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ANNUAL REPORT ON GROUND WATER IN ARIZONA

SPRING 1964 TO SPRING 1965

BY

NATALIE D. WHITE AND OTHERS

PREPARED BY THE GEOLOGICAL SURVEY
UNITED STATES DEPARTMENT OF THE INTERIOR

Phoenix, Arizona
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CONTENTS

Page

Page

ILLUSTRATIONS

ANNUAL REPORT ON GROUND WATER IN ARIZONA, SPRING 1964 TO SPRING 1965

By

Natalie D. White and others

ABSTRACT

By

Natalie D. White

The gradual depletion of ground-water supplies due to withdrawal in excess of the rate of replenishment is of major economic importance in Arizona, as more than two-thirds of the water supply for the State comes from ground water. Solutions to the problems that arise wherever ground water is pumped in large quantities require a comprehensive knowledge of the factors that control the storage capacity and the transmission of water through the saturated subsurface rocks. The current program of ground-water studies conducted by the U. S. Geological Survey in cooperation with the Arizona State Land Department includes the collection of the geologic and hydrologic data necessary to the evaluation of the ground-water resources of the State. More important, however, it also includes a comprehensive compilation and analysis of the data and research into new and better methods of analysis that will provide 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 the hydrologic data collected from spring 1964 to spring 1965.

The extensive development of the water supply, particularly in the Basin and Range lowlands province of southern Arizona, has resulted in a downward trend of the water levels in nearly all the highly developed areas in this province. The two largest agricultural areas in the State are the Salt River Valley and the lower Santa Cruz basin, and it is in these areas that the greatest water-level declines have taken place. The average decline in water level in one area of the Salt River Valley was nearly 4 feet from spring 1964 to spring 1965; in one area of the lower Santa Cruz basin the average decline during this same period was about 10 feet and has been more than 160 feet

since 1940. Other areas in the Basin and Range lowlands where large declines have taken place include the Stewart and Kansas Settlement areas in the Willcox basin, the Bowie and San Simon areas in the San Simon basin, and, to a lesser extent, the Avra Valley west of Tucson. New development in other areas, such as the northern part of the Stewart area in the Willcox basin and large parts of the Douglas basin, probably will increase the decline of the water level in these areas.

The withdrawal of ground water for all purposes was about 4.5 million acre-feet in 1964—about the same as that for the last several years. The chief use of ground water in the State is for the irrigation of crops. For the most part, the 1,154,000 acres of land cropped in Arizona in 1964 was irrigated with ground water, although about 2.6 million acre-feet of surface water was diverted for use in the State in 1964. Most of the ground water is withdrawn and used in the Basin and Range lowlands province, and two areas—the Salt River Valley and the lower Santa Cruz basin—account for nearly 70 percent of the total amount withdrawn in the State.

INTRODUCTION

By

Natalie D. White

The greatest single influence on the continuing development of Arizona is the availability of adequate water supplies. More than two-thirds of the water supply for Arizona comes from the ground-water reservoirs. Thus, ground water is important to the economy of Arizona, particularly to agriculture, which is the principal use of ground water in the State. A total of 1,154,000 acres of land was irrigated to grow crops in 1964 (Hillman, 1965); nearly 90 percent of the ground water withdrawn during 1964 was used to irrigate these crops. The ground-water supplies are vast, but they are not inexhaustible. The gradual depletion of the ground-water supplies due to withdrawal in excess of the rate of replenishment is of major economic importance to farmers and anyone interested in the continued growth of Arizona. Proper management of the water supplies is vital. Problems concerning inadequacy of supply, equitable distribution of the available supply, and deterioration in the quality of the ground water must be solved. Solutions to these and other problems that arise wherever ground water is pumped in large quantities require a comprehensive knowledge of the factors 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 this knowledge.

Since July 1939, a cooperative agreement that provides for equal financial participation in a planned program of ground-water studies has been in effect between the U.S. Geological Survey and the State of Arizona. From 1939 to 1942, the State was represented by the State Water Commissioner; since 1942 the State has been represented by the State Land Department. In the early

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June 28, 1966

To the users of Geological Survey hydrological data:

Enclosed is a copy of the "Annual Report on Ground Water in Arizona, Spring 1964 to Spring 1965," by N. D. White and others. The report was prepared by the Geological Survey in cooperation with the Arizona State Land Department and is a summary and analysis of the hydrologic data collected under the statewide ground-water program during the period spring 1964 to spring 1965. The report describes ground-water conditions throughout Arizona, with particular emphasis on the highly developed agricultural areas.

Sincerely yours,

H. M. Babcock
District Chief

Enclosure

years, the program consisted mostly of the collection of basic data concerning the development of ground-water resources. In recent years, there has been more emphasis on compilation and analysis of the hydrologic and geologic data and particularly on research into new and better methods of analysis that will provide quantitative solutions to the problems of availability, effects of withdrawal, and changes in chemical quality of the water. Analysis of hydrologic data by electrical-analog model is a new method that has many advantages over some of the standard mathematical methods. The method is based on the fact that the flow of ground water in aquifers is analogous to the flow of electrical current; thus, it is possible to simulate conditions in a ground-water system with electronic equipment and instrumentation. A resistance-capacitance electrical circuit serves as an exact analog for the flow of ground water in an aquifer. Analysis of the hydrologic data by electrical-analog methods for any basin may make it possible not only to appraise the water resources of an area and the current trend of development but also to predict what may happen in the future under different specified sets of circumstances.

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 1964 to spring 1965. Another report prepared during the year presents a somewhat more comprehensive analysis for Avra Valley (White and Burton, 1965). The report contains a prediction of the depth to water in Avra Valley for 1970. Another more comprehensive report that will be prepared this year will discuss ground-water conditions in the upper Santa Cruz basin.

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 longterm basic records necessary to a comprehensive ground-water investigation. 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 new wells. These data are compiled and analyzed, and the results are summarized each year in the "Annual Report on Ground Water in Arizona." The report is published by the State Land Department, and copies are available to the public. An additional phase of the program is aimed at a systematic analysis of current ground-water conditions and predictions of future conditions in specified basins or areas. The purpose of this phase is to make better use of the data that are collected under the main part of the statewide ground-water survey. This objective is accomplished by a more comprehensive analysis of the data than can be achieved for the annual report on ground water for the entire State and by the publication of this analysis in separate reports that will be more detailed and timely for use by the public. (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. This phase of the program includes research into new and better methods of analysis.

Summary of Current Ground-Water Programs in Arizona

In addition to the statewide ground-water survey described above, field investigations were in progress for four projects, and reports were in various stages of completion for six projects under the Federal-State cooperative program in 1964.

Projects for which fieldwork is in progress are as follows: (1) Ground-water resources of the western part of the Salt River Valley (Beardsley area). The purpose of this project is to estimate the ground-water storage capacity of the water-bearing deposits to an economical pumping depth under present conditions. (2) Basin potential of Sycamore Creek. The objective of this project is to determine the potential surface inflow to Sycamore Creek and the total outflow from the basin. (3) Water resources of southern Coconino County. Most of the large water supplies in this area are obtained either from the deeply buried C multiple aquifer system or from storage of surface water in open and leaky reservoirs. The purpose of the project is to determine the amount, availability, and movement of ground water in both the deep and the shallow aquifers. (4) Water resources of the Sacramento and Hualapai Valleys. This project is designed to determine the quality and quantity of the water resources in the area and to determine the average annual inflow and outflow.

Projects for which reports are in final stages of preparation are: (1) Subsurface geologic and hydrologic studies of western Pinal County; (2) Geology and ground-water resources of Big Sandy Valley, Mohave County; (3) Geohydrology and utilization of water in Willcox basin; (4) Change in water yield by defoliation and vegetation removal, Cottonwood Wash, Mohave County; (5) Geohydrology of the Dateland-Hyder area, Maricopa and Yuma Counties; and (6) Basin potential of Sycamore Creek (fieldwork also still in progress).

In addition to the project described above, another special projects will present the results of an electrical-analog analysis of geologic and hydrologic data for a part of central Arizona. This part of Arizona is the most highly developed agricultural area in the State, and large amounts of ground water are withdrawn each year. The water levels in the area are declining, and the aquifer is being dewatered. The analog model for the area has been constructed on the basis of geologic and hydrologic data collected over many years. The model will be used to predict future ground-water conditions in the area under an hypothesized set of conditions that relate to the withdrawal of ground water. The analog-model analysis may provide solutions to the problems that confront water management in areas where ground-water withdrawal far exceeds the replenishment, as in this part of central Arizona.

In addition to the Federal-State cooperative program, work also was in progress under agreements with several other cooperators in 1964. Two studies were being conducted in cooperation with the University of Arizona. Cooperation with other Federal agencies included projects for the U.S. Army and the Bureau of Indian Affairs. The results of the work done under these programs also benefit the State. Figure 1 is a pictorial summary of the status of current ground-water work in Arizona.

Current Publications of the Arizona District

By

Jane V. Burton

The following reports on the water resources and geology of Arizona were published or released to the open file from July 1, 1964, through June 30, 1965.

Geology and ground water of the Luke area, Maricopa County, Arizona, by R. S. Stulik and F. R. Twenter: U.S. Geol. Survey Water-Supply Paper 1779-P, 1964. 30 p., 6 pls., 2 figs.

The report presents the results of a study of the ground-water resources of the Luke area made at the request of the Corps of Engineers and the U.S. Air Force. The purpose of the study was to determine the possibility of developing a water supply of optimum quantity and quality to supplement the base supply. A method for predicting well capacities based on the percent of fine-grained material per 100 feet of aquifer penetrated by existing wells is described in the report. The higher capacity wells in the Luke area are in areas where the aquifer is composed of less than 60 percent of fine-grained materials. After a reconnaissance of the area, the U.S. Geological Survey located and supervised the drilling of two test wells that proved adequate.

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

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

Geology and ground water in the central part of Apache County, Arizona, by J. P. Akers: U.S. Geol. Survey Water-Supply Paper 1771, 1964. 107 p., 3 pls., 21 figs., 6 tables.

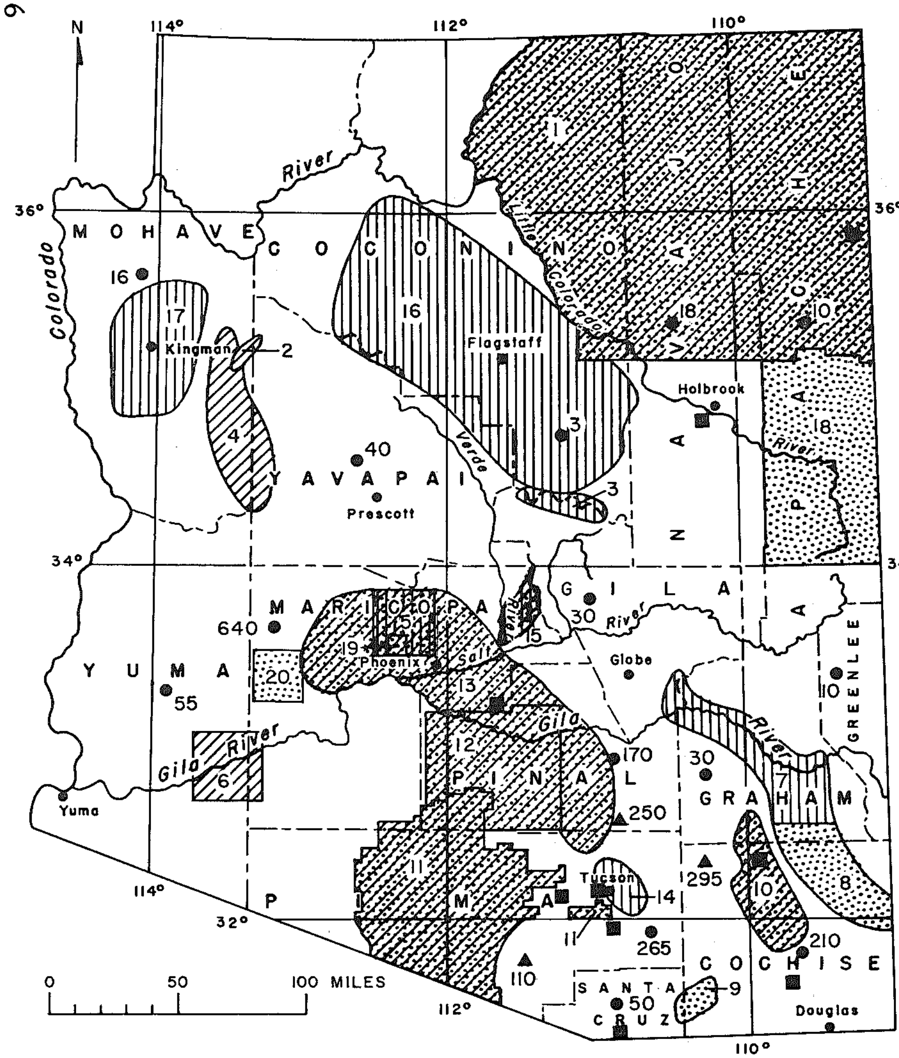


Figure 1. --Map showing summary of ground-water programs and location of data-collection sites.

AREAS OF INVESTIGATIONS

1. Navajo-Hopi Indian Reservations
2. Cottonwood Wash
3. East Verde River
4. Big Sandy Valley
5. Western part of the Salt River Valley (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. Part of central Arizona
14. Tucson basin
15. Sycamore Creek
16. Southern Coconino County
17. Sacramento and Hualapai Valleys (Kingman area)
18. Central part of Apache County
19. Luke area
20. Lower Harquahala Plains

Area where field investigation is in progress (As of June 1965)

Area for which a report is in preparation (As of June 1965)

Area for which a report was released July 1964-June 1965

A multiple pattern indicates that, although a report was released in the prescribed period, further work and (or) reports also are in progress

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

110 ▲ Well-discharge measurements made in 1964 (figure indicates number of measurements made in county)

■ Site where continuous water-stage recorder is in operation

The main aquifers in Apache County---in the Coconino Sandstone and Kaibab Limestone, which form a single hydrologic unit---contain water unsuitable for irrigation in most of the area north of the Little Colorado River and Carrizo Wash. They contain water of usable quality and in sufficient quantity for limited irrigation only in the area south of the Little Colorado River and west of St. Johns. The water in these aquifers in much of central Apache County is under artesian pressure.

The distribution and thickness of upper Miocene (?) and younger sedimentary and volvanic rocks in Arizona, by M. E. Cooley, in Abstracts from symposium on Arizona geology: Mus. Northern Arizona, 1964. p. 4.

The thickness and water-bearing characteristics of the alluvial deposits, which are the principal aquifers in the southern part of the State, are described in the abstract.

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-feet sequences in the Vekol and Slate Mountains; an overlying clastic unit is designated the Bolsa (?) Quartzite. The Bolsa (?) also is exposed in the Waterman Mountains where it rests on grantic rocks. It is overlain conformably by the Abrigo Formation of Cambrian age in the three mountain ranges.

Effects of ground-water withdrawal in part of central Arizona projected to 1969, by N. D. White, R. S. Stulik, and C. 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.

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.

Further analysis of hydrologic data for San Simon basin, Cochise and Graham Counties, Arizona, including analysis by electrical-analog model, by N. D. White and W. F. Hardt: U.S. Geol. Survey open-file report, October 1964. 63 p., 12 figs., 1 table. For publication as U.S. Geol. Survey Water-Supply Paper 1809-R.

This report concludes that the amount of ground water available from the artesian aquifer in San Simon basin is about 10 million acre-feet, and the transmissibility of this aquifer is about 20,000 gpd (gallons per day) per foot. Electrical-analog-model 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.

Annual report on ground water in Arizona, spring 1963 to spring 1964, by N. D. White, R. S. Stulik, E. K. Morse, and others: Arizona State Land Dept. Water-Resources Rept. 19, December 1964. 60 p., 27 figs.

This summary of ground-water programs in Arizona is based on hydrologic data collected from spring 1963 to spring 1964. The report discusses ground-water conditions, pumpage, and surface-water diversions in selected basins and areas in Arizona.

Basic ground-water data for western Pinal County, Arizona, by W. F. Hardt, R. E. Cattany, and L. R. Kister: Arizona State Land Dept. Water-Resources Rept. 18, December 1964. 59 p., 4 figs., 4 tables.

The report presents data collected from 1940 to 1963, including well records, drillers' logs, and quality-of-water information, for western Pinal County, the second largest agricultural area in the State.

Geology and depositional environment of Laguna Salada, Arizona, by M. E. Cooley and R. H. Hevly, in Chapters in the prehistory of eastern Arizona, II: Fieldiana: Anthropology, v. 55, chap. 8, December 1964. p. 188-200, 3 figs., 1 table.

The report discusses the alluvial deposits and volcanic flows, gives the positions of the pollen profiles and archeological sites in the geologic sequence, and summarizes the erosional and depositional events in the Laguna Salada area.

Regional hydrogeology of the Navajo and Hopi Indian Reservations, Arizona, New Mexico, and Utah, by M. E. Cooley, J. W. Harshbarger, J. P. Akers, and W. F. Hardt, wtih a section on vegetation by O. N. Hicks: U.S. Geol. Survey open-file report, December 1964. 245 p., 31 figs., 8 tables. For publication as U.S. Geol. Survey Prof. Paper 521-A.

The main aquifers in the reservations are in the Coconino, De Chelly, and Navajo Sandstones and the flood-plain alluvium along the larger streams. Water supplies for the Navajo and Hopi Indians are plentiful locally in the highlands but are deficient in other parts of the reservations. Where water shortages are chronic, dependable supplies are obtained from deep wells drilled into one or more of the deeply buried aquifers.

Stratigraphic sections of younger Precambrian and Paleozoic formations, Papago Indian Reservation, Arizona, by N. E. McClymonds and L. A. Heindl: U.S. Geol. Survey open-file report, January 1965. 101 p., 5 figs.

The outcrops of younger Precambrian and Paleozoic sedimentary formations, found in several parts of the Papago Indian Reservation, are described in this report.

Use of water by riparian vegetation, Cottonwood Wash, Arizona---A summary, by J. E. Bowie and William Kam: U.S. Geol. Survey open-file report, January 1965. 3 p.

Arizona has many miles of stream channels lined with plants that transpire large quantities of water from the channel sediments, thus depleting the flow in many streams. The report describes the project that was initiated to collect data necessary for determining the feasibility of conserving water by vegetation modification.

Water resources of Fort Huachuca Military Reservation, southeastern Arizona, by S. G. Brown, E. S. Davidson, L. R. Kister, and B. W. Thomsen: U.S. Geol. Survey open-file report, February 1965. 146 p., 18 figs., 10 tables. For publication as U.S. Geol. Survey Water-Supply Paper 1819-D.

Spring flow in two mountain streams near the Fort is adequate to supplement the presently overdeveloped ground-water supply, either through direct use or through artificial recharge to the aquifer. A second well field can be developed from ground water that now moves northeastward out of the reservation area.

Maps showing fluoride content and salinity of ground water in the Willcox basin, Graham and Cochise Counties, Arizona, by L. R. Kister, S. G. Brown, H. H. Schumann, and P. W. Johnson: U.S. Geol. Survey open-file report, March 1965. 39 p., 4 figs., 1 table. For publication as U.S. Geol. Survey Hydrol. Inv. Atlas HA-214.

The available hydrologic and geologic data relating to the chemical quality of the ground water of the Willcox basin are summarized in this report.

Salinity of the ground water in Western Pinal County, Arizona, by L. R. Kister and W. F. Hardt: U.S. Geol. Survey open-file report, March 1965. 60 p., 7 figs., 2 tables. For publication as U.S. Geol. Survey Water-Supply Paper 1819-E.

