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ANNUAL REPORT ON GROUND WATER IN ARIZONA SPRING 1958 TO SPRING 1959

BY

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PREPARED BY THE GEOLOGICAL SURVEY,
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ANNUAL REPORT ON GROUND WATER IN ARIZONA
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ABSTRACT

The collection and analysis of basic hydrologic data are integral parts of the investigation of the ground-water resources of Arizona, conducted by the U. S. Geological Survey in cooperation with the State Land Department. About 3,000 water-level measurements were made in 1,900 wells during 1958. Most of the measurements were made in the Salt River and lower Santa Cruz Valleys. Development of ground water increased in McMullen Valley, Harquahala Plains, Willcox basin, and parts of Mohave County. This report is a summary of the basic hydrologic data collected during the year, spring 1958 to spring 1959.

Pumpage of ground water in Arizona in 1958 was about the same as in 1957, about 4,500,000 acre-feet. More than 90 percent of this ground water was used for irrigation, although there was an increase in use for public supply. The trend of water levels in the heavily pumped areas continued downward, although in the spring of 1959, the water levels in some of the undeveloped basins and areas adjacent to flowing streams were higher than in previous years. These areas include: (1) Safford Valley; (2) upper San Pedro River valley; (3) Duncan Valley; and (4) parts of Pima County. There were continued rises in the Yuma and Wellton-Mohawk areas and parts of the upper Santa Cruz basin. Illustrations include: (1) Hydrographs showing fluctuations in selected wells; (2) maps showing change in water levels for the 5-year period 1954-59 for the Salt River Valley, lower Santa Cruz, Willcox, and Douglas basins; and (3) graphs showing analyses of sand samples by the sediment laboratory.

INTRODUCTION

The future economic development of Arizona is dependent on the successful use of existing water supplies for productive benefit and the availability of water supplies for an expanding economy. Pumping of ground water in large quantities in Arizona began in the 1920's. At that time most of the pumpage was from drainage wells used to reclaim water-logged land. In the 1930's the pumping of ground water increased, owing primarily to the utilization of water for irrigation. The State Legislature observed this increase in the development of ground water for irrigation and recognized the need for information on the occurrence and storage of ground water. In 1939 it appropriated funds for investigations of the ground-water resources of the State, and a cooperative agreement providing for the studies was made between the State Water Commission and the U. S. Geological Survey. Succeeding State Legislatures have appropriated funds for a continuation of these investigations, and these State funds are matched by Federal funds. Since 1942 the State Land Department has been the cooperating agency.

The work done under the cooperative program includes the collection of basic hydrologic data, geological and ground-water investigations of specific areas, and studies related to the solution of specific hydrologic problems. This report is a compilation and analysis of the basic-data-collection part of the program in 1958.

This report contains a discussion of the ground-water hydrology and summary statements of changes or trends in the ground-water conditions throughout the State by counties and areas. Sections are presented on ground-water pumpage, the sediment laboratory, and chemical quality of the water in the Phoenix area. Hydrographs are included to show comparative changes in the stage of water levels in selected wells for the last 10 years. Maps show the changes in ground-water levels for a 5-year period (1954-59) in the Salt River Valley, lower Santa Cruz, Willcox, and Douglas basins. There are graphs showing the method used in the sediment laboratory to analyze samples of the subsurface material.

Scope of Basic-Data Program

The collection of basic hydrologic and geologic data is an integral part of the studies needed to analyze the ground-water resources throughout the State. Because of the economic value to the State and Nation, particular emphasis is directed toward studies in areas of extensive irrigational and industrial development. This work includes a well inventory, periodic water-level measurements, collection of water samples for chemical analysis, and collection and cataloguing of drill cuttings from recently completed wells.

The objectives of this part of the program are (1) to evaluate the trends in ground-water levels as related to the development of ground-water supplies; (2) to delineate the present areas of greatest development and the areas where undeveloped ground-water conditions may support future development; (3) to determine the geologic and hydrologic characteristics of areas as related to the ground-water regimen; (4) to determine the changes in the chemical quality of water; (5) to provide continuous records of fluctuations of water levels in selected wells to study the net changes in ground-water storage; (6) to add to the knowledge of subsurface geology by the collection, cataloguing, and study of drill cuttings and drillers' logs from water wells and oil tests; and (7) to collect pumpage records from specific areas, when applicable.

The collection of basic data provides a foundation for ground-water research and a framework for the compilation of records in any detailed regional investigation. The data are necessary for the evaluation of the yearly changes and trends in ground-water conditions throughout the State. During the year water-level measurements and other related information are collected, tabulated, and analyzed, and the results are published in an annual report. The purpose of this report is to present the data to the people of the State in a way that is informative, interesting, and helpful. An analysis of a series of these reports covering many years reveals the effects of heavy pumping in the developed basins throughout the State. The conditions in the lesser known and undeveloped areas, the possible areas for industrial and irrigational development, the possible range in depth and yield of contemplated wells, and the areas in which the Geological Survey is making more detailed ground-water studies would also be revealed. Additional information not published in reports is on file in Phoenix and Tucson for inspection by interested parties.

Under the cooperative program, about 3,000 water-level measurements were made in 1958 in 1,900 wells. Water-level measurements and chemical analyses of water samples are available for inspection in the offices of the Geological Survey, Ground Water Branch, at Phoenix and Tucson.

Current Projects in Arizona

Ground-water studies made by the U. S. Geological Survey in Arizona are financed by means of the following: (1) cooperative agreement with the State; (2) cooperative agreements with municipalities and water districts; (3) Geological Survey noncooperative funds; and (4) transfer of federal funds from other federal agencies. This year a new project on the feasibility of capturing additional water in Rillito basin is financed by a cooperative agreement with the University of Arizona, Pima County, and the city of Tucson. The areas of new and active projects are shown on figure 1.

The cooperative program with the State includes (1) collection of basic hydrologic data (discussed under "Scope of Basic-Data Program"); (2) geologic and ground-water investigations of specific areas; and (3) studies related to the solution of specific hydrologic problems.

Ground-water investigations of specific areas consist of geologic studies, complete well inventories, measurements of pumpage or natural discharge, and descriptions of hydrologic conditions. The preliminary work, preferably done before extensive development, is invaluable as a basis for long-range study of the ground-water resources. The information obtained may be correlated with that from a similar study of the area completed after extensive development. Projects of this type include those in the lower San Pedro basin, Snowflake-Taylor area, McMullen Valley, and a part of Apache County south of the Navajo Indian Reservation.

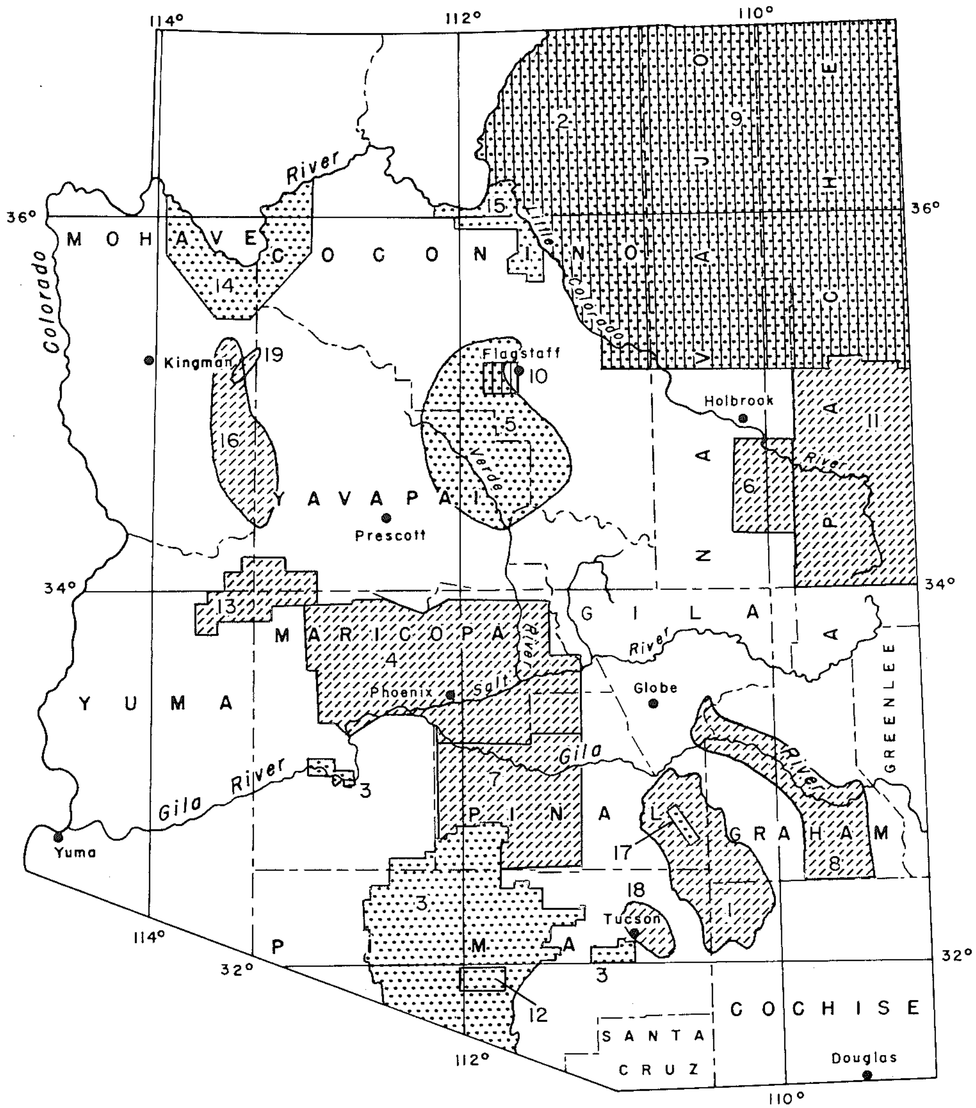
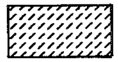


Figure 1.-- Map of Arizona showing areas of ground-water investigations.

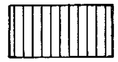
PROJECTS BY AREA

1. Lower San Pedro River basin
2. Navajo-Hopi Indian Reservations
3. Papago Indian Reservation
4. Salt River Valley
5. Verde Valley area (Modification of Mogollon Rim region)
6. Snowflake-Taylor area
7. Northwestern Pinal County
8. Safford Valley
9. Navajo Tribal well-development program
10. City of Flagstaff
11. Apache County
12. Sells Hospital site
13. McMullen Valley
14. Hualapai Indian Reservation
15. Grand Canyon National Park
16. Big Sandy
17. San Pedro-Mammoth area
18. Rillito Creek
19. Cottonwood Wash

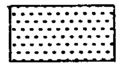
Basic hydrologic data part of State cooperative program covers entire State



Investigations financed jointly with State and Federal funds



Investigations financed jointly with other non-Federal and Federal funds



Investigations financed with noncooperative Federal funds and Federal funds transferred from other Government agencies

Studies related to the solution of specific hydrologic problems provide a more accurate quantitative determination of the ground-water resources of the State. These studies have been undertaken because of the necessity for obtaining more specific information on the occurrence, movement, recharge, storage, discharge, and chemical quality of ground water in areas of present or prospective development. The studies involve an analysis of available basic geologic and hydrologic data and the collection of basic data related specifically to these problems. Current projects of this nature are the determination of the productivity of deep aquifers in the Salt River Valley and of changes in the chemical quality of ground water at depth, the analysis of geologic and hydrologic data collected since 1903 in the lower Santa Cruz basin of Pinal County, and the study of water movement in the inner San Pedro Valley near Mammoth.

Cooperation with municipalities is exemplified by the current project with the city of Flagstaff and the recently completed project with the city of Safford. The cooperation with the city of Safford consisted of an investigation of the Bonita Creek area for obtaining additional water for the city. The Flagstaff investigation consists of determining the feasibility of developing ground water as a supply for the city; the success of the deep wells to date is discussed in this report under "Coconino County."

Work financed entirely with federal funds is done in areas where the Federal Government has a specific interest not related solely to that of the State and local cooperating agencies. Studies of the several Indian reservations are included in this arrangement, and the results of these investigations are also beneficial to the State. Projects of this type include the Navajo-Hopi country in the northeastern part of the State, and the Papago reservation west of Tucson. During 1958, ground-water reports were completed for the Hualapai reservation in the northern part of Mohave and Coconino Counties for the Indian Service and on the Grand Canyon National Park for the National Park Service. Other federal projects are the Sells (Papago) Hospital site, and the Verde Valley area of the Mogollon Rim region.

New projects this year include a study of the use of water by riparian vegetation in Cottonwood Wash, Mohave County, a geohydrologic study as related to water utilization in the Safford Valley, and the feasibility of capturing additional water in Rillito basin near Tucson.

List of Publications

The following reports on the ground-water resources and geology of Arizona were prepared and released to the open file by the Ground Water Branch of the Geological Survey in 1958 and early 1959:

Use of ground water in Arizona, by J. W. Harshbarger, in Contribution 6, Climate and Man in the Southwest, Program in Geochronology: University of Arizona Bull., 1958. 19 p., 5 figs., 1 table.

This paper presents a brief résumé of the ground-water conditions in the State. Some of the major geologic features that control the occurrence, recharge, movement, storage, and discharge of water in the ground are discussed. There is a comparison between the ground-water reservoirs prior to extensive development and the current water-table conditions. The decline of the water table in some of the heavily pumped basins has resulted in a depletion of the ground-water reservoirs.

Annual report on ground water in Arizona—spring 1957 to spring 1958, by W. F. Hardt, J. M. Cahill, and M. B. Booher: Arizona State Land Department Water Resources Report No. 5, August 1958. 60 p., 19 figs., 1 table.

This annual report is a summary of the basic hydrologic data collected during the period spring 1957 to spring 1958. It broadly describes the ground-water pumpage in the State and water-level fluctuations in the counties and principal basins. Approximately 4.5 million acre-feet of ground water was pumped in 1957 and the trend of water levels in the heavily pumped areas continued downward. The quality of water is generally satisfactory for irrigation and public supplies. However, in a few areas the dissolved solids concentration, particularly the salt content, is increasing or is too high for most uses. Illustrations include 10-year hydrographs showing water-level fluctuations in selected wells, maps showing change in water levels for the 5-year period 1953-58 for the Salt River Valley, lower Santa Cruz, Willcox, and Douglas areas, selected well logs, and a map showing location of the annual water-sampling program.

Test holes in southern Arizona valleys, by P. W. Johnson, in Arizona Geological Society Southern Arizona Guidebook II, April 2-6, 1959. 4 p., 1 fig., 1 table.

Most of the ground water in the southern part of the State occurs in the alluvial basins. To define the ground-water reservoirs adequately, the data from oil and gas exploration test holes are important. There are about 80 test holes on public record at the Arizona State Land Department. Most of the wells are in the southeastern part of the State and have bottomed in alluvial deposits. The deepest test hole in Arizona is 30 miles south of San Simon and was drilled to 7,579 feet.

Ground water in Black Mesa basin and adjacent areas, by J. P. Akers and J. W. Harshbarger, in New Mexico Geological Society Guidebook: Ninth Annual Field Conference of Black Mesa basin of northeastern Arizona, July 1958. 11 p., 8 figs.

The ground-water conditions in eight physiographic subdivisions and the water potential of the Permian and younger formations of northeastern Arizona are briefly described. The Black Mesa basin area contains large amounts of ground water in storage, but the yield to wells is not large owing to the low permeability of the fine-grained sandstones. The depths of wells needed to penetrate the aquifers range from several tens of feet to more than 2,000 feet, depending on the geologic conditions.

Geology and probable areas of ground-water development in the Hualapai Indian Reservation, Arizona, by F. R. Twenter: U. S. Geol. Survey open-file report (pending release). 94 p., 2 pls., 7 figs., 1 table.

The Hualapai Indian Reservation covers more than 1,500 square miles in a U-shaped block in northwestern Arizona. This report describes the geology and probable areas of ground-water development. The occurrence and movement of ground water is related to the lithologic, structural, and erosional features of the rocks. In this area most of the rock units are non-water-bearing. The principal aquifer is the Muav limestone although the Tertiary gravels and the lake beds are usually water bearing. Well development is possibly limited to the Hualapai Plateau west of Peach Springs Canyon and the lake beds of Truxton Valley. A geologic map and cross sections and a quality of water table are in the report.

Availability of water along the south rim, Grand Canyon National Park, Arizona, by D. G. Metzger: U. S. Geol. Survey open-file report (pending release). 79 p., 6 figs., 2 tables.

A ground-water investigation along the south rim of the Grand Canyon was made to determine if additional quantities of water could be developed to increase the water supply for Grand Canyon Village and Desert View in anticipation of expansion of the park. There is a discussion of the geologic and hydrologic features as related to the occurrence and movement of ground water. Development of water from wells offers little encouragement and possibilities are poor for development of spring water, except for increased use of Indian Garden Spring and possibly Hermit Creek. The report includes a geologic map and cross sections. Tables include well and spring records and quality of water analyses.

Preliminary report on the availability of water in the Red Lake area, Navajo Indian Reservation, Arizona and New Mexico, by J. P. Akers, N. E. McClymonds, and J. W. Harshbarger: U. S. Geol. Survey open-file report, March 1959. 21 p., 2 pls., 4 tables.

A water-resources investigation of the Red Lake area (11 miles north of Fort Defiance) was made to determine the feasibility of obtaining sufficient water for a proposed sawmill and a community of 3,000 people. The report describes the geology, the surface- and ground-water possibilities, and the quality of water. Development of ground-water sources southeast of Red Lake in a buried gravel channel of the alluvium and from volcanic cinders in Buell Park should produce sufficient water for the project. Tables include a description of rocks and their water-bearing properties, streamflow records of Crystal and Whiskey Creeks, and chemical analyses.

Agricultural Résumé for 1958

According to R. E. Seltzer (Arizona Agriculture 1959: Arizona Agr. Expt. Sta. Circ. 270, February 1959), 1,239,558 acres were irrigated in Arizona in 1958. This is an increase of nearly 90,000 acres from the previous year. About 6,200,000 acre-feet of water was used for irrigation during 1958, of which about 4,000,000 acre-feet was pumped from ground-water supplies. The largest irrigated acreages under cultivation were in cotton (387,776 acres) and alfalfa (213,950 acres). The increase in wheat production from 63,000 acres in 1957 to 123,000 acres in 1958 was probably attributable to producers' desires to establish a base-acreage history, as the State will apparently come under acreage allotments in 1960. The counties having the largest total acreage under cultivation were: (1) Maricopa, 516,700 acres; (2) Pinal, 292,430 acres; (3) Yuma, 189,950 acres; and (4) Cochise, 77,150 acres.

There was an increase in the irrigated acreage in all of the counties in the southern half of the State except for slight decreases in Gila and Cochise Counties. Maricopa County had the greatest increase of irrigated land followed by Pinal and Yuma Counties. The northeastern part of the State had a decrease in irrigated acreage and Mohave and Yavapai Counties had slight increases. Much of the increase in irrigated acreage during 1958 was the result of less participation in the soil-bank program. Only 16,674 acres, a 63 percent reduction from 1957, were placed in this program.

Seltzer (1959) stated that Arizona's cash agricultural income set an all-time record of 421 million dollars in 1958. This was 11 million dollars above the previous high in 1952. Cotton, cattle, and vegetables account for 77 percent of the State's total agricultural income. Cotton, for the 12th year was the principal money crop, although its importance relative to cattle and vegetables declined in 1958. The income from milk and eggs was about the same as in 1957, income from commercial feed grains was lower, and citrus prices were the best in years because of the disastrous freeze in Florida.

As many crops are unprofitable at pumping lifts in excess of 300 feet, the trend is continuing toward production of vegetable crops in recently developed areas in Arizona. In these areas the water table is closer to the surface than in areas where extensive pumping has taken place for a long period of time. The newly developed areas include Willcox, Aguila-Salome, Theba, Harquahala, Sahuarita, and part of Mohave County.

Precipitation

The precipitation in 1958 was above the average in Arizona for the second consecutive year. The only areas in the State with below-average precipitation were Maricopa and Pinal Counties; these counties use about 75 percent of the ground water pumped in the State. Gila County received the most rainfall during the year, and the southeastern part of the State had the largest increase of rainfall above the long-term average.

January was dry throughout the State. February was relatively wet, and March was extremely wet, particularly in and near the mountains. April, May, and June had slightly above-average precipitation. In July, the northern half of the State was deficient in rainfall while the southern part was relatively wet. August had varied conditions—some stations received much rain and others, particularly in the northwest, received little. During September, the entire State was wet, with much rain in the central part. October and November continued to be wet, and December was dry throughout the State.

