A 14197	Weyl-Zuckerman	405	*d*	
31ccc-1	A 16153	Leland Huntsman	215	153	1.4
31cdc-1	A 16416	Weyl-Zuckerman	55	*d*	
32aaa-1	A 14642	Weyl-Zuckerman	165	*d*	
(C-36-17)					
36add-1	A 16101	Norval Bracken	335	72	4.7
36ddb-1	A 16338	Albert Holt	365	80	4.6
(C-37-16)					
6cac-1	A 16118	Truman & Jones	345	91	3.8
6ccc-1	A 15509	Adams Brothers	325	120	2.7
(C-37-17)					
1ccd-1	A 15465	Heber Truman	130	*b*	*b*
1dcd-1	C 19149	Jones, Barlow & Holt	320	*b*	*b*
1ddc-1	A 16339	Leland Holt	210	*b*	*b*
11dad-1	C 18727	A. E. Pickering	95	*b*	*b*
11ddb-1	C 3139	A. P. Windsor	95	45	2.1

Table 6 (cont.). Pumpage inventory, Beryl-Enterprise District, 1953.

Coordinate number	Application or claim	OWNER	Pumpage (ac. ft.)	Acres irrigated	Acre-feet / acres
(C-37-17)					
12acc-1	A 1965	Grant Clove	290	*b*	*b*
12bdc-1	A 14183	Charles Sides	175	*b*	*b*
12cbd-1	A 15585	Charles Sides	110	*b*	*b*
12dbc-2	A 16183	Arthur Thomas	95	*b*	*b*
14acb-1	C 17896	Enterprise Town	250	*b*	*b*
14bac-1	A 16090	Jacob Busher	100	*b*	*b*
14dcd-1	A 14213	Hunt & Simpkins	65	35	1.9
15bab-3	C 7157	Nelson Thomas	10	20	0.5
	TOTAL		50,045	15,347	
	Total of selected wells used to determine rate-of-water use		42,970	13,333	Avg. 3.2

a Estimated.
b Pumped water supplemental to surface streams.
c Water from 2 wells commingled to irrigate 140 acres.
d Water from 15 wells commingled to irrigate 2,200 acres.

Discharge from Wells

During the 1953 irrigation season, a detailed inventory of ground-water use was made in the Beryl-Enterprise district. A total of 242 field measurements were made during the season on the pumping irrigation wells. In addition, static water levels were measured in selected observation wells after pumping had stopped, to determine the effect that seasonal pumping had had on water levels throughout the valley. The field measurements made during this inventory are listed in table 5.

Table 6 lists all the irrigation wells in the Beryl-Enterprise district that were measured during the 1953 pumpage inventory. This tabulation indicates that a total of 50,045 acre-feet of ground water was pumped from irrigation wells in the valley, providing the sole source of irrigation supply for 15,347 acres of farm land and the supplemental supply for an estimated 1,000 additional acres located principally at the mouths of Shoal and Pinto Creeks. The rate of ground-water use was computed only for the farms where accurate measurements of both pumpage and irrigated acreage were available for the entire year. Thus, as shown in table 6, a total of 42,970 acre-feet of ground water was pumped during the year to irrigate 13,333 acres of farm land which were selected for this rate-of-use determination. This indicates an average use of 3.2 acre-feet per acre.

The distribution of the rate of water use with respect to the number of acres irrigated is shown in figure 10, which indicates that 41 percent of the irrigated lands included in this inventory received between 3 and 4 acre-feet of water per acre during the pumping season.

Recharge

In the progress report of ground-water investigations in the Beryl-Enterprise district, published in 1950 (Fix, Nelson, Lofgren, and Butler, 1950, p. 146-180), the authors concluded in part as follows:

> "Available hydrologic data show that water is contributed to the ground-water reservoir of the Beryl-Enterprise district both by

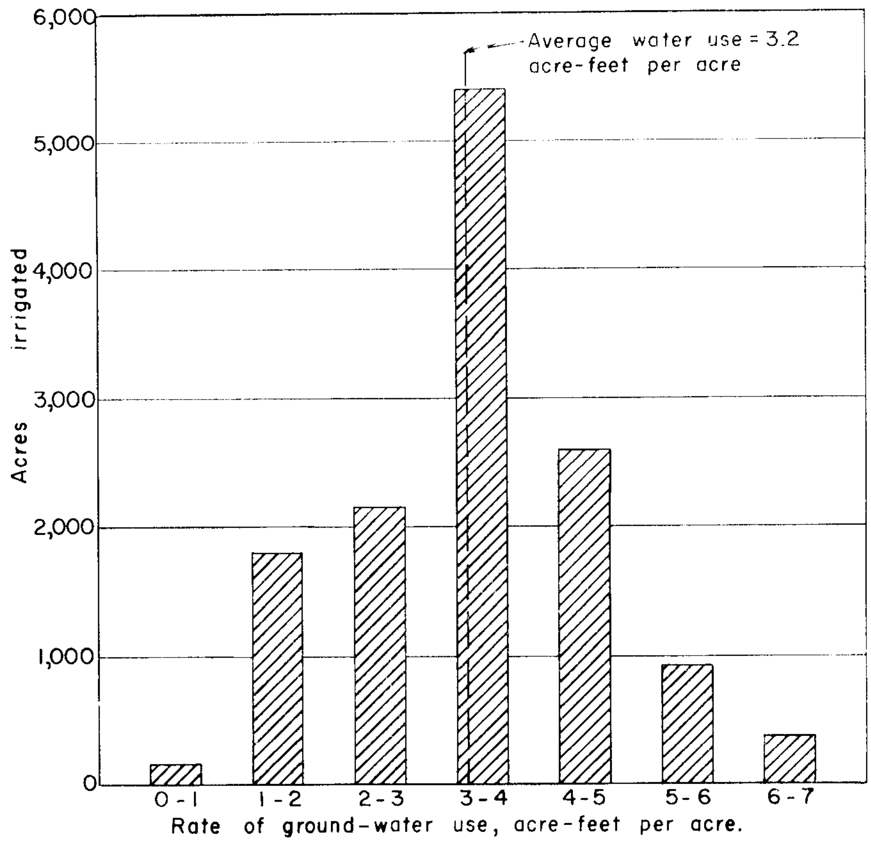


Figure 10. Distribution of pumpage in the Beryl-Enterprise district in 1953, showing rate of ground-water use with respect to the acres irrigated.

precipitation and irrigation within the district and by surface or subsurface inflow from the tributary drainage basin. The possible sources of ground-water recharge are distributed widely but irregularly around the margins of the valley and over the valley floor. So numerous are these possible sources, and so variable are the effects of climate and permeability upon the amount of recharge, that a quantitative determination of the total recharge in any period would require an immense amount of field study."

Because of the serious deficiency of precipitation that has occurred in the watershed area of the Beryl-Enterprise district during the past 15 years, recharge to the ground-water reservoir has likewise been deficient. Recharge to the valley is derived principally from Shoal, Pinto, and

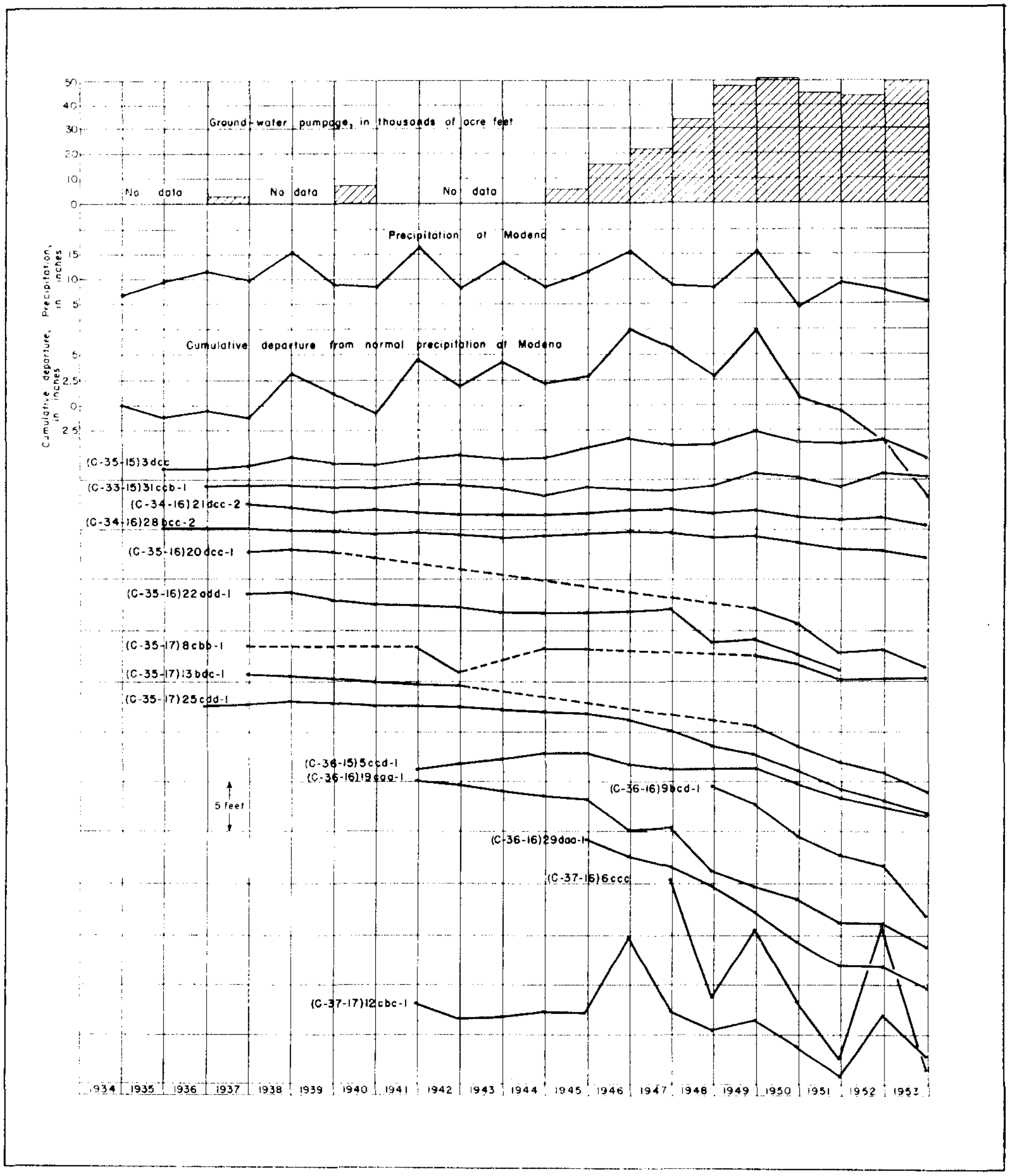


Figure 11. Annual water-level trends in 15 wells in the Beryl-Enterprise district, and other hydrologic data.

Mountain Meadow Creeks, and from numerous minor tributary dry washes that enter the valley.

Because of the large storage capacity of the underground reservoir, water levels in the district change only slightly as a result of abnormally high or extremely low stream runoff, except along the watercourse of Shoal Creek where the water-level changes in nearby wells can be correlated with the amount of water flowing in the stream. This is clearly demonstrated for the high runoff year of 1952, when an estimated 15,000

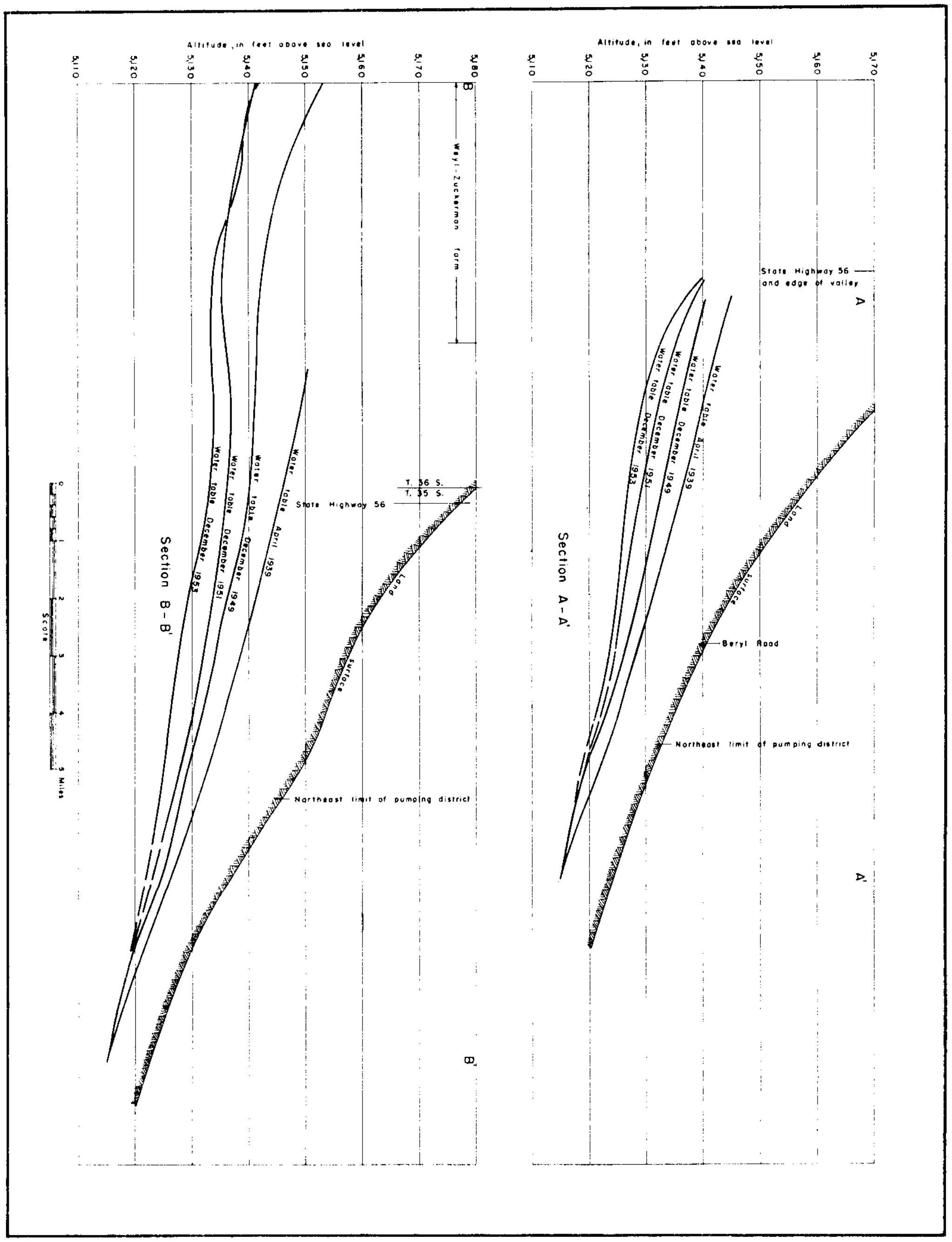


Figure 12. Profiles of the Beryl-Enterprise district showing positions of water table.

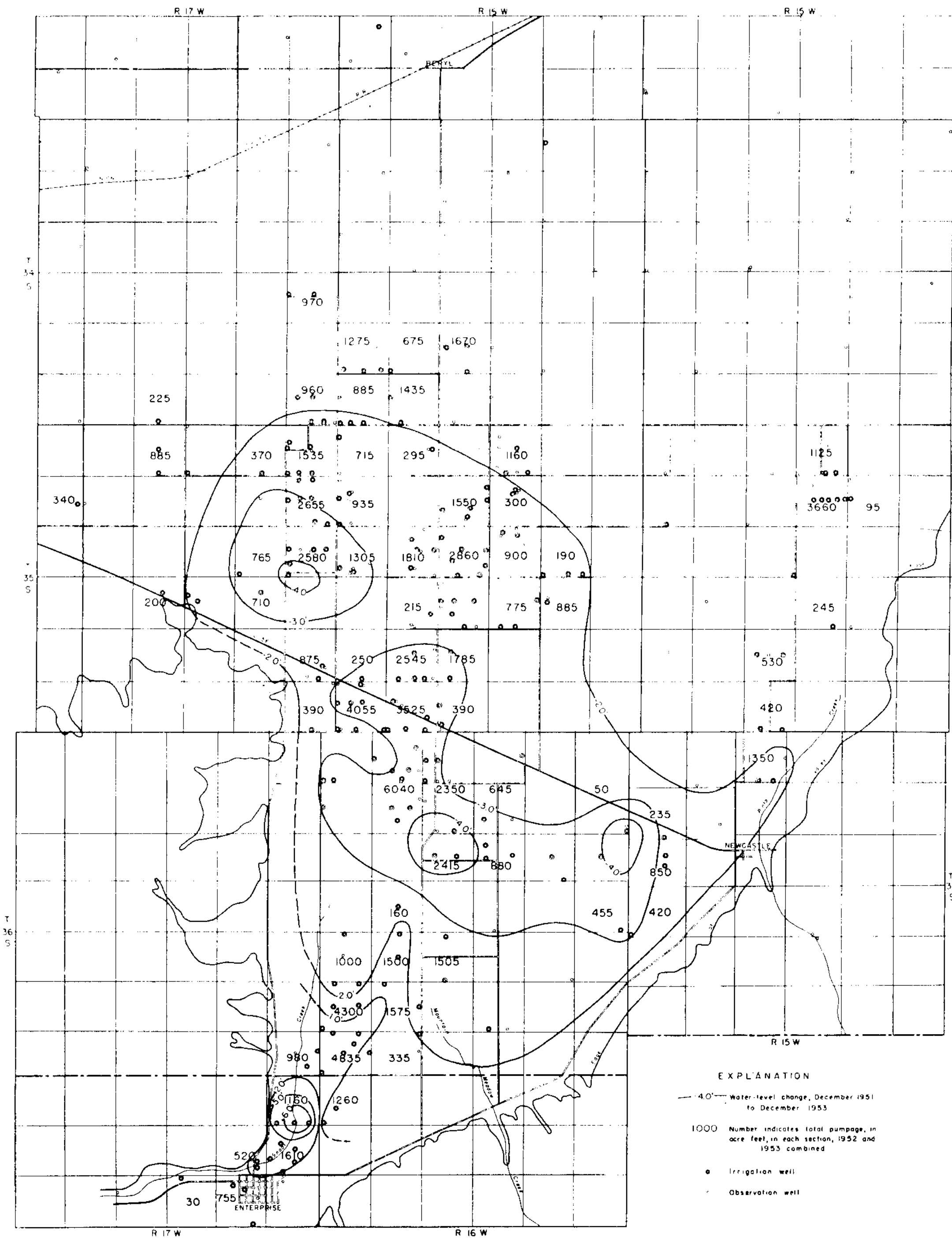


Figure 13. Map of Beryl-Enterprise district showing irrigation wells, areas of water-level decline December 1951 to Decmber 1953, and distribution of pumpage.

acre-feet of spring floodwater drained into the valley from Shoal Creek alone. During that year, the amount of recharge to the ground-water reservoir was several times greater than it had been in recent years. It is quite probable that runoff from Shoal Creek during 1952 would have extended as far north as Beryl had not the large storage reservoirs in the mountains and the several large ponds in the valley retained the bulk of the spring flood flow. Other streams also extended far beyond their usual limits of flow. Nevertheless, few wells in the district were influenced significantly by this above-average runoff.

Water-Level Trends

Water levels in wells throughout most of the Beryl-Enterprise district continued to decline during 1952-53. This downward trend is attributed largely to the accelerated use of ground water in the district, and to some extent to the cumulative deficiency of precipitation in the region. Figure 11 shows the annual water-level trends in 15 selected observation wells in the Beryl-Enterprise district, and other hydrologic data. Thus, as noted in figure 11, pumpage has increased nearly 900 percent in the district since 1945, during a period in which an accumulated deficiency of about 13 inches of rainfall was recorded. As a result, the water levels in most of the wells in the district have trended downward since heavy pumping began in 1946.