The chemical quality of the ground water in western Pinal County is nonuniform areally and stratigraphically. The main areas of highly mineralized water are near Casa Grande and Coolidge. Striking differences have been noted in the quality of water from different depths in the same well.

Stratigraphy of the Chinle and Moenkopi Formations, Navajo and Hopi Indian Reservations, Arizona, New Mexico, and Utah, by C. A. Repenning, M. E. Cooley, and J. P. Akers: U.S. Geol. Survey open-file report, May 1965. 146 p., 12 figs., 2 tables. For publication as U.S. Geol. Survey Prof. Paper 521-B.

The Chinle and Moenkopi Formations of Triassic age are present in most of the Navajo and Hopi Indian Reservations. The formations comprise a thick sequence of shaly beds, which contain several relatively thin sandstone beds. The shaly units generally are not water bearing, but a few persistent sandstone beds in the formations—mainly in the southeastern part of the area—yield water to springs and drilled wells.

Hydrologic and drill-hole data, San Xavier Indian Reservation and vicinity, Pima County, Arizona, by L. A. Heindl and N. D. White: Arizona State Land Dept. Water-Resources Rept. 20, June 1965. 48 p., 3 figs., 8 tables.

The report contains tables of well records, discharge characteristics of wells, selected drillers' logs, altitudes of the base of the older alluvium and water levels in wells, and analyses of ground water. The tables provide a ready reference to hydrologic information used in the preparation of geologic and hydrologic maps for several forthcoming interpretive reports.

Basic hydrologic data for San Simon basin, Cochise and Graham Counties, Arizona, and Hidalgo County, New Mexico, by N. D. White and C. R. Smith: Arizona State Land Dept. Water-Resources Rept. 21, June 1965. 42 p., 4 figs., 3 tables.

The basic data included in this report have provided the basis for evaluating the ground-water resources of the San Simon basin. The report makes available the well records, drillers' logs, and quality-of-water information for the San Simon basin.

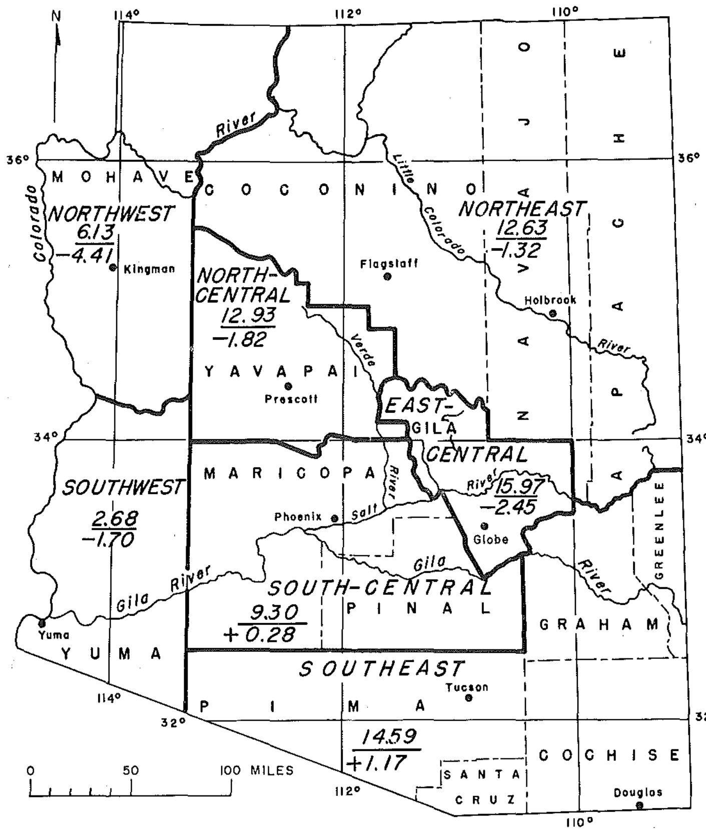
Mesozoic formations in the Vekol Mountains, Papago Indian Reservation, Arizona, by L. A. Heindl: U.S. Geol. Survey Bull. 1194-G, 1965. 9 p., 1 fig.

Mesozoic deposits in the Vekol Mountains include the following: The Phonodoree Formation consisting mostly of quartzitic rocks; the Vekol Formation consisting largely of gray-green arkoses, graywackes and pebble conglomerates, and a local basal angular conglomerate member composed mainly of volcanic material; and the Chiapuk Rhyolite, a welded ash flow. The formations are of probable late Mesozoic, possibly Cretaceous age.

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 irrigation. About half of Arizona receives less than 10 inches of precipitation annually. In general, the areas that have the highest temperatures and longest growing seasons are the most highly developed for agriculture; however, they also are the areas of lowest rainfall. Evaporation and transpiration rates are high, and only a small part of the total precipitation can be utilized beneficially, either directly by growing plants or as recharge to the ground-water reservoir. Only about 1 percent of the total annual precipitation is available for recharge; thus, it is impossible, in most areas, for natural ground-water recharge to equal ground-water withdrawal.

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 for each division for 1964 and departures from the long-term average are shown in figure 2. Precipitation for 1964 was below average throughout the State, except in the south-central division where it was less than 0.3 inch above average and in the southeast division where it was slightly more than 1 inch above average. 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. In many areas of the State the irrigation season starts as early as mid-January to early February when the farmers preirrigate the land in preparation for planting. Large-scale application of irrigation water starts in April or May. With a few exceptions, monthly precipitation rates were below average in the State from January through June, particularly in the southern part where agricultural development is



EXPLANATION

2.68 — Average precipitation for subdivision, 1964
-1.70 — Departure from long-term average

1/ Average for all stations in division, 1964.

2/ Departure from long-term average.

Month	Northwest division		Northeast division		North-central division		East-central division		Southwest division		South-central division		Southeast division	
	Precipitation 1/ (inches)	Departure 2/ (inches)	Precipitation 1/ (inches)	Departure 2/ (inches)	Precipitation 1/ (inches)	Departure 2/ (inches)	Precipitation 1/ (inches)	Departure 2/ (inches)	Precipitation 1/ (inches)	Departure 2/ (inches)	Precipitation 1/ (inches)	Departure 2/ (inches)	Precipitation 1/ (inches)	Departure 2/ (inches)
January	0.22	-0.79	0.46	-0.75	0.40	-1.03	0.78	-1.22	0.03	-0.46	0.27	-0.70	0.21	-0.77
February	Trace	-1.29	.25	-1.00	.05	-1.56	.08	-1.90	.13	-.42	.04	-.92	.10	-.92
March	.98	+.04	1.34	+.24	1.40	+.27	1.72	+.04	.23	-.12	.76	-.01	.83	+.10
April	.59	-.06	1.08	+.26	.88	+.05	.77	-.11	.12	-.05	.20	-.19	.47	+.11
May	.30	+.07	.26	-.24	.24	-.08	.01	-.33	.01	-.01	.01	-.13	.01	-.15
June	.21	+.04	.22	-.25	.41	+.02	.20	-.24	.02	-.03	.04	-.10	.14	-.35
July	.78	-.19	2.43	+.65	2.63	+.77	2.94	+.91	.38	-.02	1.66	+.60	3.78	+1.00
August	1.96	+.33	2.51	+.17	3.76	+1.07	2.88	-.07	.63	-.17	2.64	+1.08	3.21	+.07
September	.30	-.80	1.83	+.47	1.23	-.08	3.05	+1.46	.19	-.30	1.42	+.59	3.43	+2.09
October	.02	-.70	.09	-1.05	.12	-.80	.54	-.74	.27	-.05	.53	-.06	.93	+.14
November	.26	-.30	.91	+.13	.69	-.09	1.20	-.01	.48	+.26	.67	+.07	.82	+.18
December	.51	-.76	1.10	-.08	1.12	-.36	1.80	-.24	.19	-.33	1.06	+.05	.66	-.33
Annual	6.13	-4.41	12.63	-1.32	12.93	-1.82	15.97	-2.45	2.68	-1.70	9.30	+.28	14.59	+1.17

Data from U. S. Weather Bureau, 1965

Figure 2. --Precipitation data for 1964 by climatic subdivisions.

greatest. Thus, in general, it was necessary to pump ground water continuously during this part of the growing season. However, beginning in July and continuing throughout the remainder of the irrigation season, monthly precipitation was above average in the southeast and south-central divisions, although it continued to be slightly below average in the southwest division. In the northern part of the State the monthly precipitation rates departed from the long-term average sporadically and were partly below and partly above average from July through the end of the year. Another important aspect of precipitation in Arizona, particularly in the southern highly developed areas, is the heavy rains in the summer that cause damage to crops. An example is the torrential rainstorm on the upper Santa Cruz drainage basin in early September 1964. The maximum 24-hour precipitation recorded and published by the U. S. Weather Bureau (1965) was 4.52 inches at Amado, but rainfall of nearly 7 inches was reported by individuals at several places in the basin. The storm resulted in about 2 million dollars damage to crops in the area. Although storms of this nature may result in a temporary shutdown of pumps in the area of occurrence, they do not necessarily provide water for beneficial use. For the most part, the water moves rapidly through the area and carries large amounts of sediment; therefore, only a very small part of the total runoff can recharge the ground-water reservoir. Nearly all aspects of Arizona's climate indicate the continuing and growing need for the use of ground water for all phases of the culture and economy.

Surface-Water Runoff, Storage, and Diversions

By

E. B. Hodges

As is common in Arizona, stream runoff varied greatly in the 1964 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 six key gaging stations ranged from 61 to 151 percent of the median of yearly mean discharge; however, only the San Pedro River exceeded the median. The median of the yearly mean discharge is defined as the middle value of discharge when arranged in order of size. For the index stations, the median is computed from the yearly mean discharges for the 1931-60 period of record.

For the 1964 water year, the flow of the Virgin River was deficient (in the lower one-fourth of the range of discharges in the 1931-60 reference period); whereas, the flow of the San Pedro River was excessive (in the upper one-fourth of the range of discharges in the 1931-60 reference period). In general, the lowest flows were during the winter and late spring. Record-low monthly mean discharge occurred as follows: Little Colorado River from January to March; Salt River from January to March; Verde River in February; and Virgin River from December to February and in June and September. There was no flow in the Little Colorado River near Cameron from November 23 to April 3. This is the longest period of no flow at this station since records began in 1920 and the first January and February during which there was no flow for the entire month. Excessive flows occurred mostly from 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 several areas. In late July six persons were drowned on the Navajo Indian Reservation when a bridge was washed out by a flash flood. Casa Grande and Winslow were partially inundated as a result of concentrated rainfall from local storms in August. In another storm the peak discharge of the Santa Maria River near Alamo on August 2 was the second highest in a period of record that began in 1939; only the peak of 1951 was higher. On September 10 a major tropical storm covered the upper Santa Cruz River basin; rainfall of nearly 7 inches was measured at some points. Runoff from this storm caused the third highest peak discharge of record on the Santa Cruz River at Tucson and at Cortaro. The record for the Santa Cruz River at Tucson began in 1906; the highest peak discharges occurred in 1914 and 1961. The record for the Santa Cruz River at Cortaro began in 1939; the highest peak discharges occurred in 1940 and 1955. Runoff of the Santa Cruz River at Tucson for September 1964 was only slightly less than that of the record-high September runoff in 1926. Damages in the upper Santa Cruz River basin from the September 1964 storm were reported as about 2½ million dollars; of this amount, about 2 million dollars was damage to crops, mostly cotton.

The mean discharge for the 1964 water year and the relation to the median of yearly mean discharge based on the period 1931-60 for seven key gaging stations are shown below.

Station	Discharge (acre-feet)	Percent of median
Colorado River near Grand Canyon	2,727,000	----
Little Colorado River near Cameron	170,500	100
Virgin River at Littlefield	89,510	61 (deficient)
Gila River at head of Safford Valley, near Solomon	163,400	80
San Pedro River at Charleston	54,910	151 (excessive)
Salt River near Roosevelt	275,600	71
Verde River below Tangle Creek, above Horseshoe Dam	242,700	85

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 precent of median discharge has not been computed, and this gaging station is no longer used as an index station.

Storage in the principal reservoirs in Arizona as of March 31, 1965, compared with storage for the previous year, is shown below.

Reservoir	Contents, in acre-feet March 31, 1965	Contents, in acre-feet March 31, 1964
Lake Pleasant	37,320	17,370
Verde River system	172,400	33,200
San Carlos Reservoir	76,620	51,630
Salt River system	1,175,000	719,800

The total diversion of streamflow to Arizona lands in the 1964 water year was about 2,600,000 acre-feet, slightly less than in 1963. About 1,710,000 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 705,000 acre-feet of the water diverted from the Colorado River was returned to the river or discharged across the Arizona-Sonora International Boundary.

About 875,000 acre-feet of surface water was diverted from the Gila River basin in the 1964 water year. Of this amount, 665,600 acre-feet was diverted from 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.

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.

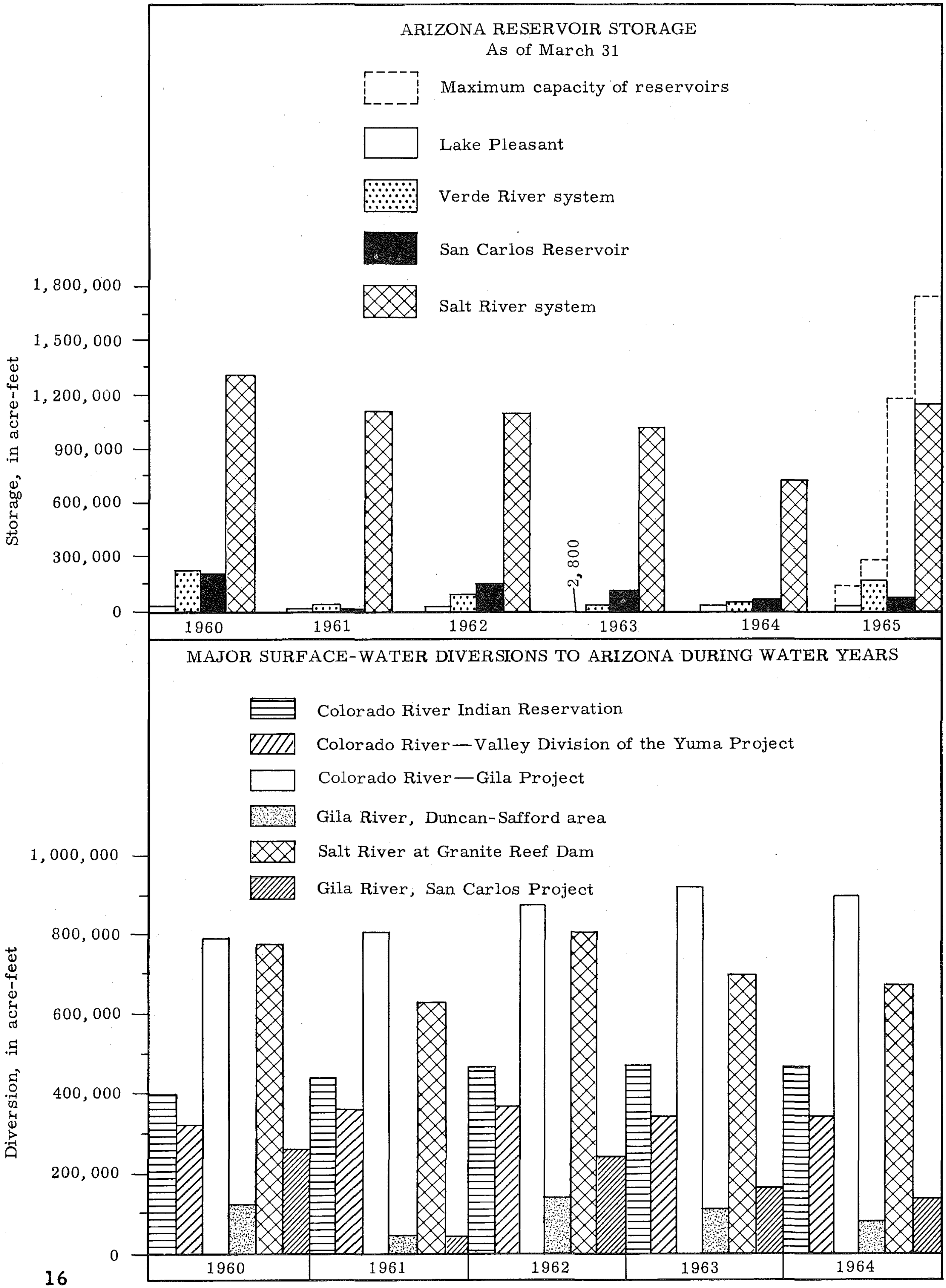


Figure 3.--Surface-water reservoir storage and diversions.

GROUND-WATER CONDITIONS BY AREAS

By

Natalie D. White

Arizona may be divided into three water provinces that are synonymous with the physiographic provinces. The occurrence of ground water in the State is controlled by the physiography and geology of the 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. Each province has certain distinctive ground-water characteristics, and the current ground-water conditions in each will be discussed separately. All wells in the State are located by the numbering system explained in figure 4. Figure 5 outlines the various basins and areas for which ground-water conditions are discussed in this report.