Although recharge to the ground-water reservoirs comes indirectly from precipitation, most of the actual recharge to the aquifers of Arizona occurs from streamflow instead of directly from rainfall. In arid climates, such as Arizona, the small amount of precipitation usually falls in sudden short bursts. In the southern part of the State, in the Basin and Range province, the precipitation from these short-duration storms runs off quickly into the streams because of the relatively high topographic relief and the soil conditions. Evaporation losses are extremely high and only very small amounts of water percolate downward to the water table. After the rainfall enters the streams as runoff and reaches the alluvial valleys, recharge to the ground-water aquifers is enhanced. However, adjacent to the streams abundant water-loving vegetation uses tremendous amounts of water and much of the infiltrating water never reaches the water table.

The rate of movement of water through sediments is very slow, and the time it takes for water to reach the water table depends on the thickness, the permeability, and the soil-moisture capacity of the unsaturated sediments. Therefore, it must be emphasized that the rainfall (or streamflow) in 1958 will have little immediate effect on the water table in the Salt River or Santa Cruz Valleys, or in other areas where the water table is very deep.

The plateau region in the northern part of the State is composed mostly of consolidated sedimentary rocks. The land is at a higher altitude than the basin country, temperatures are lower, evaporation is less, and the presence of accumulated snow on permeable cover probably allows more water to percolate downward.

The heaviest concentration of rainfall during 1958 was in the mountainous regions of Gila and Yavapai Counties and in the southeastern part of the State. Gila County had 21.22 inches of precipitation or 3.16 inches above the long-term average. Yavapai County had 18.23 inches of rainfall, 2.35 inches above the average. These areas are important sources of water to the Salt River Valley. In the lower Santa Cruz and Salt River Valleys, the amount of precipitation in 1958 was about 1 inch below the long-term average. The major detrimental result of less rainfall in these areas is the continued pumping from the ground-water reservoirs.

Precipitation for 1958 and departures from long-term averages at various stations in Arizona are shown in table 1.

Surface-Water Diversions

About 2,400,000 acre-feet of surface water was diverted for irrigation during the 1958 water year. More than half this amount, or about 1,400,000 acre-feet, was diverted from the Colorado River for use by (1) Colorado River Indian Reservation below Parker, (2) Valley Division of the Yuma Project, and (3) Gila Project. These projects use only surface water for irrigation. Of this total, about 400,000 acre-feet was returned to the Colorado River or discharged across the Arizona-Sonora International Boundary.

According to the Surface Water Branch, U. S. Geological Survey, the remaining 1,000,000 acre-feet of diverted surface water was used in combination with ground water for irrigation. About 650,000 acre-feet was diverted at Granite Reef Dam for use in the Salt River Valley. About 250,000 acre-feet from Ashurst-Hayden Dam was diverted to the San Carlos Project, and about 150,000 acre-feet was diverted from the Gila River for use in the Duncan-Safford area. Smaller diversions included those from the Gila River for the Buckeye Irrigation District, Agua Fria River at Carl Pleasant Dam, Salt and Verde Rivers above the dams, and Little Colorado River. Surface flow throughout the State ranged from 120 to 180 percent above normal with the exception of the Little Colorado River which was about 20 percent below normal.

Table 1.--Total precipitation in 1958 at selected stations and departures from long-term means (From Climatological Data, Arizona, Annual Summary 1958: U. S. Weather Bur.)

Station	Precipitation (inches)	Departure (inches)
Bowie	13.68	-
Buckeye	5.45	-
Casa Grande	8.55	+0.47
Chandler	6.07	-
Chino Valley	13.42	-
Davis Dam	5.24	-
Douglas Smelter	15.07	+3.45
Duncan	14.41	-
Eloy	8.58	-
Flagstaff	21.24	+2.77
Gila Bend	3.70	-2.21
Globe	18.18	+2.78
Holbrook	6.61	-1.14
Kingman	13.34	-
Litchfield Park	8.38	+.52
Mesa	7.12	-.57
Nogales	20.86	-
Payson	25.12	-
Phoenix Airport	8.12	+.96
Pinedale	20.58	+2.76
Prescott Airport	13.17	-2.81
Safford	12.09	+3.37
St. Johns	12.60	+1.23
Snowflake	13.74	+2.01
Tucson, University of Arizona	12.63	+2.20
Wellton	4.88	-
Wikieup	10.06	-
Willcox	13.24	-
Williams	26.62	+5.49
Yuma Airport	4.02	+.63

Well-Numbering System

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 (fig. 2). 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 (fig. 2), 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 a 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.

Personnel

Personnel of the Phoenix office who worked on this report are R. S. Stulik, J. M. Cahill, D. G. Metzger, W. Kam, F. R. Twenter, and A. C. Hill. Personnel of the Tucson office who worked on the report are M. B. Booher, C. S. English, E. K. Morse, N. D. White, C. L. Jenkins, M. F. Howard, L. A. Heindl, P. W. Johnson, and N. A. Tilghman. Those of the Holbrook office who worked on the report are J. P. Akers and E. L. Gillespie.

The project and this report were coordinated by W. F. Hardt, who wrote the introduction, the regional ground-water hydrology, and the section on pumpage. The discussion of the ground-water conditions in the Salt River Valley and most of the northern counties was written by R. S. Stulik. Discussion of conditions in the southern part of the State was written by M. B. Booher; J. P. Akers discussed Apache and Navajo Counties and H. G. Page wrote the section on the sediment laboratory. The quality-of-water section was written by L. R. Kister, chemist, Quality of Water Branch of the U. S. Geological Survey; and the illustrations were prepared by G. S. Smith. The report was prepared under the supervision of J. W. Harshbarger, district geologist.

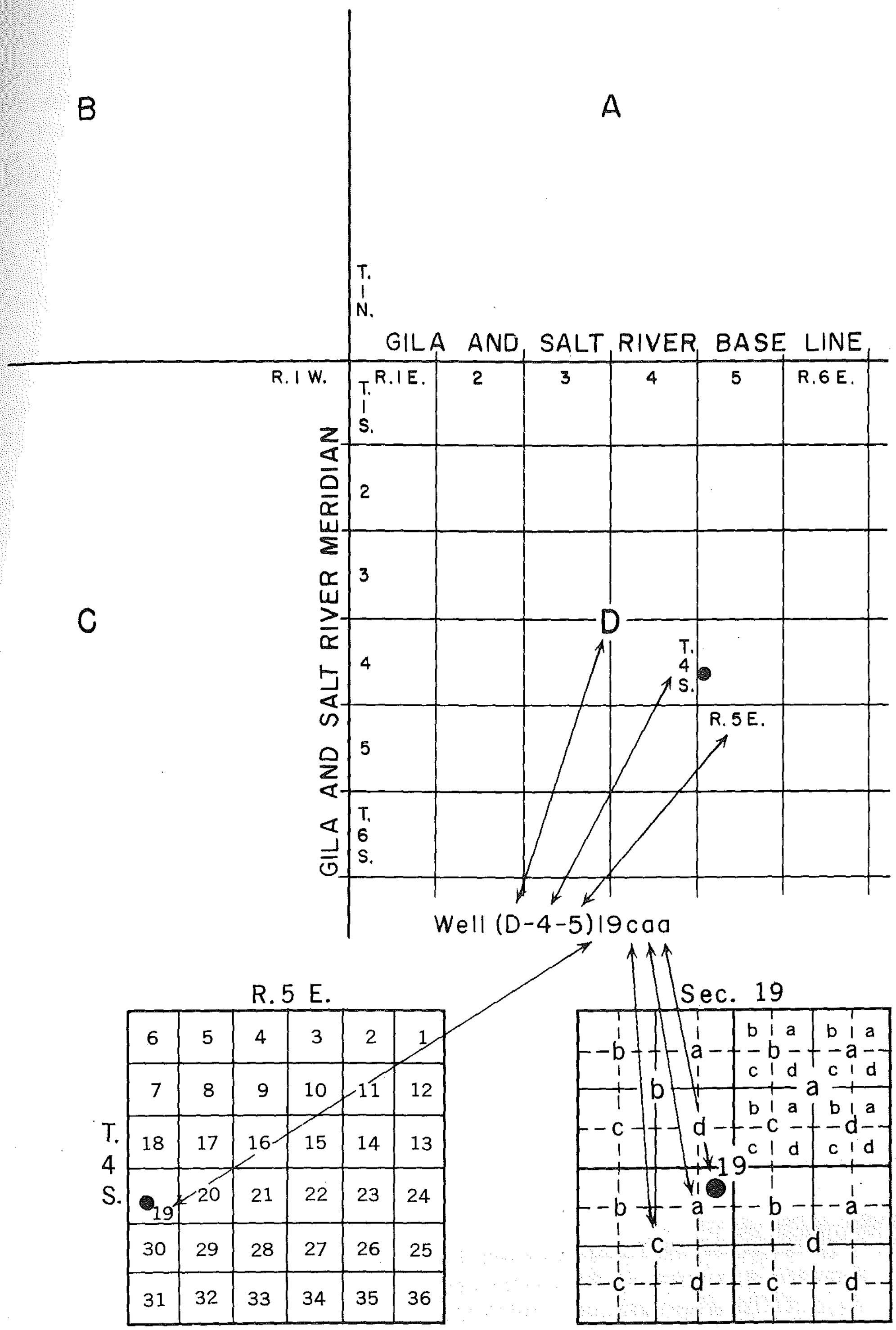


Figure 2.-- Sketch showing well-numbering system in Arizona.

Acknowledgments

Many irrigation districts, cities, well drillers, water companies, government agencies, and individuals provided splendid cooperation in furnishing information. The following organizations were particularly helpful: Arizona Corporation Commission, Arizona Water Company, Buckeye Irrigation District, City of Douglas, City of Nogales, City of Phoenix, City of Tucson, Cortaro Farms, Gila Water Commissioner, Goodyear Farms, Maricopa County Municipal Water Conservation District, Salt River Valley Water Users' Association, San Carlos Irrigation District, U. S. Bureau of Indian Affairs, U. S. Bureau of Reclamation, U. S. Weather Bureau, and Surface Water and Quality of Water Branches of the U. S. Geological Survey.

GROUND-WATER HYDROLOGY

The State has been divided into three water provinces: (1) the Plateau uplands in the northern part of the State; (2) the Central highlands; and (3) the Basin and Range lowlands in the southern part of the State. In the northern half of the State, there is little irrigation and ground-water pumping. As a result, the long-term hydrographs do not show any appreciable sustained declines. Future developments in localized areas, such as in some of the valleys of Mohave County or in parts of the Little Colorado River drainage, would cause a cone of depression or lowering of the water table in the vicinity of the pumped wells. The sedimentary deposits store tremendous amounts of water, but yield only small amounts to wells. The regional movement of the ground water in the northern part of the State is generally toward the Colorado River, and large but unknown quantities are discharged into the river.

The Central highlands lie mostly in Yavapai, Gila, and Greenlee Counties. High precipitation, rapid runoff, and low evaporation is characteristic of the water resources in this area. The direction of movement of the surface water is toward the Salt River Valley. Before the water reaches the valley, it is impounded in the mountains by Bartlett, Roosevelt, and Coolidge Dams. There is little or no ground-water underflow in these tributary valleys because the streams flow over bedrock for many miles. When the water reaches the alluvial deposits of the Salt River Valley there may be some recharge to the ground-water reservoir. To compensate for the heavy withdrawals in the Salt River Valley, it may be feasible to recharge the area artificially with surplus streamflow. It may be desirable to store the water beneath the ground rather than allow it to remain on the surface where much of it is lost to the atmosphere.

In the Salt River Valley and the lower Santa Cruz basin the water levels have continued to decline and it is obvious that the amount of water being pumped is much greater than the natural recharge. Other basins are in various stages of development and water-level measurements are essential to document the effects. In the spring of 1959, the water levels in some of the undeveloped basins and areas adjacent to flowing streams were higher than in previous years. These areas include: (1) Safford Valley; (2) upper San Pedro River valley; (3) Duncan Valley; and (4) parts of Pima County. At the present time there is little ground-water pumping or decline in water levels in the Sacramento Valley, Hualapai Valley, the Big Sandy area of Mohave County, Mohawk Valley in Yuma County, Santa Rosa and San Simon Valleys in the Papago Indian Reservation, and other smaller valleys. To develop these new areas properly, detailed geologic and hydrologic studies are needed.

The most important drainage system in the Basin and Range lowlands is the Gila River and its tributary, the Salt River. Much of the ground-water movement in the southern part of the State is toward these rivers. In the Douglas basin in Sulphur Spring Valley and San Simon Valley in the Papago Indian Reservation, ground water moves toward Mexico.

Movement of ground water in the San Simon (Rodeo, New Mexico, to Safford) and San Pedro Valleys is northward toward the Gila River. In the Safford Valley area most of the available agricultural land is being used and the pumpage varies with the amount of precipitation and the streamflow in the Gila River.

The Sulphur Spring Valley is divided into the Willcox and Douglas basins. Pumping in this area has increased during the last 10 years and water levels have declined. However, during 1958, the above-average amount of precipitation in the Douglas basin resulted in a reduction in ground-water pumpage and the decline of the water table from spring 1958 to spring 1959 was less than in previous years. The increased development in the Willcox basin during 1958 will result in greater pumping and the water levels in the area will decline. During the last 5 years there has been as much as 70 feet of decline in the water table in the Kansas Settlement area. However, the beneficial use of the ground water in this basin prevents much of the water from moving into the Willcox playa. This is one area in the State where the pumping is adjacent to the point of natural discharge.

Ground water in the Santa Cruz Valley moves northward from Nogales, past Tucson, and toward the Gila River. Heavy pumping over a period of years in the Eloy, Casa Grande, and Maricopa areas has depressed the water table and there is no underflow to the Gila River. Declining water levels and increasing pumping costs may result in a reduction in the amount of farming in the developed basins if prices remain constant. The situation in these critical areas may change to industrial developments and housing projects, which ordinarily use less water than farming. The application of artificial recharge, if feasible, may be helpful. The accelerated demand for water in the State indicates the need for intensive evaluation of the water resources.

Water-Level Fluctuations

The general trend of water levels in Arizona in 1958 continued downward in the developed basins. These declines are caused directly by pumping. Maximum declines again occurred in Maricopa and Pinal Counties. Smaller declines of the water table were measured in the Sulphur Spring and San Simon Valleys of Cochise County, and in parts of Pima County, particularly the Avra-Marana and Tucson areas. In the spring of 1959 the water levels in wells adjacent to flowing streams were higher than in previous years in the Safford Valley, upper San Pedro River valley, Duncan Valley, and parts of Pima County. The only places in the State where the water table is rising consistently is in the Wellton-Mohawk area and Yuma Mesa of Yuma County. The rise in water level is attributed to recharge from Colorado River water diverted onto the irrigated areas. These areas will have serious waterlogging problems if measures are not taken to remove the excess water.

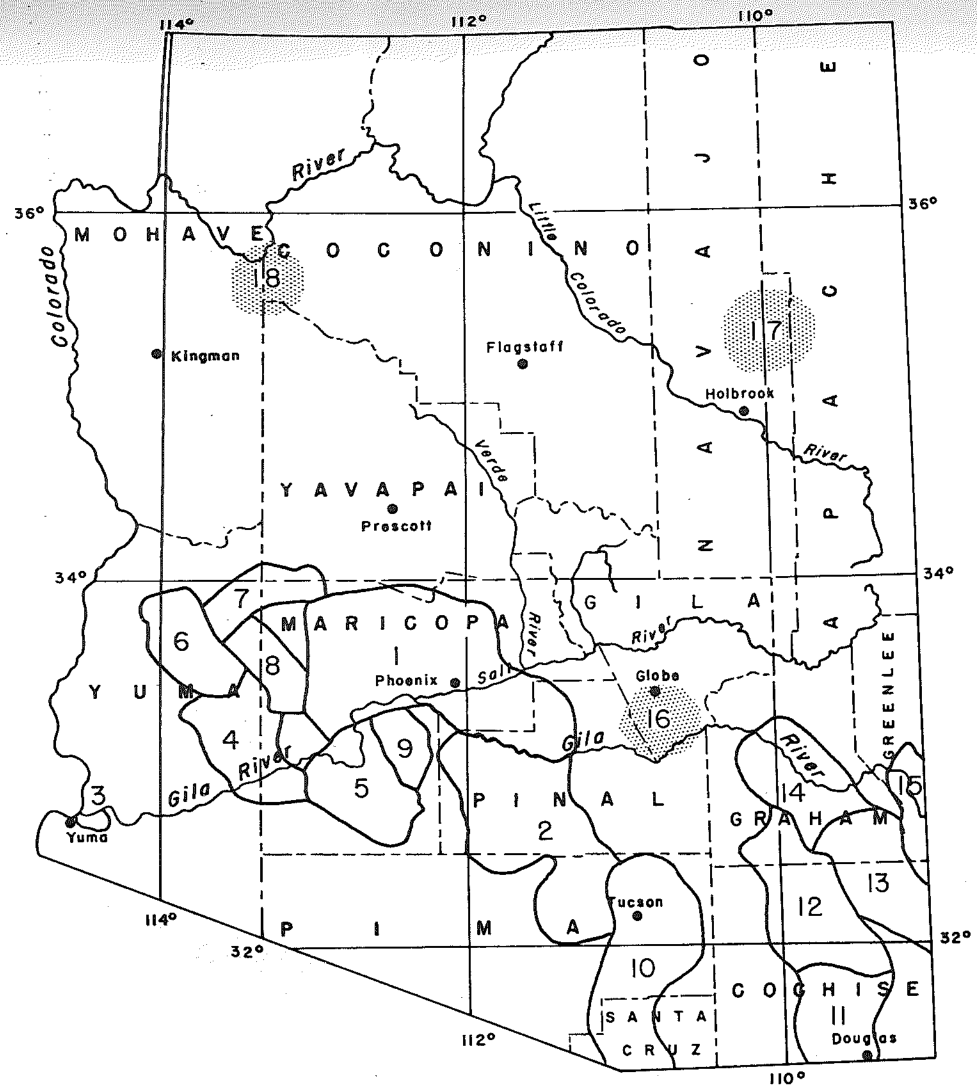
Records in the recently developed areas, such as McMullen Valley, are not long enough to establish water-level trends; but increased development and pumping will result in a declining water table. Hydrographs of selected wells in the northern half of the State show minor fluctuations.

A rise or decline of water levels in an area will show a net gain or loss of water stored for that period of time. A steady decline in the water table of a basin over a period of years indicates that ground water is being depleted. It is important to measure the water levels in wells about the same time each year to obtain consistent results. The Geological Survey makes measurements during January, February, and March of each year. At this time pumping is at a minimum, more uniform conditions prevail, and the water levels are approaching static conditions.

Most of the water-level measurements are made in the developed areas of southern Arizona where fluctuations in the ground-water reservoir are of prime importance to a large number of people. The increase in industrial development and the growth in population could affect the ground-water storage in different areas. In this event the Survey would increase the number of water-level measurements in new areas. Figure 3 is a map showing the areas in the State where ground-water levels are measured.

Apache County

Most of the ground-water development for irrigation is confined to the central part of Apache County, along the Little Colorado River near St. Johns and Hunt. The land surface in this area slopes gently toward the northwest from an altitude of about 5,700 feet at St. Johns to about 5,400 feet at Hunt. A large part of the country to the south of this area



1. Salt River Valley
2. Lower Santa Cruz basin
3. South Gila Valley
4. Palomas Plain area
5. Gila Bend area
6. Ranegras Plain area
7. McMullen Valley
8. Harquahala Plains area
9. Waterman Wash area
10. Upper Santa Cruz basin
11. Douglas basin
12. Willcox basin
13. Bowie-San Simon area
14. Safford Valley
15. Duncan Valley
16. Gila County (City of Globe, San Carlos Valley)
17. Navajo and Apache Counties
18. Coconino, Yavapai, and Mohave Counties

Figure 3.--Map showing ground-water areas and basins in Arizona where water levels are measured.

is covered by lava flows, but the irrigated lands are in broad alluvial valleys formed in sedimentary rock by the Little Colorado River. The regional dip of the rock is to the north, so that exposed strata are, in general, successively older toward the south. This regional dip is an important factor in the movement of ground water from the southeast to the northwest. The controlling factor in this movement is the difference in head of the ground-water surface between the mountain regions south and west of St. Johns and the lower discharge areas. This is the reason for artesian rise of water in most wells drilled in the area.

The depths of wells in these areas range from 200 to more than 700 feet. The static water levels range from several feet above to 40 feet below the land surface, and the maximum pumping level is about 100 feet below the land surface. In other parts of the country, just south of the Navajo reservation, the water levels in some of the stock wells are as much as 300 feet below the land surface. South of the Petrified Forest, a well was recently drilled to a water-bearing sand and flowed about 200 gpm (gallons per minute). No trend of decline or rise in water levels has been observed in Apache County, although farmers in the Hunt Valley area reported higher water levels in the spring of 1958 than for the last several years.

Cochise County

There are four principal areas of irrigation development in Cochise County: (1) Willcox basin, (2) Douglas basin, (3) Bowie-San Simon area, and (4) upper San Pedro valley.

