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ANNUAL REPORT ON GROUND WATER IN ARIZONA SPRING 1963 TO SPRING 1964

BY
NATALIE D. WHITE, R.S. STULIK, E.K. MORSE, AND OTHERS

PREPARED BY THE GEOLOGICAL SURVEY,
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ABSTRACT

By

Natalie D. White

The economy of Arizona, particularly the agricultural economy, is largely dependent on ground-water supplies for future growth and even for its continued existence at the present level. More than two-thirds of the water supply for the State is taken from the ground-water reservoirs. If the growth of Arizona and the accompanying expanded use of ground water are to continue, some means must be found to conserve the water supplies and to augment them where possible. Proper management of the ground-water resources, particularly in relation to the ever increasing use, requires a comprehensive knowledge of the hydrogeologic characteristics that control the storage capacity and the transmission of water through the saturated subsurface rocks that form the ground-water reservoirs. This report presents discussions of the ground-water conditions in selected basins and areas in the State based on hydrologic data collected during the year spring 1963 to spring 1964.

The amount of recharge to the ground-water reservoirs in most areas of the State is much less than the amount of ground water withdrawn for use. The water levels in nearly all the highly developed areas are declining, and the ground-water reservoirs are being depleted. In 1963 the areas of greatest water-level decline were the Salt River Valley and the lower Santa Cruz basin in Pinal County. Other areas where large water-level declines occurred in 1963 were the Willcox basin in Sulphur Spring Valley and the Bowie and San Simon areas in San Simon basin. In areas where surface-water supplies supplemented ground water for irrigation use, some rises in water levels were measured.

Withdrawal of ground water for all purposes was about 4.5 million acre-feet in 1963—the same as in 1962. Nearly 90 percent of the ground water withdrawn during the year was used to irrigate crops, although municipal, domestic, and industrial uses are increasing every year. The Salt River Valley and the lower Santa Cruz basin continue to be the largest users of ground water in the State.

INTRODUCTION

By

Natalie D. White

More than two-thirds of the water supply for Arizona is taken from the ground-water reservoirs, and nearly 90 percent of the ground water withdrawn is used to irrigate crops. The ground-water supplies are vast but not inexhaustible; at the present rate of use, the supplies are gradually being depleted because the rate of withdrawal far exceeds the rate of replenishment.

In order to properly manage the ground-water resources, particularly in relation to the ever increasing use, it is necessary to acquire a comprehensive knowledge of the hydrogeologic characteristics that control the storage capacity and the transmission of water through the saturated subsurface rocks. Specialized studies, continued data collection, and new methods of hydrologic analysis will provide quantitative solutions to the water problems that arise where ground water is used in large quantities.

In July 1939, a district office of the U.S. Geological Survey, Ground Water Branch, was established in Tucson, Ariz., and a cooperative agreement was put into effect between the Geological Survey and the State Water Commissioner for equal financial participation in a planned program of ground-water studies. The Federal-State cooperation has continued to the present time; since 1942, the State has been represented by the State Land Department. During the early years, the program consisted mostly of collecting basic data concerning the development of ground-water resources; the information included well inventories, periodic water-level measurements, measurements of the discharge of wells, chemical analyses of water samples, and descriptions and analyses of drill cuttings. In recent years there has been more emphasis on compilation and analysis of the hydrologic and geologic data and on obtaining quantitative solutions to the problems of availability, effects of withdrawal, and changes in chemical quality of the water.

This report presents discussions of the ground-water conditions in selected basins and areas in the State based on hydrologic data collected during the year spring 1963 to spring 1964. Two other reports prepared during the year present a somewhat more comprehensive analysis for the lower Harquahala Plains (Stulik, 1964) and part of central Arizona (White, Stulik, and Rauh, 1964). The latter report contains the 1969 predicted depth to water for part of central Arizona.

Scope of the Federal-State Cooperative Ground-Water Program

The current cooperative ground-water program in Arizona consists of three major closely related parts, which are described below. (1) The statewide ground-water survey provides the long-term basic records necessary to a comprehensive ground-water investigation. Whenever the need arises for study of a specific area or some special problem, the basic data that have been collected over a long period of years are invaluable. The work of this phase of the cooperative program includes well inventories, periodic water-level measurements, collection of water samples for chemical analysis, and collection and cataloging of drill cuttings from recently completed wells. (2) Comprehensive ground-water investigations are made in selected areas where ground-water conditions are becoming critical due to overdevelopment, where ground-water development is beginning, or where there is some special problem or interest. These more comprehensive investigations result in an overall evaluation of the water resources of an area. (3) Studies related to specific hydrologic problems, such as insufficient water supplies, equitable distribution and protection of the available supply, and deterioration in quality of water, may be needed wherever ground water is pumped in large quantities. For the most part, these studies are made in relation to the particular problem rather than to an area or basin.

Summary of Ground-Water Programs in Arizona

Ground-water programs in Arizona include cooperation with the Arizona State Land Department as explained in foregoing sections, with universities, cities, and other Federal agencies. In 1963 fieldwork was in progress for three projects, and reports were in various stages of completion for six projects under the Federal-State cooperative program. Two studies were being conducted in cooperation with the University of Arizona and one with the city of Flagstaff. Cooperation with other Federal agencies included projects for the U.S. Army, the National Park Service, the Bureau of Indian Affairs, and the Forest Service. Figure 1 is a pictorial summary of the status of current ground-water work in Arizona.

Current Publications of the Arizona District

By

Clara R. Smith

The following reports on the water resources and geology of Arizona were published or released to the open file from July 1963 through October 1964.

Cenozoic geology in the Mammoth area, Pinal County, Arizona, by L. A. Heindl: U.S. Geol. Survey Bull. 1141-E, 1963. 41 p., 3pls., 3 figs.

The report contains maps and stratigraphic analyses of seven alluvial and two volcanic Cenozoic units and suggests a revised interpretation of the Cenozoic history of the lower San Pedro Valley near Mammoth, Ariz.

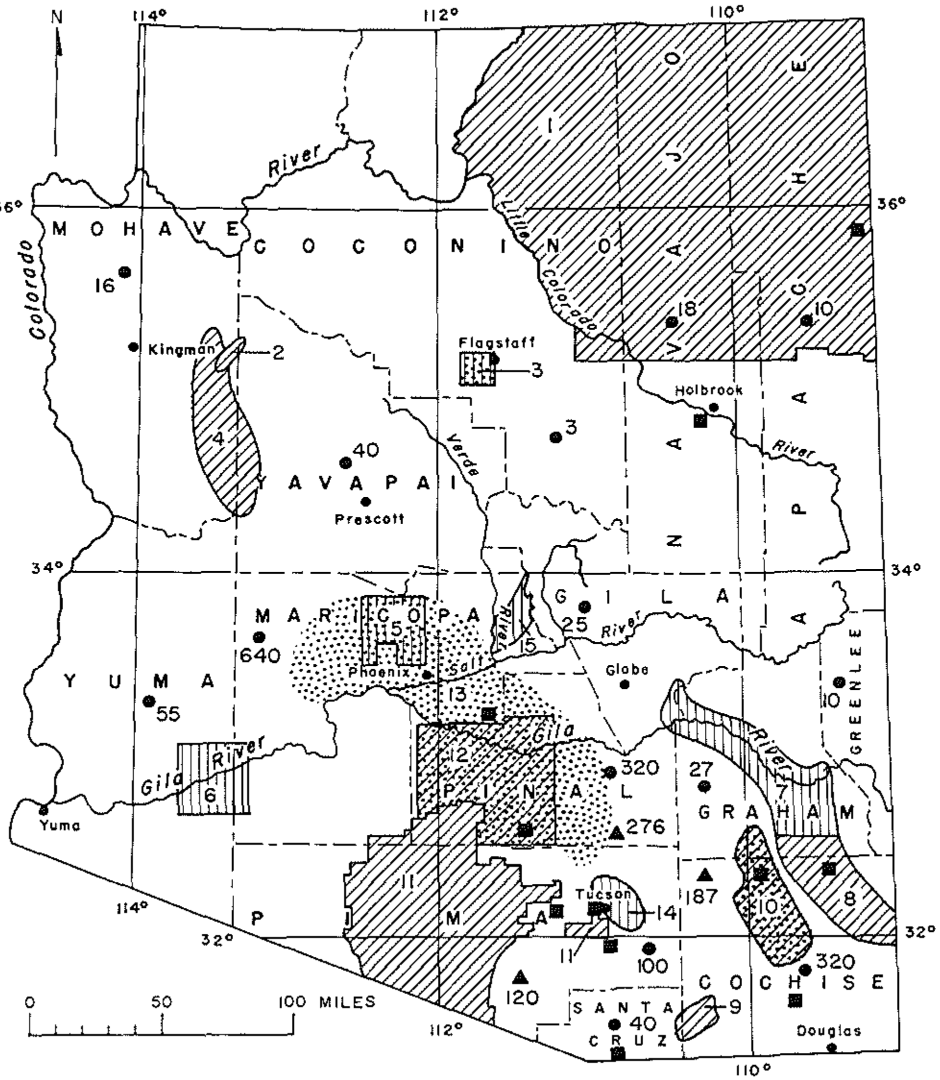


Figure 1.--Map of Arizona showing summary of ground-water programs.

AREAS OF INVESTIGATIONS

1. Navajo-Hopi Indian Reservations
2. Cottonwood Wash
3. City of Flagstaff
4. Big Sandy Valley
5. Beardsley area
6. Dateland-Hyder area
7. Arid-lands study (Safford Valley)
8. San Simon basin
9. Fort Huachuca
10. Willcox basin
11. Papago Indian Reservation
12. Western Pinal County
13. Salt River Valley
14. Tucson basin
15. Sycamore Creek

Area where field investigation is in progress (As of June 1964)

Area for which a report is in preparation (As of June 1964)

Area for which a report was released July 1963-June 1964

A double pattern indicates that, although a report was released in the prescribed period, further work also is in progress

● 40 Active observation wells (figure indicates number of observation wells in county)

▲ 187 Well-discharge measurements made in 1963 (figure indicates number of measurements made in county)

■ Site where continuous water-stage recorder is in operation

Desert floods---A report on southern Arizona floods of September 1962, by D. D. Lewis: Arizona State Land Dept. Water Resources Rept. 13, April 1963. 30 p., 18 figs., 2 tables.

The floods of September 26-28, 1962, in southern Arizona are vivid examples of intense floods resulting from rainfall on small parts of a river basin. As much as 6 inches of rainfall was recorded over a part of the area. The total volume of water discharged by the flood must have been considerably more than 125,000 acre-feet, although runoff in the Santa Cruz River near Laveen was only 17,400 acre-feet, which indicates that most of the water disappeared before it reached this point.

Surface water records of Arizona, 1962, by Arizona district: U.S. Geol. Survey open-file report. 185 p., 2 figs.

The surface-water records for the 1962 water year for gaging stations and miscellaneous sites within the State of Arizona and a few pertinent gaging stations in bordering States are given in this report.

Basic ground-water data of the Willcox basin, Graham and Cochise Counties, Arizona, by S. G. Brown, H. H. Schumann, L. R. Kister, and P. W. Johnson: Arizona State Land Dept. Water Resources Rept. 14, July 1963. 93 p., 15 figs., 4 tables.

This report presents the basic data collected chiefly during the period 1945 to 1960 in the Willcox basin. The data are necessary in planning and analyzing water-recources development in the area.

Annual report on ground water in Arizona, spring 1962 to spring 1963, by Natalie D. White, R. S. Stulik, E. K. Morse, and others: Arizona State Land Dept. Water Resources Rept. 15, September 1963. 136 p., 47 figs., 5 tables.

The report discusses water-level changes or trends in Arizona for the period spring 1962 to spring 1963, pumpage for the principal areas of ground-water use, and surface-water diversions. The report also contains a comprehensive discussion of the hydrology of the Plateau uplands, a section on methods of analysis of hydrologic data, and a discussion of ground-water recharge with special reference to recharge resulting from the flood of September 1962 in the Santa Cruz River valley.

Floods of August 1963 in Prescott, Arizona, by B. N. Aldridge: U.S. Geol. Survey open-file report, October 1963. 12 p., 8 figs., 2 tables.

On August 19, 1963, four small tributaries to Granite Creek poured water into the city of Prescott at a combined rate of more than 7,000 cubic feet per second and caused about $400,000 worth of damage. Higher floods may have occurred in the last 50 years, but none of them caused nearly as much damage.

Synopsis of ground-water conditions on the San Francisco Plateau near Flagstaff, Coconino County, Arizona, by J. P. Akers, M. E. Cooley, and P. E. Dennis: U.S. Geol. Survey open-file report, January 1964. 30 p., 3 figs.

This report summarizes features of the available ground-water supply near Flagstaff. Water levels are from 500 to 1,000 feet below land surface, but deep wells drilled in fractured zones along the Oak Creek fault at the Woody Mountain well field and along the Anderson Mesa fault at Lake Mary furnish Flagstaff with a dependable water supply.

Effects of ground-water withdrawal in part of central Arizona projected to 1969, by Natalie D. White, R. S. Stulik, and Clara L. Rauh: Arizona State Land Dept. Water Resources Rept. 16, July 1964. 25 p., 7 figs.

About 75 percent of the ground water pumped in Arizona is withdrawn from alluvial aquifers in the study area. Long-term records of water-level measurements and ground-water pumpage are used to predict the status of the ground-water reservoir in 1969. These predictions are shown in the form of depth-to-water maps.

Surface water records of Arizona, 1963, by Arizona district: U.S. Geol. Survey open-file report. 191 p., 2 figs.

The Surface-water records for the 1963 water year for gaging stations and miscellaneous sites within the State of Arizona and a few pertinent gaging stations in bordering States are given in this report.

Water resources of the Sycamore Creek watershed, Maricopa County, Arizona (a progress report), by B. W. Thomsen and H. H. Schumann: U.S. Geol. Survey open-file report, August 1964. 28 p., 11 figs.

The Sycamore Creek watershed is representative of many small watersheds in the Southwest where much of the streamflow accumulates in the mountainous areas and disappears rather quickly into the alluvial deposits adjacent to the mountains. Most of the average annual water yield from the 165 square miles of mountain area disappears as surface flow in the alluvial deposits and travels slowly to the Verde River as ground water.

Effects of ground-water withdrawal, 1954-63, in the lower Harquahala Plains, Maricopa County, Arizona, by R. S. Stulik: Arizona State Land Dept. Water Resources Rept. 17, September 1964. 8 p., 5 figs.

Withdrawal of ground water for irrigation use in the lower Harquahala Plains has increased from about 33,000 acre-feet in 1954 to about 200,000 acre-feet in 1963. From 1954 to 1963 water levels declined as much as 200 feet and are continuing to decline at an increasing rate.

Younger Precambrian formations and the Bolsa (?) Quartzite of Cambrian age, Papago Indian Reservation, Arizona, by L. A. Heindl and

N. E. McClymonds, in Geological Survey research 1964: U.S. Geol. Survey Prof. Paper 501-C, 1964. p. 43-49, 3 figs.

The Apache Group of younger Precambrian age crops out in 1,500-foot sequences in the Vekol and Slate Mountains. An overlying clastic unit is designated the Bolsa (?) Quartzite and is also exposed in the Waterman Mountains where it rests on granitic rocks. It is overlain conformably by the Abrigo Formation of Cambrian age in the three mountain ranges.

Further analysis of hydrologic data for San Simon basin, Cochise and Graham Counties, Arizona, including analysis by electrical-analog model, by Natalie D. White and William F. Hardt: U.S. Geol. Survey open-file report, October 1964. 63 p., 12 figs., 1 table. For publication as a U.S. Geol. Survey water-supply paper.

This report concludes that the amount of ground water available from San Simon basin is about 10 million acre-feet, and the transmissibility of the lower aquifer is about 20,000 gallons per day per foot. Electrical-analog analysis predicts the water level will decline as much as 120 feet near Bowie and 160 feet near San Simon from 1960 to 1980 under an hypothesized pumping regimen based on the present increasing rate of pumping.

Geohydrologic data in the Navajo and Hopi Indian Reservations, Arizona, New Mexico, and Utah---Part III, Selected lithologic logs, drillers' logs, and stratigraphic sections, by M. E. Cooley, J. P. Akers, and P. R. Stevens: Arizona State Land Dept. Water Resources Rept. 12-C, October 1964. 157 p., 3 figs., 3 tables.

The geohydrologic data in this report consist of information about the geology of the Navajo and Hopi Indian Reservations in northeastern Arizona, northwestern New Mexico, and southeastern Utah. The report consists of a compilation of 161 lithologic logs, 168 drillers' logs, and 76 stratigraphic sections.

The following papers were prepared by personnel of the U.S. Geological Survey and published in the Arizona Geological Society Digest, volumes 5 and 6:

(1) Cenozoic geology of Arizona---A 1960 resume, by L. A. Heindl, v. 5, November 1962. p. 9-24.

(2) Should the term "Gila Conglomerate" be abandoned?, by L. A. Heindl, v. 5, November 1962. p. 73-88.

(3) Geomorphology and the age of volcanic rocks in northeastern Arizona, by M. E. Cooley, v. 5, November 1962. p. 97-115.

(4) The Mogollon Highlands---their influence on Mesozoic and Cenozoic erosion and sedimentation, by M. E. Cooley and E. S. Davidson, v. 6, November 1963. p. 7-35.

(5) A reinterpretation of the anticlinal structure exposed in the northwest face of Pusch Ridge, Santa Catalina Mountains, Arizona, by E. F. Pashley, Jr., v. 6, November 1963. p. 49-53.

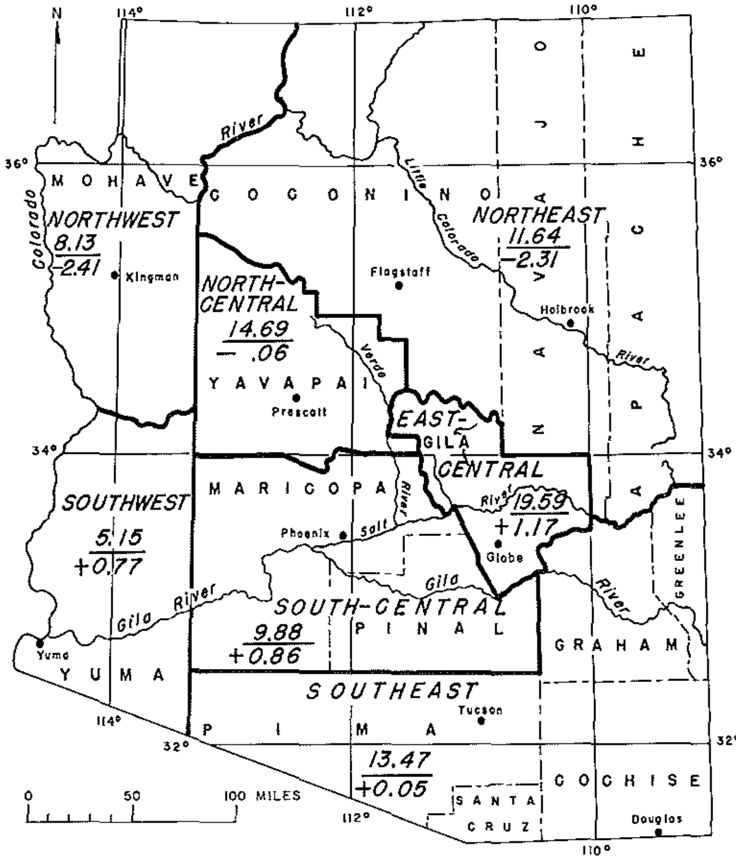
Agricultural Resume for 1963

A total of 1,165,800 acres of land was irrigated to grow crops in 1963 (Hillman, 1964). Ground water is the major source of irrigation water, and, thus, declining water levels are a major economic problem to farmers. A total of 387,000 acres of cotton and 193,000 acres of alfalfa was planted in 1963; lesser acreages were planted in barley, sorghum, and vegetables. In general, cotton and alfalfa require more water than the other principal crops. Maricopa (509,400 acres), Pinal (253,540 acres), Yuma (176,210 acres), and Cochise (79,610 acres) Counties continued to have the largest amount of land under cultivation.

Climate

The arid to semiarid climate of most of Arizona bears a direct relation to the need for irrigation of crops and, in particular, to the necessity of using ground water for this irrigation. About half of Arizona receives less than 10 inches of precipitation annually. In general, the regions of low rainfall have the highest temperatures and longest growing seasons and, thus, are the areas that are most developed for agriculture. In these areas, large evaporation and transpiration rates leave only a small part of the total precipitation that can be utilized for growth of benefical plants. Likewise, only a small part---about 1 percent per year---of the total precipitation is available for recharge to the ground-water reservoirs. These combined factors are the reason that natural ground-water recharge can not equal ground-water pumpage.

