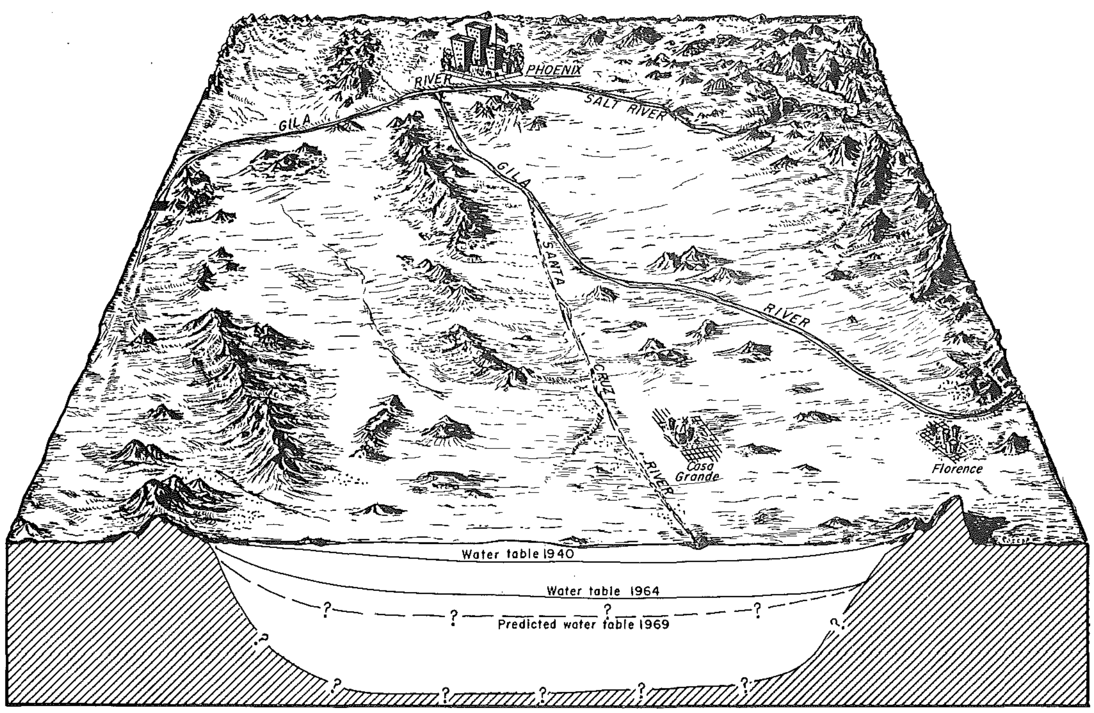
WATER RESOURCES REPORT NUMBER SIXTEEN

ARIZONA STATE LAND DEPARTMENT

OBED M. LASSEN, COMMISSIONER

EFFECTS OF GROUND-WATER WITHDRAWAL IN PART OF CENTRAL ARIZONA PROJECTED TO 1969

BY
NATALIE D. WHITE, R.S. STULIK, AND CLARA L. RAUH



PREPARED BY THE GEOLOGICAL SURVEY,
UNITED STATES DEPARTMENT OF THE INTERIOR

Phoenix, Arizona
July 1964

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EFFECTS OF GROUND-WATER WITHDRAWAL IN PART OF CENTRAL ARIZONA PROJECTED TO 1969

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Natalie D. White, R. S. Stulik, and Clara L. Rauh

ABSTRACT

The agricultural economy of Arizona is greatly dependent on ground-water supplies. About two-thirds of the State's water needs is supplied by ground water, and about 90 percent of the ground water pumped in the State is used to grow crops. Most of the ground water used is being withdrawn from storage; the water levels are declining and the ground-water reservoirs gradually are being depleted.

The study area, which consists of the Salt River Valley and that part of the lower Santa Cruz basin and the adjacent area along the Gila River within Pinal County, accounts for about 75 percent of the ground water pumped in the State. The effect of ground-water withdrawal in the area is a regional lowering of the water table. The historical data—water-level measurements and ground-water pumpage—have been used to predict the status of the ground-water reservoir for 1969. These predictions are shown in the form of depth-to-water maps for this future date. The method used to make the predictions consisted mainly of determining past trends in ground-water conditions, as indicated by water-level changes in individual wells, and projecting these trends to the year 1969. The projections were based on the assumption that ground-water pumpage during the next 5 years (spring 1964 to spring 1969) will continue at about the same annual rate as during the last few years.

In the Salt River Valley, the depth to water in the spring of 1964 ranged from only a few feet to more than 500 feet below land surface. Depth to water is shallowest near the Salt and Gila Rivers and deepest along the edges of the valley and in areas of concentrated pumping. The same general pattern predominates for the predicted 1969 depth to water; however, the predicted minimum depth to water is slightly less than 50 feet, and the maximum is more than 500 feet in several parts of the area.

In the lower Santa Cruz basin the depth to water is shallowest near the Gila River and deepest in the areas of concentrated pumping. In 1969 the predicted depth to water along the Gila River is from 50 to 100 feet below land surface; the predicted depth to water is more than 550 feet southwest of Stanfield in spring 1969.

INTRODUCTION

The ever increasing use of ground water in the highly developed agricultural areas of Arizona has created the need for more specialized studies of the results of ground-water withdrawal. In nearly all areas where ground water is used extensively to irrigate crops, the rate of withdrawal is greatly in excess of the rate of replenishment. Thus, most of the ground water used is being withdrawn from storage; the water levels are declining and the ground-water reservoirs are being depleted. To what extent and for how long these conditions can continue without adverse effects on the economy of Arizona are not known.

The agricultural economy of Arizona is greatly dependent on ground-water supplies. About two-thirds of the State's entire water needs is supplied by ground water, and about 90 percent of the ground water pumped in the State is used to grow crops.

Purpose and Scope of the Study

Many factors are involved in the effect of the withdrawal of ground water on an aquifer; but, the most important ones probably are the characteristics that determine the ability of the aquifer to store and transmit water. The ability of the aquifer to store water (coefficient of storage) is important on a long-term basis because it determines the amount of water available for use from a given section of saturated material. The ability of the aquifer to transmit water (coefficient of transmissibility) has a more immediate effect because it determines the yield of wells. Transmissibility and the coefficient of storage determine the amount of lowering of the water level resulting from the withdrawal of a given amount of water from an aquifer. Whenever water is withdrawn from an aquifer, water levels are lowered near the discharging well. Water is removed from storage concurrently with the lowering of water levels; thus, a cone of depression is formed in the water table. Expansion of the cone and removal of water from storage must continue until recharge is increased, natural discharge decreased, or a combination of both by an amount equal to the rate of pumping the well. Development of the cone is determined by the rate at which water moves through the aquifer, by the storage coefficient of the aquifer, and by the aquifer boundaries. The radius of the cone at any given time is inversely proportional to the square root of the coefficient of storage of the aquifer; the depth of the cone, but not its rate of lateral growth, is affected by the rate of discharge of a single well or a closely spaced group of wells. When many wells are pumped in an area, the cones of depression will in time overlap, which will result in a regional lowering of the water table. If the pumping of wells continues at a rate in excess of any possible increase in recharge or decrease in natural discharge, then the only source of the water is continued removal from storage and expansion and deepening of the regional cone of depression. It is the magnitude of this effect that must be determined in order to properly manage and control the ground-water resources of an area.

This investigation is a pilot study and was undertaken to determine the feasibility of making predictions of the future effects of ground-water withdrawal with the data available; it is the first attempt to make such predictions for any area in Arizona.

In general, the effect of ground-water withdrawal in the study area at the present time is the regional lowering of the water table. Water levels have been measured and the amount of ground water pumped has been calculated for this area for many years. These historical data have been used to predict the status of the ground-water reservoir for 1969. The predictions are shown in the form of depth-to-water maps for this future date.

The method used to make the predictions consists mainly of determining past trends in ground-water conditions, as indicated by water-level changes in individual wells, and projecting these trends into the future. The projections were based on an hypothesized regimen of ground-water withdrawal.

