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Ground-water resources of the Duncan Basin, Arizona

by

L. C. Halpenny, H. M. Babcock,
R. B. Morrison and J. D. Hem

Prepared in cooperation with
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O. C. Williams, Commissioner

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Plate 1. Map of Duncan Valley, Arizona, showing locations of wells used for irrigation and water-level observation and alluvial fill of inner valley.

2. Map of Duncan Valley, showing generalized geology.

Figure 1. Cross-section through Gila River flood plain, along Arizona-New Mexico State Line.

2. Graph showing fluctuation of water level, in observation wells, runoff at State line in acre-feet, and water pumped for irrigation in acre-feet, Duncan Basin, Greenlee County, Arizona.

INTRODUCTION

Purpose and cooperation

The need for state regulation of ground-water resources in Arizona has become increasingly apparent. Inasmuch as such regulation must be based upon adequate information as to the quantity, quality, and use, as well as the source and movement of the ground water, the Arizona State Legislature in 1945 appropriated funds for the investigation of each ground-water basin in the state. The investigations are being made by the Geological Survey, United States Department of the Interior, under a cooperative agreement with the Arizona State Land Department, O. C. Williams, Commissioner.

Much of the data contained herein were collected during an investigation of the water resources of the Duncan Basin on the Gila River in 1939-1941 by the United States Geological Survey in cooperation with the State of Arizona and the United States Engineer Department. Since 1941 periodic measurements of water levels and an inventory of the pumpage have been made each year. Field work was done by H. M. Babcock, D. H. Bratton, R. L. Cushman, E. M. Cushing, H. G. Fernandez and L. C. Halpenny, engineers, R. B. Morrison, geologist, and J. D. Hem, chemist, under the direct supervision of Samuel F. Turner, district engineer (Ground Water), of the Geological Survey.

Location

The Duncan Basin is a part of the structural trough that extends from the vicinity of Clifton, Arizona, southeastward to the vicinity of Lordsburg, New Mexico. As described in this report, the basin lies entirely within Greenlee County, Arizona, between the confluence of the San Francisco and Gila Rivers and the intersection of the Gila River with the Arizona-New Mexico State Line.

Southeast of the state line that part of the trough through which the Gila River flows is called the Virden Valley, and the remainder, which has interior surface drainage, is known as the Animas Basin. The division between the Duncan Basin and the Virden Valley is purely arbitrary. It was selected in an attempt to separate the problems of the Arizona portion of the entire valley from those of the New Mexico portion. However, this boundary has no geologic nor hydrologic basis, and it is believed that from the ground-water standpoint, the entire trough is inter-related.

The lower end of the Duncan Basin is limited by the Peloncillo Mountains, through which the Gila River has cut a narrow gorge. The Steeple Rock Mountains lie along the northeast side of the basin, and the Peloncillo Mountains lie along the southwest side. The basin ranges in width from 2 to 15 miles and is about 23 miles long. The basin consists of two parts: the higher, uncultivated land which slopes down from the mountains on either side, and the inner valley, which is one sixth mile to 2½ miles in width and contains all of the irrigated land.

Climatological data

Precipitation is about 10 inches a year at Duncan, according to a five-year record of the U. S. Weather Bureau. No records of the temperature in the Duncan Basin are available. However, the mean annual temperature at Safford, which is in the nearest comparable area and has an elevation of 2,900 feet, is 62.5 degrees Fahrenheit. In 1944 the temperature range at Safford was from $+12^{\circ}$ to $+114^{\circ}$. The frost-free season at Safford lasts about six months. The elevation of the inner valley of the Duncan Basin ranges from 3,335 feet above sea level at the gaging station at the lower end of the valley to 3,736 feet at the state line.

History of development

The Duncan Basin was first settled by farmers about 1875. Originally the farmers used water diverted from the Gila River to irrigate their lands. However, especially in dry years, the river supply was inadequate and beginning about 1935 the river supply was supplemented by ground water.

In 1940 there were 27 irrigation wells in operation. This number increased to 44 wells by January 1, 1946, and further drilling is in progress. Table 1 presents records of typical domestic and irrigation wells in the inner valley. Plate 1 shows the location of all irrigation wells and all wells in which water levels are measured periodically.

The 1940 census lists 151 irrigated farms with a total farm population of 1,156 in Greenlee County. A field survey by engineers of the Geological Survey showed 4,669 acres under irrigation in 1941. The principal crops are alfalfa, grain, cotton and vegetables.

Previous investigations

Earlier studies by the Geological Survey in the Duncan Basin are described in the following reports:

Surface water resources:

1. U. S. Geol. Survey 21st Ann. Rept.: pp. 335-38, 1900.
2. Storage of water on Gila River, Ariz.: by J. P. Lippincott, U. S. Geol. Survey Water-Supply Paper 33, 1900.
3. Surface-water supply of the Colorado River Basin: U. S. Geol. Survey water-supply papers for each year beginning with 1899.

Geology and ground-water resources:

1. Water resources of Safford and Duncan-Virden Valleys, Ariz. and N. Mex., by S. F. Turner and others, 1941 (mimeographed report).
2. Records of wells and springs, well logs, water analyses and map showing locations of wells and springs, Duncan-Virden Valley, Greenlee County, Ariz., and Hidalgo County, N. Mex., by R. B. Morrison and H. M. Babcock, 1942 (mimeographed report).
3. Geology and ground-water conditions in the Duncan Basin, Ariz., by R. B. Morrison, 1942 (unpublished manuscript).
4. Water levels and artesian pressure in observation wells in the United States, part 6, Southwestern States and Territory of Hawaii:

   Calendar year 1940, Water-Supply Paper 911, pp. 63-72, 1941.
   Calendar year 1941, Water-Supply Paper 941, pp. 43-48, 1942.
   Calendar year 1942, Water-Supply Paper 949, pp. 28-31, 1943.
   Calendar year 1943, Water-Supply Paper 991, pp. 43-47, 1945.
   Calendar year 1944, water-supply paper in preparation.
   Calendar year 1945, water-supply paper in preparation.

GEOLOGY OF THE DUNCAN BASIN AND ITS RELATION TO GROUND-WATER SUPPLIES

Character of basin

The Duncan Basin is a deep trough that is partly filled with more or less unconsolidated deposits of gravel, sand, silt and clay (see pl. 2). The trough lies between mountain blocks of older rocks which are mostly volcanic lava, although older granite, gneiss and porphyry are exposed near Clifton and older sedimentary rocks are exposed six miles upstream along Apache Creek. The older rocks which comprise the mountain blocks are hard and resistant and for the most part impermeable, although they may carry some water which issues as springs from cracks, fissures and weathered zones along the sides of the mountains. Nevertheless, the ground water in the Duncan Basin occurs principally in the unconsolidated deposits of the basin. Therefore this report deals chiefly with the ground water in these deposits.

The mountain blocks perform two major functions with respect to ground water in the basin: (1) because of their higher elevations they have greater annual rainfall and thus contribute a large share of the water which enters the basin; (2) because they are composed of relatively impermeable rocks they tend to confine the ground water within the basin.

Older alluvial fill

The unconsolidated deposits of the Duncan Basin were derived from the hard rocks of the mountain blocks and were washed into the basin by streams and by sheet runoff. The main body of these deposits, termed here the older alluvial fill, was deposited in an enclosed basin so that a shallow lake of the playa or semi-playa type was formed along the axis of the basin. The older alluvial fill underlies all of the area shown in white on plate 2. The thickness of the older alluvial fill may be 1,000 feet or more. There are no deep wells in the Duncan Basin, and the thickness of the older alluvial fill must be estimated by comparison with similar deposits in the Safford Basin. The deepest well in the Safford Basin reached 3,767 feet without reporting bedrock, and encountered several deep water-bearing beds. It is possible, therefore, that deep aquifers exist in the Duncan Basin.

Near the mountains on both sides of the valley the older alluvial fill consists chiefly of boulders, gravel and conglomerate with small amounts of silt and sand. The conglomerate is mostly in the northwest end of the basin. The width of this "gravel zone" is from 1 to 2 miles on each side of the basin. The "gravel zone" of the older alluvial fill is partly consolidated and only moderately permeable. Layers of relatively impermeable caliche originally occurred throughout the upper part of the gravel zone, but streams have cut channels through these layers. Water from rain and from stream-flow enters the fill along the stream channels and moves slowly toward the axis of the basin; where it is discharged by artesian springs and seeps which rise along faults near the axis of the basin.

The materials which comprise the older alluvial fill gradually become finer toward the interior of the basin, grading first to interbedded sand and silt with some gravel, then to silt with some sand, and finally, along the axis of the valley in the "lake-bed zone" to silt and clay with local stringers of sand. The silts and clays of the "lake-bed zone" are impermeable and they contain traces of salt and gypsum in places, but no beds of rock salt or gypsum are known.