The U.S. Weather Bureau has subdivided the State into seven sections for the purpose of computing average precipitation values. The monthly and annual averages by division for 1963 and departures from the long-term average for each of the divisions are shown in figure 2. For the most part, precipitation for 1963 was below average in the northern part of the State and only slightly above average in the southern part. Of more significance, however, are the monthly precipitation rates in relation to the growing season and the resulting need for more or less ground water. With a few minor exceptions, monthly precipitation rates were below average in the State from January through July, making it necessary to pump ground water continuously throughout a large part of the growing season. However, in August precipitation was considerably above average in the southeast and south-central divisions where agricultural development is greatest, and pumps could be shut down in some areas; it was also above average in the east-central and north-central divisions where much of the surface water originates that fills the storage reservoirs on the Salt and Verde Rivers. In September and October precipitation was above average in parts of the State and below average in other parts; in



EXPLANATION

5.15 Average precipitation for division, 1963
+0.77 Departure from long-term average

1/ Average for all stations in division, 1963.

2/ Departure from long-term average.

Month	Northwest division		Northeast division		North-central division		East-central division		Southwest division		South-central division		Southeast division	
	Precipitation1/ (inches)	Departure2/ (inches)	Precipitation1/ (inches)	Departure2/ (inches)	Precipitation1/ (inches)	Departure2/ (inches)	Precipitation1/ (inches)	Departure2/ (inches)	Precipitation1/ (inches)	Departure2/ (inches)	Precipitation1/ (inches)	Departure2/ (inches)	Precipitation1/ (inches)	Departure2/ (inches)
January	0.23	-0.78	0.68	-0.53	0.45	-0.98	1.20	-0.80	0.21	-0.28	0.72	-0.25	0.74	-0.24
February	1.07	-.22	.99	-.26	1.57	-.04	2.46	.48	.33	-.22	1.31	.35	1.10	.08
March	.64	-.30	.56	-.56	.85	-.28	1.09	-.59	.25	-.10	.58	-.19	.49	-.24
April	.51	-.14	.51	-.31	.59	-.24	.83	-.05	.04	-.13	.32	-.07	.39	.03
May	Trace	-.23	.03	-.47	.01	-.31	Trace	-.34	Trace	.02	Trace	-.14	.01	-.15
June	.07	-.10	.03	-.44	.02	-.37	.05	-.39	.02	-.03	Trace	-.14	.05	-.44
July	.10	-.87	.81	-.97	.74	-1.12	.65	-1.38	.02	-.38	.21	-.85	2.41	-.37
August	1.60	-.03	4.53	2.19	5.30	2.61	8.35	5.40	.83	.03	3.86	2.30	4.33	1.19
September	1.68	.58	1.35	-.01	1.69	.38	1.03	-.56	1.60	1.11	.43	-.40	1.35	.01
October	.94	.22	1.00	-.14	1.28	.36	1.46	.18	1.29	.97	1.11	.52	1.00	.21
November	1.28	.72	.91	.13	2.13	1.35	2.18	.97	.56	.34	1.26	.66	1.34	.70
December	.01	-1.26	.24	-.94	.06	-1.42	.29	-1.75	.00	-.52	.08	-.93	.26	-.73
Annual	8.13	-2.41	11.64	-2.31	14.69	-.06	19.59	1.17	5.15	.77	9.88	.86	13.47	.05

Data from U.S. Weather Bureau, 1964

Figure 2.--Precipitation data for 1963 by climatic subdivisions.

November it was above average throughout the State and in December it was below average.

Surface-Water Runoff, Storage, and Diversions

By

E. B. Hodges

As is common in Arizona, stream runoff varied greatly during the 1963 water year---from month to month throughout the year and from place to place in the State. The variations are related to differences in precipitation, temperature, topography, and geology. The yearly mean discharge at five key gaging stations ranged from 49 to 140 percent of the median of yearly mean discharge; however, all were below the median except the Gila River station. The yearly mean discharge is computed by averaging the daily discharges. The median of the yearly mean discharge is defined as the middle value of discharge when arranged in order of size; or, if there is no middle value of discharge, then the average of the two middle ones. For the index stations, the median is computed from the yearly mean discharges for the 1931-60 period of record.

For the 1963 water year, the flow of the Little Colorado and Verde Rivers was in the low one-fourth of the range of discharges in the 1931-60 reference period. In general, the lowest flows were during winter to mid-summer. Record-low monthly flows occurred as follows: the Little Colorado River in January; the Salt River in July; and the Verde River in November, May, and July. Flows in the high one-fourth of the range of discharges in the 1931-60 reference period occurred mostly during July to September, as a result of a series of storms in nearly every area of the State.

The intense storms were followed by damaging floods in many instances. Two severe floods occurred in and near Prescott within a 3-day period in August (Aldridge, 1963); although these were not the largest floods known, they were the most damaging. Local flooding in the Yuma area in September also caused extensive damage.

The mean discharge for the 1963 water year and the relation to the median of yearly mean discharge based on the period 1931-60 for six key gaging stations are shown on following page.

Station	Discharge (acre-feet)	Percent of median
Colorado River near Grand Canyon . . .	2,742,000	----
Little Colorado River near Cameron	84,260	49
Gila River at head of Safford Valley, near Solomon	286,300	140
Salt River near Roosevelt	379,000	97
Verde River below Tangle Creek, above Horseshoe Dam	180,600	63
San Pedro River at Charleston.	33,620	93

Because of storage in Lake Powell (Glen Canyon), which began in March 1963, and in other upstream reservoirs, the discharge of the Colorado River near Grand Canyon no longer represents natural runoff. The percent of median discharge has not been computed, and this gaging station is no longer used as an index station.

Storage in principal reservoirs in Arizona as of March 31, 1964, compared with storage for the previous year, is shown below.

Reservoir	Contents, in acre-feet	
	March 31, 1964	March 31, 1963
Lake Pleasant	17,370	2,800
Verde River system	33,200	31,290
San Carlos Reservoir.	51,630	120,800
Salt River system	719,800	1,018,000

Total diversion of streamflow to Arizona lands in the 1963 water year was more than 2,725,000 acre-feet, about the same as in 1962. About 1,755,000 acre-feet was diverted from the Colorado River for use by the Colorado River Indian Reservation, the Gila Project, and the Valley Division of the Yuma Project. These projects use only surface water for irrigation. About 815,000 acre-feet of the water diverted from the Colorado River was returned to the river or discharged across the Arizona-Sonora International Boundary.

About 970,000 acre-feet of surface water was diverted from the Gila River basin in the 1963 water year. Of this amount, 700,100 acre-feet was diverted from the Salt River at Granite Reef Dam. The other significant surface-water diversions are in the Duncan-Safford areas and for the San Carlos Project. Each of these is used in combination with ground water.

Figure 3 shows a comparison of diversions and reservoir storage for a 5-year period.

Personnel

This report is prepared through the combined efforts of the staff in the Arizona district of the U.S. Geological Survey. The sections in which ground-water conditions by basins or areas are discussed were, in general, prepared by the person most familiar with the particular area. H. C. Schwalen, who prepared the sections on the upper Santa Cruz basin, Avra-Marana area, and Chino Valley, and R. J. Shaw, who collected the field data on which these discussions were based, are employed by the University of Arizona, Agricultural Engineering Department.

In addition to those persons listed as authors, several other people contributed substantially to the preparation of the report. G. S. Smith and F. H. Rascop prepared the illustrations. Others who worked on the report include William Kam, Rita Michunovich, Carol L. Jenkins, Helen S. Price, and Jane Burton. The data upon which the report is based were collected by E. K. Morse, R. S. Stulik, T. W. O'Brien, R. L. Thompson, F. E. Arteaga, and H. W. Steppuhn.

Acknowledgments

Many irrigation districts, cities, well drillers, water and power companies, government agencies, and individuals provided exceptional cooperation in furnishing information. The following organizations were particularly helpful: Arizona Corporation Commission, Arizona Public Service, Arizona Water Company, Buckeye Irrigation District, city of Phoenix, city of Tucson, Cortaro Farms, Gila Water Commissioner, Goodyear Farms, Maricopa County Municipal Water Conservation District, Roosevelt Irrigation District, Roosevelt Water Conservation District, Salt River Valley Water Users' Association, Salt River Power District, San Carlos Irrigation District, Southwest Gas Corporation, Sulphur Springs Valley Electrical Cooperative, Tucson Gas and Electric Company, U.S. Bureau of Indian Affairs, U.S. Bureau of Reclamation, and U.S. Weather Bureau.

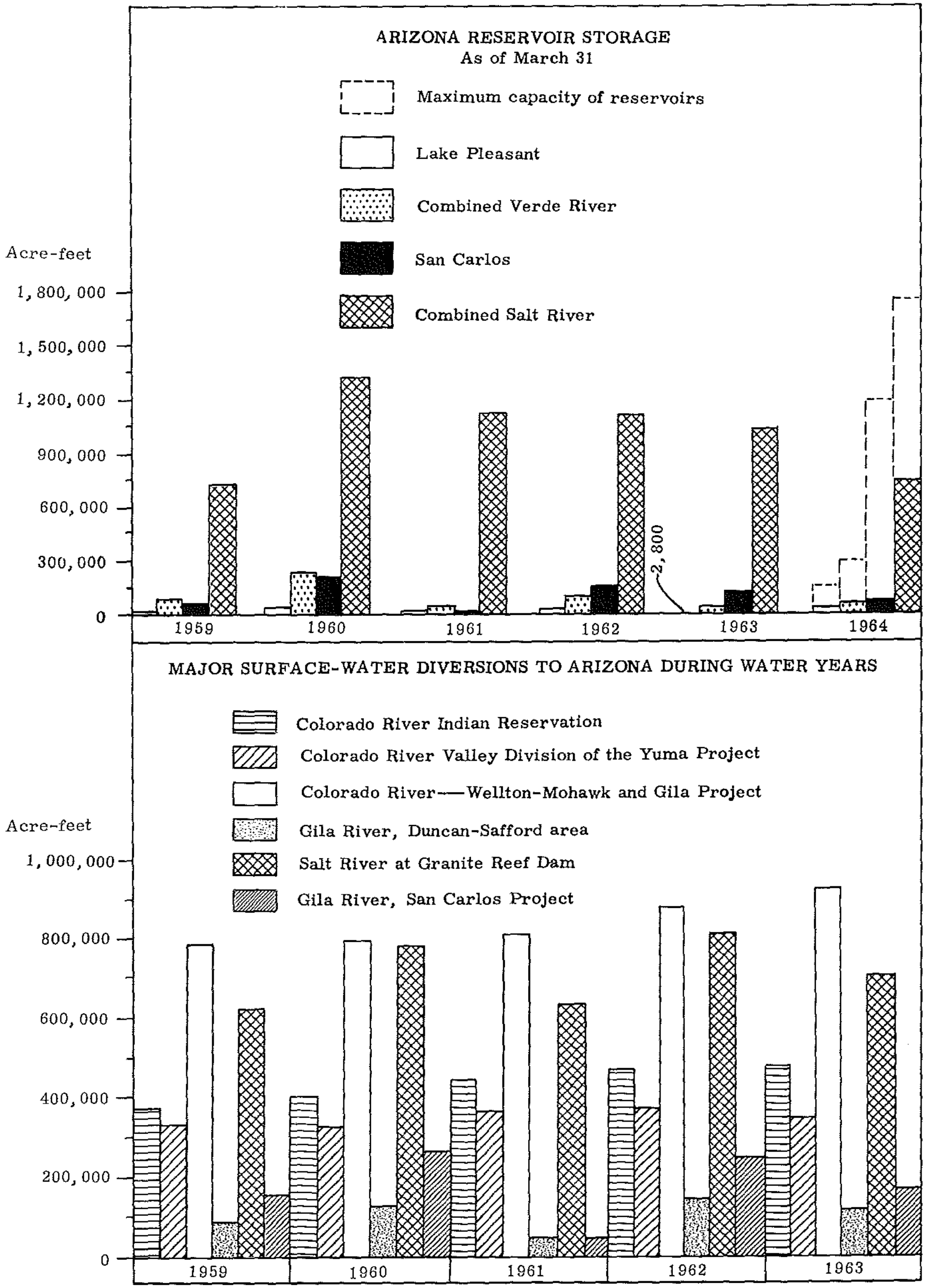


Figure 3.--Surface-water reservoir storage and diversions in Arizona.

GROUND-WATER CONDITIONS BY AREAS

By

Natalie D. White

The occurrence of ground water in Arizona is controlled by the geology and physiography of the three water provinces. These provinces are (1) the Plateau uplands or Colorado Plateaus province in the northern part of the State, (2) the Basin and Range lowlands province in the southern part of the State, and (3) the Central highlands province, which is transitional between the other two provinces. All wells in the State are located by the numbering system explained in figure 4. The following sections describe the current ground-water conditions in the major developed basins and areas in each of the water provinces (fig. 5).

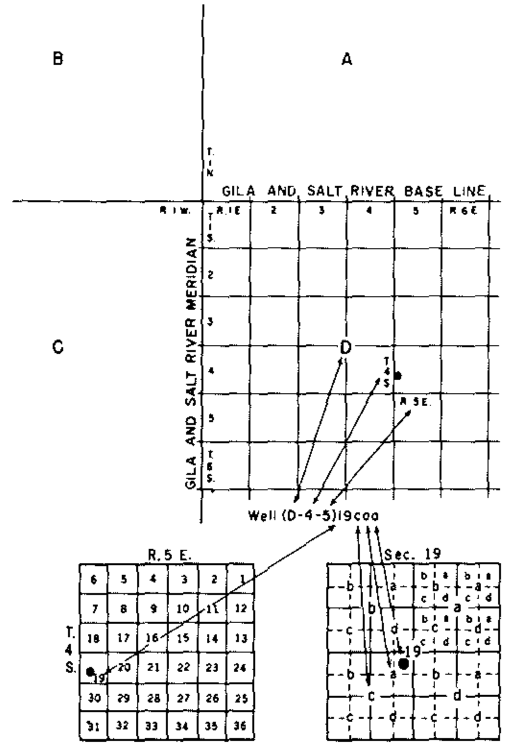
Basin and Range Lowlands Province

By

Natalie D. White

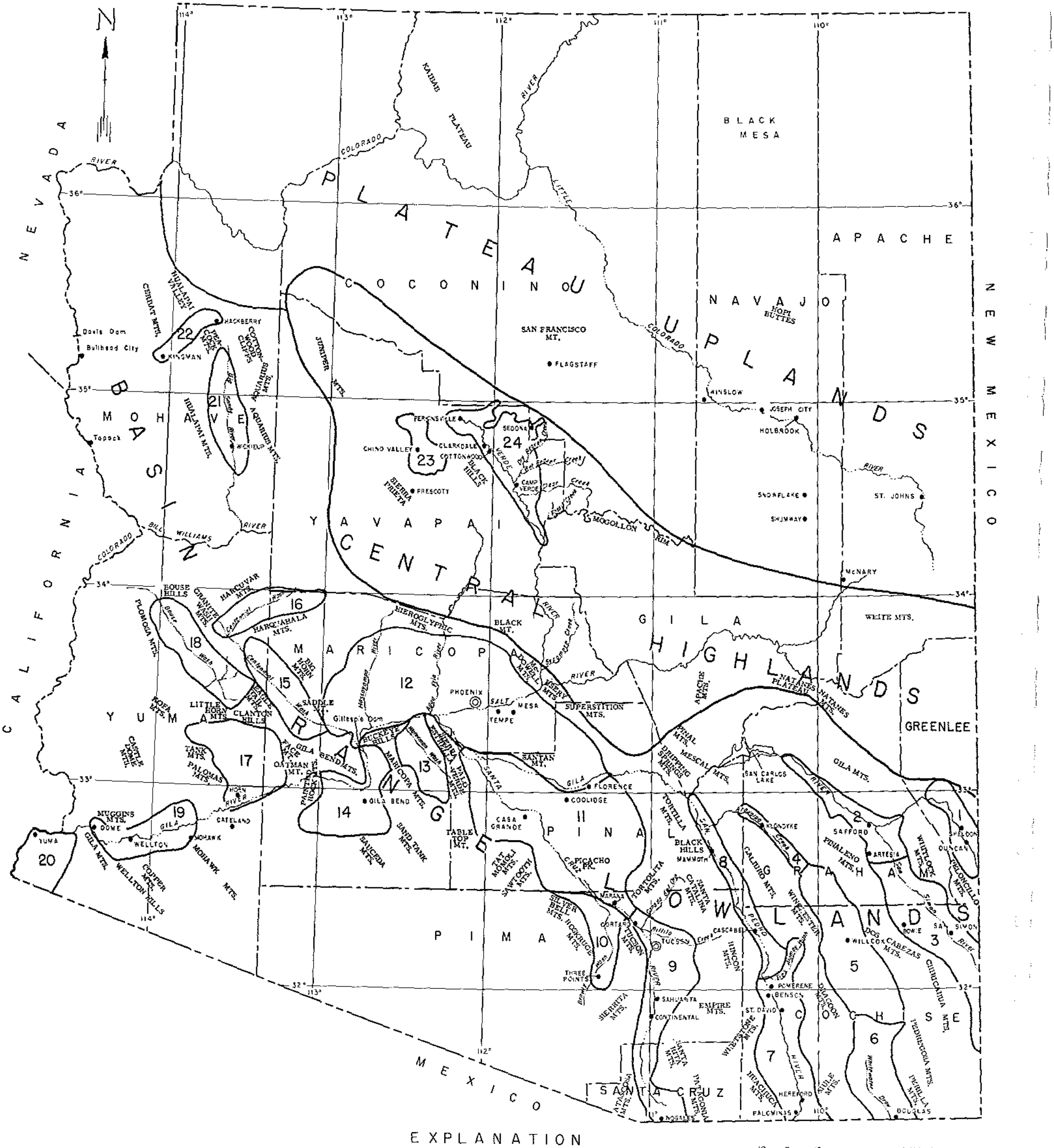
The Basin and Range lowlands province is characterized by isolated mountain blocks separated by broad alluvial-filled basins. The broad flat basin surfaces provide ideal land for agriculture, and more than 90 percent of the cultivated land in the State is within this province.

More than 1 million acres of land is irrigated in the Basin and Range lowlands province with about 6.5 million acre-feet of water annually; municipal, industrial, and domestic use account for another half a million acre-feet annually. About two-thirds of the water used is supplied by ground water; of the ground-water supply nearly 75 percent is pumped from the alluvial aquifers in the lower Santa Cruz basin and Salt River Valley area. Thus, it is in these two areas that water levels are declining at the greatest rate. Other areas where there are significant declines in the water level include the Willcox basin, Avra Valley, and parts of the San Simon basin. The ground-water conditions in individual basins throughout the Basin and Range lowlands province, beginning in the southeast corner of the State and going generally westward and northward, are discussed in the following paragraphs.



The well numbers used by the Geological Survey in Arizona are in accordance with the Bureau of Land Management's system of land subdivision. The land survey in Arizona is based on the Gila and Salt River meridian and base line, which divide the State into four quadrants. These quadrants are designated counterclockwise by the capital letters A, B, C, and D. All land north and east of the point of origin is in A quadrant, that north and west in B quadrant, that south and west in C quadrant, and that south and east in D quadrant. The first digit of a well number indicates the township, the second the range, and the third the section in which the well is situated. The lowercase letters a, b, c, and d after the section number indicate the well location within the section. The first letter denotes a particular 160-acre tract, the second the 40-acre tract, and the third the 10-acre tract. These letters also are assigned in a counterclockwise direction, beginning in the northeast quarter. If the location is known within the 10-acre tract, three lowercase letters are shown in the well number. In the example shown, well number (D-4-5)19caa designates the well as being in the NE$\frac{1}{4}$NE$\frac{1}{4}$SW$\frac{1}{4}$ sec. 19, T. 4 S., R. 5 E. Where there is more than one well within a 10-acre tract, consecutive numbers beginning with 1 are added as suffixes.

Figure 4. --Well-numbering system in Arizona.



EXPLANATION

BASINS AND AREAS

1. DUNCAN BASIN
2. SAFFORD BASIN
3. SAN SIMON BASIN
4. ARAVAIPA VALLEY
5. WILLCOX BASIN
6. DOUGLAS BASIN
7. UPPER SAN PEDRO BASIN
8. LOWER SAN PEDRO BASIN
9. UPPER SANTA CRUZ BASIN
10. AVRA-MARANA AREA
11. LOWER SANTA CRUZ BASIN AND ADJACENT AREA ALONG GILA RIVER
12. SALT RIVER VALLEY
13. WATERMAN WASH AREA
14. GILA BEND AREA
15. HARQUAHALA PLAINS AREA
16. MCMULLEN VALLEY AREA
17. PALOMAS PLAIN AREA
18. RANEGRAS PLAIN AREA
19. WELLTON-MOHAWK AREA
20. SOUTH GILA VALLEY, YUMA MESA, AND YUMA VALLEY AREA
21. BIG SANDY VALLEY
22. KINGMAN-HACKBERRY AREA
23. CHINO VALLEY
24. VERDE VALLEY

Figure 5.--Map of Arizona showing basins and areas for which ground-water conditions are discussed.

Duncan Basin

By

E. S. Davidson

In the Duncan basin (fig. 5, No. 1) most wells are drilled in the alluvium in the inner valley underlying the flood plain of the Gila River. The water table ranges in depth from a few feet to about 40 feet below land surface. Water levels in wells in the irrigated parts of the basin declined about 1 foot from spring 1963 to spring 1964 and are at about the same level as in spring 1959. The hydrograph of the water level in well (D-7-31)4 illustrates the general water-level trend in the area, and that for well (D-8-32)32 illustrates a local water-level rise that began in 1962 (fig. 6).