The amount of ground water pumped annually in the study area has been about the same for the last few years; therefore, for purposes of projecting the effects of the withdrawal it was assumed that this rate will continue during the next 5 years (spring 1964 to spring 1969). It must be considered, however, that any deviation from the hypothesized set of conditions will directly affect the amount of change in the water levels in the aquifer. Further, any differences in the composition and texture of the subsurface materials at greater depths would affect the rate of change in the water levels for a given amount of withdrawal of water. For example, if the declining water table encounters a clay lens or any less permeable material, less water will be available for the same amount of decline in water level or the water level will decline at a faster rate for the same amount of withdrawal. Changes in the chemical quality of the water at greater depths must also be considered in the appraisal of future conditions. If water of poorer quality is encountered in the aquifer, the effect might be a shift of pumping to another area or the pumping of larger amounts of water to leach away the effects of the use of water of poor quality on the cropland. All these factors directly affect the accuracy of the predictions made in this study.

Location and Extent of the Area

The study area consists principally of the Salt River Valley and that part of the lower Santa Cruz basin and the adjacent area along the Gila River in Pinal County (fig. 1). The area is in the Basin and Range lowlands province and, in general, may be described as a broad flat valley surrounded by mountain masses ranging in height from a few hundred to as much as 3,000 feet above the alluvial valley. The overall difference in altitude of the valley lands from the highest to the lowest point is only about 800 feet.

The lower Santa Cruz basin and the Salt River Valley meet in a common boundary along the Gila River. The two areas constitute a single hydrologic system; however, a ground-water divide is formed over a buried ridge roughly paralleling the Gila River. For convenience, current ground-water conditions and predictions for 1969 will be discussed separately for the Salt River Valley and the lower Santa Cruz basin and the adjacent area along the Gila River.

Previous Investigations

Several studies for the Salt River Valley and the lower Santa Cruz basin have been reported in the literature.

1905. Lee, W. T., Underground waters of Salt River Valley, Arizona: U. S. Geol. Survey Water-Supply Paper 136, 196 p.

1943. Turner, S. F., and others, Ground-water resources of the Santa Cruz basin, Arizona: U. S. Geol. Survey open-file report, 84 p., 3 pls., 4 figs.

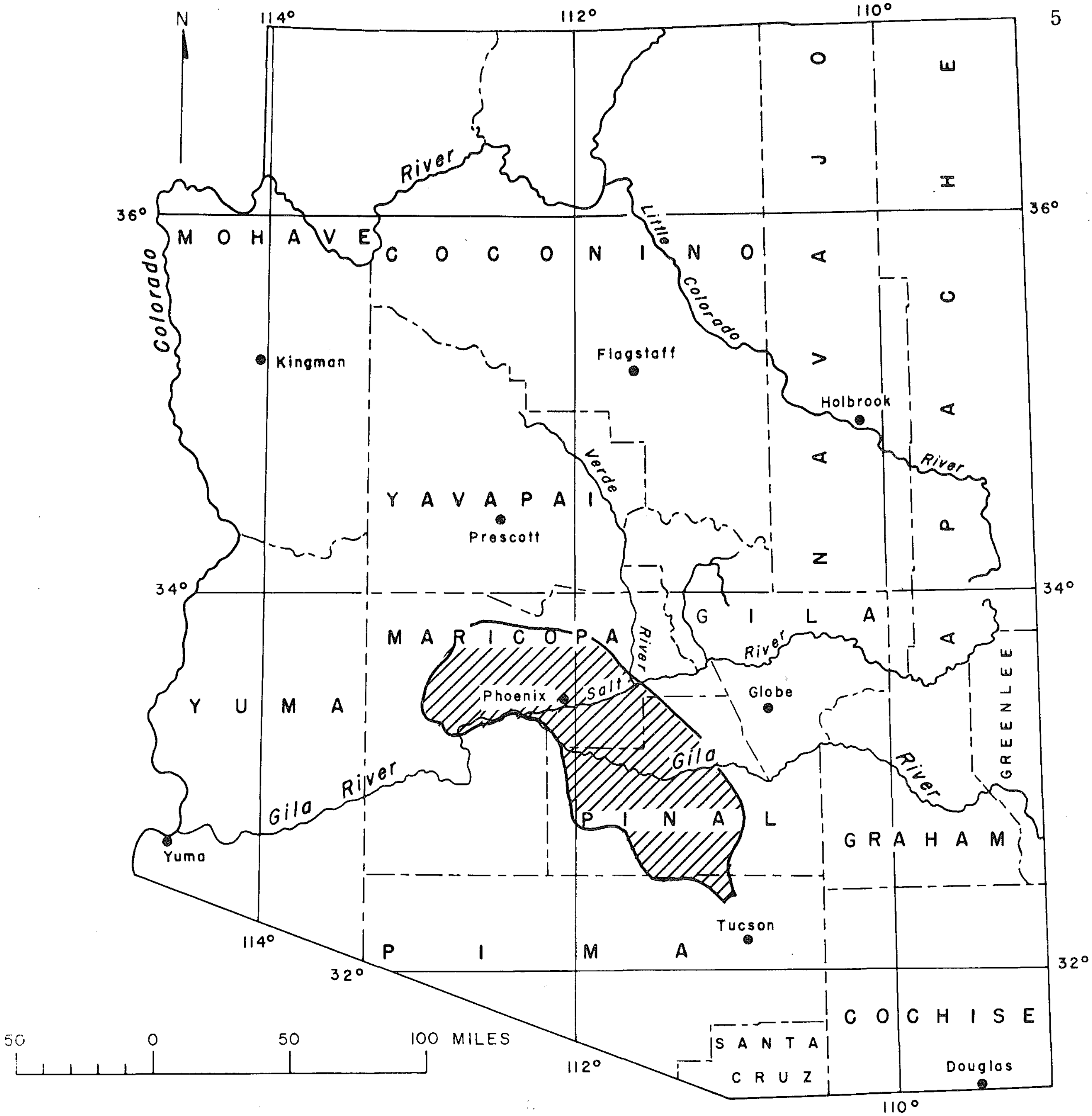

Figure 1.--Map of Arizona showing the area of study.

1947. McDonald, H. R., Wolcott, H. N., and Hem, J. D., Geology and ground-water resources of the Salt River Valley area, Maricopa and Pinal Counties, Arizona: U. S. Geol. Survey open-file report, 45 p., 4 pls., 3 figs., 7 tables.

1947. Turner, S. F., and others, Further investigations of the ground-water resources of the Santa Cruz basin, Arizona: U. S. Geol. Survey open-file report, 7 p., 4 figs., 4 tables.

1952. Cushman, R. L., Lower Santa Cruz area, Pima and Pinal Counties, in Ground water in the Gila River basin and adjacent areas, Arizona—a summary, by L. C. Halpenny and others: U. S. Geol. Survey open-file report, p. 115-136.

1952. Hem, J. D., The "salt balance" concept and its application to the Salt River Valley area, Arizona, in Ground water in the Gila River basin and adjacent areas, Arizona—a summary, by L. C. Halpenny and others: U. S. Geol. Survey open-file report, p. 147-149.

1952. Wolcott, H. N., Salt River Valley area, Maricopa and Pinal Counties, in Ground water in the Gila River basin and adjacent areas, Arizona—a summary, by L. C. Halpenny and others: U. S. Geol. Survey open-file report, p. 137-146, 4 pls., 2 tables.

In addition to the above reports, a comprehensive study of the water resources of the area has been completed recently, and the report describing the results is in review. Among other detailed analyses of the ground-water conditions, the report gives an evaluation of the amount of ground water available from storage in the area.

In addition to the foregoing, current ground-water conditions in both areas are discussed in the "Annual report on ground water in Arizona."

HYDROLOGIC SETTING

The hydrology of the study area is typical of that throughout the Basin and Range lowlands province of central and southern Arizona. Topographically the area is typically a broad, relatively flat valley whose floor is surrounded and, in a few places, pierced by rugged mountain masses. The lower Santa Cruz basin is drained by the Gila and Santa Cruz Rivers and by small washes emerging from the mountains. The Salt River Valley is drained principally by the Salt, Agua Fria, and Hassayampa Rivers, but a small part on the east and south is drained by the Gila River.