Alluvial fill of inner valley and tributary washes

After the older alluvial fill was deposited, the Gila River entered the basin and cut a valley in the fill (see fig. 1). This started a cycle of erosion that included development of gorges through the mountain barriers and rapid cutting of the fill in the interior of the basin. After the first rapid cutting the erosion slackened, and an erosion surface was developed on the softer areas of older alluvial fill. This surface is about 50 to 100 feet below the original depositional level and it slopes gently toward the Gila River. It is covered with a thin mantle of gravel, and is the main "mesa" level above the river plain near Duncan.

Subsequently the river accelerated its rate of erosion and cut a second, narrower valley, about 200 feet deep, within the larger one. This valley was then re-filled to a depth of 50 to 100 feet with materials brought in by the river and its tributary washes. The part of the basin underlain by these younger deposits is called the inner valley and includes all of the irrigated lands. The alluvial fill of the inner valley consists of beds of gravel, sand and silt which are irregular and discontinuous, so that wells very close together may encounter water-bearing beds at entirely different depths. However, as the layers of silt are not continuous, water from the surface may percolate downward, often by circuitous routes, to recharge the underlying ground-water reservoir. Wells in the inner valley produce from 170 to 2,250 gallons per minute.

GROUND-WATER RESOURCES

Older alluvial fill

Occurrence of ground water

Along the sides of the basin ground water is found in the beds of sand and gravel that occur in the "gravel zone" of the older alluvial fill. The lake-beds of the older alluvial fill near the center of the basin are believed to be largely silt and clay, but they probably contain some fingers of sand and gravel that represent extensions of the gravel zone. These fingers of sand and gravel very likely contain water under artesian pressure, which would supply wells penetrating them. However, only one well has tapped the water-bearing beds of the older fill and therefore the extent and depth of these beds are not known.

Source of ground water

Recharge of the older fill is from rainfall and from seepage from streams crossing the outcrops of sands and gravels deposited near the mountains. Direct recharge from rainfall is probably small because relatively impermeable caliche at and near the land surface in the older alluvial fill acts as a partial barrier except where it has been cut through along tributary stream channels. A large part of the water in these tributary streams usually sinks into the alluvium lining the channels, in which it moves downstream as underflow. A part of this underflow is fed into permeable beds of the underlying older alluvial fill. Probably the ground water is unconfined in the "gravel zone" but as it moves toward the center of the basin it may enter the fingers of sand and gravel that extend through the lake beds and be confined under artesian pressure. The water probably becomes mineralized as a result of contact with the salty clay and silt beds of the older alluvial fill.

According to Schwennesen[1], the slope of the water table is such that ground water from the Animas Basin may enter the Duncan Basin from the south in the vicinity of Franklin. This is also indicated by studies of the change in chemical quality of water in the Gila River near Franklin.

Discharge of ground water

Some of the water in the permeable beds in the older fill eventually reaches the surface through artesian springs that rise along faults. One such spring is found in Rainville Wash, east of Duncan. Others appear along the course of the Gila River. Not all of the faults will transmit water, as some of them are sealed with clay. Some of the water of the older fill moves slowly upward through the most permeable parts of the lake-bed zone and enters the alluvium of the inner valley of the Gila River. Since the water from the older alluvial fill is more mineralized than that from the river alluvium, its presence has been detected by chemical analysis of water samples.

Alluvial fill of inner valley and tributary washes

Occurrence of ground water

Ground water is found in the sand and gravel beds of the alluvial fill of the inner valley of the Gila River. These beds are the source of water for all of the irrigation wells in the basin. Smaller quantities of ground water are found in the alluvial fill in some of the larger tributary washes, where several domestic and stock wells are located. In many of the tributary washes, however, the alluvial deposits are only a foot or two in thickness, and thus cannot supply water for wells.

It is well to emphasize the fact that the water-bearing beds in the alluvium of the inner valley are not continuous. A bed of gravel may be 10 feet in thickness at one point, and at a distance of 100 feet it may be only 2 feet in thickness. These water-bearing beds are found throughout the inner valley, although they are less extensive from Five O'Clock Wash to Goat Camp Creek.

Source of ground water

Ground water in the alluvial fill of the inner valley is derived primarily from three sources: (1) Water which enters the alluvial fill of the inner valley from the older alluvial fill in the form of springs and diffused upward seepage; (2) underflow of the Gila River and its tributary washes; (3) water which enters the alluvial fill from rainfall and from infiltration of irrigation water (both from canals and from fields). If the water table were lowered below the level of the Gila River, recharge from the river would also occur. All values given here for recharge are from a previous report of this office[2].

1/ Schwennesen, A. T., Ground water in the Animas, Playas, Hachita and San Luis Basins, N. Mex.: U. S. Geol. Survey Water-Supply Paper 422, pp. 89-90 and 112, 1918.

2/ Turner, S. F., and others, Water resources in the Safford and Duncan-Virden Valleys, Ariz. and N. Mex.: U. S. Geol. Survey mimeographed report, pp. 43-46, 1941.

The total recharge in the inner valley of the Duncan Basin from all sources during 12 months beginning October 1, 1939, and ending October 1, 1940, was about 28,000 acre-feet.

Recharge to alluvial fill of inner valley from older alluvial fill.- The recharge from this source amounted to about 2,500 acre-feet of water during the 12-month period selected. This, of course, is equal to the discharge of ground water from the older fill.

Underflow.-Water stored within the earth is nearly always in motion, although in some places the rate of movement is only a few inches a year. "Underflow" is a term used to describe a particular case of this movement of ground water, that which occurs through a channel of permeable material underlain by relatively impermeable material. Underflow is frequently associated with surface flow in rivers, although it may occur when there is no surface flow in the overlying stream. The rate of underflow is determined by three factors: the slope of the water table, the cross-sectional area of the water-bearing material where the flow is to be measured, and the permeability of the water-bearing material. The rate of underflow may be expressed as gallons per minute or per day, miners inches, cubic feet per second, acre-feet per day or per year, or any other convenient units. In this report, the values given for underflow are in terms of cubic feet per second and acre-feet per year.

Underflow of the Gila River through the alluvial fill of the inner valley at the Arizona-New Mexico State Line has been calculated to be about 10 cubic feet per second or 7,200 acre-feet per year, based upon the following factors: The width of the alluvial fill of the inner valley at the State line was 1 6 miles, the average saturated thickness was 70 feet, the slope was 13 feet per mile, and the coefficient of permeability was 5,000 units[3/]. This coefficient was obtained from the results of a pumping test and from laboratory tests of samples of the water-bearing materials. This underflow of 10 second-feet is derived from recharge from the surface flow of the river and from all other sources in the Gila River Valley above the State line.

Underflow from tributary washes is largely concentrated in the Arizona portion of the "Duncan-Virden Valley". The 1941 report showed that in the entire valley as defined in that report it totaled about 12 cubic feet per second, or about 8,700 acre-feet in a year. About 80 percent of this underflow, or about 7,000 cubic feet a year, occurred in the Duncan Basin, downstream from the State line.

Infiltration from irrigation and rainfall.-According to the 1941 report, approximately one-third of all water passing through canals and about one-fourth of all water applied to the fields for irrigation percolates downward to the ground-water reservoir. This means that one-half of all the surface water diverted and one-fourth of all the water pumped enters the ground-water reservoir. In the entire "Duncan-Virden Valley" this amounted to about 17,000 acre-feet of recharge between October 1, 1939, and October 1, 1940. The part

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3/ Gallons per day through one square foot under a hydraulic gradient of one foot per foot.

applicable to the Duncan Basin would be about 60 percent, based upon the ratio of 4,669 acres irrigated in the Arizona portion to 7,769 acres in the entire valley. Thus, the recharge from this source in the Duncan Basin was about 10,200 acre-feet during the 12 months.

During the same 12-month period, recharge from rainfall on the alluvial fill of the inner valley of the Duncan Basin was between 350 and 700 acre-feet.

Discharge of ground water

Water is discharged from the ground-water reservoir in the alluvial fill of the inner valley both by pumping and by natural discharge. Natural discharge occurs by means of transpiration and evaporation in the area occupied by phreatophytes, or plants whose roots draw moisture directly from the ground-water reservoir; by evaporation from bare, wet land surfaces in the river bottoms; by underflow out of the basin along the Gila River; and by seepage from the ground-water reservoir into the river.