Safford Basin

By

E. S. Davidson

In the Safford basin (fig. 5, No. 2) ground water is withdrawn principally from the alluvium in the inner valley that underlies the flood plain of the Gila River. Shallow wells are completed in the alluvium, and a few deep artesian wells tap deeply buried aquifers in the basin. A more complete discussion of the aquifers in the basin is contained in two previous reports (White, Stulik, and others, 1962; White, Stulik, Morse, and others, 1963).

From the head of the valley to Geronimo, water levels in wells selected for measurement were from 14 to 58 feet below land surface in spring 1964. Water levels in the heavily irrigated parts of the Gila River drainage have been influenced by the greater-than-average flow of the Gila River from spring 1963 to spring 1964 and especially from August through October. The water levels were from a few tenths of a foot to 4 feet higher in spring 1964 than in spring 1963 and from 1 to 4 feet higher than in spring 1959.

Hydrographs of the water level in wells (D-6-28)31, (D-6-24)5, and (D-4-22)13 (fig. 6) illustrate the general rise in the shallow water-table aquifer dating from 1957; the hydrograph for well (D-7-27)2 shows the same rise for the artesian aquifer beneath the shallow aquifer.

Water levels in the Artesia area declined about 2 feet from spring 1963 to spring 1964 and about 6 feet since spring 1959. Sparse records for the Cactus Flat area indicate a 5-year water-level decline of more than 10 feet, but most of the decline occurred from spring 1963 to spring 1964. The wells in this area tap artesian aquifers, and the water levels are subject to large variations due to slight changes in the pressure head of the aquifer; therefore, the decline may not represent a long-term condition due to pumping.

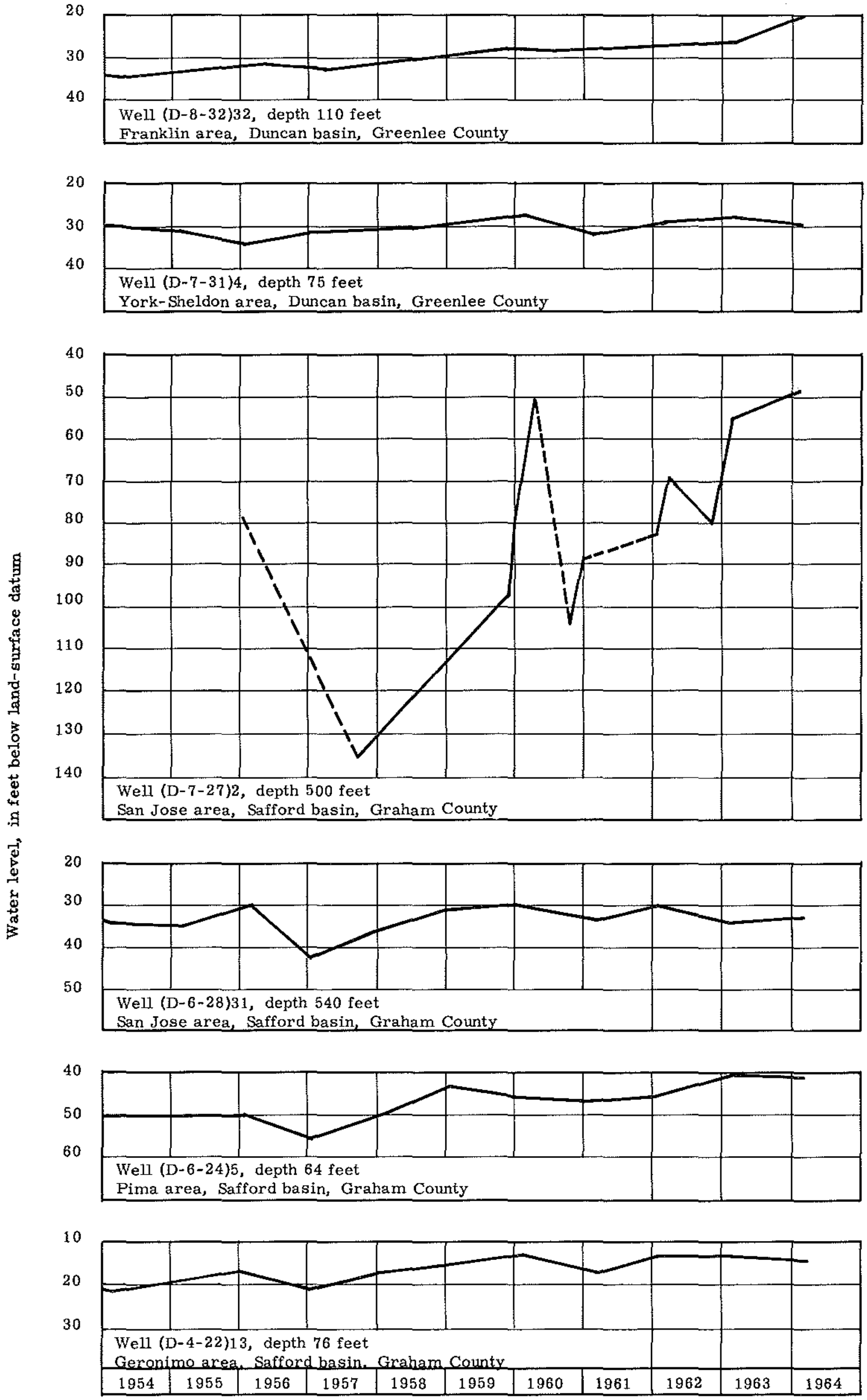


Figure 6. --Water levels in selected wells, Duncan and Safford basins.

San Simon Basin

By

Natalie D. White

The San Simon basin (fig. 5, No. 3) is part of a northwest-trending structural trough that extends from south of the International Boundary to Globe, Ariz.; it is bounded on the east by the Peloncillo Mountains and on the southwest and west by the Chiricahua, Dos Cabezas, and Pinaleno Mountains. The subsurface material in the San Simon basin has been described by White (1963).

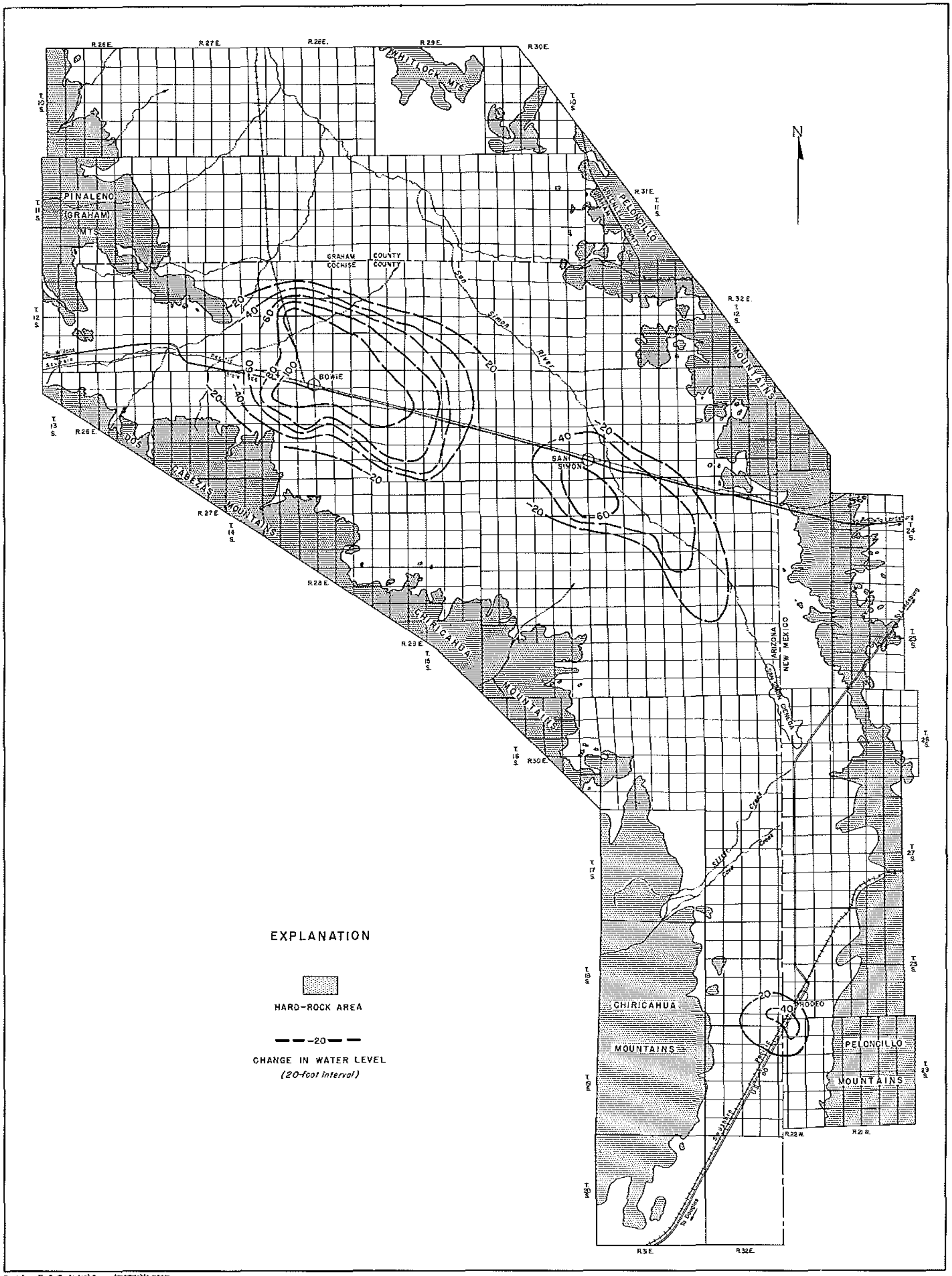
There are two major areas of ground-water development in the basin: (1) the Bowie area, centered around the town of Bowie on the west side of the basin; and (2) the San Simon area, centered around the town of San Simon near the San Simon River on the east side of the basin. Another smaller area of development in the basin is on the Arizona-New Mexico State line near Rodeo, New Mexico.

Bowie area.--In most parts of the Bowie area groundwater is under artesian head. However, several wells have been drilled along the basin flank a few miles south of Bowie where ground water is under water-table conditions. In addition, on the southwestern edge of the area, the water level in a few wells had dropped below the bottom of the confining layer so that these wells are now operating under water-table conditions. The water level in wells in the Bowie area ranged from less than 120 to nearly 370 feet below land surface in the spring of 1964. The greatest depths to water are in the water-table wells south of Bowie.

Water-level fluctuations in the artesian wells ranged from less than 5 to nearly 30 feet from spring 1963 to spring 1964. From spring 1959 to spring 1964, the water-level declines in these wells averaged about 40 feet. Figure 7 shows contours of the change in water level from spring 1954 to spring 1964 and indicates that in this 10-year period the water level in the artesian wells in the center of the area of heaviest pumping declined as much as 100 feet. The water level in well (D-13-29)18 (fig. 8) declined about 33 feet from spring 1959 to spring 1964.

The decline in water level in wells south of Bowie was as much as 100 feet from spring 1954 to spring 1964 (fig. 7) and nearly 70 feet from spring 1959 to spring 1964. The apparent rise in water level of nearly 20 feet in well (D-13-28)16 (fig. 8) from spring 1963 to spring 1964 is an anomaly; the 1963 water level may be low due to pumping of the well prior to the measurement.

In the essentially undeveloped area between Bowie and San Simon, the depth to water is somewhat shallower than in the two areas of development; one well about 10 miles southeast of Bowie was flowing in the spring of 1964. However, the cones of depression from the two developed areas are extending into this area, and the water level in a well about 9 miles southwest of Bowie has dropped to 25 feet below land surface; this well was flowing in 1957.



Base from U. S. Geological Survey topographic maps; San Simon, 1915; Chiricahua, 1917

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Figure 7.-- Map of San Simon basin, Cochise and Graham Counties, Ariz., showing change in ground-water level from spring 1954 to spring 1964.

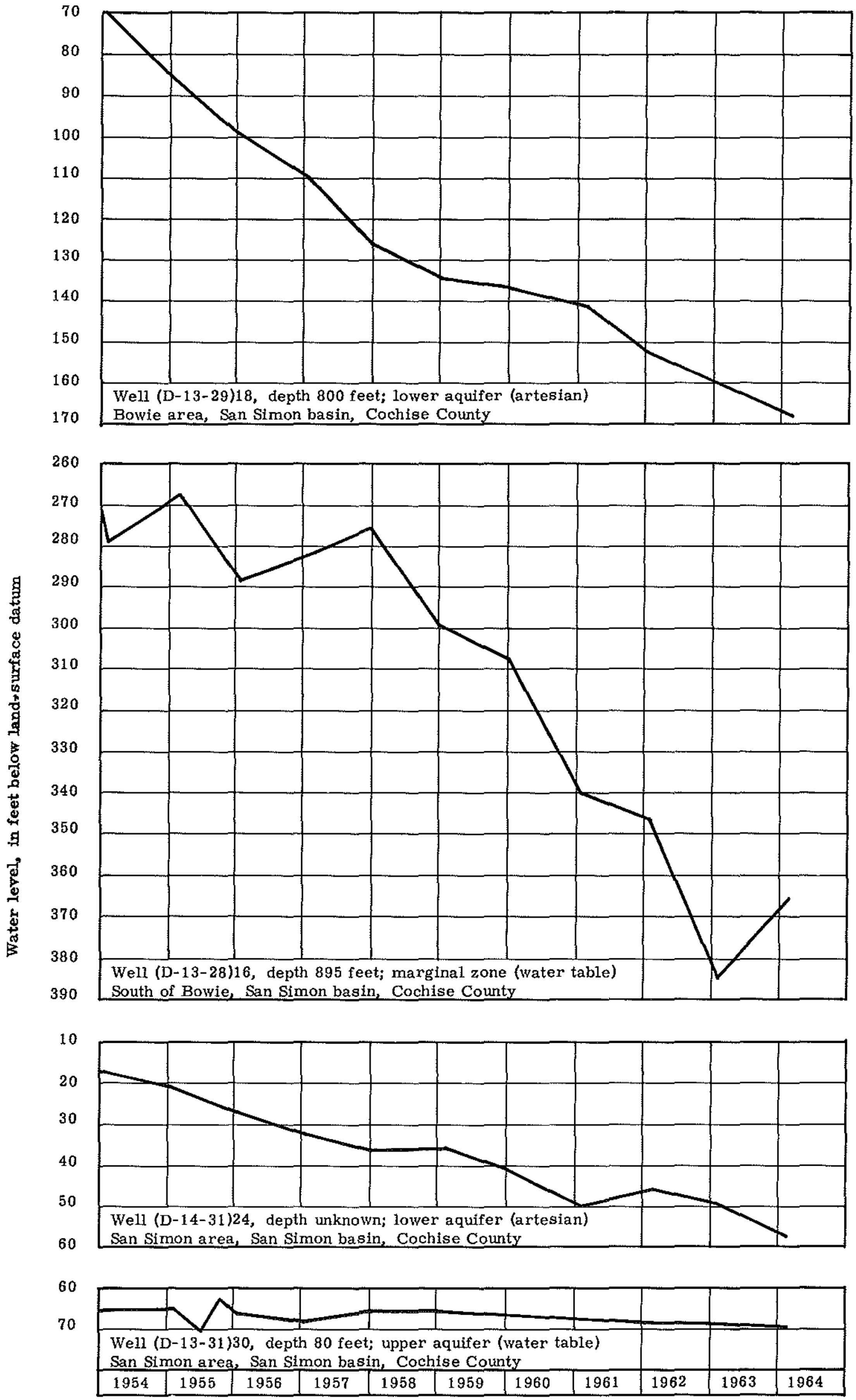

Figure 8.--Water levels in selected wells in the San Simon basin.

San Simon area. --Ground water occurs under artesian head and under water-table conditions in the San Simon area.

The depth to water in the artesian wells in the San Simon area ranged from less than 20 to more than 150 feet below land surface in the spring of 1964. The water-level changes in these wells ranged from a slight rise to a decline of nearly 25 feet from spring 1963 to spring 1964 and from a slight rise to more than 30 feet of decline from spring 1959 to spring 1964. Figure 7 shows that there was more than 60 feet of decline from spring 1954 to spring 1964. The water level in well (D-14-31)24 (fig. 8) declined slightly more than 20 feet from spring 1959 to spring 1964.

Water levels in water-table wells in the San Simon area and the lesser developed area to the west ranged from about 40 to 80 feet below land surface in the spring of 1964. Changes in water level in these wells ranged from a rise of about 2 feet to a decline of about 2 feet from spring 1963 to spring 1964; from spring 1959 to spring 1964 changes in water level ranged from a rise of about 4 feet to a decline of about 4 feet. The water level in well (D-13-31)30 (fig. 8) declined about 1 foot from spring 1963 to spring 1964 and about 4 feet from spring 1959 to spring 1964.

In and near the San Simon Cienaga water levels are less than 25 feet below land surface, although only 2 miles to the east and to the west of the cienaga, the water level measured in wells in the spring of 1964 was about 160 feet below land surface.

Rodeo area. --The development of ground water for irrigation in the Rodeo area is comparatively minor; however, near Rodeo some water is withdrawn for irrigation use, and the water levels are declining. In the spring of 1964 water levels in this area ranged from about 100 to slightly more than 175 feet below land surface. From spring 1963 to spring 1964 water-level changes in wells in this area ranged from a slight rise to a decline of about 4 feet; from spring 1959 to spring 1964 water-level changes ranged from a slight rise to a decline of more than 20 feet. Figure 7 shows that there has been as much as 40 feet of decline in the area during this period. In the area between Rodeo and the San Simon Cienaga the development of ground water for irrigation is comparatively recent. Data are insufficient to determine any significant pattern of water-level change, although there seems to be some slight decline. The water level in well (D-18-32)11 (fig. 9) declined about 4 feet from spring 1959 to spring 1964; the water level in well (D-18-32)26 rose about 2 feet from spring 1963 to spring 1964 (fig. 9).

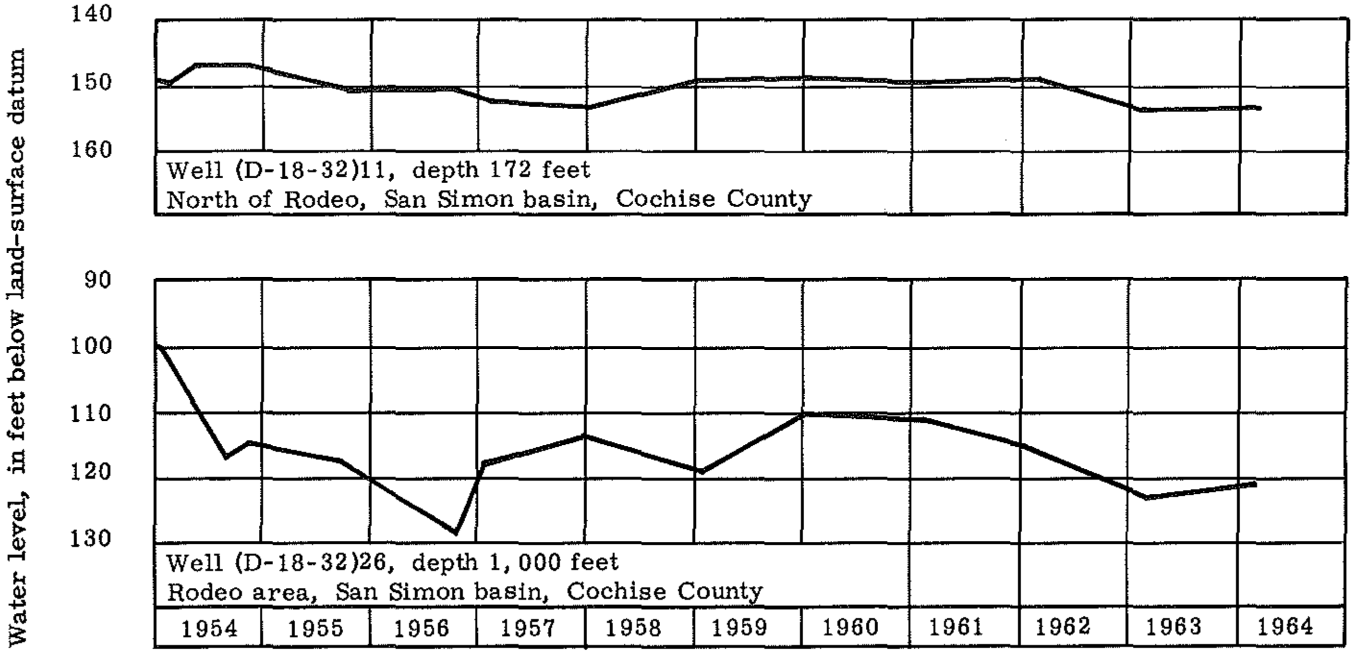

Figure 9. --Water levels in selected wells in the southern part of the San Simon basin.