The hydrographs (fig. 11) show a declining trend during the period of record, except for two wells in the northeast part of the valley. Thus, the hydrographs of wells (C-33-15)31ccb-1 near Beryl and (C-35-15)3dcc in the vicinity of the Clark Ranch both showed net rises in water level during their respective periods of record, although the hydrograph of the latter well shows a downward trend during 3 of the last 4 years. The hydrographs of two wells of the group, (C-37-16)6ccc and (C-37-17) 12cbc-1, respectively, show rises in water level in response to the high runoff of Shoal Creek in the years 1949 and 1952; however, the long-term trends of the water levels in these wells have been decidedly downward. One well in the Shoal Creek area recorded a 37-foot rise in water level during the 3-week period of high runoff in 1952.

The declining trend of water levels, especially in the areas of heavy pumping, is clearly illustrated in the two profiles of figure 12. These two profiles show the positions of the water table below the land surface along two sections through the pumping district as of April 1939, December 1949, December 1951, and December 1953. The locations of the two profile sections A-A′ and B-B′ are shown in figure 9. It is interesting to note that during each of the periods 1949-51 and 1951-53 there has been as much change in water table along these profile lines as occurred during the period 1939-49. The net effect of this decline has been one of lowering and flattening of the water table in the area of the principal irrigated acreage; there has been little or no effect in the northern part of the valley. The decline has also had the effect of steepening the water-table gradient northward from Enterprise into the valley. The effect of the heavy runoff of 1952 is clearly shown in the south end of section B-B′, where a well-defined ground-water mound in 1953 projects above the position of the water table of 1951.

The extent of the water-table decline during the period December 1951 to December 1953 is further illustrated in figure 13. This figure is a map of the Beryl-Enterprise district showing irrigation wells, areas of water-level decline from December 1951 to December 1953, and the distribution of ground-water pumpage by sections. Thus, it is demonstrated that the areas of decline include the sections of significant pumping. In the central part of the valley water levels declined as much as 5 feet, whereas in a small area along Shoal Creek north of Enterprise water levels rose more than 7 feet. In conformity with the trend begun in 1946, the area of declining water levels continues to expand. Even in 1952, when above-normal recharge occurred, water levels throughout most of the valley maintained their downward trend. This suggests that, even in this year, more water was being pumped from the ground-water basin than was replenished by recharge.

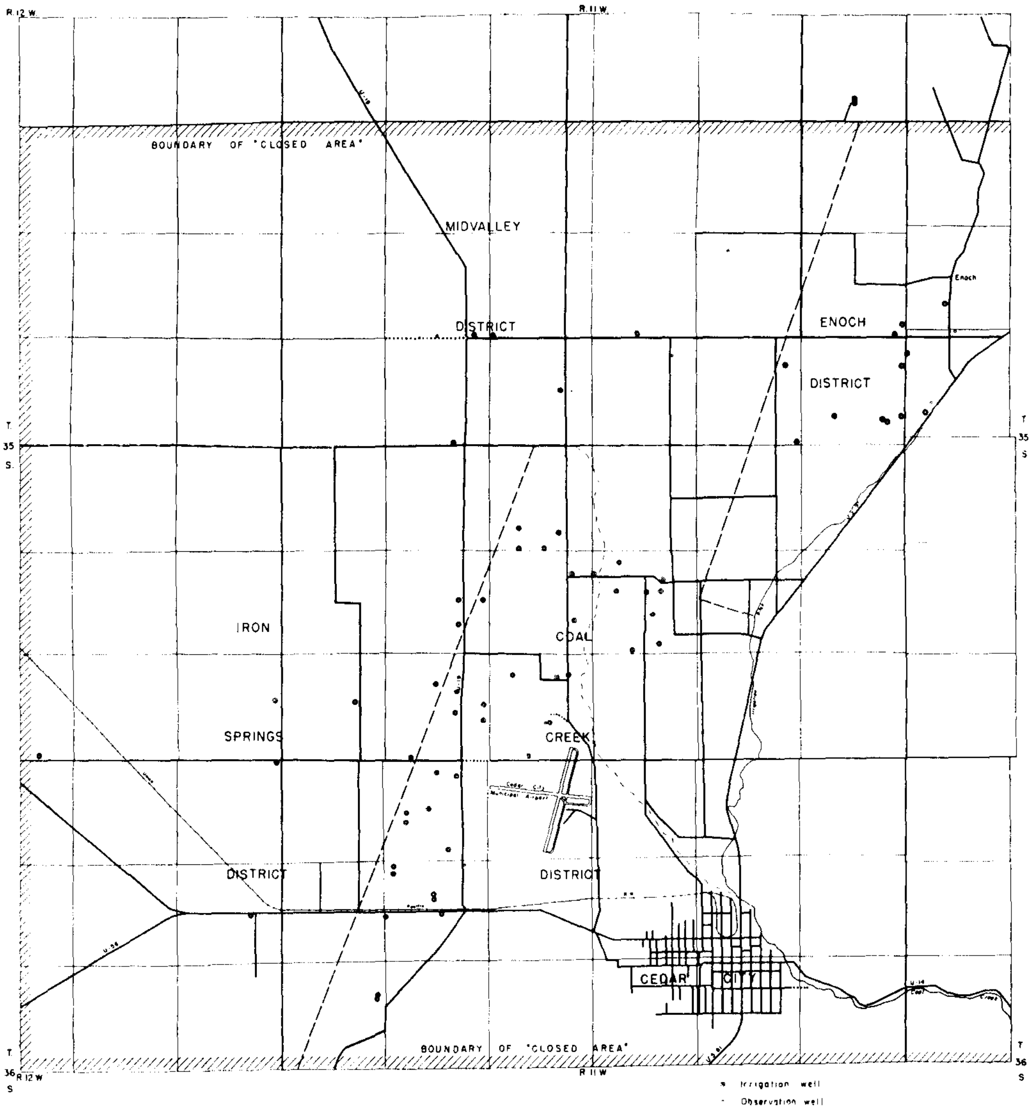


Figure 14. Map of "closed area" of Cedar City Valley.

CEDAR CITY VALLEY

By R. L. BARNELL AND W. B. NELSON

Ground-Water Development

After a detailed investigation of the ground-water resources of Cedar City Valley, Thomas (Thomas and Taylor, 1946; and Thomas, Nelson, Lofgren, and Butler, 1952) divided the valley into 8 ground-water districts, their separation being based principally on natural barriers and differences in ground-water occurrence. Parts of four of these districts are shown in figure 14 — namely, the Iron Springs, Coal Creek, Midvalley, and Enoch districts. The first three of these districts are situated on the alluvial fan of Coal Creek, which extends far into the valley, and the trends of water levels in these districts are closely related to the runoff of this stream. The fourth district, namely, the Enoch

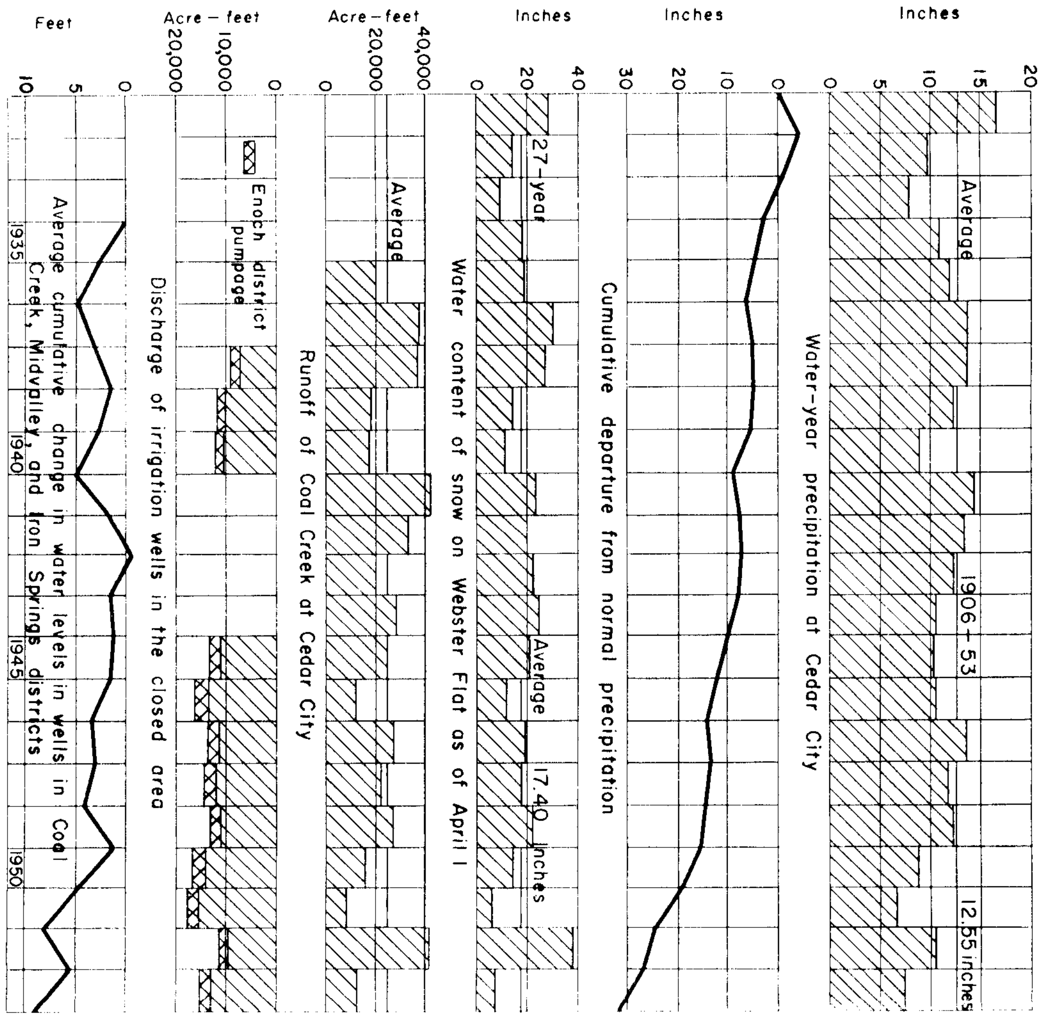


Figure 15. Hydrologic data for Cedar City Valley, 1930-53.

district, is hydrologically unrelated to the other three, receiving its recharge mainly from the mountains to the east.

Because of the downward trend of water levels, especially in the vicinity of heavily pumped wells, part of the Iron Springs, Coal Creek, and Midvalley districts, including most of the large irrigation wells in the valley, was closed to additional development of ground water, except for domestic and stock wells. The present extent of the "closed area" is shown in figure 14. Since this closure, a large municipal supply well has been drilled within the "closed area," and several irrigation wells have been drilled slightly beyond the boundary.

Since 1938 the total number of irrigation wells in operation in the "closed area" has ranged from 52 to 64, and ground-water pumpage has ranged from 9,100 to more than 17,700 acre-feet per year. This record, together with other hydrologic data pertaining to Cedar City Valley, is shown in figure 15. Wells constitute the only source of irrigation water on many farms; they are supplemental to surface water on other tracts. Thus, the quantity of ground water pumped varies greatly from year to year, depending largely on the availability of water diverted from surface streams for irrigation.

Discharge from Wells

As listed in table 7, a total of 15,410 acre-feet of ground water was pumped from the 63 irrigation wells in the "closed area" of Cedar City Valley in 1953. This pumpage is about 20 percent greater than the pumpage in 1940, but considerably less than the pumpage in both 1950 and 1951. The decrease in pumpage in 1953 from that of 1950 and 1951 can be attributed partly to a regional lowering of water level which has the effect of decreasing the discharge of each well. It is interesting to note that, in the high-runoff year of 1952, only 11,480 acre-feet of ground water was pumped, equivalent to only 65 percent of the pumpage of the previous year, which was deficient in stream runoff.

During the 1953 irrigation season a total of 143 field measurements were made on the pumping wells in the "closed area" of the valley to determine the rate of well discharge. In addition, more than 100 measurements of static water level were made in the area during periods of no pumping, to determine ground-water trends throughout the valley. Part of these data are listed in table 8.

Recharge

Cedar City Valley is situated within an extensive drought area which prevails in the southwestern part of the United States. Precipitation at Cedar City during the past few years has been the lowest on record, with 20.7 inches of cumulative deficiency from normal precipitation having been recorded during the period 1947-53, inclusive. In general this trend of deficient rainfall has been in effect since 1932, only 5 of the succeeding years having had above-normal precipitation. During the 48 years of record, precipitation at Cedar City has ranged from 6.66 inches in 1950 to 18.76 inches in 1941, with a mean annual average of 12.55 inches.

As noted in figure 15, there are a few years in which a poor correlation exists between annual precipitation as measured at Cedar City and the total runoff in nearby Coal Creek. This is notably the case in 1952 when precipitation at Cedar City was considerably less than normal yet the runoff from Coal Creek was nearly the highest of record. In many of these years a closer correlation is maintained between the records of snow accumulation as measured on selected snow courses on the

Table 7. Estimated pumpage from wells within the "closed area" of Cedar City Valley, 1940-53.

Coordinate number	State number	OWNER	Depth (feet)	ESTIMATED ANNUAL PUMPAGE, ACRE-FEET 1940	1945	1950	1951	1952	1953
		COAL CREEK DISTRICT							
(C-35-11)									
21ccd-1	C 4880	George Parry	172	140	230	220	200	90	130
21cdb-1	C 9926	Rulon Esplin	176	210	110	270	140	130	145
21dbd-2	C 1222	Ezra Rollo	232	160	240	210	180	100	110
21dcc-1	C 11597	Wilford Fife	180	170	160	170	100	110	25
27aca-1	C 5222	Walker Well	108	240	330	360	500	330	480
27acc-1	C 382	Fernleigh Gardner	113	190	180	270	280	150	150
27acd-1	C 5224	Bower Well	114	170	420	270	210	200	415
27adc-1	C 8127	Owen Matheson	148	180	130				
27bab-2	C 1215	Grant Hunter	150	330	310	290	330	130	170
27bbc-1	C 8175	Munford Well	117	310	290	370	370	230	160
27bdb-1	C 1216	Grant Hunter	156	220	290	220	250	90	270
27cdd-1	C 8182	Bulldog Well	147	280	290	290	480	160	540
27dbb-1	C 5223	Luke & Halterman	99	430	360	330	430	210	310
27dcd-1		Ren Luke	150	440	290	480	440	300	180
28aac-1	C 14222	Perry Brothers	93	190	250	260	260	250	245
28dab-1	C 6491	Ray Melling	162	190	220	230	180	130	150
29add-1	C 11606	K. L. Jones	110	140	170	280	550	360	400
32abd-2	C 14003	Orson Bryant	256	350	290	390	370	110	250
32aca-1	A 12242	John Sherratt	223	260	240	350	330	300	360
32acd-1	C 8176	Kimball Jensen, et al	168	290	270	380	430	250	355
32add-1	C 6935	Corry & Davis	89	430	360	420	520	580	605
32daa-1	C 490	E. T. Higbee	207		270	260	350	290	365
33aac-1	C 5126	Cottonwood Well		340	230	330	320	210	540
33abd-1	C 11590	W. K. Granger	187	170		310	400	230	345
33bac-1	C 5131	Fred Biederman	239	400	230	300	370	200	300
33dbc-1	C 14012	W. H. Wood	140	170	410	420	350	130	155
33cdd-1	C 411	Richard Leigh	116	110	200	110		70	10
(C-36-11)									
5abd-1	A 12255	Fred Perry	166		120	370	360	240	380
5baa-1	A 12636	Fred Perry	132		80	290	330	150	240
5bdd-1	C 13503	Sidney Ashdown	144	290	150	260	290	200	240

Table 7 (cont.). Estimated pumpage from wells within the "closed area" of Cedar City Valley, 1940-53.

Coordinate number	State number	OWNER	Depth (feet)	ESTIMATED ANNUAL PUMPAGE, ACRE-FEET 1940	1945	1950	1951	1952	1953
(C-36-11)									
5cab-1	C 13509	Kent Smith	230	340	20	350	280	110	460
5cac-1	C 13510	Kent Smith	220	260	300	330	210	90	345
5dcb-1	C 5091	Warren Bullock	144	290	360				
5dcc-1	C 13487	Leonard Bullock	150	310	250	410	400	380	345
8bba-1	A 11977	Alfred Stucki	158	410	180	290	400	200	435
8bba-2	C 13983	E. B. Williams		220	90	170	250	120	260
8bda-1	C 6560	E. B. Williams	150	110	270	100	150	50	60
8bda-2	C 6561	E. B. Williams	80				30	30	10
8cab-1	C 8180	Higbee, Smith & Jones	200	220	310	310	290	210	75
8cbb-1	C 317	Lehi Jones	60	50	230	270	270	140	225
18ada-1	C 4881	Branch Agricultural College	100	100		140	220	150	95
18ada-4	C 15422	Branch Agricultural College	245		130	290	280	130	
		IRON SPRINGS DISTRICT							
(C-35-11)									
29acd-1	C 13512	K. L. Jones	300	230	320	340	300	250	230
29dbd-1	C 1230	Alex Williams	91	120	50	200	230	220	240
31acd-1	C 13498	Kimball Jensen	472	120	200	260	220	280	270
32bda-1	A 11872	John H. Beal	200			210	410	370	445
32ccd-1	C 5098	Corry, Palmer & others	287	430	460	490	440	280	395
(C-35-12)									
34dcd-1	C 4873	Reuben T. Shay	120	10					
36daa-1	A 11745	Joseph Foster	400			90	100	40	100
(C-36-12)									
1aaa-2	C 13995	Irad DeMill	366	100	110	210	210	170	80
12dba-1	C 15411	Branch Agricultural College	600	170	280	210	260	150	270
		MIDVALLEY DISTRICT							
(C-35-11)									
8ddd-1	C 11596	John Sherratt		60	80	150	170	100	120
9ccc-1	A 12069	John Heaton	300			140	260	160	170
10ccc-1	C 6739	Charlotte Esplin	459	30					
10cdd-1	C 6740	Elwin Armstrong	499	80	160	130	170	10	140

16acd-1	C 3390	Cline Bauer	268	290	250	260	330	160	360
17dcd-1	A 12341	Conrad Bauer	200		150	140	190	110	100
		ENOCH DISTRICT[1]							
(C-35-10)									
7cad-1	A 12056	Francis Matheson	101	200	200	190	200	160	120
7cdd-1	C 15342	Parson Webster	70	40		20	30	30	
18bbc-1	A 12114	Stanley Smith			250	180	190	40	75
18cca-1	A 22528	Cedar City	285						185
(C-35-11)									
12ddd-2	A 12320	C. S. Smith	238		200	170	120	80	145
12ddd-1	A 12455	West Enoch Irrigation Co.	250	440	320	320	280	310	265
13ada-1	A 12093	West Enoch Irrigation Co.	279			300	280	240	290
13cac-3	C 19305	Norman Bullock				40	40	20	
13dda-1	A 11849	East Union Irrigation Co.	206		120	330	320	250	425
13ddb-2	C 8178	East Union Irrigation Co.	166	260	270	370	370	210	290
13dbd-3	C 491	East Union Irrigation Co.	166	290	330	400	400	260	220
14aac-1	C 13713	W. H. Grimshaw	334	220	120	40	50	60	70
14ddd-3	C 14002	David Murie	158	110	130	70	70	20	70

PUMPAGE, BY GROUND WATER DISTRICT, IN ACRE-FEET

Coal Creek district	9,110	9,260	11,370	12,110	7,510	10,335
Iron Springs district	1,270	1,420	2,010	2,170	1,760	2,030
Midvalley district	460	640	820	1,120	530	890
Enoch district[1]	1,560	1,940	2,430	2,350	1,680	2,155
TOTAL	12,400	13,260	16,630	17,750	11,480	15,410

NUMBER OF WELLS PUMPED FOR IRRIGATION

Coal Creek district	36	38	38	38	40	39
Iron Springs district	9	7	9	9	8	8
Midvalley district	4	4	5	5	5	5
Enoch district[1]	7	9	12	12	12	11
TOTAL	56	58	64	64	65	63

[1] Part that is within the closed area.

Table 8. Measurements of water level and discharge of irrigation wells in the "closed area" of Cedar City Valley, 1953.