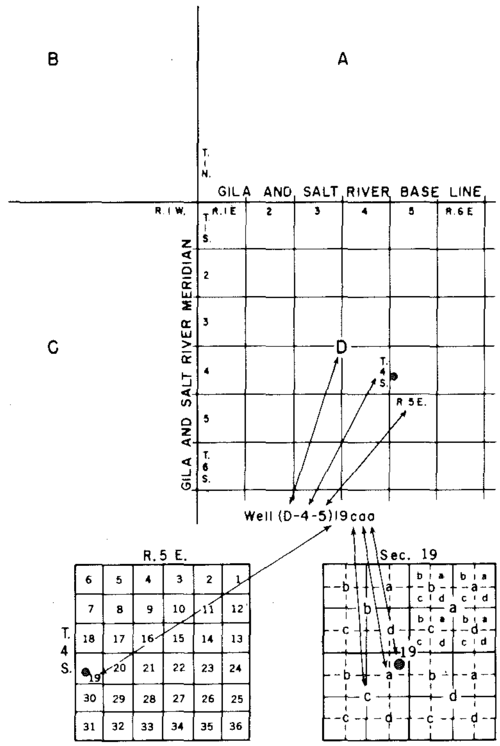
Basin and Range Lowlands Province

By

Natalie D. White

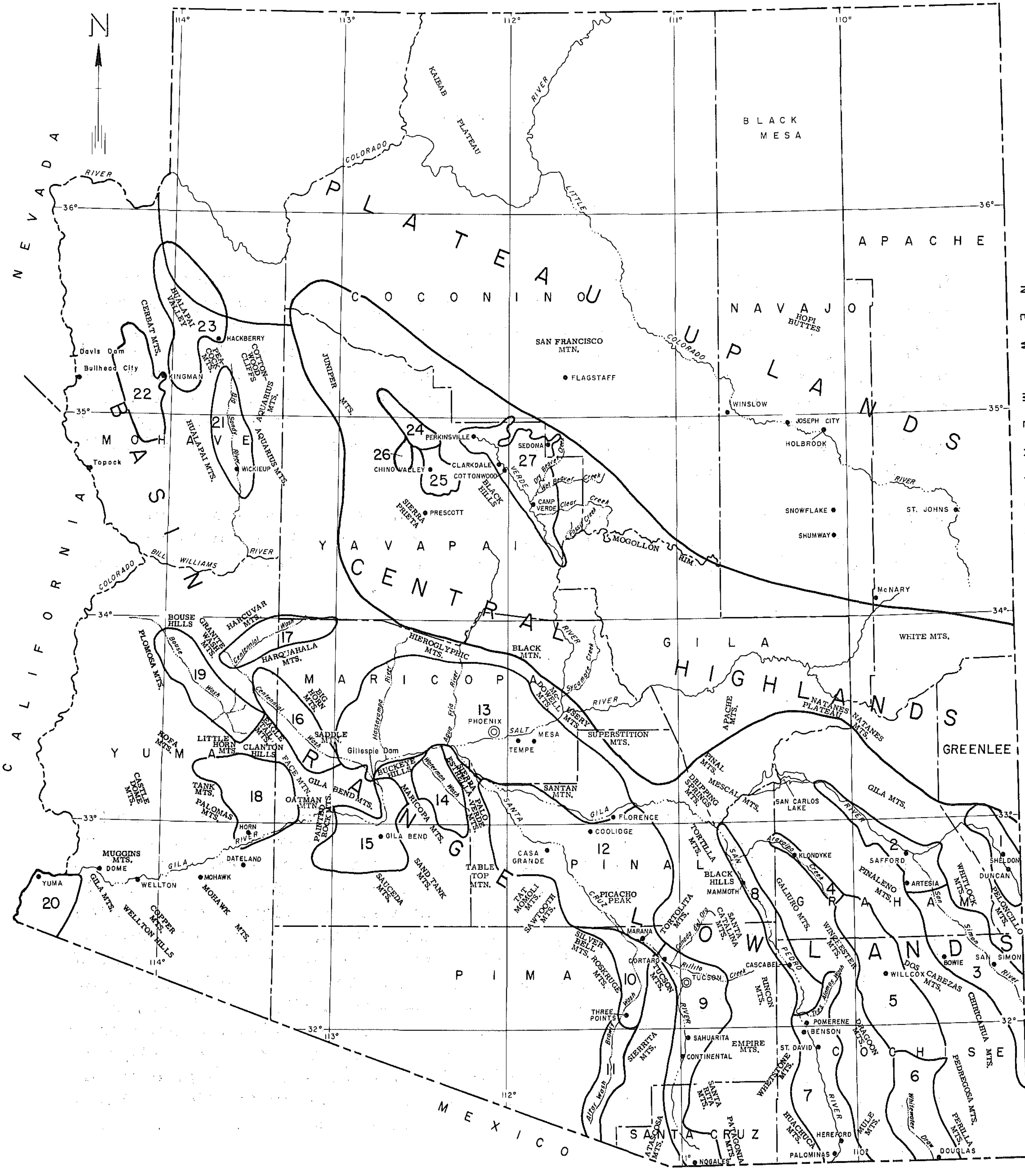
The Basin and Range lowlands province consists of broad gently sloping valleys and basins and high isolated mountain ranges that rise sharply above them. For the most part, the basins are filled with alluvial materials, which, in places, are as much as several thousand feet thick. The unconsolidated or weakly consolidated sediments within this alluvium store large amounts of ground water and yield it readily to wells. The climate in the province is arid to semiarid, growing seasons are long, and the environment generally is favorable for crops and light industry.

During the last few decades there has been extensive development of the water supply in the Basin and Range lowlands province, and it is by far the most extensively developed of the three provinces from the standpoint of ground-water use. More than 1 million acres of land is irrigated using more than 6½ million acre-feet of water annually. The ground-water reservoirs are the main source of water used for irrigation. The vast reserves of ground water are being depleted, and the result is a downward trend of the water levels in nearly all the highly developed areas in the Basin and Range lowlands province. The following paragraphs give discussions of the ground-water conditions in all the developed areas in the province by basins and areas beginning at the eastern edge of the State.



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.



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 VALLEY
11. ALTAR VALLEY
12. LOWER SANTA CRUZ BASIN AND ADJACENT AREA ALONG GILA RIVER
13. SALT RIVER VALLEY
14. WATERMAN WASH AREA
15. GILA BEND AREA
16. HARQUAHALA PLAINS AREA
17. MCMULLEN VALLEY AREA
18. PALOMAS PLAIN AREA
19. RANEGRAS PLAIN AREA
20. SOUTH GILA VALLEY, YUMA MESA, AND YUMA VALLEY AREA
21. BIG SANDY VALLEY
22. SACRAMENTO VALLEY
23. HUALAPAI VALLEY
24. BIG CHINO VALLEY
25. LITTLE CHINO VALLEY
26. WILLIAMSON VALLEY
27. VERDE VALLEY

Figure 5.-- Basins and areas for which ground-water conditions are discussed.

Duncan Basin

By

E. S. Davidson

In the Duncan basin (fig. 5, No. 1) water levels in a few selected irrigation wells are measured regularly to aid in recording and anticipating the long-term effect of pumping ground water for irrigation purposes. Most irrigation wells in the basin obtain water from the alluvium underlying the flood plain of the Gila River. The alluvium is a long, sinuous, shoestringlike deposit in the central part of the Duncan basin and is as much as 3 miles wide and 100 feet thick. The deposit is stream-deposited mixtures and lenslike beds of sand, gravel, and silt. The water level in the deposit ranges from 1 to 40 feet below land surface.

Water levels measured in irrigation wells in spring 1965 were at almost the same level as in spring 1964 and from about the same to 3 feet higher than in spring 1960. The hydrographs of the water level in wells (D-8-32)32 and (D-7-31)4 (fig. 6) show changes typical of the area.

Safford Basin

By

E. S. Davidson

The majority of irrigation wells in the Safford basin (fig. 5, No. 2) tap the alluvium that underlies the flood plain of the Gila River under conditions similar to those in the Duncan basin. The water levels are from about 10 to 60 feet below land surface and fluctuate in response to the flow of the Gila River and the amount of Gila River water applied to irrigated fields in the area (White, Stulik, and others, 1962; White, Stulik, Morse, and others, 1963). From spring 1964 to spring 1965 water levels in wells at the head of the valley declined from 3 to nearly 20 feet, as illustrated by the hydrographs of the water level in wells (D-7-27)2 and (D-6-28)31 (fig. 6). In the area between the head of the valley and Safford, water levels declined about 5 feet; from Safford to Geronimo, water levels declined about 1 foot or rose slightly. The changes in water level in wells (D-6-24)5 and (D-4-22)13 (fig. 6) probably are typical for this area. Water levels measured in the Cactus Flat-Artesia area are about equal to or slightly higher than those measured in spring 1964.

San Simon Basin

By

Natalie D. White

The San Simon basin (fig. 5, No. 3), in the southeast corner of Arizona, 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 hydrology of the San Simon basin has been discussed in two recent reports (White, 1963; White and Hardt, 1965). The report by White and Hardt (1965) uses the electrical-analog method to analyze the hydrologic data for the basin and to predict the changes in water level in the artesian aquifer that will take place from 1960 to 1980 under an hypothesized pumping regimen. The basic hydrologic data on which both reports are based also have been published recently (White and Smith, 1965). Because these reports contain comprehensive discussions of the geology and hydrology of the San Simon basin, the following paragraphs will contain only a discussion of the depth to water in spring 1965 and the changes in water levels from spring 1964 to spring 1965.

In the Bowie area the depth to water in spring 1965 in wells that tap the artesian aquifer ranged from about 115 feet below land surface in a nonirrigation well near the northeast edge of the area to about 230 feet in the center of the irrigated area. The water levels in the artesian wells declined from 2 to 12 feet from spring 1964 to spring 1965. The water level in well (D-12-28)35 (fig. 7) declined only slightly more than 3 feet from spring 1964 to spring 1965, which indicates a reduction in the rate of decline that has occurred during the last several years. The water level in a well at the southwest edge of the artesian area was about 290 feet below land surface in spring 1965. Here, the blue clay unit that forms the confining layer is thin, and the water level in the well probably has dropped below the bottom of this unit; thus, the well is operating under water-table conditions. Water levels in water-table wells in the marginal zone along the basin flank a few miles south of Bowie are somewhat deeper than in the artesian area. The water level in three of these wells was 332, 367, and 374 feet below land surface in spring 1965; the water level in these three wells declined 6, 2, and 5 feet, respectively, from spring 1964 to spring 1965. The erratic fluctuation of the water level in well (D-13-28)16 (fig. 7) cannot be explained at the present time, but it probably is a function of the time of measurement in relation to the pumping of the well.

The depth to water in the artesian wells in the San Simon area ranged from less than 15 to nearly 160 feet below land surface in spring 1965. The water-level changes in these wells ranged from a rise of nearly 2 feet to a decline of about 5 feet from spring 1964 to spring 1965. The water level in well (D-14-31)24 (fig. 7) declined slightly more than 3 feet from spring 1964 to spring 1965. The water level was measured in only two water-table wells in the San Simon area in spring 1965; the water level in these two wells was about 65 and 70 feet below land surface. The water level in well (D-13-30)24 (fig. 7) remained essentially stable from spring 1964 to spring 1965.

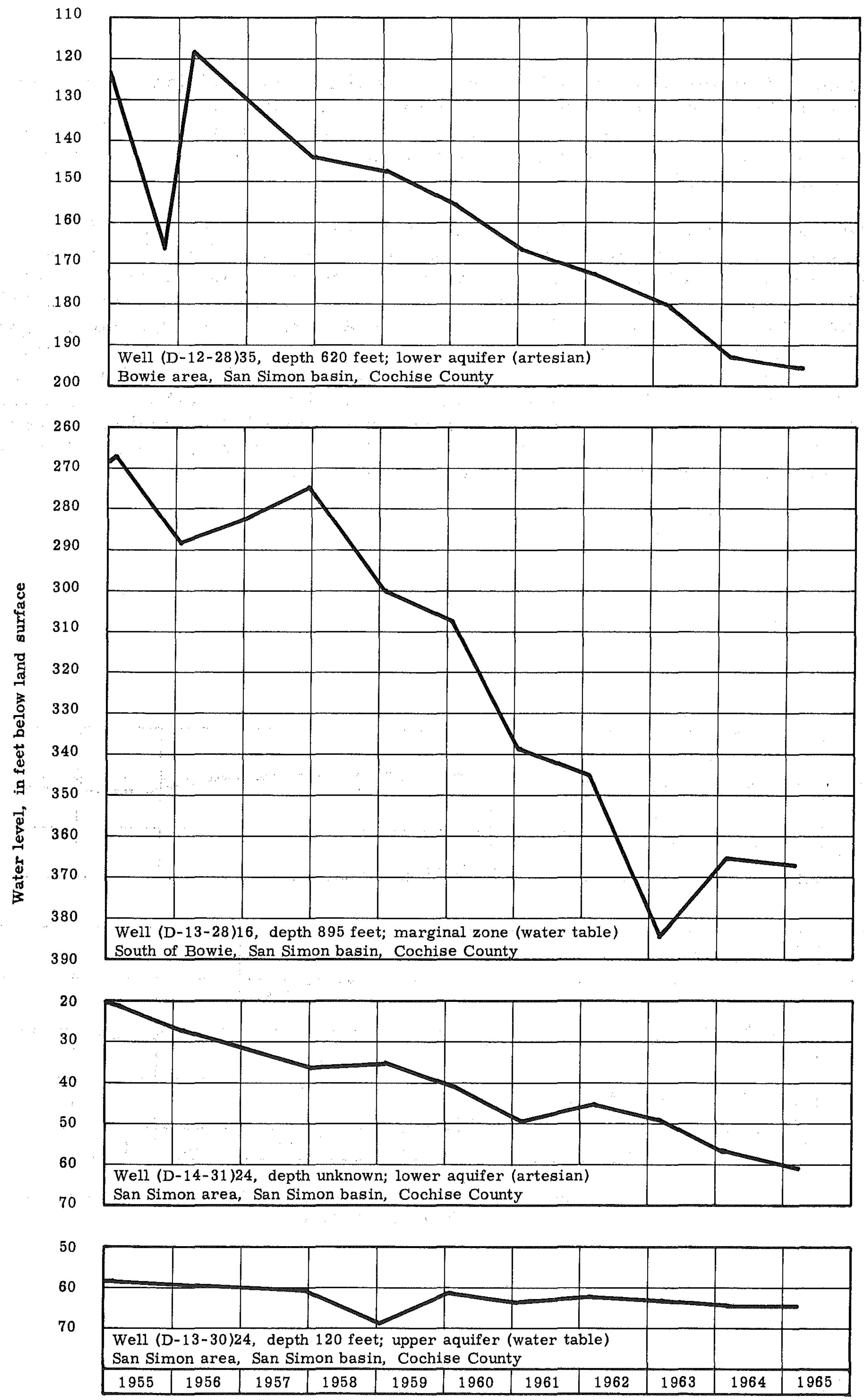


Figure 7. --Water levels in selected wells in the San Simon basin.

The cones of depression caused by pumping in the Bowie and San Simon areas are gradually extending into the undeveloped area between San Simon and Bowie. The water level in a well about 9 miles southwest of Bowie had dropped to nearly 28 feet below land surface in spring 1965; the well had been flowing as late as 1957.

In the Rodeo area, the development of ground water for irrigation is not as great as in the Bowie and San Simon areas. However, near Rodeo, some ground water is withdrawn for irrigation use, and water levels are declining slightly. In spring 1965 water levels near Rodeo ranged from less than 110 to more than 160 feet below land surface, and water-level changes ranged from slight rises to a decline of more than 7 feet from spring 1964 to spring 1965. The water level in wells (D-18-32)11 and (D-18-32)26 (fig. 8) rose slightly from spring 1964 to spring 1965. About 5 miles south of Rodeo, the water level in a few irrigation wells is nearly 200 feet below land surface; in a lesser developed area about 10 miles north of Rodeo water levels, for the most part, are from 70 to 90 feet below land surface.

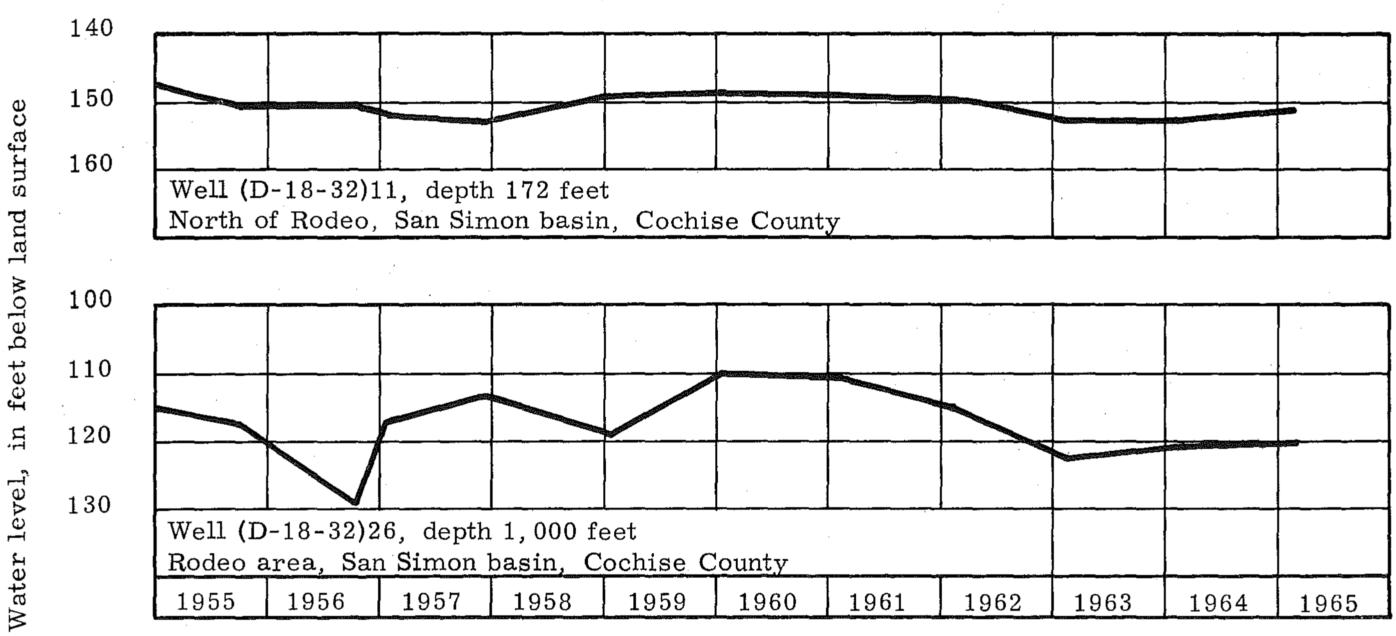


Figure 8.--Water levels in selected wells in the southern part of the San Simon basin.

Aravaipa Valley

By

S. G. Brown and Natalie D. White

Aravaipa Valley (fig. 5, No. 4) extends from a drainage divide at the headwaters of Aravaipa Creek northwestward for a distance of about 44 miles and drains into the San Pedro River at a point about 15 miles upstream from the confluence of the San Pedro and Gila Rivers. The bordering mountains rise steeply above the valley floor and are cut by numerous canyons that carry floodwater from the mountain slopes into the valley. The entire valley is comparatively narrow. From the headwaters downstream for about 22 miles the valley is from about ½ to 1½ miles wide; from about 4 miles northwest of Klondyke to the mouth it is less than a quarter of a mile wide and in places only about a tenth of a mile wide. Aravaipa Creek is perennial in this latter reach, but the valley is too narrow to support agriculture.

Aravaipa Valley is the northwesternmost part of a structural trough that extends from Mexico to the Gila River; the central and southern parts of the trough are occupied by the Sulphur Spring Valley, which includes Willcox and Douglas basins. Meinzer and Kelton (1913, p. 25) state: "The divide northwest of the Sierra Bonita ranch, which is the divide between Sulphur Spring and Arivaipa (sic) valleys, was once farther north than it is at present. The stream-built slopes in Arivaipa Valley have been extensively eroded in recent geologic time." Meinzer and Kelton (1913, p. 27) also state: "The stream-built slopes in Gila Valley have in recent time become deeply and extensively eroded, and the erosive process has been carried up the tributary valleys***. When the gullies in the Arivaipa had, by erosion at their heads, gnawed their way to the original divide between the Arivaipa and Sulphur Spring valleys they did not stop growing but attacked the smooth southward-sloping surface at the head of Sulphur Spring Valley. In this manner the divide was gradually shifted southward, and Arivaipa Valley was expanded at the expense of Sulphur Spring Valley. This piracy on the part of the Arivaipa is still going on and will continue indefinitely unless stopped by some conflicting process." In a discussion of the geologic history of the Willcox basin and particularly in reference to the formation of pediments and the deposition of eroded materials in the lower parts of the basin, Jones and Cushman (1947, p. 5) state: "Aravaipa Creek, north of the Willcox Basin, began to remove the valley fill by headward erosion, probably after the pediments were formed. Thus was formed the inner and lower valley of Aravaipa Creek. "In a discussion of underflow from the Willcox basin Cushman and Jones (1947, p. 15) state: "The elevations of water levels in wells in the vicinity of the surface drainage divide at the northern boundary of the Willcox Basin indicate that the perched or semi-perched ground water moves in the same direction as the surface drainage but that the ground-water divide in the main water table is south of the surface drainage divide." The inferred movement of the surface-drainage divide cannot be either verified or discounted at present, and the surface-drainage divide, as described in this report, is north of the ground-water divide between the Willcox basin and Aravaipa Valley. However, the ground-water divide is only tentatively established, and additional data are needed before it can be accurately delineated. It is also possible that as more ground water is withdrawn in the north part of the Willcox basin, causing the cone of depression to spread, the ground-water divide will move northward toward the present surface divide between the Willcox basin and Aravaipa Valley.

In spring 1965 the water level was measured in six wells in Aravaipa Valley; the depth to water ranged from less than 10 to about 80 feet below land surface. All the wells measured are drilled into the shallow alluvium along Aravaipa Creek, and the water levels are affected by recharge from precipitation, by flow in the creek, and by the pumping schedules. From spring 1964 to spring 1965 declines in the water level ranged from ½ foot to 1½ feet in three wells; rises of about 1¼ to 1-3/4 feet were measured in two wells. The changes from spring 1960 to spring 1965 were equally as variable. Aravaipa Valley probably is one of the few areas in Arizona where the rate of withdrawal of ground water does not exceed the natural recharge. The amount of decline that occurs at a particular location in one year may easily be overcome by a corresponding rise in water level during the following year.