Sulphur Spring Valley

By

S. G. Brown

The Sulphur Spring Valley (fig. 5, Nos. 5 and 6) in southeastern Arizona is part of a structural trough that extends from the Gila River on the north into Mexico on the south. Willcox basin, which has no external drainage, is in the northern three-fifths of the valley; whereas, Douglas basin drains southward into Mexico and is in the southern two-fifths of the valley. A drainage divide in the buttes and ridges south of Pearce separates the Willcox basin from Douglas basin. A drainage divide at the headwaters of Aravaipa Creek marks the northern end of the Willcox basin.

Willcox basin. --Water levels were measured in 122 wells in the Willcox basin (fig. 5, No. 5) in the spring of 1964. In the extensively developed Kansas Settlement area (fig. 10) water levels continued the rapid decline of the last few years, although rises in water level were noted in a few wells between the Kansas Settlement road and the Willcox Playa. From 1959 to 1964, measured changes in water level ranged from a rise of 24 feet to declines of more than 80 feet; the average change in water level during this period was a decline of 43 feet. From spring 1963 to spring 1964, water-level changes ranged from an isolated rise of 18 feet in one well to a decline of 69 feet in one well. Water-level declines from spring 1963 to spring 1964 averaged slightly less than 7 feet.

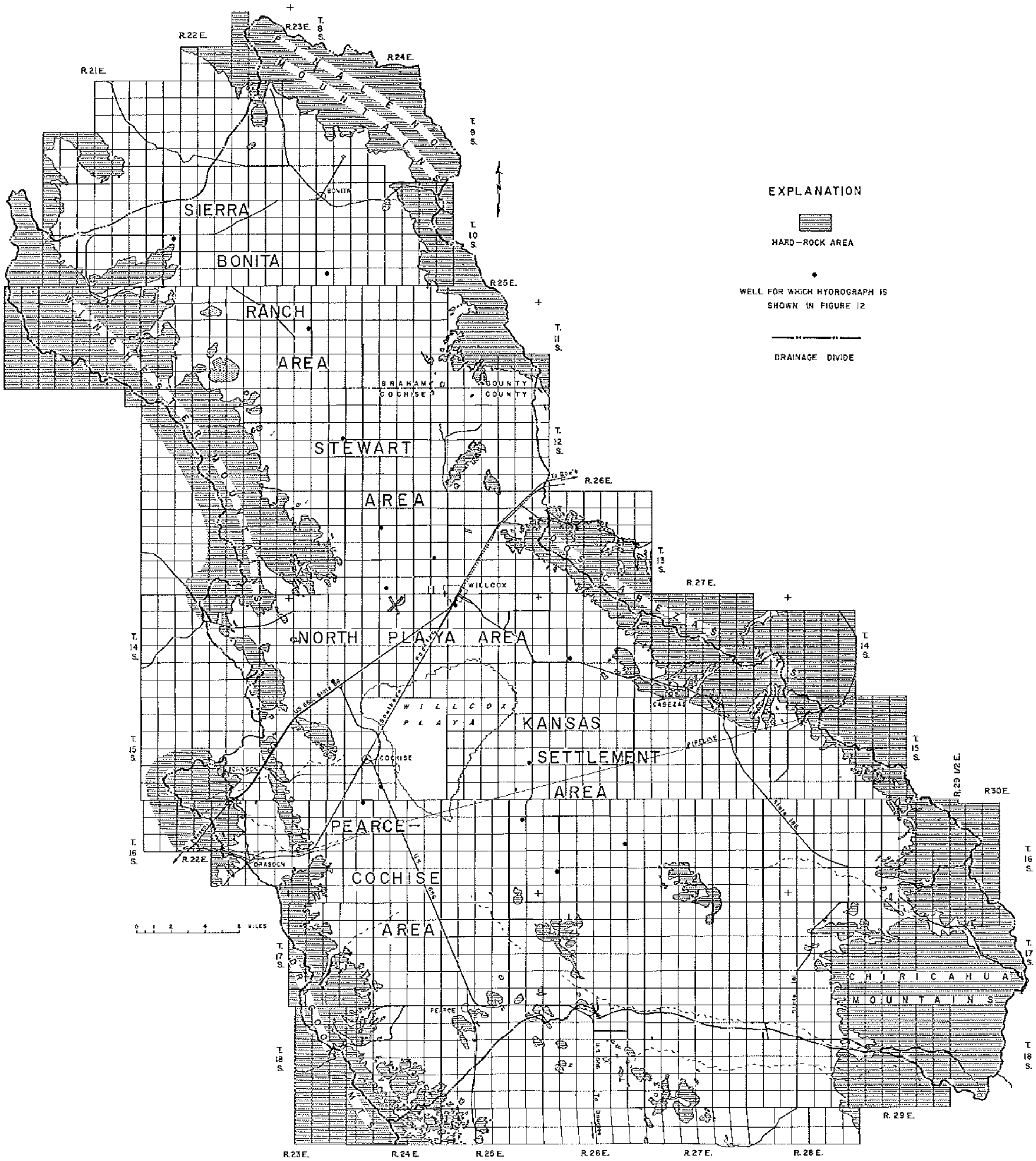

Figure 10.-- Index map for Willcox basin, Cochise and Graham Counties, Ariz.

Water levels in wells in the Stewart area (fig. 10) northwest of Willcox also have continued to decline. From 1959 to 1964 declines of as much as 26 feet were measured in two wells, and a rise of 2 feet was measured in one well. The average change in water level during the 5-year period was a decline of about 7 feet. From spring 1963 to spring 1964 the average decline in water level, as measured in 56 wells, was more than 2 feet.

In the Cochise-Pearce area (fig. 10) the average change in water level from spring 1959 to spring 1964 was a decline of 6 feet; water-level changes during this period ranged from a rise of 5 feet to a decline of more than 20 feet. From spring 1963 to spring 1964 water-level changes ranged from a rise of 1 foot to a decline of 6 feet; the average water-level change was a decline of about 1 foot.

The water levels in wells (D-13-24)16 and (D-16-26)7 in the highly developed Stewart and Kansas Settlement areas, respectively, show declines typical of the areas (fig. 11). The water level in well (D-14-24)30 (fig. 11) is typical of an area where there is only a small amount of ground-water development.

The cumulative net change in average water level has been computed for five areas in the Willcox basin using the average water level in 1952 as a base (fig. 12). The five areas (fig. 10) were chosen on the basis of the time that development of ground water began, the amount of ground-water withdrawal, and geographic location. In addition to the average declines for each of the five areas, data are plotted for several representative wells in each of the areas. For the most part, the curves show a downward trend of the water level; however, in part of the area where there is little ground-water development for irrigation (such as the Sierra Bonita Ranch area) the curves show little or no decline or even slight rises in the average water levels. However, any increase in pumping for irrigation will accelerate the downward trends of the water levels and reverse any existing upward trends, as the slight decline in average water levels shows that withdrawals already equal or slightly exceed average recharge to the area. The rate of decline is not as great in the Stewart area as it is in the Kansas Settlement area. The rise in water level in a few wells in these two areas may be caused, in part, by infiltrating tailwater from upslope irrigation and, in part, by interaquifer flow through wells from deeper zones of higher head.

Douglas basin. --In the spring of 1964 water levels were measured in 105 wells in the Douglas basin (fig. 5, No. 6). Depth to water in the Douglas basin ranges from about 30 to 150 feet below land surface and in most areas is less than 100 feet below land surface. From 1959 to 1964 the average change in water level was a decline of about 5-½ feet, although water-level changes ranged from rises of as much as 12 feet to declines of as much as 30 feet. Figure 13 shows contours of the change in water level in the basin for the 5-year period. From 1963 to 1964 the average water-level change was a decline of 0.4 foot. Of the 105 wells measured, the water level in 29 wells either rose or did not change since spring 1963; the average rise was 5.6 feet. Declines were measured in 76 wells, and the average decline was 2.7 feet.

The water level in wells (D-18-26)28, (D-22-26)28, and (D-21-26)2 declined

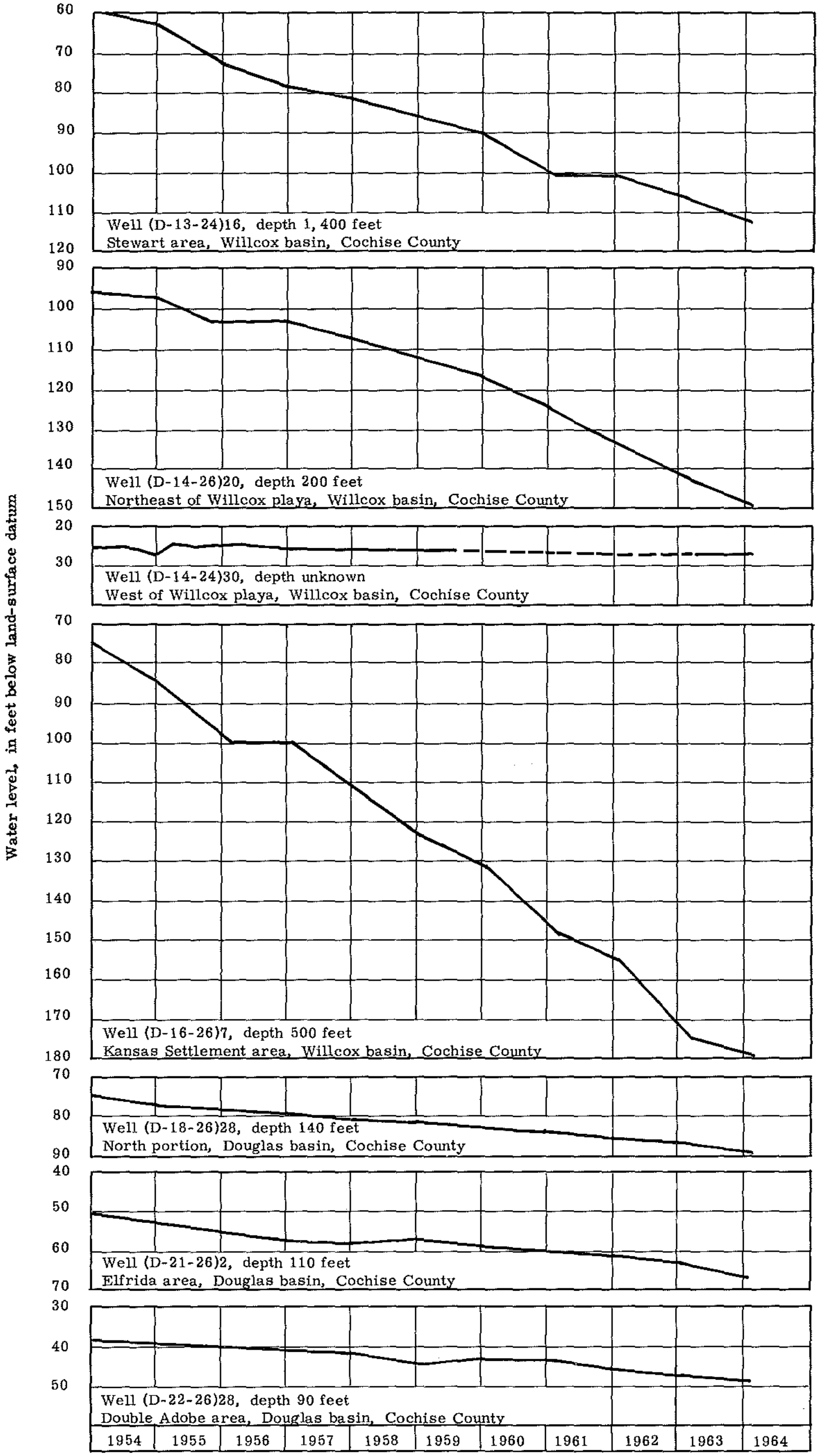

Figure 11.--Water levels in selected wells in Sulphur Spring Valley.

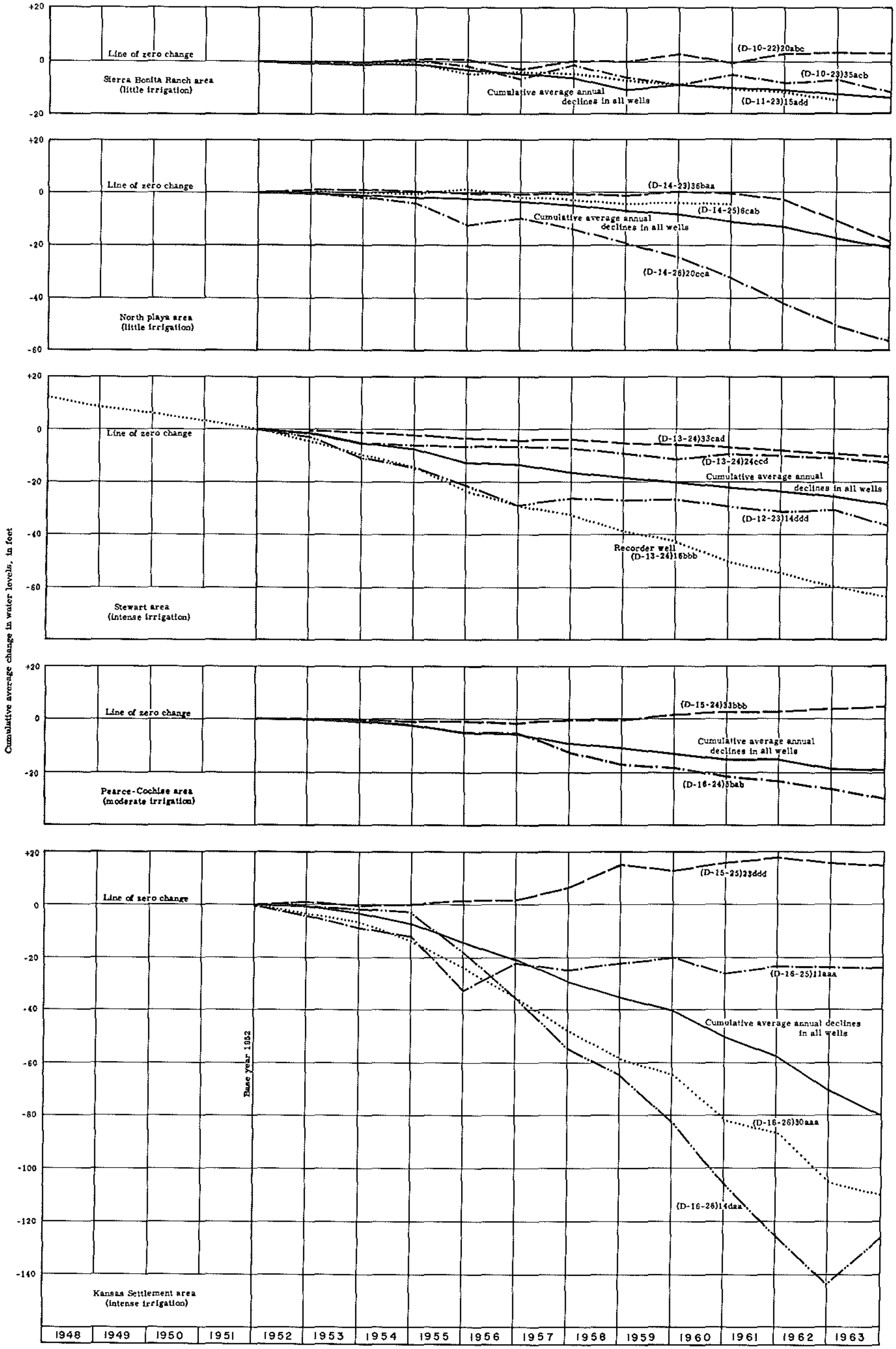

Figure 12.—Cumulative change in water levels, Willcox basin.

1, 2, and 3 feet, respectively, from spring 1963 to 1964; this decline is the continuation of a gradual decline in the water level that began about 1950 (fig. 11).

San Pedro River Valley

By

Natalie D. White

The San Pedro River valley (fig. 5, Nos. 7 and 8) is divided into the upper and lower San Pedro basins. The upper San Pedro basin (fig. 5, No. 7) extends from the International Boundary to the Narrows near Tres Alamos. The lower San Pedro basin (fig. 5, No. 8) extends from the Narrows to the Gila River near Winkleman. Davidson (in White and others, 1963) described the rocks in the San Pedro River valley and their relation to the hydrology of the area.

Upper San Pedro basin.--In the upper San Pedro basin (fig. 5, No. 7) ground water is withdrawn from the water-table and artesian aquifers for irrigation, chiefly in the areas between Palominas and Hereford and between St. David and Pomerene. The depth to water in wells along the flood plain of the river ranged from less than 30 to more than 85 feet below land surface in the spring of 1964. Water-level fluctuations in these wells are erratic due to recharge from flow in the San Pedro River and irregular pumping of the wells. Water-level declines ranged from about 2 to 7 feet from spring 1959 to spring 1964; from spring 1963 to spring 1964 water-level changes ranged from a rise of about 8 feet to a decline of 5 feet. The water level in well (D-16-20)34 declined about 2 feet (fig. 14) from spring 1963 to spring 1964, but no overall pattern of rise or decline is discernible. Some artesian wells along the flood plain of the river flowed at the surface, and the water levels in other artesian wells were more than 30 feet below land surface in spring 1964. The change in water level in well (D-17-21)32 (fig. 14) probably is typical of these wells; in general the water level is declining slightly. From spring 1963 to spring 1964 a rise in water level was indicated due to the fact that the measurement in 1963 had been influenced by recent pumping of the well. The water level in the deeper wells along the flanks of the valley ranged from about 30 to more than 300 feet below land surface in spring 1964. The water level in well (D-20-20)32 (fig. 14) declined less than 2 feet from spring 1963 to spring 1964.

Lower San Pedro basin.--Most of the water used for irrigation in the lower San Pedro basin (fig. 5, No. 8) is withdrawn from shallow wells along the flood plain of the river. South of Mammoth a few deep wells along the flood plain yield small amounts of water under artesian pressure.

The depth to water in wells along the flood plain of the river generally is less than 60 feet below land surface but increases rapidly to the northeast and southwest away from the river. Water levels in the shallow wells fluctuate erratically, depending on the flow in the river and the pattern of pumping.

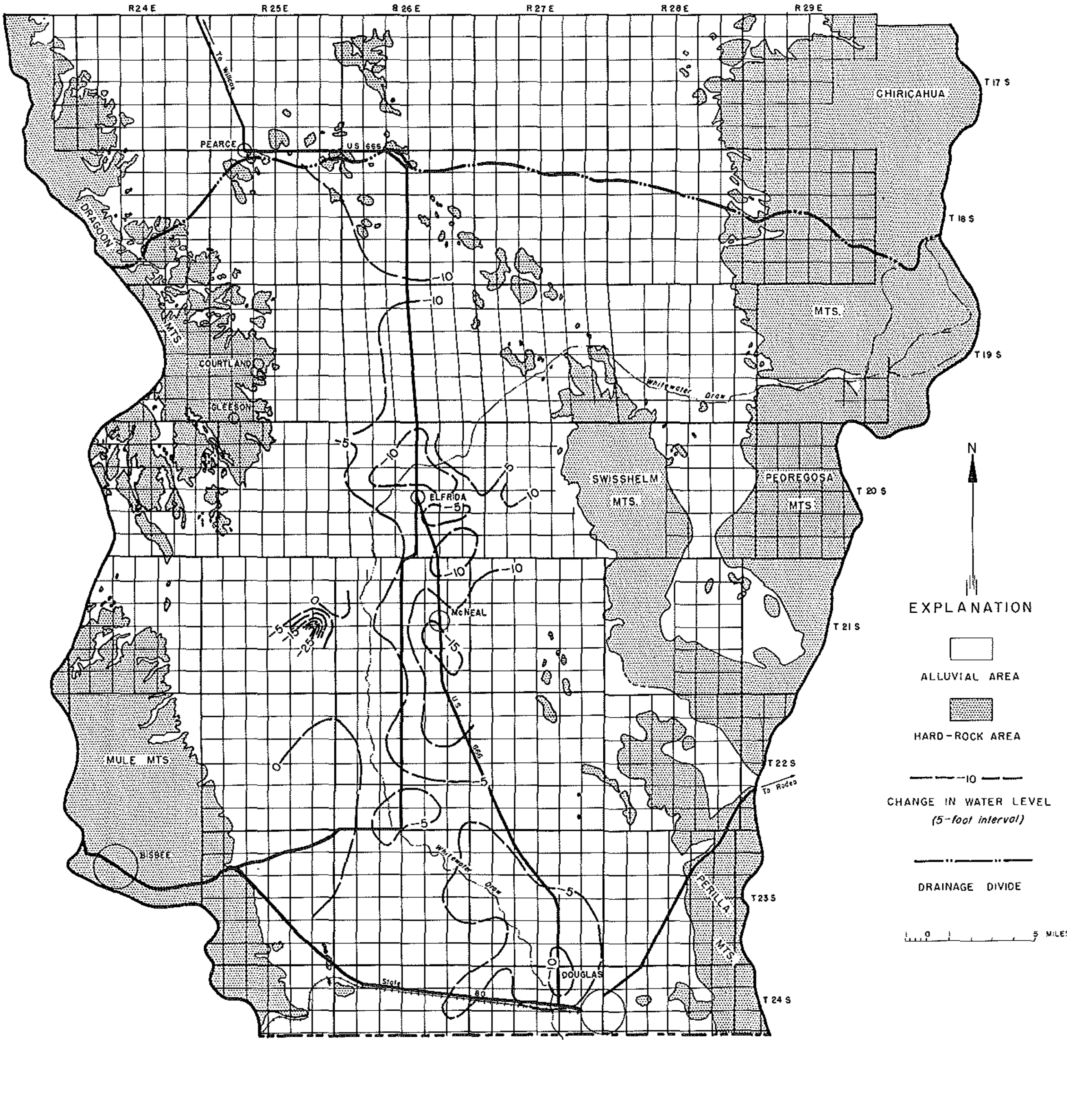

Figure 13.--Map of Douglas basin, Cochise County, Ariz., showing change in ground-water level from spring 1959 to spring 1964.