Willcox basin

The Willcox basin lies in the northern part of the Sulphur Spring Valley. The basin extends from a drainage divide at the headwaters of Aravaipa Creek southward to a drainage divide among the buttes and ridges near the town of Pearce. Along the eastern side of the basin are the Pinaleno, Dos Cabezas, and Chiricahua Mountains, and along the western side are the Winchester, Little Dragoon, and Dragoon Mountains. The basin ranges from about 15 to 30 miles in width, is about 50 miles long, and covers about 1,500 square miles. Although most of the basin is within Cochise County, approximately 250 square miles in the northern part is in Graham County. The altitude of the valley floor ranges from 4,135 feet, at the Willcox playa, to about 4,500 feet at the lowest point of the drainage divide at the headwaters of Aravaipa Creek.

There are two main cultivated areas in the Willcox basin (fig. 4), the Stewart area and the Kansas Settlement area. The Stewart area, northwest of Willcox, is generally restricted to Tps. 12 and 13 S., Rs. 23 and 24 E. The irrigated area includes somewhat less than 20,000

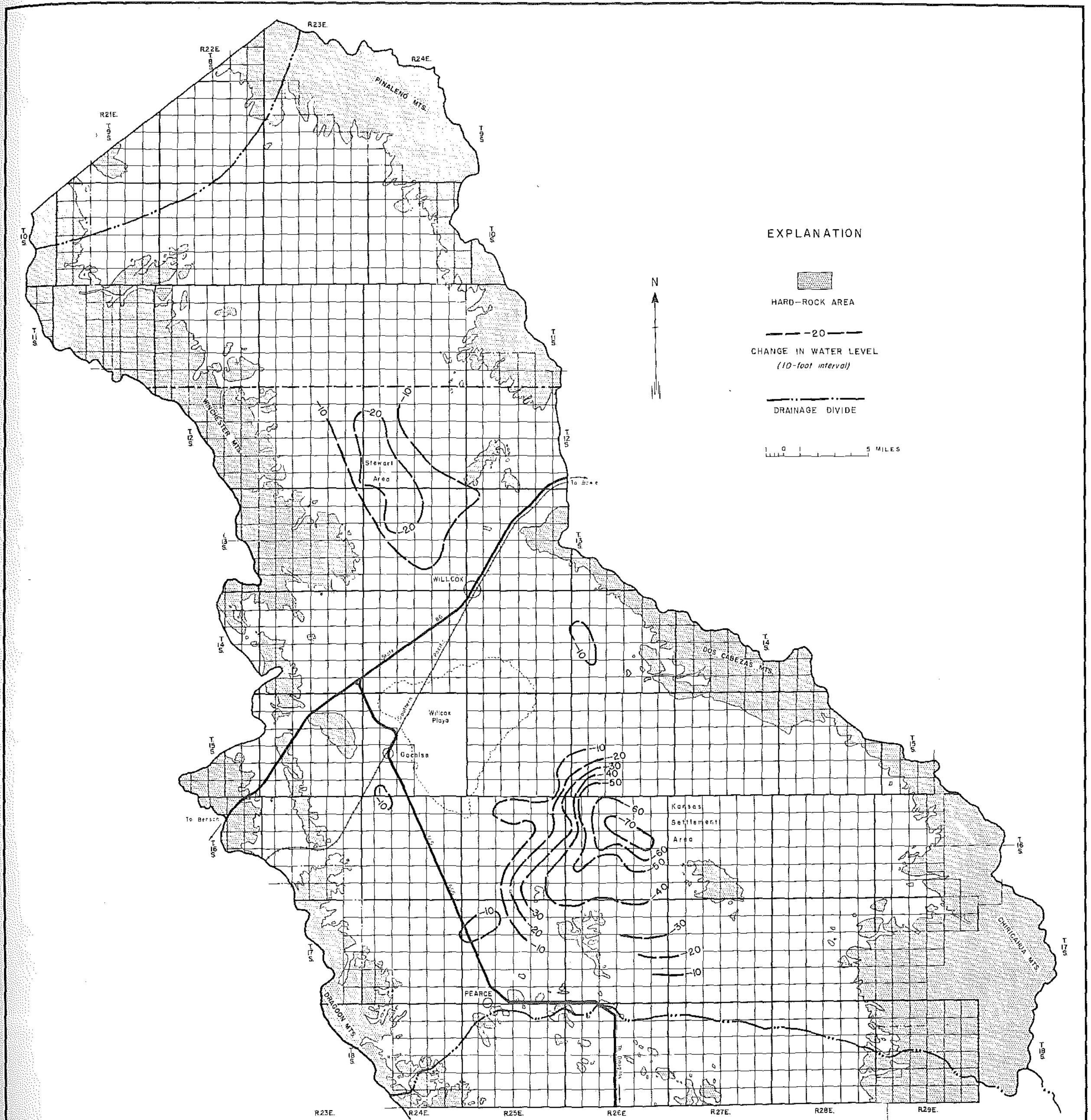


Figure 4.--Map of Willcox basin, Cochise County, Arizona, showing change in ground-water level from spring 1954 to spring 1959

acres. The Kansas Settlement area lies about 8 miles south of Willcox and includes the eastern half of Tps. 15 and 16 S., R. 25 E., and all of T. 16 S., R. 26 E. This area includes about 35,000 acres under irrigation and the irrigated acreage is expanding rapidly. There is about 5,000 acres under irrigation between Cochise and Pearce.

The natural ground-water gradient in the Willcox basin is toward the playa. North of the playa the ground-water movement is southward from the divide near Aravaipa Creek, and south of the playa it is northward in the vicinity of Pearce. Most of the time the playa is dry and partly encrusted with white salts; occasionally it is covered by a shallow body of water derived from runoff. Many years ago, this playa probably intersected the water table. A water-table contour map, based on water-level measurements made in the spring of 1959, shows that the pumping of ground water for irrigation intercepts some of the underflow and has caused a cone of depression in both the Stewart and Kansas Settlement areas. These cones of depression have reduced the amount of subsurface flow to the playa and thereby reduced the loss of water to the atmosphere by evaporation. Continued pumping could reverse the gradient and allow the water beneath the playa to move toward the heavily pumped areas.

In the Stewart area, water-level fluctuations for the period spring 1958 to spring 1959, based on 40 water-level measurements, ranged from a rise of less than 1 foot to a decline of about 6 feet. In the 5-year period spring 1954 to spring 1959 (fig. 4) water levels declined from about 10 feet along the fringe areas to more than 20 feet in the center of the heavily pumped areas. The water level in well (D-13-24)16 (fig. 5), in the heavily pumped area, declined about 5 feet from spring 1958 to spring 1959, about 30 feet from spring 1954 to spring 1959, and about 48 feet from spring 1949 to spring 1959. The depth to water in the Stewart area in the spring of 1959 ranged from about 20 feet near the town of Willcox to about 130 feet on the northern edge of the irrigated area.

From spring 1958 to spring 1959 fluctuations in water levels in 60 wells in the Kansas Settlement area ranged from a rise of about 3 feet near the playa to a decline of about 20 feet in the heavily pumped areas. In the 5-year period spring 1954 to spring 1959 declines ranged from about 70 feet in the newly developed areas to about 10 feet along the south side of the playa (fig. 4). The water level in well (D-14-26)20 (fig. 5) declined about 5 feet from spring 1958 to spring 1959, about 18 feet from spring 1954 to spring 1959, and about 22 feet from spring 1949 to spring 1959. The depth to water in the Kansas Settlement area in the spring of 1959 ranged from 30 to about 230 feet below the land surface.

The water level in well (D-14-23)36 (fig. 5), outside the cultivated area on the west side of the Willcox playa, has fluctuated slightly during the 17 years of record.

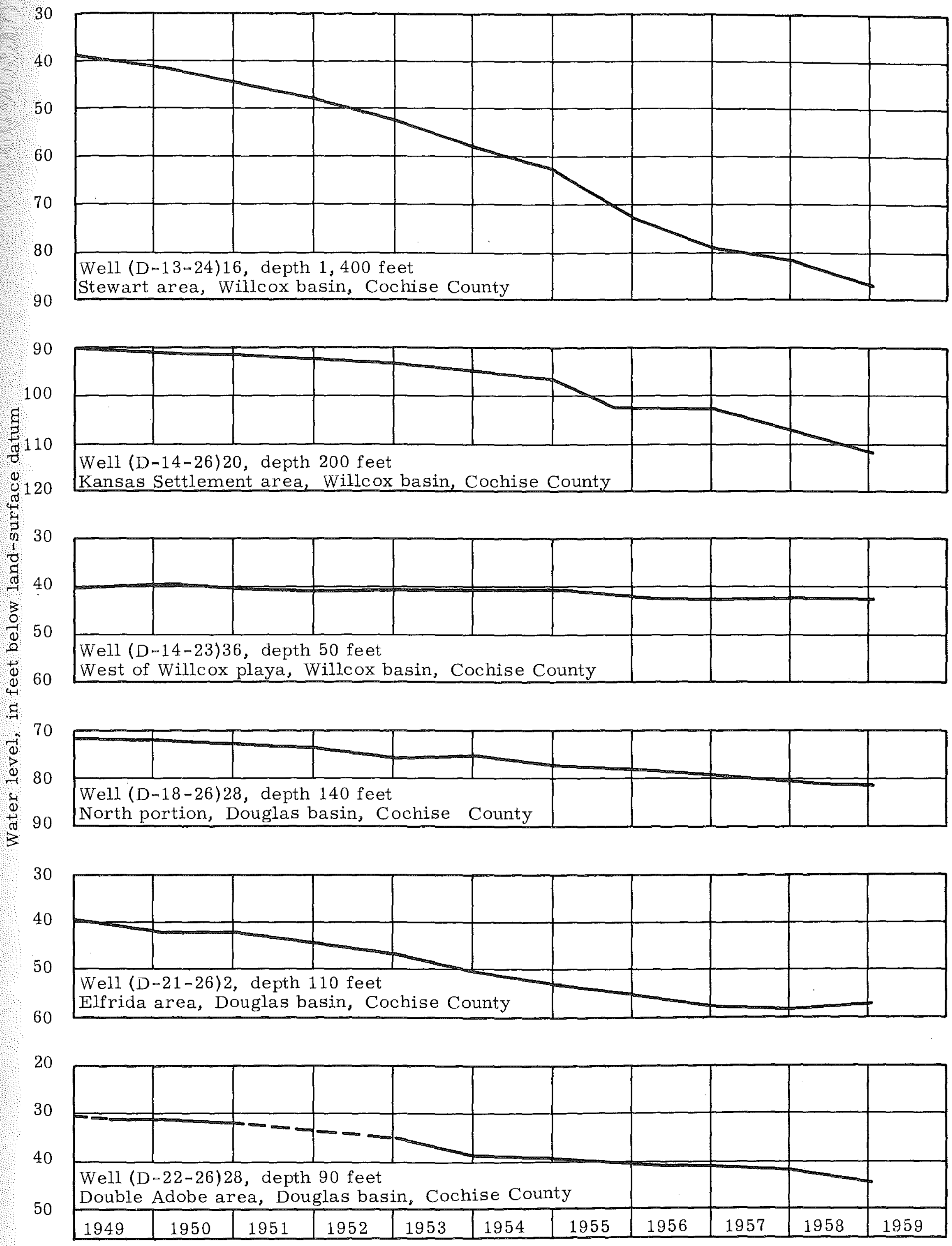


Figure 5.--Water levels in selected wells in the Willcox and Douglas basins, Cochise County.

Douglas basin

This area is south of the Willcox basin in the southern part of the Sulphur Spring Valley. It is separated from the Willcox basin by the surface-water drainage divide formed by a series of buttes and ridges; Six-Mile Hill, Township Butte, and Turkey Creek Ridge are the most prominent. Along the east side are the Chiricahua, Pedregosa, and Perilla Mountains; on the south is the International Boundary; and on the west are the Mule and Dragoon Mountains. The basin is about 40 miles long, 30 miles wide and includes an area of about 1,200 square miles. The altitude ranges from 4,400 feet in the vicinity of the drainage divide in the north to about 3,900 feet at the International Boundary. The cultivated areas are centered along Whitewater Draw which heads in the Chiricahua Mountains and enters the main part of the valley around the northern end of the Swisshelm Mountains. The channel loses its identity in the cultivated lands northeast of Elfrida, but reappears southwest of McNeal, and trends southward into Mexico. Whitewater Draw is a perennial stream in the 2-mile reach immediately north of the International Boundary. This surface flow is caused by the stream channel intersecting the water table. The direction of ground-water movement in this basin is southward toward Douglas and Mexico. The gradient from Pearce to Douglas, a distance of about 40 miles, averages slightly less than 10 feet per mile. In the area near Douglas, the gradient is a little steeper and is influenced by Whitewater Draw. The pumping in the basin has not greatly influenced the ground-water movement, although there is a slight flattening of the water table about 15 miles northwest of Douglas.

In the Douglas basin water-level fluctuations for the period spring 1958 to spring 1959 ranged from a rise of about 4 feet to a decline of nearly 6 feet, and for the 5-year period spring 1954 to spring 1959 (fig. 6) from no change to a decline of 15 feet. The water level in well (D-18-26)28 (fig. 5), in the northern part of the basin, declined about 1 foot from spring 1958 to spring 1959, about 6 feet from spring 1954 to spring 1959, and about 10 feet from spring 1949 to spring 1959. The water level in well (D-21-26)2 (fig. 5), in the center of the heavily pumped Elfrida-McNeal area, rose about 1 foot from spring 1958 to spring 1959. This rise is probably due to less pumping last year because of an abundance of rainfall. For the 5-year period spring 1954 to spring 1959 the water level in this well declined about 6 feet, and about 17 feet from spring 1949 to spring 1959.

The water level in well (D-22-26)28 (fig. 5), in the Double Adobe-Douglas area, declined about 2 feet from spring 1958 to spring 1959, about 6 feet for the 5-year period spring 1954 to spring 1959, and about 14 feet from spring 1949 to spring 1959. The depth to water in the Douglas basin in spring 1959 ranged from 40 to 130 feet but in most wells the water levels were less than 100 feet below land surface.

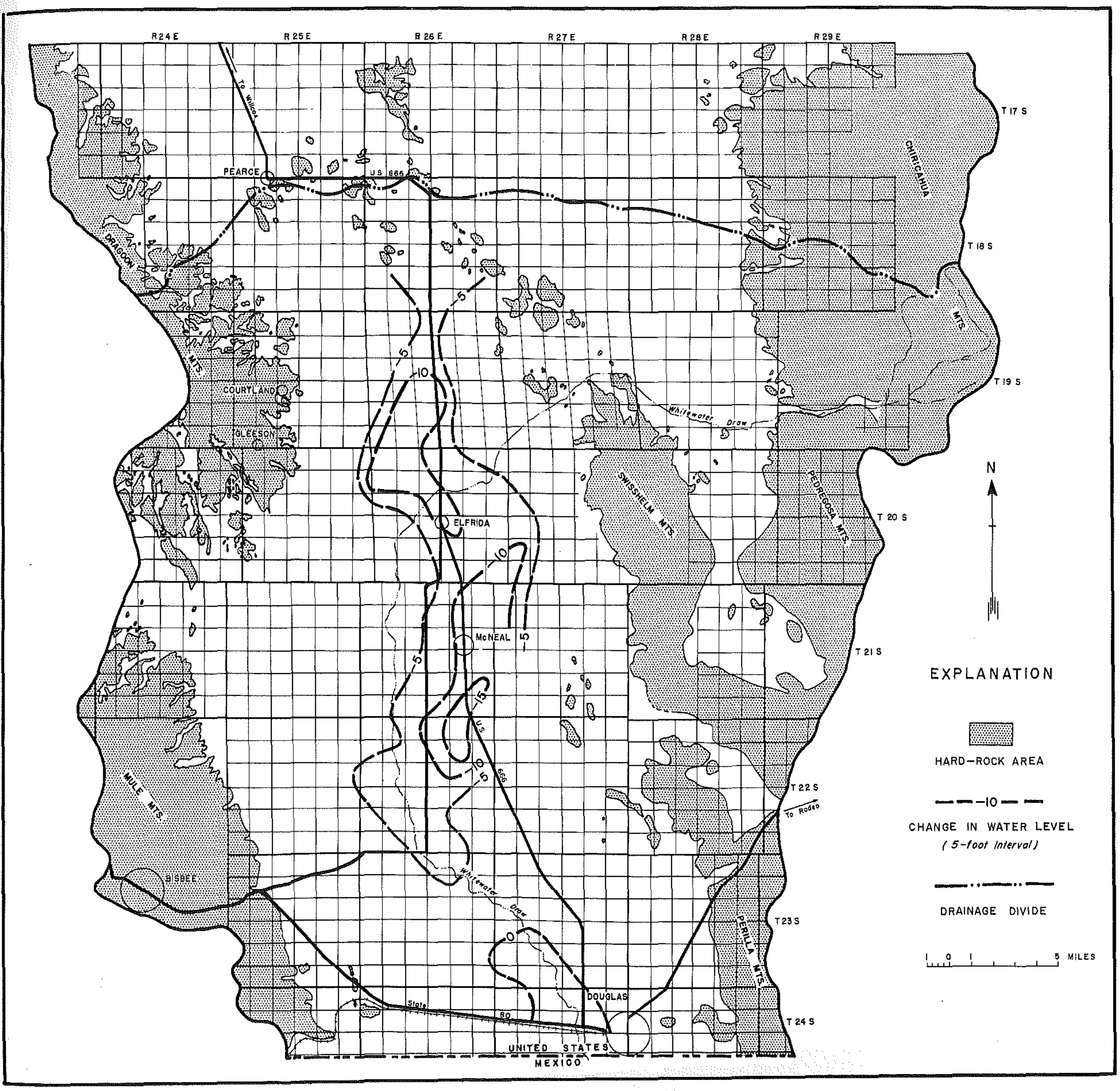


Figure 6.--Map of Douglas basin, Cochise County, Arizona, showing change in ground-water level from spring 1954 to spring 1959

Bowie-San Simon area

The Bowie area is on the western slope of the San Simon Valley in the vicinity of the town of Bowie, and the San Simon area is near the town of San Simon on the eastern side of the valley. The San Simon basin is part of a structural trough lying between two parallel chains of mountains. The Peloncillo Mountains lie to the east and the Chiricahua, Dos Cabezas, and Pinaleno Mountains to the west. This valley trends northwest, and extends from the vicinity of Rodeo, N. Mex. to the Safford Valley and the Gila River. There are approximately 1, 200 square miles in the Bowie-San Simon area of this valley. Altitudes range from 3, 350 to 4, 000 feet.

The general movement of ground water in this valley is from the divide near Rodeo, N. Mex., northwestward down the valley, to Safford and the Gila River. Ground water moves also from the bordering mountain ranges toward the axis of the valley. In the Bowie area, the movement is influenced by the Dos Cabezas Mountains and is northeastward toward the center of the valley. San Simon is at the axis of the valley adjacent to the main surface drainage of San Simon Creek, and the ground-water movement is toward the northwest.

Forty water-level measurements were made in this basin during the spring of 1959. The depth to water ranged from about 100 to 340 feet in the vicinity of Bowie and from about 20 to 60 feet in the artesian aquifers near San Simon. In the Bowie area, water-level fluctuations for the period spring 1958 to spring 1959 ranged from a rise of about 4 feet to a decline of more than 30 feet. For the 5-year period spring 1954 to spring 1959 declines ranged from about 35 feet to more than 80 feet in the irrigated areas. The water level in well (D-13-29)18 (fig. 7) declined about 6 feet during the last year. For the 5-year period the decline was about 65 feet. The major part of the decline of the water table started in 1952 when irrigation pumpage was greatly increased.

In the San Simon area water-level fluctuations for the period spring 1958 to spring 1959 ranged from a rise of about 4 feet to a decline of more than 13 feet. For the 5-year period spring 1954 to spring 1959 water-level fluctuations ranged from a rise of about 10 feet to a decline of more than 24 feet. The water level in well (D-14-31)3 (fig. 7) declined about 1 foot from spring 1958 to spring 1959. For the 5-year period spring 1954 to spring 1959 the water level in this well declined about 14 feet and more than 32 feet since spring 1949.