Pumpage.-The irrigation wells in the Duncan Basin range in discharge from 170 to 2,250 gallons a minute; in depth, from 29 to 150 feet; in pumping lift, from 10 to 45 feet; and in diameter, from 6 to 20 inches. Most of the wells are used to supplement surface-water diversions, and only a few are used as a sole supply of irrigation water. Table 1 lists records of these wells and plate 1 shows the location of them.

The Geological Survey has kept a record of the water pumped in the Duncan-Virden Valley since October 1, 1939 (see table 2). Figure 2 is a graph showing the quantity of water pumped in comparison with river flow at the Arizona-New Mexico State line and fluctuations of the water level in wells. The number of irrigation wells in use has increased greatly during this time and the amount of water pumped in 1944 was 3½ times that pumped in 1940. Table 2 shows the pumpage from irrigation wells in the Duncan Basin.

Natural discharge.-The amount of water used by phreatophytes in the "Duncan-Virden Valley", including the lands in New Mexico, during the period October 1, 1939, to October 1, 1940, was approximately 12,500 acre-feet. About 75 percent of this, or 9,400 acre-feet, was discharged in the Duncan Basin. During the same period evaporation from wetted lands in the Duncan Basin caused a loss of about 1,200 acre-feet.

Underflow out of the valley at the gaging station near Clifton is computed to be less than 0.5 cubic foot per second, or about 350 acre-feet a year, based upon a width of 0.04 mile, a thickness not exceeding 100 feet, a slope of 13 feet per mile, and a coefficient of permeability of 5,000 gallons a day per square foot.

The natural discharge into the river from the ground-water basin represents the amount by which the recharge exceeds the discharge resulting from pumping, evaporation, phreatophyte use, and underflow out of the basin. Because pumping and the use of water by phreatophytes are more or less seasonal, the discharge of ground water into the river varies greatly. In times of heavy pumping there may be no ground-water discharge into the river, and the flow may even be reversed, with the river feeding the ground-water reservoir. The measurements made during the previous investigation showed the ground-water discharge into the river to vary from 4 to 25 cubic feet per second but, as indicated above, there may be times when the river loses water into the ground.

Fluctuations of the water table

The principal factors that affect the level of the ground-water reservoir in the inner valley of the Duncan Basin are discussed below.

The effects of precipitation upon the water table are as follows: (1) Rainfall on the cropped area reduces the irrigation requirements so that less water needs to be pumped, and rainfall on the river-bottom area reduces the amount of ground water used by phreatophytes; (2) Some of the rainfall percolates directly to the ground-water reservoir. The reduction in use and the addition of water are both factors that tend to raise the water level.

Phreatophytes affect the level of the ground-water reservoir, as their use of water varies from month to month. It is greatest during July and August, and causes the water table in the river bottoms to decline considerably. Some of the plants of this class in the Duncan Basin use as much as 5 acre-feet of water a year per acre of growth of average density.

The length of time that canals are in use and the frequency of irrigation affect the amount of recharge. During periods of heavy irrigation with river water, little water is pumped from wells, and the water levels tend to rise partly because the use of ground water is decreased and partly because water is being added to the ground-water reservoir by downward percolation.

The pumping of an irrigation well lowers the water levels in proportion to the volume pumped, creating a cone of depression near the well. As pumping continues the cone deepens and expands and water moves toward the well from farther and farther away, thus tending to lower the general water level.

The stage of the Gila River affects the ground-water levels by controlling the slope of the water table. A rise in river level during a flood causes a corresponding rise in water level in nearby wells. This effect is usually of short duration and the water table declines as the river surface is lowered after a flood.

The graphs of water-level fluctuations shown in figure 2 represent typical conditions in the Duncan Basin. Well 61, located downstream from an area of heavy pumping, shows annual declines in water level as a result of pumping, and periods of recovery each fall when pumping is curtailed. In wells 5 and 171, which are some distance away from heavily pumped wells, the water-level changes have a trend similar to those in well 61, but on a smaller scale. Many measurements of water levels have been made in the basin by the Geological Survey, and the results are published in reports listed in the section on previous investigations (p. 4).

The fact should be kept in mind that the water level in the ground-water reservoir in the Duncan Basin is usually controlled by the water level in the river. Thus, water levels will not decline as rapidly in the Duncan Basin as they would in an area where they are not controlled by a perennial stream.

SAFE YIELD

The "safe yield" of a ground-water reservoir is "the practicable rate of withdrawing water from it perennially for human use"[4/]. In an irrigated area, such as the Duncan Basin, where losses through evaporation and transpiration are large, the use to which the water is put and the area of application greatly influence the safe yield. The picture is complicated further by the presence of a through-flowing stream (the Gila River) which is intimately related to the ground-water reservoir. Thus the determination of the safe yield of ground water in the basin involves an appraisal of both surface and underground water resources.

The relationship between the ground-water reservoir of a basin and a through-flowing river may vary from one extreme, where the ground-water reservoir feeds the river, to the other extreme, where the river feeds the ground-water reservoir. The relationship in the Duncan Basin is predominantly of the first type, that is, the water table slopes toward the Gila River and the ground-water body feeds the river. In this type of ground-water reservoir, the part of the water pumped that is evaporated and transpired and thus does not return to the ground-water reservoir, represents an eventual loss in the flow of the river, because it is water that would otherwise have reached the river. However, during the heavy pumping season, the relationship in part of the basin is of the second type, that is, the ground-water reservoir is fed by the surface stream. Under these conditions, pumping will increase the slope of the water table away from the river, and thus increase the rate of loss in flow of the river. Therefore, under either or both conditions, large-scale ground-water withdrawals tend to reduce the flow of the stream, so that it is necessary to determine the extent to which this is permissible before the safe yield can be estimated.

QUALITY OF WATER

All the studies of quality of water in the basin were made by John D. Hem of the Geological Survey. A comprehensive report describing the water analyses and interpreting these analyses is being prepared by Mr. Hem for both the Safford Basin and the "Duncan-Virden Valley", and will be published as a water-supply paper of the Geological Survey. The discussion given in the present report is adapted from the 1941 report on water resources of the area and from the water-supply paper in preparation.

Chemical character of the ground water

Water samples from 24 wells were analyzed and were found to differ greatly in chemical character. Analyses of typical waters are given in table 3. The dissolved solids in the samples analyzed ranged from 250 to 2,500 parts per million, but most of the waters ranged in concentration from 300 to 900 parts per million. Water from the older fill is usually higher in total mineral content than that from the recent alluvium. It contains a relatively large proportion of sodium salts, and fluoride, and is lower in total hardness.

4/ Meinzer, O. E., Outline of methods for estimating ground-water supplies: U. S. Geol. Survey Water-Supply Paper 638-c, p. 99, 1931.

Chemical character of the surface water

The data available on quality of water of the Gila River in the Duncan Basin are contained in analyses of samples taken during seepage measurements at periods of low flow in 1940 and 1941. Water samples collected from the river at the Arizona-New Mexico State line showed water of moderate mineral content, the total dissolved solids ranging from 180 to 406 parts per million. The water was predominantly of the calcium bicarbonate type and suitable for irrigation.

Between the Arizona-New Mexico State line and the bridge on State Highway 75 at Duncan, the river usually showed a loss in flow because of heavy pumpage in this area, but during the winter when very little water was pumped, the reach usually showed a gain in flow. However, the mineralization of the water in the river usually showed a marked increase between these points. It is evident that, to produce such an increase, some highly mineralized water must have seeped into the river, but in too small a quantity to balance the loss in flow. This seepage inflow must have been high in sodium sulfate and chloride because these constituents of the river water increased most.

Between the highway bridge at Duncan and the Colmenero Canal heading, 4.3 miles below Duncan, there was some further increase in the sodium sulfate content of the water. From this point to Cosper's Crossing, one mile north of Sheldon, there was no appreciable change in the chemical character of the water. The river always showed a loss in flow through this section and at times of low flow the river bed was frequently entirely dry at Sheldon. At these times, it remained dry for a distance of about five miles.

During periods of low flow the river always showed a gain of at least eight cubic feet per second in the two miles immediately above York Canyon. The water in the river at York had a much lower mineral content than the water that disappeared in the vicinity of Sheldon, indicating that the water gained was of very good quality. Several large washes enter the river in the gaining section, and underflow from them probably accounted for a part of this gain. The balance of the gain is underflow of the river, forced to the surface by the narrowing of the inner valley fill at this point.

From York to the gaging station at the lower end of the basin there were no significant changes in the chemical quality of the Gila River water.