From spring 1963 to spring 1964 water-level changes generally ranged from a rise of 2 feet to a decline of 2 feet; however, the water level in two wells, in which the water level fluctuates with flow in Aravaipa Creek, declined 6 and 10 feet, respectively, due to lack of flow in the creek. From 1959 to 1964 water-level changes ranged from a rise of about half a foot to a decline of 3 feet. The water level in wells (D-13-19)23 and (D-8-17)19 (fig. 14) fluctuates mainly in response to flow in the San Pedro River--rising during periods of runoff in the river and declining in dry periods.

Upper Santa Cruz Basin

By

H. C. Schwalen[1]/

The part of the Santa Cruz River valley extending from the International Boundary north to the Rillito Narrows, about 16 miles northwest of Tucson, is included in the upper Santa Cruz basin (fig. 5, No. 9). It has been divided into the Cortaro-Canada del Oro, Tucson, Sahuarita-Continental, and Santa Cruz County areas. The annual water-level-measuring program of the Agricultural Engineering Department includes measurement of about 1,500 wells in the basin.

Cortaro-Canada del Oro area.--The Cortaro-Canada del Oro area (fig. 15) is north of Rillito Creek between the Santa Catalina and the Tucson Mountains and south and east of the Tortolita Mountains. Pumping of ground water in the area is confined mainly to the Cortaro bottom lands, which occupy the flood plain along the Santa Cruz River between the Rillito Narrows and the mouth of Rillito Creek.

From spring 1963 to spring 1964 water-level declines of from 1 to 3 feet occurred in a large part of the area. However, the water level in well (D-11-14)2 (fig. 16) in the upper Canada del Oro area adjacent to the stream declined about 9 feet from spring 1963 to spring 1964. Water-level rises ranged from 1 to 3 feet above the Rillito Narrows; there has been little decline in the water table from Cortaro to the Rillito Narrows.

Tucson area.--The Tucson area (fig. 15) is the wide central part of the Santa Cruz River valley from Rillito Creek on the north to the south line of T. 15S., Rs. 13 and 14E. It includes the irrigated lands in the San Xavier Indian Reservation and the area southeast of Tucson.

Measurements in spring 1964 indicated water-level declines of from 3 to 5 feet in a large part of the metropolitan area, and declines of more than 10 feet occurred in some small isolated areas. The water level in well (D-15-13)2 (fig. 16), although it fluctuates with flow in the Santa Cruz River

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[1]/ Agricultural engineer, Agricultural Engineering Department, University of Arizona.

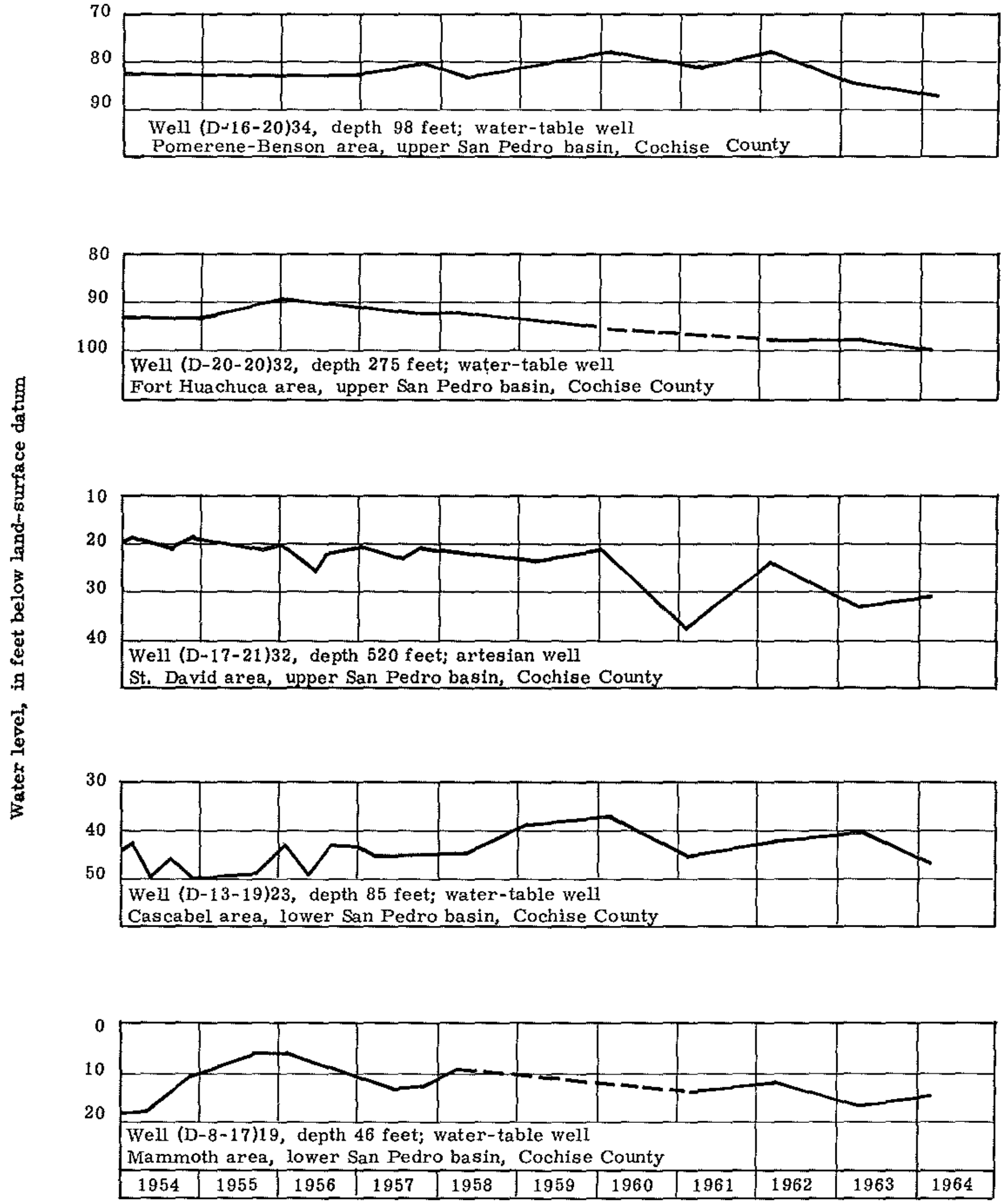

Figure 14.--Water levels in selected wells in the San Pedro River valley.

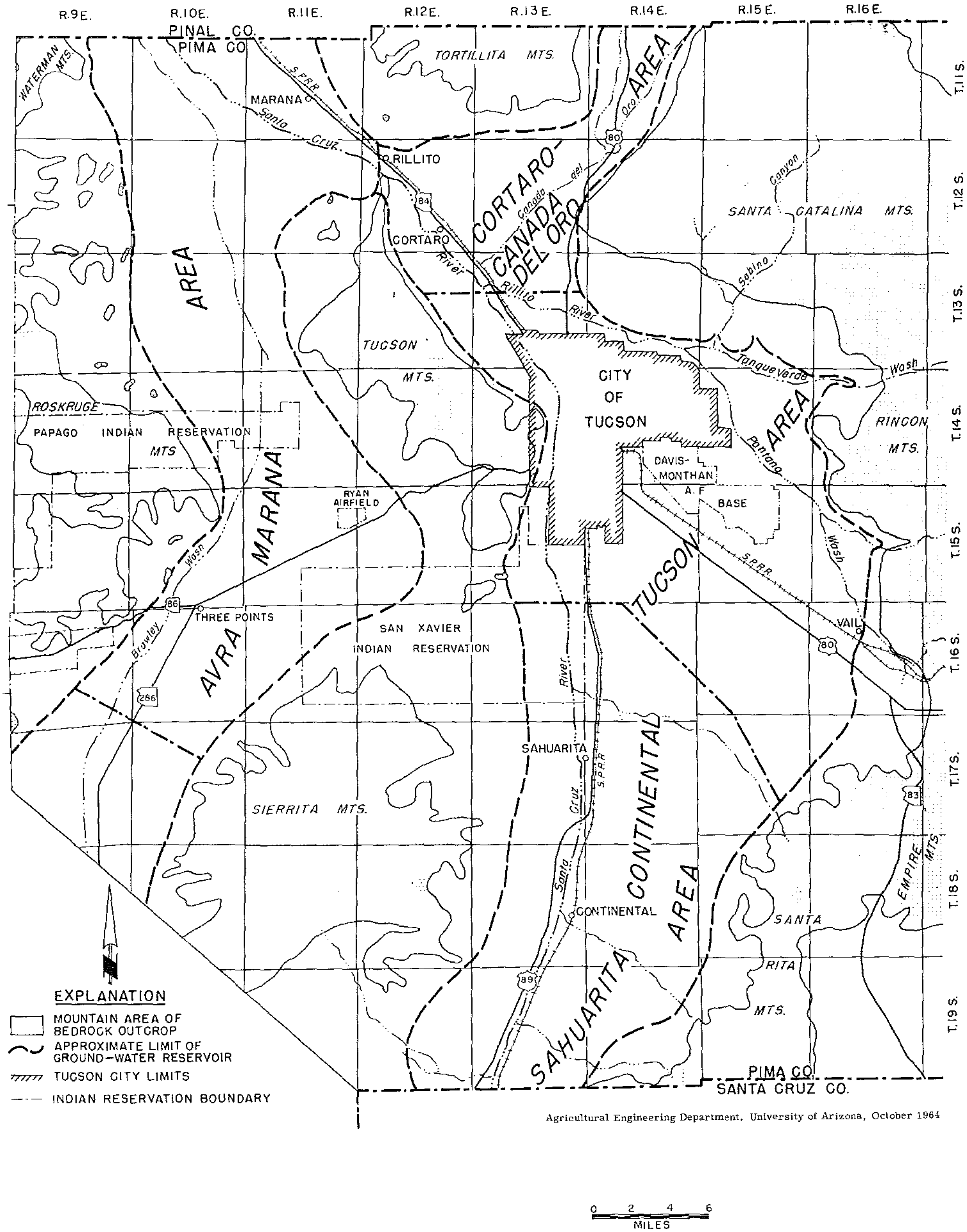

Figure 15.--Index map for upper Santa Cruz basin, Pima and Santa Cruz Counties, Ariz.

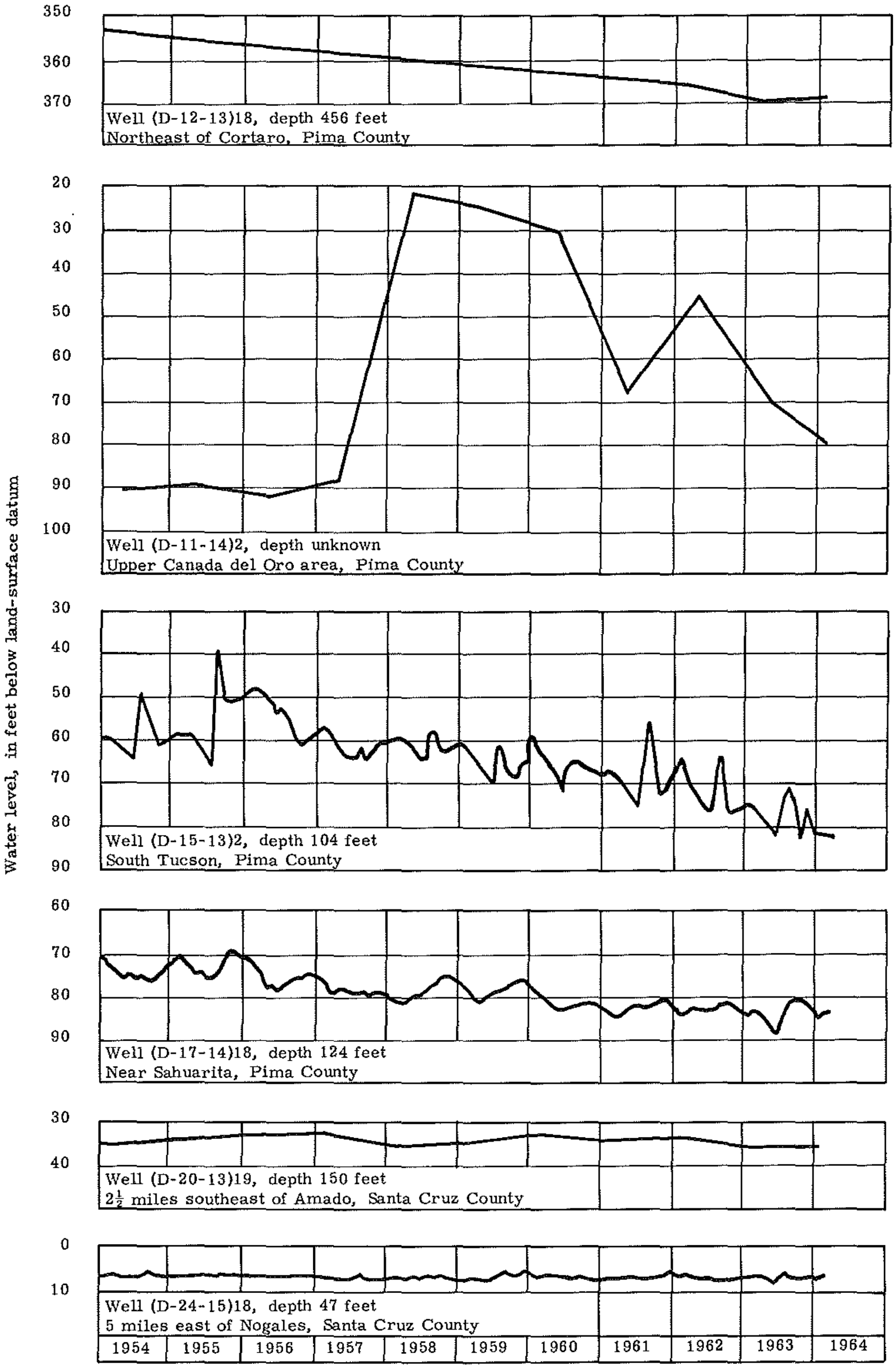

Figure 16.--Water levels in selected wells in the upper Santa Cruz basin.

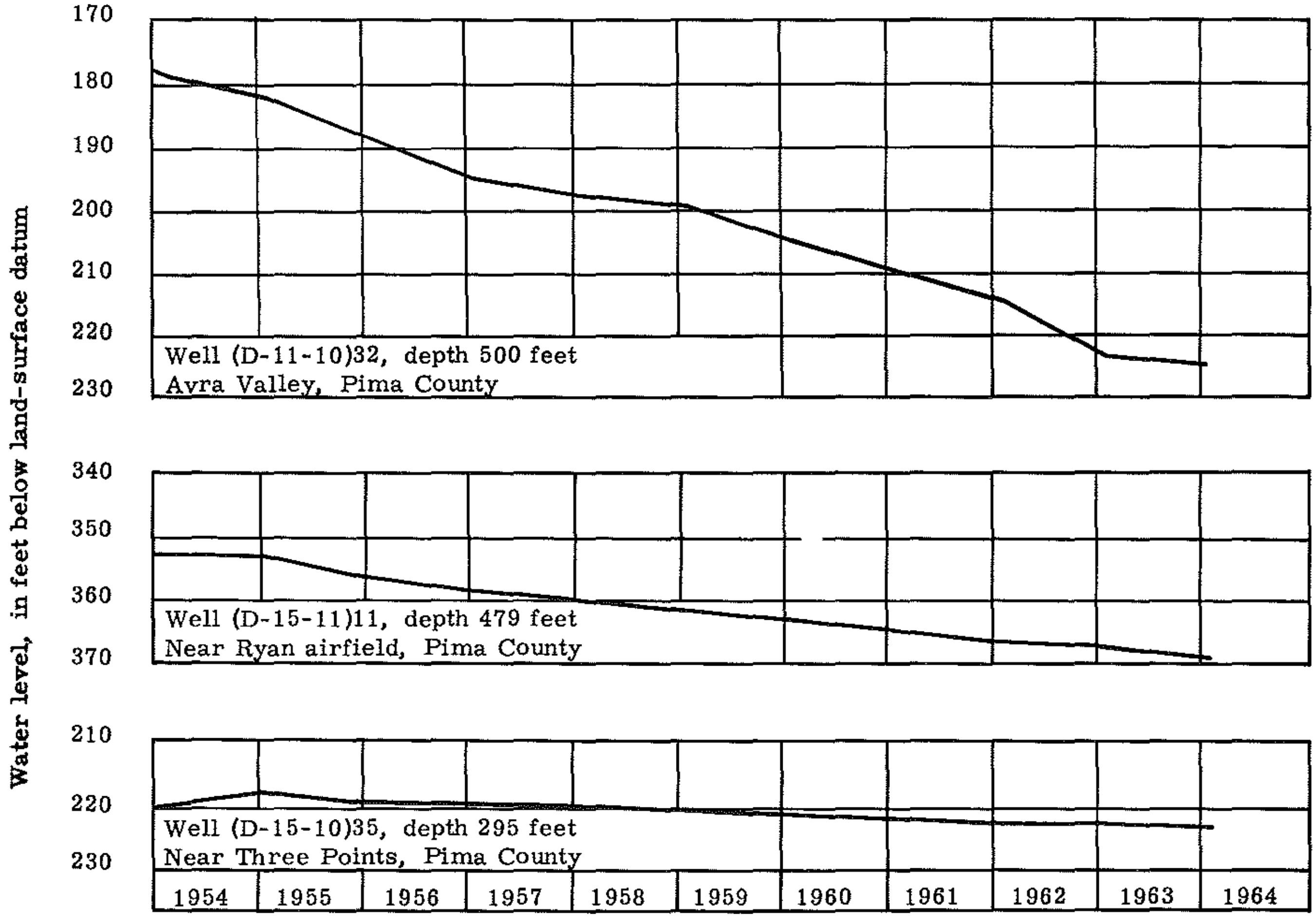

Figure 17.--Water levels in selected wells in the Avra-Marana area.

A recent report (White, Stulik, and Rauh, 1964) describes current ground-water conditions in the area and predicts the status of the water table to the year 1969. The prediction of the water level is shown as a depth-to-water map for that time.

The Salt River Valley is the largest area of agricultural development in the State and, consequently, is first in the amount of ground water pumped annually. For the most part, water levels in the Salt River Valley continued to decline at varying rates during 1963. The maximum declines were in the heavily pumped areas such as Deer Valley, northwest of Litchfield Park, and east of Mesa; minimum declines occurred in the areas where surface-water diversions supplemented ground-water withdrawal. Figures 21, 22, and 23 are hydrographs of the cumulative net change in water levels in five of the areas of the Salt River Valley. Average declines in these areas ranged from about 3 feet to nearly 10 feet from spring 1963 to spring 1964. Depth to water in the Salt River Valley in the spring of 1964 ranged from a few feet to more than 500 feet below land surface.