Upper San Pedro valley

The upper San Pedro basin is defined as the drainage area of the north-flowing San Pedro River between the International Boundary on the south and the narrows at the Tres Alamos dam site, about 8 miles north

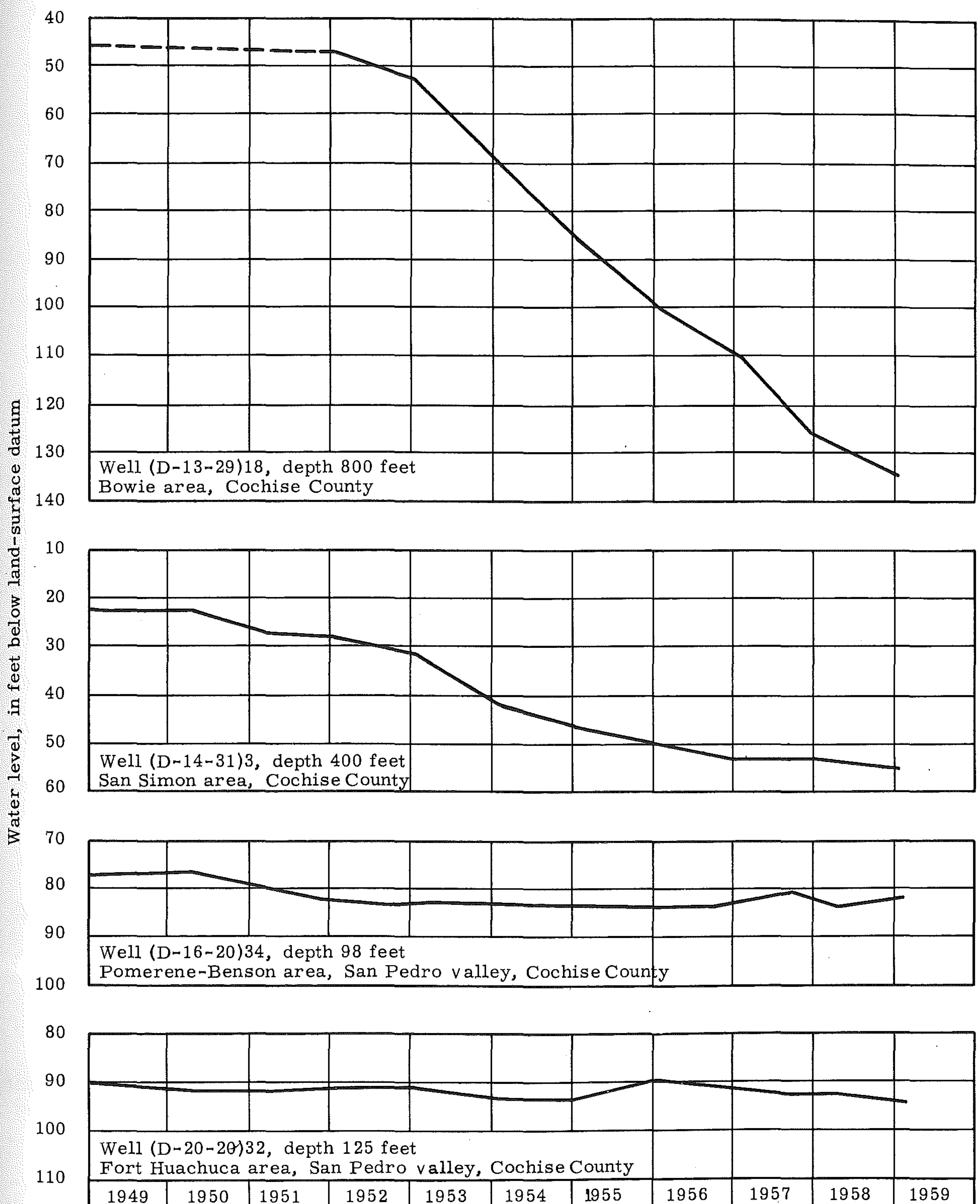


Figure 7.--Water levels in selected wells in the Bowie-San Simon area and upper San Pedro basin, Cochise County.

of the town of Pomerene, Ariz. The east boundary is the drainage divide extending from the southern end of the Winchester Mountains, southward through the Little Dragoon, Dragoon, and Mule Mountains. The west boundary is the drainage divide between the San Pedro and Santa Cruz Rivers along the Rincon, Whetstone, and Huachuca Mountains.

The direction of the ground-water movement is similar to the land-surface drainage—the ground-water divide is in Mexico and the water moves to the north, similar to the San Pedro River. Water also moves toward the center of the valley from the bordering mountains.

Water-level fluctuations ranged from a rise of about 8 feet to a decline of nearly 5 feet for the period spring 1958 to spring 1959, and for the 5-year period spring 1954 to spring 1959 rises in water levels ranged from 1 foot to about 9 feet. The upper San Pedro valley is undeveloped and pumpage is at a minimum. The general rise of the water table during the last 5 years is attributed to increased precipitation and streamflow in the upper San Pedro valley. The water level in well (D-16-20)34 (fig. 7) near Pomerene rose about 1 foot from spring 1958 to spring 1959 and declined about 5 feet since the spring of 1949. The water level in well (D-20-20)32 (fig. 7) declined about 1 foot from spring 1958 to spring 1959, and declined about 4 feet since the spring of 1949. The depth to water in the spring of 1959 ranged from 10 to more than 300 feet below land surface. The depths to water in the wells adjacent to the San Pedro River are less than 100 feet.

Coconino County

In parts of Coconino County wells less than 100 feet deep yield limited supplies of water. Water levels in these wells are readily affected by precipitation and in some localities the shallow wells are not dependable during periods of drought. In the central part of the county, particularly near Flagstaff, wells more than 1,000 feet deep may yield small to moderate amounts of water. Short distances away, other wells may yield little or no water. The success of these wells depends on the local geology and structure. North of Williams and Flagstaff, the Colorado River and Grand Canyon intercept the water table and possibilities of ground-water development are generally poor, with little or no yield of water to wells. However, in some parts of this region, structural conditions may be favorable for successful wells. East of the Little Colorado River in the Tuba City area, wells from 200 to 700 feet deep yield small to moderate amounts of water. Water levels in shallow wells in the vicinity of Williams rose less than 1 foot during 1958, and depth to water in these wells ranged from about 2 to 6 feet below land surface. In the Flagstaff area, water-level fluctuations ranged from a rise of about 6 feet to a decline of less than 1 foot. The hydrograph of well (A-22-6)26 (fig. 8) illustrates fluctuations in a shallow perched water-table well near Flagstaff.

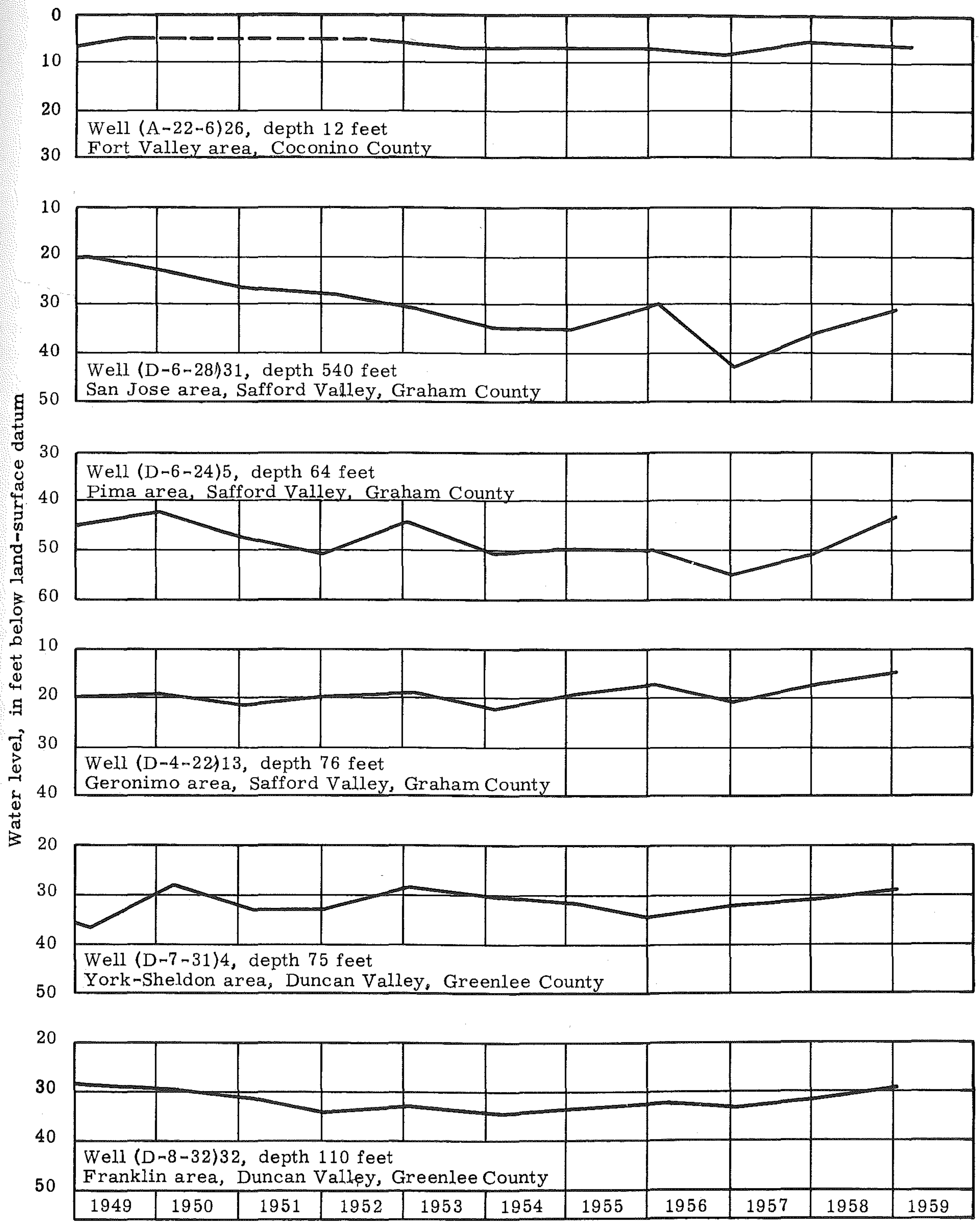


Figure 8. --Water levels in selected wells, Coconino, Graham, and Greenlee Counties.

Water levels in the 4 deep wells drilled for the city of Flagstaff are between 1,050 and 1,250 feet below land surface. There has been little fluctuation in the water level in these wells from 1956 to 1959. The wells yield from 200 to 500 gpm and are an important source of water for the city.

Gila County

The mountainous terrain of Gila County is probably unfavorable for the storage of large amounts of ground water. The principal streams in the county are the Salt River and Tonto Creek, which drain into Roosevelt Lake. The lake and parts of Tonto Creek are underlain by alluvial deposits which store ground water. The only outlet for water from this lake is by regulated surface flow at Roosevelt Dam. In the southern part of the county, the tributaries of the San Carlos River east of Globe consist of alluvial deposits. The movement of ground water is in the same direction as the surface flow—toward San Carlos Lake.

In Gila County, ground-water levels are measured in and near the city of Globe and in the San Carlos Valley of the San Carlos Indian Reservation. The Globe area is on the northern slope of the Pinal Mountains; Pinal Creek and Icehouse Canyon Creek are the two major streams in this area. Most of the wells are shallow, and the water levels fluctuate in response to surface flow and local domestic pumping. No particular pattern of rise or decline could be determined. Above-average precipitation occurred in the spring of 1958, and in the winter of 1958-59 there was below-average rainfall. The water levels were above average in the spring of 1959 but were slightly lower than the previous year. The San Carlos Valley is in a trough traversed by the San Carlos River, which flows southward to the San Carlos Reservoir. The basin is bounded on the east by Natanes Mountain; on the south by the Turnball Range; on the west by the eastern ridges of the Mescal, Pinal, and Apache Mountains; and on the north, in part, by the Gila Range. Along the flood plain of the San Carlos River about 1,000 acres have been developed for irrigation. The wells are shallow in depth and are recharged by the summer floods of June and July. No decline in water level has been recorded.

Graham County

Most of the water-level measurements made in Graham County were in the Safford Valley, which lies entirely within the county. This valley is bounded on the north by the Gila Mountains, on the east by the Peloncillo Mountains, and on the southwest by the Pinaleno and Santa Teresa Mountains. The basin is about 50 miles long and 15 to 20 miles wide. The cultivated lands lie along the Gila River and are 1/2 to 3-1/2 miles from the river.

The Safford Valley is an extension of the San Simon Valley and the ground water moves in a northwestward direction along the valley toward Coolidge Dam. Most of the recharge to the inner Safford Valley probably comes from the Gila River where it enters the alluvial-filled valley about 15 miles east of Safford. Although the diversion canals take all or most of the low flow, leakage from these canals recharges the alluvium. During periods of high runoff, the canals divert only a small part of the surface flow and the surplus water in the river recharges the porous inner-valley fill. At the end of the valley, this underflow discharges into San Carlos Lake. There has been increased interest in drilling wells, ranging in depth from 200 to 1,000 feet, into the older alluvium on the sides of the valley. Many of the wells yield warm water under artesian pressure.

From spring 1958 to spring 1959 the water levels in the Safford Valley rose from about 2 feet to more than 12 feet. This rise in the water table is attributed to recharge from streamflow of the Gila River. Discharge of the Gila River above Safford Valley during 1958 was above normal, and most of the monthly discharges of the river compare closely to the record highs of 1941. In March 1958, the Gila River had the highest daily discharge since records began in 1914.

The water level in well (D-6-28)31 (fig. 8), at the head of the valley, rose about 4 feet from spring 1958 to spring 1959, although it was about 11 feet lower in the spring of 1959 than in the spring of 1949. The water level in well (D-6-24)5 (fig. 8) in the cultivated area below Pima rose about 6 feet from spring 1958 to spring 1959, and was about the same in the spring of 1959 as in the spring of 1949. The water level in well (D-4-22)13 (fig. 8) in the downstream part of the Safford Valley rose about 3 feet from spring 1958 to spring 1959, and about 5 feet from spring 1949 to spring 1959. In the spring of 1959, the depths to water in the Safford Valley ranged from about 15 to 60 feet below the land surface and were comparable to the water levels in the spring of 1950. In the spring of 1959, the low flow of the Gila River reduced the amount of surface water available for diversion for agricultural irrigation, and ground-water pumping was started about 1 month earlier than in previous years. The increased withdrawals of ground water will substantially lower the water table in the inner valley this summer if there is little recharge from the Gila River.

Greenlee County

Most of Greenlee County consists of mountains and forests, and the developed area is in the southern part of the county. This area is adjacent to the Gila River and is called the Duncan basin. The basin is a part of a structural trough that extends northwestward from the vicinity of Lordsburg, N. Mex. The eastern margin of the Duncan basin is set arbitrarily at the Arizona-New Mexico State line where the Gila River enters Arizona, and on the west the basin terminates about a mile upstream from the junction of the San Francisco and Gila Rivers. The basin is enclosed on the northeast by the Steeple Rock Mountains and on the southwest by the Peloncillo Mountains. Water-level rises from spring 1958 to spring 1959 were from about 1 foot to more than 6 feet. For the 5-year period spring 1954 to spring 1959 the water table rose from about 2 to more than 14 feet. During 1958 there was a large amount of precipitation, and the runoff of the Gila River in the Duncan Valley was above normal. In the spring of 1959 the water level in well (D-7-31)4 (fig. 8) in the York-Sheldon area near the Gila River was about 2 feet higher than in the spring of 1958; this was about 1 foot higher than in the spring of 1954, and about 7 feet higher than in the spring of 1949. The water level in well (D-8-32)32 (fig. 8) in the Franklin area rose about 3 feet from spring 1958 to spring 1959, but declined about 1 foot from spring 1949 to spring 1959. The depth to water in the Duncan basin ranges from about 10 to nearly 70 feet below the land surface.

Maricopa County

In 1958 about 516,700 acres were under irrigation in Maricopa County (Seltzer, 1959), which accounted for about 40 percent of the total irrigated acreage in Arizona. The five principal areas of irrigation in Maricopa County are (1) Salt River Valley, (2) Gila Bend area, (3) Waterman Wash area, (4) Harquahala Plains area, and (5) Dendora area. The Salt River Valley is by far the largest in agricultural development.

Salt River Valley

The Salt River Valley comprises the valley lands in the vicinity of Phoenix and tributary valleys such as Paradise Valley and Deer Valley, as well as lands west of the Hassayampa River and the lower reaches of Centennial Wash. Most of the area is drained by the Salt, Agua Fria, and Hassayampa Rivers, but a small part on the east and south is drained by the Gila River. The area is bounded on the north by the Hieroglyphic Mountains and Black Mountain; on the northeast and east by the McDowell, Usery, and Superstition Mountains; on the south by the Gila River to the Santan Mountains, then by the Maricopa-Pinal County line to the Sierra Estrella Mountains; and on the southwest and west by the Buckeye Hills, Gila Bend Mountains, Saddle Mountain, and an arbitrary line from the Big Horn Mountains to the Hassayampa River.

The Salt River Valley is subdivided into the following areas: (1) Queen Creek-Higley-Gilbert-Magma area, (2) Tempe-Mesa-Chandler area, (3) Phoenix-Glendale-Tolleson area, (4) Paradise Valley area, (5) Litchfield-Beardsley-Marinette area, (6) Liberty-Buckeye-Hassayampa area, (7) lower Hassayampa-Tonopah area, and (8) lower Centennial-Arlington area. Although the Magma subarea lies in Pinal County, it is included in the discussion of Maricopa County because it is a part of the Salt River Valley.

In the Salt River Valley the direction of ground-water movement conforms in general to the direction of slope of the land surface. In some places the natural direction of movement has been reversed and ground water is now moving toward major cones of depression that have resulted from heavy withdrawals. As of the spring of 1959 there were three such depressions in the area—northeast of Gilbert, in Deer Valley, and northwest of Litchfield Park. Most of the ground water in the eastern part of the Salt River Valley flows toward the depression northeast of Gilbert. In the central part of the valley most of the ground water flows to the west but some of it flows toward the depression in Deer Valley. In the northwestern section of the valley, the ground water generally flows southward toward the depression northwest of Litchfield Park but some water flows toward the depression in Deer Valley. In the Liberty-Buckeye-Hassayampa area the water generally flows to the southwest, but some water flows north toward the depression near Litchfield Park. In the area west of the Hassayampa River the ground water flows southward toward Gillespie Dam.

<u>Queen Creek-Higley-Gilbert-Magma area.</u> --During 1958 most of the water levels in wells in the Queen Creek-Higley-Gilbert-Magma area continued to follow the previously observed downward trend of the water table in this area. In the period spring 1958 to spring 1959 water-level fluctuations in the area ranged from a decline of 17 feet in a well near Magma to a rise of 7 feet in a recently abandoned irrigation well southeast of Chandler. In the 5-year period spring 1954 to spring 1959 water-level changes ranged from a rise of 7 feet to a decline of more than 60 feet (fig. 9). The maximum declines in 5 years occurred at Magma, and there was about 30 feet of decline at Gilbert, Higley, and Queen Creek. The minimum declines during the 5-year period spring 1954 to spring 1959 were observed in the southwestern and eastern parts of the area.

In the part of the area east of the Roosevelt Water Conservation District Canal, declines for the period spring 1958 to spring 1959 were as much as 11 feet as shown by the hydrograph for well (A-1-6)23 (fig. 10). Declines in the vicinity of Magma averaged about 13 feet for the period spring 1958 to spring 1959. As in previous years the water table in the southwestern part of this area declined but little and in some places there were rises of as much as 4 feet. Ground water is used only to supplement surface-water irrigation in this part of the area, and seepage from the canals influences the water-table fluctuations. The hydrograph of well (D-2-6)31 (fig. 10) shows the effects of this seepage.

The water level in well (D-2-10)8 (fig. 10), in the extreme eastern part of the area, had a minimum decline because there is no pumping of ground water for irrigation nearby. In the spring of 1959 water levels in the cultivated parts of the Queen Creek-Higley-Gilbert-Magma area ranged from 422 feet below land surface in a well south of Granite Reef Dam to 57 feet below land surface in a well 9 miles southwest of Higley. The depths to water near Magma were about 300 feet, at Higley about 175 feet, at Gilbert about 200 feet, and at Queen Creek about 250 to 300 feet below land surface.