Ground Water

The most important source of ground water in the area is the alluvial fill, which is from a few hundred to several thousand feet thick. The principal aquifers in the alluvial fill are permeable lenses of sand and gravel interfingered with relatively impermeable lenses of clay and silt. Water-bearing beds of sand and gravel occur at many depths, and a single well may penetrate several water-bearing strata. The aquifers generally are interconnected, and a single water table is common in most of the area, although recent data indicate that in part of the area water-bearing beds may be present at considerable depth below a relatively impermeable silt and clay lens. Data are insufficient at the present time to determine the extent or the characteristics of this aquifer.

The movement of ground water is always in the direction of the slope of the water table. Prior to extensive development of ground water in the valley area, the slope of the water table conformed in general to that of the land surface. The depth to water is greater near the mountains than in the central part of the valley because, toward the mountain fronts, the slope of the land surface is considerably greater than that of the water table. In several places the natural pattern of movement has been disrupted by pumping; in a few places the natural direction of movement has been reversed, and ground water is moving into cones of depression that have resulted from extensive withdrawal.

The area described in this study accounts for about 75 percent of the ground water pumped in the State. In the last 5 years, spring 1959 to spring 1964, about 16 million acre-feet of ground water was withdrawn from the aquifer underlying the area.

Surface Water

Some surface water is used for irrigation in parts of the study area. The total amount of surface water available in any given year affects the amount of ground water needed to irrigate the valley lands.

A reservoir system on Salt River at and below Roosevelt Dam (sec. 20, T. 4 N., R. 12 E.) provides storage for 1,755,000 acre-feet of water. The system consists of four storage reservoirs created by four dams on Salt River: Roosevelt Lake, formed by Roosevelt Dam; Apache Lake, formed by Horse Mesa Dam, 17 miles downstream from Roosevelt Dam; Canyon Lake, formed by Mormon Flat Dam, 27 miles downstream from Roosevelt Dam; and Saguaro Lake, formed by Stewart Mountain Dam, 37 miles downstream from Roosevelt Dam. In addition, a reservoir system on Verde River consisting of two storage reservoirs created by Horseshoe and Bartlett Dams provides storage for 322,300 acre-feet of water. Water from both systems is used for irrigation in the Salt River Valley. During the last 5 years (spring 1959 to spring 1964), about 3,600,000 acre-feet of water was diverted at Granite Reef Dam downstream from the two reservoir systems for use in the Salt River Valley.

The San Carlos Reservoir, formed by Coolidge Dam on the Gila River, provides storage for 1,206,000 acre-feet of water. From spring 1959 to spring 1964, about 832,000 acre-feet of water was released for irrigation use on the San Carlos Project in part of the lower Santa Cruz basin and the adjacent area along the Gila River.

The preceding paragraphs show that about 4,400,000 acre-feet of surface water was diverted for irrigation use in the study area from 1959 to 1964.

APPRAISAL OF GROUND-WATER CONDITIONS

The importance of ground water to the development and economy of the study area can be shown by a comparison of the use of ground water and surface water in recent years. In the preceding sections it was stated that during the last 5 years about 16 million acre-feet of ground water was used, but only about 4.4 million acre-feet of surface water was diverted for use. Thus, four-fifths of all water used in the area was ground water.

The current status of the ground-water reservoir in the study area is the result of many years of agricultural development and the accumulative effects of large-scale withdrawal of ground water. Some agricultural lands were irrigated with surface water in the Salt River Valley and the lower Santa Cruz basin in the 1800's and to some extent in prehistoric times. It was not until the early 1900's, however, that ground water was used to irrigate crops. For the most part, development in the two areas has been parallel.

In the Salt River Valley about 36,000 acre-feet of ground water was pumped from wells in 1904 (Lee, 1905). By 1920, a water-logging problem existed in a large part of the area, and wells were drilled to lower the water table. Subsequently, these wells were used to pump water for supplemental irrigation, and the water table began to decline. In 1922, more than 100,000 acre-feet of ground water was pumped for irrigation (McDonald, Wolcott, and Hem, 1947), and the amount pumped annually has continued to increase since that time resulting in a continuing downward trend of the water table.

In the lower Santa Cruz basin the first irrigation wells were drilled in 1914; by 1920, 140 irrigation wells were in use. In the early 1940's and with the beginning of World War II, there were large increases in agricultural development, and in 1942 about 170,000 acres of land was cultivated in the area. Hundreds of new wells were drilled and water levels began to decline at a rapid rate. The decline of the water levels has continued to the present, although few new wells have been drilled since 1956.

Salt River Valley

The Salt River Valley (fig. 2) is comprised of the valley lands near Phoenix, tributary valleys such as Paradise and Deer Valleys, lands west of the Hassayampa River, and the lower reaches of Centennial Wash. The Salt River Valley is divided into the following subareas (fig. 2): (1) Queen Creek-Higley-Gilbert-Magma area, (2) Tempe-Mesa-Chandler area, (3) Phoenix-Glendale-Tolleson-Deer Valley area, (4) Paradise Valley area, (5) Litchfield Park-Beardsley-Marinette area, (6) Liberty-Buckeye-Hassayampa area, (7) lower Hassayampa-Tonopah area, and (8) lower Centennial area.

In the Salt River Valley the direction of ground-water movement conforms, in general, to the direction of slope of the land surface. In several places the natural direction of movement has been altered, and ground water is now moving toward major cones of depression, which were caused by intensive ground-water withdrawals. As of the spring of 1964, there were three such depressions in the area—northeast of Gilbert, in Deer Valley, and northwest of Litchfield Park. Ground water in the eastern part of the valley is moving toward the depression northeast of Gilbert. In the central part of the valley most ground water moves toward the west; however, some water moves toward the depression in Deer Valley. In the northwestern part of the Salt River Valley most ground water moves southward toward the depression; northwest of Litchfield Park, however, some water moves toward the depression in Deer Valley. In the Liberty-Buckeye-Hassayampa area ground-water movement is generally in a southwest direction paralleling the Gila and Salt Rivers. There is some movement of ground water from this area toward the depression near Litchfield Park. In the area west of the Hassayampa River, ground water generally moves southward toward Gillespie Dam, and some water moves toward the small cone of depression southeast of Tonopah.

The depth to water in the Salt River Valley in the spring of 1964 ranged from only a few feet to more than 500 feet below land surface (fig. 3). Topography, lithology, and areal concentration of pumping are the main factors that control depth to water. Depth to water is shallowest near the Salt and Gila Rivers, and deepest along the edges of the valley and in areas of concentrated pumping. Water levels frequently are shallow near the canals, due to recharge from the canals.

During the last few years, pumping of ground water in the Salt River Valley has averaged about 2,200,000 acre-feet annually. The prediction of the depth to water for the spring of 1969 is based on the assumption that this rate of withdrawal will continue in the next 5 years (spring 1964 to spring 1969).

In general, ground-water conditions vary somewhat in the subareas of the Salt River Valley. Consequently, the subareas will be discussed separately in the following paragraphs.

Queen Creek-Higley-Gilbert-Magma area.--Water levels in the Queen Creek-Higley-Gilbert-Magma area continue to reflect the previously observed downward trend of the water table. From spring 1959 to spring 1964, water-level changes ranged from small rises southeast of Chandler to declines of more than 60 feet in the areas northeast of Mesa and north of Magma (fig. 2). As in previous years, the decline of the water table appears to be slight in the southwest part of the area. However, the measured water surface in a part of this area may be that of a perched water table that is recharged by seepage from nearby canals. This perched water table is the probable source of the water that cascades into irrigation wells in this part of the area. In the past the cascading water has caused erroneous water-level measurements; therefore, the rate of decline of the true water table is not accurately known. In this part of the area, however, ground water is used only to supplement surface water for irrigation, so the rate of decline probably is not excessive.