Coordinate number	Static measurements		Pumping measurements		
	Date	Depth to water[1] (feet)	Date	Depth to water[1] (feet)	Discharge (gpm)
(C-34-10)					
30ddc-1					
31caa-1			6/23	67.5	565
(C-34-11)					
36cdd-1	3/13	1.40	6/22	59.9	295
	12/7	11.93	8/4	68.0	197
			9/15	67.3	
36cdd-2			6/22	67.4	324
			8/4	93.0	512
			9/15	92.1	
(C-35-10)					
7cad-1	3/13	33.69	6/23	50.2	
	12/7	37.12	9/3	51.0	247
18bbc-1			6/23	70.5	216
			8/10	73.0	148
(C-35-11)					
8ddd-1			6/19	51.0	160
			8/10	50.4	170
9ccc-1	3/13	11.56	6/22	74.9	202
	12/7	17.49	8/4	70.0	207
			9/15	74.3	207
10cdd-1			6/22		184
			8/4		157
12ddd-1			6/22		355
			8/4		350
12ddd-2			6/23	69.0	274
			8/4		257
13ada-1	3/13	41.89			
	12/7	51.85	8/4	87.2	457
			9/15	85.5	
13cac-3			9/3		50
13dda-1			6/23	90.0	930
			8/4		853
			9/15		785
13ddb-2			6/23		360
			8/4		288
13ddb-3			6/23		234
			8/5		234
			9/3		230
14aac-1					
14ddd-3			6/22		148
16acd-1			6/22		450
			8/4		450
			9/15		455
17dcd-1	12/7	22.39	6/19	66.5	70
			8/10	55.5	212
21ccd-1			6/22	70.5	216
			7/30	70.0	238
21cdb-1			6/22	71.5	284
			7/30	72.4	274
21dbd-2	12/7	35.88	6/15	46.8	328
			8/10	57.5	328
21dcc-1	3/13	31.55	6/22	52.5	270
	12/9	38.18	7/30	54.6	202
27aca-1			6/15	61.3	665
			7/30	66.1	634
			9/15		600

Table 8 (cont.). Measurements of water level and discharge of irrigation wells in the "closed area" of Cedar City Valley, 1953.

Coordinate number	Static measurements		Pumping measurements		
	Date	Depth to water[1] (feet)	Date	Depth to water[1] (feet)	Discharge (gpm)
(C-35-11)					
27acc-1	3/13	43.46	6/15	61.3	234
	12/7	52.07	6/23	61.5	
			7/30	65.5	171
			9/15	63.8	216
27acd-1			6/16	72.3	575
			6/23	71.9	
27bab-2			6/15	52.3	324
			6/23	52.3	
			7/30	53.2	270
27bbc-1	12/7	46.23	6/17	49.0	500
			6/23	49.5	
27bdb-1			6/15	55.8	638
			7/30	57.5	584
27cdd-1	12/6	68.48	6/15	85.3	862
			7/30	87.1	822
			9/15	86.9	
27dbb-1			6/16		445
27dcd-1			6/16		540
			7/30	87.8	472
28aac-1			6/16	50.4	442
28dab-1			6/17	63.0	342
			7/30	66.3	180
29acd-1	3/13	35.73	6/19	74.4	288
			8/4	75.7	
			9/14	74.8	300
29add-1			6/19	71.8	490
			8/4	73.9	463
			9/14	74.0	463
29dbd-1			6/19	68.2	243
			8/4	73.2	306
			9/14	78.0	
31acd-1			6/22	64.1	355
			8/3	65.0	346
			9/14	65.0	333
32abd-2			6/19	71.5	625
			8/10	75.8	615
			9/14	73.0	
32aca-1	3/13	46.71	6/19	66.9	423
	12/7	55.83	8/4	69.1	392
			9/14	70.5	410
32acd-1			6/19		485
			8/3		423
32add-1			6/19	75.3	715
			8/4	78.6	685
			9/14	78.4	
32bda-1			6/13	65.2	685
			9/15	67.9	560
32ccd-1			6/22		503
			8/3		497
32daa-1			6/19	76.2	588
			7/23	80.5	540
33aac-1	12/7	75.80	6/17	88.4	805
			7/30	92.7	785
			9/3	91.3	785
33abd-1			6/17		596
			7/30		557
33bac-1			6/17	73.2	525
			7/30	76.6	490
33dbc-2			6/17	93.8	530

Table 8 (cont.). Measurements of water level and discharge of irrigation wells in the "closed area" of Cedar City Valley, 1953.

Coordinate number	Static measurements		Pumping measurements		
	Date	Depth to water[1] (feet)	Date	Depth to water[1] (feet)	Discharge (gpm)
(C-35-12)					
36daa-1	12/7	20.00	6/22	75.3	122
(C-36-11)					
5abd-1	3/13	57.41	6/19	78.4	805
	12/7	67.37	8/5	80.2	785
5baa-1			6/18	70.0	585
			8/10		515
5bdd-1			6/18	66.2	410
			8/3	67.0	378
5cab-1			6/18	74.6	625
			8/10	76.3	625
			9/14	75.5	
5cac-1			6/18	68.3	638
			8/10	68.3	634
5dcc-1			6/18	69.2	453
			8/3		413
			9/15	72.3	
8bba-1			6/18	65.6	570
			8/3	66.0	543
			9/14	64.3	
8bba-2			6/19	62.2	490
			8/3	63.7	462
8bda-1			8/3		200
8bda-2			6/18		45
8cab-1	3/13	38.64	8/3		190
8cbb-1			6/18	61.0	280
			8/10	61.0	252
18ada-1	12/7	44.08	6/18	68.4	144
			8/3	68.4	90
			9/14	67.4	
(C-36-12)					
1aaa-2	3/13	12.72	6/22	52.6	103
	12/7	22.09	8/3	52.5	120
12dba-1	3/13	16.22	6/18	46.4	346
	12/7	22.35	8/10	46.9	360

[1] Below land surface.
All wells are powered by electric motors.

watershed areas. Thus, as shown in figure 15, the bar graph of water content of snow as measured on Webster Flat seems to correlate closely each year with the runoff graph for Coal Creek, and it is probably more directly related to water-level conditions in the valley than is the Cedar City precipitation record.

Streamflow records, which are available for Coal Creek for the years 1916-20 and 1935-53, are shown for the latter period in figure 15. Considering only the years for which a complete water record is available, runoff from Coal Creek has ranged from a maximum of 41,060 acre-feet in 1941 to only 9,080 acre-feet in 1951 and averaged 24,600 acre-feet for the period. During 7 of the last 11 years, the runoff of Coal Creek has been below this average value.

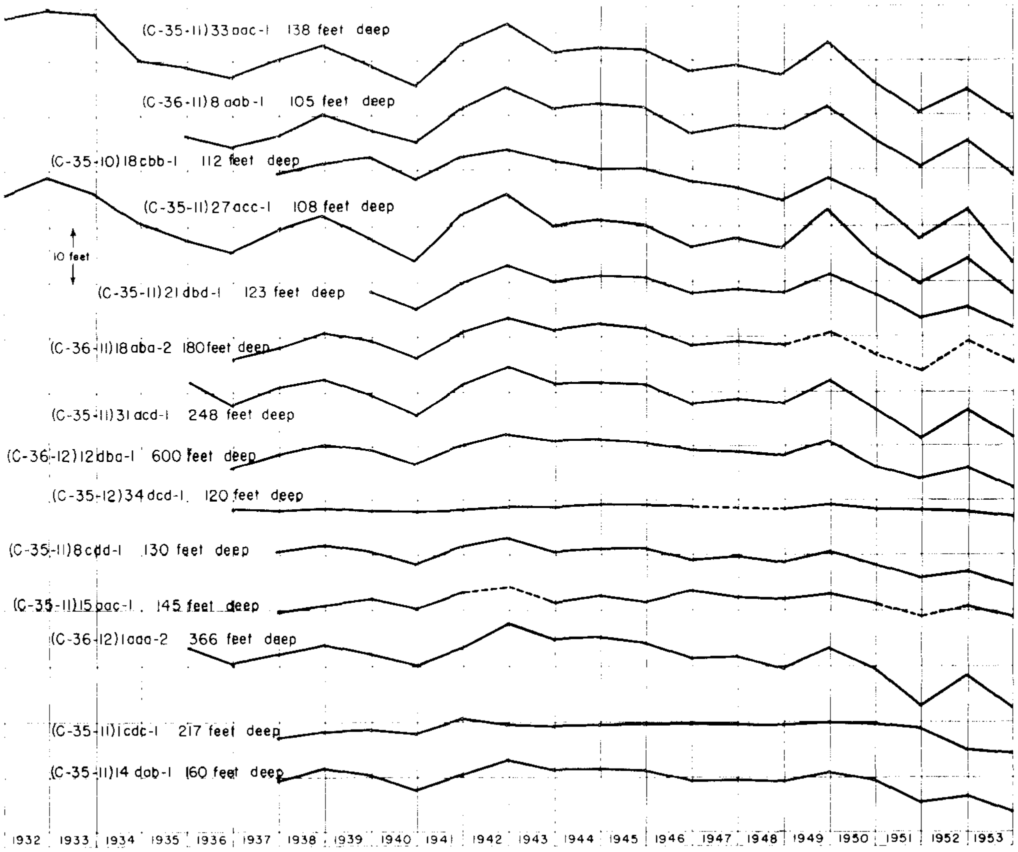


Figure 16. Annual water-level trends in 14 wells in Cedar City Valley, Utah.

Water-Level Trends

As shown in figure 16, the water levels in most of the wells in the valley fluctuate in about the same manner in response to changes in the runoff of Coal Creek. Thus, high runoff recharges the underground water basin, results in a reduction in pumping, and contributes to a general rise in water levels. Conversely, the extended period of deficient runoff of the past several years caused heavy draft on the ground-water reservoir resulting in the lowest water levels on record in many of the wells. The lowering of water levels has also reduced the yields of wells.

The irrigated areas in the vicinity of Cedar City serve as a recharge area for districts farther down the fan. Thus, there is a marked correlation between the quantities of water spread for irrigation in the upper areas and the trend of water levels in the lower districts. This is clearly shown by comparing the records of 1947 and 1949. During these two years the total runoff of Coal Creek was about the same, and the total pumpage from wells was comparable. The runoff characteristics in these two years, however, were considerably different, resulting in entirely different water-level conditions in the lower districts of the fan. In 1947 the early spring runoff occurred too early to be of value to the farmers in the area, and much of the water wasted past the potential recharge areas unused. In 1949, however, the high spring runoff of Coal Creek occurred several weeks later in the season, and all the flood water was used for irrigation on the recharge areas. The additional recharge in 1949 resulted in a rise in water levels in wells, which were 3 to 4 feet higher than in 1947. In 1952, a year of abnormally high stream runoff, most of the spring runoff was not diverted for irrigation, and average water levels failed to reach the high levels attained in 1949, a year when less than half the 1952 spring runoff occurred.

Possibilities of Artificial Recharge

The close relation between ground-water conditions and the streamflow characteristics of Coal Creek suggests the possibility that the quantity of water stored in the ground-water reservoir could be materially increased by artificial recharge. It is believed that far more water could be placed in underground storage in some years by the planned spreading of surplus stream runoff.

PAROWAN PUMPING DISTRICT

By R. G. Butler and R. L. Barnell

Although Parowan Valley is only 19 miles north of Cedar City Valley, the two areas are separate and distinct and are here discussed as two independent ground-water basins. Not only are the irrigation wells and the croplands in the two basins dissimilar, as to both size and type, but also the records of precipitation and conditions of ground-water recharge differ.

As noted in figure 17, the annual precipitation at Parowan varies only slightly from one year to the next, in marked contrast to the other basins of southern Utah. This is further illustrated in the curve of accumulated departure from normal precipitation, which indicates a rainfall deficiency at Parowan of only 2.7 inches during the period 1947-53, as compared with an accumulated departure of 20.7 inches at Cedar City. Likewise, during the two years of exceptionally high stream runoff, 1949 and 1951, respectively, precipitation at Parowan was considerably above normal, whereas at Cedar City a below-normal rainfall was recorded.

Ground-Water Development

The several ground-water districts in Parowan Valley are outlined in figure 18. This map shows also the location of all irrigation wells in the valley and the area in the central part of the district that is "closed" to further ground-water appropriation. The boundaries of the "closed area" were first established in 1935 and have been enlarged on several occasions to encompass the present area delineated in figure 18. Within this "closed area," few wells have been drilled since 1940, and these were for the most part replacement wells for nearby abandoned installations. Since 1940, 19 irrigation wells have been drilled beyond the boundaries of the "closed area," clustered in 3 groups in the Buckhorn, Paragonah, and Summit districts.

In 1940 there were 395 known wells in Parowan Valley, of which about 300 flowed by artesian pressure during at least part of each year. Thirty wells were pumped for irrigation during 1940, with a combined discharge of 6,030 acre-feet. Subsequent drilling increased the number of irrigation wells in operation to a total of 50 in 1953, and the total pumpage from these wells amounted to 11,460 acre-feet. As noted in figure 17, the annual pumpage ranged from about 10,000 to 11,500 acre-feet during

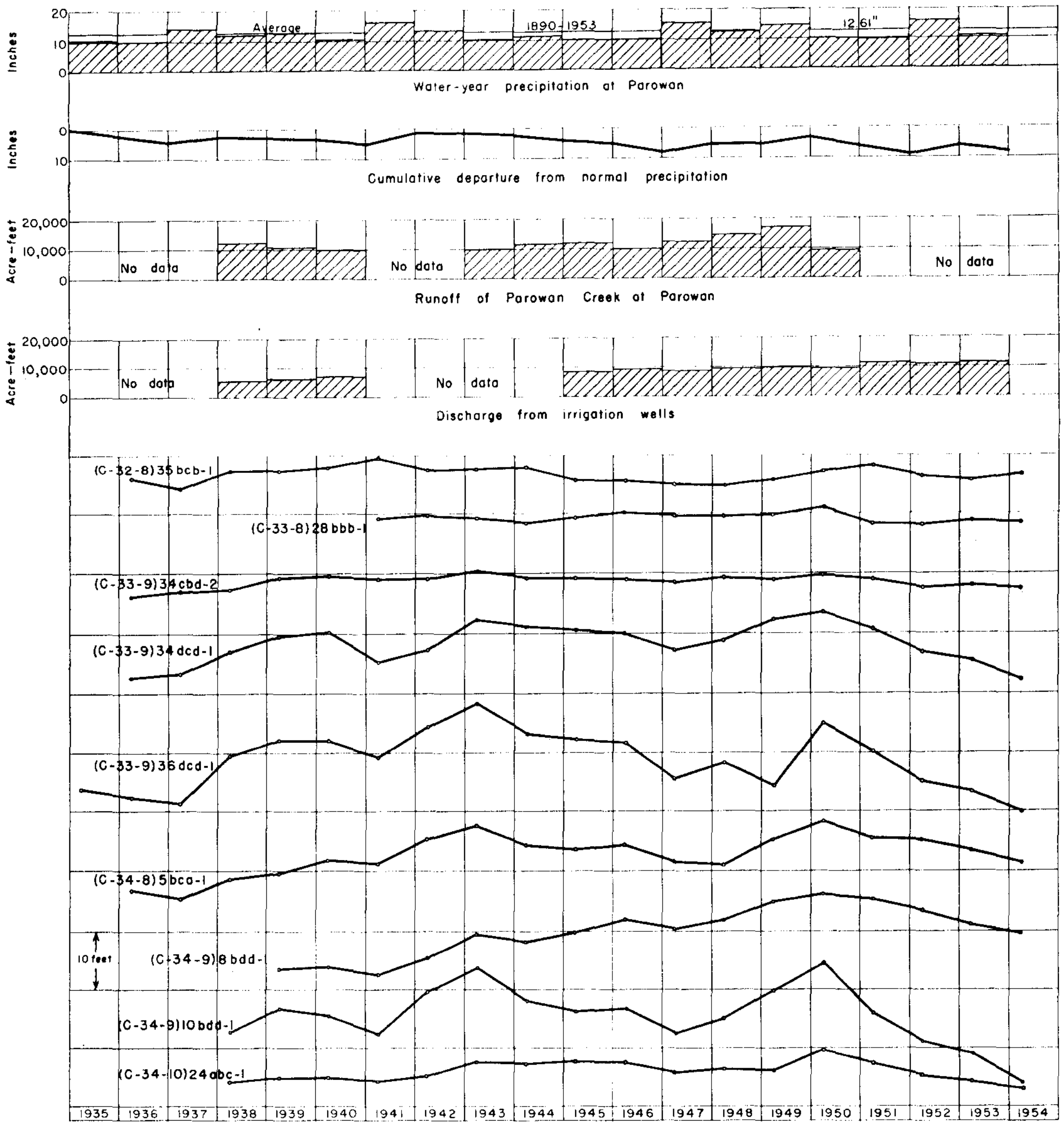


Figure 17. Hydrologic data and water-level trends in Parowan Valley, 1935-54.

the period 1950-53, inclusive, and in no year during the past 9 has the annual pumpage deviated more than 15 percent from the annual average of 10,000 acre-feet. Apparently, seasonal variations of rainfall and surface runoff have little influence on the quantity of ground water pumped each year. This is probably due to the fact that irrigated acreage varies but little from one year to the next, and few fields in the valley use ground water to supplement a surface stream supply.

It is estimated that in 1940 less than half the water that entered the ground-water reservoir in Parowan Valley was used beneficially (Thomas and Taylor, 1946, p. 198). In that year, estimates showed 6,400

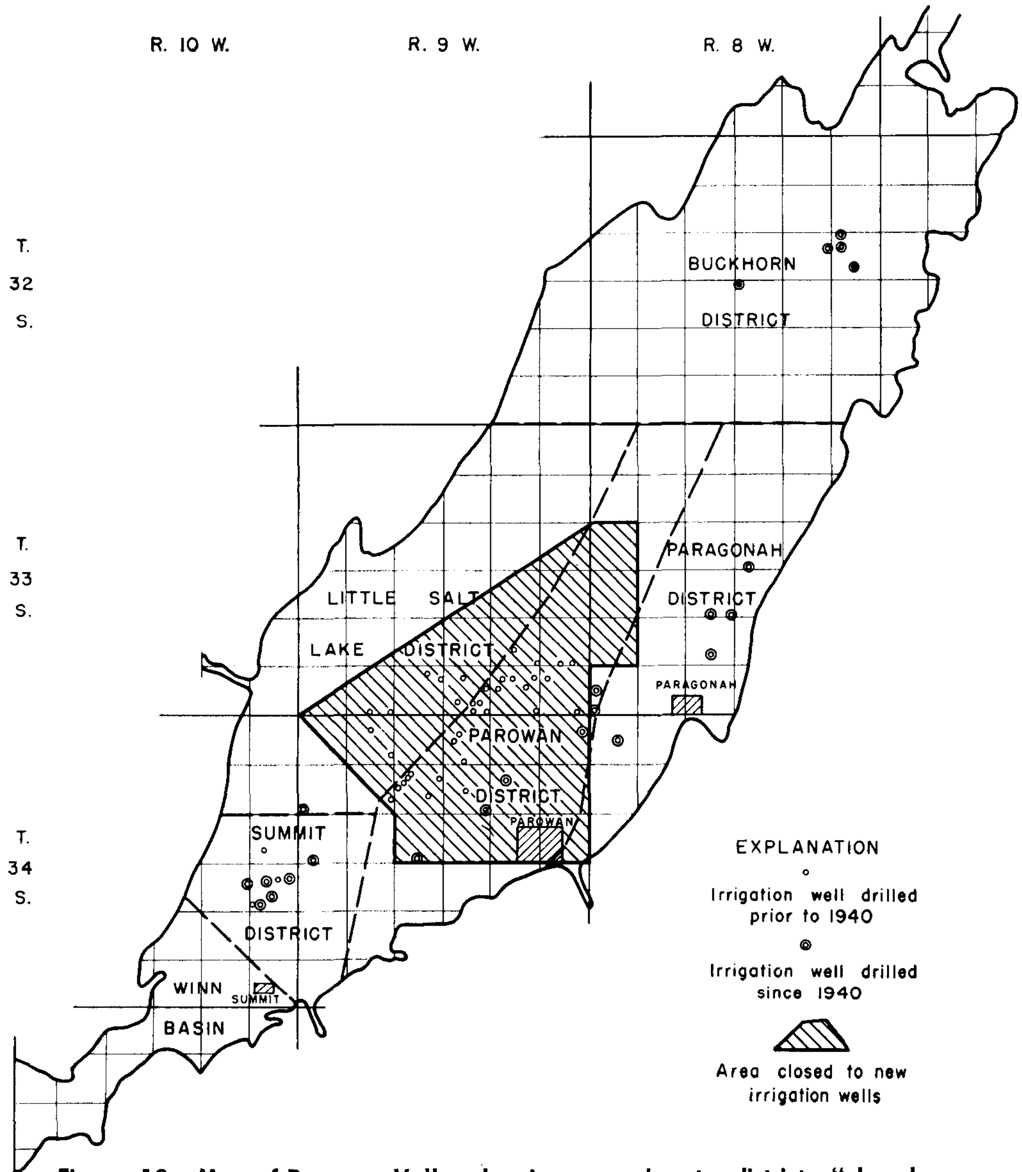


Figure 18. Map of Parowan Valley showing ground-water districts, "closed area," and location of irrigation wells.

acre-feet of water pumped from wells for irrigation, about 700 acre-feet derived from flowing wells for irrigation, a small quantity withdrawn from flowing wells for beneficial purposes other than irrigation, and about 1,400 acre-feet wasting from flowing wells, the total discharge from all wells being about 8,500 acre-feet. The ground-water discharge by springs and by evapotranspiration was estimated to have been about 10,700 acre-feet; thus, the total ground-water discharge in 1940 was about 19,000 acre-feet. Although some development has taken place since these estimates were compiled, it is probable that each year as much water discharges from the ground-water reservoir without being put to beneficial use as is put to such use.