In addition to the water levels measured in wells within the surface drainage of Aravaipa Valley, water levels were measured in three wells in the area between the surface-drainage divide and the ground-water divide that separates Aravaipa Valley and the Willcox basin. The water level in two of these wells is less than 10 feet below land surface and represents a perched water body. In the third well the water level was more than 400 feet below land surface and is part of the regional water table in Aravaipa Valley. The shallow water levels fluctuate in response to recharge from precipitation and to pumping. The deep water level is not affected by recharge from precipitation, and further records are necessary to determine the effects of pumping.

Sulphur Spring Valley

By

S. G. Brown and Natalie D. White

Sulphur Spring Valley (fig. 5, Nos. 5 and 6), in southeastern Arizona, trends north-northwestward for about 90 miles from the International Boundary to a drainage divide at the headwaters of Aravaipa Creek. The structural trough, of which the valley is a part, extends from the Gila River on the north into Mexico on the south. Sulphur Spring Valley is a broad alluvial-filled valley bounded by parallel chains of mountains typical of the Basin and Range lowlands province of southern Arizona. The Willcox basin (fig. 5, No. 5) occupies the northern three-fifths of the valley; it has no external drainage outlet, and water moves from all directions toward a large depression known as the Willcox Playa. The northern boundary of the Willcox basin is the drainage divide at the headwaters of Aravaipa Creek. The southern two-fifths of Sulphur Spring Valley---Douglas basin (fig. 5, No. 6)---is drained by Whitewater Draw, which is a tributary to the Yaqui River, that flows southward into Mexico. The Douglas basin is separated from the Willcox basin on the north by a drainage divide in the buttes and ridges south of Pearce. Ground-water conditions in the two basins—Willcox and Douglas—are discussed separately below.

Willcox basin.--The depth to water was measured in more than 100 wells in the Willcox basin in spring 1965. These include measurements in nearly 50 new wells north of the presently developed Stewart area (fig. 9) and mostly in Graham County. At the time most of these new wells were measured they had not been pumped, except for testing.

Figure 10 shows cumulative net changes in average water levels for five areas in the Willcox basin using the average water level in 1952 as a base. The five areas (fig. 9) were chosen on the basis of the time that development of ground water began, the amount of ground-water withdrawal, and geographic location. All the curves show a downward trend of the water level, which indicates that even in the areas of lesser development the withdrawal of ground water exceeds the rate of replenishment.

Water-level declines continued to be greatest in the extensively developed Kansas Settlement area (fig. 9) southeast of the Willcox Playa; however, water-level rises were measured in a few wells between the Kansas Settlement road and the playa. The average decline in water level in the Kansas Settlement area was nearly 9 feet from spring 1964 to spring 1965; this decline is based on changes in 31 wells. In the 5-year period spring 1960 to spring 1965, the average water-level decline was nearly 42 feet, which is about half of the total decline for the 13-year period of record shown on the hydrographs (fig. 10).

In the Stewart area (fig. 9), although water levels are declining as a result of the withdrawal of ground water in excess of the rate of replenishment, the declines are not as great as in the more highly developed Kansas Settlement area. From spring 1964 to spring 1965 the average water-level decline in the Stewart area was about 2 feet; from spring 1960 to spring 1965 the decline was about 10 feet. The rate of decline in this latter 5-year period is slightly less than during the earlier years of the period of record shown on the hydrographs (fig. 10).

In the north playa area (fig. 9) between the Stewart and Kansas Settlement areas the average decline in water level was nearly 4 feet from spring 1964 to spring 1965 and nearly 16 feet from spring 1960 to spring 1965. The amount of decline in the 5-year period is more than 60 percent of the total decline during the 13 years of record (fig. 10). In recent years the cone of depression in the Kansas Settlement area has begun to spread into this area and has caused larger declines.

In the Sierra Bonita ranch area (fig. 9) development of ground water presently is minor. The average change in water level in this area was only slightly more than 1½ feet from spring 1964 to spring 1965 and about 15 feet from spring 1960 to spring 1965. However, more than 50 new wells have been drilled recently in this area, and pumping of these wells probably will cause increased declines in water levels.

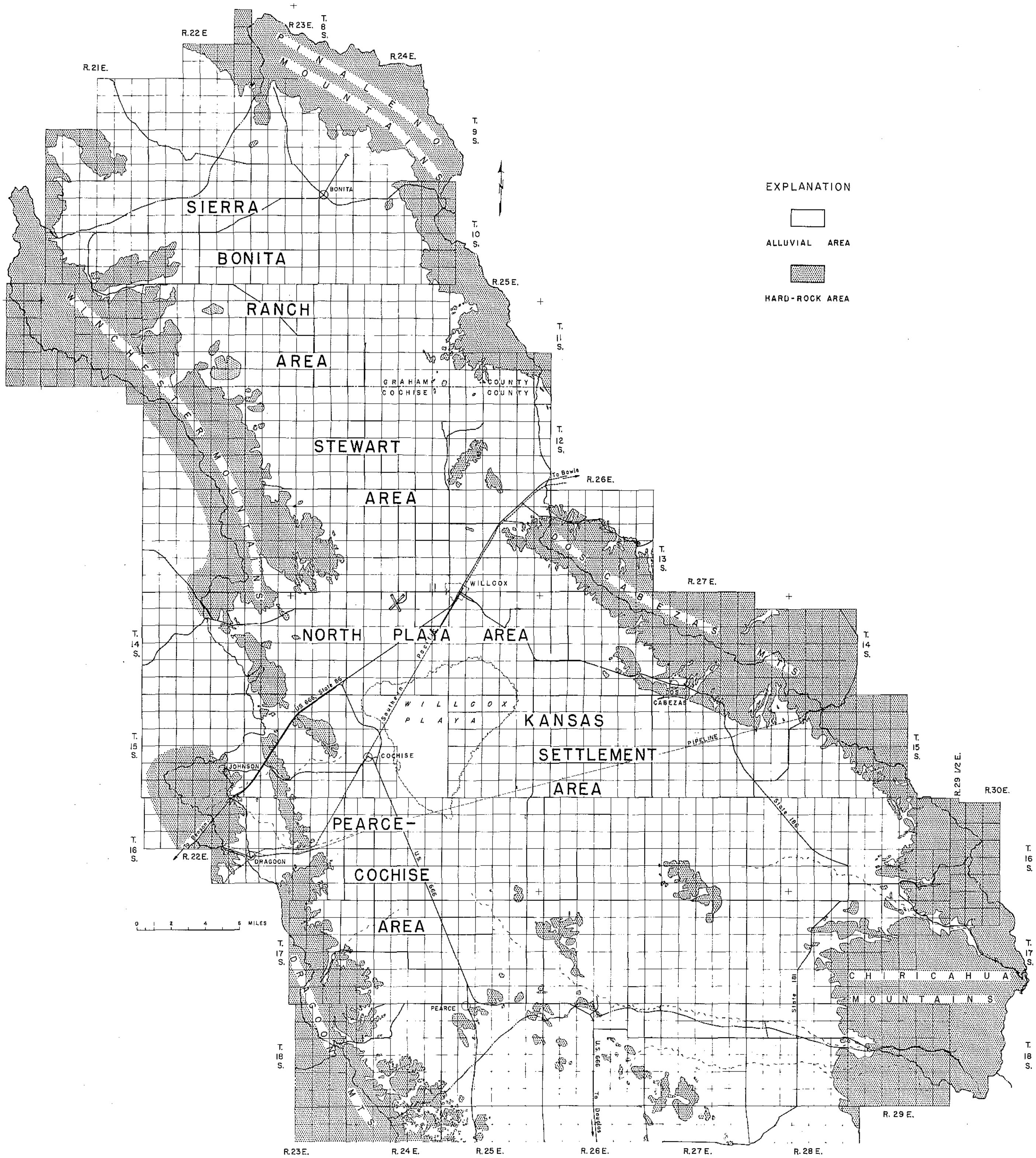


Figure 9. -- Subareas in Willcox basin.

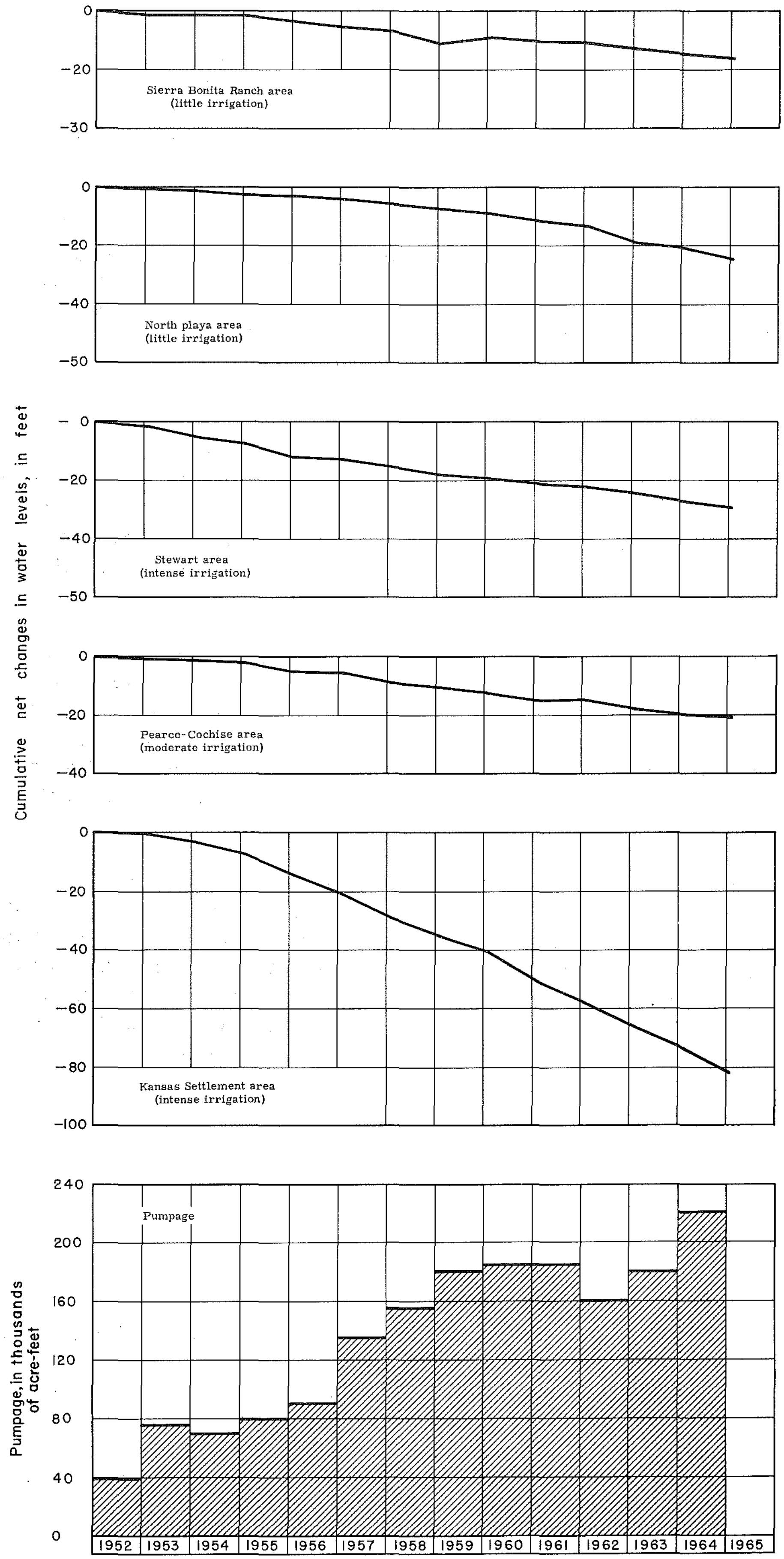


Figure 10. --Cumulative changes in water levels and pumpage, Willcox basin.

In the Pearce-Cochise area (fig. 9), southwest of the Kansas Settlement area and the Willcox Playa, the average change in water level from spring 1964 to spring 1965 was slightly more than 1 foot. From spring 1960 to spring 1965 the average water-level decline in this area was about 8 feet and about 21 feet for the 13-year period of record (fig. 10). Development of ground water in this area is comparatively minor at the present time.

Douglas basin.--The depth to water was measured in more than 60 wells in the Douglas basin (fig. 5, No. 6) in spring 1965. For the most part, the depth to water in the basin ranges from about 30 to 150 feet below land surface; however, in a few wells in outlying areas near the mountains the water level was as much as 200 feet below land surface in spring 1965. Along the central part of the basin the depth to water is generally less than 100 feet below land surface.

Both rises and declines in water level were recorded from spring 1964 to spring 1965, but the average change in water level was a decline of about 1 foot. From spring 1960 to spring 1965 the average change in water level was a decline of slightly more than 6 feet. For the most part, the greater declines in water level are in the Elfrida-McNeal area where the pumping of ground water for irrigation currently is the greatest.

Many new wells have been drilled recently in the Douglas basin; more than 150 wells have been drilled in the last year. In late spring 1965 the Douglas basin was declared a "critical ground-water area" by the Arizona State Land Commissioner, and, theoretically, no more new wells can be drilled in the basin. The beginning of operation of the many new wells that have already been drilled probably will cause an increase in the rate of water-level decline in the basin.

During the early part of 1965 a complete inventory of the existing wells in the basin was made by personnel of the Geological Survey; many samples of drill cuttings were collected from the wells that were being drilled, and in 1966 a more comprehensive report on the ground-water conditions in the area will be prepared. The report will be similar to others prepared under the expanded phase of the statewide ground-water program, which was designed to make better use of the data that are collected each year.

San Pedro River Valley

By

Natalie D. White

The San Pedro River heads in Sonora, Mexico, flows northward, and crosses into Arizona just south of Palominas. The valley is divided into the upper and lower San Pedro basins (fig. 5, Nos. 7 and 8). The upper San Pedro basin (fig. 5, No. 7) extends from the International Boundary on the south to the Narrows near Tres Alamos, about 8 miles north of Pomerene. The lower San Pedro basin (fig. 5, No. 8) extends from the Narrows to the Gila River near Winkelman. The subsurface rocks in the San Pedro River valley and their relation to the hydrology of the area were described by Davidson (in White and others, 1963).

Upper San Pedro basin.--Although the upper San Pedro basin (fig. 5, No. 7) has not been developed extensively and pumping of ground water is at a minimum, some ground water is withdrawn from both 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 the shallow water-table wells along the flood plain of the river ranged from about 20 to nearly 85 feet below land surface in spring 1965. 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 less than 1 foot to about 4 feet from spring 1960 to spring 1965. From spring 1964 to spring 1965 water-level changes ranged from a rise of nearly 4 feet to a decline of nearly 5 feet. The water level in well (D-16-20)34 (fig. 11) rose nearly 4 feet from spring 1964 to spring 1965; the erratic pattern of the water-level fluctuations in this well is the result of the recharge and pumping described above. Some of the artesian wells along the flood plain of the San Pedro River were flowing in spring 1965, but in some wells the water level was as much as 50 feet below land surface. The change in water level in well (D-17-21)32 (fig. 11) probably is typical of these wells. In general the water level is declining slightly, although for the last 2 years a rise in water level was indicated because the measurement made in 1963 had been influenced by recent pumping of the well. In the deeper wells on the flanks of the valley the water levels measured in spring 1965 ranged from less than 40 to more than 200 feet below land surface; however, miscellaneous measurements for other years show that the water level is more than 300 feet below land surface in parts of the outlying area. The water level in well (D-21-21)29 (fig. 11) declined less than 1 foot from spring 1964 to spring 1965.

Lower San Pedro basin.--Shallow wells drilled into the stream-bed alluvium supply most of the water used for irrigation in the lower San Pedro basin. South of Mammoth a few deep wells along the flood plain of the river yield 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 upslope away from the river. The water level in one well at the south end of the basin, about half a mile from the river, was 115 feet below land surface in spring 1965. Water levels in the shallow wells fluctuate erratically, depending on the flow in the river and the pattern of pumping. From spring 1964 to spring 1965 water-level changes ranged from a rise of nearly 12 feet to a decline of about 6 feet; however, for the most part, water-level rises predominated throughout the basin. The water level in wells (D-13-19)23 and (D-8-17)19 rose nearly 8 feet from spring 1964 to spring 1965, probably in response to the flow in the San Pedro River.

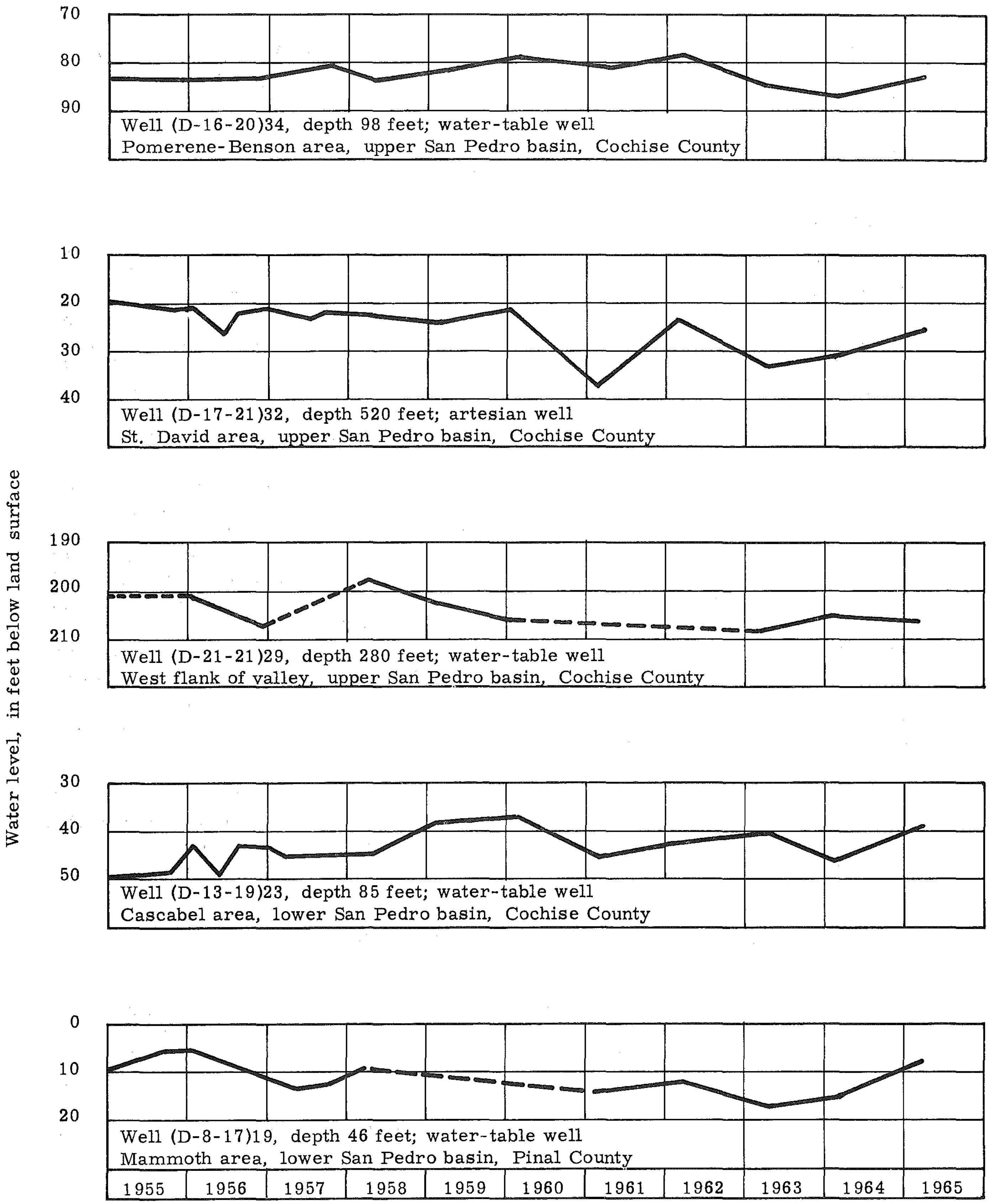


Figure 11. --Water levels in selected wells in the San Pedro River valley.