Relation of quality of water to its use

Irrigation

It is probable that no serious problem exists at present regarding the quality of irrigation waters in the Duncan Basin, as most of the water used for irrigation comes from the Gila River. The river water is normally of suitable quality for irrigation. If it should become necessary to use ground water exclusively for irrigation of a given tract, some care would be required in its use to prevent damage to the soil, at least in the central portion of the basin where the ground waters contain high percentages of sodium. Nine of the 24 ground-water samples analyzed were from irrigation wells. The dissolved solids in this group range from 309 to about 2,500 parts per million. Of the nine samples analyzed, six contained more sodium than calcium and magnesium.

Domestic use

Most of the domestic well waters sampled in the Duncan Basin were only moderately mineralized, containing less than 1,000 parts per million of dissolved solids. Fluoride is one of the most objectionable constituents of waters in the basin. Fluoride was determined in water samples from 15 wells used for domestic and irrigation purposes. Fourteen of the samples contained 1.1 to 9.6 parts per million of fluoride. The sample from one well, at Sheldon, had no measurable amount of fluoride. The highest value found, 9.6 parts per million, was in the sample from the deeper of two wells furnishing water for the Town of Duncan. Most of the higher fluorides were found in waters having high concentration of sodium salts.

Hardness was determined or computed for all the ground waters from the basin that were analyzed. It ranged from 52 to 578 parts per million. Most of the waters in the lower ranges of hardness occurred near Duncan, where sodium concentrations were high. Most of the samples analyzed would be classified for domestic use as relatively hard waters.

Relation of quality of water to ground-water recharge and source

Common salt and gypsum occur widely throughout the lake and playa beds in the older alluvial fill. Artesian seeps and springs sometimes carry these salts to the alluvial fill along the river, where they are mixed with the normally good water of the alluvial fill. The increase in mineral content of the water in the Gila River at low stages in the reach above the Duncan highway bridge indicates, as previously shown, that some of the water from the older fill enters the inner valley near Franklin.

Although no wells that obtained water from tributary wash underflow were sampled in the Duncan Basin, samples from wells of this type in nearby Safford Basin indicate that this water usually has a low mineral content. As previously shown, the Gila River in periods of low flow always shows, in the reach above York, an increase in flow and a decrease in mineralization of the water. This probably indicates that a rather large amount of underflow enters the river in this reach from several large tributary washes.

Discharge of dissolved salts from basin

According to the rather small number of analyses, the water discharged from the basin in the Gila River below Guthrie appears to be slightly higher in dissolved solids and appreciably lower in hardness than that entering the basin at the State line. The data that have been obtained are not complete enough to indicate whether the total amount of dissolved matter carried from the basin by the river is larger or smaller than the amount entering it in surface flow and underflow.

SUMMARY AND CONCLUSIONS

The principal proven ground-water reservoir of the Duncan Basin is the sand and gravel fill of the inner valley along the Gila River. The water in this ground-water reservoir is derived from underflow into the inner valley along the Gila River and tributary washes, by recharge from canal seepage, irrigation and rainfall, and by movement of water from the underlying beds, through fault springs and diffused upward seepage. The total amount of recharge to the inner valley of the Duncan Basin was about 28,000 acre-feet the twelve months from October 1, 1939, to October 1, 1940.

The development of ground-water supplies to supplement surface-water diversions has been steadily increasing in the Duncan Basin for the last ten years. All the wells with adequate capacity for irrigation use derive their water from the sand and gravel fill in the inner valley. The amount of water pumped has varied each year during the period of measurement beginning in 1940, with a minimum of 1,348 acre-feet in 1941 and a maximum of 8,600 acre-feet in 1944.

Water was also discharged from the ground-water reservoir by evaporation and transpiration in the river-bottom area, by underflow out of the basin, and by seepage into the river. During the period October 1, 1939, to October 1, 1940, it is estimated that 10,600 acre-feet of water was evaporated and transpired in the river-bottom area, and that the underflow out of the basin was about 350 acre-feet. The amount of seepage into the river was not estimated, as this could not be done without extremely detailed work.

Water in the Gila River in the Duncan Basin is usually moderately mineralized, and is suitable for irrigation use. The water from many of the wells, however, has a rather high mineral content, with too great a percentage of sodium salts to be safe for irrigation use without at least occasional irrigation with Gila River water. Water from the wells used for domestic purposes was only moderately mineralized, but the fluoride content in all but one of the domestic wells sampled was higher than is considered desirable for use by small children.

Because of the intimate relation between the water in the ground in this basin and the water flowing in the Gila River, the regulation of withdrawal of ground water will be affected by the legal rights to the use of the river waters. Therefore, in arriving at a determination of the principles that are to serve as a basis for regulation of ground water withdrawals, careful consideration must be given to the interrelation of water from the two sources. To illustrate the intricacy of the problems involved, waters of the following four types or sources are cited:

1. Ground water derived by recharge from appropriated surface water, such as seepage from canals and from the irrigated lands. If this ground water is not intercepted by pumping, a part of it will be lost by evaporation and transpiration, but the remainder will eventually re-enter the river downstream and there become available for diversion. However, in many places it might be practicable to intercept this water partially by means of wells or to reduce the losses by lining the canals, thus in effect cutting off the source of some of the flow in the river channel downstream.

2. Ground water derived from recharge by tributary-wash inflow and from natural recharge on outcrop areas, such as that which augments the flow of the Gila River above York. If this ground water is intercepted before it reaches the river, the flow of the river will thereby be decreased even though such interception would tend to reduce losses by evaporation and transpiration. Diversion of such ground water might be made by wells near the source.

3. Ground water saved by destruction of natural river-bottom growth or by reduction of evaporation and transpiration through a lowering of the water table caused by pumping. Except for that in areas covered with river-bottom growth, there is only a small amount of additional cultivable land. The ground water saved by clearing such land would be available for use either by additional water-well developments on the land or by allowing it to return to the river for later diversion. Some ground water which would otherwise be lost by evaporation and transpiration could doubtless be saved through lowering of the water table by pumping from wells.

4. Surface water that now moves downstream in the Gila River to meet prior claims. Much of this water is used en route by phreatophytes or lost through evaporation. Removal of river-bottom growth would save some of this water for beneficial use.

Table 1. Records of typical domestic and irrigation wells, Duncan Basin, Arizona

No.	Location	Owner	Driller	Date completed	Altitude above sea level (feet)	Depth of well (feet)	Diameter of well (in.)
	T. 6 S., R. 30 E.						
2	NW¼SE¼ sec. 1	Minnie L. Eaton	Dewey Lloyd	1945	-	65	16
	T. 6 S., R. 31 E.						
5	SE¼NW¼ sec. 7	Warner Foote	U. S. Geological Survey	1941	3,453.16	15	1
12	NW¼NW¼ sec. 20	J. M. Wilton	G. Duncan	-	-	26	48
14	SE¼SE¼ sec. 19	Victor Rowden	R. D. Sidey	-	3,508.81	80	12
21	NE¼SW¼ sec. 17	J. M. Wilton	do.	-	-	56	14
28	SE¼SE¼ sec. 18	H. Grady and H. Shade	Eugene Clayton	1944	-	67	20
29	SW¼SE¼ sec. 18	Casterillo Estate	-	-	-	-	-
30	SW¼SE¼ sec. 19	Willis Cosper	-	-	-	81	16
30-A	NW¼NW¼ sec. 17	J. W. Foote	S. Mathew	1944	-	35	14
	T. 7 S., R. 31 E.						
31	SW¼NW¼ sec. 4	- Barney	-	-	3,544.99	-	20
d/ 35	NE¼NE¼ sec. 8	Z. A. Woods	R. D. Sidey	-	3,536.06	29	12
36	NE¼NW¼ sec. 16	M. M. Cosper	do.	-	3,550.36	27	12
37	Do.	do.	do.	-	3,548.92	38	16
39	Do.	do.	do.	-	-	50	16
42	NE¼NE¼ sec. 21	M. C. M. Campbell	do.	1934	-	93	30

a/ Measuring point was usually top of casing, top of pump base, top of water pipe clamp, or top of well curb.
b/ T, turbine, Cf, centrifugal; B, bucket; G, gas; O, diesel oil; H, hand; number indicates horsepower.