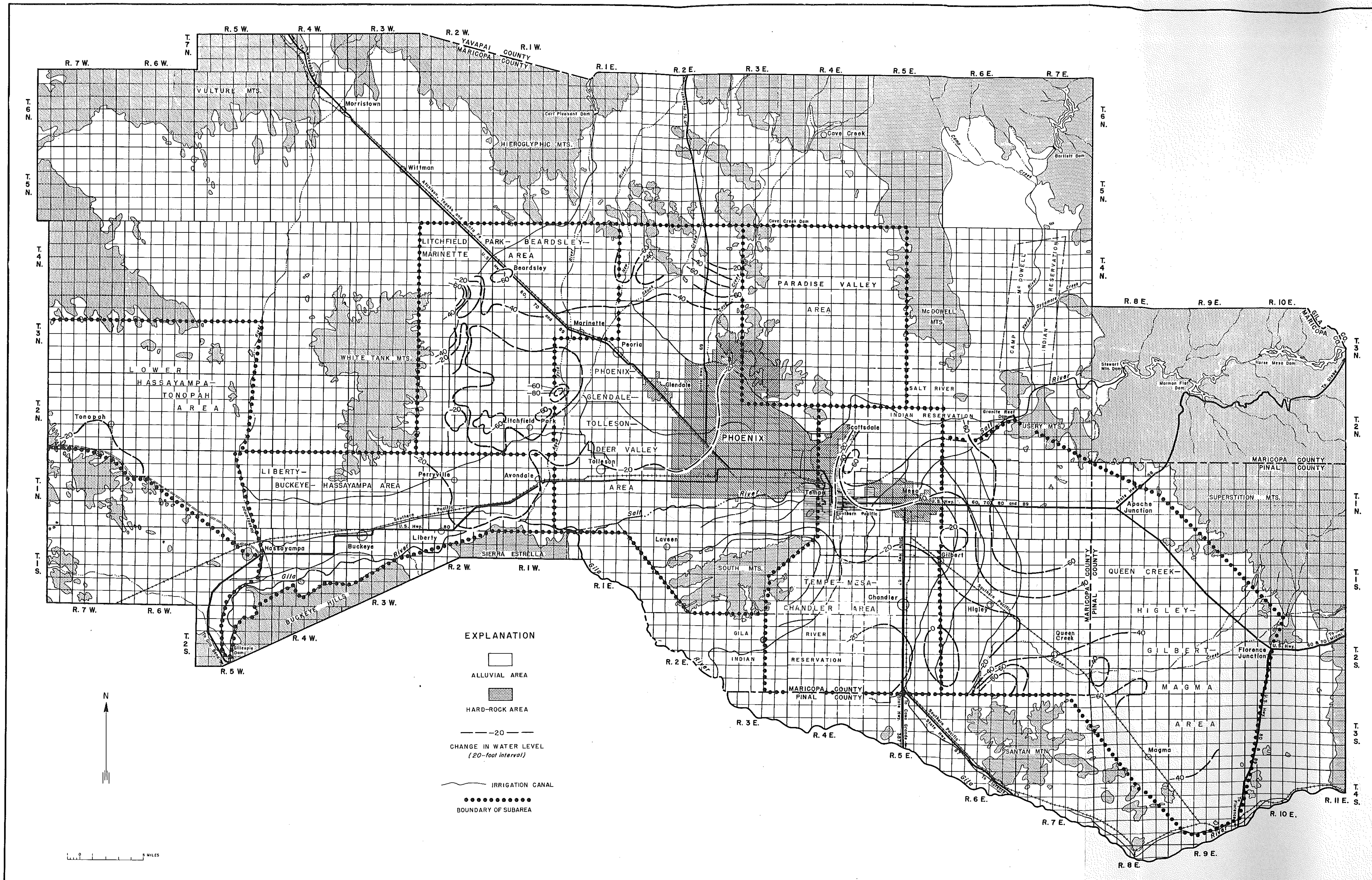

Figure 2.--Map of Salt River Valley, Maricopa and Pinal Counties, Ariz., showing change in ground-water level from spring 1959 to spring 1964.

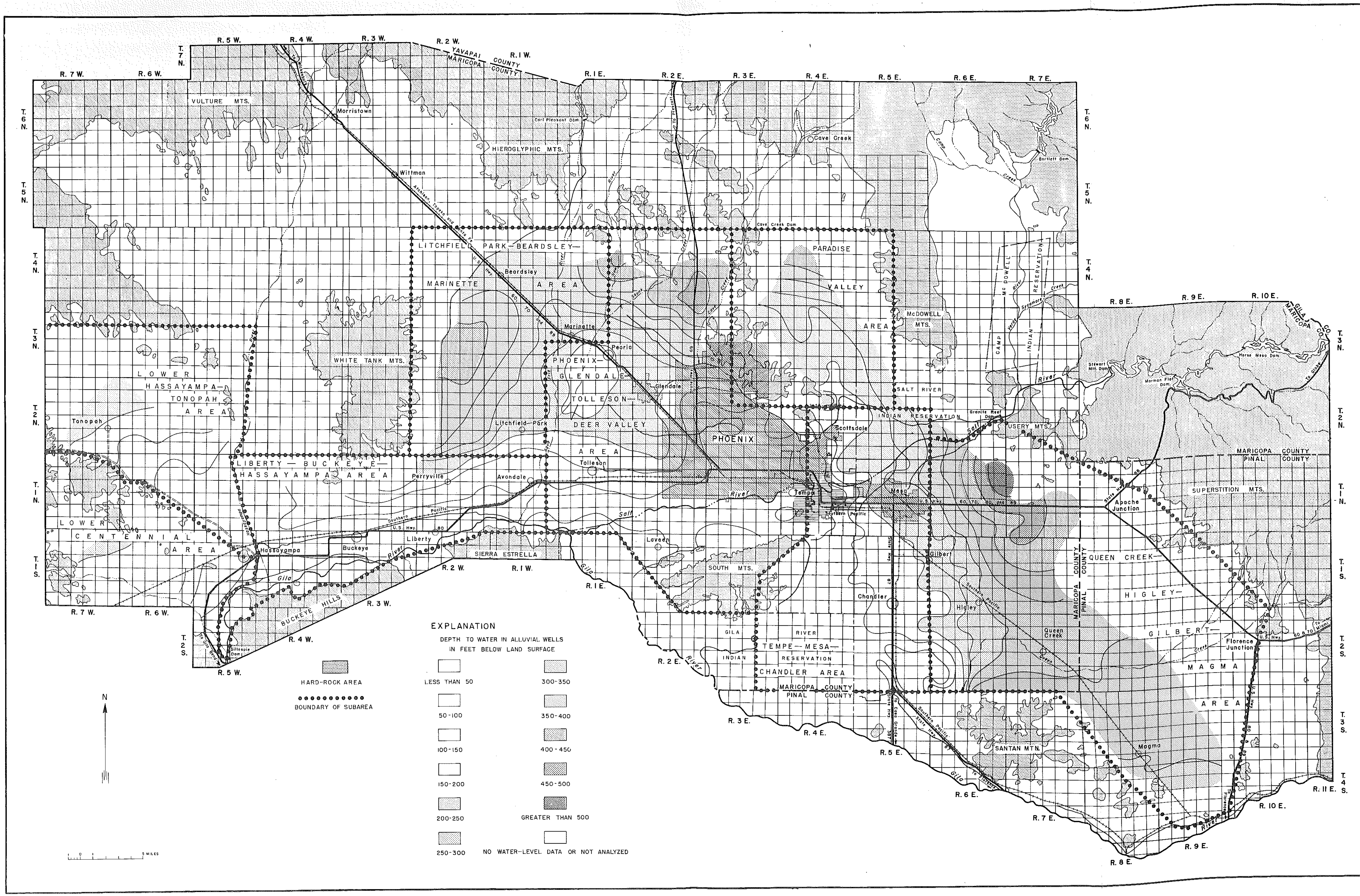

Figure 3.--Map of Salt River Valley, Maricopa and Pinal Counties, Ariz., showing depth to water as of spring 1964.