Upper Santa Cruz Basin

By

Natalie D. White

The Santa Cruz River heads in San Rafael Valley, Santa Cruz County, Ariz., flows southward into Mexico, turns west and then north, and reenters Arizona about 6 miles east of Nogales at an altitude of about 3,700 feet. From this point, it flows northward and then northwestward and joins the Gila River near the Pinal-Maricopa County line. The upper Santa Cruz basin (fig. 5, No. 9) is that part of the river valley that extends from the International Boundary to the Rillito Narrows where the Tucson and Tortolita Mountains form a partial barrier to the movement of ground water. The total drainage area of this part of the river valley is more than 3,500 square miles. Within the upper Santa Cruz basin, the Santa Cruz River receives inflow from Sonoita Creek, Nogales Wash, Sopori Creek, Rillito Creek, and Canada del Oro Wash. It is, however, an intermittent stream and flows only during and immediately following heavy rains. In parts of its course, the river provides recharge to the ground-water reservoir during floodflows.

From the International Boundary to about the south edge of T. 15 S., the development of ground water is confined largely to a strip about 2½ to 3 miles wide along the flood plain of the river. In this area ground water is used mainly for the irrigation of crops, although some water is used for mining operations on the west side of the valley between Sahuarita and Continental. From the International Boundary to about 4 miles north of the Pima-Santa Cruz County line, water levels in wells along the Santa Cruz River generally were less than 50 feet below land surface in spring 1965; in many wells the water level was less than 25 feet, and in a few wells near the junction of Sonoita Creek the water level was less than 10 feet below land surface in spring 1965. Fluctuations of the water level in wells in this part of the upper Santa Cruz basin reflect recharge from floodflows in the river. From spring 1964 to spring 1965, the water level rose in nearly all the wells near the river; the water level in well (D-24-15)18 (fig. 12) changed very little from spring 1964 to spring 1965. The well is equipped with a continuous water-stage recorder, and the record shows the rise in water level resulting from flow in the river during the summer months. In the part of the area that extends from about 4 miles north of the Pima-Santa Cruz County line to the south edge of T. 15 S., water levels in wells along the river generally were less than 100 feet below land surface at the north and south ends of the area. In the area between Continental and Sahuarita, where large amounts of ground water are withdrawn for irrigation, water levels were from about 100 to nearly 150 feet below land surface in spring 1965. Throughout the area, water levels in wells only a few miles upslope from the flood plain of the river are much deeper. About 4 miles west of Sahuarita, the water level in several wells was more than 400 feet below land surface. For the most part, water levels in wells near the river rose from spring 1964 to spring 1965; away from the river, water levels declined slightly. The water level in well (D-17-14)18 (fig. 12) rose about 6 feet from spring 1964 to spring 1965; the further rise in water level during the fall months may indicate recharge from

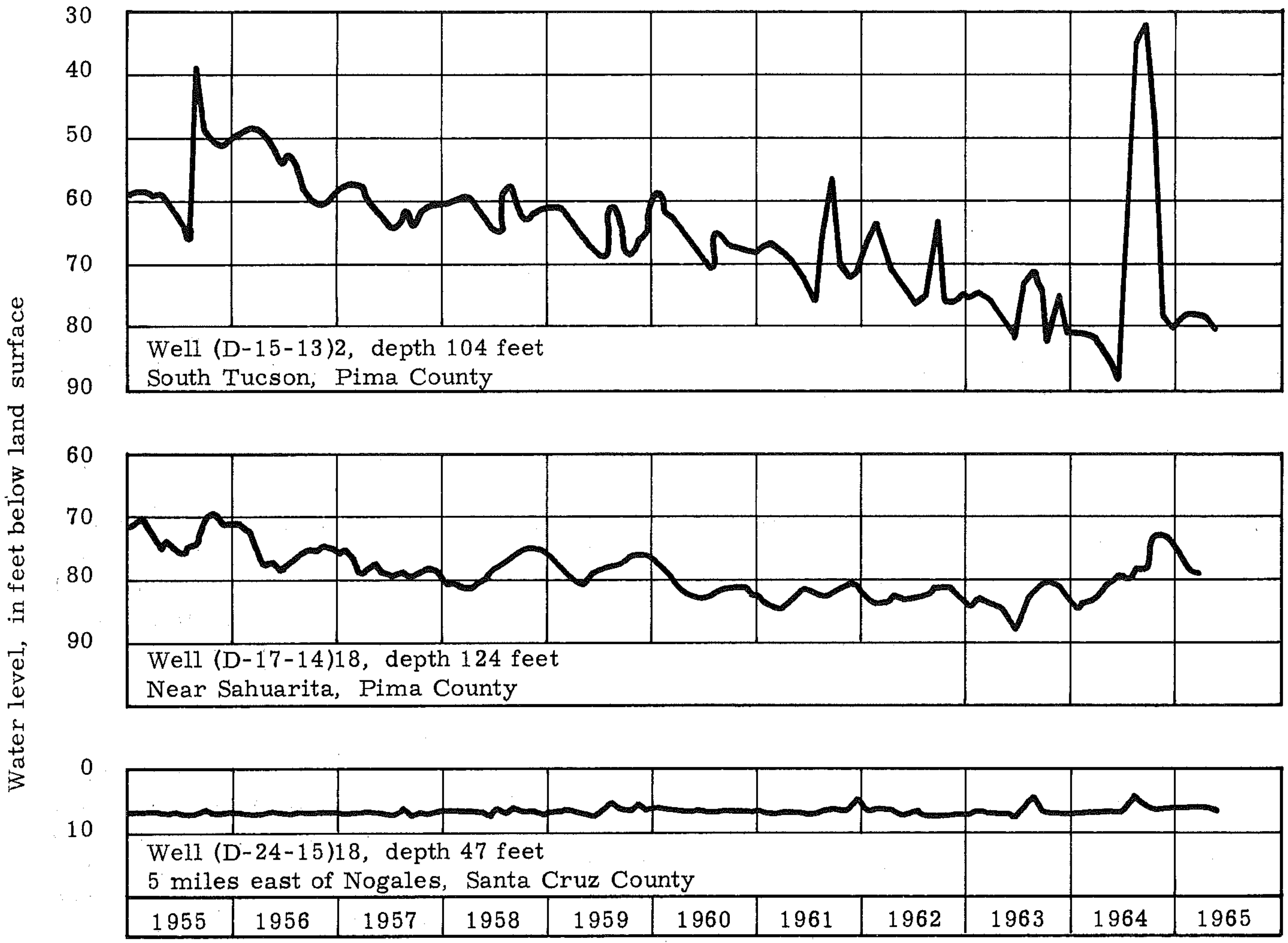


Figure 12.--Water levels in selected wells in the upper Santa Cruz basin.

floodflow in the river.

From the south edge of T. 15 S. north to Rillito Creek the valley widens out. The city of Tucson and the metropolitan area are in this part of the upper Santa Cruz basin, and the greatest use of ground water is for municipal supply, although some land is irrigated along the Santa Cruz River and Rillito Creek. As in other parts of the upper Santa Cruz basin, water levels are shallowest along the river and other drainages. Water levels in wells along the Santa Cruz River and Rillito and Tanque Verde Creeks generally were less than 100 feet below land surface in spring 1965 and in places were less than 50 feet. In the center of the area between the main drainages, water levels were more than 250 feet below land surface. Fluctuations of the water level in well (D-15-13)2 (fig. 12) are typical of the area along the river; a general decline of the water level is evident, but the water level also fluctuates with flow in the river. In areas away from the river the water level generally is declining in the area.

From the mouth of Rillito Creek north to the Rillito Narrows there has been large-scale development of ground water for agriculture, mostly along the flood plain of the Santa Cruz River. Some ground water is pumped from the aquifer along the stream channel of Canada del Oro for irrigation and domestic use. In the triangular area bounded by the Santa Cruz River, Canada del Oro, and the base of the Tortolita Mountains, water is withdrawn mostly for domestic use and irrigation of small gardens and golf courses. Water levels along the Santa Cruz River generally were less than 100 feet below land surface in spring 1965. Along Canada del Oro water levels ranged from less than 100 feet at the upper end to nearly 200 feet along the central part and were from less than 100 to about 120 feet near its junction with the Santa Cruz River. At the Rillito Narrows where water leaves the upper Santa Cruz basin, the water levels deepen from about 100 to 250 feet below land surface in a distance of about 3 miles. In general, water levels are declining throughout this part of the upper Santa Cruz basin.

Avra and Altar Valleys

By

Natalie D. White

Avra and Altar Valleys (fig. 5, Nos. 10 and 11) comprise a north-trending basin that extends from a drainage divide about 3 miles north of the International Boundary to where it joins the Santa Cruz basin about 5 miles north of the Pima-Pinal County line. Altar Wash forms the axis of the valley, heads a few miles north of the drainage divide, flows northward, and joins Brawley Wash at an indefinite point about 6 miles south of the Tucson-Ajo highway. Altar Valley is the upper or southern part of the basin, and Avra Valley is the lower or northern part. An arbitrary dividing line between the two valleys extends diagonally across Brawely Wash just south of Three Points; the northern boundary of Avra Valley is formed arbitrarily by the Pima-Pinal County line. Altar Valley is narrow, and only a small amount of ground water is pumped;

Avra Valley is a broad flat-lying area that is highly developed for agriculture. About 30,000 acres of land was under cultivation in Avra Valley in 1964. Ground water is the source of supply for irrigation of these lands. A recent report (White and Burton, 1965) discusses the water resources of Avra Valley and contains a projection of the status of the ground-water reservoir to 1970.

There is a wide variation in the depth to water in Altar Valley. In spring 1965 the depth to water along the central part of the valley ranged from about 100 to nearly 400 feet below land surface. The lesser depth to water is at the extreme south end of the valley, and the greater depth is about in the central part; at the north end of the valley the depth to water in spring 1965 ranged from about 140 to more than 175 feet. However, only a little more than 4 miles east of the wash at the north end of the area, the depth to water in spring 1965 was more than 700 feet below land surface. Changes in water level in the area are minor and generally reflect only the pumping of individual wells and possibly some recharge from flow in the washes. The water level in well (D-21-8)27 (fig. 13) rose nearly 7 feet from spring 1964 to spring 1965.

In the highly developed Avra Valley the depth to water in spring 1965 ranged from about 200 to more than 400 feet below land surface. The depth to water is greatest on the southeast edge of the area and least on the southwest edge and at the north end of the valley. Changes in water level reflect the pumping of ground water in excess of the rate of replenishment, although there is some evidence that water levels may be affected by recharge from floodflows. From spring 1964 to spring 1965 the change in water level in wells measured each spring ranged from a rise of more than 10 feet to a decline of more than 30 feet; for the most part, however, the changes in water level were from a rise of less than 5 feet to a decline of about 20 feet. The rises in water level may be due to recharge from floodflow, but the data are insufficient to make a definite statement. The water level in well (D-15-10)35 (fig. 13), at the south end of the valley where only a small amount of ground water is pumped, declined less than half a foot from spring 1964 to spring 1965. In the central part of the valley and at the north end where the pumping of ground water is greater, the water level in wells (D-13-10)8 and (D-11-10)32 (fig. 13) declined about 10 and 5 feet, respectively.

Lower Santa Cruz Basin and Adjacent Area Along the Gila River

By

Natalie D. White

The lower Santa Cruz basin is the lower part of the valley of the Santa Cruz River; its common boundary with the upper Santa Cruz basin is the Rillito Narrows between the Tucson and Tortolita Mountains. Hydrologically, an adjacent area along the Gila River is part of the lower Santa Cruz basin, and, thus, this discussion contains information pertinent to the entire area (fig. 5, No. 12). The area, as described, consists of more than 1,000 square miles of valley floor of low relief; in 1964, 253,925 acres was cropped

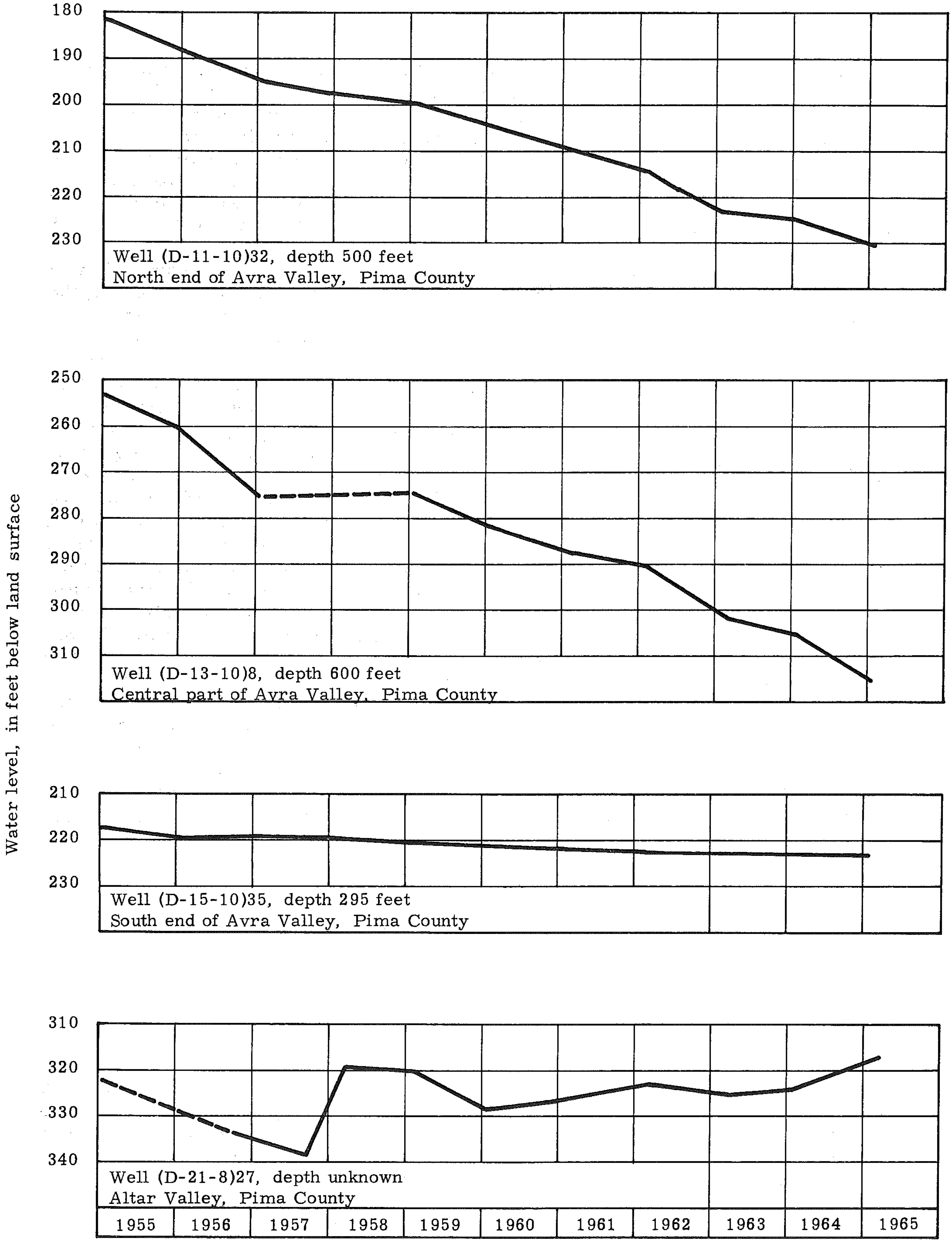


Figure 13. --Water levels in selected wells in Avra and Altar Valleys.

in Pinal County (Hillman, 1965), mostly in this area. It is the second largest agricultural area in the State and, consequently, is also second in the amount of ground water pumped each year. Several recent reports contain information on the water resources of the area. White, Stulik, and Rauh (1964) described current ground-water conditions in the area and predict the status of the water table to 1969. The basic ground-water data for the area are presented in a report by Hardt, Cattany, and Kister (1964), and the chemical quality of the ground water is discussed in a report by Kister and Hardt (1965).

In addition to the subsurface controls on the storage and transmission of water in the ground-water reservoir, current ground-water conditions in the area are a function of the amount of ground water pumped and the annual recharge, which vary greatly for the three subareas—the Eloy area, Casa Grande-Florence area, and Stanfield-Maricopa area. Some surface water is available from the Gila River in the Casa Grande-Florence area, but the Stanfield-Maricopa and Eloy areas are entirely dependent on pumping of ground water for irrigation of crops. There is some recharge to the ground-water reservoir in the Casa Grande-Florence area, but it is nearly negligible in the Stanfield-Maricopa and Eloy areas. The depth to water in spring 1965 range from less than 50 to more than 500 feet below land surface. In the Eloy area the depth to water ranged from about 120 to more than 350 feet below land surface; in the Casa Grande-Florence area the depth to water ranged from about 50 to more than 200 feet; and in the Stanfield-Maricopa area the depth to water ranged from about 100 to more than 550 feet below land surface in spring 1965. Changes in water level also vary widely throughout the area; figure 14 shows cumulative net changes in average water levels for the three areas of development. In the Eloy area the average decline was about 8 feet from spring 1964 to spring 1965 and nearly 32 feet from spring 1960 to spring 1965. In the Casa Grande-Florence area the average decline was about 6½ feet from spring 1964 to spring 1965 and nearly 22 feet from spring 1960 to spring 1965. In the Stanfield-Maricopa area the average decline was about 10 feet from spring 1964 to spring 1965 and about 37 feet from spring 1960 to spring 1965. The total average decline of the water level in these areas since the beginning of record in 1940 was about 150 feet in the Eloy area, nearly 100 feet in the Casa Grande-Florence area, and about 164 feet in the Stanfield-Maricopa area.

Salt River Valley

By

R. A. Rukkila

The Salt River Valley (fig. 5, No. 13) comprises the valley lands near Phoenix, the tributary Paradise and Deer Valleys, lands west of the Hassayampa River, and the lower reaches of Centennial Wash. The area is drained by the Salt, Agua Fria, and Hassayampa Rivers, except for a small part on the east and south drained by the Gila River.