Well records obtained by H. M. Babcock, R. L. Cushman, and R. B. Morrison

No.	Water Level: Depth below measuring point (feet) a/	Water Level: Date of measurement	Pump and power b/	Use of water c/	Temp. °F	Remarks
2	-	-	T,G	I	-	-
5	8.40	April 11, 1946	None	N	68	Driven sandpoint for water-level measurements.
12	24.42	Jan. 20 1946	C,W	D	-	Dug well.
14	36.12	do.	T,G 35	I	-	Estimated discharge, 400 gallons a minute.
21	21 e/	Sept. 1944	T,G 22½	I	-	Reported discharge, 1,000 gallons a minute.
28	18 e/	April 1944	T,G	I	-	Reported discharge, 1,250 gallons a minute with drawdown to 65 feet.
29	-	-	-	I	-	-
30	24.80	April 11, 1946	T,G	I	-	-
30-A	13 e/	March 1944	Cf,G	I	-	Reported discharge 800 gallons a minute.
31	31.48	April 11, 1946	T,O 150	I	-	Discharge, 2,250 gallons a minute. Measured June 1940.
d/ 35	12.18	Nov. 7 1939	T,G 60	I	-	Discharge, 910 gallons a minute, measured June 1940.
36	22.18	April 11 1946	C,H	D	53	Well was drilled for irrigation use.
37	18.16	do.	T,G 60	I	-	-
39	17 e/	-	T,G 85	I	-	Reported discharge 1,000 gallons a minute.
42	58.16	Nov. 7, 1939	C,G 2½	D,I	-	Dug and drilled well.

c/ I, irrigation; D, domestic; S, stock; N, not used.
d/ See Table 3 for water analysis.
e/ Water level reported.

Table 1-Cont. Records of typical domestic and irrigation wells, Duncan Basin, Ariz

No.	Location	Owner	Driller	Date completed	Altitude above sea level (feet)	Depth of well (feet)	Diameter of well (in.)
49	NE$\frac{1}{4}$NW$\frac{1}{4}$ sec. 34	W. M. Zumwalt	- Harris	-	3,593.68	60	8
54	NE$\frac{1}{4}$NW$\frac{1}{4}$ sec. 21	Ernest Campbell	-	-	-	58	12
55	NW$\frac{1}{4}$SW$\frac{1}{4}$ sec. 10	R. Sexton	-	-	-	-	40
56	SW$\frac{1}{4}$NW$\frac{1}{4}$ sec. 21	A. N. Campbell	-	-	-	16	63
	T. 8 S., R. 31 E.						
63	NE$\frac{1}{4}$SE$\frac{1}{4}$ sec. 3	M. W. McKelvey	C. W. Freelove	1939	3,608.51	106	6
66	SW$\frac{1}{4}$NE$\frac{1}{4}$ sec. 11	Franklin Irrigation Dist.	do.	do.	3,622.07	71	20
69	NW$\frac{1}{4}$SE$\frac{1}{4}$ sec. 11	do.	do.	do.	3,624.30	75	20
72	SE$\frac{1}{4}$SE$\frac{1}{4}$ sec. 12	J. C. Campbell	-	1934	3,661.23	60	48
73	NW$\frac{1}{4}$NE$\frac{1}{4}$ sec. 13	R. J. Golding	L. Farrington	1939	-	87	10
75	NE$\frac{1}{4}$SE$\frac{1}{4}$ sec. 13	O. W. Claridge	-	1940	-	53	20
76	SE$\frac{1}{4}$SW$\frac{1}{4}$ sec. 12	Crotts and Stevens	Eugene Clayton	1944	-	76	16
	T. 8 S., R. 32 E.						
92	SW$\frac{1}{4}$SE$\frac{1}{4}$ sec. 17	Raymond Davis	-	1923	3,704.73	71	50
94	NW$\frac{1}{4}$SW$\frac{1}{4}$ sec. 18	J. Hancock	-	-	-	-	12
96	NW$\frac{1}{4}$NW$\frac{1}{4}$ sec. 19	Luis Deane	-	-	3,653.98	30	50
97	NE$\frac{1}{4}$NW$\frac{1}{4}$ sec. 19	F. Francese	-	-	-	50	12
100	SW$\frac{1}{4}$SE$\frac{1}{4}$ sec. 19	W. M. Zumwalt	-	-	3,668.78	36	48
106	SW$\frac{1}{4}$NE$\frac{1}{4}$ sec. 34	Broughton Lunt	-	1936	-	60	12
107	SW$\frac{1}{4}$NW$\frac{1}{4}$ sec. 34	Heaton Lunt	R. D. Sidey	1935	-	64	12
109	SE$\frac{1}{4}$SE$\frac{1}{4}$ sec. 28	do.	do.	-	-	60	12
a/ 111	SE$\frac{1}{4}$SW$\frac{1}{4}$ sec. 28	Franklin Irrigation Dist.	C. W. Freelove	1939	3,671.67	77	20

No.	Water Level: Depth below measuring point (feet) a/	Water Level: Date of measurement	Pump and power b/	Use of water c/	Temp. °F	Remarks
49	53.51	April 11, 1946	C,H	D	61	-
54	-	-	T,G 25	I	-	-
55	-	-	T,G	I	-	Dug and drilled well.
56	-	-	T,G	I	-	Discharge, 300 gallons a minute, measured April 1946.
63	67.37	April 11, 1946	None	N	-	-
66	12.30	Mar. 1 1940	T,O 150	I	53	Discharge, 1,980 gallons a minute, measured 1940.
69	9.68	Jan. 31, 1940	T,O 150	I	65	Discharge, 1,250 gallons a minute, measured 1940.
72	50.32	April 11, 1946	B,H	D	67	Well is bottomed in hard clay.
73	14.50	Oct. 4, 1940	T,G 70	I	-	Reported discharge, 1,800 gallons a minute.
75	-	-	T,G 70	I	-	Discharge, 880 gallons a minute, measured July, 1940
76	16 e/	March 1944	T,O	I	-	Reported discharge, 2,000 gallons a minute.
92	69.84	April 11, 1946	B,H	D	68	Lower part of well is in clay lake beds.
94	-	-	Cf, G 60	I	-	Discharge, 240 gallons a minute, measured July 3, 1940.
96	29.25	April 11, 1946	C,W	D,S	63	Dug well.
97	8.06	May 6, 1940	T,G 70	I	-	Discharge, 690 gallons a minute, measured July 2, 1940.
100	25.65	April 11, 1946	B,H	D	61	Dug well
106	-	-	T,G 60	I	-	Reported discharge, 900 gallons a minute.
107	12 e/	July 1935	T,G 45	I	-	Reported discharge, 1,800 gallons a minute.
109	4.00	March 3, 1941	T,G 40	I	-	Reported discharge, 900 gallons a minute.
d/ 111	11.00	March 13, 1944	T,O 150	I	58	Discharge, 1,350 gallons a minute, measured 1940.

Table 1-Cont. Records of typical domestic and irrigation wells, Duncan Basin, Ariz

No.	Location	Owner	Driller	Date completed	Altitude above sea level (feet)	Depth of well (feet)	Diameter of well (in.)
120	NE¼NW¼ sec. 32	D. E. Wilkins	-	1910	3,691.72	18	40
122	SW¼SE¼ sec. 32	Delbert Meyers	- Berry	-	3,717.00	110	4
124	NW¼NE¼ sec. 33	W. H. T. Cosper	R. D. Sidey	1939	-	66	12
125	SE¼SW¼ sec. 33	V. L. Crotts	-	1900	3,713.91	-	30
126	SW¼SE¼ sec. 33	do.	-	-	-	150	12
d/ 130	SE¼NW¼ sec. 34	G. Moffett	-	-	-	55	12
131	SW¼NE¼ sec. 34	Franklin Irrigation Dist.	C. W. Freelove	1939	3,696.30	92	20
132	NE¼SW¼ sec. 34	G. Lunt	-	-	3,696.32	-	18
133	SE¼SW¼ sec. 34	Floyd McDaniels	-	-	3,689.61	32	36
134	NW¼SE¼ sec. 34	G. Lunt	-	-	3,693.50	50	12
136	SE¼NE¼ sec. 34	Franklin Irrigation Dist.	C. W. Freelove	1939	3,726.64	89	20
146	NE¼SE¼ sec. 34	Valley Canal Co.	Eugene Clayton	1944	-	64	20
147	SE¼NE¼ sec. 34	Broughton Lunt	-	do.	-	85	20
148	NE¼SE¼ sec. 19	Black & McCleskey Canal Company	Blackie Gross	do.	-	74	20
149	NW¼NW¼ sec. 28	W. Lunt	-	-	-	-	16
150	NW¼SW¼ sec. 17	S. W. Coon	George Liverman	1945	-	80	16
151	SW¼SE¼ sec. 18	do.	D. Lloyd	1944	-	67	16
152	SE¼NW¼ sec. 29	B. Lunt	-	do.	-	50	20
	<u>T. 9 S., R. 32 E.</u>						
153	SE¼NW¼ sec. 4	Chas. Scadlock	-	1945	-	71	8
160	NE¼NE¼ sec. 3	Franklin Irrigation Dist.	C. W. Freelove	1939	3,693.96	77	20
161	Do.	do.	do.	do.	3,693.97	80	20