Depth to water (fig. 3) in the Queen Creek-Higley-Gilbert-Magma area in the spring of 1964 ranged from less than 100 feet to more than 500 feet below land surface. The deep water levels were east of Mesa; the shallow water levels were southwest of Higley.

Figure 4 shows that the predicted depth to water for spring 1969 ranges from less than 100 to more than 500 feet below land surface.

Tempe-Mesa-Chandler area.--The overall downward trend of water levels in the Tempe-Mesa-Chandler area, observed since 1940, continued through the spring of 1964 (fig. 2). For the most part the larger declines were northeast of Mesa where pumping is concentrated. The water levels declined least near Tempe and south of Chandler. From spring 1959 to spring 1964 the water table declined more than 50 feet northeast of Mesa and about 20 feet in Tempe.

Depth to water (fig. 3) in the Tempe-Mesa-Chandler area in the spring of 1964 ranged from less than 100 to more than 300 feet below land surface. The shallow water levels were near Tempe and south of Chandler; the deep water levels were northeast of Mesa.

The predicted depth to water for spring 1969 (fig. 4) ranges from less than 100 feet below land surface south of Chandler to about 400 feet northeast of Mesa.

Phoenix-Glendale-Tolleson-Deer Valley area.--Although much of the cropland in the Phoenix-Glendale-Tolleson-Deer Valley area has been converted to residential use, water levels in the area continue to decline. From spring 1959 to spring 1964 water-level declines (fig. 2) ranged from almost no change to more than 60 feet; the maximum declines were in Deer Valley where pumping is concentrated. South of the Arizona Canal in the Salt River Project, the water-level declines decreased toward Tolleson and ranged from 20 to 40 feet from spring 1959 to spring 1964. Ground water is used in the Salt River Project to supplement surface-water supplies; therefore, ground-water demands in the project are not as great as elsewhere. Along the mountains north and south of Phoenix the water-level declines were small because of canal seepage and the lack of concentrated pumping.

Depth to water (fig. 3) in the Phoenix-Glendale-Tolleson-Deer Valley area in the spring of 1964 ranged from less than 50 to more than

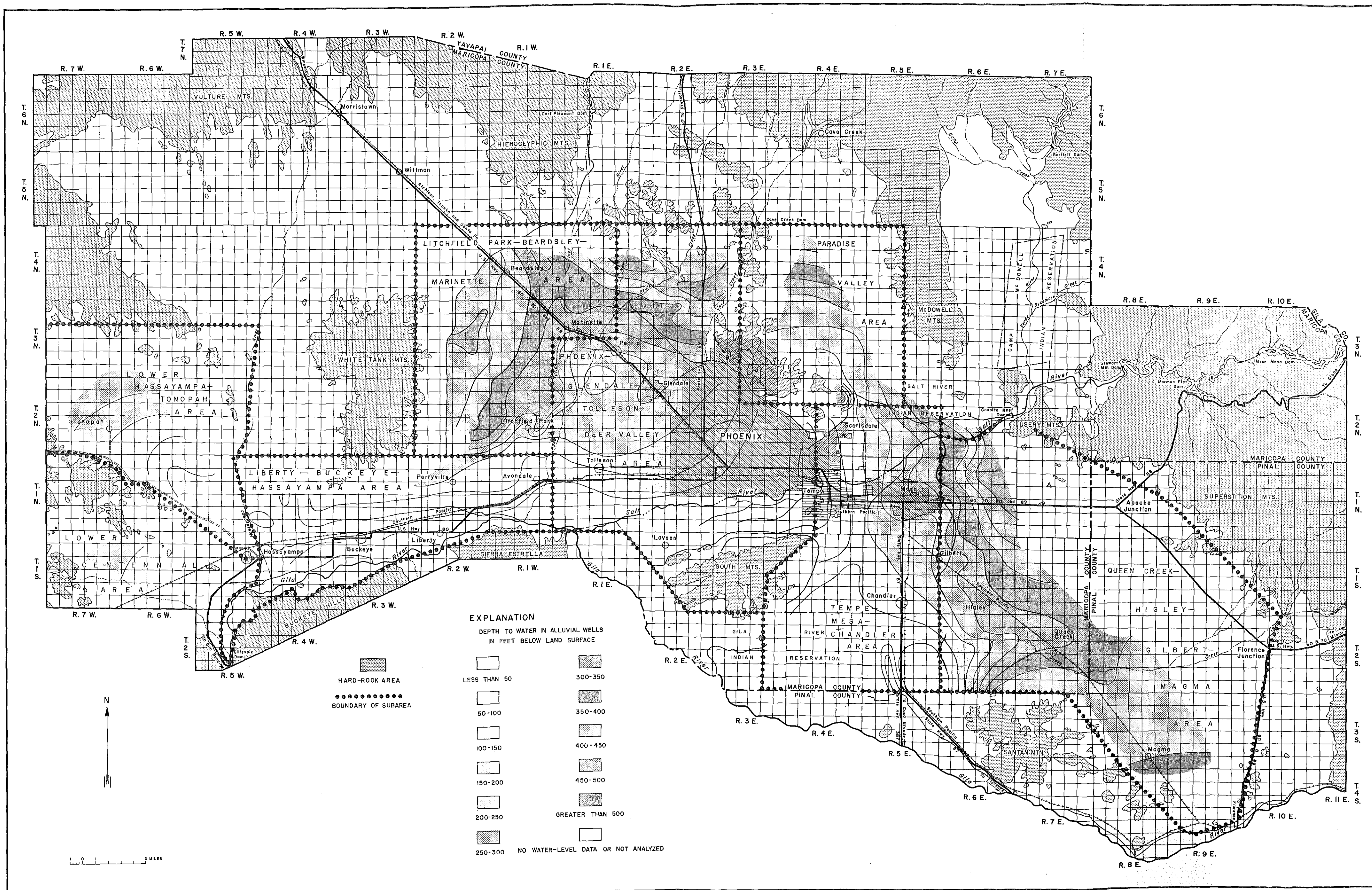

Figure 4.--Map of Salt River Valley, Maricopa and Pinal Counties, Ariz., showing predicted depth to water for spring 1969.

450 feet below land surface. The shallow water levels were in Phoenix near the main canals and along the Salt and Gila Rivers near Laveen; the deep water levels were in Deer Valley.

The predicted depth to water for spring 1969 (fig. 4) ranges from less than 100 feet below land surface along the Salt River to more than 500 feet in Deer Valley.

Paradise Valley area.--Withdrawal of ground water for agricultural purposes in Paradise Valley is minor compared to that in other parts of the Salt River Valley. As a result, the rate of water-level decline has been minimal except in several small areas where concentrated pumping has formed localized cones of depression. For the most part, water-level declines in Paradise Valley (fig. 2) were less than 20 feet from spring 1959 to spring 1964.

Depth to water (fig. 3) in the Paradise Valley area in the spring of 1964 ranged from slightly more than 150 to more than 400 feet below land surface. Water levels in the southern part of the area are comparatively shallow but are deeper toward the north.

The predicted depth to water for spring 1969 (fig. 4) ranges from less than 200 to more than 450 feet below land surface.

Litchfield Park-Beardsley-Marinette area.--Ground water is the major source of water available for agricultural use in the Litchfield Park-Beardsley-Marinette area. From spring 1959 to spring 1964 water-level declines (fig. 2) ranged from more than 80 to less than 20 feet. The maximum decline was northeast of Litchfield Park where a small steep cone of depression has resulted from several wells pumping from a zone of predominantly fine-grained material. Major water-level declines also occurred northwest of Litchfield Park and north of Peoria—areas where concentrated ground-water withdrawal has caused large cones of depression. The minimum declines were observed in the southern part of the area and near the canal that borders the area on the west. Cascading water in wells in this part of the area suggests that perched water tables exist here also.

Depth to water (fig. 3) in the Litchfield Park-Beardsley-Marinette area in the spring of 1964 ranged from slightly less than 150 to about 450 feet below land surface. The shallow water levels were in the southern part of the area; the deep water levels were near New River in the northeast corner of the area.