A report by White, Stulik, and Rauh (1964) describes the ground-water con-

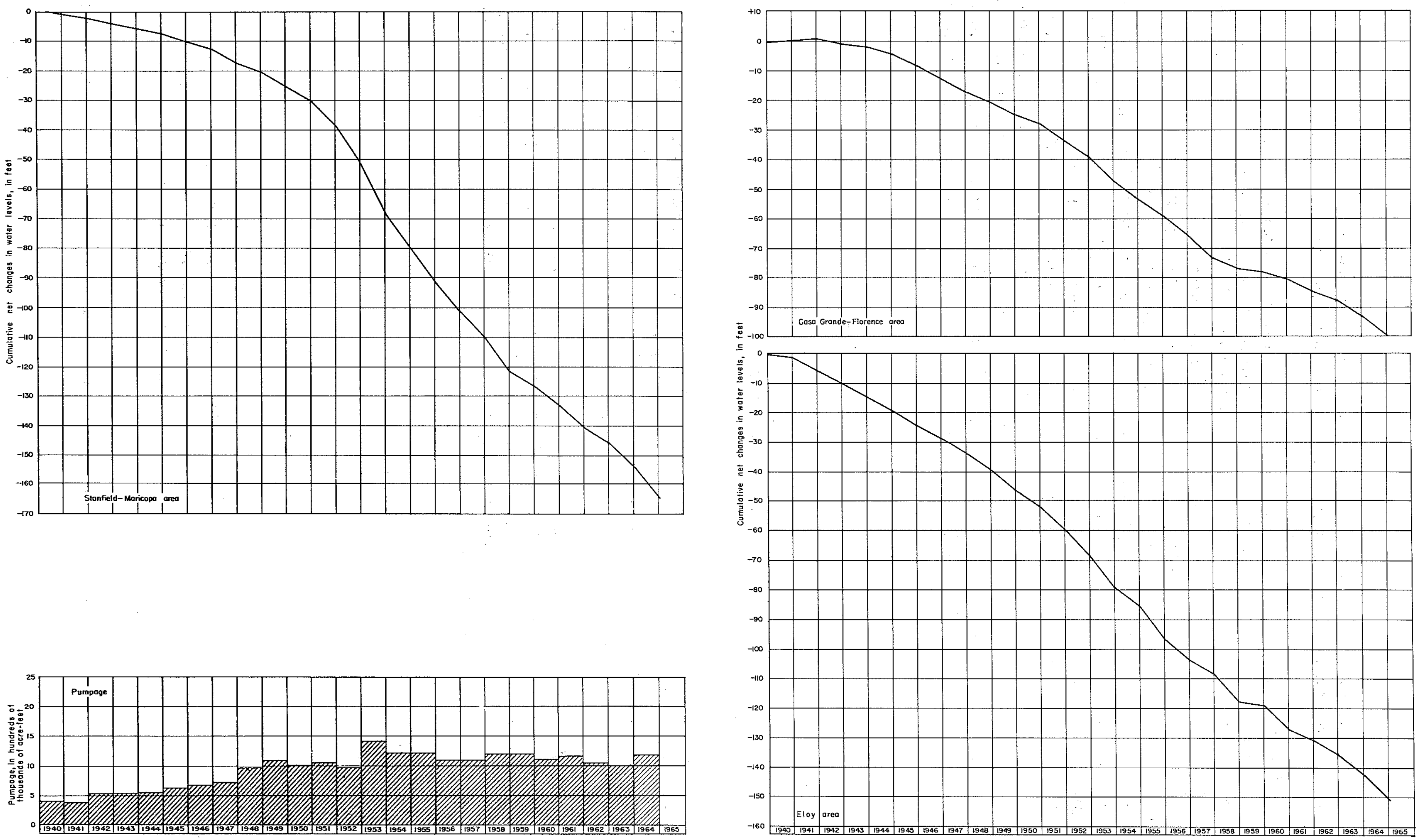


Figure 14.--Cumulative net changes in water levels by areas and total annual pumpage in the lower Santa Cruz basin within Pinal County.

ditions in the area and predicts the status of the water table to 1969. The predictions are shown in the form of a depth-to-water map for the future date.

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 per year. In general, water levels in the Salt River Valley continued to decline at varying rates in 1964. The maximum declines were in the heavily pumped Litchfield-Beardsley-Marinette area and the north part of the Phoenix-Glendale-Tolleson area. Minimum declines occurred in the areas where surface-water diversions supplemented ground-water withdrawal. Hydrographs of the cumulative net changes in water level (figs. 15, 16, and 17) indicate that from spring 1964 to spring 1965 the average declines in the five subareas of the Salt River Valley ranged from three-tenths of a foot in the Liberty-Buckeye-Hassayampa area to nearly 4 feet in the Beardsley-Marinette area. Measured depths to water below land surface in the Salt River Valley in the spring of 1965 ranged from 10 feet near Queen Creek northeast of Florence Junction to 490 feet in a well near Cave Creek in Deer Valley.

Waterman Wash Area

By

R. A. Rukkila

The Waterman Wash area (fig. 5, No. 14) is an area of about 400 square miles drained by the northwest-trending Waterman Wash. 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 occurred.

From spring 1964 to spring 1965 water levels continued to decline, as shown by the hydrograph of the water level in well (C-2-2)25 (fig. 18); the water level in this well has declined more than 50 feet since 1955. The maximum depth to water measured in the spring of 1965 was 401 feet below land surface in a well a mile south of Mobile.

Gila Bend Area

By

Otto Moosburner

The Gila Bend area (fig. 5, No. 15) is that part of the Gila River valley that extends from Gillespie Dam on the Gila River to a point 36 miles downstream near the Painted Rock Narrows. The northeastern part of the Gila Bend area is known as Rainbow Valley.

From spring 1964 to spring 1965, the water level in most wells declined

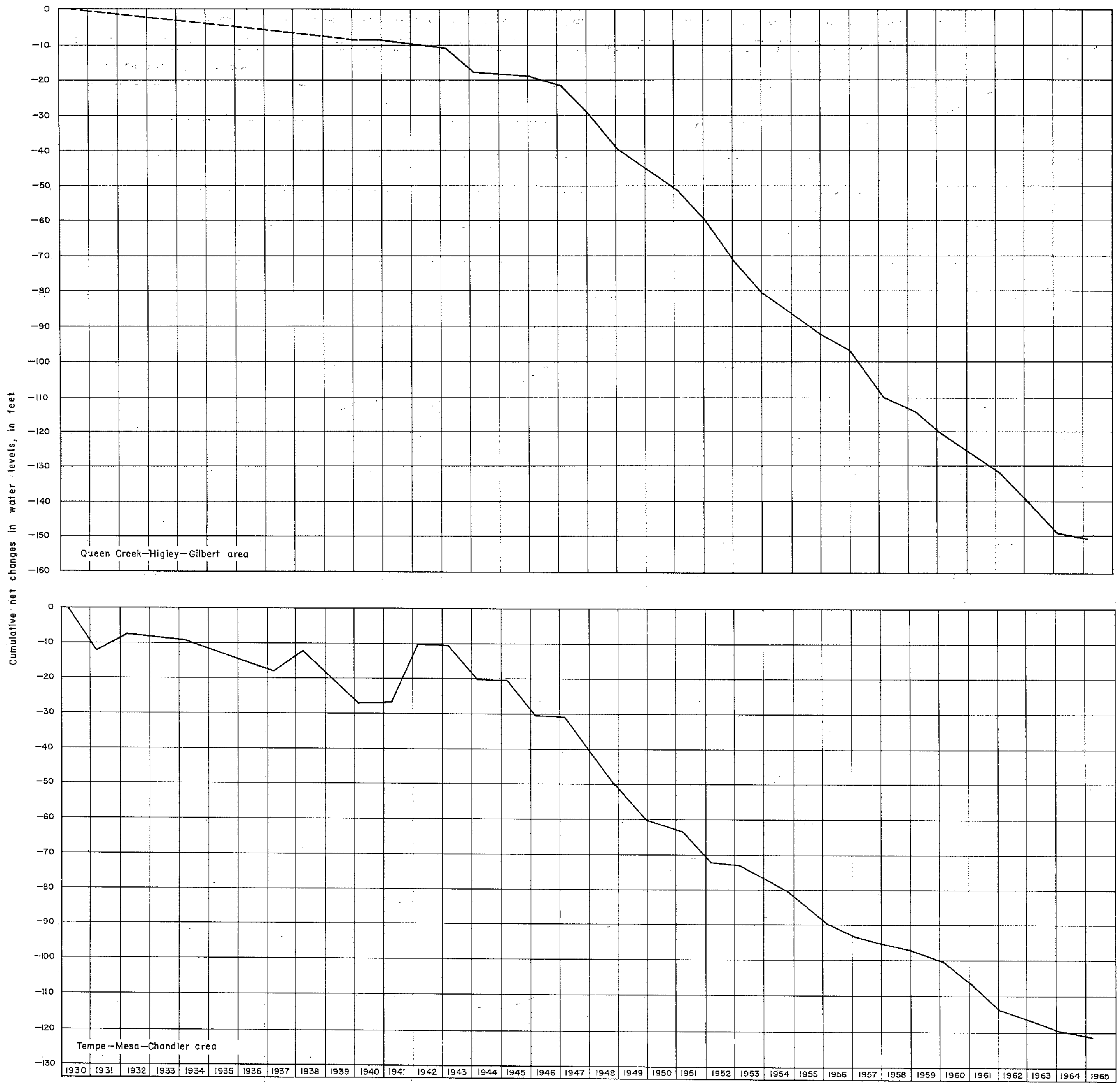


Figure 15. --Cumulative net changes in water levels in the Queen Creek-Higley-Gilbert and Tempe-Mesa-Chandler areas of the Salt River Valley.

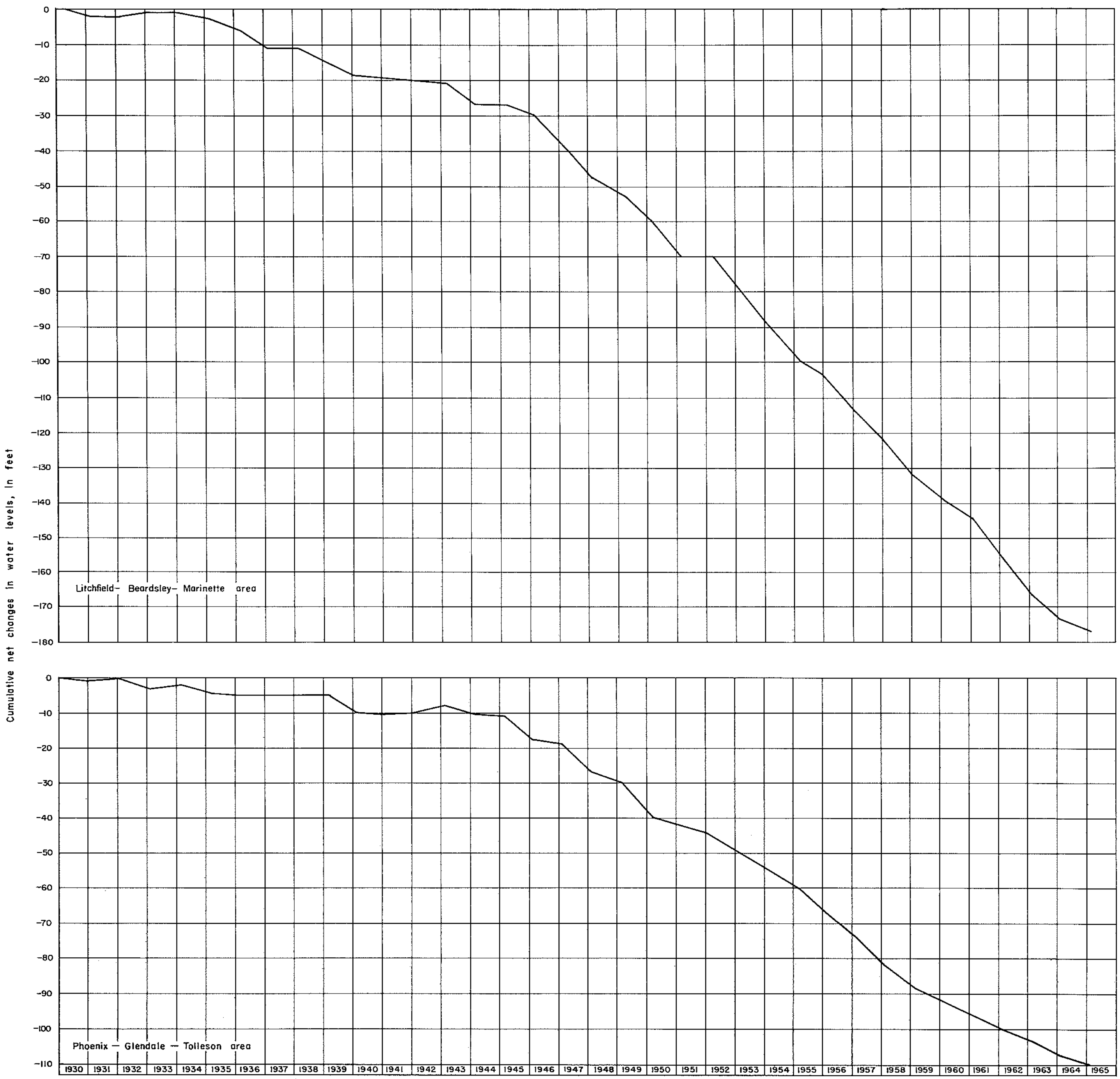


Figure 16.—Cumulative net changes in water levels in the Litchfield Park-Beardsley-Marinette and Phoenix-Glendale-Tolleson areas of the Salt River Valley.

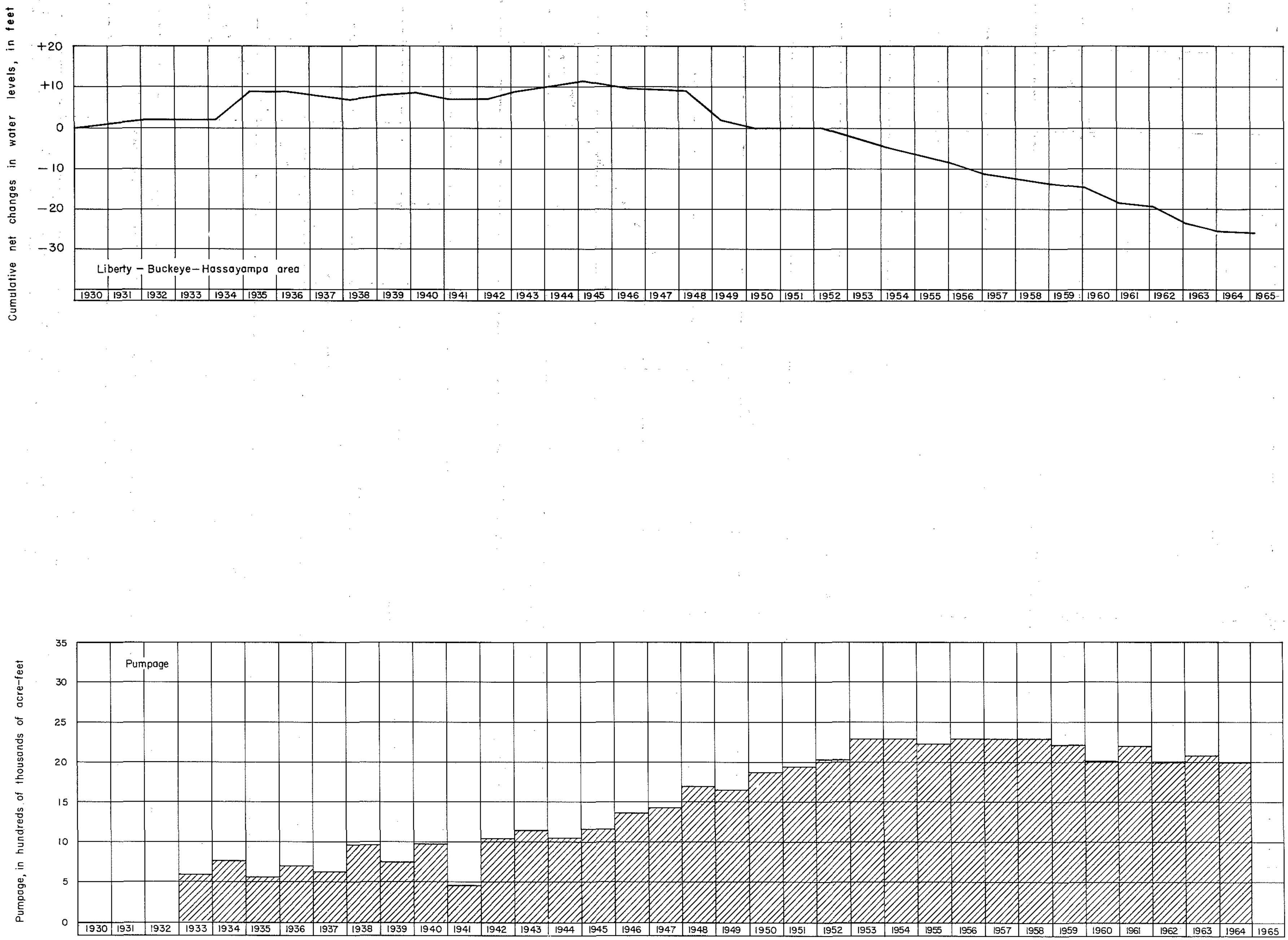


Figure 17.—Cumulative net changes in water levels in the Liberty-Buckeye-Hassayampa area and total annual pumpage in the Salt River Valley.

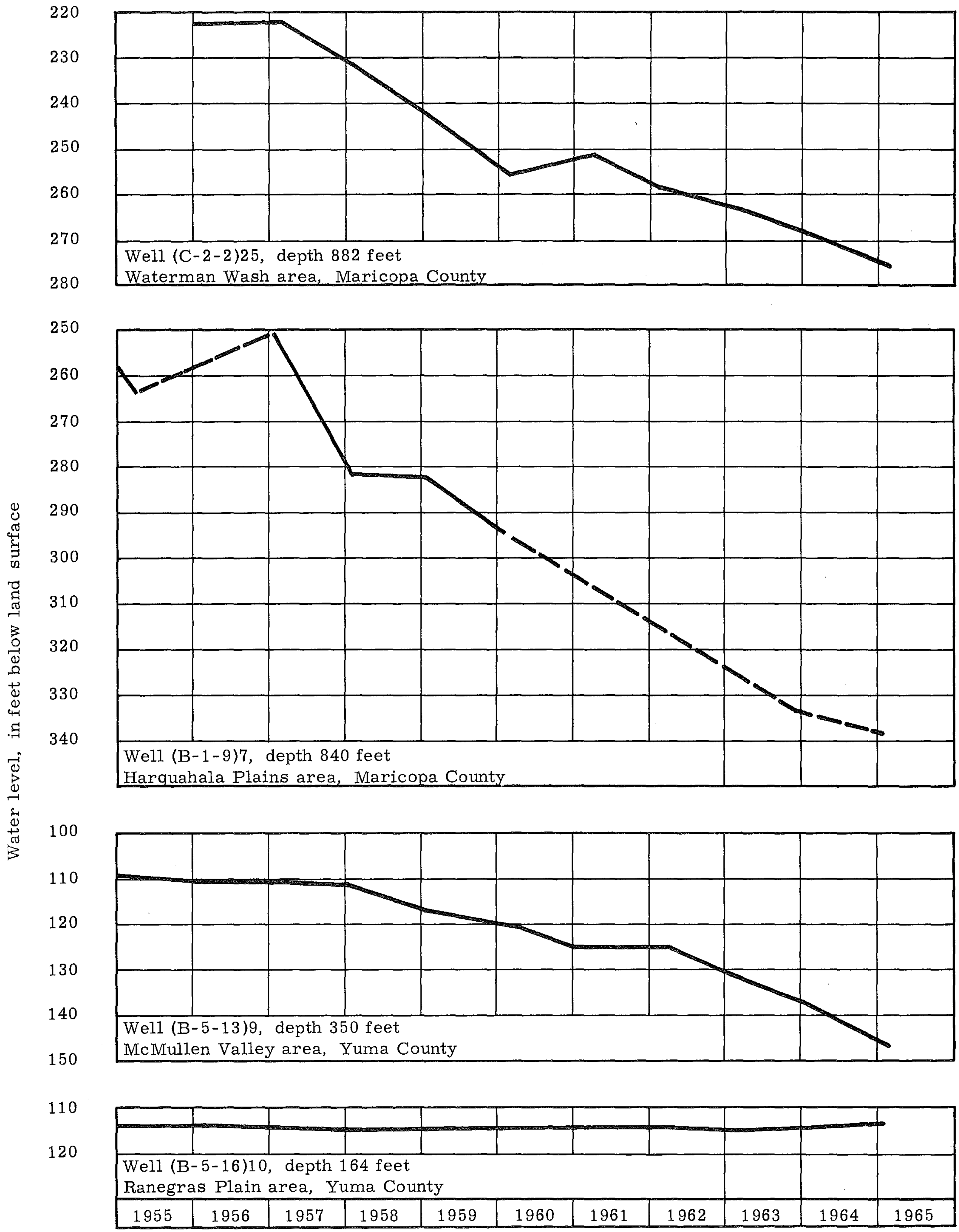


Figure 18.--Water levels in selected wells in several areas in the Basin and Range lowlands province.

slightly. Nearly all the measured water levels were within 2 feet of the spring 1964 water levels, although a maximum decline of about 12 feet was measured. The maximum rise in water level was about a foot. In the spring of 1965 the depth to water in the Gila Bend area ranged from about 24 to about 285 feet below land surface.