No.	Water Level: Depth below measuring point (feet) a/	Water Level: Date of measurement	Pump and power b/	Use of water c/	Temp. °F	Remarks
120	10.61	April 11, 1946	C,H	S	54	Dug well.
122	25.13	do.	C,H	D,S	66	-
124	16 e/	-	T,G 27	I	-	Discharge, 980 gallons a minute, measured July 10, 1941.
125	23.20	April 11, 1946	B,H	S	-	Dug well.
126	25.10	April 29, 1940	T,G 60	I	-	Discharge 170 gallons a minute, measured July, 1940.
d/ 130	-	-	Cf,G 60	I	61	Discharge, 450 gallons a minute, measured August, 1940.
131	20.54	Feb. 1, 1945	T,O 150	I	64	Discharge 1,850 gallons a minute, measured March 1941.
132	18.20	Feb. 26 1941	T,G 75	I	-	Discharge, 890 gallons a minute, measured June 4, 1940.
133	10.46	April 11, 1946	Cf,G	I	-	Dug well.
134	13.80	Mar. 5, 1941	T,G 60	I	-	-
136	45.76	April 11, 1946	T,D 150	I	-	-
146	25 e/	May 1944	T,G	I	-	Discharge, 1,100 gallons a minute, measured April 11, 1946.
147	-	-	T,G	I	-	-
148	14 e/	Feb. 21 1944	T,G 55	I	-	Discharge, 1,600 gallons a minute, measured April 11, 1946.
149	-	-	T,G	I	-	-
150	50 e/	Sept. 1945	T,G 5	I	-	Reported discharge, 200 gallons a minute.
151	18 e/	July 1944	T,G 35	I	-	Reported discharge, 1,500 gallons a minute.
152	-	-	T,G	I	-	-
153	30 e/	Jan. 1945	T,E 3	I	-	Located in town of Franklin
160	9.61	Jan. 20, 1946	T,O 150	I	-	-
161	10.21	do.	T,O 150	I	-	-

Table 1-Cont. Records of typical domestic and irrigation wells, Duncan Basin, Ari

No.	Location	Owner	Driller	Date completed	Altitude above sea level (feet)	Depth of well (feet)	Diameter of well (in.)
162	NE$\frac{1}{4}$NE$\frac{1}{4}$ sec. 3	Franklin Irrigation Dist.	C. W. Freelove	1939	3,703.60	89	20
d/ 171	NE$\frac{1}{4}$NW$\frac{1}{4}$ sec. 9	-	-	1938	3,744.00	38	36
172	NE$\frac{1}{4}$NW$\frac{1}{4}$ sec. 4	Crotts and Odell	Eugene Clayton	1944	-	61	10
173	Do.	V. L. Crotts	do.	do.	-	69	12
174	SE$\frac{1}{4}$NW$\frac{1}{4}$ sec. 4	O. G. O'Dell	Frank Starkey	do.	-	60	10

a/ Measuring point was usually top of casing, top of pump base, top of water pipe clamp, or top of well curb.

b/ T, turbine, Cf, centrifugal; B, bucket; G, gas; O, diesel oil; H, hand; number indicates horsepower.

No.	Water Level: Depth below measuring point (feet) a/	Water Level: Date of measurement	Pump and power b/	Use of water c/	Temp. °F	Remarks
162	22.24	April 11, 1946	T,O 150	I	-	-
d/ 171	36.12	do.	B,H	D	67	Dug well.
172	24 e/	1944	T,G	I	-	Reported discharge, 700 gallons a minute.
173	30 e/	do.	T,G	I	-	Reported discharge, 600 gallons a minute.
174	35 e/	Dec. 1944	T,G 30	I	-	Reported discharge, 500 gallons a minute.

c/ I, irrigation; D, domestic; S, stock; N, not used.
d/ See Table 3 for water analysis
e/ Water level reported.

Table 2. Water pumped from wells, Duncan Basin, Arizona 1940-1945.

	1940	1941	1942	1943	1944	1945
Acre-feet	2,436	1,348	1,600	6,800	8,600	6,500

Table 3. Analyses of typical ground waters, Duncan Basin, Arizona
(Well numbers correspond to numbers on plate 1.
Analyses by John D. Hem
Chemical constituents in parts per million.)

Well Number	35	111	130	171
Depth, feet	29	77	55	381
Date sampled	10-3-40	8-7-40	10-1-40	10-21-40
Specific conductance ($K \times 10^5$ at 25°C)	54	99	141	222
Calcium (Ca)	56	83	62	45
Magnesium (Mg)	14	25	27	39
Sodium and potassium (Na+K)	42	109	210	436
Bicarbonate (HCO_3)	248	397	331	295
Sulfate (SO_4)	53	153	368	893
Chloride (Cl)	22	44	45	15
Fluoride (F)	-	-	2.0	3.5
Nitrate (NO_3)	-	-	-	24
Dissolved solids	309	610	877	1601
Total hardness as $CaCO_3$	197	310	266	273
Percent sodium	32	43	63	78