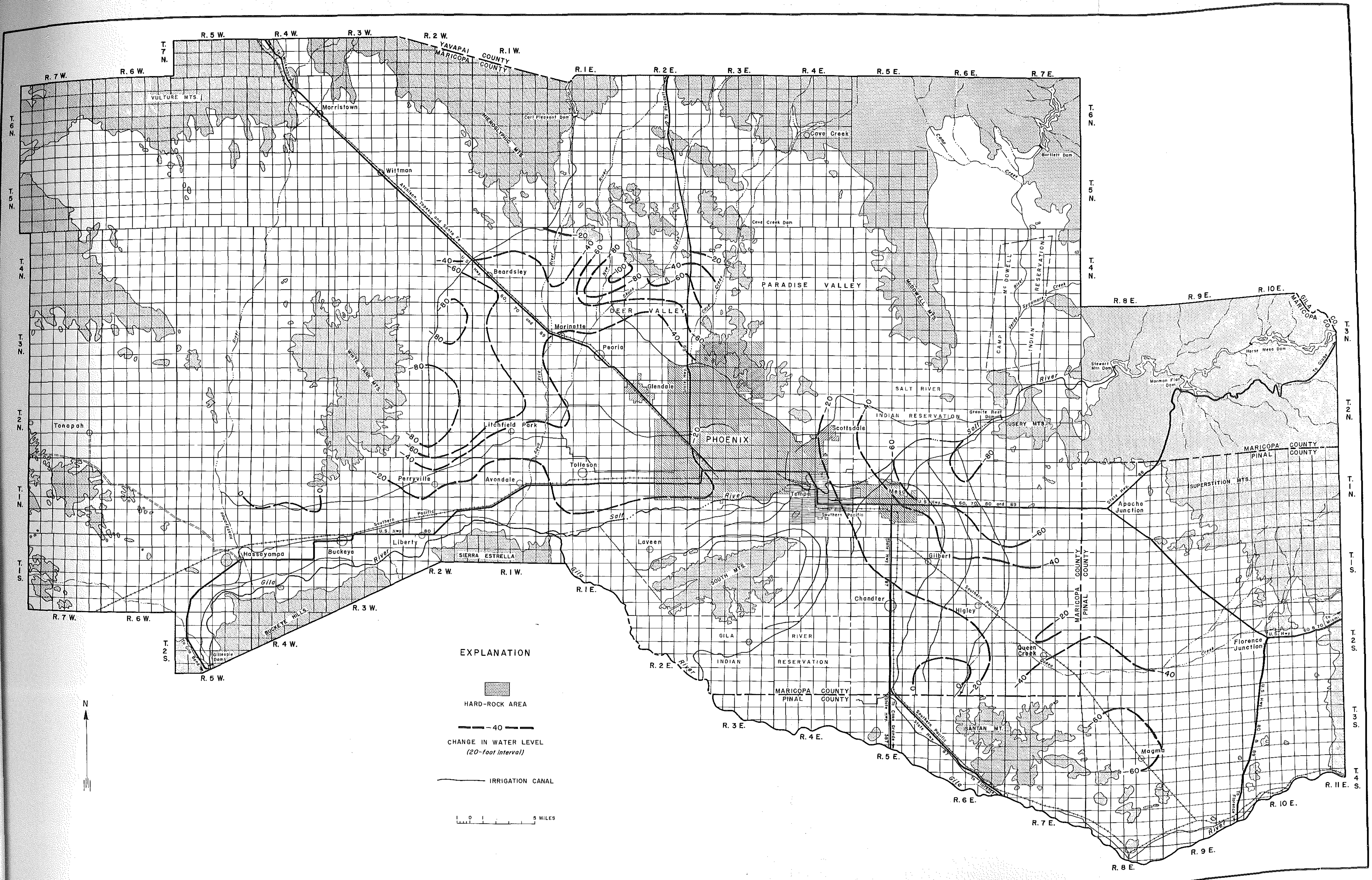


Figure 9.--Map of Salt River Valley area, Maricopa and Pinal Counties, Arizona, showing change in ground-water level from spring 1954 to spring 1959

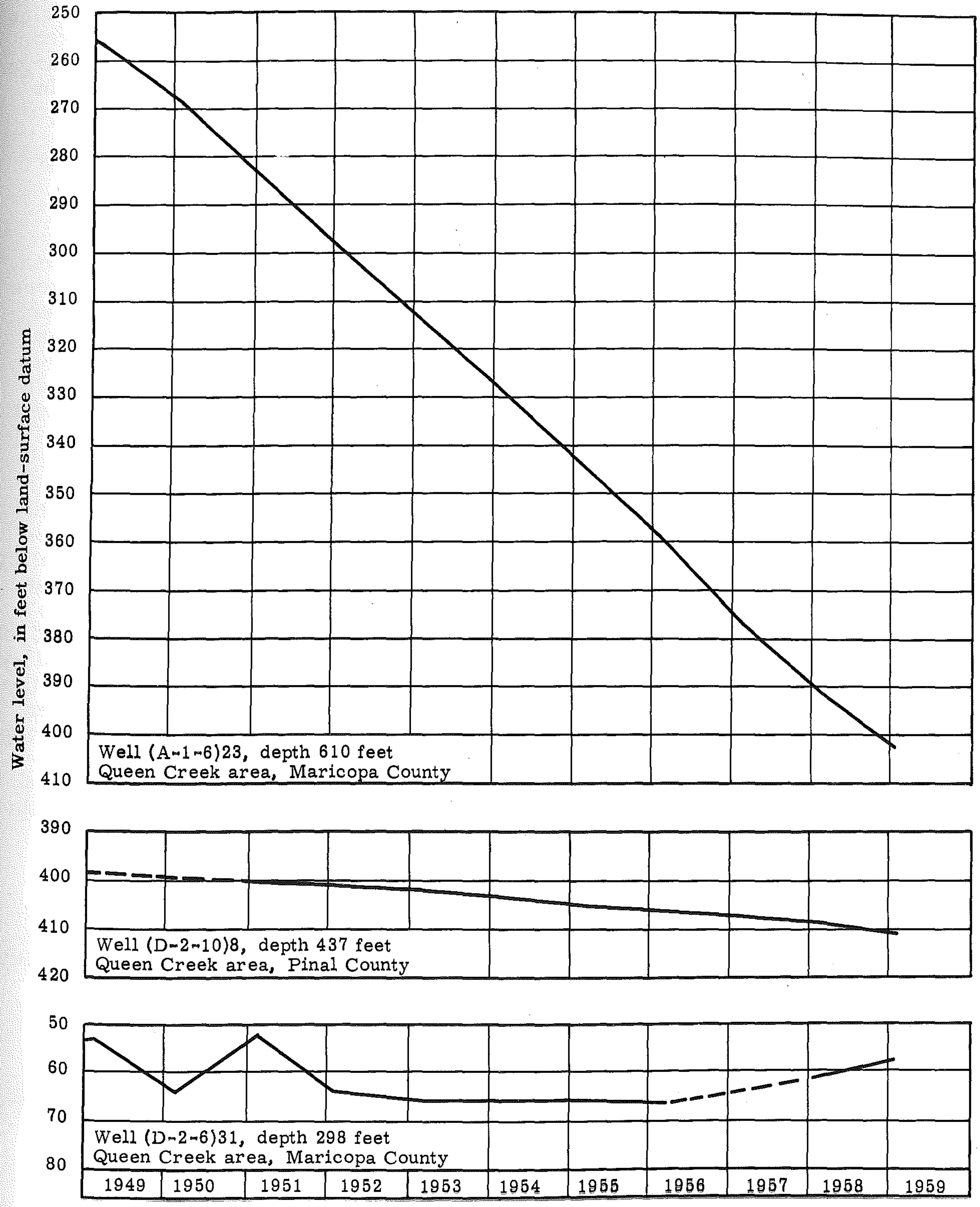


Figure 10.--Water levels in selected wells in Queen Creek area, Maricopa and Pinal Counties.

Tempe-Mesa-Chandler area.--In the period spring 1958 to spring 1959, water-level fluctuations in the Tempe-Mesa-Chandler area ranged from no decline to a decline of about 17 feet. For the most part, the larger declines occurred northeast of Mesa where pumping is concentrated. In the area west of Chandler water-level declines averaged about 3 feet, whereas south of Chandler declines ranged from less than 1 foot to as much as 10 feet. The hydrograph for well (A-2-4)26 (fig. 11) shows the trend of the continuous decline in water levels northwest of Mesa.

During the 5-year period spring 1954 to spring 1959 the water table declined about 80 feet northeast of Mesa, from 40 to 60 feet in Mesa, and about 20 feet in Tempe. Declines throughout the rest of the area were progressively less to the south, and were about 10 feet south of Chandler (fig. 9). In the spring of 1959 the depth to water below land surface was from 250 to 300 feet northeast of Mesa, 150 feet at Chandler, from 175 to 200 feet at Mesa, and less than 100 feet at Tempe. The shallowest water level measured in the area was 60 feet below land surface in an abandoned irrigation well 1 mile south of Tempe.

Phoenix-Glendale-Tolleson area.--During the period spring 1958 to spring 1959 water-level fluctuations ranged from rises of 6 feet to declines of more than 34 feet. The greatest declines occurred in Deer Valley where all irrigation water is obtained from ground-water sources. Most of the recorded declines in Deer Valley during the period spring 1958 to spring 1959 exceeded 12 feet and some were more than 20 feet. The hydrograph for well (A-3-2)12 (fig. 11) shows declines typical of the Deer Valley area. In the area south of the Arizona Canal in the Salt River Project, the water-table declines decreased in the direction of Tolleson and the water level in well (A-1-1)6 (fig. 12) rose about 2 feet from spring 1958 to spring 1959. Ground water is used in the Salt River Project to supplement surface-water supplies; therefore, ground-water demands within the project are not as great as elsewhere. Water-table rises were measured in wells in northern Phoenix, where seepage from the Arizona Canal serves to partially replenish ground-water supplies.

During the 5-year period spring 1954 to spring 1959 water-level fluctuations ranged from almost no change to declines of 104 feet (fig. 9). As in the period 1953 to 1958, the largest declines occurred in Deer Valley between Skunk Creek and New River. Along the mountains to the north and south of Phoenix the water-level declines were small because of canal seepage and lack of concentrated pumping. The 5-year declines in the center of the Phoenix-Glendale-Tolleson area were about 15 to 40 feet. In the spring of 1959 depths to water below land surface ranged from 50 to 150 feet in Phoenix, 175 to 200 feet in Glendale, 150 feet in Tolleson, and about 300 to 425 feet in Deer Valley. In north Phoenix, adjacent to the Arizona Canal, water levels were less than 20 feet below the land surface.

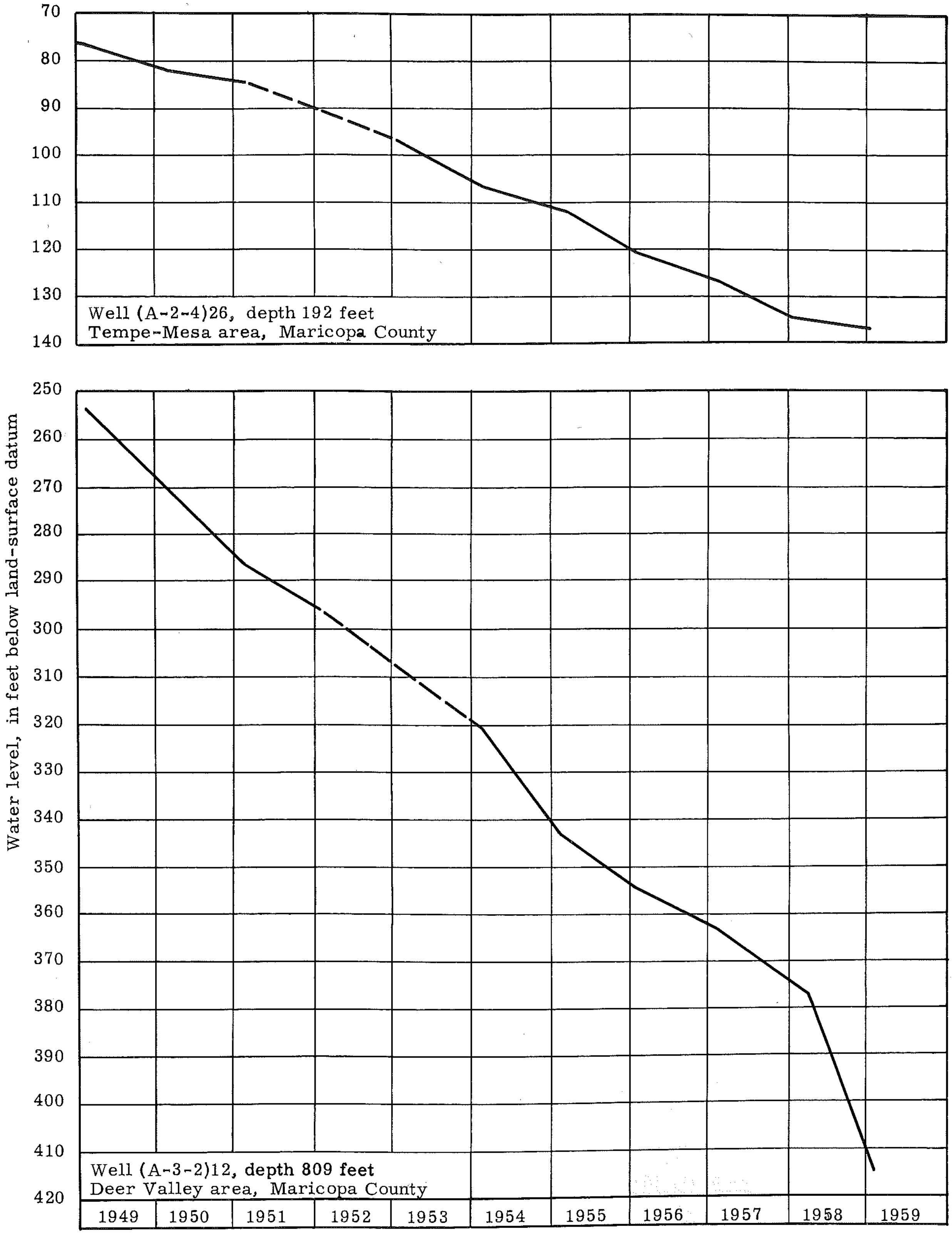


Figure 11.--Water levels in selected wells in Tempe-Mesa and Deer Valley areas, Maricopa County.

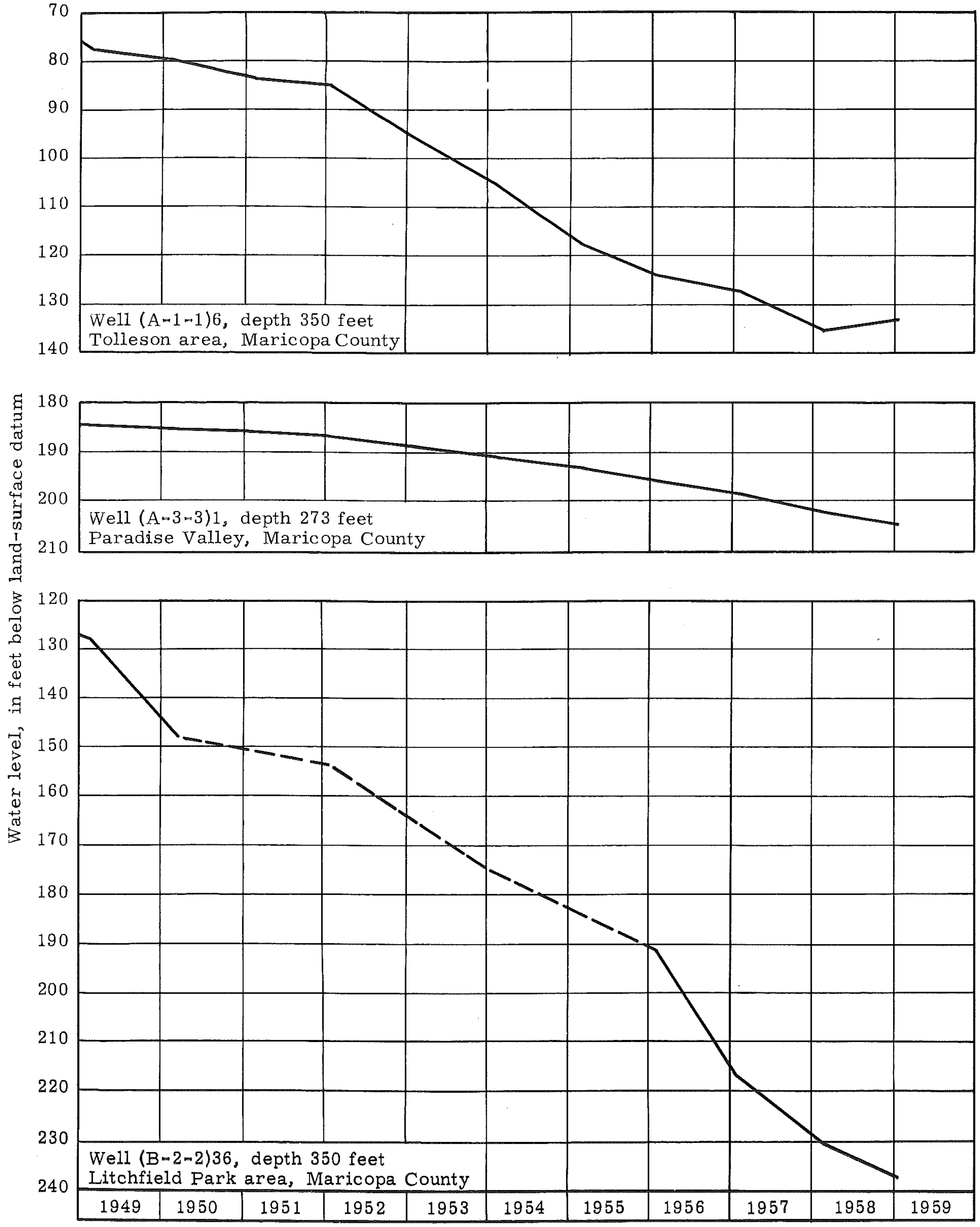


Figure 12.--Water levels in selected wells in Tolleson, Paradise Valley, and Litchfield Park areas, Maricopa County.

Paradise Valley area. --There were minor water-table fluctuations in the Paradise Valley area in the period spring 1958 to spring 1959. The greatest decline in water level was 8 feet in an irrigation well 2 miles north of Scottsdale. The only rise in water level in the area was less than 1 foot in an abandoned oil test hole away from the cultivated area. Water levels in most of the observation wells in the area declined about 2 feet during the period spring 1958 to spring 1959. Pumping of ground water for agricultural purposes in Paradise Valley has been minor compared to pumping in other parts of the Salt River Valley. For the 5-year period spring 1954 to spring 1959 water-table declines ranged from 2 to 16 feet, and therefore do not fall within the contour interval of the decline map (fig. 9). The hydrograph for well (A-3-3)1 (fig. 12) shows a continuous downward trend of the water table, although the decline is of small magnitude. In the spring of 1959 the depth to water in most of the Paradise Valley area ranged from 175 to 438 feet below the land surface and averaged about 250 feet, although near Cave Creek Dam a water level of 30 feet below the land surface was measured.

Litchfield Park-Beardsley-Marinette area. --Ground water constitutes the major source of water available for agriculture in the Litchfield Park-Beardsley-Marinette area. In the period spring 1958 to spring 1959 water-level declines ranged from about 7 feet near Litchfield Park to more than 15 feet in the northern part of the area. The water level in well (B-2-2)36 (fig. 12), in a heavily pumped area, has declined more than 120 feet since 1947.

During the 5-year period spring 1954 to spring 1959 water-level declines ranged from more than 90 feet in the northeastern part of the area to about 80 feet in the western part (fig. 9). In the southern part of the area water levels declined about 20 feet. The maximum declines occurred in areas of deep water levels. In the spring of 1959 the depth to water in the northeastern part of the area was about 348 feet below land surface; along the White Tank Mountains the depth to water was about 423 feet. The White Tank Mountains are an effective barrier to ground-water movement from the west into the area east of the mountains and west of Litchfield Park. The maximum declines in this area are caused partly by the cones of depression having reached the impermeable area of the White Tank Mountains. In the spring of 1959 the minimum depth to water was 130 feet in an irrigation well along the canal southwest of Litchfield Park. In the Litchfield Park area, the depth to water is from 130 to 330 feet below land surface, in Marinette from 250 to 350 feet, and at Beardsley about 275 feet.

Liberty-Buckeye-Hassayampa area. --Water-level fluctuations in this area from spring 1958 to spring 1959 ranged from a rise of about 1 foot along the Hassayampa River to a decline of about 8 feet north of Perryville. Water levels in most of the Liberty-Buckeye-Hassayampa area follow the same downward trend as in other areas in the Salt River

Valley. However, the rate of decline is much less because the shallow water table is continually recharged from irrigation water applied to cultivated land upstream. The hydrograph for well (B-1-3)32 (fig. 13) shows the typical water-level trend for this area. During the 5-year period spring 1954 to spring 1959 the water level in this well declined about 2 feet, and about 13 feet during the 10-year period spring 1949 to spring 1959. The water levels in the Liberty-Buckeye-Hassayampa area fluctuated slightly during the 5-year period spring 1954 to spring 1959 (fig. 9). The water levels in the area west of Buckeye rose slightly, while in the vicinity of Perryville they declined more than 20 feet. In the spring of 1959 the depths to water below land surface in irrigation wells ranged from about 31 feet southwest of Buckeye to about 212 feet north of Perryville.

The depth to water in the Hassayampa area is about 80 feet below land surface; near Buckeye the water table ranges from 80 feet to about 150 feet below land surface. At Liberty and adjacent to the Gila River south to the Gillespie Dam, water levels are less than 50 feet below land surface.