Table 9. Estimated pumpage from wells in Parowan Valley, 1940-53.

Coordinate number	State number	OWNER	Depth (feet)	ESTIMATED ANNUAL PUMPAGE, ACRE-FEET					
				1940	1945	1950	1951	1952	1953
		PAROWAN DISTRICT							
(C-33-8)									
31bcc-1	A 21305	H. M. Adams					200	220	375
31ccc-1	A 17398	Charles Burton				300	290	210	420
(C-33-9)									
25cdd-4		A. H. Orton		160	250	310	260	230	160
25dcc-3	C 7898	S. P. Pritchard		60	200	210	250	230	200
26cac-8	C 6759	Wm. M. Eyre				100	150	190	200
26ddd-1	C 13807	M. E. Trimmer		190	340			10	
34aad-1	C 1227	Eugene Warren		30	130	180	140	150	170
34daa-3	C 13495	Rulon Dalton		110	110	140	150	100	35
34dbd-1	C 493	O. M. Lyman	425	170	190	150	140	200	130
34dbd-4	A 13395	O. M. Lyman		140	160	140	240	250	165
34dcd-1	C 6750	C. L. Robinson		270	340	430	360	360	325
34ddd-1	C 13496	Rulon Dalton	515	220	190	240	230	200	160
35aad-4	C 16414	Harold Dalton		270	210	250	270	210	235
35acd-1	C 13810	W. Scott Day	500	270	450	280	310	250	280
35bac-1	C 11216	Clark Orton		160	190	220	230	200	175
35bad-1	C 7848	Reid Orton	608	120	120	190	250	170	175
35cbb-1	C 4554	W. Scott Day	300	50	80	70	90	90	
35ddd-1	C 13812	W. Scott Day	500	410	400	370	410	310	200
36bbc-1	C 1264	Harold Dalton	560	70	350	220	150	180	165
36dcd-1	C 494	H. L. Adams	499	140	210	180	200	190	75
(C-34-8)									
6add-1	A 22891	Jay S. Evans							145
1aac-1		H. L. Adams						150	540
(C-34-9)									
3bcd-1	C 920	S. A. Halterman	560	400	260	330	400	440	365
3cba-3	C 20834	S. A. Halterman			180	210	170	140	160
3cdd-2	C 1170	Clair Rowley	355	190	220	230	250	40	250
8dad-1	C 495	LeRoy Stubbs			180	220	250	230	235
9aad-1	C 13987	L.D.S. Church	126	200	250	270	290	290	180
9baa-4	a 2297	Harley Dalton		140	280	380	440	390	325
9bbd		J. N. Evans				60	210	300	245
9bbd-1	C 5786	J. N. Evans	600	210	380	300	300	180	155
9bca-4	C 4871	Peter Gurr		300	350	290	240	330	255
9bcc-1	C 4870	Peter Gurr	540	260	380	280	240	280	175
9dbc-1	C 1224	F. H. A.	540				120	120	125
10bdd-1	C 8801	Clair Rowley	500		180	200	220	30	120
11		Claude Lister						20	245
16cdd-2	A 22566	Joseph Holyark					200	250	215

Table 9 (cont.). Estimated pumpage from wells in Parowan Valley, 1940-53.

Coordinate number	State number	OWNER	Depth (feet)	ESTIMATED ANNUAL PUMPAGE, ACRE-FEET 1940	1945	1950	1951	1952	1953
		LITTLE SALT LAKE DISTRICT							
(C-33-9)									
28dcd-1	C 1231	Arthur B. Evans	716	200					
32cdd-4	C 19512	Edgar Benson			170	120	130	110	75
32ddd-1	C 10620	C. L. Robinson			130	220	70	160	120
33aad-1	C 1233	John P. Bayles	740	290	300	240	260	220	175
33abd-1	C 1232	Arthur B. Evans	400		210	230	270	240	270
34bad-1	C 3717	Dee Evans	472		170	150	110	80	75
34cbd-4	C 5694	Dee Robinson	489	350	360	420	340	250	405
(C-34-9)									
5bda-1	C 5089	H. E. Bayles		420	500	430	430	430	525
5dad-1	C 5089	J. C. Robinson	665	540	520	580	540	460	410
7ccc	A 21797	Peter Gurr					320	180	260
		SUMMIT DISTRICT							
(C-34-10)									
13cca-1	C 17658	Ray Lyman	107			110	170	260	225
23ada-1	A 17047	Ray Lyman				280	260	180	250
24aac-1	A 16640	Lyle Farrow				180	210	190	320
24abc-1	A 12115	Earl Bunn	104			50	100	40	
24bbd-1	A 22520	Ray Lyman					210	270	280
24cab-1	A 16803	Raymond Farrow				120	130	190	240
24cbc-1	A 12241	John Farrow	247	50		160	120	80	150
24cbc-2		John Farrow					180	130	300
		PUMPAGE, BY GROUND WATER DISTRICT, IN ACRE-FEET							
Parowan				4,180	6,580	6,750	7,650	7,140	7,380
Little Salt Lake				1,800	2,360	2,390	2,470	2,130	2,315
Summit				50	330	900	1,200	1,340	1,765
TOTAL				6,030	9,270	10,040	11,320	10,610	11,460
		NUMBER OF WELLS PUMPED FOR IRRIGATION							
Parowan				24	27	29	32	35	34
Little Salt Lake				5	8	8	9	9	9
Summit				1	4	6	7	8	7
TOTAL				30	39	43	48	52	50

Table 10. Measurements of water level and discharge of irrigation wells in Parowan Valley, 1953.

Coordinate number	Static measurements		Pumping measurements		
	Date	Depth to water[1] (feet)	Date	Depth to water[1] (feet)	Discharge (gpm)
(C-33-8)					
15ccd-1[2]	3/12	16.70			
	12/8	19.06			
21dcc-1[2]			6/28	87.0	1050
21ddd-1[3]			8/11		850
28cda-1[2]			6/27	85.0	1030
			9/3	79.6	880
31bcc-1			6/26	56.0	635
			8/7	54.6	680
			9/16	55.0	
31ccc-2			6/25	61.9	560
			9/16	64.9	545
(C-33-9)					
25cdd-4			6/26	39.8	215
			8/7	39.8	215
25dcc-3	12/7	7.34	6/26	49.5	445
			8/7	44.4	430
26cac-8			6/26		345
			8/7	32.6	340
32cdd-4			6/26	38.0	95
			8/11	40.3	95
			9/16	40.0	
32ddd-1			6/25		270
			8/6		250
33aad-1			6/25	49.5	395
			8/7	63.4	365
			9/16	59.0	380
33abd-1	12/8	1.68	6/25	60.2	350
			8/11	62.6	340
			9/16	62.0	
34aad-1			6/25	46.5	250
			8/7	48.1	235
34bad-1			8/7	75.3	360
34cbd-4			6/24	64.0	635
			8/11	86.0	935
			6/25		100
			8/7		105
34dbd-1			6/25		180
			8/7		180
			9/16	55.9	
34dbd-4			6/25		290
			8/7		280
34dcd-1			6/25	63.0	460
			8/6	64.7	485
			9/16	68.3	
34ddd-1			6/25	64.5	345
			8/11	64.6	340
			9/16	69.0	
35aad-4			6/26		410
			8/7		390
35acd-1			6/26	62.5	375
			8/7	67.5	330
35bac-1	12/8	8.82	6/26	52.3	280
			8/7	52.7	265
			9/16	49.0	
35bad-1			6/26		250
			8/7		220
35ddd-1			6/25	44.5	360
			8/7	44.8	345
			9/16	46.3	
36bbc-1	12/8	14.36	6/26	48.0	315
			8/11	49.0	300
			9/16	45.9	
36dcd-1	3/12	44.69	6/25	71.0	155
	12/8	51.77	8/7	73.5	120
			9/16	71.9	

Table 10 (cont.). Measurements of water level and discharge of irrigation wells in Parowan Valley, 1953.

Coordinate number	Static measurements Date	Static measurements Depth to water[1] (feet)	Pumping measurements Date	Pumping measurements Depth to water[1] (feet)	Discharge (gpm)
(C-34-8)					
6bdd-1	12/8	62.20	6/26	96.3	415
			8/7	94.6	415
(C-34-9)					
1aac			6/25	70.5	870
			8/7	77.5	815
3bcd-1			6/24	73.8	565
			8/6	75.4	480
			9/17	76.7	475
3cba-3			6/24	53.8	220
			8/11	54.1	220
			9/17	53.1	
3cdd-2			6/24	84.1	400
			8/6	84.5	370
			9/17	85.6	
5bda-1			8/11	59.3	590
			9/16	57.5	
5dad-1			6/24	66.0	520
			8/6	68.2	655
7ccc-1	3/12	7.82	6/24	76.5	815
	12/8	10.37	8/6	74.5	830
8dad-1			6/24		330
			8/11		275
			8/31		265
9aad-1			6/24		215
			8/4		215
9baa-4	12/8	11.61	6/24	51.0	435
			8/6	51.5	430
			9/17	54.0	
9bbd			6/24	70.2	310
			8/6	67.8	400
			9/17	66.4	
9bbd-1			6/24		190
			8/6		215
9bca-4			6/24		395
			8/6		405
9bcc-1			6/24		340
			8/6		350
9dbc-1	3/12	29.85	6/24	73.5	
	12/8	34.22	8/6	71.6	310
10bdd-1	3/12	57.92	6/24	78.6	165
	12/8	67.39	8/6	81.6	150
			9/17	79.6	
11bca-1	4/10	84.20	6/24	104.1	1280
	12/8	94.32	8/6	109.0	1200
16cdd-2	3/12	49.63	6/24	106.2	410
	12/8	59.09	8/6	105.0	330
			9/17	101.1	
13cca-1	12/8	43.04	6/23	62.3	485
			9/17	55.8	540
23add-1			6/23		390
			8/5		435
24aac-1	3/12	54.01	6/23		585
	12/8	56.72	8/5		555
24bbd-1			6/23	82.4	500
			8/5	82.3	465
			9/17	78.5	
24cab-1			6/24		460
24cbc-2	3/12	92.60	6/23	120.9	530
	12/8	95.17	8/5	119.5	560
24cbc-1			6/23		260
			8/5	110.5	275

[1] Below land surface.
[2] Powered by diesel engine.
[3] Powered by gas engine.
[4] Powered by propane engine.
All wells not otherwise indicated are powered by electric motors.

Table 11. Pumpage inventory, Parowan Valley, 1953.

Coordinate number	Application or claim	OWNER	Pumpage (ac. ft.)	Acres irrigated	Acre-feet / acres
(C-33-8)					
31bcc-1	A21305	Howard M. Adams	375	146	2.6
31ccc-2	A17398	Charles Barton	420	129	3.3
(C-33-9)					
25cdd-4		A. H. Orton	160	60	2.7
25dcc-3	C 7898	S. P. Pritchard	200	55	3.6
26cac-8	C 6759	W. M. Eyre	200	64	3.1
32cdd-4	C19512	Edgar Bensen	75	38	2.0
32ddd-1	C10620	C. L. Robinson	120	78	1.5
33aad-1	C 1233	John P. Bayles	175	91	1.9
33abd-1	C 1232	Arthur B. Evans	270	120	2.2
34aad-1	C 1227	Eugene Warren	170	78	2.2
34bad-1	C 3717	Dee Evans	75	38	2.0
34cdb-4	C 5694	Dee Robinson	405	150	2.7
34daa-3	C13495	Rulon Dalton	35	*a*155	1.3
34dbd-1	C 493	O. M. Lyman	130		
34dbd-4	A13395	O. M. Lyman	165	158	1.9
34dcd-1	C 6750	C. L. Robinson	325	155	2.1
34ddd-1	C13496	Rulon Dalton	160	*a*	
35aad-4	C16414	Harrell Dalton	235	56	4.2
35acd-1	C13810	W. Scott Day	280	132	2.2
35bac-1	C11216	Clark Orton	175	77	2.3
35bad-1	C 7848	Reid Orton	175	72	2.4
35ddd-1	C13812	W. Scott Day	200	180	1.1
36bbc-1	C 1264	Harrell Dalton	165	90	1.8
36dcd-1	C 494	H. L. Adams	75	225	
(C-34-8)					
6add-1	A22891	Jay S. Evans	145	69	2.1
(C-34-9)					
1aac		H. L. Adams	540	160	3.4
3bcd-1	C 920	S. A. Halterman	365		
3cba-3	C20834	S. A. Halterman	160	277	1.9
3cdd-2	C 1170	Clair Rowley	250	102	2.4
5bda-1	C 3716	H. E. Bayles	525	116	4.5
5dad-1	C 5089	J. C. Robinson	410	238	1.7
7ccc-1	A21797	P. H. Gurr	260	175	1.5
8dad-1	C 495	LeRoy Stubbs	235	117	2.0
9aad-1	C13987	L. D. S. Church	180	150	1.2
9baa-4	A 2297	Harley Dalton	325	120	2.7
9bbd-1		J. N. Evans	245		
9bbd-1	C 5786	J. N. Evans	155	140	2.9
9bca-4	C 4871	P. H. Gurr	255		
9bcc-1	C 4870	P. H. Gurr	175	160	2.7
9dbc-1	C 1224	F. F. A. Chapter	125	88	1.4
10bdd-1	C 8801	Clair Rowley	120	100	1.2
11bca-1	A22996	Claude Lister	245		
16cdd-2	A22566	Joseph Holyark	215	85	2.5
(C-34-10)					
13cca-1	C17658	Ray Lyman	225	80	2.8
23ada-1	A17047	Ray Lyman	250	*b*160	3.3
24aac-1	A16640	Lyle Farrow	320	65	4.9
24bbd-1	A22520	Ray Lyman	280	*b*	
24cab-1	A16803	Raymond Farrow	240	118	2.0
24cbc-2	A22575	John Farrow	300		
24cbc-1	A12241	John Farrow	150	118	3.8

a Water from 2 wells commingled to irrigate 155 acres.
b Water from 2 wells commingled to irrigate 160 acres.

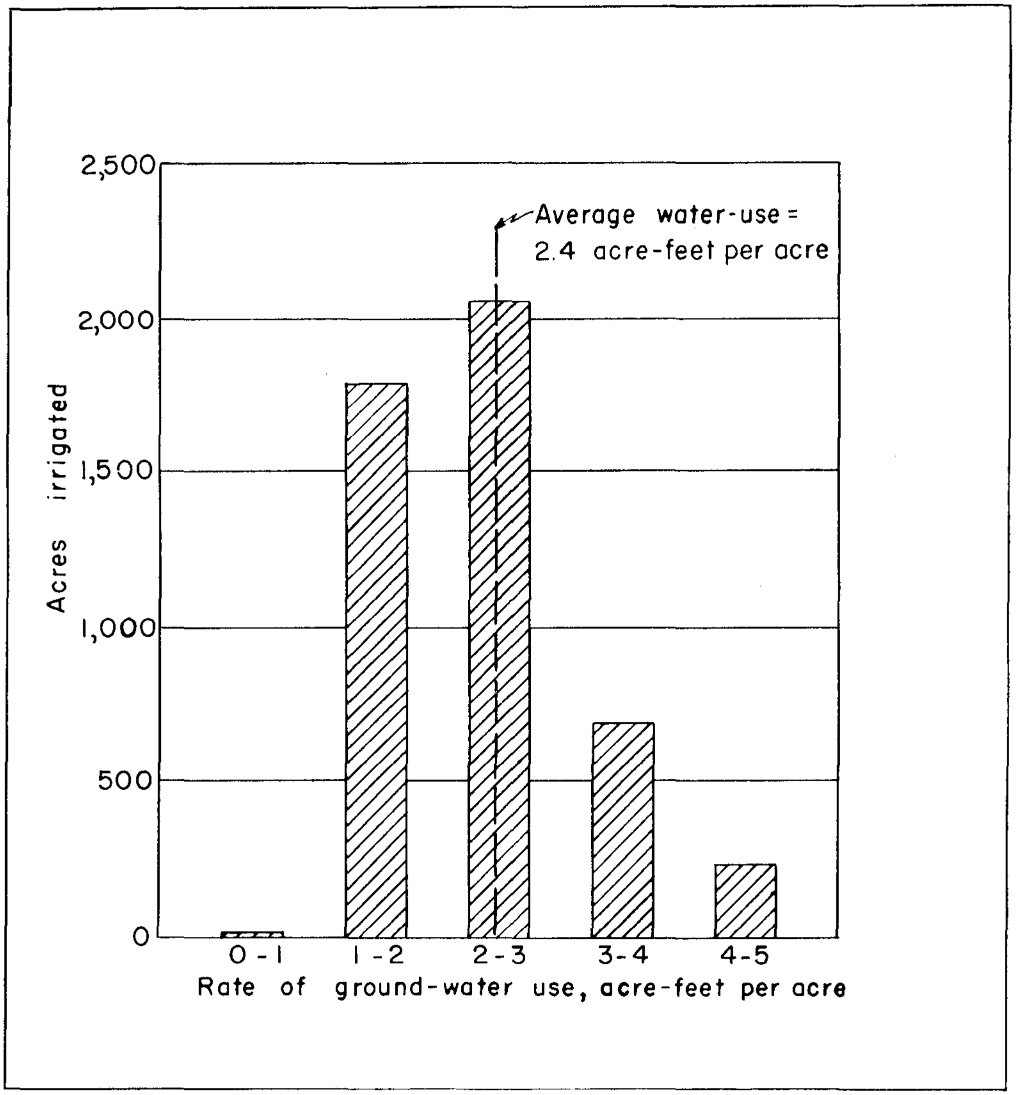


Figure 19. Distribution of pumpage in Parowan Valley in 1953, showing rate of ground-water use with respect to acres irrigated.

Discharge from Wells

Most of the wells in Parowan Valley flow at the land surface for a few weeks in the spring of each year. During the season of heavy pumping, however, drawdowns of 40 to 70 feet occur in most wells in the district. Many of the wells are equipped with electric pumping equipment. During the 1953 irrigation season a total of 11,460 acre-feet of water was pumped from 53 irrigation wells. In addition, 15 irrigation wells were known to be idle during the year, making a total of 68 units in the valley.