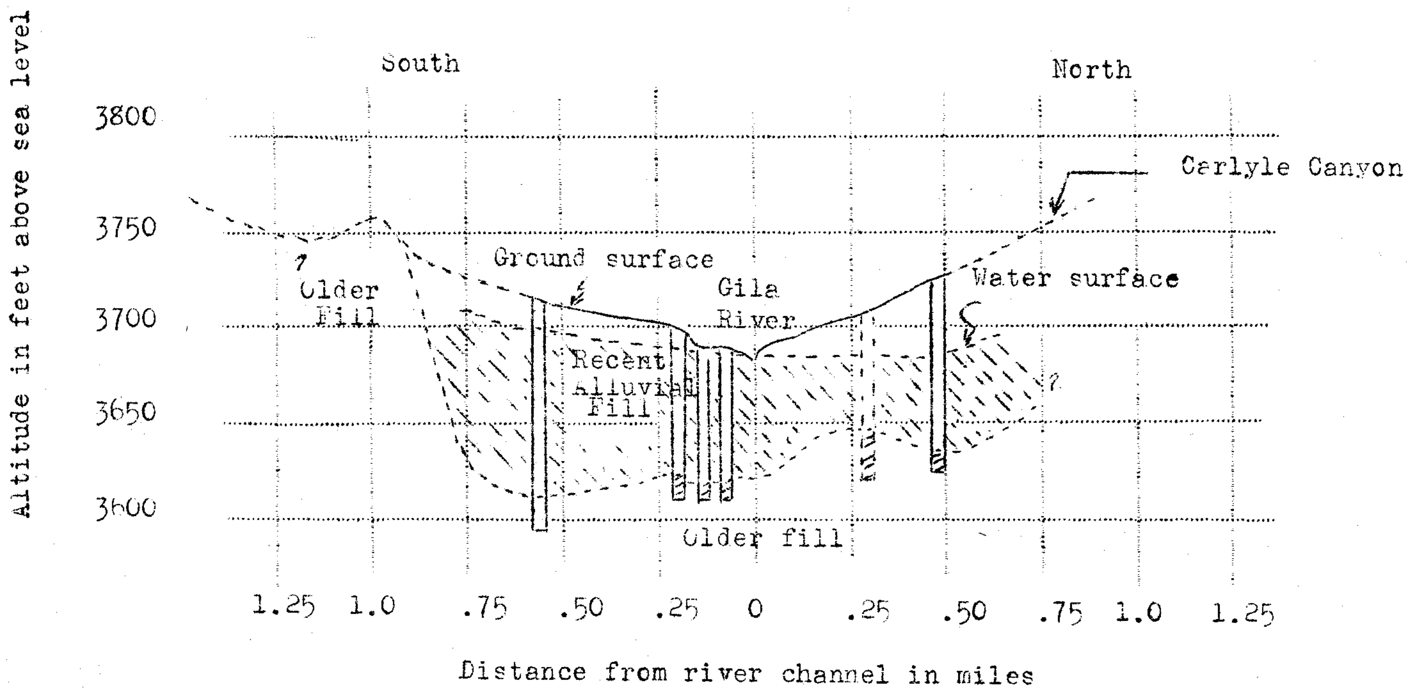

FIGURE 1

CROSS SECTION THROUGH GILA RIVER FLOOD PLAIN
DUNCAN - VIRDEN VALLEY

Section taken along Arizona - New Mexico line

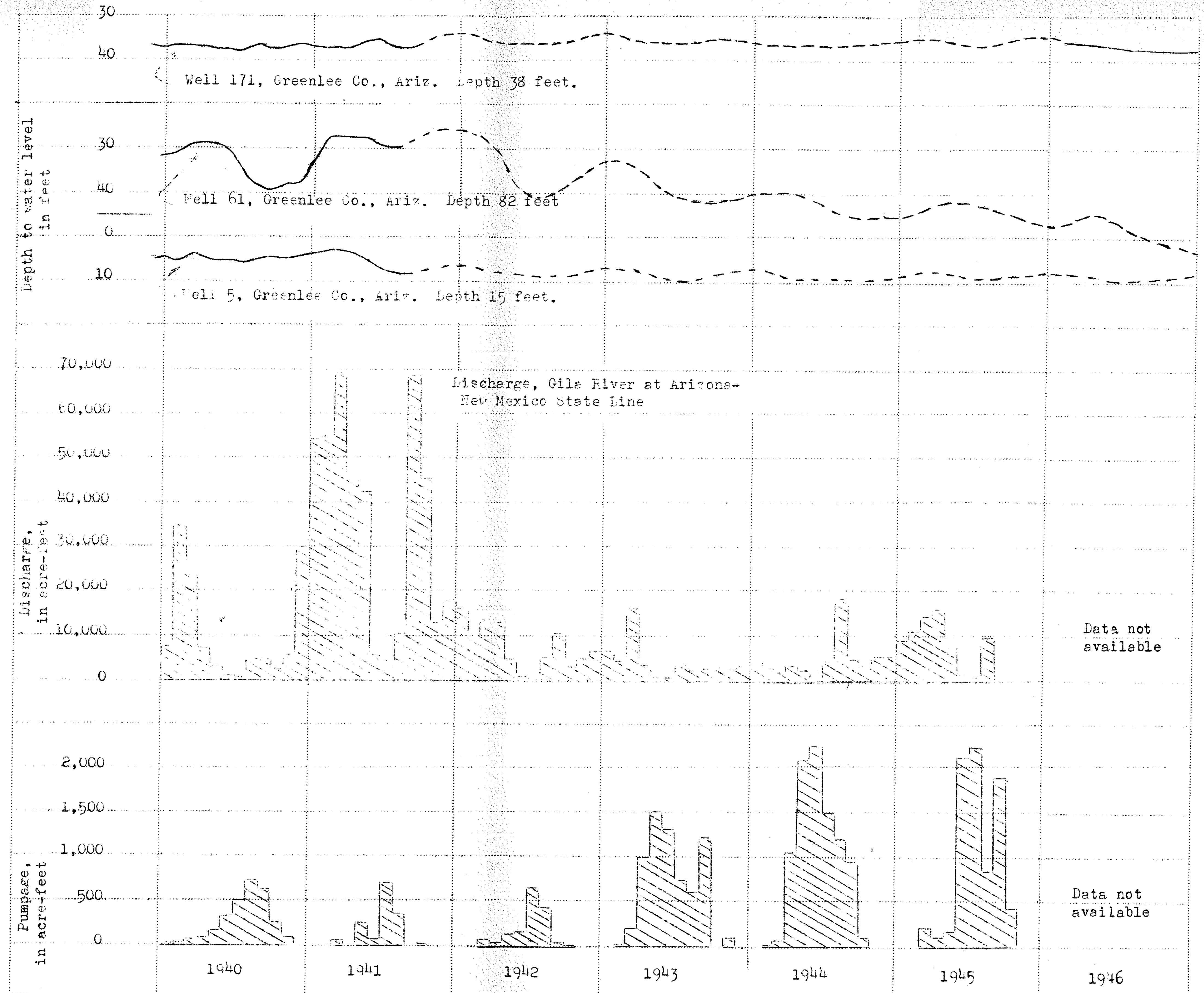

Figure 2. Graphs showing fluctuations of water level in observation wells, runoff at State line in acre-feet, and water pumped for irrigation in acre-feet, Duncan Basin, Greenlee County, Arizona.

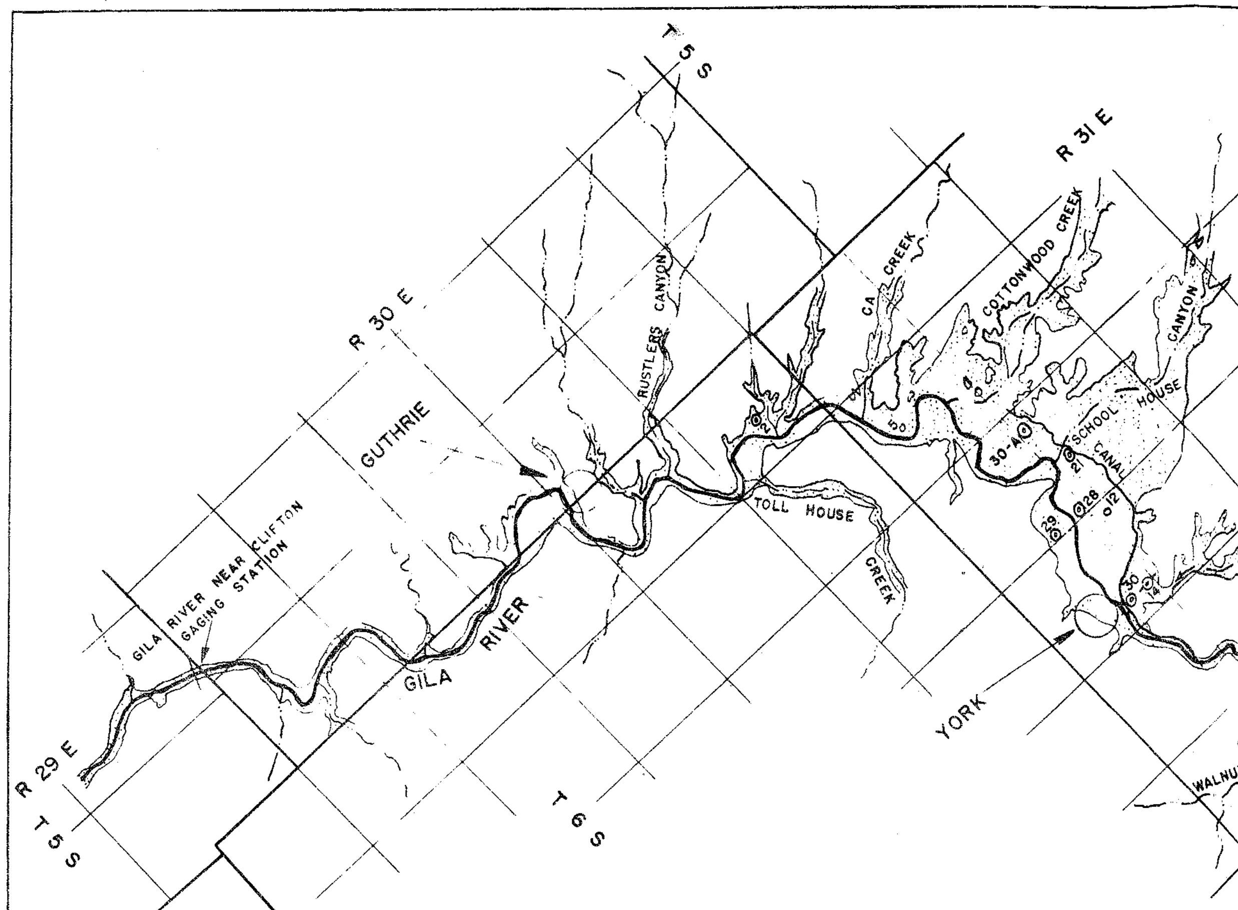

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PLATE I. MAP OF DUNCAN VALLEY, ARIZONA

SHOWING LOCATION OF WELLS USED FOR IRRIGATION AND WATER LEVEL OBSERVATION AND ALLUVIAL FILL OF INNER VALLEY.