Lower Hassayampa-Tonopah area.--The steady decline of water levels in the lower Hassayampa-Tonopah area began about 1955, due to the increase in the pumping of ground water for agriculture, and has continued to the present time. Most of the water levels in the lower Hassayampa-Tonopah area declined from 5 to 10 feet during the period spring 1958 to spring 1959 and there were declines in excess of 20 feet in the Tonopah area. The hydrograph for well (B-2-7)26 (fig. 13) is a typical example of the position of the water table in the basins of Arizona before and after agricultural development. In the spring of 1959, water levels in the area ranged from about 13 feet below land surface in an abandoned well near the Hassayampa River to more than 230 feet near Tonopah.

Lower Centennial-Arlington area.--Ground-water levels in the lower Centennial-Arlington area declined slightly during 1958. Generally water-level declines ranged from less than 1 foot to about 6 feet, although there were several small rises in water levels in wells along the Gila River. The greatest water-level declines occurred in irrigation wells in the cultivated areas in the lower part of T. 1 N., R. 6 W. In the spring of 1959, depths to water within the cultivated area ranged from about 23 feet near the junction of Centennial Wash and the Gila River to more than 220 feet in the lower part of T. 1 N., R. 6 W.

Gila Bend area

The Gila Bend area extends irregularly from Gillespie Dam on the Gila River to a point 36 miles downstream. The area is bounded by the Gila Bend Mountains and the Buckeye Hills on the north, the Maricopa

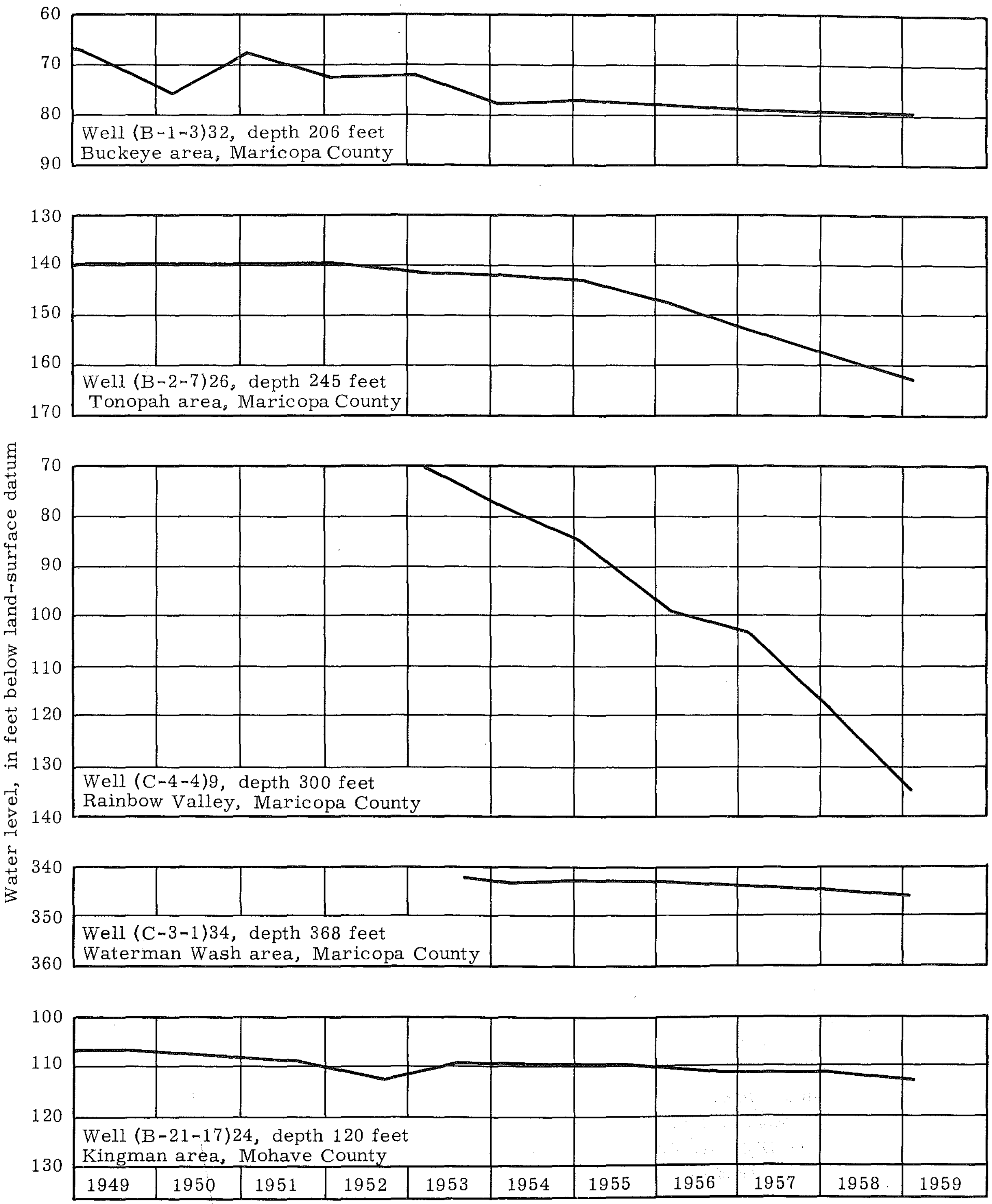


Figure 13.--Water levels in selected wells, Maricopa and Mohave Counties.

and Sand Tank Mountains on the east, the Sauceda Mountains on the south, and the Painted Rock Mountains on the west.

Ground water generally moves southward parallel to the Gila River. In the northern end of the basin a depression exists where continual pumping is diverting water into the Gillespie Canal. This water is used to irrigate land downstream near Theba. Ground water leaves the area in the western part of the basin through the narrows at Gila River Canyon at the north end of the Painted Rock Mountains and beneath the Sentinel lava flows at the southwestern end of the basin.

In the spring of 1959 about 125 irrigation wells were in operation. This is an increase of about 10 wells since 1958 and 35 wells since 1957. Most of the wells are in the northeastern part of the Gila Bend basin, known as Rainbow Valley.

During the period spring 1958 to spring 1959 the greatest water-level declines were in the Rainbow Valley area and ranged from about 3 to 16 feet. The water level in well (C-4-4)9 (fig. 13) in Rainbow Valley declined about 16 feet from spring 1958 to spring 1959 and declined about 55 feet during the 5-year period spring 1954 to spring 1959. In the western part of the Gila Bend basin, water-level fluctuations during the period spring 1958 to spring 1959 ranged from no change south of the Painted Rock Mountains to a decline of about 8 feet north of Theba. In the spring of 1959 the depth to water in irrigation wells ranged from about 50 feet below land surface along the flood plains of the Gila River to about 260 feet below land surface in the Rainbow Valley area.

Waterman Wash area

This area, drained by Waterman Wash, is bounded on the north by the Buckeye Hills and outliers of the Sierra Estrella, on the northeast and east by the Sierra Estrella and Palo Verde Mountains, on the south by the Haley Hills, and on the southwest and west by the Maricopa Mountains. The physiographic division between the Waterman Wash area and Rainbow Valley is a low alluvial ridge that extends northward from the Maricopa Mountains to the Buckeye Hills.

Most of the agricultural development and water-level declines are in the northern part of the Waterman Wash area. During the period spring 1958 to spring 1959 water-level declines ranged from about 1 foot to more than 10 feet, with the largest declines in the northern part of the basin. The southern part of the area has not been developed for agriculture and the principal use of ground water is for stock supplies. The hydrograph for well (C-3-1)34 (fig. 13) shows that development to the north is beginning to effect ground-water supplies in the southern part of the area. In the Waterman Wash area the depth to water in the spring of 1959 ranged from about 133 to 346 feet below land surface.

Harquahala Plains area

This area is a northwest-trending basin drained principally by Centennial Wash. It is bounded on the northeast by the Big Horn Mountains, on the northwest by the Harquahala and Little Harquahala Mountains, on the southwest by the Eagletail Mountains, and on the southeast by Saddle Mountain and the Gila Bend Mountains.

In the spring of 1959 about 60 irrigation wells were in use in the Harquahala Plains area as compared to about 30 during 1956. Most of the development is in the southeastern part of the area where the yields of the wells range from about 800 to 3, 200 gpm. In the northwest part of the basin wells yield about 600 to 1, 200 gpm. During the period spring 1958 to spring 1959 water-level declines in the Harquahala Plains area ranged from 3 to 20 feet; however, these measurements may not be indicative of the static water-level conditions in the area because of year-round pumpage. In the spring of 1959, depths to water below land surface ranged from about 29 feet in the extreme southeast to about 370 feet in the northwestern part of the Harquahala Plains.

During the summer of 1958 pumping lifts were measured in 15 wells in the southeast end of the valley. The greatest pumping lifts were 400 feet in a well 5 miles northwest of Saddle Mountain and 398 feet in a well 10 miles west of Saddle Mountain. In the area 6 miles west of the south end of Saddle Mountain, the pumping lifts in 5 wells were less than 250 feet and one lift was from 207 feet.

Mohave County

The areas of ground-water withdrawal in Mohave County are: (1) Along the Big Sandy River; (2) in the vicinity of Hackberry and Kingman; and (3) near Truxton. Some withdrawal of ground water occurs along the Colorado River south of Davis Dam but not enough data are available to permit any estimate of the amount of water used.

The Big Sandy Valley is drained by the Big Sandy River, which receives water from Trout, Burro, and Cottonwood Creeks and Little Sandy Wash, as well as many other washes. The area is more than 60 miles long and is bounded by the Hualapai, Peacock, Rawhide, and Artillery Mountains on the west, and the Cottonwood Cliffs, Aquarius Cliffs, and Aquarius Mountains on the east. Most of the agricultural development in the area is along the flood plains of the Big Sandy River.

Water levels in wells in the Big Sandy Valley fluctuated little from spring 1958 to spring 1959. These wells are shallow and water levels are readily affected by recharge from the Big Sandy River. In the spring of 1959, depths to water below land surface in this area ranged from about 11 feet near Wickieup to about 115 feet 12 miles upstream.

Ground-water pumping in the Hackberry and Kingman area is mostly for public supply. Water-level fluctuations near Kingman ranged from a rise of about 1 foot to a decline of about 1 foot. The water level in well (B-21-17)24 (fig. 13) indicates the trend in this area. In most of the wells near Hackberry the water level rose during the period spring 1958 to spring 1959—the water level in one well rose 7 feet. The depth to water below land surface in this area ranged from about 51 feet south of U. S. Highway 66 to about 510 feet near Antaris.

Three wells are used to irrigate land near Truxton. The period of record for these wells is too brief to indicate any definite trend of the water table. In spring 1959 the depth to water in a well at Truxton was about 146 feet below land surface, a rise of less than 1 foot since the spring of 1958.

Navajo County

Most of Navajo County lies within the Navajo and Hopi Indian Reservations. The principal crop in this area is corn, and irrigation water is usually obtained from small streams or springs. Only small amounts of ground water are pumped from wells. South of the Indian reservations, most of the ground water used for irrigation is from wells and the development is confined to the area along the Little Colorado River between Hay Hollow and Joseph City, and to the Snowflake-Taylor area. Nearly all the ground water used for irrigation in this area is obtained from the Coconino sandstone. South of the Little Colorado River, the quality of water from this aquifer is generally good but to the north the water is likely to be salty.

The regional dip of strata and the movement of ground water in the area is toward the north. Where the Coconino sandstone is not exposed at the surface, the water may be under artesian pressure and in topographically low areas, wells penetrating the Coconino sandstone may flow. In other areas, water levels may be as much as 160 feet below the land surface. The yields of 37 irrigation wells are reported to range from 400 to more than 3,000 gpm. According to a driller's report, a well 200 feet deep about 4 miles northwest of Woodruff produced 1,800 gpm with only 6 feet of drawdown from a static water level of 16 feet below the land surface. A well completed in April 1958 at Woodruff produces 1,800 gpm with 26 feet of drawdown from a static level of 45 feet below the land surface.

No trend in fluctuation of water levels has been established in the area, but during the drier part of the growing season of 1957, pump bowls were lowered in some wells in Hay Hollow because the water levels declined.

In the last year or two there has been an increased interest in obtaining more ground water for irrigation in Navajo County and several new wells have been drilled. Recently, large-diameter gravel-packed wells about 200 feet deep and yielding 800 to 1,000 gpm have been drilled adjacent to the Little Colorado River and the Rio Puerco. There is continued interest in agricultural expansion in the Goodwater area and between Holbrook and Winslow.

Pima County

Pima County consists of a series of alluvial valleys divided by several mountain ranges. The general trend of these physiographic features is in a north-south direction. The most important basins in the county are Altar, Avra, San Simon (Papago Indian Reservation) and Santa Cruz Valleys. At present, most of the development is in the Santa Cruz Valley in the eastern part of the county. This valley is arbitrarily called the upper Santa Cruz basin and extends from Mexico to the Rillito narrows (about 15 miles northwest of Tucson). The downstream part is called the lower Santa Cruz area and lies mostly in Pinal County, although the Avra-Marana area lies in Pima County. In Pima County, the upper Santa Cruz basin is bordered on the east by the Santa Catalina, Tanque Verde, Rincon, and the Santa Rita Mountains; on the west by the Tucson and Sierrita Mountains; and on the north by the Tortolita Mountains. The altitude ranges from about 3,000 feet at the Pima-Santa Cruz County line to about 1,900 feet at the Pima-Pinal County line.

The movement of the ground water in the upper Santa Cruz basin is northward toward the highly developed areas in the vicinity of Casa Grande. The Santa Cruz River forms the long axis of the basin and has an important effect on the occurrence and movement of the ground water because the river recharges the ground-water reservoir in Santa Cruz County. From Calabasas (9 miles north of Nogales) to Tucson, a distance of about 55 miles, the average ground-water gradient is about 20 feet per mile. This is about the same gradient as the Santa Cruz River.

About 15 miles northwest of Tucson, the basin is constricted between the Tucson and the Tortolita Mountains at Rillito narrows. Much of the ground-water underflow is confined to a narrow trough at this point, and only a relatively thin layer of alluvium covers the bedrock from the Tortolita Mountains to this trough. Consequently, most of the ground water moves toward the trough. Because of this constriction in cross-sectional area, the ground-water gradient is steep and was steep under natural conditions before large-scale pumping took place in the Casa Grande area.

Water-level fluctuations in Pima County are discussed as follows: (1) Avra-Marana area, (2) Rillito-Tucson area, (3) Tucson-Continental area, and (4) Tanque Verde-Pantano area.

Avra-Marana area

Water-level fluctuations for the period spring 1958 to spring 1959 ranged from a rise of about 5 feet to a decline of nearly 13 feet. In the 5-year period spring 1954 to spring 1959 the water levels declined about 20 to 40 feet in the area extending from Marana to a point about 7 miles southwest. The water level in well (D-11-10)32 (fig. 14) rose about 2 feet from spring 1958 to spring 1959, declined about 22 feet from spring 1954 to spring 1959, and about 38 feet from spring 1949 to spring 1959. The water level in well (D-15-10)35 (fig. 14) in the southern part of the Avra Valley declined very little during the 5-year period spring 1954 to spring 1959 and only 6 feet since 1949. The range in depth to water below land surface in the spring of 1959 was from about 190 to 320 feet.

Rillito-Tucson area

Water-level fluctuations in this area from spring 1958 to spring 1959 ranged from a rise of about 6 feet to a decline of about 2 feet. For the 5-year period spring 1954 to spring 1959 fluctuations ranged from a rise of about 5 feet to a decline of more than 20 feet. The water level in well (D-12-12)16 (fig. 14) in the heavily pumped area along the Santa Cruz River rose about 6 feet from spring 1958 to spring 1959, and is about the same as in the spring of 1949. The rise in the water level is attributed to less pumpage in the Rillito-Cortaro area. The water level in well (D-15-13)2 (fig. 14), beside the Santa Cruz River near Tucson, fluctuates seasonally, rising after periods of surface flow in the river and declining when the flow ceases. From spring 1958 to spring 1959 the water level declined about 1 foot and is about the same as in the spring of 1954. From spring 1949 to spring 1959 the water level in this well declined about 20 feet. The depth to water below land surface in the Tucson-Rillito area ranged from about 60 to 140 feet in the spring of 1959.

Tucson-Continental area

Water-level fluctuations in this area during the period spring 1958 to spring 1959 ranged from a rise of about 6 feet to a decline of about 6 feet. For the 5-year period spring 1954 to spring 1959 the declines ranged from about 2 to 20 feet. The water level in well (D-17-14)18 (fig. 14) rose about 4 feet from spring 1958 to spring 1959, but is about 4 feet lower than it was in the spring of 1954, and about 16 feet lower than in the spring of 1949. The depth to water below land surface in this area in the spring of 1959 ranged from about 50 to 130 feet.

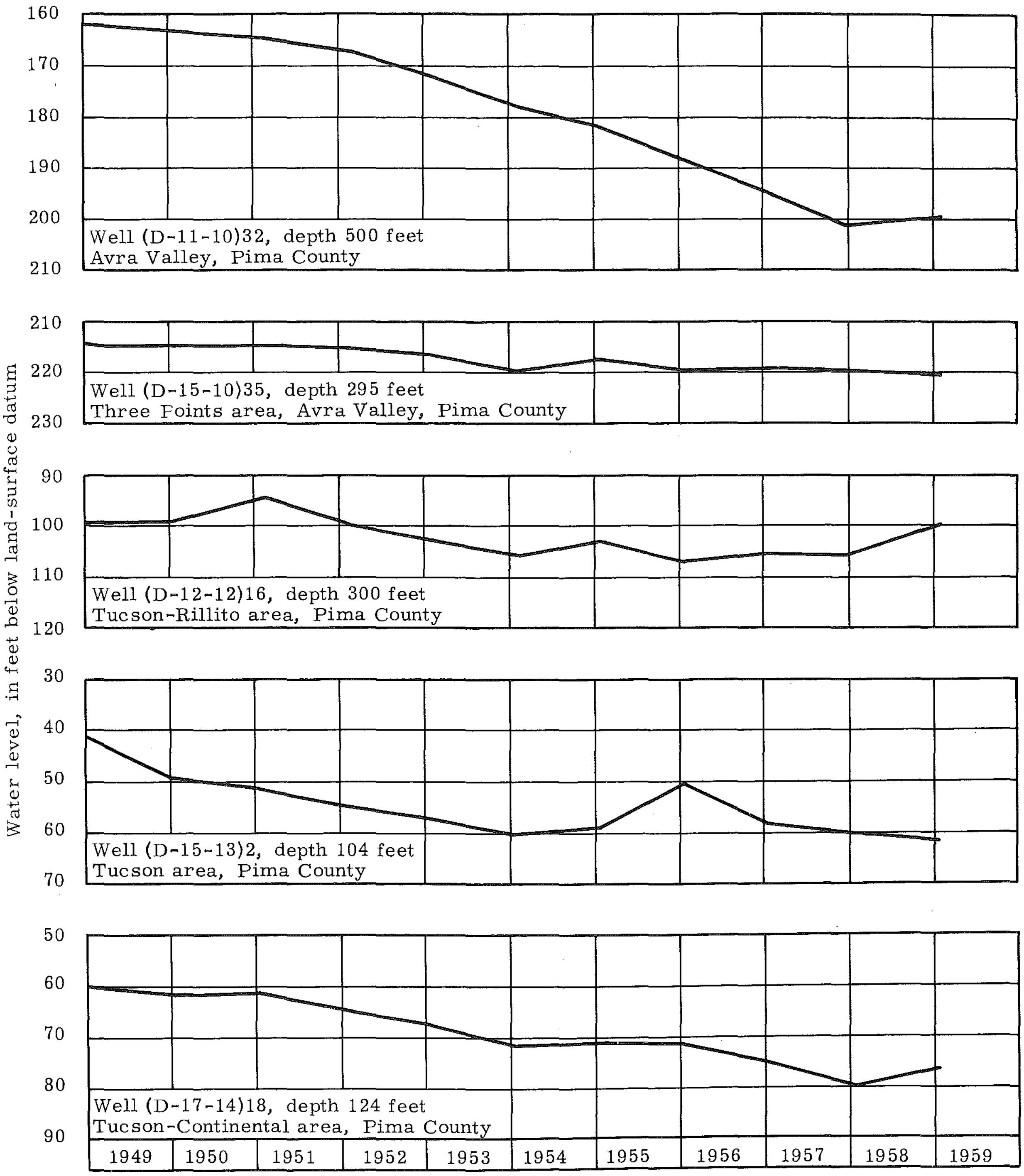


Figure 14.--Water levels in selected wells, Pima County.

Tanque Verde-Pantano area

The water-level fluctuations in this area during 1958 ranged from a rise of about 5 feet along Rillito Creek to a decline of about 9 feet along Pantano Wash. The rises along Rillito Creek and also along Tanque Verde Wash were due to the recharge of the ground-water reservoir from surface runoff from the mountain areas. In the spring of 1959 the depth to water below land surface ranged from about 10 feet along Tanque Verde Wash to more than 260 feet in the foothills near the Rincon Mountains.