Table 9 lists the 54 irrigation wells from which significant quantities of ground water were pumped in the past 5 years. It shows for each well the compartive pumpage for the years 1940 and 1945-53. Notably, this table does not include 5 wells in the Buckhorn district (see fig. 18) and 4 wells in the Paragonah district. These wells are new installations and were not pumped for irrigation in 1953, except well (C-33-8)28cda-1 which was pumped sporadically at about 2¼ cfs., and for which no accurate measurements are available. This table also summarizes by districts the number of wells pumped for irrigation and the quantity of ground water pumped for each of the past 5 years.

As part of the 1953 ground-water inventory, periodic measurements of water level and pumping discharge were made of all irrigation wells in Parowan Valley. The data from this inventory are given in table 10. The information is summarized in table 11, which lists for each well the annual pumpage in acre-feet, acres irrigated, and the rate of ground-water use in acre-feet per acre. It is noted that water use in the valley ranged from 1.1 to 4.9 acre-feet per acre, with an average use of 2.4 acre-feet per acre. The pumpage-distribution diagram of figure 19 shows the rate of ground-water use in acre-feet per acre with respect to the number of acres irrigated. It also indicates that more than 80 percent of the total area in the valley used between 1 and 3 acre-feet of ground water per acre of cropland.

In the western part of the valley the water table at the beginning of each irrigation season is near the land surface, and subirrigation from the shallow water table supports much of the demand of the croplands. As the water table declines during the pumping season, however, surface irrigation is required. Thus, some land in the area gets by with one or two irrigations during the year, whereas farms on the higher lands require 5 to 8 waterings in a season. No attempt was made in this study to evaluate these variables.

Water-Level Trends

The hydrographs of 9 scattered observation wells, based on water-level measurements in March of each year, are shown in figure 17. In general, the same trend prevails in all wells; however, the magnitude of the fluctuations varies considerably. Wells in this valley fluctuate as much as 60 feet during a season, but in most instances return to about the same water level each year after pumping stops.

During the past 4 years, water levels in wells and seasonal precipitation have generally trended downward. This trend is apparent in the hydrographs of wells (C-33-9)34cbd-2 and (C-33-9)34dcd-1. These wells, although less than a quarter of a mile apart are separated by a fault, and their seasonal fluctuations are not alike. There is, however, a general downward trend of water levels in both wells. Water levels in wells (C-33-9)36dcd-1 and (C-34-9)10bdd-1 showed a net decline of 11 to 20 feet in the past 4 years, and are now at the lowest observed stage of record. Similarly, the water level in well (C-34-8)5bca-1 has declined about 6 feet, despite the fact that its level is 5 feet higher than the low point of 1937.

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STATE OF UTAH

JOSEPH M. TRACY, State Engineer

PUMPING COSTS IN SOUTHWESTERN UTAH

By W. B. NELSON
U. S. GEOLOGICAL SURVEY

Prepared in cooperation with the

GEOLOGICAL SURVEY
W. E. WRATHER, *Director*

UNITED STATES DEPARTMENT OF THE INTERIOR

1954

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By W. B. NELSON

INTRODUCTION

In computing the costs involved in pumping ground water for irrigation, two types of costs must be considered. The first is fixed costs which are only indirectly related to the actual quantities of water pumped and which include such items as initial purchase price of well, pump, motor, etc., interest on the investment, and depreciation. The second type of costs includes the actual operating costs of the pumping plant, including such items as outlays for fuel or electricity, maintenance and repairs, etc. These operating costs are more or less directly related to the quantity of water pumped and are affected by the overall plant efficiency, total pumping lift, cost of fuel or electricity, and care given the plant. Too frequently many of the hidden costs related to pumping a well are underestimated in determining the cost of water for irrigation.

An attempt is sometimes made to set definite limits to the pumping lifts which are economical under given conditions. This is difficult to do, because many factors enter into the consideration, and the actual cost of the water per acre-foot is only one of them. Thus, a well used to supply water for livestock may be operated profitably at a greater cost per acre-foot for water than an irrigation well used to water ordinary crops. The yield of and the price received from any crop will frequently be the limiting factors in determining economical pumping lifts.

Because of the complexity of the cost structure related to pumping a well, no attempt is made in this report to evaluate all the cost factors that must be considered by a well owner. For a thorough discussion of these aspects the reader is referred to publications of the United States Department of Agriculture, bulletins of the Utah State Agricultural College, and handbooks put out by the various pump manufacturers. In this study, only the costs that are charged by local power companies for electrical energy consumed are considered. The study is limited also to two typical pumping districts in southwestern Utah, identified as district A and district B, and to the electric power supplied by two companies, one in each district. As most of the water in these districts is pumped with electrical energy supplied by these two companies, the purposes of this study will be met even though the scope of the report is thus limited.

OVERALL PUMPING EFFICIENCY

Because of its close relation to the cost of operating pumps, the overall efficiency of a pump installation is important. The perfect plant would have a 100-percent overall efficiency, but such an efficiency has never been achieved. In actual practice, the plant efficiencies will range from 30 to 70 percent, depending on the size, design, state of repair, and operating speed of the equipment. The difference between the actual and the theoretical performance is represented by plant losses, such as mechanical friction of the moving parts of the motor and pump, hydraulic friction of the water in the pump column, transformer losses, etc. By careful design and proper maintenance, these losses can be cut to a minimum.

In general, the overall efficiency of a pumping unit is a ratio of power input to water output, usually expressed as a percentage. This is sometimes referred to as the "wire-to-water" efficiency, and it refers to the percentage of the power consumed, in foot pounds of energy, that is effective in lifting water from the well, also in terms of foot pounds of energy. Thus, it is determined that an electric-pump installation having an overall efficiency of 100 percent would consume 1.024 kilowatt-hours of power to pump 1 acre-foot of water through a vertical lift of 1 foot. On this same basis, it would take 10.24 kilowatt-hours of power to pump 10 acre-feet of water 1 foot, or 1 acre-foot of water a vertical distance of 10 feet. A pumping unit having an overall efficiency of only 50 percent would consume twice as much electric power to accomplish the same water output.

The overall efficiency of a pump installation is materially affected by (1) the pumping lift in the well, (2) the quantity of water pumped, and (3) the mechanical condition of the motor and pump installation; and it may change significantly from one season of the year to the next. Thus, as the water levels in the well decline as pumping continues, and as the mechanical parts of the equipment become worn and out of repair, the "wire-to-water" efficiencies may fluctuate through a wide range. This is especially true of the old centrifugal-pump installations that at one time predominated in the pumping districts of southwestern Utah, and of any installations that are operated in a range of extreme underload or overload.

COST OF PUMPING WATER IN DISTRICT A

In 1954, 136 wells were pumped for irrigation in district A. Of this total, 125 wells were powered with electricity and 11 wells were powered with diesel or gas engines. The wells powered with electricity had electric motors ranging from 5 to 75 horsepower. The discharge of the wells ranged from 0.5 cfs (cubic feed per second) to 4.5 cfs. Pumping lifts ranged from 25 feet to 110 feet.

The local power company has set up electrical power rates which apply to irrigation wells between April 1 and September 30 of each year. These rates are based on (1) kilowatt-hours used, and (2) horsepower demand. A power-company representative visits each well monthly and at that time records the number of kilowatt-hours consumed during the month and recomputes the horsepower demand. The horsepower demand is the actual horsepower the electric motor is using. It may be above or below the rated horsepower of the motor.

The monthly billing for power used by each well is based on a charge of $2.50 per horsepower demand plus $0.01 per kilowatt-hour for the first 275 kilowatt-hours per horsepower demand plus $0.005 per kilowatt-hour for all remaining power consumed. The longer a well is pumped, the cheaper the daily rate becomes. Figure 1 (a) shows the monthly billing rate per horsepower demand for irrigation wells in district A using local power rates. For each horsepower of demand, curve (a) starts with an initial cost of $2.50, continues at the rate of $0.01 per kilowatt-hour for 15.4 days (a demand of 1 hp equals 17.9 kwh in 1 day or 275 kwh in 15.4 days), then changes to a rate of $0.005 per kilowatt-hour for the remaining days of the month. Curve (b) shown in figure 1 indicates the average cost per day for each horsepower of demand. For example, a well installation having a 10-horsepower demand and operating 24 hours per day for 10 days would have an average power cost of $4.30 per day. This same installation if operated at this same horsepower demand for a period of 25 days would have an average power cost of $2.46 per day, or an average cost of slightly more than half the cost for the 10-day period. The average daily cost for any particular pumping plant can

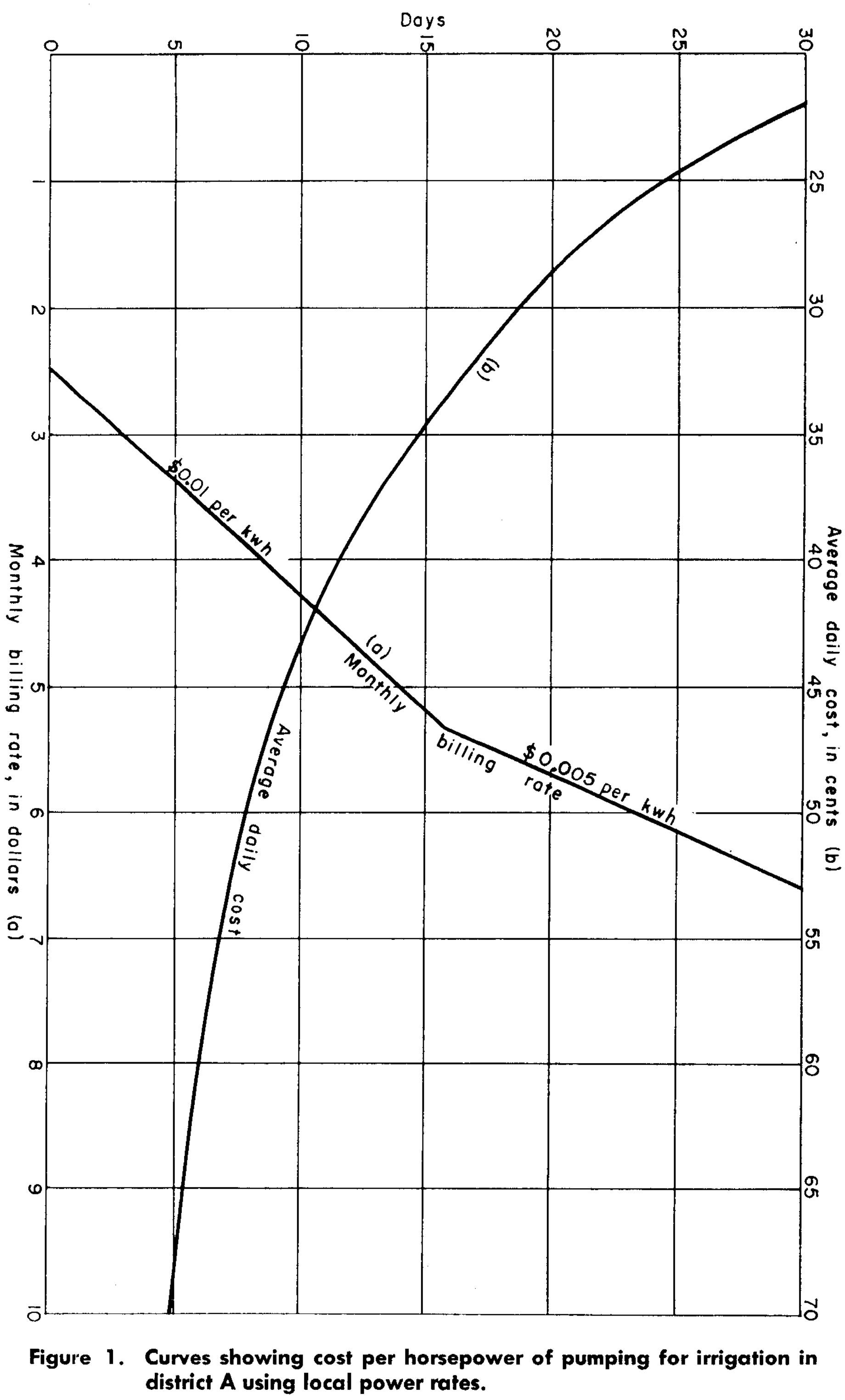

Figure 1. Curves showing cost per horsepower of pumping for irrigation in district A using local power rates.

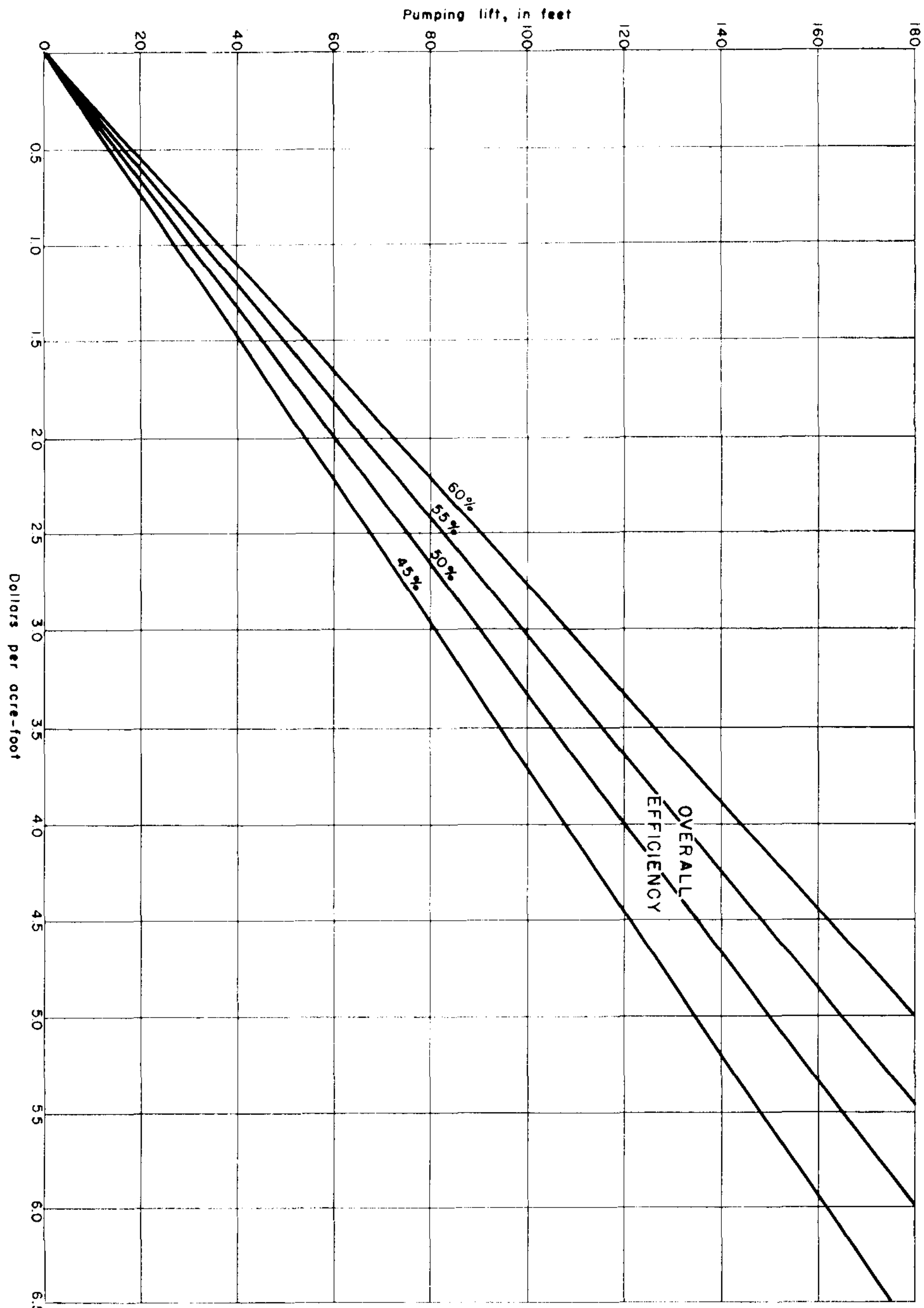

Figure 2. Curves showing cost per acre-foot of pumping water for irrigation in district A for different pumping lifts and four different efficiencies. (Based on rates of local power company and on an assumed 25 days of operation per month.)

be obtained by multiplying the value taken from curve (b), shown in figure 1, by the number of horsepower consumed by the motor. Figure 2 was constructed on the basis of this rate of power use and 25 days per month of pumping. The cost per acre-foot of water pumped was determined for pumping lifts ranging from 0 to 180 feet and for overall efficiencies of 45, 50, 55, and 60 percent, respectively. No allowances were made for discounts of any kind.

The curves in figure 2 show that the overall efficiency of a pumping installation is closely related to the cost of pumping water. The cost per acre-foot of water gets progressively greater as pumping lifts increase and as overall efficiencies decrease. For example, at a pumping lift of 40 feet the cost per acre-foot is $0.93 at 60-percent overall efficiency, whereas at 45-percent overall efficiency the cost per acre-foot is $1.23, an increase in cost of $0.30 per acre-foot. At a pumping lift of 100 feet the cost per acre-foot is $2.34 at 60-percent overall efficiency, and at 45-percent overall efficiency the cost per acre-foot is $3.10, an increase of $0.75 per acre-foot. Also, the cost per acre-foot would be the same for two wells, one operating at 45-percent overall efficiency and with a pumping lift of 64.5 feet and the other one operating at 60-percent overall efficiency and with a pumping lift of 85.5 feet.

The cost of pumping water for periods other than 25 days can be determined from figure 1(b). For example, if a 10-horsepower motor with an actual 11.0 horsepower demand ran for only 20 days, the cost would be computed as follows: 11 X ($0.285—$0.246) = 11.0 X $0.039 = $0.43. Thus, it would cost $0.43 a day more to operate for 20 days than it would to run for 25 days. If it were pumping 675 gpm, which is 1.5 cfs or 3 acre-feet per day, the cost per acre-foot would increase by $0.43/3 = $0.14. If the pump ran the full month (30 days) instead of 25 days, the decrease in cost per day would be 11.0 X (0.246—$0.220) = 11.0 X $0.026 or $0.29 per day. If 3 acre-feet of water a day were pumped, the saving per acre-foot would be $0.29/3 = $0.097 per acre-foot.

COST OF PUMPING WATER IN DISTRICT B

In district B the local power rates are based on monthly use, and no demand charge is assessed. For the first 120 kilowatt-hours per horsepower of demand the cost is $0.02 per kilowatt-hour and the cost for the remainder of the month is $0.015 per kilowatt-hour. Figure 3(a) is a curve showing the monthly billing rate for pumping for irrigation in district B, based on local power rates. For each horsepower of demand, 17.9 kwh is consumed in a 24-hour day, thus it takes 6.7 days of pumping before the rate per horsepower changes from $0.02 to $0.015 per kilowatt-hour. Figure 3(b) shows the average cost per horsepower per day of pumping for irrigation in district B, based on local power rates. The average cost per day changes very little beyond 25 days. Between 20 and 25 days the average cost per day changes from $0.298 to $0.292 per horsepower.