The predicted depth to water for spring 1969 (fig. 4) ranges from about 150 to more than 500 feet below land surface.

Liberty-Buckeye-Hassayampa area.--Generally, water levels in the Liberty-Buckeye-Hassayampa area follow the same downward trend that is typical for the Salt River Valley. However, the rate of decline is much less, probably because the shallow water table is recharged by irrigation water applied to cultivated land upstream. From spring 1959 to spring 1964 water levels near Perryville and Avondale declined from 20 to 40 feet (fig. 2); in the rest of the area declines were less than 20 feet (fig. 2).

Depth to water (fig. 3) in the Liberty-Buckeye-Hassayampa area in the spring of 1964 ranged from less than 50 to about 300 feet below land surface. The shallower water levels were along the Gila River; the deeper water levels were north of Perryville.

The predicted minimum depth to water for spring 1969 (fig. 4) is less than 50 feet below land surface along the Gila River. Data were insufficient to estimate the maximum depth to water for this area.

Lower Hassayampa-Tonopah area.--The accelerating rate of water-level decline in the lower Hassayampa-Tonopah area has accompanied the increasing withdrawal of ground water for irrigation. At present there are about 60 irrigation wells in the area; most of these are near Tonopah. In this part of the area water-level declines from spring 1959 to spring 1964 were more than 20 feet (fig. 2). Declines were progressively less to the east, and some small rises were observed near the Hassayampa River where water levels are readily affected by surface-water flow.

Depth to water (fig. 3) in the lower Hassayampa-Tonopah area in the spring of 1964 ranged from less than 100 feet below land surface along the Hassayampa River to more than 200 feet near Tonopah.

The predicted depth to water for spring 1969 (fig. 4) ranges from less than 100 to more than 250 feet below land surface.

Lower Centennial area.--From spring 1959 to spring 1964 water-level declines (fig. 2) in the lower Centennial area generally were less than

20 feet. In the center of the area there is a prominent depression in the water-table surface, and it is here that the maximum declines occur.

Depth to water (fig. 3) in the lower Centennial area in the spring of 1964 ranged from less than 50 feet below land surface along the Gila River to more than 200 feet in the western part of the area.

Data were insufficient to predict the depth to water for spring 1969 (fig. 4) in the lower Centennial area; however, the maximum predicted depth to water probably is more than 200 feet.

Lower Santa Cruz Basin and Adjacent Area Along the Gila River

The lower Santa Cruz basin and adjacent area along the Gila River (fig. 5) consists of more than 1,000 square miles of valley floor of low relief. In 1963, 253,540 acres was cropped in Pinal County (Hillman, 1964), mostly in this area. This amount of cultivated acreage reflects the trend of a slight decrease that has continued for the last few years. The conversion of agricultural land to residential use may have taken some land from agriculture, but the decrease in cultivated acreage probably is related more directly to the economics of deep pumping lifts in parts of the area.

The general direction of ground-water movement in the lower Santa Cruz basin is northwestward toward the Gila River. Prior to extensive pumping in the area, ground water moved down the valley through the Red Rock and Eloy areas toward the Sacaton Mountains; at the base of the mountains part of the flow was diverted toward Coolidge and thence to the Gila River, and part was diverted toward Stanfield, Maricopa, and the Gila River. In the adjacent area along the Gila River the direction of movement was essentially parallel to the river. However, large ground-water withdrawals beginning in the early 1940's have altered the direction of ground-water movement in the area, and two large depressions have formed in the water table—one centering principally near Eloy and Coolidge and the other near Maricopa and Stanfield. Hardt (1963, p. 86) states: "A ground-water divide has formed between the cones of depression near Casa Grande; ground water moves east toward Coolidge and west toward Stanfield. The ground-water divide is above a north-trending buried ridge consisting of nonwater-yielding materials. The permeable alluvial sediments overlying the buried ridge are comparatively thin; well yields from these sediments are small, and the quality of water is poor. Because of the cone of depression near Eloy and Coolidge, little ground water now moves northwestward parallel to the Santa Cruz River to the Stanfield area, except possibly through the gap between the Casa Grande and Silver Reef Mountains. Ground-water depressions are deep and numerous between Stanfield and Maricopa. The deepest ones are along the eastern flank of the Table Top and Palo Verde Mountains and the Haley Hills and at the southwest corner of the Sacaton Mountains."

The southern part of the study area is a single hydrologic basin and has been divided arbitrarily into four parts. Three of the subareas—the Casa Grande-Florence area, the Eloy area, and the Stanfield-Maricopa area—are in the lower Santa Cruz basin; the adjacent area along the Gila River (called the Gila River area) is the fourth subarea (fig. 5). The Eloy area includes about 440 square miles, the Casa Grande-Florence area includes about 260 square miles, the Stanfield-Maricopa area includes about 400 square miles, and the Gila River area includes about 475 square miles. The Casa Grande-Florence area and the Gila River area receive some surface water from the Gila River and the canal system of the San Carlos Irrigation and Drainage District; the Eloy area and the Stanfield-Maricopa area are dependent entirely on ground water for irrigation of crops.

During the last few years, pumping of ground water in the area has averaged about 1,100,000 acre-feet annually. The prediction of the depth to water for spring 1969 was based on the assumption that this rate of withdrawal will continue in the 5-year period spring 1964 to spring 1969.

About 27 million acre-feet of sediments was dewatered in the lower Santa Cruz basin and adjacent area along the Gila River from spring 1959 to spring 1964. This value was obtained by planimetering the area under successive contours of the change in water level (fig. 5) and multiplying this area by the average change. Nearly 5.5 million acre-feet of ground water was pumped during this period. If the average specific yield of the sediments in this area is about 0.15 (written communication, W. F. Hardt, U.S. Geological Survey, 1964), then the dewatering of this volume of sediments would produce slightly more than 4 million acre-feet of water. That is, this amount of water was withdrawn from storage in the alluvial reservoir, and less than 1.5 million acre-feet was supplied by recharge or underflow of "new" water into the area during the 5-year period.

The amount of ground water pumped, the change in water levels, the volume of sediments dewatered, and the annual recharge vary greatly for the four subareas. Consequently, these areas will be discussed separately.