Harquahala Plains Area

By

P. C. Briggs

The Harquahala Plains area (fig. 5, No. 16) is a northwest-trending basin drained principally by Centennial Wash. The withdrawal of ground water for irrigation increased from about 33,000 acre-feet in 1954 to about 200,000 acre-feet in 1963 (Stulik, 1964). From 1954 to 1964 water levels declined as much as 200 feet and are continuing to decline at an increasing rate. The hydrograph of the water level in well (B-1-9)7 (fig. 18) shows the decline in an irrigation well in the cultivated area; the water level in this well declined more than 40 feet from spring 1960 to spring 1965. In the spring of 1965 the depth to water in observation wells ranged from 89 feet to 450 feet below land surface.

McMullen Valley Area

By

P. C. Briggs and R. A. Rukkila

The McMullen Valley area (fig. 5, No. 17) is a northeast-trending valley about 48 miles long 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. There are two separate areas of irrigation development, one near Aguila and the other in the Wenden-Salome area.

In the cultivated area near Aguila it is nearly impossible to obtain successive water-level measurements from any one well because of continual pumping. However, spot measurements of water levels in wells in the heavily pumped area northwest of Aguila indicate a decline of as much as 52 feet in the water level from 1958 to 1965.

In the Wenden-Salome area water-level changes from spring 1964 to spring 1965 were more than 10 feet. The hydrograph of the water level in well (B-5-13)9 (fig. 18) shows the water-level changes prior to and after development of ground-water supplies for irrigation. Prior to 1958 the water level in this well declined only about 1 foot per year; however, because of increased development, the rate of water-level decline also increased. From spring 1960 to spring 1965 the water level in this well declined about 27 feet. The depth to water below land surface in McMullen Valley in the spring of 1965 ranged from 143 feet near Salome to 516 feet near Aguila.

Palomas Plain Area

By

Otto Moosburner

Palomas Plain (fig. 5, No. 18) is an alluvial area that extends northwestward from the Gila River between the Oatman and Face Mountains on the east and the Palomas, Tank, and Kofa Mountains on the west. From spring 1964 to spring 1965 water-level changes ranged from a rise of about 4 feet to a decline of about 3 feet; for the most part, water levels fluctuated less than 1 foot. In the spring of 1965 the depth to water below land surface ranged from 21 feet along the Gila River to more than 290 feet in a newly developed area about 8 miles northeast of Hyder. A comprehensive report entitled "Geohydrology of the Dateland-Hyder Area, Maricopa and Yuma Counties, Arizona," which is in preparation, will include a discussion of the ground-water conditions in the Palomas Plain area.

Ranegras Plain Area

By

Otto Moosburner

Agricultural development and ground-water withdrawal in the Ranegras Plain area of northern Yuma County (Fig. 5, No. 19) have remained virtually unchanged in the last several years. As a result, water-level changes have been slight. From spring 1964 to spring 1965 changes in water levels ranged from a rise of about 4 feet to a decline of about 4 feet. For the most part, water-level changes were less than 2 feet. The hydrograph of the water level in well (B-5-16)10 (fig. 18) shows water-level changes typical of the undeveloped parts of the area. There has been no significant change in the water level in this well during the last 10 years. Depth to water below land surface in the Ranegras Plain area in the spring of 1965 ranged from about 36 to 226 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.

The South Gila Valley is that part of the Gila River flood plain south of the Gila River and bounded on the south by an extensive terrace known as Yuma Mesa. During 1964, as in previous years, ground water was the principal source of irrigation water. Water from the Colorado River has been applied to some land in this area since May 1965, and by July 1965, the surface supply will be available to all lands in the district. From spring 1964 to spring 1965 there was little overall change in water levels in the South Gila Valley, as indicated by the hydrograph of the water level in well (C-8-21)21 (Fig. 19). The depth to water below land surface in most of the area in spring 1965 ranged from about 12 to 18 feet. Water levels are being controlled in a large part of the area by a system of drainage wells, which was installed in 1961 and expanded in 1964.

Yuma Mesa is south of the South Gila Valley, east of the 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, although a small quantity of ground water is used. The use of ground water is expected to increase when pumping of additional wells---drilled in 1964 and early 1965---is begun, particularly on the outer fringes of the area served by Colorado River water. In parts of the irrigated area, particularly adjacent to the Yuma Valley, the general rise in water levels continued and was several feet during 1964. The hydrograph of the water level in well (C-9-23)31 (fig. 19) shows water-level fluctuations that are typical in this area. In the unirrigated areas adjacent to the Yuma Mesa Irrigation District boundaries the ground-water levels also continued to rise; from spring 1964 to spring 1965 water-level rises were from about ½ to 1 foot. The depth to water in the irrigated parts of Yuma Mesa ranged from about 7 to 35 feet below land surface and from about 70 to 145 feet in the undeveloped parts of Yuma Mesa in spring 1965.

Yuma Valley is that part of the Colorado River flood plain in Arizona that is south and east of the Colorado River and west of Yuma Mesa. The Colorado River is the principal source of irrigation water in the Yuma Valley. However, some land between the levee and the river from Yuma downstream to the International Boundary is irrigated by ground water. In addition to the response to seasonal fluctuations in flow of the Colorado River, water levels in wells adjacent to the river declined from about ½ to 1 foot from spring 1964 to spring 1965. Water levels ranged from about 14 to 19 feet below land surface in this part of the Yuma Valley. In most of the valley area, water levels are controlled by a system of surface drains, which maintains fairly constant water levels. In the center of the valley water levels generally declined a few hundredths of a foot, and in the part of the valley along the margin of Yuma Mesa water levels continued to rise. According to the Yuma County Water Users' Association, water levels in the valley rose in some areas. For the most part, water levels in Yuma Valley ranged from about 6 to 14 feet below land surface in the spring of 1965. However, in an area of about 1,760 acres adjacent to Yuma Mesa and about 240 acres on the west side of the Yuma Valley the water level was less than 4 feet below land surface in spring 1965.

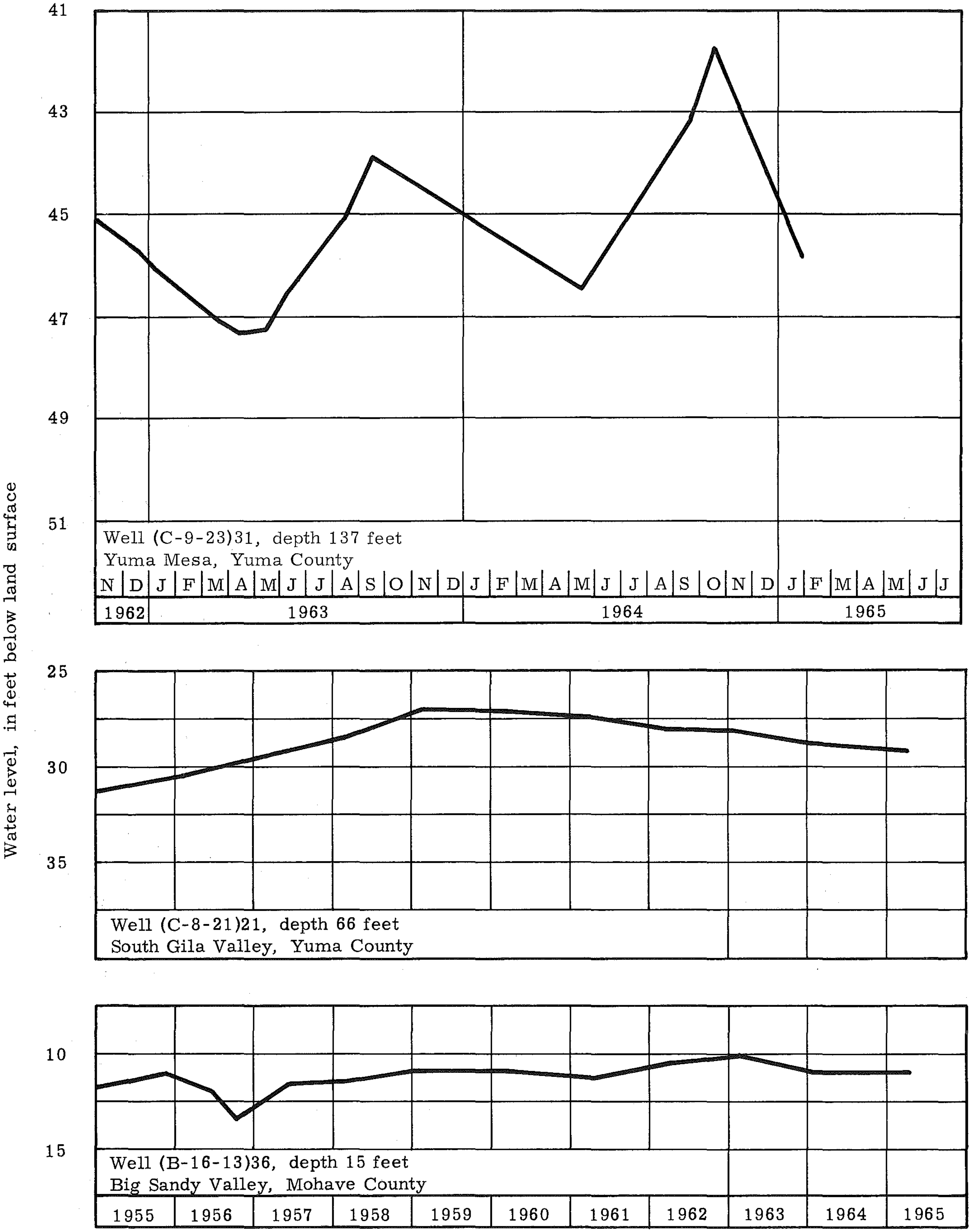


Figure 19.--Water levels in selected wells in parts of Yuma and Mohave Counties.

Big Sandy Valley

By

Otto Moosburner

The Big Sandy Valley (fig. 5, No. 21) is drained by the Big Sandy River, which receives water from Trout Creek, 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 in response to recharge from flow in the river. From spring 1964 to spring 1965 water-level changes in these wells ranged from a rise of less than 3 feet to a decline of less than 1 foot. 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. 19). The overall water-level fluctuations in this well have, in general, been within 2 to 3 feet of the original water level during the period of record. Depth to water below land surface in the spring of 1965 ranged from 12 feet along the flood plain near Wickieup to about 375 feet in a stock well near the extreme north end of the area.

Sacramento and Hualapai Valleys

By

C. B. Bentley

Sacramento and Hualapai Valleys (fig. 5, Nos. 22 and 23) are north-south-trending alluvial-filled valleys in Mohave County. Kingman is in a saddle of volcanic rocks along the divide between the two valleys and is considered as part of the Sacramento Valley in this report.

In Sacramento Valley the depth to water generally ranges from about 300 feet below land surface at Yucca, 25 miles south of Kingman, to more than 1,200 feet at the north end of the valley, but at Kingman the depth to water is about 100 to 150 feet below land surface. Water levels in wells in the Sacramento Valley---except at Kingman---have remained nearly constant since the earliest reported measurements made 60 years ago. A well field near the north end of the valley has been developed recently by the Duval Corp. to supply water for their Mineral Park mine and concentrator. Withdrawal of ground water from this well field may cause water levels in the valley to decline. Water levels in the Kingman well field have declined about 1 foot per year for at least 20 years; the hydrograph of the water level in well (B-21-17)24 (fig. 20) shows this trend for the 10-year period 1955-65.

The Hualapai Valley, with the exception of the Hackberry well field, is mostly undeveloped. However, a few deep irrigation wells have been drilled recently, and in May 1965 the city of Kingman put a well into operation that

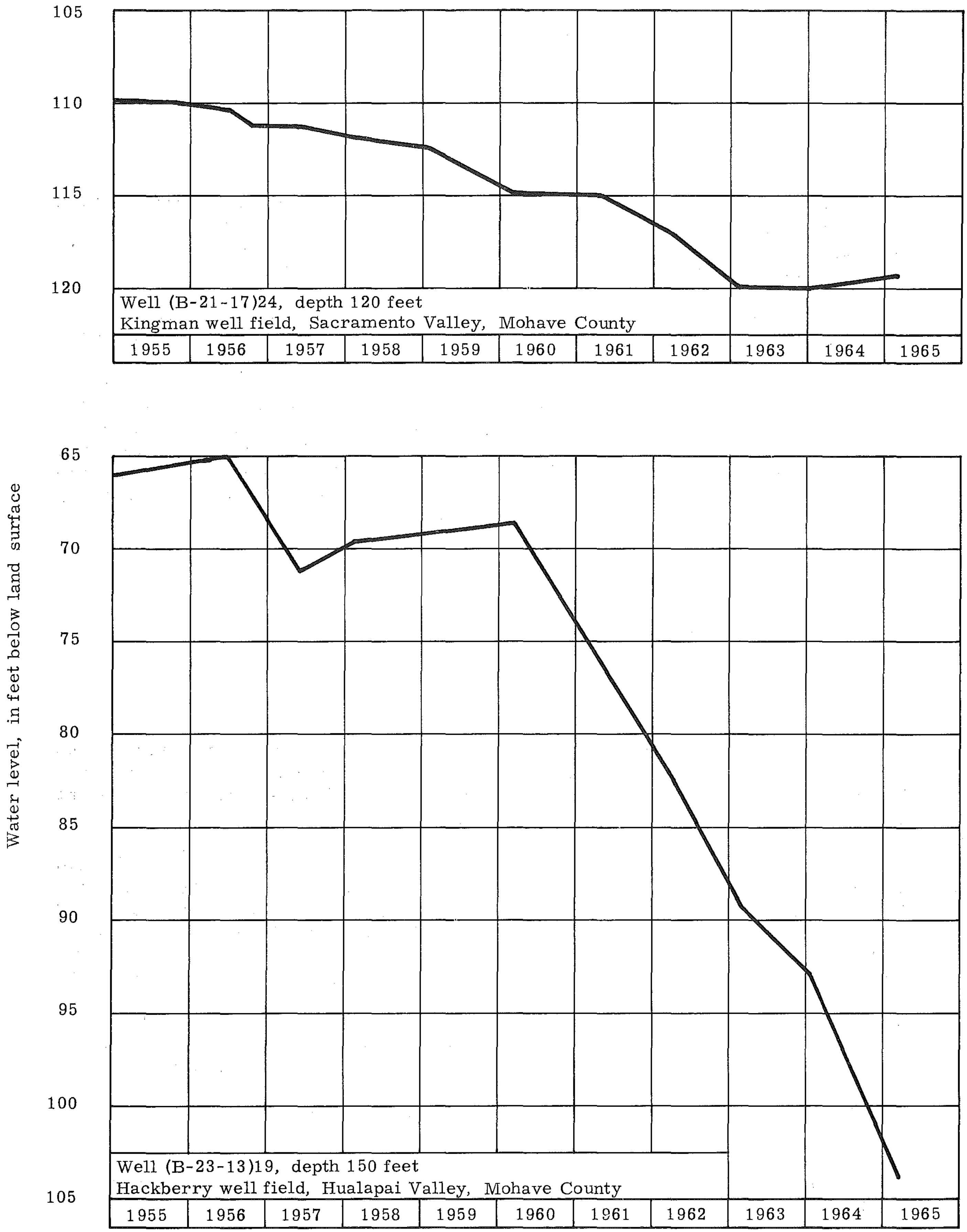


Figure 20. --Water levels in selected wells in Sacramento and Hualapai Valleys.

produces 800 gpm (gallons per minute). The depth to water is about 250 feet below land surface at the north end of the valley and more than 600 feet at the south end; however, the depth to water in wells in the Hackberry well field at the southeast edge of the valley is only about 90 to 200 feet below land surface. The water from the Hackberry well field provides part of the municipal supply for Kingman. Water levels in the valley---except at Hackberry---have remained constant, as indicated by recent measurements. Water levels in wells in the Hackberry well field have declined 6 to 8 feet per year during the last 5 years, as shown by the hydrograph of the water level in well (B-23-13)19 (fig. 20).

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. In this province, water-bearing sandstone beds constitute a large storage reservoir for ground water, but well yields generally are small because the rocks are fine grained and do not transmit water freely. However, in a few areas faults and fractures increase the permeability of the formation, which permits water to move more freely, and well yields are large.

For the most part, the Plateau uplands province is undeveloped, and the amount of ground water pumped for irrigation or other purposes is small. Hence, there have been no sustained declines in water levels in this province to the present time. Only slightly more than 30,000 acres of land was cultivated (Hillman, 1965) in the province in 1964. However, there has been some increase in the use of ground water for agriculture in the Snowflake area and near Tuba City, for operation of a pulp mill at Snowflake, and for municipal use in the Flagstaff area. The current ground-water conditions in the Plateau uplands province are discussed by counties because development is not concentrated in particular areas.

Apache County

By

E. H. McGavock

Near St. Johns, Hunt, Window Rock, and Chinle in Apache County ground water is withdrawn mostly from fine-grained consolidated sandstone. Near Red Lake, Chinle, and Sanders wells also are drilled in alluvium.