Most of the pumps serviced by the local power company in district B are run almost continuously during June, July, and August and intermittently during April, May, and September. A period of 25 pumping days a month was used in calculating the cost of pumping. Figure 4 includes 4 curves showing cost per acre-foot of pumping water for irrigation in district B, based on local power rates. The curves show cost for pumping lifts of 0 to 180 feet and for four different overall efficiencies, namely, 45, 50, 55, and 60 percent. No allowances were made for discounts. The curves emphasize that overall efficiencies play a large part in the cost of pumping water. For example, at a pumping lift of 40 feet,

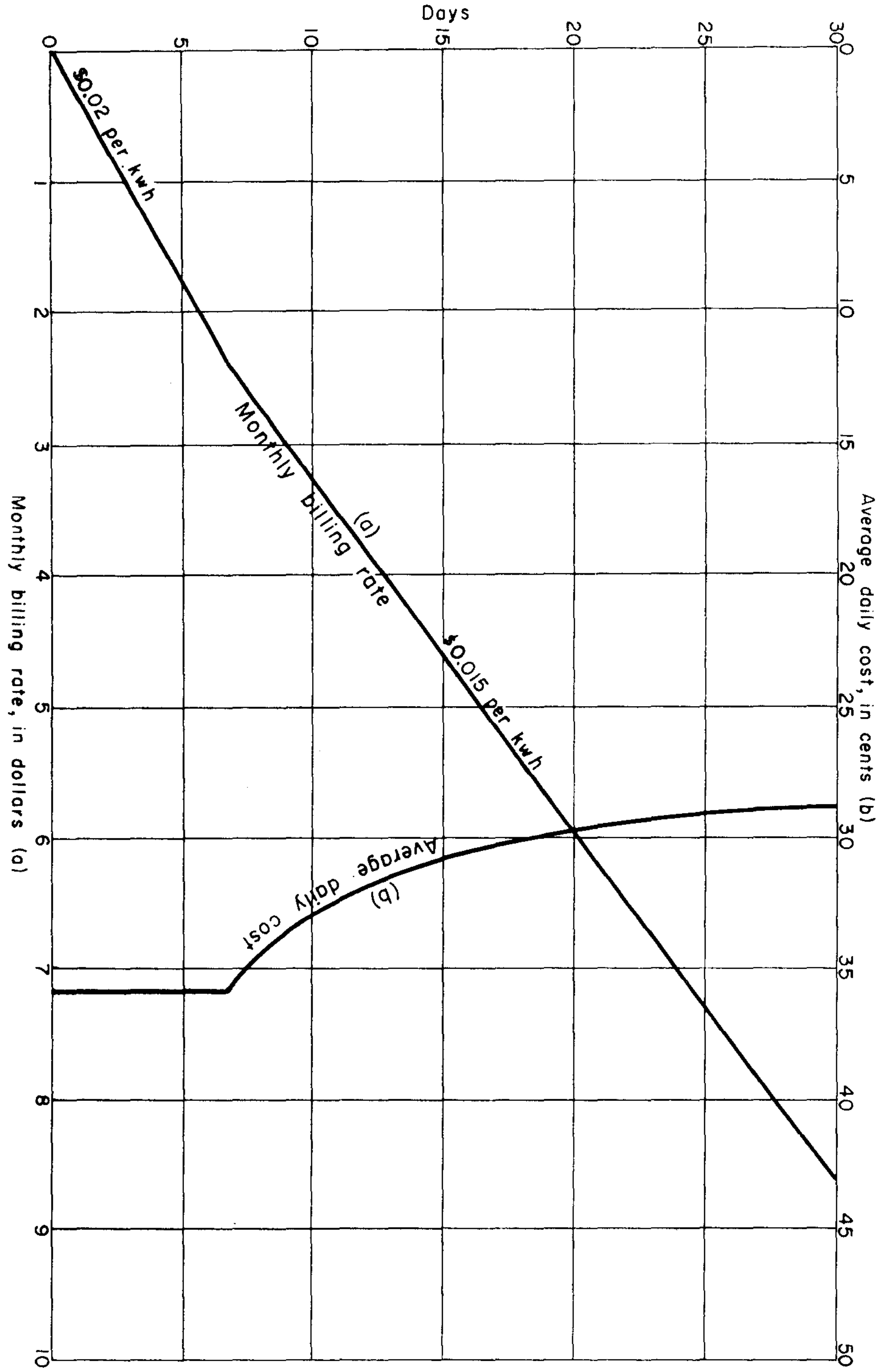

Figure 3. Curves showing cost per horsepower of pumping for irrigation in district B using local power rates.

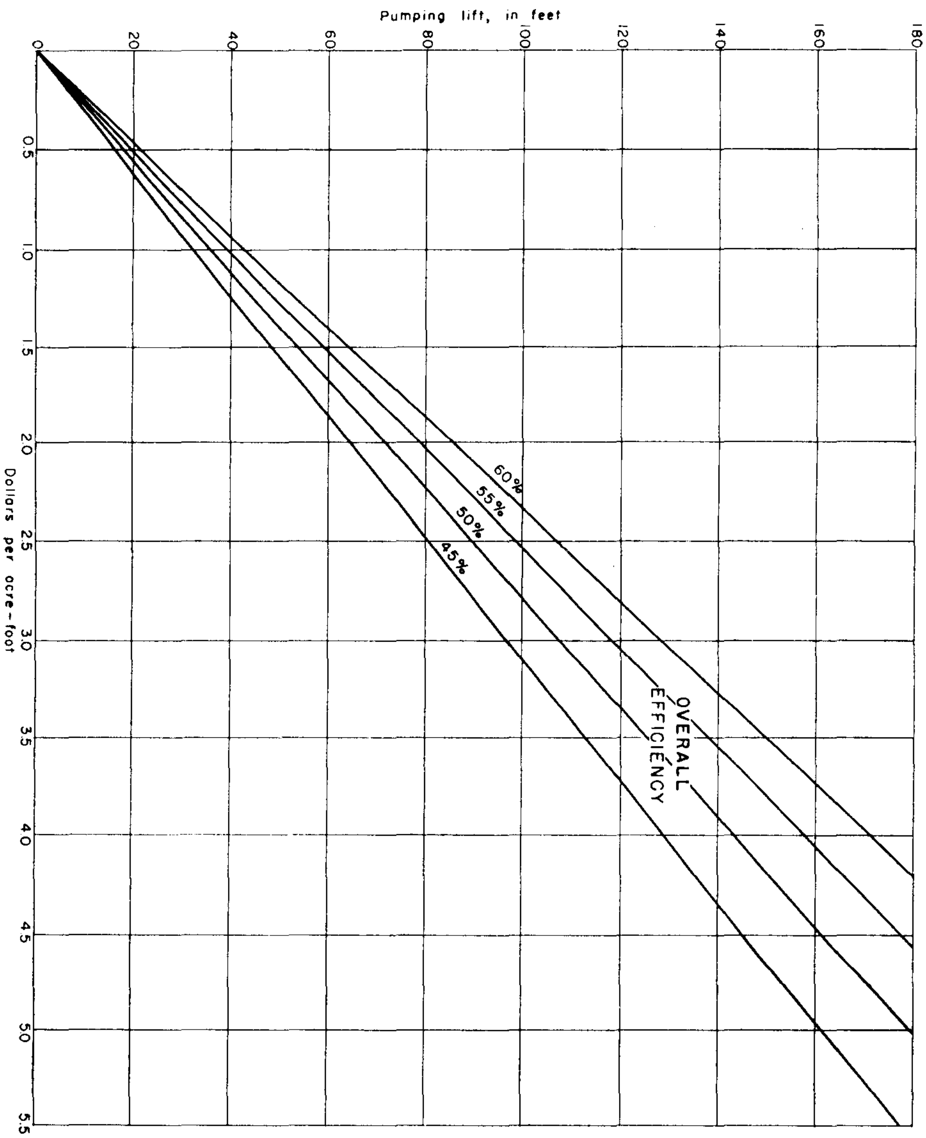

Figure 4. Curves showing cost per acre-foot of pumping water for irrigation in district B for different pumping lifts and four different efficiencies. (Based on rates of local power company and on an assumed 25 days of operation per month.)

the cost per acre-foot at 60-percent overall efficiency is \$1.10, whereas at 45-percent overall efficiency the cost per acre-foot is \$1.48. At a pumping lift of 100 feet, the cost per acre-foot at 60-percent overall efficiency is \$2.78, whereas at 45-percent overall efficiency the cost per acre-foot is \$3.70. The cost of pumping of water is the same for two pumping units, one pumping from 67.5 feet at 45-percent overall efficiency and the other pumping from 90 feet at 60-percent overall efficiency.

CONCLUSIONS

In district A, the cost per horsepower of pumping for irrigation is about \$5.20 for the first 15 days and about \$1.40 additional for the last 15 days of the month. In district B the cost per horsepower of pumping for irrigation is about \$4.60 for the first 15 days and about \$4.00 additional for the last 15 days of the month. This comparison shows that in the case of a well operating in district A there is little incentive for turning off the pump during the last half of the month even though the irrigation requirement may have been satisfied or nearly satisfied during the first half. Because the initial demand charge represents at least 38 percent of the monthly power bill, the water pumped during the last 15 days costs less than one-third as much as water pumped during the first 15 days of the month. On the other hand, in district B the cost of power for pumping is more uniform throughout the month. Although the operating cost for the first 15 days of a well in district B is somewhat less (\$4.60) than for a similar well in district A (\$5.20), the uniformity of the monthly rate makes water during the last half of the month cost nearly as much as during the first half of the month. This, of course, would tend to discourage unnecessary pumping.

In analyzing the field data and power costs of wells operating in two pumping districts of southwestern Utah, it was noted that overall pumping efficiencies range from as low as 35 to nearly 70 percent. Although many farmers are conscious of increased costs resulting from increased pumping lifts, relatively few fully appreciate the relation of inefficient pump installations to increased pumping costs. This relationship is clearly indicated in figures 2 and 4.

STATE OF UTAH

JOSEPH M. TRACY, State Engineer

GROUND-WATER POSSIBILITIES OF BEDROCK AQUIFIERS IN SOUTHEASTERN UTAH

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By B. E. LOFGREN

INTRODUCTION

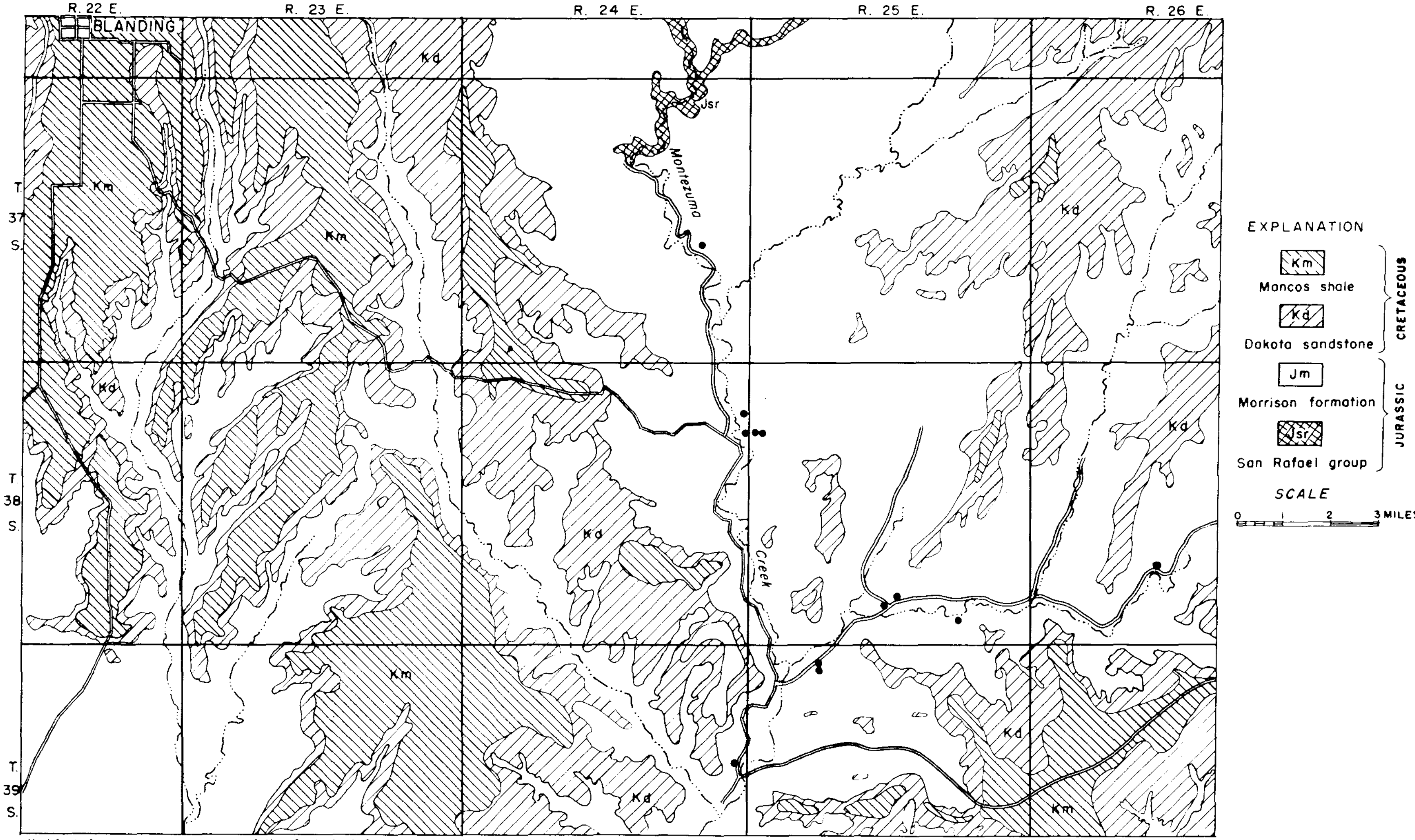
Throughout the vast region of southeastern Utah the scant desert vegetation and the network of rugged dry washes attest the scarcity of rainfall and the deficiency of natural stream runoff. This deficiency of water is the dominating factor in the restricted development of the region, and the never-ending quest for more water has prompted exploration of the water-bearing bedrock formations as a possible source of future supply. The area is characterized by flat-lying sedimentary rocks, which are only partially covered by a thin veneer of alluvium. The monotonous flatness of the region is interrupted only locally by the igneous mountain masses which project above the skyline, and by the complex network of steep-walled canyons which make traveling through the area sometimes difficult.

Numerous wells have been drilled in the region to supplement the limited surface supply. These, however, have been largely restricted to the sandy alluvium overlying the shallow bedrock. Especially in areas near Moab, LaSal, Monticello, and Blanding have these "alluvial" wells been in use for many years. For the most part, however, these wells have furnished only small quantities of water of relatively poor quality.

Although the availability of good-quality ground water from buried bedrock aquifers has been recognized since 1908, when scattered oil-test wells throughout the area yielded artesian flows from deep sources, it was not until the summer of 1951 that the success of two flowing wells in the Montezuma Creek valley demonstrated the economic feasibility of "bedrock" water as a source of irrigation supply. Several deep wells drilled a number of years ago in the Bluff area have flowed for many years and have been used for domestic and garden supplies. The success of the two wells in the Montezuma Creek valley, however, and of several others drilled subsequently in the immediate vicinity, has so stimulated the interest for further drilling that there is now some concern as to the possible overdevelopment of the area. The locations of several wells in the Montezuma Creek valley are shown in figure 1.

PURPOSE AND SCOPE

As part of the Statewide ground-water investigation being made by the United States Geological Survey, in cooperation with the State Engineer of Utah, a program of water-level measurements in selected observation wells in southeastern Utah has been in progress since 1935. Records of water levels and artesian pressures in these scattered wells are available in the open file in the Salt Lake City office of the Ground Water Branch of the Geological Survey. This report is an attempt to summarize the general occurrence of ground water in the broad area extending from Moab on the north to the Arizona State line and from the Colorado border westward to the Comb Ridge monocline. The geology and the general features of the area have been discussed in several published reports of the U. S. Geological Survey (Baker, 1933; Dane, 1935; and Gregory, 1938). An unpublished report by G. A. Waring entitled "Ground-water in part of southeastern Utah and southwestern Colorado" covered much of the area considered in this report and served as a helpful reference.



Modified from photogeologic maps of the Geological Survey prepared in cooperation with the Atomic Energy Commission.

Figure 1. Geologic map of the Blanding-Montezuma Valley area, Utah, showing the location of water wells drilled.

Table 1. Average monthly and annual precipitation at 6 stations in southeastern Utah during their respective periods of record. From records of the U. S. Weather Bureau.

	Years of record	Elevation (feet)	January	February	March	April	May	June	July	August	September	October	November	December	Annual	Average summer precipitation (May thru Sept.)
Blanding	45	6,035	1.05	1.20	1.08	0.94	0.76	0.58	0.99	1.24	1.47	1.29	0.82	1.35	12.77	5.04
Bluff	29	4,320	0.60	0.73	0.70	0.53	0.41	0.32	0.67	0.74	0.87	0.80	0.41	0.71	7.49	3.01
Moab	61	4,000	0.73	0.69	0.88	0.73	0.72	0.43	0.81	0.79	0.98	0.99	0.65	0.86	9.26	3.73
Monticello	31	7,060	1.25	1.44	1.57	1.09	0.87	0.72	1.51	1.88	1.62	1.86	1.09	1.36	16.25	6.60
Montezuma Creek	7	6,780	1.73	1.12	1.06	1.03	0.88	0.88	1.08	1.30	1.02	1.09	0.53	1.40	13.13	5.16
Thompson	29	5,150	0.59	0.56	0.73	0.67	0.51	0.51	0.85	0.91	0.97	1.10	0.49	0.72	8.60	3.75

PRECIPITATION

Precipitation in southeastern Utah is characterized by wide variations in seasonal and annual rainfall, and by long periods of deficient rainfall. Summer storms are infrequent and short. Scattered showers lasting for an hour or less and furnishing rain to only a few square miles frequently contribute the entire precipitation for a month at a given station. Few days in each year have precipitation. As noted in table 1, the average annual precipitation ranges from less than 8 inches at Bluff to more than 16 inches on the eastern flank of the Abajo Mountains as recorded at Monticello. Figure 2 shows the monthly precipitation at Monticello and Blanding.

The influence of altitude on precipitation is shown in figure 3 by two curves which are based on a correlation of the data from the 6 precipitation stations in the area. The relationship that exists between the average precipitation as measured at the 6 stations and the respective station elevations approximates a straight line. In general, in an average year, an increase of 1 inch of rainfall occurs with each 440 feet of rise in elevation throughout the area. It is also noted (fig. 3) that a proportionately larger percentage of the summer precipitation occurs at the lower elevations, the summer storms contributing about the same pattern of rainfall at all elevations.

As rainfall throughout most of the area is inadequate for the growth of crops, irrigation is necessary in all localities except in a small area east and southeast of Monticello. An important use of ground water in this area is for a supplemental water supply to meet the requirements of the farm crops.

GROUND-WATER DEVELOPMENT

As early as 1908, during the "oil boom" of southeastern Utah, scattered oil-test wells in several areas reportedly encountered artesian flows of ground water. Several of these wells are known to be still flowing; however, little reliable information regarding the drilling of these wells is now available. Artesian wells at Buff, drilled as early as 1909, obtain water from depths ranging from 800 to more than 1,100 feet; tap water in the Wingate, Navajo, and probably Shinarump formations; and supply most of the domestic and irrigation needs of the residents of the area. Water from shallow wells, drilled principally into the unconsolidated alluvium overlying the bedrock in many areas, has been used from the earliest days of settlement to the present. Water from this source, however, has been limited to the relatively small demands of domestic and stock water supplies. Some of these shallow wells have been drilled into the saturated upper strata of the Dakota sandstone, which underlies much of the area, and have thus derived a modest supply of domestic water.

In September 1951, two wells, (D-39-25)5aca-1 and (D-39-25)5aca-2, were drilled in the Montezuma Creek valley south and east of Blanding. The success of these wells not only demonstrated the economic feasibility of developing irrigation water from bedrock aquifers in the area, but also started a clamor for additional irrigation wells throughout the region. Although originally drilled as oil tests, these wells encountered good-quality ground water, under high artesian heads, in three deep bedrock aquifers. Since the original discovery, 6 water wells have been drilled in the Montezuma Creek area, and more than 20 applications to drill large-yield wells have been filed with the State Engineer's office. The existing wells range in depth from 400 to 600 feet and derive their water

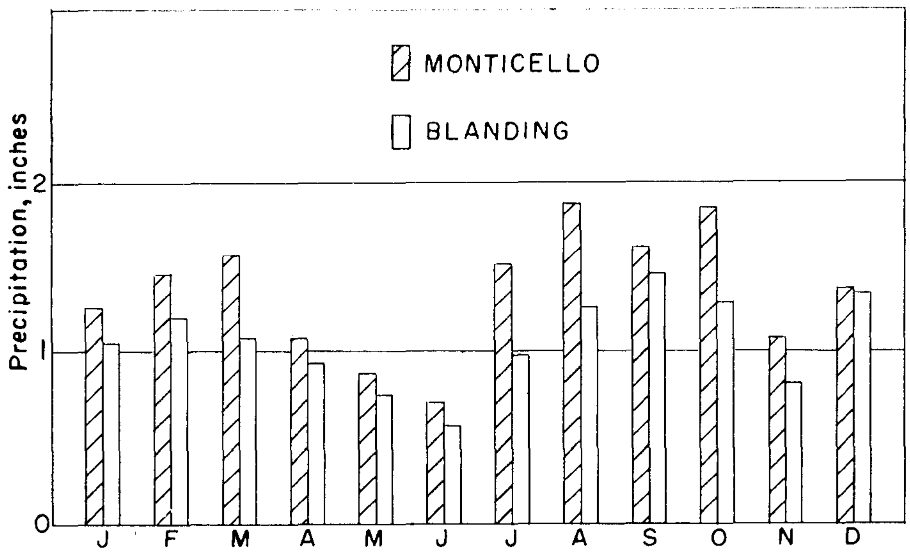


Figure 2. Average monthly precipitation at Monticello and Blanding, Utah.