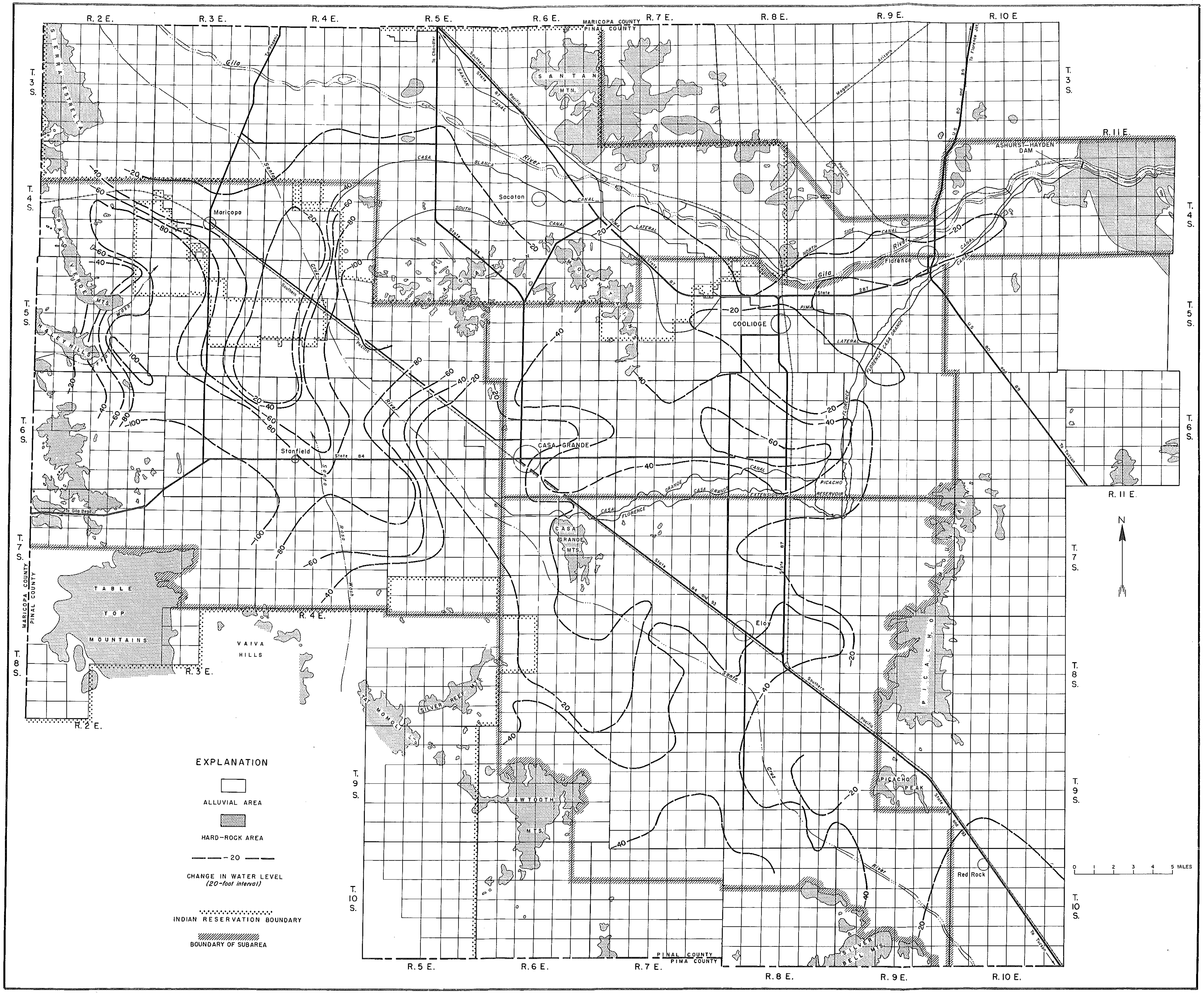

Figure 5.-- Map of lower Santa Cruz basin and adjacent area, Pinal County, Ariz., showing change in ground-water level from spring 1959 to spring 1964.

Eloy area.--Water-level declines (fig. 5) in the Eloy area from spring 1959 to spring 1964 ranged from less than 20 feet west of the Casa Grande Mountains and south of Red Rock to nearly 60 feet in a large area extending from the north edge of the Silverbell Mountains through the center of the area as far north as Eloy. In one small area about 3-1/2 miles east of the Casa Grande Mountains and just south of the Florence-Casa Grande Extension, the water table declined more than 60 feet from spring 1959 to spring 1964.

From spring 1959 to spring 1964 nearly 9 million acre-feet of sediments was dewatered in the Eloy area; nearly 1.5 million acre-feet of ground water was pumped during this period. Recharge to the ground-water reservoir in this area is known to be small; if it is assumed that there was no recharge to the ground-water reservoir during this period, the maximum specific yield of the sediments would be 0.17. Considering that some small amount of recharge does occur, then the value of 0.15 for specific yield as used in the preceding section probably is valid. Computations using a specific yield of 0.15 indicate that about 1.35 million acre-feet of water was removed from storage, and only about 150,000 acre-feet was supplied by recharge or underflow of new water into the area.

Depth to water (fig. 6) in the Eloy area in the spring of 1964 ranged from less than 120 to nearly 350 feet below land surface. The deeper water levels were south of Eloy on the east side of the area; the shallower water levels were west of the Casa Grande Mountains.

Figure 7 shows that the predicted depth to water for spring 1969 ranges from about 120 to more than 400 feet below land surface. Comparison of the two maps—depth to water, spring 1964 (fig. 6) and predicted depth to water, spring 1969 (fig. 7)—indicates an average decline in water level of about 30 to 35 feet for the 5-year period in the Eloy area.

Casa Grande-Florence area.--Water-level declines (fig. 5) in the Casa Grande-Florence area from spring 1959 to spring 1964 ranged from less than 20 to more than 60 feet. The lesser declines were along the canals on the east edge of the area and near Casa Grande; the greatest declines were northwest of Picacho Reservoir. Along the south side of the Gila River water-level declines were generally between 20 and 40 feet.

From spring 1959 to spring 1964 about 4.5 million acre-feet of sediments was dewatered in the Casa Grande-Florence area; about 1.4 million acre-feet of ground water was pumped during the same period. Applying a

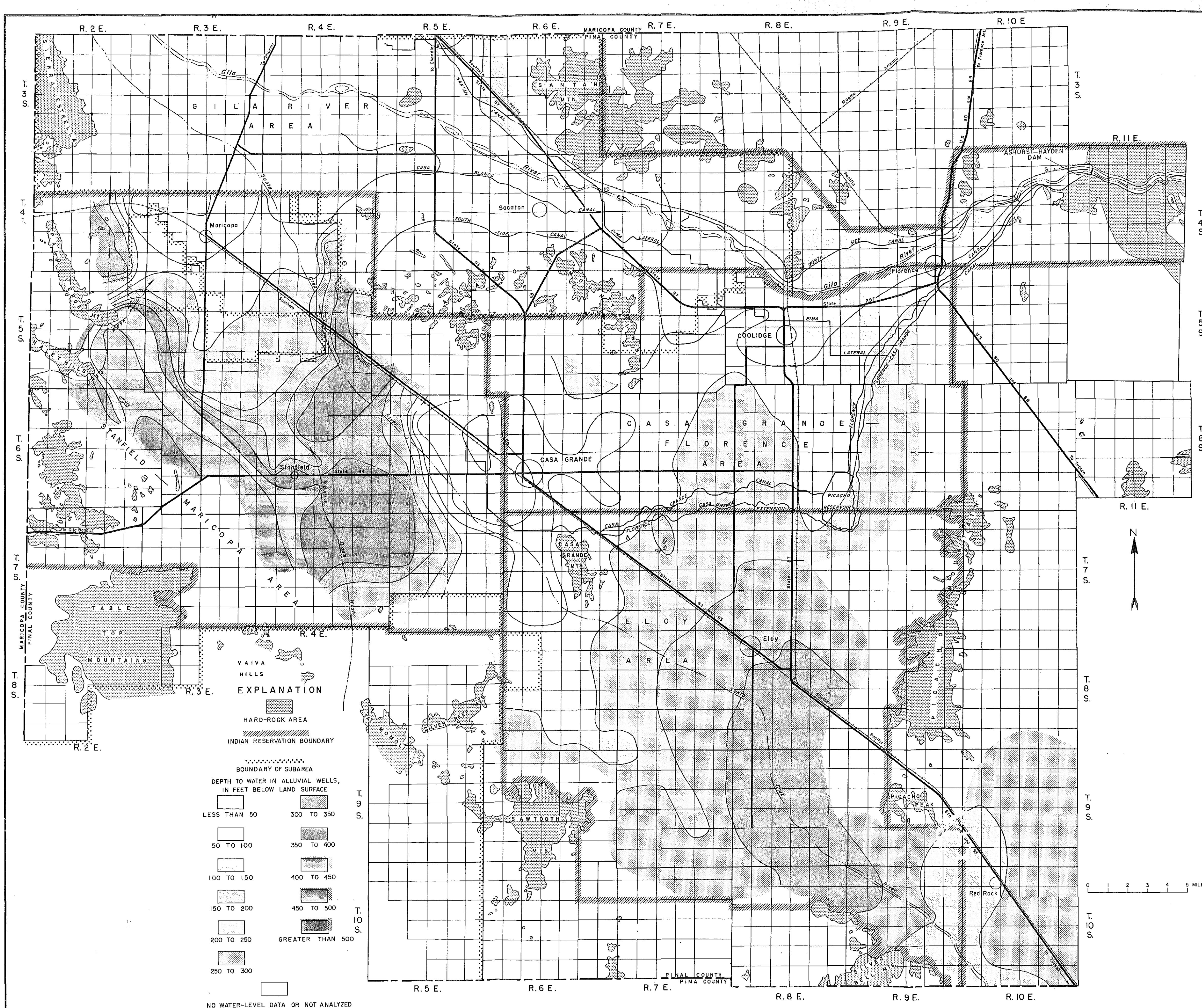

Figure 6.—Map of lower Santa Cruz basin and adjacent area, Pinal County, Ariz., showing depth to water as of spring 1964.