Pinal County

About 90 percent of the lower Santa Cruz basin is within Pinal County and the remainder is in Pima County. The lower Santa Cruz area is part of a large drainage basin of the Gila River and is the second largest irrigation area in the State. The area is roughly triangular in shape, and is bounded on the east by the Tucson and Tortolita Mountains. The northern boundary follows an arbitrary line westward from Ashurst-Hayden Dam to the Santan Mountains, thence northward to the Pinal-Maricopa County line, thence westward along the county line to the Gila River, and thence northwestward along the river to the line between Rs. 1 and 2 E. The western boundary is formed by the Sierra Estrella, Palo Verde, Table Top, Tat Momoli, Silver Reef, Sawtooth, Silver Bell, Waterman, and Roskruge Mountains. The southern boundary is an arbitrary line between Tps. 15 and 16 S. The common boundary of the lower Santa Cruz area and the upper Santa Cruz basin is the Rillito narrows between the Tucson and Tortolita Mountains. The valley floor of the area covers about 2, 200 square miles and ranges in altitude from about 2, 500 feet at the southern boundary to about 1, 000 feet at the northwest corner. The broad valley south of the Pinal-Pima County line is referred to as the Avra-Marana area, as reported in the Pima County section of this report.

The movement of ground water in the lower Santa Cruz basin is toward the northwest and the Gila River. The subsurface flow is influenced by heavy pumping, which causes areas of depression in the water table. In the Eloy area, the flow is from the Red Rock area, parallel to the Santa Cruz River and toward the Casa Grande and Coolidge areas. In the vicinity of the Casa Grande area, the ground-water movement is in two directions, a diversion caused by the Sacaton Mountains. Part of the flow is toward Coolidge and thence to the Gila River, and part of the flow is to the west toward Stanfield. Between Stanfield and Maricopa there is a ground-water depression and water is moving toward it from all sides. There probably is little discharge of water to the Gila River in the Maricopa area.

About 4 miles west of Casa Grande and 6 miles east of Stanfield the ground-water gradient is more than 75 feet per mile. This drop in the water table is similar to that observed at the Rillito narrows.

The areas of irrigation development in Pinal County are: (1) the Casa Grande-Florence area; (2) the Maricopa-Stanfield area; and (3) the Eloy area.

Casa Grande-Florence area

In the period spring 1958 to spring 1959, water-level fluctuations ranged from rises of 1 to 15 feet to declines of about 10 feet. Water levels in some of the wells in this area rose during 1958 due to less pumping than in previous years. More surface water was available for diversion from the Gila River at Ashurst-Hayden Dam in 1958 than in any year since 1944. The greatest declines were along the Casa Grande Canal. In the 5-year period spring 1954 to spring 1959 (fig. 15) declines ranged from about 20 to 40 feet. The water level in well (D-6-6)7 (fig. 16) declined about 9 feet from spring 1958 to spring 1959, about 40 feet from spring 1954 to spring 1959, and more than 60 feet from spring 1949 to spring 1959. Depths to water below land surface in the spring of 1959 ranged from 50 to about 230 feet in the Casa Grande-Florence area.

Maricopa-Stanfield area

Water levels during the period spring 1958 to spring 1959 declined from a few feet to as much as 40 feet. The water levels are deeper in the Maricopa-Stanfield area than in other parts of the basin. In the western part of this area, along the mountains, water levels declined about 20 to 40 feet. In the 5-year period spring 1954 to spring 1959 (fig. 15) declines ranged from 20 to 120 feet. The greatest declines were in the western portion of the basin near the mountains. The water level in well (D-7-5)22 (fig. 16) declined about 10 feet from spring 1958 to spring 1959, about 16 feet from spring 1954 to spring 1959, and about 50 feet from spring 1949 to spring 1959. The depths to water below land surface in the spring of 1959 ranged from 70 to nearly 500 feet.

Eloy area

Water-level fluctuations in this area from spring 1958 to spring 1959 ranged from small rises of about 2 feet to a decline of more than 30 feet. In the 5-year period spring 1954 to spring 1959 water-level declines ranged from about 20 to more than 60 feet (fig. 15). The greatest declines were in an area north of Eloy near the Casa Grande Canal. The water level

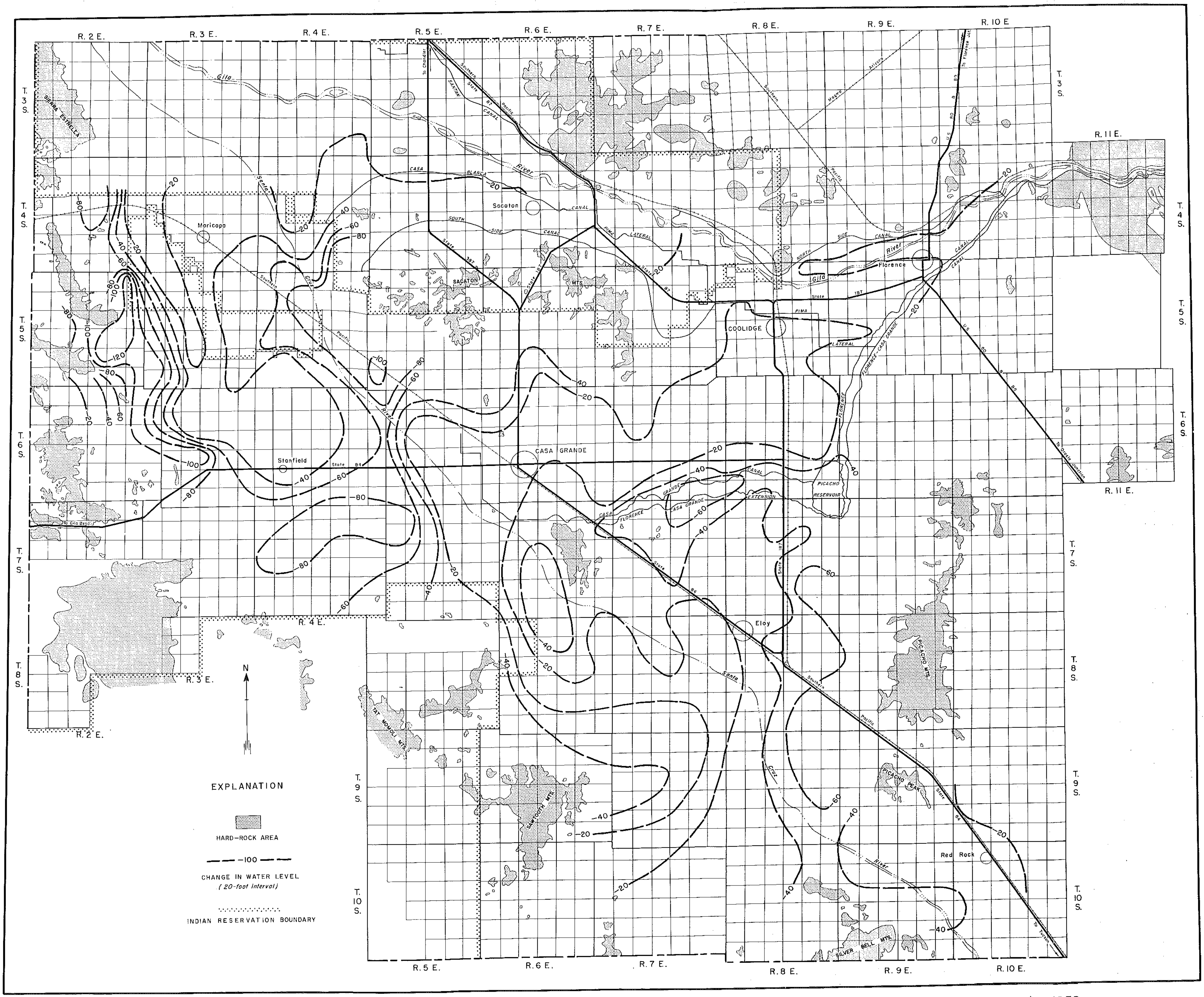


Figure 15.--Map of lower Santa Cruz basin and adjacent areas, Pinal County, Arizona, showing change in ground-water level from spring 1954 to spring 1959

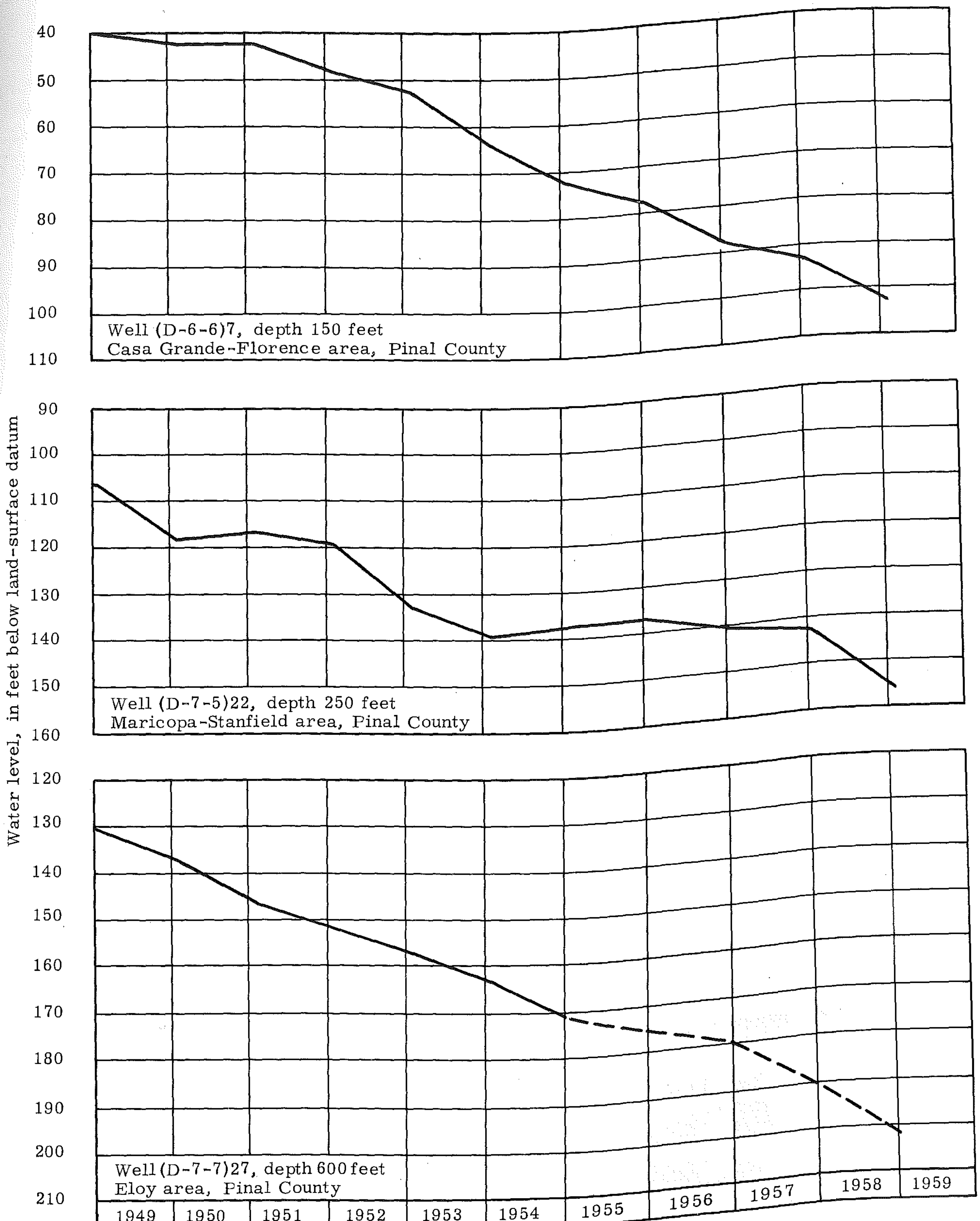


Figure 16.--Water levels in selected wells, Pinal County.

in well (D-7-7)27 (fig. 16) declined about 10 feet from spring 1958 to spring 1959, about 40 feet from spring 1954 to spring 1959, and more than 70 feet from spring 1949 to spring 1959. The depths to water in this area ranged from about 150 to more than 300 feet below the land surface in the spring of 1959.

During the last 5 years the water table in the valley between Picacho Peak and the Silver Bell Mountains has declined from 20 to 40 feet. Studies of the subsurface geology in this area indicate a less permeable horizon about 250 feet below the present static water level. When the water table reaches this depth, the rate of decline will be greatly accelerated, assuming constant pumpage.

Santa Cruz County

The southern part of the upper Santa Cruz basin lies in Santa Cruz County. It is bounded on the north by the Pima County line, on the east by the Santa Rita and Patagonia Mountains, on the south by the International Boundary, and on the west by the Tumacacori and Atascosa Mountains. Altitudes range from about 3,700 feet at the International Boundary to about 3,000 feet at the Santa Cruz-Pima County line. In 1958 about 7,000 acres were irrigated (Seltzer, 1959). From spring 1958 to spring 1959 water levels rose from about 1 foot to more than 18 feet; for the 5-year period spring 1954 to spring 1959 water-level fluctuations ranged from rises of 1 to 25 feet to declines of less than 3 feet. This general rise in water level is attributed to recharge from the Santa Cruz River during the last few years. The water level in well (D-22-13)35 (fig. 17) responds rapidly to recharge from Sonoita Creek and the Santa Cruz River. The water level in this well rose about 17 feet from spring 1958 to spring 1959, about 25 feet from spring 1954 to spring 1959, and was about 20 feet higher in spring 1959 than in spring 1949. The depths to water in this area in the spring of 1959 ranged from about 10 to 40 feet below land surface. Ground-water levels in most of the upper Santa Cruz Valley have been rising steadily and conditions are better now than at anytime during the last 5 years. However, large pumping drafts or low runoff in the Santa Cruz River could result in declining water levels because of the small ground-water storage capacity of the valley.

Yavapai County

There are four principal areas of ground-water development in Yavapai County: (1) Verde Valley; (2) Chino Valley; (3) Skull Valley; and (4) Peeples Valley.

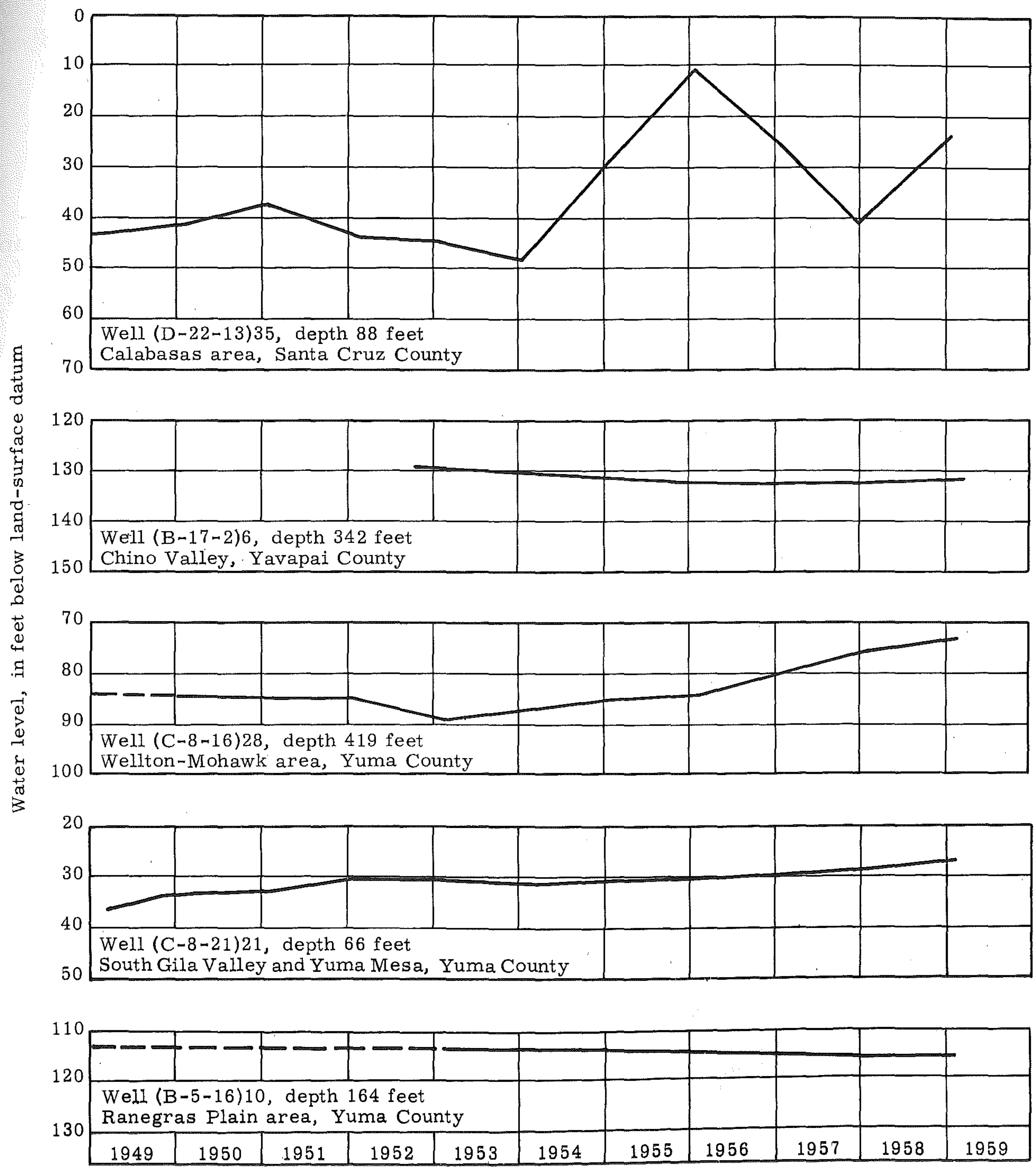


Figure 17.--Water levels in selected wells, Santa Cruz, Yavapai, and Yuma Counties.

Verde Valley

The Verde Valley is a northwest-trending valley extending from Perkinsville to the junction of Fossil Creek and Verde River. It is bounded on the west by the Black Hills and on the east by the Mogollon Rim. Verde River, Oak Creek, West Clear Creek, and Beaver Creek flow into the valley. The towns of Clarkdale, Cottonwood, Camp Verde, and Sedona lie within the area.

The Verde Valley area is divided into the Clarkdale-Cottonwood-Camp Verde area and the Sedona area. In the Clarkdale-Cottonwood-Camp Verde area the principal source of ground water is the Verde formation of Pliocene(?) or Pleistocene age. In the Sedona area the principal source of ground water is the Supai formation of Pennsylvanian and Permian age.

Clarkdale-Cottonwood-Camp Verde area.--In this area water is used mainly for farming, domestic, and industrial purposes. The three major sources of water supplies in the Clarkdale-Cottonwood-Camp Verde area are (1) the Verde River and other streams, (2) shallow wells near the river, and (3) deeper drilled wells which penetrate various permeable zones of the Verde formation. The Verde formation is a lake-bed deposit composed of alternating strata of sandstone, conglomerate, siltstone, claystone, and limestone. In some parts of the valley there is sufficient artesian pressure to cause wells to flow.

Although most of the water used for agriculture in the valley is diverted from the Verde River, there are 6 irrigation wells in the area. The average depth of these wells is about 600 feet and the depth to water is about 100 feet below land surface. In the northern part of the valley, water for livestock is usually obtained from wells as much as 800 feet deep.

About 60 domestic wells have been drilled to depths of more than 100 feet in the valley; most of these wells tap the Verde formation. There were artesian rises in most of the wells during drilling; near Cottonwood, Page Springs, McGuireville, and Camp Verde there are 13 flowing wells. In the non-flowing wells, depths to water ranged from a few feet to more than 200 feet below land surface. Reported data from well owners and drillers suggest that, at the present time, water-level fluctuations are influenced only by climatic conditions. Most of the industrial wells drilled by the mining companies in the Verde Valley were abandoned when the mines closed, although a few are being used for public supply.

Sedona area.--Prior to 1949 sufficient water supplies for the Sedona area were available from surface flow in Oak Creek and shallow wells adjacent to the creek. During the past few years, the increase in population has required the development of more convenient and dependable domestic water supplies. In 1949 a successful domestic well was drilled to a depth of 530 feet about 3 miles west of Sedona. At the present time about 30 wells, averaging 600 feet in depth, are bottomed in the Supai formation which is the major source of domestic water supplies, exclusive of Oak Creek. The average depth to water in these wells is about 400 feet below land surface.