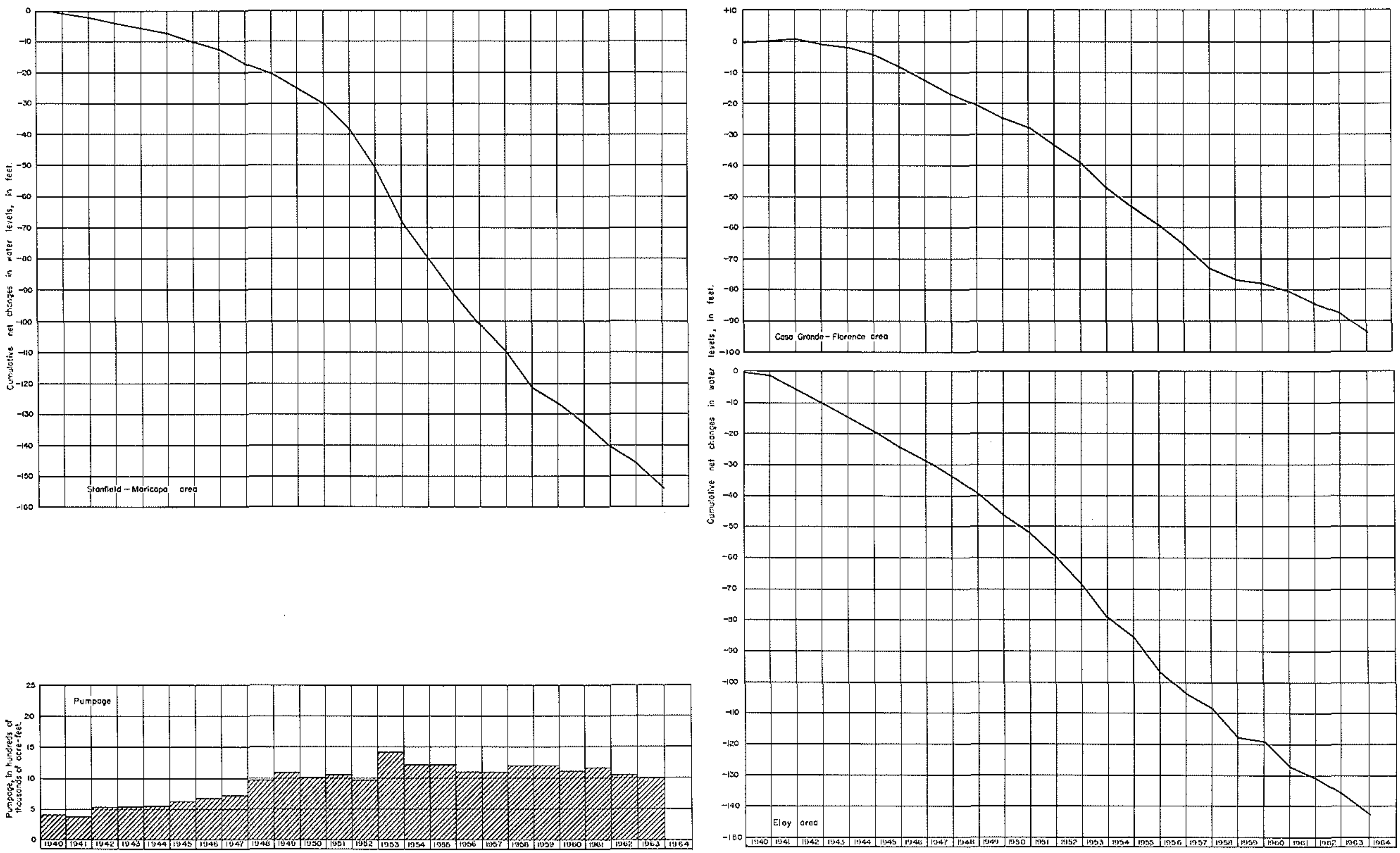

Figure 18.--Cumulative net changes in water levels by areas and total annual pumpage in the lower Santa Cruz basin within Pinal County.

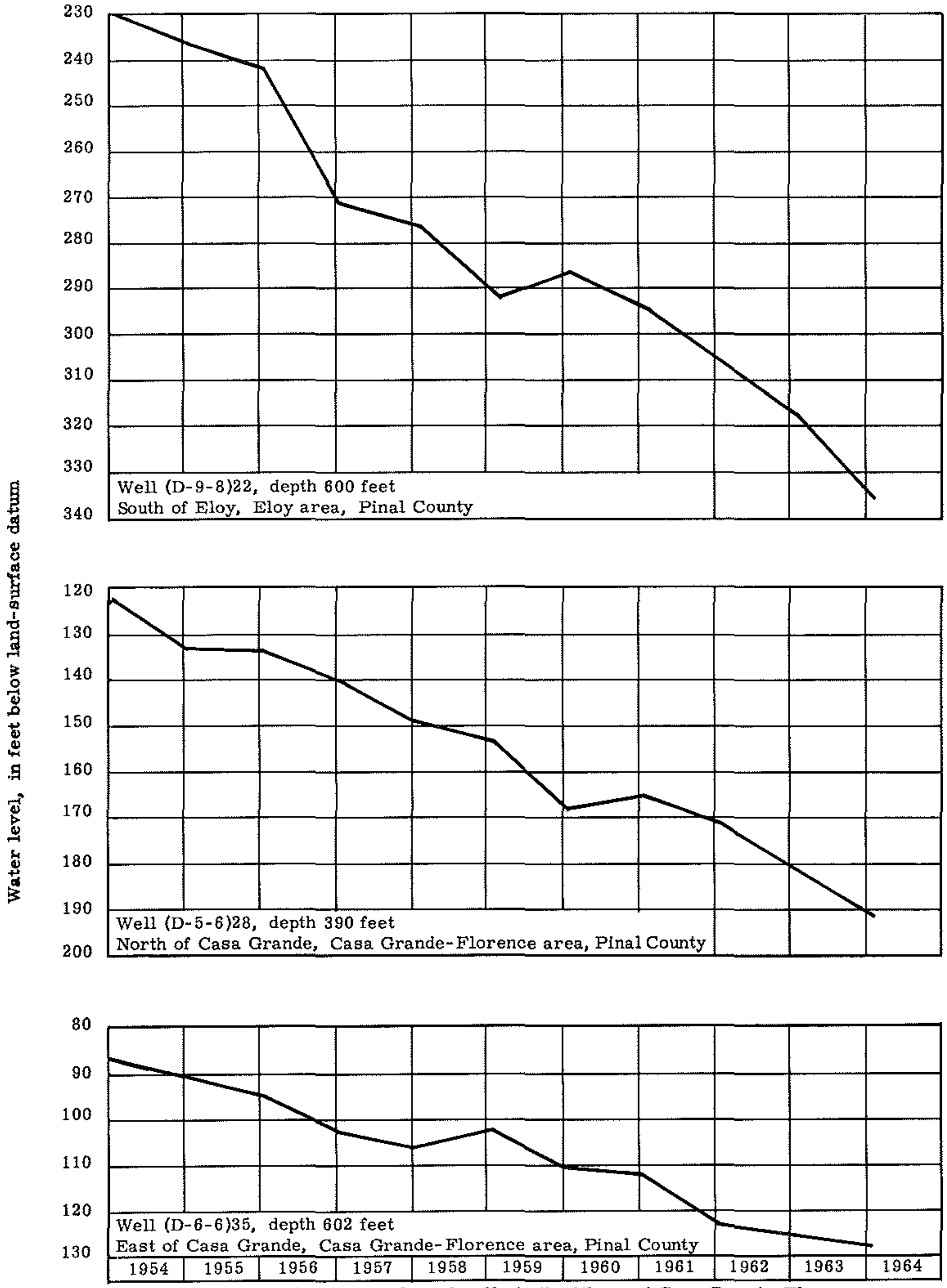

Figure 19.--Water levels in selected wells in the Eloy and Casa Grande-Florence areas, lower Santa Cruz basin.

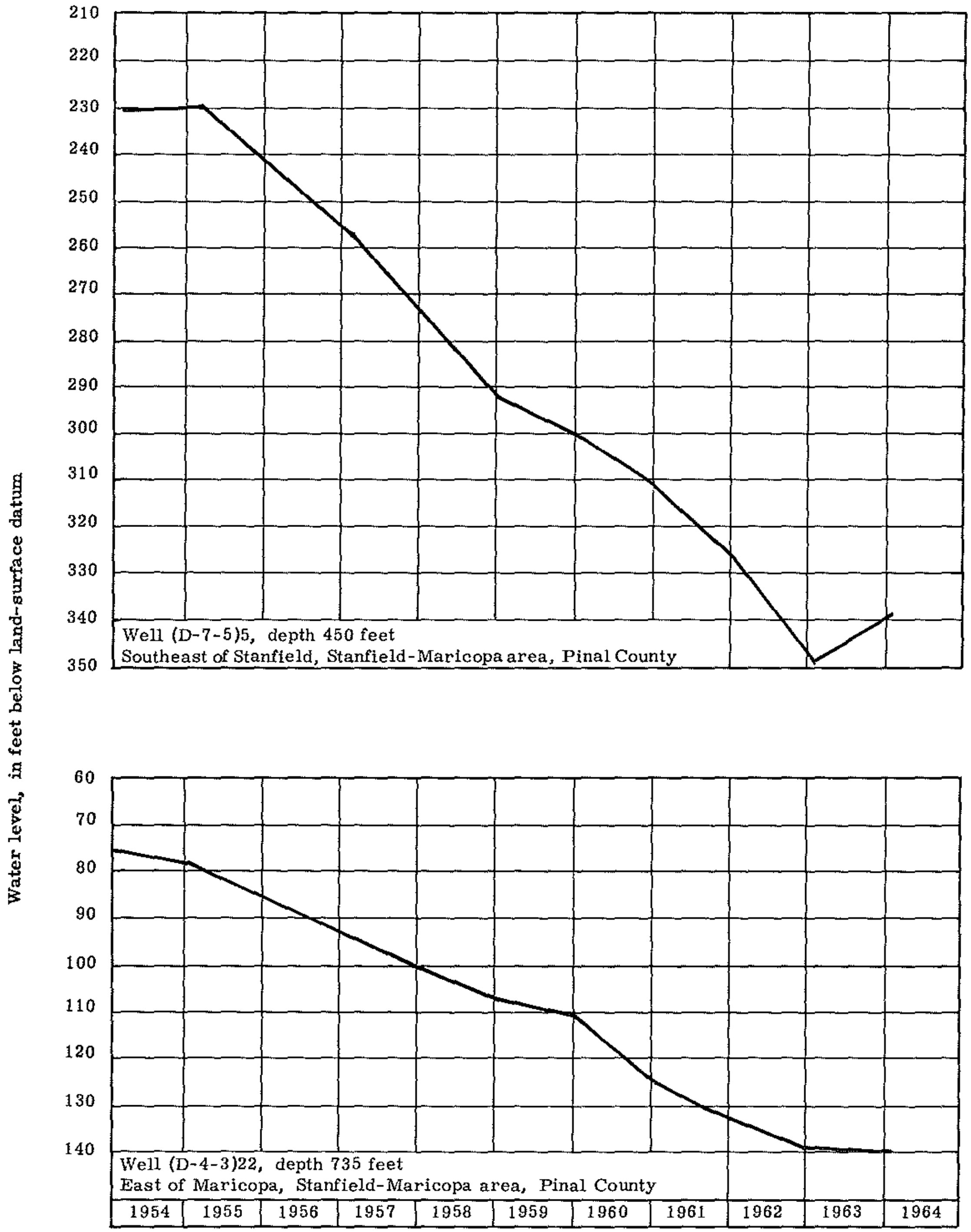

Figure 20.--Water levels in selected wells in the Stanfield-Maricopa area, lower Santa Cruz basin.

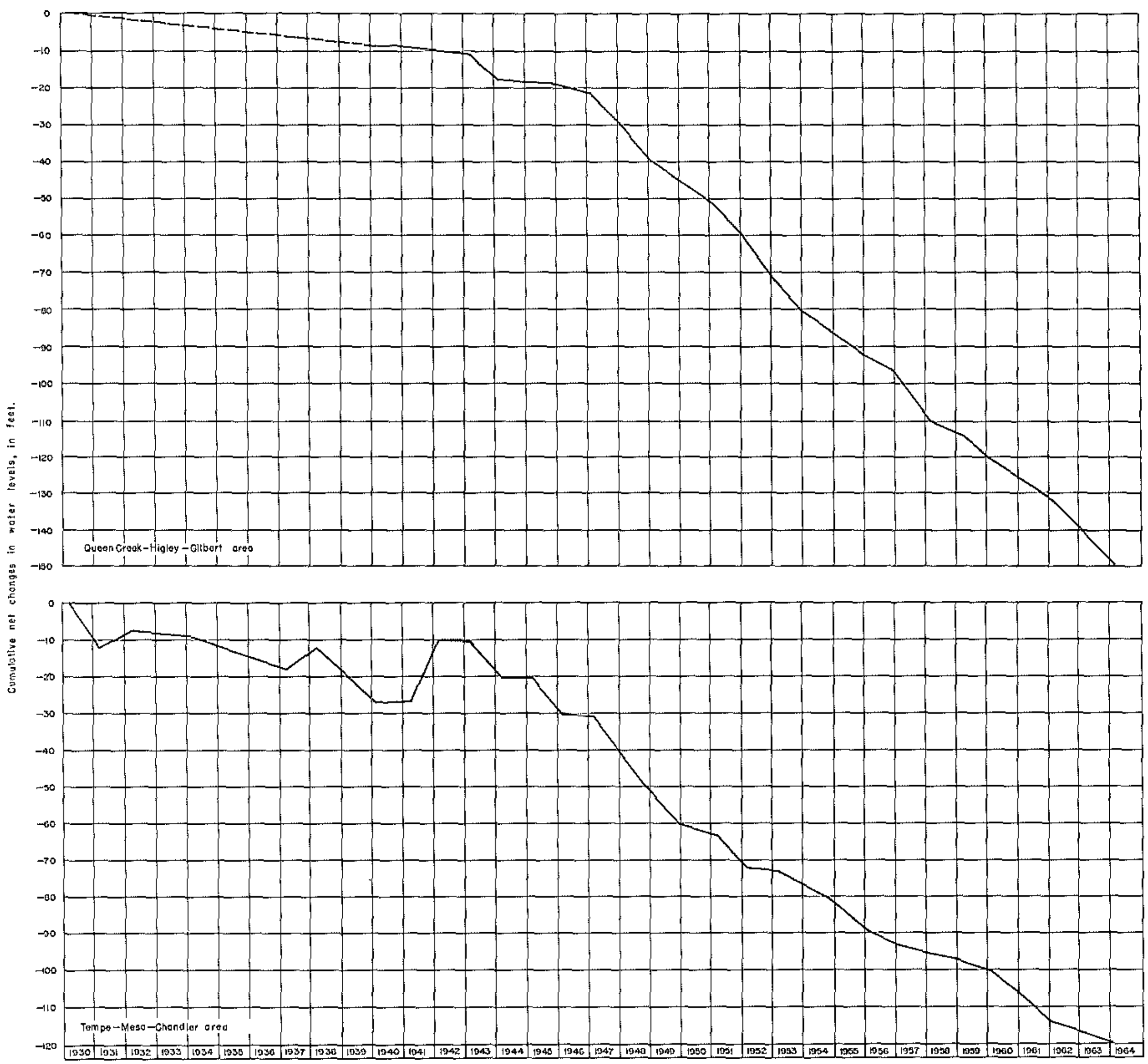

Figure 21.--Cumulative net changes in water levels in the Queen Creek-Higley-Gilbert and Tempe-Mesa-Chandler areas of the Salt River Valley.

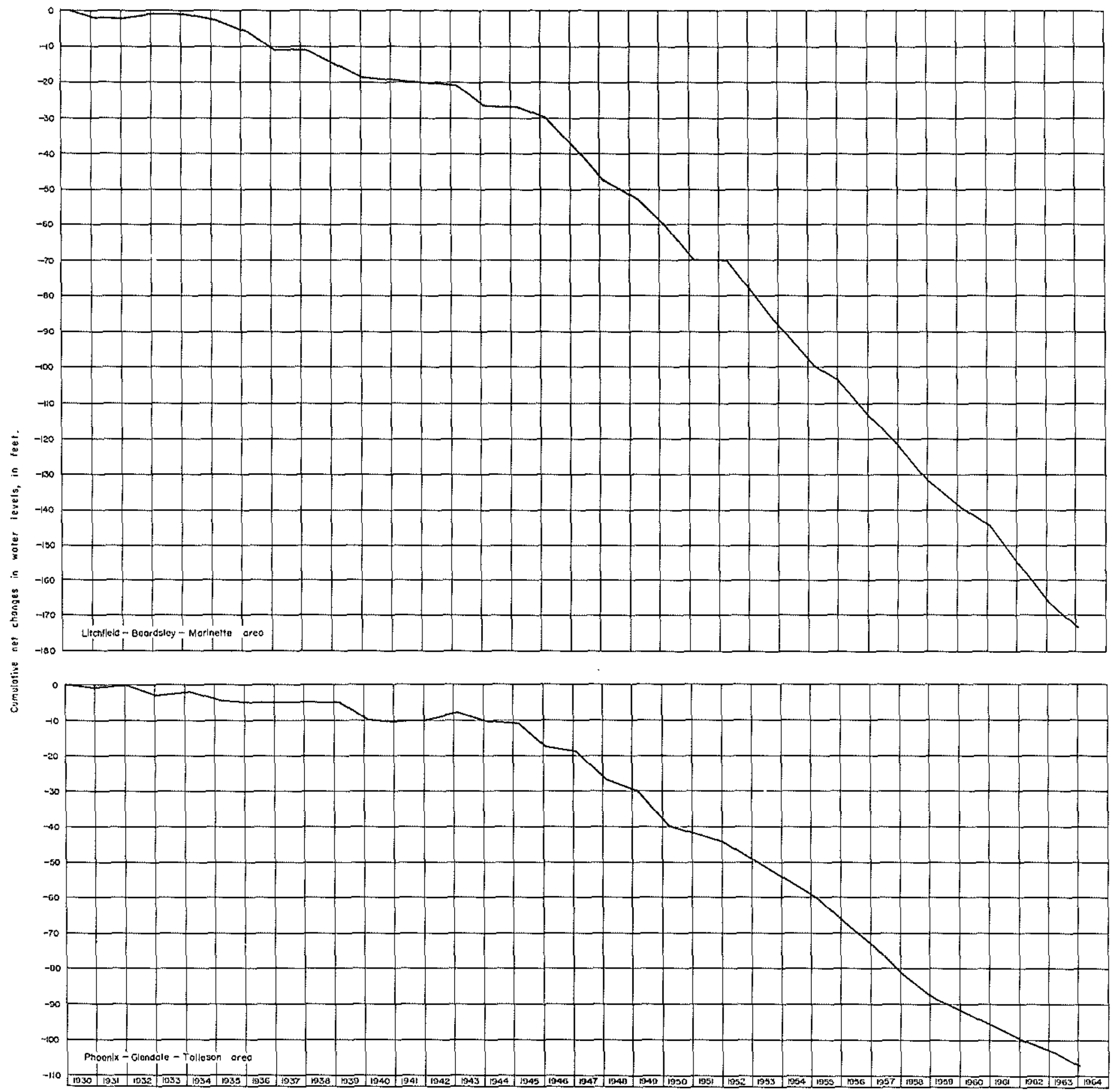

Figure 22.-- Cumulative net changes in water levels in the Litchfield Park–Beardsley–Marinette and Phoenix-Glendale-Tolleson areas of the Salt River Valley.

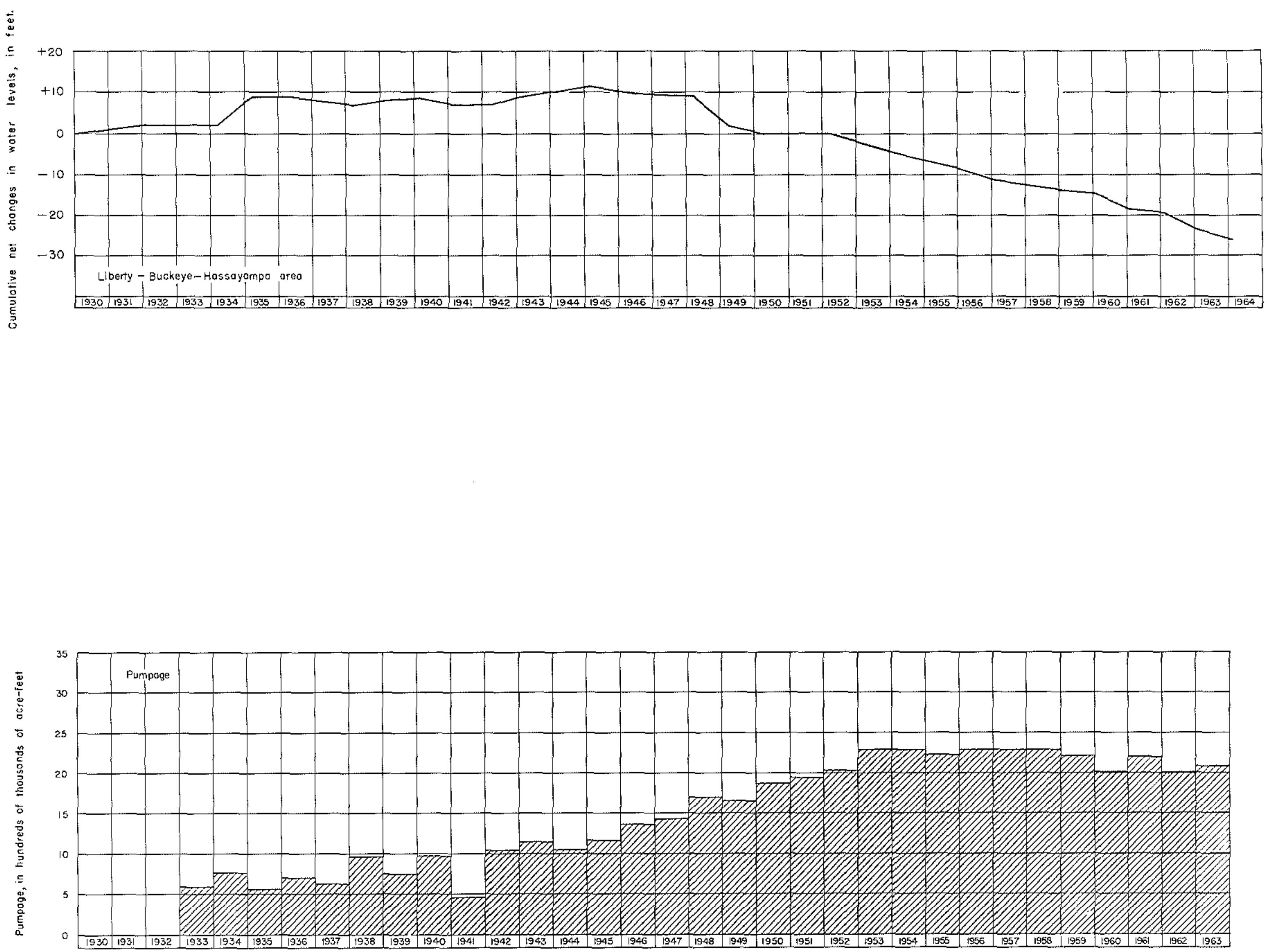

Figure 23.—Cumulative net changes in water levels in the Liberty-Buckeye-Hassayampa area and total annual pumpage in the Salt River Valley.