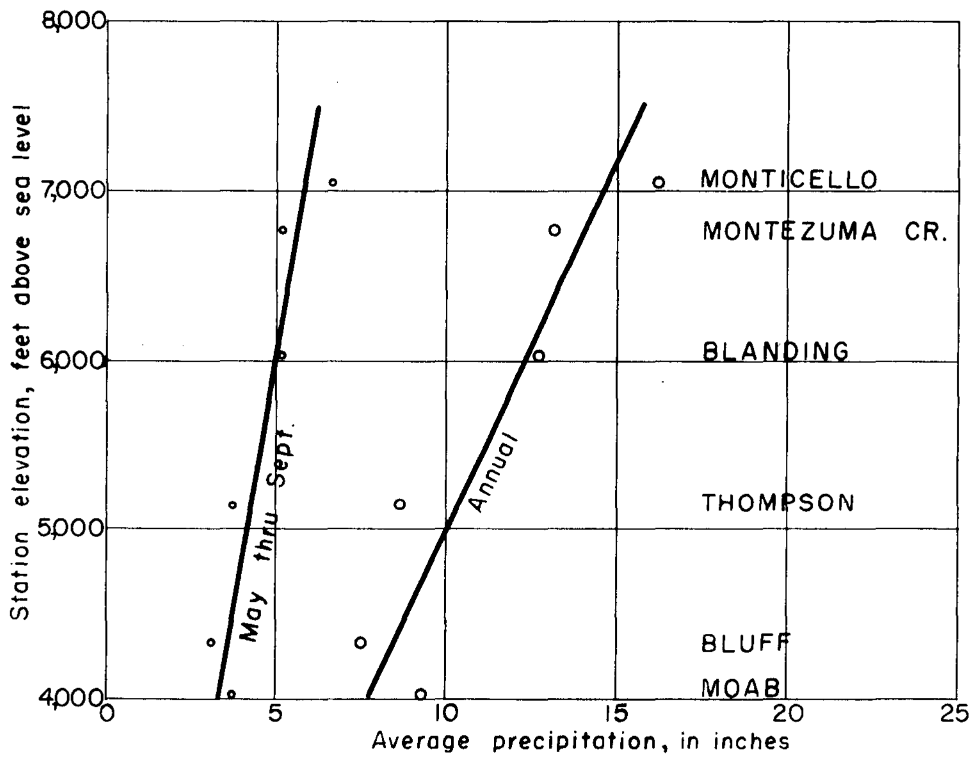


Figure 3. Relation of precipitation in southeastern Utah to station elevation.

principally from the Entrada and Navajo sandstones. Although some wells in this area are separated by as much as 10 miles, they are producing water of similar chemical quality under about the same type of geologic conditions. A number of recent oil-test wells drilled in the region have encountered artesian ground water in several of the still deeper formations, suggesting a possible source of ground-water supply in extensive areas of southeastern Utah where water from other sources is limited. The success of "bedrock" wells, especially in the Montezuma Creek area, has stimulated the interest for continued drilling throughout the region, and it is contemplated that several prospect wells will be drilled in the near future in areas as yet untested.

OCCURRENCE OF GROUND WATER

Southeastern Utah is characterized by horizontally bedded sedimentary rocks ranging in age from Carboniferous to Late Cretaceous. The surface and near-surface rock formations include sandstone, mudstone, claystone, and limestone, the sandstones representing less than 30 percent of the total thickness. Most of the sandstone formations are capable of transmitting and storing water and are potential sources of ground water; some of them, however, are not water bearing. The mudstones, claystones, and limestones are relatively impermeable and are the confining formations which hydraulically separate the bedrock aquifers one from the other.

The generalized geologic section of southeastern Utah (fig. 4) shows the principal formations that are the source of ground water in the several producing areas. No attempt is made to report on the natural seeps and springs that occur.

SHALLOW WELLS EAST OF MONTICELLO

Ground water in the broad, flat Sage Plain areas east of Monticello is derived principally from the thin veneer of surface alluvium that overlies the Dakota sandstone, and from the upper few feet of this rather permeable sandstone. Practically all wells in this area are shallow, and, for the most part, water-supply requirements are relatively small. The logs of the following wells give an idea of the character and thickness of the water-bearing material in this area:

1. Well (D-33-25) 26bdc-1, State Claim No. C-8236, 150 feet deep, drilled in 1934.

Driller's log	Thickness (ft)	Depth (ft)	Formation
Dirt	10	10	Alluvium
Clay	8	18	
Clay, sandy	15	33	
Sandstone, white	21	54	Dakota sandstone
Conglomerate	13	67	
Sandstone, quartz (some water)	35	102	
Sandstone, coarse (water)	20	122	
Gypsum	28	150	Morrison formation

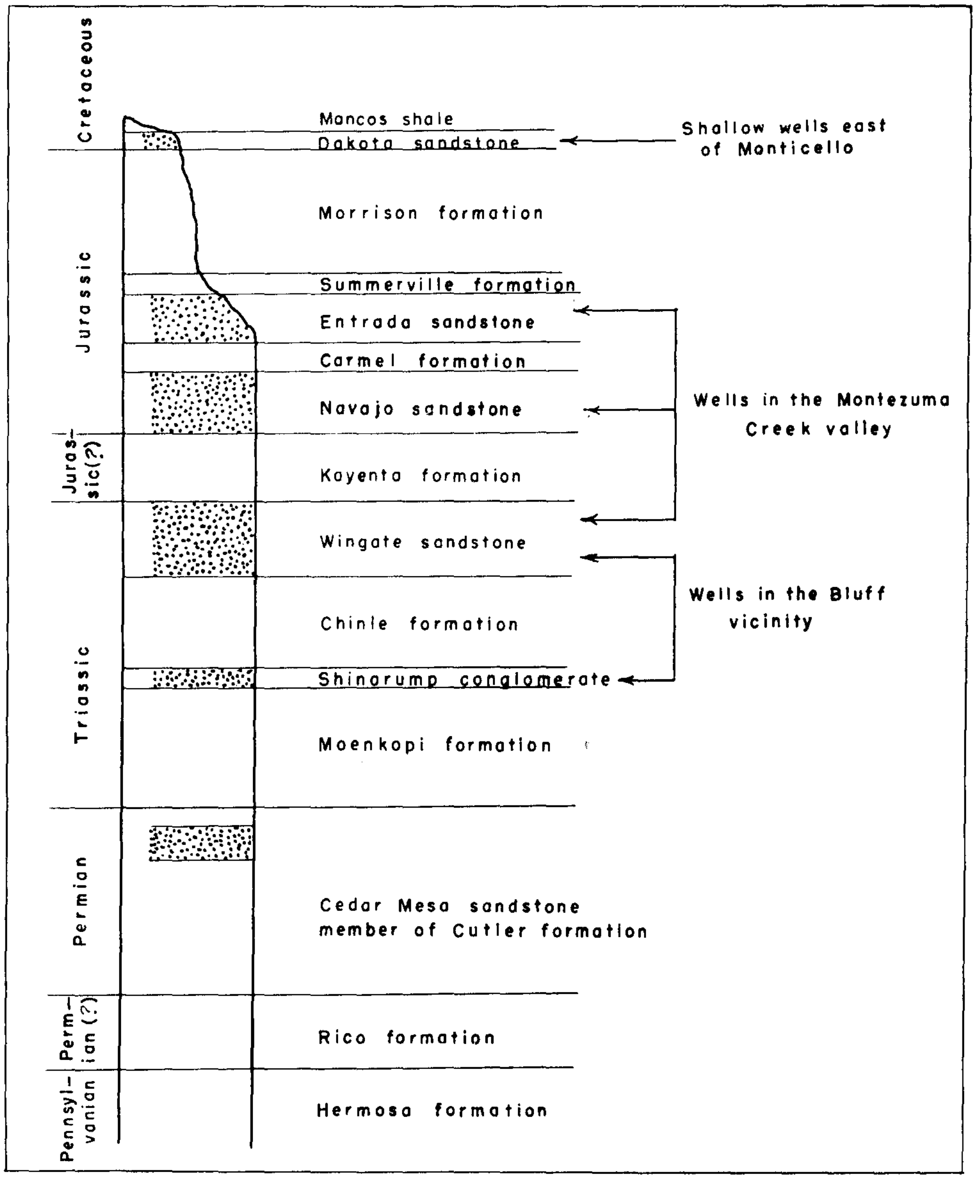


Figure 4. Generalized geologic section of southeastern Utah, showing the formations having favorable ground-water possibilities.

A deep oil-test well about 13 miles east of Monticello is reported to have encountered ground water under artesian conditions at several different depths, suggesting that additional quantities of water might be developed by deeper drilling in this area.

2. Well (D-33-24)4ca-1, 176 feet deep, drilled in 1934.

Driller's log	Thickness (ft)	Depth (ft)	Formation
Clay, sandy	30	30	Mancos shale
Shale, gray	55	85	Mancos shale
Sandstone, white	13	98	Dakota sandstone
Conglomerate	14	112	Dakota sandstone
Conglomerate, soft	6	118	Dakota sandstone
Shale, blue	4	122	Dakota sandstone
Sandstone, hard, white	11	133	Dakota sandstone
Sandstone, soft, white (water)	43	176	Dakota sandstone

3. Well (D-34-24)25aad-1, State Application No. A-16754, 225 feet deep, drilled in 1945.

Driller's log	Thickness (ft)	Depth (ft)	Formation
Soil and clay, brown	20	20	Mancos shale
Shale, dark gray	15	35	Mancos shale
Shale, some gravel	5	40	Mancos shale
Sandstone, limy	3	43	Mancos shale
Sandstone, muddy, hard	7	50	Mancos shale
Sandstone, brown	14	64	Mancos shale
Shale, gray	2	66	Mancos shale
Sandstone, brown	59	115	Dakota sandstone
Sandstone, light gray	15	130	Dakota sandstone
Sandstone, white (water)	66	196	Dakota sandstone
Shale, brown	6	202	Morrison formation
Shale, calcium, blue-gray	23	225	Morrison formation

WELLS IN THE MONTEZUMA CREEK AREA

The first real interest in developing ground water from bedrock sources in the Montezuma Creek valley was created when the Hathaway Drilling Co. encountered large flows of good-quality water in two oil-test wells drilled in sec. 5, T. 39 S., R. 25 E., in the fall of 1951. The locations of these wells are shown in figure 1. The deeper of these two wells began at the base of the Morrison formation and reportedly yielded flows of good-quality water from the Entrada, Navajo, and Wingate sandstones. The shut-in pressure of this well, as measured by the Geological Survey in January 1954, was 145 psi (335 feet of water head), and the temperature of the water was 63° F. The shut-in pressure of the shallower well, with a reported depth of 600 feet, was 53 psi (122 feet of water head), and the temperature of the water was 62° F. Although no sustained flow tests of these wells have been made, each well is reported to yield a relatively large volume of good-quality water when opened fully. The following modified driller's log of the deep oil test shows the formations that were penetrated:

Oil-test well (D-39-25)5aca-1, State Application No. A-23436, reported 7,621 feet deep, drilled in 1951.

Formation	Thickness (ft)	Depth (ft)
Morrison fm.	252	252
Entrada ss. (water)	278	530
Carmel fm.	25	555
Navajo ss. (water)	135	690
Kayenta fm.	50	740
Wingate ss. (water)	380	1,120
Chinle fm.	1,250	2,370
Shinarump cgl.	117	2,487
Moenkopi fm. / Cutler fm.	2,051	4,538
Rico fm.	72	4,610
Hermosa fm.	730	5,340
Paradox member of Hermosa fm.	2,014	7,354
Leadville ls.	101	No bottom

The yields of wells in this area range from about 400 to 500 gpm when first opened, but after a month of continuous flow the yields drop to about 80 gpm, and pressure heads drop concurrently. Thus, well (D-38-25)7cba-1 when first drilled to a depth of 520 feet in 1953 reportedly flowed at the rate of 470 gpm with a closed-in pressure of 105 psi (242 feet of water). It was noted that the yield of this well declined rapidly to 240 gpm, dropped to 210 gpm after 3 days of continuous discharge, and after 30 days flowed at an estimated rate of 145 gpm. This suggests that the Entrada and Navajo sandstones which yield water to this well are of relatively low permeability.

A number of deep oil-test wells drilled in outlaying areas near to the Montezuma Creek valley have yielded significant flows of artesian water in several of the deep bedrock aquifers, suggesting a possible source of irrigation water throughout much of this area. The success of wells has greatly stimulated the interest in further drilling, and prospect wells in areas heretofore untested are contemplated. It should be kept in mind, however, that as yet no large quantities of water have been drawn from these bedrock aquifers, and practically nothing is known concerning the effects of continued withdrawals on the perennial yields of the aquifers.

Although the sandstone aquifers that are producing significant quantities of ground water in these areas are extensive and the quantities of ground water stored in these formations are large, the permeabilities are relatively low. Rapidly declining artesian pressures have been experienced throughout the area during periods of sustained flow, and problems of mutual interference between nearby producing wells and of small yield per foot of drawdown are to be expected.

Figure 1 is a geologic map of the Blanding-Montezuma Creek area and shows also the location of wells drilled in the area. Table 2 lists 12 wells shown on figure 1 and gives the geologic formation from which each derives its water supply. The geologic map (fig. 1) shows that rocks ranging from the Entrada sandstone up through the Mancos shale are exposed in this area. In general, these strata are relatively flat lying, with a regional dip of from 1 to 3 degrees to the south. As indicated in table 2 and in figure 4, the Entrada, Navajo, and Wingate sandstones are the important producing aquifers in the area of this report, with some water being derived from the deep Shinarump conglomerate. These formations appear to be continuous from the high outcrop areas to the

Table 2. Records of 12 wells drilled in the Montezuma Creek area.

	Well coordinate number	State application number	Owner	Depth (feet)	Water source	Static pressure (feet in water)	Remarks
1.	(D-37-24) 24cbb-1	A-24609	Max Dalton	....	Entrada sandstone	+3 ft. reported	Flowing well farthest north
2.	(D-38-24) 12aaa-1	A-23461	Lois K. Tatro	920	Entrada and Navajo sandstone	+240 ft. reported	....
3.	(D-38-24) 12add-1	A-24863	H. C. Perkins #1	....	Entrada and Navajo sandstone	....	....
4.	(D-38-25) 7bcd-1	A-24608	H. C. Perkins #2	520	Entrada and Navajo sandstone	+245 ft. reported	....
5.	(D-38-25) 7bdc-1	A-24608	H. C. Perkins #3	....	Entrada and Navajo sandstone	....	....
6.	(D-38-25) 27ccc-1	A-24435	Ray V. Redd	....	Entrada and Navajo sandstone	....	....
7.	(D-38-25) 33ada-1	A-23520	Jack Pehrson	....	Entrada and Navajo sandstone	....	....
8.	(D-38-25) 35bd	Oil Test	Glasco #1	beyond 6,200	Entrada, Navajo, Wingate sandstones	....	....
9.	(D-35-26) 28ac	Oil Test	Hathaway Co.	beyond 6,000	Entrada, Navajo, Wingate sandstones	....	....
10.	(D-39-25) 13aba-1	A-23671	James P. Redd	444	Did not reach Navajo sandstone	....	No water encountered
11.	(D-39-25) 5aca-1	A-23183	Ray V. Redd	600	Entrada and Navajo sandstone	+122 ft. measured	....
12.	(D-39-25) 5aca-2	A-23436	Ray V. Redd	7,261	Entrada, Navajo, Wingate sandstones	+335 ft. measured	....

north and northwest, and ground water apparently moves along the dip of these water-producing formations. As the possibility of long-term ground-water development hinges on the amount of recharge and the location of the recharge areas, a study of these features is contemplated.

WELLS IN THE BLUFF AREA

Flowing "bedrock" wells have been drilled in the Bluff area along the banks of the San Juan River to supplement supplies obtained from shallow dug wells, from springs of low yield and poor water quality, and from the San Juan River itself. This region lies in a broad structural basin into which the water-bearing standstones of the Navajo, Wingate and Shinarump formations dip, and drilled wells have been yielding good-quality ground water for more than 50 years. These early wells have been supplemented in recent years by several additional drilled wells, so that now most of the water now used in the area is derived from bedrock sources. Most of the wells in this area produce from the Wingate sandstone, but a few are drilled deep enough to encounter water in the Shinarump conglomerate.

Some of the first wells drilled in the Bluff area have been permitted to flow without restriction for many years, and artesian pressures have declined from a reported high of more than 150 feet in 1909 to approximately 80 feet at present. As of this writing, about a dozen "bedrock" wells are producing, and these are largely clustered in a narrow strip east of the town of Bluff and adjacent to the San Juan River. Most of the wells are producing from depths between about 500 and 700 feet below the land surface.

Between the San Juan River and Blanding, and in much of the area to the east, geologic conditions are similar to those at Bluff and Blanding, and ground water under artesian pressure can be anticipated. In most of the area, however, the elevation of the land surface is sufficiently high to preclude the possibility of flowing wells.

SUMMARY

1. Although it has been estimated that not more than one quarter of 1 percent of the ground water discharged by wells in Utah is derived from bedrock sources, at least five bedrock aquifers are becoming increasingly important as sources of ground water in the southeastern part of the State.

2. The success of recently completed wells has demonstrated the feasibility of developing water from bedrock for irrigation purposes and has stimulated the interest for additional drilling. It is contemplated that additional bedrock wells will be drilled in the next few years.

3. Although the producing sandstone aquifers are widespread and store large quantities of good-quality ground water, the permeability of these sandstones appears to be relatively low. Thus, problems of declining artesian pressure, small yield per foot of drawdown, mutual interference between wells, and high pumping lifts can be expected as development continues.

4. Arable land is not abundant in the areas where ground water can be economically developed. Since the closure, by court order, of extensive areas in the southeastern part of the State that were formerly open to homesteading and desert entry, good farm land adjacent to a potential water supply is at a premium. With both water and land as possible

limiting factors, it is not expected that extensive tracts will be opened to farming in the foreseeable future.

5. Ground-water development in each of these newly developed areas is being watched rather closely, and periodic measurements of head are being made in selected observation wells. It is contemplated also that well-discharge and aquifer-performance tests will be run on representative wells in the near future. As this general area now produces a large part of the total "bedrock" water of the State, the success of wells in this area will guide development in other localities.

6. None of the "bedrock" wells in this area, or elsewhere in Utah, derive a supply of ground water from limestone.

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STATE OF UTAH

JOSEPH M. TRACY, State Engineer

INVESTIGATION OF GEOLOGY AND OCCURRENCE OF GROUND WATER IN THE WEBER BASIN PROJECT AREA, FARMINGTON TO WILLARD, UTAH: A PROGRESS REPORT

By J. H. FETH
U. S. GEOLOGICAL SURVEY

Prepared in cooperation with the

GEOLOGICAL SURVEY
W. E. WRATHER, *Director*

UNITED STATES DEPARTMENT OF THE INTERIOR

1954

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INVESTIGATION OF GEOLOGY AND OCCURRENCE OF GROUND WATER IN THE WEBER BASIN PROJECT AREA, FARMINGTON TO WILLARD, UTAH: A PROGRESS REPORT

By JOHN H. FETH

INTRODUCTION

A joint investigation of the geology and ground-water resources of part of the East Shore area,[1] extending from Farmington to Willard,

1. The East Shore area includes lands lying between the west front of the Wasatch Mountains and the east shore of Great Salt Lake. The area of the present study is shown on the map, fig. 1.

has been undertaken by the U. S. Geological Survey and the U. S. Bureau of Reclamation. The investigation constitutes part of the program of planning for the Weber Basin Project. This project, authorized by Congress in 1949, is now under construction by the Bureau of Reclamation.