For the most part, there has been no consistent long-term decline of the

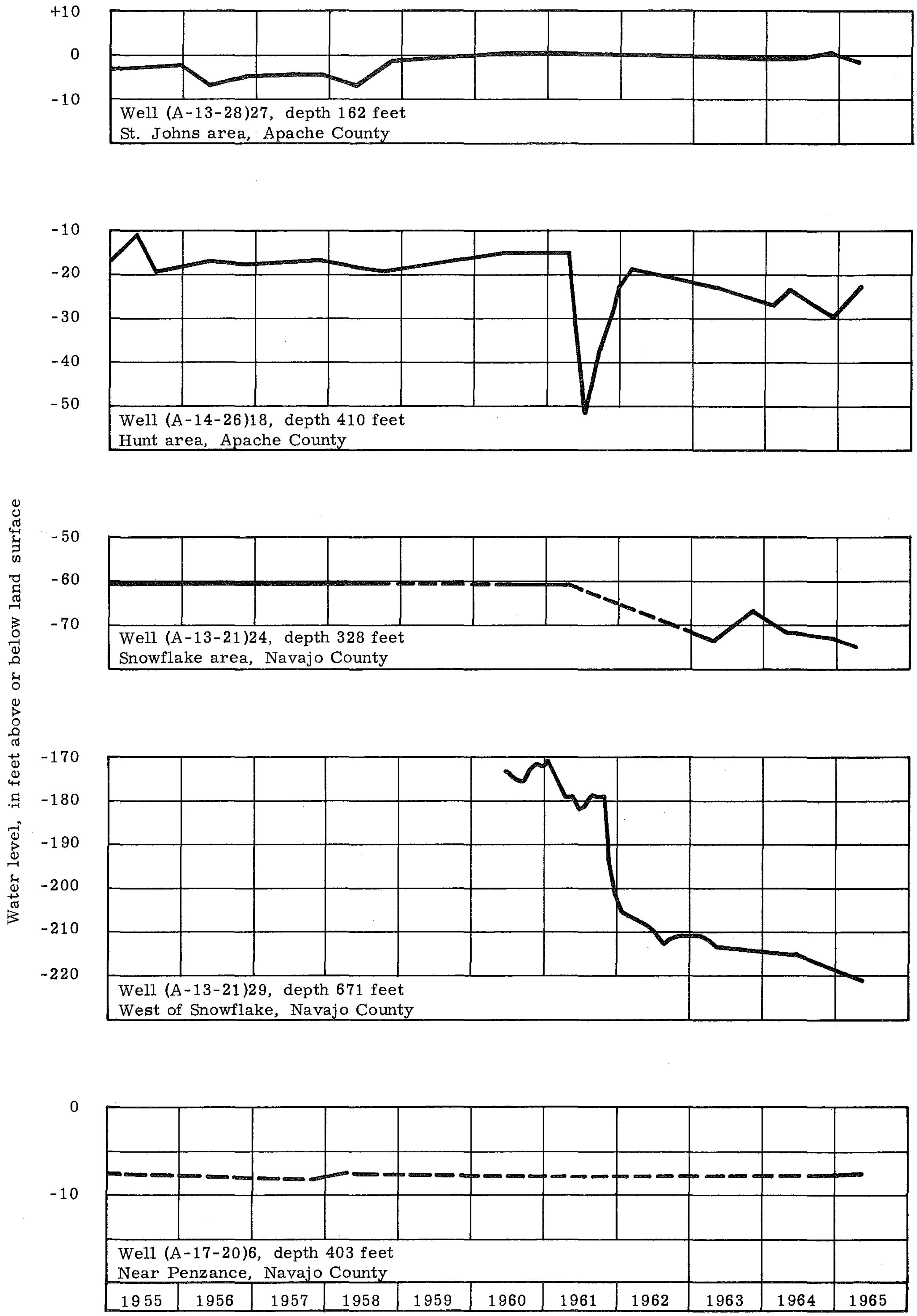


Figure 21. --Water levels in selected wells in the Plateau uplands province.

water levels in Apache County. The hydrograph of the water level in well (A-13-28)27 (fig. 21) at St. Johns shows some seasonal variation in the water level but indicates that there has been no general decline in the area. The water level in this well has remained unchanged in the last 5 years. A slight downward trend of the water level near Hunt may be indicated by the hydrograph of the water level in well (A-14-26)18 (fig. 21). The water level in this well declined about 7 feet from spring 1960 to spring 1965; however, from spring 1964 to spring 1965 the water level rose about 4 feet.

Navajo County

By

E. H. McGavock

In Navajo County the principal development of ground water has been for irrigation and domestic use in the Little Colorado River valley and the Snowflake-Taylor area. Ground water also is withdrawn for industrial use near Snowflake and Joseph City. Most wells are drilled in fine-grained sandstone aquifers, which yield water under artesian pressure in much of the area.

The hydrograph of the water level in well (A-13-21)24 (fig. 21) at Snowflake indicates a decline of nearly 15 feet from spring 1960 to spring 1965. West of Snowflake, the downward trend of the water level is continuing, as shown by the hydrograph of the water level in well (A-13-21)29 (fig. 21).

Near Holbrook and Penzance, water levels have remained stable during the last 10 years. Changes in the water level in well (A-17-20)6 (fig. 21) probably are typical for this area. North of the Little Colorado River at Joseph City, water levels in wells fluctuate greatly, but no long-term declines have been recorded.

Coconino County

By

E. H. McGavock

Ground-water withdrawal in Coconino County has been limited by the great depth to water. For the most part, water levels range from 200 to 1,900 feet below land surface in much of the area. Northwest of Flagstaff the water table is below the effective depth of wells, but near Tuba City some wells flow. Presently, a number of shallow wells—10 to 200 feet deep—are being drilled into the interbedded lava, sand, and clay in the Flagstaff area. Most of these wells are dependent on local precipitation for recharge and may be dry, or nearly so, during years of low precipitation. The yields of these wells range from 1 to 450 gpm, but most of the wells yield less than 1 gpm. Water levels in seven shallow wells rose an average of 5 feet following the near-record precipitation at Flagstaff in the winter of 1964.

No general decline of water levels in Coconino County has been noted, except at Tuba City where the flow of wells and springs reportedly has decreased.

Central Highlands Province

By

Natalie D. White

The Central highlands consist mostly of rugged mountain masses made up of indurated igneous, metamorphic, and crystalline rocks and well-consolidated sedimentary rocks. These materials contain little space for the storage of ground water. Small amounts of ground water are stored in fractured and faulted zones; where the fractures are at the surface, ground water issues as springs. A few small valleys between the mountains contain varying thicknesses of alluvial deposits that store some ground water and are suitable for agricultural development. The large amount of precipitation in this province is the source of streamflow that is utilized extensively for agricultural irrigation in the Phoenix basin.

Less than 15,000 acres of land was cultivated in the Central highlands province in 1964 (Hillman, 1965). Chino and Verde Valleys are the main areas of agricultural development and ground-water use in the province; in Verde Valley some surface water from the Verde River is used to irrigate crops. A small amount of land is developed for agriculture along the flood plains of the tributaries to the Gila and Salt River drainages in Gila County.

Chino Valley

By

H. W. Hjalmarson

Chino Valley (fig. 5, Nos. 24, 25, and 26), as described in this report, consists of three alluvial areas in Yavapai County north of Prescott—Big Chino Valley (fig. 5, No. 24), Little Chino Valley (fig. 5, No. 25), and Williamson Valley (fig. 5, No. 26). The physical geography of Chino Valley is similar to that of many areas in the Central highlands province of Arizona. The surface-water drainage area is about 2,530 square miles; the altitude of the land surface ranges from 4,350 to 7,600 feet above mean sea level. The vegetation varies from heavy forests at high altitudes to range grasses on the valley floor. The average annual precipitation ranges from about 12 inches in the valley to about 17 inches in the surrounding mountains.

The alluvial-filled valleys contain water under artesian and water-table conditions. Water under water-table conditions is associated with alluvial sediments throughout the valley. Water under artesian conditions is associated with buried lava flows, which may be interbedded with volcanic ash, cinders, and alluvial deposits in many places in the valley; in other places water under artesian conditions is associated with interbedded layers of clay, sand, and gravel.

Big Chino Valley.--About 20,000 acre-feet of ground water was withdrawn from aquifers in Big Chino Valley for irrigation during 1964. The depth to water in artesian wells near the center of the valley was about 30 feet below land surface in spring 1965. The depth to water in water-table wells at the south end of the valley was about 130 feet below land surface. Water levels in these wells have been declining slightly during the last 10 years, as shown by the hydrograph for well (B-17-2)6 (fig. 22). The water-level decline in this well probably resulted from the withdrawal of ground water to supply artificial lakes in the south end of the valley during 1960, 1961, and 1962.

Little Chino Valley.--Ground water is under water-table and artesian conditions in Little Chino Valley. Near the south end of the valley, the depth to water in some artesian wells was as much as 350 feet below land surface in spring 1965. In the north end of the valley, artesian pressure is sufficient to cause some wells to flow. Water levels in artesian wells in the central part of the valley have been declining at an average rate of about 3 feet per year for the last 10 years. The hydrographs of the water levels in wells (B-16-2)21 and (B-16-2)35 (fig. 22) show this decline.

In 1964 about 12,000 acre-feet of water was withdrawn for irrigation and about 2,100 acre-feet for municipal use by Prescott from the aquifers in Little Chino Valley. In addition, about 500 acres of land was irrigated with water from Watson Lake and Willow Creek Reservoir.

Williamson Valley.--In 1964 about 2,000 acre-feet of water was withdrawn from artesian and water-table aquifers for irrigation in Williamson Valley. For the most part, water levels in the valley are shallow, and in the central part some wells are flowing. In general, water levels have declined slightly during the last 10 years. The depth to water in artesian well (B-16-4)14 (fig. 22) was 7 feet below land surface in spring 1965. The water level in this well fluctuates erratically, but the general trend is a slight decline.

Verde Valley

By

H. W. Hjalmarson

The Verde Valley (fig. 5, No. 27) trends northwestward from the junction of Fossil Creek and the Verde River to Perkinsville. The valley 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 Pleistocene Verde Formation. In the Sedona area the principal source of ground water is the Permian and Pennsylvanian Supai Formation. A comprehensive discussion of the geology and ground water in

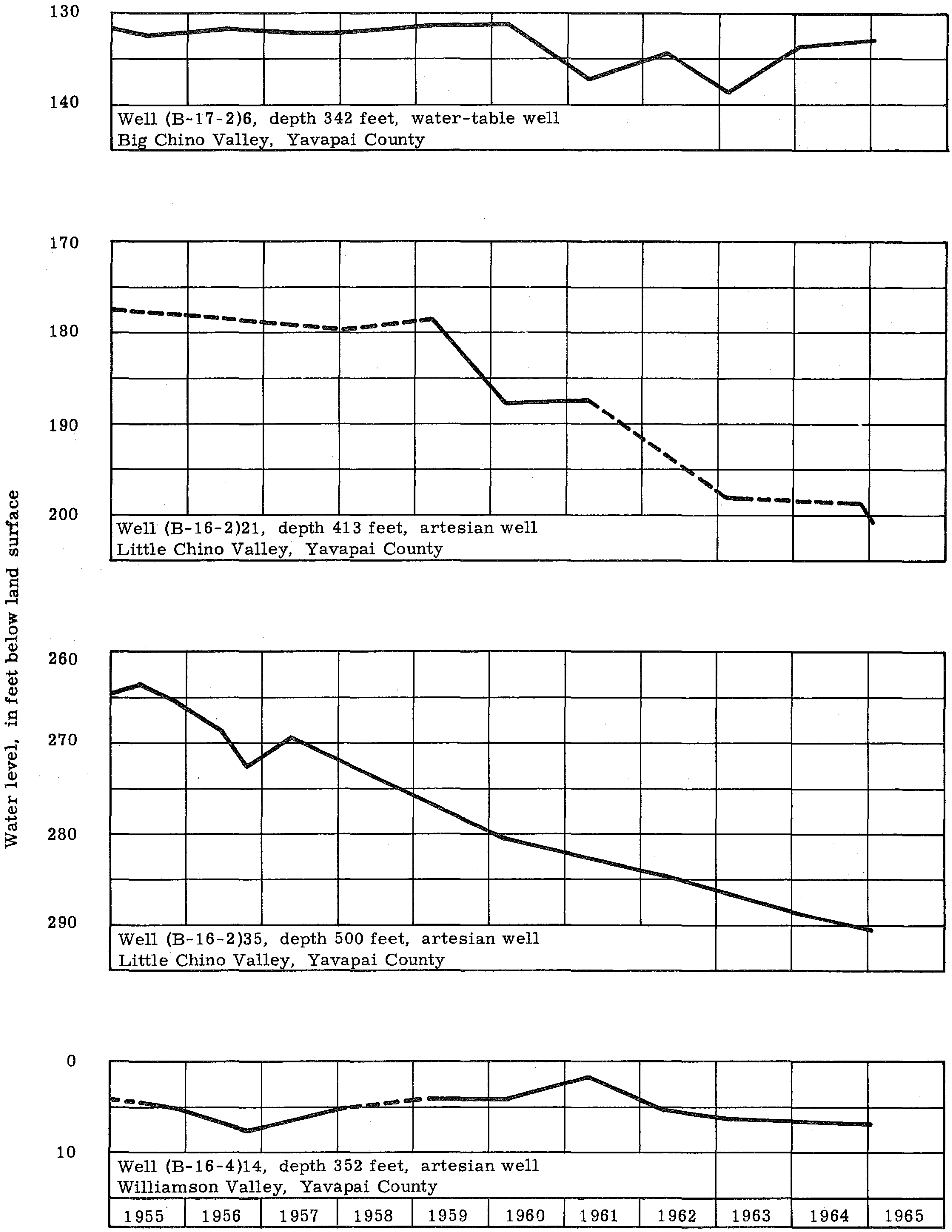


Figure 22. --Water levels in selected wells in Chino Valley.

the Verde Valley is contained in a report by Twenter and Metzger (1963).

Clarkdale-Cottonwood-Camp Verde area.--The principal sources of ground water in the Clarkdale-Cottonwood-Camp Verde area are the limestone beds of the Verde Formation. For the most part, ground water is under artesian conditions in these limestone units. Where the limestone units are confined above and below by aquicludes, they are not hydrologically connected; thus, the depth to water depends on the particular limestone unit or units penetrated. Some wells are flowing; in nonflowing wells the depth to water ranges from a few feet to more than 200 feet below land surface. Water levels generally rose from spring 1964 to spring 1965; the maximum measured rise was 9 feet.

Sedona area.--More than 180 acre-feet of water was withdrawn from this area for domestic use during 1964. Water-level changes were minor from spring 1964 to spring 1965. Measured depths to water ranged from 127 to 585 feet below land surface as of spring 1965.

Gila County

By

Jane V. Burton

Gila County---named after one of the three major rivers that flows through the county---is in the east-central part of the State, almost entirely in the Central highlands province. It is the fourth smallest county in the State and contains 3,040,000 acres of mostly mountainous terrain, about half of which is the San Carlos Indian Reservation. The altitude of this mountainous area ranges from about 2,120 to 7,150 feet above mean sea level.

Mining and livestock are the principal industries, and copper is the leading mineral. Mountain lakes and streams have attracted tourists in recent years. Because of the terrain, agriculture is limited to small areas, mostly along the flood plains of the Gila and Salt Rivers and their tributaries.

Surface-water resources consist mainly of the major perennial streams that flow into the reservoirs of the Salt and Gila River systems. The three major sources of ground water are the perched water in the crystalline rocks, numerous mountain springs, and alluvial deposits along the stream drainages.

Globe, the county seat of Gila County, is one of the three main areas where water levels are measured annually. Water levels in wells are shallow and tend to fluctuate in response to surface flow and local domestic pumping. From spring 1964 to spring 1965 the water level in the wells near Globe rose slightly.

The two other areas where water levels are measured annually are Dripping Spring Valley and the San Carlos Indian Reservation. In Dripping Spring Valley water levels in wells along the valley floor declined slightly from spring 1964 to spring 1965. The water levels are affected mostly by surface runoff and drainage from the surrounding mountains.

The water levels in the wells on the San Carlos Indian Reservation along Ranch Creek generally remained constant from spring 1964 to spring 1965.

USE OF GROUND WATER

By

Natalie D. White, R. A. Rukkila, and Jane V. Burton

About 4.5 million acre-feet of ground water was withdrawn from the underground reservoirs in Arizona in 1964---about the same amount as in the last several years. The chief use of ground water in the State is for the irrigation of crops. About 1,154,000 acres of land was cropped in Arizona in 1964 according to Hillman (1965). For the most part, these crops are irrigated with ground water, although about 2.6 million acre-feet of surface water was diverted for use in the State during 1964. Most of the ground water is withdrawn and used in the Basin and Range lowlands province, and two areas---the Salt River Valley and lower Santa Cruz basin---account for nearly 70 percent of the total amount of ground water withdrawn in the State.

Salt River Valley

Nearly 2,000,000 acre-feet of ground water was pumped from underground storage in the Salt River Valley during 1964---slightly less than in 1963. Of the total amount of ground water pumped, only about 90,000 to 100,000 acre-feet was for municipal and industrial purposes, and the remainder was used to irrigate crops. The Salt River Valley is the largest agricultural area in the State; about 500,000 acres was cropped in the area in 1964. In addition to the ground water pumped, nearly 700,000 acre-feet of surface water was diverted from the Salt River at Granite Reef Dam for use in the valley, mostly for agriculture. An additional 70,000 acre-feet of water was diverted from the Salt and Verde Rivers upstream from Granite Reef Dam for municipal use by Phoenix.

Lower Santa Cruz Basin

About 1,150,000 acre-feet of ground water was withdrawn from the aquifers in the lower Santa Cruz basin in Pinal County during 1964. Of this, less than 25,000 acre-feet was used for municipal and industrial purposes, and the remainder was used to irrigate crops. The basin is the second largest agricultural area in the State and, thus, accounts for a large part of the total withdrawal of ground water in the State. In 1964, 253,925 acres of land was cropped in Pinal County (Hillman, 1965); most of this land is in the lower Santa Cruz basin. In the three developed areas in the lower Santa Cruz basin, only ground water is used for irrigation or other purposes in the Eloy and Stanfield areas, but in the Casa Grande-Florence area ground water is supplemented by a small amount of surface water from the Gila River. In 1964, about 120,000 acre-feet of surface water from this source was diverted for use in the area.

Upper Santa Cruz Basin

About 175,000 acre-feet of water was withdrawn from the underground storage reservoirs in the upper Santa Cruz basin in 1964. Ground water is the chief source of water supply in the basin. Although the use of water for municipal, industrial, and domestic purposes is increasing, irrigation use continues to exceed other uses. In 1964, nonirrigation use of water in the basin was about 65,000 acre-feet, of which nearly 45,000 acre-feet was pumped from wells operated by the Tucson water utility for use in the rapidly growing metropolitan area.

Avra Valley

In 1964, slightly more than 115,000 acre-feet of ground water was used to irrigate crops in Avra Valley. The area is highly developed for agriculture, and ground water is the only source of water supply. Excessive rainstorms, which caused some crop damage during the growing season, may have provided some water that resulted in a slight reduction in the amount of ground water pumped.

Willcox Basin

Only ground water is used to irrigate crops in the three areas of agricultural development in the Willcox basin; use of water for other purposes is minor. In 1964 slightly more than 220,000 acre-feet of ground water was pumped from the underground reservoirs in Willcox basin---an increase of about 40,000 acre-feet over the amount used in 1963. The increase is due to an increase in the amount of land cultivated. A compilation of data for Cochise County (Page, 1965) indicates that about 82,000 acres of land is now cultivated in contrast to only 61,000 acres in 1962, when only 160,000 acre-feet of ground water was pumped. No data on crop acreage are available for 1963. Based on the number of acres irrigated in each of the three areas (Page, 1965), the amount of groundwater pumped in each area is as follows: Stewart area, 70,000 acre-feet; Kansas Settlement area, 125,000 acre-feet; and Pearce-Cochise area, 25,000 acre-feet.

Douglas Basin

Nearly 60,000 acre-feet of ground water was withdrawn from the ground-water reservoir in the Douglas basin in 1964. For the last several years, the amount of ground water pumped in this area has been estimated because no data were available to compute an accurate figure. Ground water is the only available source of water supply in the basin; the irrigation of crops is the main use of water. In late 1964 and early 1965 many new wells were drilled in the Douglas basin, and many acres of land were cleared for cultivation. When irrigation of the new land and pumping of the new wells begin, the amount of ground water withdrawn probably will increase greatly.

San Simon Basin

According to Page (1965), about 30,000 acres of land was irrigated in the Arizona part of the San Simon basin in 1964 in contrast to only 18,400 acres in 1962. Some corresponding increase in cultivated acreage probably also has taken place in the part of the San Simon basin near Rodeo, New Mexico. In 1964 nearly 75,000 acre-feet of ground water was pumped to irrigate crops in the basin. Only ground water is available for irrigation, and other uses of ground water are minor.

Other Areas

A number of other areas in southern Arizona also use ground water for the irrigation of crops and other purposes. For the most part, data are insufficient to compute the amount of ground water pumped in these areas separately, and, thus, only an estimate of the total is given. The areas where relatively large amounts of ground water are pumped each year include the Safford basin, San Pedro River valley, Harquahala Plains area, McMullen Valley, Palomas Plain area, Gila Bend area, and Waterman Wash area. The amount of ground water withdrawn from the underground reservoirs in these areas probably was 650,000 acre-feet in 1964. 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 highlands provinces.

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