Waterman Wash Area

By

R. S. Stulik

The Waterman Wash area (fig. 5, No. 13) is an area of about 400 square miles drained by Waterman Wash, a northwest-trending ephemeral stream. Only the northern part of the area has been developed for agriculture, and it is in this part that most of the water-level declines have been observed. From spring 1963 to spring 1964 water levels continued to decline, as is shown by the hydrograph of the water level in well (C-2-2)25 (fig. 24). The maximum depth to water measured in the spring of 1964 was 401 feet below land surface in a well 1 mile south of Mobile.

Gila Bend Area

By

R. S. Stulik

The Gila Bend area (fig. 5, No. 14) is that part of the Gila River valley extending from Gillespie Dam on the Gila River to a point 36 miles downstream near the Painted Rock Narrows. The northern end of the Gila Bend area is known as Rainbow Valley.

From spring 1963 to spring 1964, water-level changes in the Gila Bend area ranged from a rise of about 10 feet in the west end of the area to a decline of about 4 feet in Rainbow Valley. In the spring of 1964 the measured depth to water in the Gila Bend area ranged from about 24 feet below land surface in the west end of the area to about 285 feet in Rainbow Valley.

Harquahala Plains Area

By

R. S. Stulik

The Harquahala Plains area (fig. 5, No. 15) is a northwest-trending basin drained principally by Centennial Wash.

A recent report (Stulik, 1964) noted that the withdrawal of ground water for irrigation has increased from about 33,000 acre-feet in 1954 to about 200,000 acre-feet in 1963. From 1954 to 1964 water levels have declined as much as 200 feet and are continuing to decline at an increasing rate. The hydrograph for well (B-2-9)13 (fig. 24) shows the decline in an irrigation well in the cultivated area. In the spring of 1964 depth to water ranged from less than 50

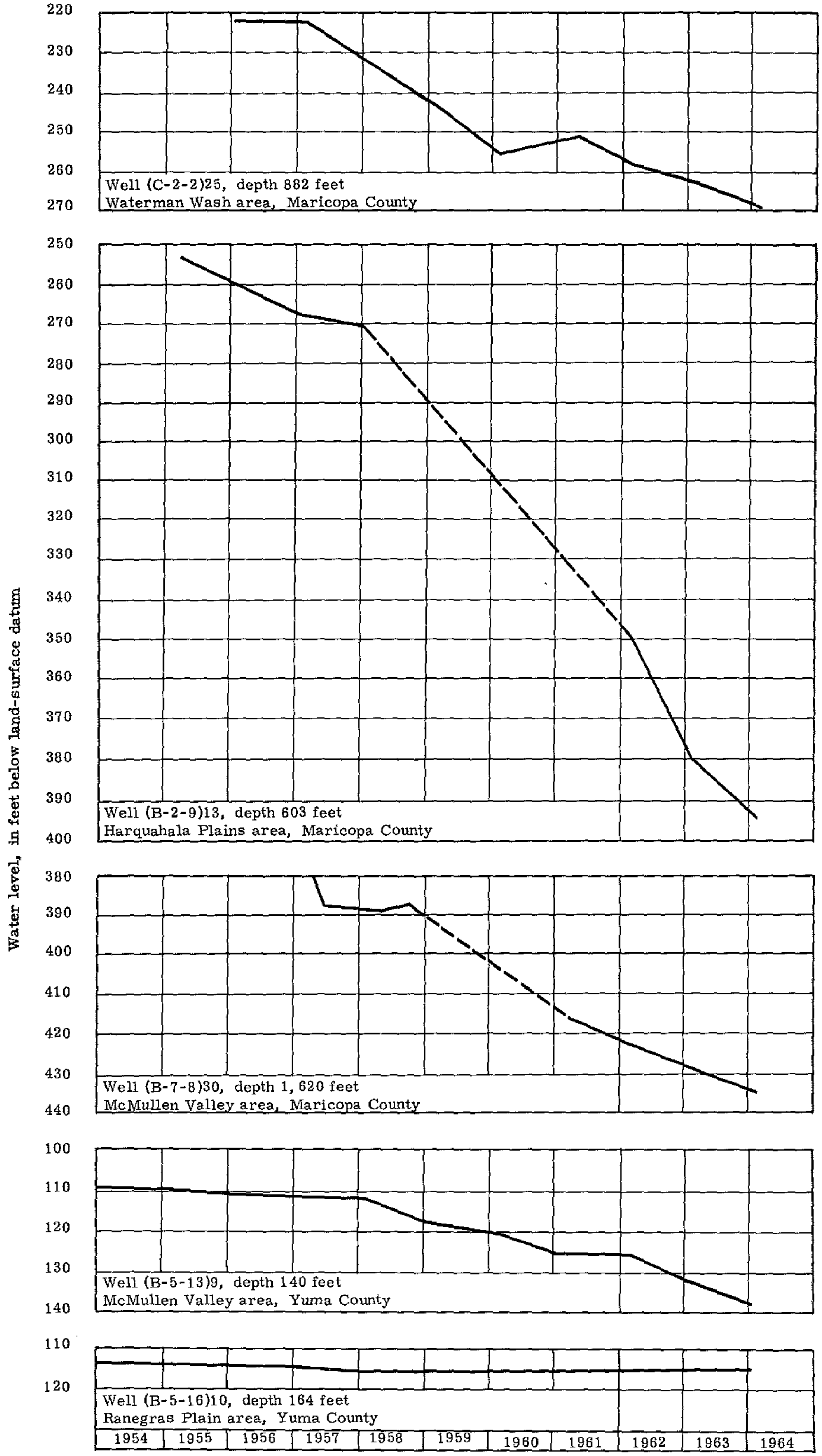

Figure 24.--Water levels in selected wells in several areas in the Basin and Range lowlands province.

feet to more than 400 feet below land surface.

McMullen Valley Area

By

R. S. Stulik

The McMullen Valley area (fig. 5, No. 16) is a northeast-trending valley about 40 miles long lying between the Harcuvar and Harquahala Mountains. The west half of the area is in Yuma County and the east half is in Maricopa and Yavapai Counties. The two areas of irrigation development are near Wenden and Aguila.

From spring 1963 to spring 1964 measured water-level changes were as great as 6 feet southeast of Aguila. In the larger cultivated area north of Aguila water-level data are nearly impossible to collect because of continual pumping. As a result, the amount of decline that has occurred here is not known. The hydrograph of well (B-7-8)30 (fig. 24) shows the decline in a well southeast of Aguila where pumping is less concentrated.

Near Wenden water-level changes from spring 1963 to spring 1964 were as great as 8 feet. The hydrograph of the water level in well (B-5-13)9 (fig. 24) shows the water-level changes prior to and after development of ground-water supplies for irrigation. Depth to water below land surface in McMullen Valley in the spring of 1964 ranged from slightly less than 100 feet near Salome to about 480 feet near Aguila.

Palomas Plain Area

By

R. S. Stulik

Palomas Plain (fig. 5, No. 17) is an alluvial area that extends northwestward from the Gila River in Yuma and Maricopa Counties. Most of the agricultural development is in Yuma County, although some development has begun in Maricopa County.

From spring 1963 to spring 1964 water levels rose from less than half a foot to slightly more than 1 foot in an undeveloped area northeast of Hyder and along the river bottom north of Hyder. Elsewhere in the area water-level changes ranged from almost no decline to a decline of nearly 2 feet. The maximum decline measured occurred in a well south of the developed area northwest of Hyder. In the spring of 1964 the depth to water below land surface ranged from 21 feet along the Gila River to about 265 feet south of Hyder.

Ranegras Plain Area

By

R. S. Stulik

Agricultural development in the Ranegras Plain area of northern Yuma County (fig. 5, No. 18) has increased very little in the last several years, and as a result water-level changes are slight. From spring 1963 to spring 1964 most of the observed water-level changes were less than 1 foot. The hydrograph of the water level in well (B-5-16)10 (fig. 24) shows water-level changes typical of the undeveloped parts of the area. Essentially, there has been no change in the water level in this well during the last 10 years. The depth to water in the Ranegras Plain area in the spring of 1964 ranged from about 32 feet to about 230 feet below land surface.

South Gila Valley, Yuma Mesa, and Yuma Valley Area

By

F. J. Frank

In the South Gila Valley, Yuma Mesa, and Yuma Valley area (fig. 5, No. 20), in the extreme southwestern corner of Arizona, water levels are affected by the use of Colorado River water for irrigation. In general, water levels are rising or show little overall change.

The South Gila Valley is that part of the Gila River flood plain south of the Gila River and bounded on the south by Yuma Mesa. Ground water is the principal source of irrigation water, although a system using Colorado River water is under construction. From spring 1963 to spring 1964 overall changes in water levels in the South Gila Valley were minor. The water level in well (C-8-21)21 (fig. 25) declined less than 1 foot from spring 1963 to spring 1964. Depth to water in most of the area in spring 1964 was from about 12 to 18 feet below land surface. In the South Gila Valley the water table is being controlled in a large part by nine drainage wells installed during 1961.

Yuma Mesa is south of South Gila Valley, east of Yuma Valley, and is limited arbitrarily on the south by the boundary between the United States and Mexico. In this area the principal source of water for irrigation is the Colorado River, but a relatively small amount of ground water is used in the outer fringes of the area. The rise in water levels in the irrigated parts of Yuma Mesa continued and amounted to several feet from spring 1963 to spring 1964. Water levels in this area started to rise in early summer and reached maximum levels in early fall. The hydrograph of the water level in well (C-9-23)31 (fig. 25) shows this trend. Along the unirrigated outer margin of Yuma Mesa water levels were about the same in spring 1964 and in spring 1963. The depth to water in the irrigated parts of Yuma Mesa ranged from about 8 to 35 feet below land surface and from about 70 to 145 feet in the undeveloped parts of Yuma Mesa in spring 1964.

Yuma Valley is that part of the Colorado River flood plain in Arizona lying south and east of the Colorado River and west of Yuma Mesa. The Colorado River is the principal source of irrigation water in Yuma Valley. However, some land between the levee and the river from the city of Yuma south to the International Boundary is irrigated by pumping from ground water. With the exception of a response to seasonal fluctuation in flow of the Colorado River, there was little change in the water level in wells adjacent to the Colorado River from spring 1963 to spring 1964. Water levels ranged from 13 to 17 feet below land surface in this part of Yuma Valley. In most of the valley area, water levels are controlled by the surface-drainage system and, with a few exceptions, very little change occurred from spring 1963 to spring 1964. However, in the center of the valley water levels rose a few hundredths of a foot, and in the part of the valley along the margin of Yuma Mesa water levels rose several feet, reflecting the continued rise of water levels on the mesa. In March 1964 another well was added to the drainage system for additional control in this part of the valley. Water levels in the valley as a whole ranged from about 3 to 14 feet below land surface in the spring of 1964.

Big Sandy Valley

By

R. S. Stulik

The Big Sandy Valley (fig. 5, No. 21) is drained by the Big Sandy River, which receives water from Trout and Burro Creeks, Cottonwood and Little Sandy Washes, and many other washes. Most of the agricultural development is along the flood plain of the Big Sandy River.

Water levels in the shallow wells along the flood plain of the Big Sandy River fluctuate erratically due to recharge from flow in the river. From spring 1963 to spring 1964 water-level changes in these wells ranged from a rise of less than 1 foot to a decline of about 7 feet. For the most part, water levels in the area fluctuated only slightly as shown in the hydrograph of the water level in well (B-16-13)36 (fig. 25). Depth to water below land surface in the spring of 1964 ranged from 11 feet near Wickieup to about 395 feet in a stock well near the extreme north end of the area.

Kingman-Hackberry Area

By

R. S. Stulik

The Kingman-Hackberry area (fig. 5, No. 22), which is largely undeveloped, trends in a northeast direction from near Kingman to Hackberry. Ground

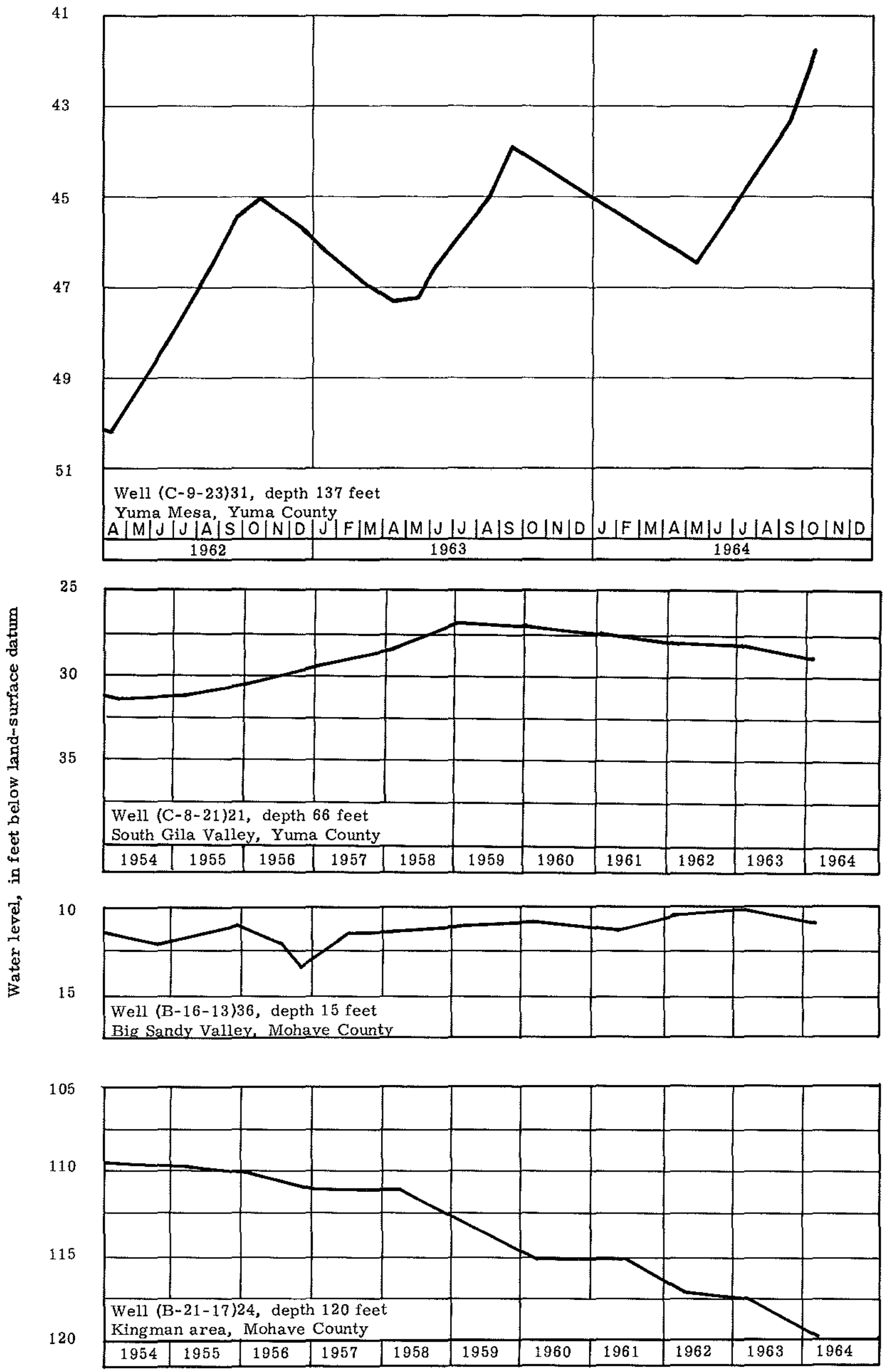

Figure 25.--Water levels in selected wells in several areas in Yuma and Mohave Counties.

water in the Kingman-Hackberry area is used mostly for public supply.

From spring 1963 to spring 1964 water-level changes in the area ranged from a rise of about 4 feet to a decline of about 4 feet. The hydrograph of the water level in well (B-21-17)24 (fig. 25) shows water-level changes in a well in Kingman. In the spring of 1964 depth to water in the Kingman-Hackberry area ranged from about 32 feet below land surface in a well north of Kingman to about 522 feet below land surface in an abandoned well near Antare.

Plateau Uplands Province

By

Natalie D. White

The Plateau uplands province includes a variety of landforms--canyons, buttes, mesas, and volcanic mountains. The altitude ranges from about 4,000 to 13,000 feet above mean sea level but is mostly between 5,000 and 7,000 feet. The soil covering in most places is thin, and vegetation is sparse below altitudes of 6,000 feet. Forests abound above altitudes of 6,000 feet; grasses and shrubs provide pasture for cattle and sheep at all altitudes and support a large part of the economy of the area.

Development of ground water for irrigation or other purposes is comparatively small, and no sustained declines of the water levels are evident at the present time. Only about 30,000 acres of land was cultivated in the province in 1963. Recently there has been some increase in the use of ground water due to a small increase in agricultural development in the Snowflake area and near Tuba City, installation of a new pulp mill at Snowflake, and an increase in population in the Flagstaff area. The effects of these increases in pumping of ground water are discussed in the following paragraphs. Because development in the Plateau uplands is not concentrated in particular areas, the ground-water conditions in this province are discussed by counties.

Apache County

By

E. H. McGavock

The Permian Coconino Sandstone and Kaibab Limestone are the chief aquifers yielding water to irrigation, stock, and domestic wells in the central part of Apache County. Water levels have remained relatively stable for the last 6 years, although there may be a slight downward trend as indicated by the hydrograph of the water level for well (A-13-28)27 (fig. 26). Pumping in the Hunt area has caused some wells to cease flowing. The water level in many irrigation wells declines during the summer pumping season but recovers during the winter. The hydrograph of the water level in well (A-14-26)18

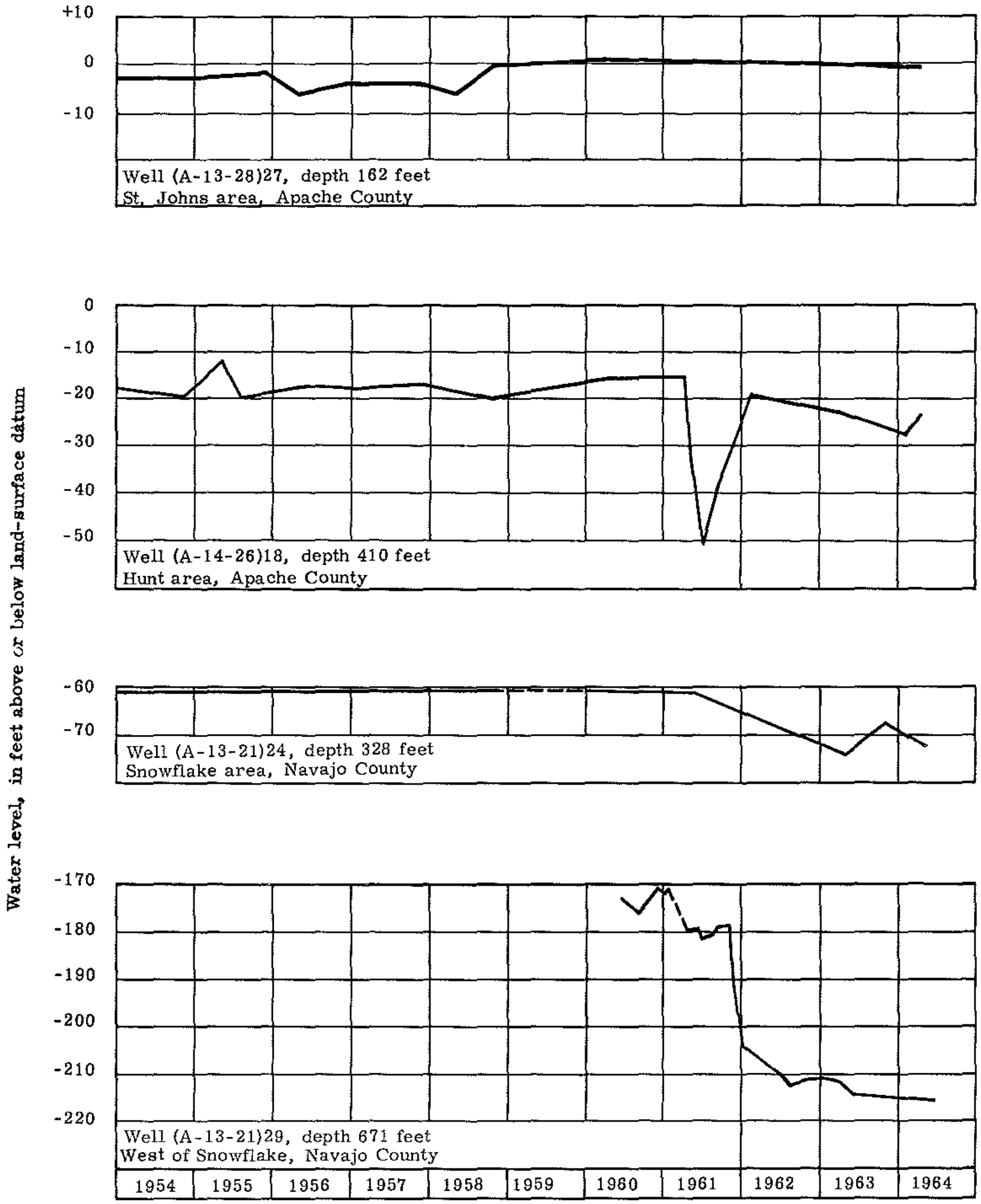

Figure 26.--Water levels in selected wells in the Plateau uplands province.