In 1951 a limited cooperative program was arranged for the summer months only between the Bureau of Reclamation and the Geological Survey, and P. E. Dennis, Geologist, U. S. Geological Survey, mapped a part of the foothill area. In December 1952 the present investigation was provided for in a cooperative agreement bewteen the Bureau of Reclamation and the Geological Survey. Field work was carried on during the last quarter of fiscal year 1953 and was continued under a renewed agreement in fiscal year 1954. It is intended that the joint investigation will continue until completion of a final report on June 30, 1956. A preliminary report is planned for June 30, 1955.

An area of about 350 square miles is included in the present investigation. The southern boundary is set arbitrarily at the line separating Tps. 2 and 3 N., as the northern limit of the Bountiful district, earlier studied by the Geological Survey and reported upon by H. E. Thomas and W. B. Nelson in the 26th Biennial Report of the Utah State Engineer in 1948. The northern boundary is at the northern limit of T. 8 N. On the west, the investigation will extend to the shore of Great Salt Lake and, on the east, to the contact between rocks of the Wasatch Mountains and deposits formed by waters of Pleistocene Lake Bonneville or by deposition from streams or mudflows discharging from the mountains.

The general objectives of the investigation are as follows:

(1) To obtain information from which a plan may be formulated for a drainage system that will (a) reduce the effects of upward leakage from artesian aquifers; (b) lower the water table on project lands to where sustained agricultural production may be maintained; (c) guard project lands against "waterlogging" due to irrigation; (d) protect non-project lands that might be affected by seepage from irrigated project lands; and (e) provide the data necessary for the design and construction of such a system.

(2) To determine to what extent drainage flows, water from artesian relief wells, and water from additional water-supply wells can be used for project purposes. Use of these potential supplies would increase the water supply to the project and permit increased agricultural and industrial development of the area. Utah has much more land suitable for development than it has supplies of surface water for irrigation.

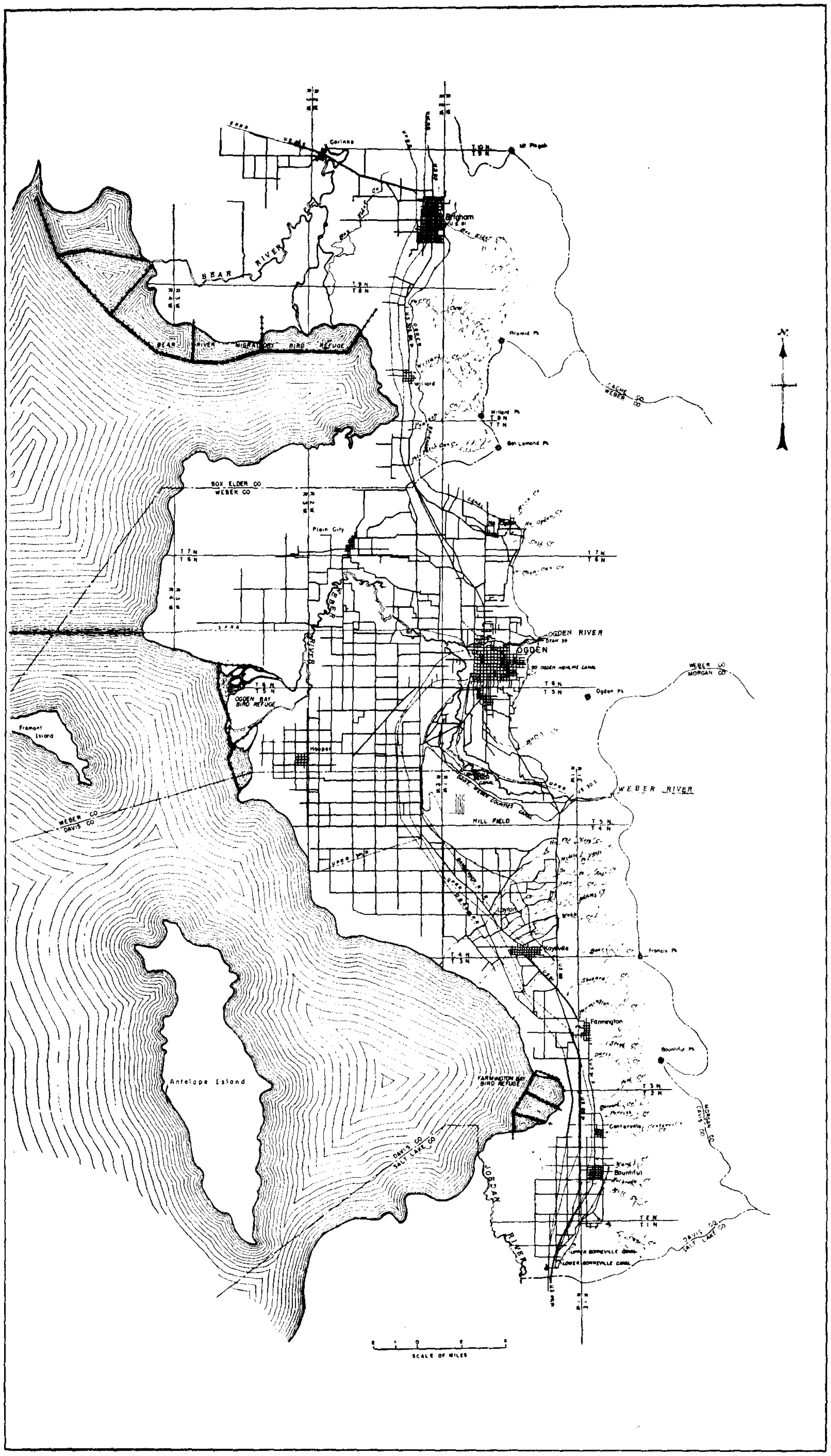

Figure 1. Map of East Shore area, Utah.

Development of significant quantities of underground water would, by interconnections and exchanges with projects both north and south of the Weber Basin Project, permit the utilization of a portion of this very productive but now barren land. The results of this study will therefore have an important effect on the development of not only the Weber Basin area but of the whole State.

To the foregoing statement might be added the following more detailed objectives of the ground-water investigation:

(1) To establish a historic, pre-project, record of water levels, artesian pressures, and chemical quality of ground water in the area.

(2) To determine as far as possible areas of recharge and of discharge, the latter with special reference to the effect of upward leakage upon waterlogging of lands.

(3) To cooperate with the investigation of drainage in the location of areas favorable for reclamation of waterlogged lands by installation of pressure-relief wells.

(4) To determine aquifer characteristics with reference to potential productivity of the aquifers, and with reference to design and installation of wells intended either to relieve pressures, or to produce water for project use, or both.

(5) To determine the relation of stratigraphy and geologic structures to localizing areas of landsliding, such as along benchlands adjacent to Weber Canyon west of the mountains, and to suggest methods of possible control.

PERSONNEL AND ACKNOWLEDGMENTS

The present investigation is being conducted under the direction of A. N. Sayre, Chief, Ground Water Branch, U. S. Geological Survey, and E. O. Larson, Director, Region 4, U. S. Bureau of Reclamation, and under the general supervision of H. A. Waite, District Geologist, Ground Water Branch, Salt Lake City, and of C. D. Woods, Projects Engineer (USBR). J. H. Feth, Geologist, Ground Water Branch, Geological Survey, has responsibility for field direction of the ground-water investigation and the geologic studies. W. H. Greenhalgh, Engineer (USBR), has charge of the Bureau personnel directly engaged in the drainage and ground-water investigation. V. D. Jensen, Engineer (USBR), and R. J. Brown, Soil Scientist (USBR), are engaged directly in ground-water investigation. The regional laboratory of the Bureau of Reclamation is making chemical analyses of water samples, and personnel of the materials laboratory have been helpful in making particle-size analyses of sediment samples. Many other members of the Weber Basin Project staff are cooperating by furnishing information and services.

Background data and current information relative to this study are available from many sources. Among the more important of these are the following: an inventory of artesian wells prepared by the Geological Survey, unpublished reports in the files of the Geological Survey, and data on chemical quality of waters in the area, also on file in the laboratory of the Geological Survey. J. G. Connor, District Chemist, has been most helpful in discussing problems relating to the chemistry of ground waters in the area under investigation, and in providing analyses of waters related to special problems encountered during the investigation to date.

Data have been obtained by drainage engineers of the Weber Basin Project that effectively outline areas of waterlogging and define the shallow

water table. Shallow piezometers and piezometer clusters provide adequate information on differential pressures across strata of low permeability in areas of upward leakage. A pilot surface drain is presently under construction and will furnish helpful information on occurrence of near-surface ground water in the Hooper area.

Thanks are also due many residents of the area who have permitted installation of water-stage recorders on their wells, or allowed access to wells for periodic measurements; to Federal and municipal officials who have made available facilities and records of many kinds; and to members of the faculty and staff of the University of Utah who have given generously of their time and of their knowledge of the geology of the region in orienting the writer in his geologic studies.

WORK ACCOMPLISHED TO JUNE 1954

The present discussion of work accomplished is limited to that performed under the cooperative agreement between the Geological Survey and the Bureau of Reclamation, without reference to other work in the area done in the past by the Geological Survey or by other agencies, nor does it include other phases of the Weber Basin Project conducted solely by the Bureau of Reclamation.

In the summer of 1951, P. E. Dennis mapped the geology of about 20 square miles lying in a band along the base of the Wasatch Mountains and wrote a memorandum report, unpublished, in which the major problems related to occurrence of ground water in the Weber Basin Project area are outlined. The full-scale joint investigation was undertaken in March 1953.

Geologic mapping of the entire area is continuing. Drillers' logs of more than 1,200 wells in the area have been obtained from the office of the State Engineer. From these data, profiles have been prepared in an attempt to define zones of high permeability and zones of low permeability in the unconsolidated materials underlying the project area. Drill cuttings have been obtained from a number of wells penetrating to depths of 115 to 500 feet. Some of these suites of samples have been processed and described. Samples of sediments from numerous surface exposures have been obtained and studied in an attempt to establish criteria, both paleontologic and other, by which deposits of each of the major stages of Pleistocene Lake Bonneville can be distinguished one from another, and on the basis of which postdepositional faulting can be mapped. Study of superficial lithology and particle-size analyses of the sediments appear to offer little encouragement. Study of differential weathering of pebbles in gravel, or of different minerals in grains of sand size, has not provided useful information as yet. Differentiation of strata deposited at various stages of the lake depends so far upon very cautious use of color, reddish tones seeming to be characteristic of the older, Alpine, formation and yellowish-tan tones of the Provo formation, and of data on the altitude at which the strata are now found. The zonation of the lakebeds on the basis of fossil ostracodes, found abundantly in many places, is the object of a research program of D. J. Jones of the University of Utah. His preliminary report is expected to be made public before the end of 1954. Meanwhile, he has provided assistance in identifying forms and interpreting their age significance in relation to the history of Lake Bonneville and the sequence of its sediments.

Faulting in the sediments deposited by Lake Bonneville appears to be important in several ways in relation to the occurrence of ground water. In some areas, as northwest of Ogden City, it appears that subsurface faults are genetically related to differential pressure heads, to the presence of high-chloride waters, and to water temperatures higher than the regional averages for wells of equivalent depths. Along the margins of the benchlands, fault zones appear to channelize the discharge of ground waters moving laterally above zones of low permeability, and so to cause saturated areas in which landsliding is particularly active. It is possible that fractured zones related to faulting may provide channelways through which recharge of the deeper aquifers takes place. In the western part of the East Shore area, fault zones are thought to govern the localization of spring mounds that discharge water, much of it highly mineralized, and some of it at temperatures ranging from 100° to 140°F.

It is thus thought that determination of faulting is important in many respects in the present investigation. As some of the determination rests upon establishment of criteria by which sediments of the several lake stages can be differentiated, a large part of the geologic phase of the investigation so far has been related to a study of the sediments and an attempt to find the needed criteria.

The hydrologic phase of the investigation is closely tied to the geologic studies. Aquifer (pumping) tests have been run on 10 wells to date of writing (August 1954), and the data resulting from interpretation of the tests are being correlated with information obtained by mapping and by study of logs of wells. Three observation wells have been drilled by the Bureau of Reclamation within a reach in Weber Canyon extending 2 miles west of the Wasatch Mountains. These observation wells provide information on the following: (a) characteristics of the aquifers in one of the most promising parts of the area for future ground-water development; (b) interference between wells penetrating these aquifers; and (c) behavior of the aquifers as recharge takes place either naturally from flow in the Weber River, or artificially as river water was introduced into a large borrow pit at the mouth of Weber Canyon during a 6-weeks test period in the spring of 1953. Additional recharge studies will be made whenever possible.

The observation-well program in the East Shore area dates back to 1936, when the Geological Survey began observations on 16 wells. At the present writing, more than 150 wells are measured periodically, 15 on a weekly basis. Recording gages are installed on 11 of the 15 wells. In addition, occasional measurements are made on other wells, and the data obtained from all sources have been compiled into piezometric-surface maps showing the configuration of the pressure surface at two periods in the first year of observation. These maps permit general interpretation of the direction of movement of ground waters from areas of recharge to zones of discharge.

In the period January 1953 to March 1954 the Bureau of Reclamation dug a 3.3-mile tunnel through part of the Wasatch Mountains adjacent to and paralleling the lower canyon of the Weber River. After penetrating about 1,000 feet of rock, tunneling operations encountered ground water. Discharge of ground water from the tunnel has continued from that time to the time of writing. Records of discharge have been kept since July 1953, when a flume was installed at the west portal of the tunnel, and show a continuous yield ranging from about 300 to a little more than 600 gallons per minute. Throughout the period of record, this discharge has been accepted by the unconsolidated sediments upon which the water is discharged, and it is believed that essentially the entire flow from the tunnel is recharged to aquifers in and adjacent to the mouth of Weber Canyon.

Low flows in the Weber River during the late winter and early spring of 1954 permitted determination of inflow to the river in the lower 3 miles of its rock-walled canyon. These measurements, repeated three times, indicate an increment of nearly 5 second-feet in the reach. Studies of the chemical quality of the river at various points, and of the quality of water visibly discharging as seeps from the sides of the canyon, indicate that the increment all occurs in the lower 1½ miles. These findings were confirmed by a concurrent series of studies of the radon content of the river waters and waters from the seeps, performed by A. S. Rogers, of the Geological Survey.

The data in the two preceding paragraphs supplement information available from the piezometric-surface maps mentioned above, and information regarding occurrence of springs along the mountain front. The data suggest that recharge is reaching ground-water aquifers from a multitude of points, most of them subsurface, along the mountain front. Recharge from the Weber River in the first 1½ miles below the rock-walled canyon is a significant factor in the ground-water picture. Recharge from the Ogden River, and from other streams along the west front of the Wasatch Mountains, appears to be of less importance than recharge from either the Weber River or the many concealed sources that are inferred to exist.

Studies of the chemical quality of waters in the area are in progress. To date of writing about 100 water samples have been analyzed in the Bureau of Reclamation laboratory, Salt Lake City. These samples have been taken from wells, springs, seeps, rivers, and drains. Results of the analyses will be correlated with information on water temperatures and pressure heads in an attempt to determine more closely zones of active recharge, and directions of movement of the waters underground. The data will permit delineation of areas of highly mineralized water and will assist in locating fault zones thought to occur underground without surface expression. The chemical-quality information will also provide an important historical reference point from which to gage the future influence of operation of the Weber Basin Project upon water qualities. It is expected, for example, that partial demineralization of soils and ground waters will occur in areas affected by the drainage program. Some of those areas presently contain a potentially injurious amount of mineral matter.

Most of the ground waters in the East Shore area appear to be suitable for irrigation and it now appears that the chemical quality of waters will be a limiting factor in development of only a few relatively localized areas. Many of the waters sampled are suitable for most uses to which water is put in the region. This favorable condition is especially true in reference to the more productive aquifers.

In determining the volumes of ground water that can be withdrawn from the East Shore area on a sustained-yield basis, it is necessary to determine the amount presently discharged annually. This determination involves measurements of discharge of all kinds, such as flow and pumpage from wells, discharge from springs, and runoff from streams and drains leaving the area. It also involves discharge by evaporation and by transpiration. In that connection, a study of evapotranspiration has been started, with the U. S. Weather Bureau cooperating. The Weather Bureau has made available a class A weather station and evaporation pan. These instruments have been installed at the Ogden Bay Bird Refuge and are serviced daily by the refuge manager, Noland Nelson.

In conjunction with the evapotranspiration studies, growing tanks containing plantings of the most common native water-loving plants of the region will be installed and transpirative-use studies made both in the tanks and, where possible, under field conditions. A map showing distribution of vegetative types, native and cultivated, is being prepared. Data obtained on consumptive use of water by native vegetation and by crops will be used to make an overall estimate of the annual evapotranspirative use of water in the area.

Discharge of ground water also takes place from bare or salt-crusted surfaces, especially in areas of upward leakage of water under artesian pressure. An attempt is being made to measure the rate of discharge per unit area by measuring the amount of salt-crust deposited in a certain period of time in each of 6 sample areas. By determining that value and relating it to the amount of dissolved solids contained in a water sample obtained at shallow depth in each test area, it is hoped that an average rate of leakage per unit area can be determined. If such a rate can be estimated within a reasonable margin of error, then it will be possible to delineate and measure the total area in which upward leakage and evaporation are taking place and so arrive at a quantitative estimate for the entire area under study.

FUTURE WORK PLANNED

It is proposed that the investigation described in the foregoing pages will continue through June 1956 and that a final report will be prepared. The major lines of approach have been outlined and work has started. The investigation is intended to proceed in each of the fields described—geology, hydrology, quality of water, and evapotranspiration. No phase of the study is complete or nearly complete at the present writing.

It is intended, however, that during the next 1 to 1½ years, emphasis will be placed on certain facets, especially on determination of areas of exceptional receptivity to recharge, and upon experiments in induced recharge in one or more such areas, and on location and construction of one or more pilot pressure-relief wells. Actual observation of the effect of a pressure-relief well is a vital part of the study, so that projection of pressure-relief effects and location of sites for future relief wells can be based on practical experience in operation of a well, as well as upon data obtaind by aquifer tests, from geologic mapping, and from aquifer studies based on profiling drillers' logs of wells.

Periodically, drillers' records will be compiled in the State Engineer's office. Studies of quality of water and water temperature will be continued and will be correlated with other data by means of map overlays and of profiles and other graphical devices.

Geologic mapping will be extended over the entire area of investigation. Stratigraphic studies of the lake deposits will be continued to the end, it is hoped, that it will be possible to delineate fault structures with considerable assurance. Location of faulted areas in the benchlands will permit determination, at least in part, of points at which precautions against land slippage will need to be taken. Study of deep-well cuttings will continue as time and availability of samples permit, and the information obtained will be used in conjunction with other aquifer studies to indicate favorable areas in which to develop new sources of ground water, and to determine depths at which productive aquifers may be encountered in the various parts of the area.

In the time allotted for the present study, and with the available facilities and personnel, it should be possible to obtain an overall picture of geologic and hydrologic conditions in the project area sufficiently complete to permit intelligent planning for the utilization of ground-water resources and for relief of lands requiring drainage. The area is large and the ground-water problems are exceptionally complex. The investigation now in progress will produce much information regarding the geology, hydrology, geochemistry, and evapotranspiration in the area. As development of water resources continues, however, and as additional lands are drained and irrigated, existing hydrologic relations will be changed. In consequence, periodic review of these conditions will be needed to keep abreast of the effects of the development.