Chino Valley-Skull Valley-Peeples Valley

Water-level fluctuations in the Chino Valley area during the period spring 1958 to spring 1959 ranged from a rise of 3 feet in the lower end of Chino Valley to a decline of 2 feet in the upper end of the area. The hydrograph for well (B-17-2)6 (fig. 17) shows the water-level trend in the area near Paulden where wells are the only source of irrigation water. In the spring of 1959 the water levels in non-flowing irrigation wells ranged from about 4 to 255 feet below land surface.

In Skull Valley water-level rises ranged from 9 feet to less than 1 foot. The irrigation wells in this area are in shallow alluvium and are readily affected by precipitation.

During the period spring 1958 to spring 1959 ground-water levels in Peeples Valley rose about 3 feet. Small quantities of water are pumped from this area and the water-table fluctuations are only seasonal.

Yuma County

There are five principal areas of irrigation development in Yuma County: (1) Palomas Plain area; (2) Wellton-Mohawk area; (3) south Gila Valley and Yuma Mesa area; (4) McMullen Valley area; and (5) Ranegras Plain area.

Palomas Plain area

Palomas Plain is an alluvial area that extends northwest from the Gila River between a spur of the Gila Bend and the Palomas Mountains. The area lies in Yuma and Maricopa Counties but most of the agricultural development is in Yuma County, and the discussion is therefore included in this section of the report.

During the period spring 1958 to spring 1959 water-level fluctuations in wells in the Palomas Plain area ranged from a rise of about 3 feet near Horn, a station on the Southern Pacific Railroad, to a decline of about 8 feet in a well several miles north of Horn in the center of concentrated pumpage. In the spring of 1959 the depth to water below land surface in the irrigated area ranged from about 20 feet along the Gila River to more than 280 feet near Turtle Back Mountain.

Wellton-Mohawk area

The Wellton-Mohawk area is a flat desert plain that extends from Dome upstream along the Gila River for a distance of about 46 miles. The area is bounded on the west by the Gila Mountains; on the north by the Muggins and Castle Dome Mountains; on the east by Texas Hill; and on the south by the Wellton Hills, the Copper Mountains, and an arbitrary line extending northeast along U. S. Highway 80 to the Mohawk Mountains.

Pumping of ground water for irrigation nearly ceased in the area during 1957 because of the operation of the Wellton-Mohawk reclamation project. In 1957 only about 19 irrigation wells were in operation compared to about 60 during 1952. Five of the irrigation wells in operation during 1957 are in the new area of development north of Texas Hill, adjacent to the boundary of the reclamation project.

During the period spring 1958 to spring 1959 water levels in wells in the Wellton-Mohawk Irrigation District rose 2 to 6 feet. The water level in well (C-8-16)28 (fig. 17) rose about 14 feet from spring 1954 to spring 1959 and about 3 feet from spring 1958 to spring 1959. The only water-level declines in the area occurred north of Texas Hill outside of the irrigation district where the water level in one well declined more than 14 feet during the period spring 1958 to spring 1959. The depth to water below land surface in the area ranged from about 7 feet in a well near the Gila River to about 101 feet in the area north of Texas Hill.

South Gila Valley and Yuma Mesa area

The south Gila Valley lies along the Gila River flood plain where ground water is the principal source of irrigation water. The area is bounded on the north by the Gila River and on the east, west, and south by the Gila River terrace. The Yuma Mesa area consists of the land between the south terrace of the Gila River and the "A" Canal.

Owing to the effects of gravity irrigation on the Yuma Mesa area, water levels in the wells in the south Gila Valley and Yuma Mesa areas continued to rise during the period spring 1958 to spring 1959; water-level rises for this period ranged from about half a foot to 2 feet. The water level in well (C-8-21)21 (fig. 17) has risen steadily—about 5 feet since 1954 and about 10 feet since 1949. The hydrograph for this well shows conditions typical of the south Gila Valley and Yuma Mesa area.

The depth to water below land surface in the spring of 1959 ranged from about 70 feet on the Yuma Mesa to about 11 feet in the south Gila Valley.

McMullen Valley area

The McMullen Valley area is a northeast-trending valley about 40 miles long lying between the Harcuvar and Harquahala Mountains. The western half of the area lies within Yuma County, and the eastern half lies in Maricopa and Yavapai Counties. As most of the area is in Yuma County, it is discussed in this section of the report.

The use of ground water for irrigation in the area dates back to the early 1900's when small acreages were irrigated in the Harrisburg Valley southeast of Salome. However, more than half the present irrigation wells in McMullen Valley have been drilled since 1955. The two areas of most recent development are near the towns of Wenden and Aguila.

Only a small amount of basic data was collected in the Aguila area in the spring of 1959 because of the effects of year-round pumping on the water levels. The water level declined about 6 feet in a domestic well on the north fringe of the cultivated area and about 1 foot in an unused irrigation well in the northwest part of the area. In the early summer of 1958 pumping levels were measured in 8 wells in the heavily pumped area north of Aguila. The lifts ranged from 360 to 500 feet with drawdowns of about 30 to 120 feet. During the period spring 1958 to spring 1959 water-level fluctuations ranged from no change to a decline of about 5 feet in the Salome-Wenden area. This area has not been developed as extensively as the Aguila area and the water levels are nearer the surface. Depths to water below land surface in the Salome-Wenden area ranged from about 88 feet to 246 feet. About 30,000 acre-feet of water was pumped in McMullen Valley during 1958, about 10,000 acre-feet more than during 1957.

Ranegras Plain area

This area lies in northern Yuma County and is bounded on the north by the Bouse Hills, on the east by the Granite Wash Mountains, and on the west by the Plomosa Mountains.

Agriculture in the Ranegras Plain area has increased very little in the last 5 years. During 1958 there were about 15 irrigation wells equipped to pump water but not all of these wells were in operation.

From spring 1958 to spring 1959 water-level fluctuations in the Ranegras Plain area ranged from a rise of 3 feet to a decline of less than 1 foot. Most of the water levels in the area changed little during the period. The hydrograph for well (B-5-16)10 (fig. 17) shows water-level fluctuations typical of the undeveloped parts of the area. The depth to water in the spring of 1959 ranged from about 67 feet to 224 feet below land surface.

Pumpage

The amount of ground water pumped in Arizona during 1958 was about 4,500,000 acre-feet; this amount is not significantly different from that pumped during the last three years. The annual pumpage has been nearly constant the last few years despite increased pumping lifts. Most of the ground-water withdrawal has been for irrigation use, and less than 400,000 acre-feet has been used for municipal, industrial, and domestic purposes. Although the nonirrigation uses of ground water have increased because of population growth and industrial expansion, the increase in water usage is relatively small in comparison to agricultural needs. For example, agricultural ground-water pumpage is about one million acre-feet per year in the lower Santa Cruz basin, comprised of the Eloy, Casa Grande, Coolidge, Florence, Stanfield, and Maricopa areas. By comparison, all the private water companies in the State and the public municipalities of Phoenix, Tucson, Bisbee, Casa Grande, Coolidge, Florence, Miami, and Superior pump less than 150,000 acre-feet of ground water per year. Thus, large increases in population in the State do not materially affect the total ground-water pumpage. However, any increase in pumpage in a localized area, such as a city, can present serious problems. The amount of ground water pumped from industrial wells, mostly in Phoenix and Tucson, is unknown but is probably less than 200,000 acre-feet for the State. In addition, some industries buy water from the public utilities. Much of the industrial development consists of light industries and large amounts of water are not needed. Also, some industries use ground water for air-conditioning purposes and return it to the aquifer.

From 1957 to 1958 there was an increase in irrigated land of nearly 90,000 acres, mostly in Maricopa and Pinal Counties. Normally, this would result in an increase in ground-water pumpage; however, during 1958 large amounts of surface water were available from the Gila River at Safford and in the San Carlos Project in Pinal County. About 75 percent of the ground-water pumped is from the Salt River Valley and the lower Santa Cruz basin. There has been increased development and pumping in Willcox basin, McMullen Valley, the Harquahala Plains area, and parts of Mohave County. A typical example is McMullen Valley where pumpage (in acre-feet) was 6,000 in 1953, 20,000 in 1957, and 30,000 in 1958. The use of water for irrigation in the upper Santa Cruz basin (Nogales to Tucson) and Safford area remained about the same as last year. The Douglas basin had less development and pumping, and in the Gila Bend area pumping has increased. In the Yuma and Wellton-Mohawk areas, surface water is utilized more than ground water. Wells in Apache County, near St. Johns and Hunt, yield moderate amounts of water, and some wells southwest of Hunt flow during the winter months. In Navajo County, most of the pumping is along the Little Colorado River in the vicinity of Winslow and Holbrook, and in the Snowflake-Taylor area. In northern Arizona there is little ground-water pumping for industrial and agricultural development.

The use of water for public supply has continued to increase throughout the State, particularly in Phoenix and Tucson. The Arizona Corporation Commission reports that about 16-1/2 billion gallons of water (50,600 acre-feet) was pumped in 1958 by all the private water companies in the State. This figure, which does not include the water pumped by public municipalities is about 1-1/2 billion gallons (4,600 acre-feet) less than in 1956. This reduction in pumpage by the private water companies is due to the acquisition of many of these companies by the municipalities, particularly Phoenix and Tucson, and there is a corresponding increase in the pumpage figures for the municipal water systems. During 1956, the Phoenix water department pumped 46 mgd (million gallons per day), of which 8 mgd was ground water. In 1958 it acquired 55 wells from various private water companies and pumped 70 mgd, of which 28 mgd was ground water. Water consumption in Tucson has increased similarly. During 1957 the city pumpage was 23 mgd, and in 1958 nearly 9-1/2 billion gallons of water (29,100 acre-feet) or 26 mgd was used. The city supply is obtained entirely from ground-water sources. Total pumpage in the Tucson area for domestic, industrial, and urban use is more than 40 mgd. Other cities throughout the State have had similar increases in water consumption. Ajo, Bisbee, Casa Grande, Coolidge, Florence, Miami, San Manuel, Superior, Winkleman, and Yuma together used about 4.8 billion gallons of water (14,700 acre-feet) in 1957 and 5.3 billion (16,300 acre-feet) in 1958. Most of these towns, except Yuma, use ground water.

Ground-water pumpage for agriculture in the Salt River Valley area is estimated to be from about 2 to 2.5 million acre-feet per year. The urbanization of the Phoenix area has taken some land out of production, but new agricultural development, particularly in the Gila Bend area and in the western part of Maricopa County has increased the total acreage in cultivation in the county from previous years.

SEDIMENT LABORATORY

The alluvial basins are the most important ground-water storage reservoirs in Arizona. Therefore, samples of the material encountered in the drilling of wells are an important tool in analyzing the subsurface geohydrology of the basins. The data obtained from the analysis of a great number of well-cutting samples aid in the understanding of the depositional history of the valley fills and their relationship to the ground-water conditions in the State.

The Ground Water Branch of the Geological Survey has a laboratory for the analysis of samples of well cuttings and rock outcrops. The well cuttings are collected in bags at 10-foot intervals by the driller. In the laboratory, the material is examined for texture and composition, particle-size distribution, degree of sorting, cementation, color, porosity and permeability. This description of the subsurface material is valuable to well drillers, geologists, and engineers in helping to solve ground-water problems and for well development. These data may help determine (1) the best type of well construction, including the proper setting and size of casing perforations to produce the maximum amount of water, (2) thickness of water-bearing zones, (3) quality-of-water characteristics, (4) different lithologic units, such as lake deposits, and (5) best zones for possible artificial recharge. These data may be helpful in identifying the water-bearing zone, yield of wells, and type of drilling conditions in a particular area. Large expenditures of money and time may be saved by careful interpretation of the laboratory data.

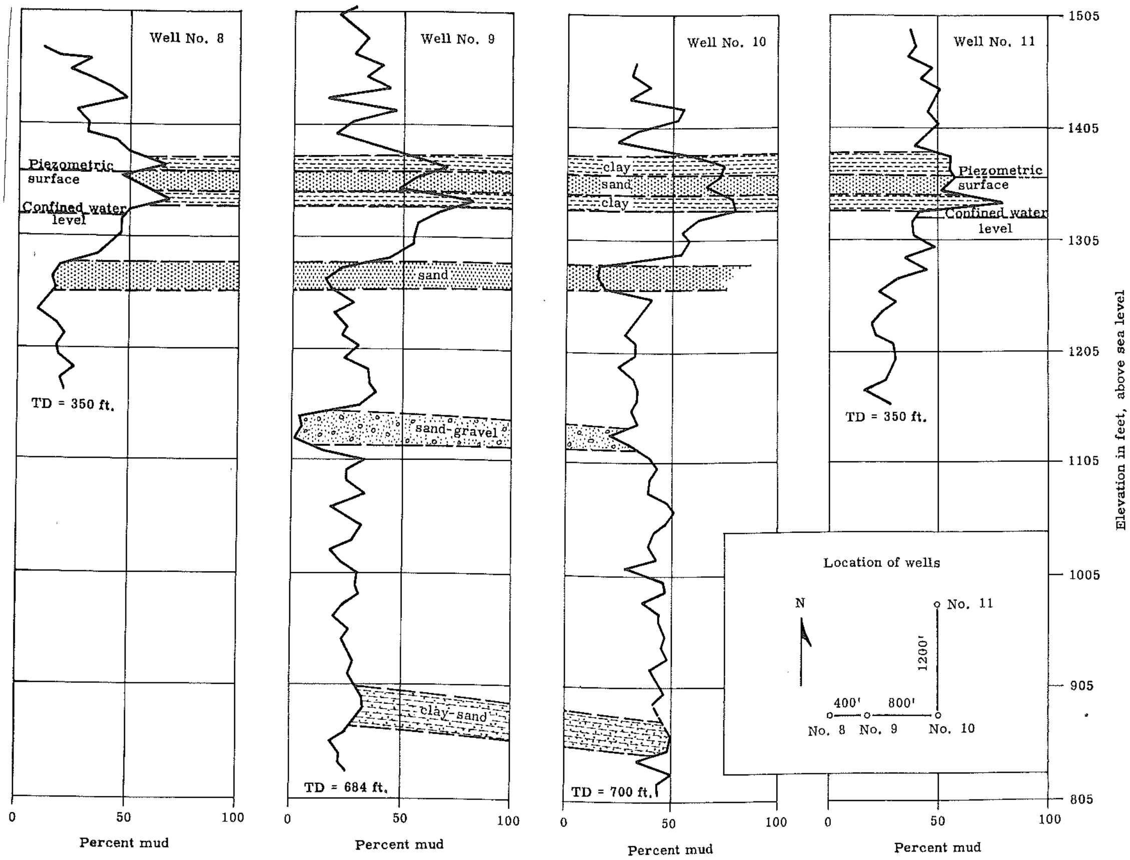
Samples were collected from four adjacent wells on the Papago Indian Reservation at Chuichu. Figure 18A shows how the graphed analyses of the silt and clay-size parts of the drill cuttings have been used to correlate clay, sand, and gravel layers in the area. This same principle may be used for a larger area by the comparison of many detailed analyses. The grain-size distribution in an outcrop sample of upper alluvium is helpful in determining the hydrologic characteristics of the material (fig. 18B). For example, this sample is poorly sorted (no uniformity of grain size), indicating a poor aquifer, but it also contains less than 2 percent of silt and clay, a factor in favor of a good aquifer.

Other types of analyses, such as porosity-permeability, grain-size, rock-composition, heavy-mineral analysis, and other petrographic work may be illustrated similarly and are tools of the hydrologist for solving ground-water problems.

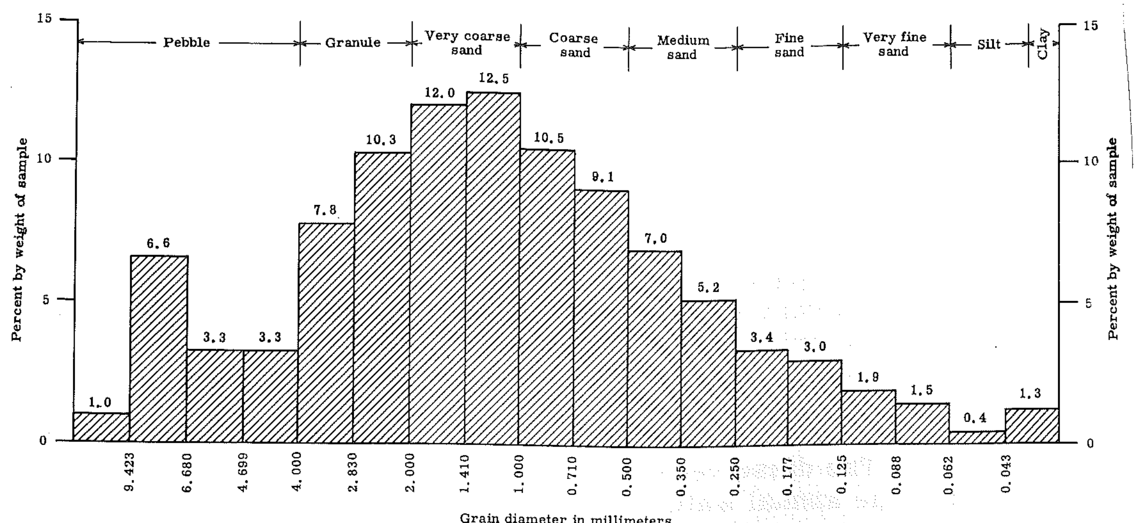
After the laboratory has completed the analysis, the well cuttings are deposited in sample libraries maintained by the Arizona Bureau of Mines and the Arizona State Land Department, where they may be examined by interested parties. It is anticipated that with the increased coverage through additional samples, a valuable tool will be available for detailed study of the subsurface geology and hydrology of Arizona.

CHEMICAL QUALITY OF WATER IN THE SALT RIVER VALLEY AREA

The chemical quality of surface and ground water in the Salt River Valley varies greatly as shown by analyses of samples of water collected daily at sites on the Salt, Gila, Verde, and Agua Fria Rivers since 1951, and of samples of ground water collected periodically from wells in the area.



A. Graph showing variation of mud (clay, silt) content with depth of wells and some subsurface correlation between wells at Chuichu



B. Grain-size distribution in outcrop sample of upper alluvial formation of Tucson basin, Pantano Wash, 10 miles northeast of Tucson, Ariz. Lab sample No. R-1.

FIGURE 18.--GRAPHS SHOWING LABORATORY ANALYSES OF WELL CUTTINGS AND OUTCROP SAMPLES

The average mineral concentration of the surface water entering the Salt River Valley as measured on the Salt River below Stewart Mountain Dam and on the Gila River at Kelvin is about 700 and 650 ppm (parts per million), respectively. The Verde River below Bartlett Dam contains about 300 ppm of dissolved salts and the Gila River below Gillespie Dam contains an average of about 2,500 ppm of salts, ranging from more than 5,000 to less than 1,500 ppm, depending on the flow in the river.

The quality of the ground water differs from place to place, owing to the influence of the composition of the subsurface material and the activities of man. Concentrations of dissolved solids in the ground water range from about 300 ppm in the Agua Fria River drainage in the northern part of the Salt River Valley area, to more than 6,000 ppm in the vicinity of Chandler. Other areas in which the ground water contains excessive amounts of dissolved salts are (1) near the confluence of the Salt and Gila Rivers, (2) along the Salt River west of Phoenix, and (3) along the Gila River below the Salt River to Gillespie Dam. The highly mineralized ground waters in the Salt River Valley area contain a predominance of sodium chloride with large amounts of calcium and sulfate; the water of better quality is largely of the calcium and magnesium bicarbonate type.

About 3 to 4 million tons of dissolved salts per year is applied to the soil through the use of ground and surface water for irrigation in the Salt River Valley area. About 650,000 tons of salt comes from surface water and about 3-1/2 million tons comes from ground water—assuming the average salt content of the ground water is 1,000 ppm and the annual pumpage is about 2-1/2 million acre-feet.

When irrigation water is applied to the soil, part of it is evaporated or transpired to the atmosphere. The remaining soil solution is a concentrate of the original water applied, and successive applications of water may eventually carry the minerals down to the water table and increase the salt content of the water in that zone. It may be several years before the effect of the added increment of highly mineralized waters to the underground reservoir is noticed. If the flow of ground water is through permeable sediments, much of the objectionable saline water added by irrigational recharge may be removed from the area. However, in a large part of the Salt River Valley, the rate of ground-water movement is very slow owing to low gradients of the water table. Some of the high salinity may also come from soluble deposits laid down in a local playa environment during the deposition of the valley fill.

Salts are accumulating in the western end of the valley in the Buckeye area. The dissolved solids are increasing each year, as shown by analyses of the annual water samples from selected wells. Much of the increased concentration of salts is brought about because inflowing water carries dissolved solids into the Salt River Valley, but there is little movement of water to remove dissolved solids from the basin.

Problems of "salt balance" arising from use of water on arid lands are extremely complex. Without an adequate water-sampling program allowing for a systematic appraisal and exploration of many of the facets of salt-accumulation problems, little progress will be made toward analyzing and solving the quality-of-water problems in Arizona.