(fig. 26), completed in the Coconino Sandstone, shows this trend.

The quality of the water in the Coconino Sandstone is generally good south of the Little Colorado River in the area west of Hunt and Concho. In the St. Johns area the quality of the water is only fair, and between the Little Colorado and Puerco Rivers the water usually is unsuitable for irrigation.

The Permian De Chelly and Coconino Sandstones yield small to moderate amounts of water to wells in Chinle Valley and the Defiance Plateau area of northern Apache County. Depths to water vary widely in the area. Near Sunrise Trading Post water levels are more than 1,600 feet below land surface; near Many Farms, several wells flow.

The Jurassic and Triassic (?) Navajo Sandstone furnishes small to moderate quantities of good-quality water to wells in the Dinnehotso area. Near Rough Rock about 30 gpm (gallons per minute) of fair-quality water can be obtained from wells that penetrate the Navajo Sandstone, Upper Triassic (?) Kayenta. Formation, and the upper part of the Wingate Sandstone Upper Triassic. Small quantities of fair-quality water can be obtained from Cretaceous rocks on Black Mesa; Jurassic rocks yield fair-to good-quality water to wells in the Teec Nos Pos area.

The Pliocene (?) Bidahochi Formation yields from 5 to 50 gpm of good-quality water to wells south and east of Sanders and in a few areas near Klagetoh.

Near Red Lake north of Fort Defiance wells in stream alluvium yield 100 to 200 gpm. Along Chinle Wash near Chinle and Many Farms, the alluvium may yield 300 to 400 gpm, and several irrigation wells are being drilled in this area. Some wells near Sanders produce as much as 600 gpm from alluvium along the Puerco River.

Navajo County

By

E. H. McGavock

The major development of ground-water supplies in Navajo County is concentrated between the Little Colorado River and the Mogollon Rim. Water is withdrawn mainly from the Coconino Sandstone for irrigation, industrial, stock, and domestic uses. Recharge along the Mogollon Rim has been sufficient to prevent any widespread decline of water levels in the area. Locally, pumping for industrial or irrigation uses causes marked seasonal declines and may be creating an overall decline in water levels near Snowflake and Joseph City.

In the Snowflake-Hay Hollow area there are about 35 irrigation wells that produce from 150 to 2,000 gpm. The water level in most of these wells shows only a seasonal decline; however, a general decline in water level is indicated about 4 miles west of Snowflake, as shown by the hydrograph of the water level in well (A-13-21)29 (fig. 26). Near Joseph City, Holbrook, and Woodruff, water levels in wells in the Coconino Sandstone decline during the summer pumping season, but no overall long-term declines have been observed. East of Holbrook the alluvium along the Puerco River furnishes water of fair quality to irrigation, stock, and domestic wells.

The Dakota (Cretaceous) and Navajo Sandstones and the Toreva Formation (Upper Cretaceous) are the major aquifers in the northern two-thirds of Navajo County. The Dakota Sandstone and Toreva Formation furnish small quantities of fair-quality water to stock, domestic, and school wells in the Black Mesa area. The Navajo Sandstone yields water of good quality to most wells north of Black Mesa. Water levels range from 200 to 500 feet below land surface; no long-term declines have been observed.

Coconino County

By

E. H. McGavock

The Coconino Sandstone is the most important aquifer presently developed in Coconino County. Well yields in the Coconino Sandstone range from less than 5 to 600 gpm; the yield is dependent mainly on the amount of fracturing in the rocks. The locations of the well fields for Flagstaff—Woody Mountain and Lake Mary well fields—were chosen to take advantage of increased permeability due to fracturing along faults. In some instances, however, fractured zones allow water to percolate downward through the Coconino Sandstone so that water is below the effective depth of wells in much of the Coconino Plateau. A hole 2,500 feet deep was completed recently near Williams without encountering water.

The quality of water in the Coconino Sandstone is excellent near Flagstaff and in the southeast part of the county. The quality of the water is progressively worse northeastward from Flagstaff; north of the Little Colorado River the water may be unfit for stock use.

Five wells in the Woody Mountain well field produce from 200 to 600 gpm of water from the Coconino Sandstone and the Permian and Pennsylvanian Supai Formation. Water levels in the well field range from about 1,000 to 1,200 feet below land surface. The only well currently in operation in the Lake Mary well field yields about 300 gpm from a pumping level of less than 1,000 feet. A significant part of Flagstaff's water supply comes from glaciofluvial deposits on the east side of San Francisco Mountain.

The Navajo Sandstone yields small to large quantities of good-quality water to wells in the northeast part of Coconino County. Yields range from 5 to 1,300 gpm except in an area near Copper Mine Trading Post where the Navajo Sandstone may be dry. Water levels are as much as 1,400 feet below land surface, but near Tuba City several wells flow. The only measured declines occurred in the Page area due to pumping for the Glen Canyon Dam construction.

Central Highlands Province

By

Natalie D. White

The Central highlands province forms a topographic high in the central part of the State and separates the Plateau uplands from the Basin and Range lowlands. The province consists principally of rugged sharply pinnacled ranges and mountains, which are several thousand feet higher in altitude than the adjoining valleys of the Basin and Range lowlands and generally lower than the high mesas in the Colorado Plateaus. It is in this province that Arizona receives its greatest amount of precipitation; summer thundershowers are common and winter snowfall is heavy. Although a large part of this precipitation is evaporated from the land surface or transpired from vegetation, it is nevertheless the source of streamflow that is utilized extensively for agricultural irrigation in the Phoenix basin.

Because the province is largely mountainous and only a few small alluvial valleys are suitable for agricultural use, less than 15,000 acres of land was cultivated in the province in 1963, and that acreage mostly was in Chino and Verde Valleys. Some surface water from the Verde River is used to irrigate land in part of Verde Valley, but ground-water use in the province is small.

Chino Valley

By

H. C. Schwalen[1]

Chino Valley (fig. 5, No. 23) is north of Prescott in Yavapai County. A small amount of surface water is available from Willow Creek Reservoir and Watson Lake, but, for the most part, ground water is used for irrigation and other purposes. A part of the municipal water supply for Prescott is obtained from wells in Chino Valley, and a few outlying wells pump water for domestic and stock supplies.

Ground water occurs under water-table and artesian conditions in Chino Valley. The area in which ground water is under artesian pressure is about 3 miles wide and extends from 3 miles south to 3 miles north of the small town of Chino Valley. About 10 miles north of the town of Chino Valley near Paulden and east along Granite Creek and in Lonesome Valley, ground water is under water-table conditions.

Flowing artesian water was first discovered about 2 to 3 miles north of the town of Chino Valley in 1930. In 1964 only two wells in the area were flowing

1/ Agricultural engineer, Agricultural Engineering Department, University of Arizona.

throughout the year, and their discharge is reduced greatly during the summer pumping season. In the south end of the area the water level in artesian wells is as much as 300 feet below land surface. Water levels in water-table wells measured in spring 1963 ranged from more than 130 to nearly 270 feet.

The artesian-pressure surface declines rapidly during the summer pumping season—as much as 35 feet in the north end of the area—but generally recovers following the pumping season to within a few feet of the previous spring level. From spring 1963 to spring 1964 water-level declines in artesian wells generally ranged from 2 to 4 feet. In the south end of the area the water-level decline in well (B-16-2)34 (fig. 27) was about 3 feet from spring 1963 to spring 1964. In the center of the area, near the town of Chino Valley, the water level in well (B-16-2)21 (fig. 27) declined about 4 feet from spring 1963 to spring 1964. The water level in well (B-16-2)3 (fig. 27), in the north end of the area, declined about 2 feet from spring 1963 to spring 1964; in spring 1964 the water level was nearly 10 feet above land surface.

For the most part, water levels in water-table wells near Paulden rose from spring 1963 to spring 1964. The hydrograph of the water level in well (B-17-2)6 (fig. 27) shows the water-level trend in this area. Near Del Rio the water level in wells rose about half a foot from spring 1963 to spring 1964. Along Granite Creek and in Lonesome Valley the average water-level decline was about 2.5 feet. The hydrograph of the water level in well (B-16-1)14 (fig. 27) shows the uniform and continuous decline of the water table in this area, probably resulting from the concentrated pumping in the central part of Chino Valley more than 6 miles away.

Verde Valley

By

R. S. Stulik

The Verde Valley (fig. 5, No. 24) trends northwestward from the junction of Fossil Creek and the Verde River to Perkinsville. The area is divided into the Clarkdale-Cottonwood-Camp Verde area and the Sedona Area. In the Clarkdale-Cottonwood-Camp Verde area the principal source of ground water is the Pliocene (?) or Pleistoncene Verde Formation. In the Sedona area the principal source of ground water is the Supai Formation. A comprehensive discussion of the Verde Valley is contained in a recently published report (Twenter and Metzger, 1963).

Clarkdale-Cottonwood-Camp Verde area.--Most of the ground-water supplies in the Clarkdale-Cottonwood-Camp Verde area are obtained from wells that penetrate the Verde Formation. Ground water in the Verde Formation is under artesian head; in some parts of the area the artesian head is sufficient to cause wells to flow. In the non-flowing wells depth to water ranges from a few feet to more than 200 feet below land surface.

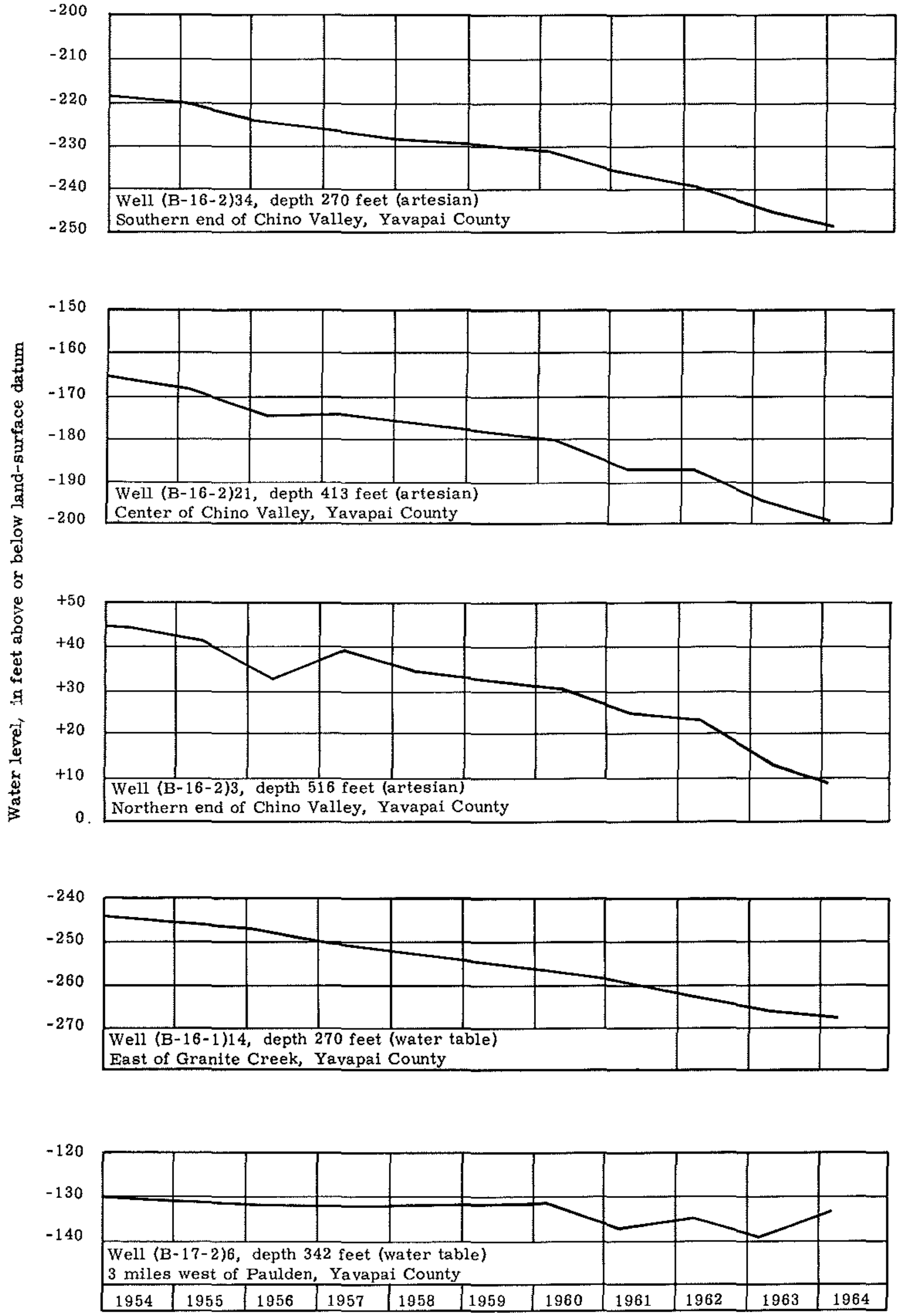

Figure 27.--Water levels in selected wells in Chino Valley.

From spring 1963 to spring 1964 water-level changes in the Clarkdale-Cottonwood-Camp Verde area ranged from a rise of about 4 feet to a decline of about 10 feet. Depth to water in wells measured in spring 1964 ranged from about 16 to about 147 feet below land surface.

Sedona area.--Domestic water supplies sufficient to meet the demands of an increasing population constitute the principal use of ground water in the Sedona area. The principal source of ground water in the Sedona area is the lower member of the Supai Formation. Measured depth to water in the area ranged from about 126 feet to 583 feet below land surface in the spring of 1964. Data were insufficient to determine the amount of water-level changes that occurred from spring 1963 to spring 1964.

Gila County

By

Clara R. Smith

Gila County is situated almost entirely in the Central highlands province in the east-central part of the State. The terrain is mostly rugged mountains having altitudes as great as 8,000 feet above mean sea level.

The area receives from about 12 to more than 24 inches of precipitation annually; several major perennial streams originate in the county and carry surface water to the reservoirs of the Gila and Salt River systems. Ground water occurs mostly as discharge from numerous springs in the mountains, perched supplies in the crystalline rocks, and in the alluvial deposits along the stream drainages. Due to the mountainous terrain, agricultural development is restricted mostly to the flood plains along the tributaries to the Gila and Salt River drainage.

In the Gila County, ground-water levels are measured principally in three areas—in and near Globe, in the Dripping Spring Valley, and on the San Carlos Indian Reservation. In the Globe area water levels in wells along the valley floor are shallow and fluctuate rapidly in response to flow in the two major drainages in the area—Pinal Creek and Ice House Canyon. For the most part, water levels in this area rose from spring 1963 to spring 1964, although no overall long-term trend of the water level is discernible.

In Dripping Spring Valley, at the southern tip of the county, water levels in wells along the valley floor rose from spring 1963 to spring 1964. The water levels in these wells are affected by surface flow from the surrounding mountain areas.

Water levels in wells along Ranch Creek in the San Carlos Indian Reservation declined slightly from spring 1963 to spring 1964, although no overall long-term trend of the water table is discernible. Water levels in wells in this area are affected by surface-water runoff from the surrounding mountains.

USE OF GROUND WATER

By

E. K. Morse, R. S. Stulik, and Clara R. Smith

Nearly 4.5 million acre-feet of groundwater was withdrawn from the ground-water reservoirs in Arizona in 1963—about the same as in 1962. About 90 percent of this water is used for irrigation, mostly in the Basin and Range lowlands province. In addition to the 4.5 million acre-feet of ground water withdrawn, slightly more than 2.7 million acre-feet of surface water was diverted for use in the State in 1963. Thus, nearly two-thirds of the State's water supplies came from ground water. The Salt River Valley and the lower Santa Cruz basin continued to be the largest users of ground water in the State.

Salt River Valley

Slightly more than 2,100,000 acre-feet of ground water was pumped from underground storage in the Salt River Valley in 1963. Pumpage in the Salt River Valley may be considered conveniently in terms of the location of areas east or west of the Agua Fria River. East of the Agua Fria River, which includes the Queen Creek-Higley-Gilbert-Magma, Phoenix-Glendale-Tolleson-Deer Valley, Tempe-Mesa-Chandler, and Paradise Valley areas, pumpage in 1963 was about 1,240,000 acre-feet. West of the Agua Fria River, which includes the Litchfield Park-Beardsley-Marinette, Liberty-Buckeye-Hassayampa, lower Centennial, and Tonopah areas, pumpage in 1963 was about 900,000 acre-feet.

Lower Santa Cruz Basin

Nearly 1,000,000 acre-feet of ground water was withdrawn from the alluvial reservoir in the lower Santa Cruz basin of Pinal County in 1963. For the most part, this water was used to irrigate crops in the three major areas of agricultural development in the basin. The amount of ground water pumped in each of the three developed areas during 1963 is as follows: Eloy area, 250,000 acre-feet; Casa Grande-Florence area, 290,000 acre-feet; and Stanfield-Maricopa area, 440,000 acre-feet. Other uses of water amounted to about 20,000 acre-feet during 1963.

Upper Santa Cruz Basin

About 180,000 acre-feet of ground water was pumped from the underground reservoirs in the upper Santa Cruz basin during 1963. The underground reservoirs are the principal developed sources of water supplies in the basin.

Although the use of water for irrigation continues to exceed that for other purposes, municipal, domestic, and industrial uses are increasing, largely due to the rapid growth of metropolitan Tucson. Nearly 70,000 acre-feet of ground water was used for nonirrigation purposes during 1963, of which more than 45,000 acre-feet was pumped from wells operated by the city of Tucson water utility for municipal use in metropolitan Tucson.

Avra-Marana Area

The Avra-Marana area includes the Avra Valley and a small area near Marana. Several thousand acres of farmland is irrigated with ground water in the area. In 1963, about 115,000 acre-feet of ground water was pumped for irrigation use in the area, about 25,000 acre-feet less than in 1962. The reduction in use probably is attributable to the occurrence of rain during the growing season.

Willcox Basin

The three main areas of agricultural development in the Willcox basin of northern Sulphur Spring Valley are the Stewart area, the Kansas Settlement area, and the Pearce-Cochise area. Only ground water is used to irrigate crops in these areas, and the use of ground water for purposes other than irrigation is minor. In 1963 about 180,000 acre-feet of ground water was pumped in the basin. The distribution among the three areas, based on estimates of the number of acres under cultivation, is as follows: Kansas Settlement area, 95,000 acre-feet; Stewart area, 63,000 acre-feet; and Pearce-Cochise area, 22,000 acre-feet.

San Simon Basin

Ground water is the only source of supply for the irrigation of farmland and other purposes in the San Simon basin. About 65,000 acre-feet of water was withdrawn from the aquifers in the San Simon basin in 1963, the same as in 1962. Distribution of the pumpage among the three areas of development, based on estimates of the number of acres under cultivation, is as follows: Bowie area, 25,000 acre-feet; San Simon area, 23,000 acre-feet; and Rodeo-Cienaga area (Arizona and New Mexico), 17,000 acre-feet.

Other Areas

A number of other areas in the southern part of Arizona use groundwater for the irrigation of crops. For the most part, data are not sufficient to compute the amount of ground water pumped separately for each of the areas. The areas where comparatively large amounts of ground water are pumped for irrigation and other uses include: Safford basin, Douglas basin, Harquahala Plains area, McMullen Valley, Palomas Plain area, and Gila Bend area. The amount of ground water withdrawn from the underground reservoirs in these areas probably was slightly more than 600,000 acre-feet in 1963. An additional 150,000 to 200,000 acre-feet of ground water was used for the irrigation of small areas of farmland and by private water companies and individuals locally throughout the State. This amount includes the ground water withdrawn in the Plateau uplands and Central highland provinces.

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