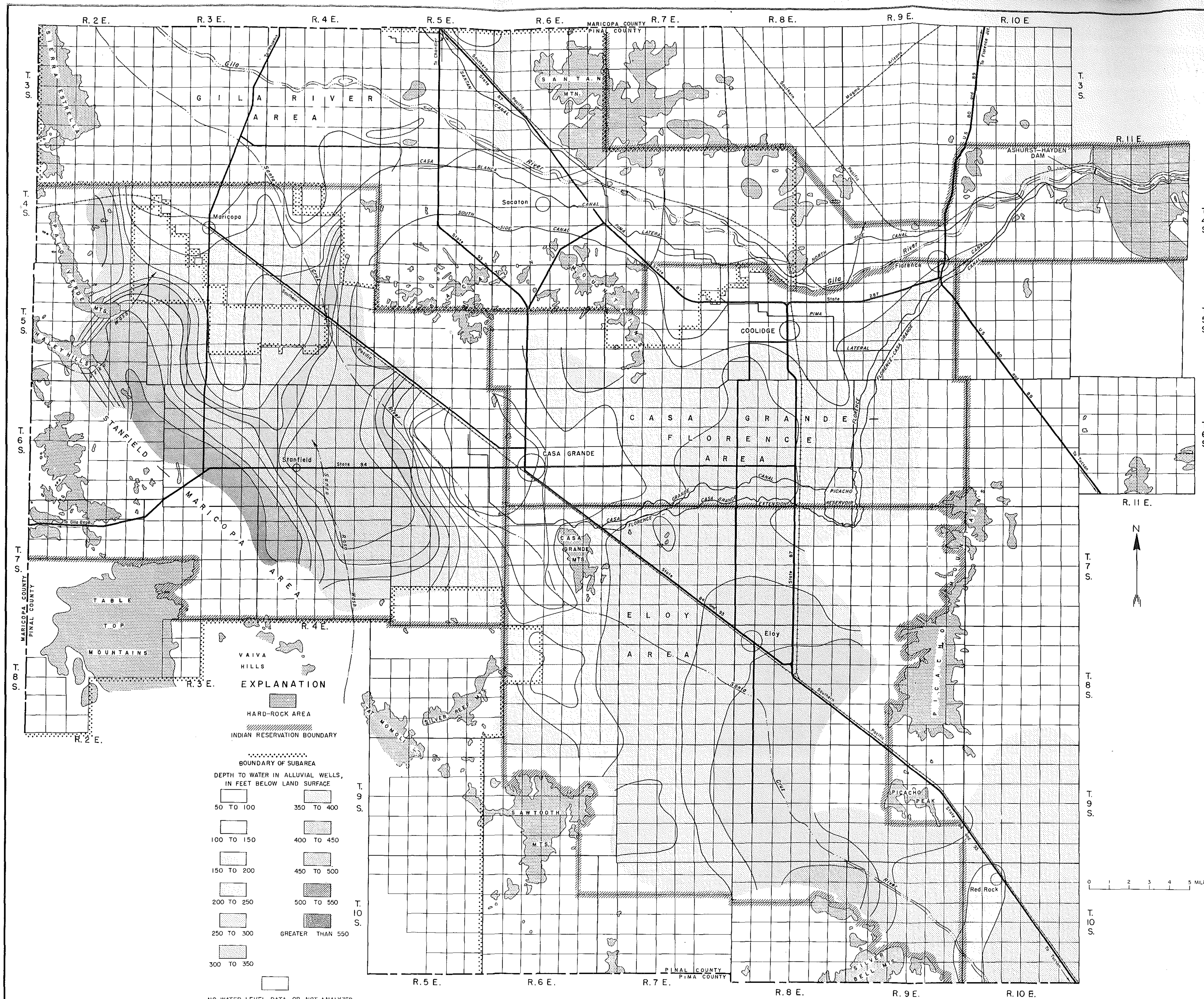

Figure 7.--Map of lower Santa Cruz basin and adjacent area, Pinal County, Ariz., showing predicted depth to water for spring 1969

specific yield of 0.15 to this volume of sediments dewatered and comparing this figure to the total amount of ground water withdrawn indicates that nearly 700,000 acre-feet of water was supplied by recharge or underflow of new water into the area, and slightly more than 700,000 acre-feet was withdrawn from storage. This area receives some surface water from the Gila River and the canal system of the San Carlos Irrigation and Drainage District; part of this water is recharged to the ground-water reservoir.

Depth to water (fig. 6) in the Casa Grande-Florence area in the spring of 1964 ranged from less than 100 feet in a small area south and west of Casa Grande to more than 200 feet near the center of the area and along the east edge. Depth to water was less than 150 feet along the Gila River.

The predicted depth to water (fig. 7) for spring 1969 in the Casa Grande-Florence area ranges from about 100 feet near Casa Grande to more than 250 feet near the center of the area. The predicted depth to water is less than 200 feet along the Gila River. Comparison of figures 6 and 7 indicates an average decline in the water level of about 30 to 35 feet from spring 1964 to spring 1969.

<u>Stanfield - Maricopa area.</u>--Water-level declines (fig. 5) in the Stanfield-Maricopa area from spring 1959 to spring 1964 ranged from less than 20 to as much as 100 feet. Declines were generally less than 20 feet on the east side of the area near Casa Grande, on the fringe of the area north of Maricopa, and in a part of the elongated depression between Stanfield and Maricopa. The largest declines were on the northwest edge of the area at the base of the Sacaton Mountains and in a band extending from about a mile south of the Palo Verde Mountains to south of Stanfield. Declines were as much as 80 feet in a large part of the area between Stanfield and Maricopa.

From spring 1959 to spring 1964 more than 12 million acre-feet of sediments was dewatered in the Stanfield-Maricopa area. Nearly 2.2 million acre-feet of ground water was pumped during this period. Computations using a specific yield of 0.15 indicate that about 1.8 million acre-feet of water was removed from storage, and only about 400,000 acre-feet of water was supplied by recharge or underflow of new water into the area.

In the spring of 1964 depth to water (fig. 6) in the Stanfield-Maricopa area ranged from less than 100 feet below land surface in a small area north and slightly west of Maricopa to more than 500 feet in a small area west and slightly north of Stanfield. The depth to water was more than 350 feet below land surface in a large part of the area.

Figure 7 shows that the predicted depth to water for spring 1969 ranges from about 100 feet below land surface to more than 550 feet. The predicted depth to water is more than 400 feet in a large part of the area. Comparison of figures 6 and 7 indicates an average decline in the water level of about 60 feet from spring 1964 to spring 1969.

Gila River area. --Water-level declines (fig. 5) in the Gila River area from spring 1959 to spring 1964 ranged from less than 20 to about 40 feet. Declines are smaller in this area due to less pumping and to recharge from the river.

Less than 1.8 million acre-feet of sediments was dewatered in the Gila River area from 1959 to 1964; it is estimated that about 400,000 acre-feet of water was pumped during this period. Computations using a specific yield of 0.15 indicate that about 260,000 acre-feet of this water was removed from storage and the remainder was supplied by recharge and underflow of new water into the area. This area receives some surface water from the Gila River and the canal system of the San Carlos Irrigation and Drainage District. A part of this water is recharged to the ground-water reservoir. Some recharge also may occur from floodflow of the Gila River.

Depth to water (fig. 6) in the Gila River area in spring 1964 was, for the most part, between 50 and 150 feet below land surface. The water levels in this area are influenced by the Gila River and are shallower than in the three areas in the lower Santa Cruz basin.

Figure 7 shows that the predicted depth to water for spring 1969 in the Gila River area ranges from less than 100 to nearly 200 feet below land surface in most of the area. Comparison of figures 6 and 7 indicates an average decline in the water level of only about 20 feet from spring 1964 to spring 1969.

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