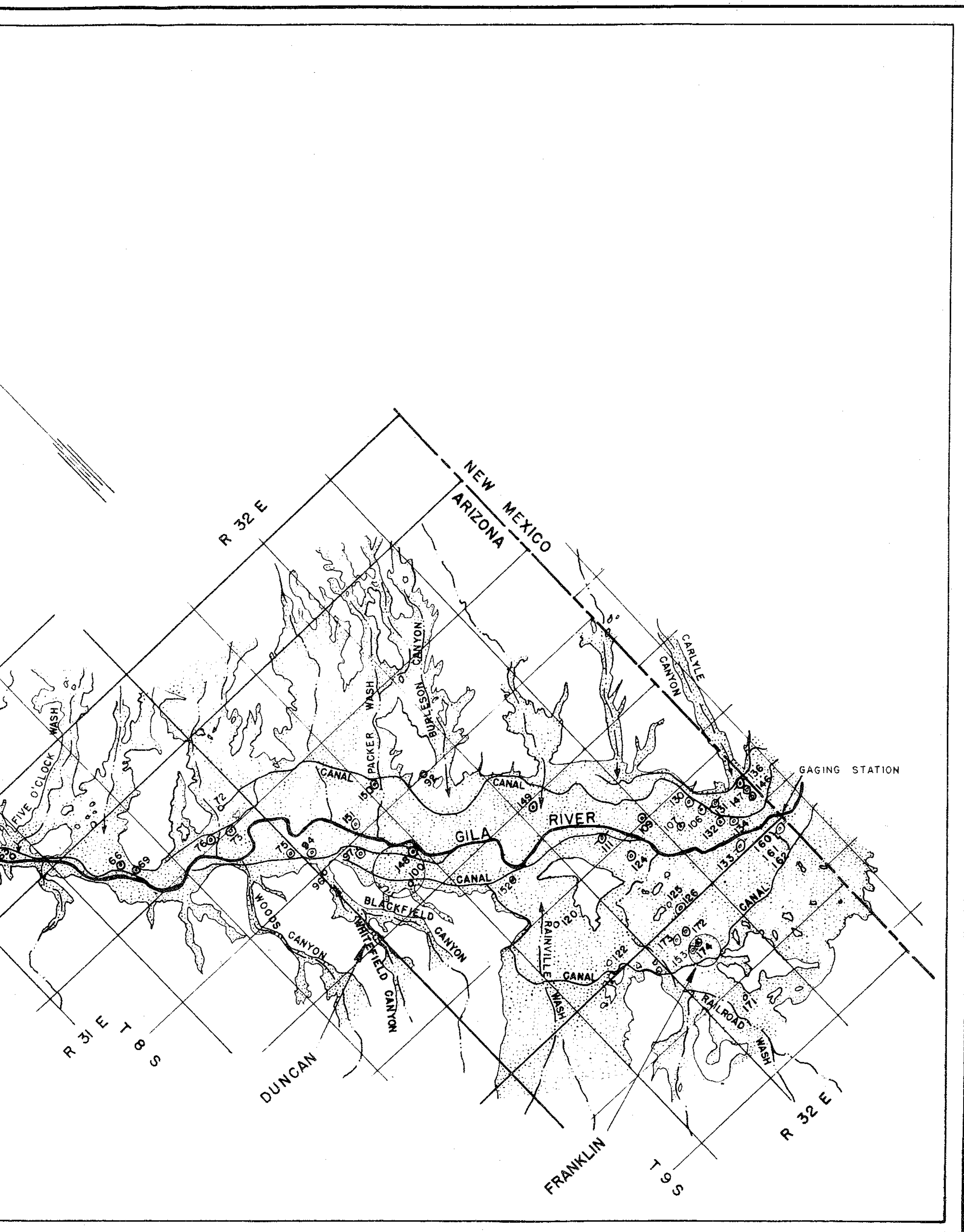
SCALE

1 0 1 2 MILES

EXPLANATION

- ◎ IRRIGATION WELL
- -◎- IRRIGATION WELL USED FOR OBSERVATION OF WATER LEVEL
- o DOMESTIC WELL USED FOR OBSERVATION OF WATER LEVEL
- (stippled) ALLUVIAL FILL OF INNER VALLEY


T 6 S
CANYON
HOUSE
YORK CREEK
APACHE CREEK
STOVE WASH
CANAL
BITTER CREEK
CHINA CAMP CREEK
GOAT CAMP CREEK
SANDIA WASH
WALNUT CREEK
T 7 S
R 32 E
FIVE O'CLOCK WASH
PACKER WASH
GILA RIVER
SHELDON WASH
SHELDON
WOODS CANYON
DUNCAN
R 31 E
T 8 S
RIZONA
LES


NEW MEXICO
ARIZONA
R 32 E
CARLYLE CANYON
GAGING STATION
PACKER WASH
BURLESON CANYON
FIVE O'CLOCK WASH
CANAL
GILA RIVER
WOODS CANYON
BLACKFIELD CANYON
WHITEFIELD CANYON
RAINVILLE WASH
RAILROAD WASH
R 31 E
T 8 S
DUNCAN
FRANKLIN
T 9 S
R 32 E

RLN
11481

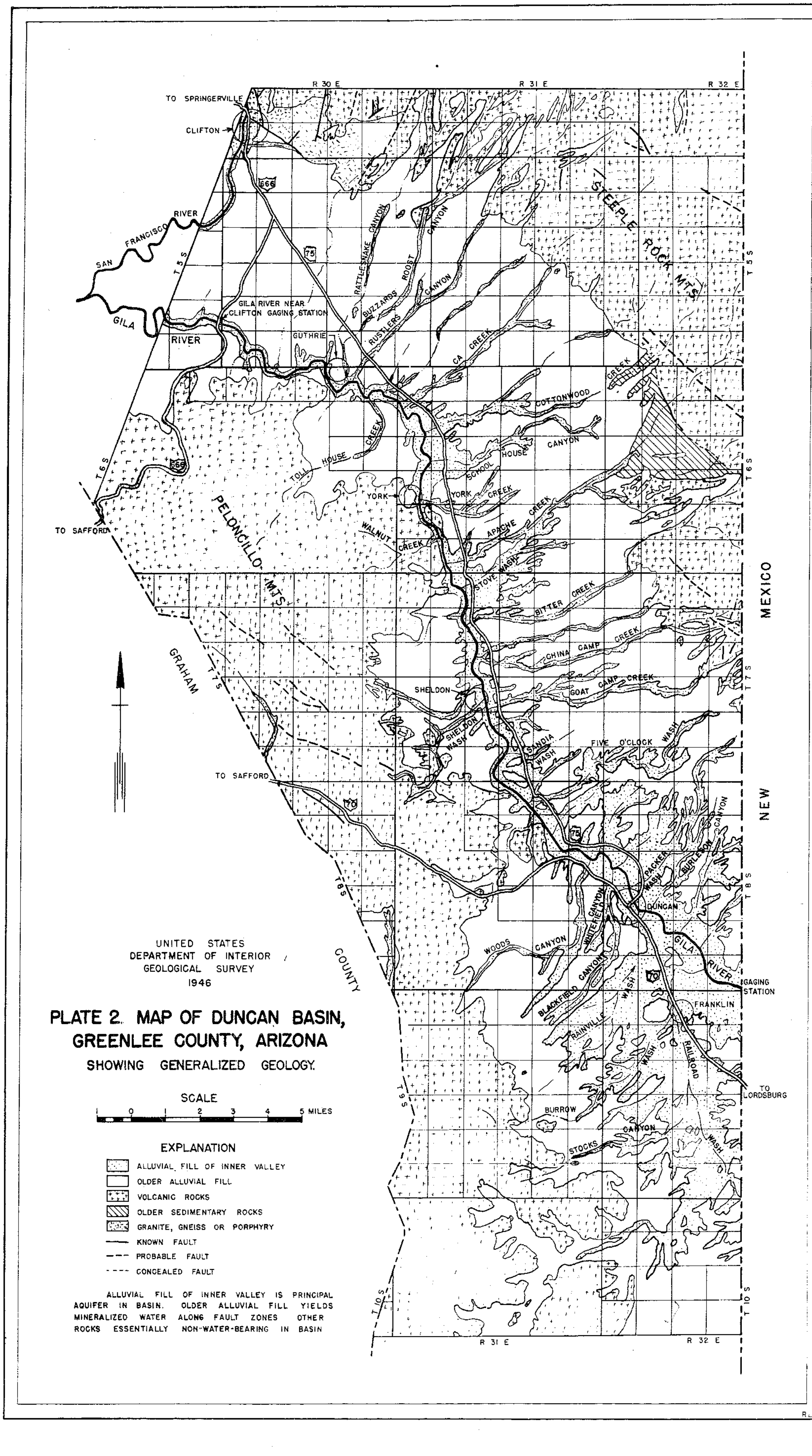


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PLATE 2. MAP OF DUNCAN BASIN, GREENLEE COUNTY, ARIZONA

SHOWING GENERALIZED GEOLOGY.

SCALE

1 0 1 2 3 4 5 MILES

EXPLANATION

- ALLUVIAL FILL OF INNER VALLEY
- OLDER ALLUVIAL FILL
- VOLCANIC ROCKS
- OLDER SEDIMENTARY ROCKS
- GRANITE, GNEISS OR PORPHYRY
- KNOWN FAULT
- PROBABLE FAULT
- CONCEALED FAULT

ALLUVIAL FILL OF INNER VALLEY IS PRINCIPAL AQUIFER IN BASIN. OLDER ALLUVIAL FILL YIELDS MINERALIZED WATER ALONG FAULT ZONES OTHER ROCKS ESSENTIALLY NON-WATER-BEARING IN BASIN