WATER-RESOURCES REPORT NUMBER THIRTY-EIGHT

ARIZONA STATE LAND DEPARTMENT

OBED M. LASSEN, COMMISSIONER

ANNUAL REPORT ON GROUND WATER IN ARIZONA SPRING 1967 TO SPRING 1968

PREPARED UNDER THE DIRECTION OF
H.M. BABCOCK, DISTRICT CHIEF
ARIZONA DISTRICT, WATER RESOURCES DIVISION

*Water Rights Adjudication Team
Civil Division
Attorney General's Office:

COMPILED BY THE GEOLOGICAL SURVEY
UNITED STATES DEPARTMENT OF THE INTERIOR

PHOENIX, ARIZONA
FEBRUARY 1969

CONTENTS

	Page
Introduction	1
Purpose and scope of the ground-water programs in Arizona	4
Federal-State cooperative ground-water program	4
Programs in cooperation with other agencies	6
Current publications of the Arizona district	6
Summary of ground-water conditions	7
Basin and Range lowlands province	9
Duncan and Safford basins	9
San Simon basin	13
Willcox basin	15
Douglas basin	15
San Pedro River valley	20
Upper Santa Cruz basin	20
Altar and Avra Valleys	24
Lower Santa Cruz basin	24
Salt River Valley	29
Waterman Wash area	34
Gila Bend basin	34
Harquahala Plains area	34
McMullen Valley	38
Gila River drainage from Painted Rock Dam to Texas Hill	38
Ranegras Plain area	41
Wellton-Mohawk area	41
Yuma area	43
Sacramento and Hualapai Valleys	43
Central highlands province	46
Big Chino, Little Chino, and Williamson Valleys	46
Verde Valley	46
Plateau uplands province	50
Apache County	50
Navajo County	53
Coconino County	53

CONTENTS

ILLUSTRATIONS

Page

Figure 1. Map showing areas for which ground-water data are given - - 2

2. Diagram of well-numbering system in Arizona - - - - - - - - - 3

3. Map showing summary of current ground-water programs - - 5

4. Graphs showing estimated annual ground-water pumpage and irrigated acreage in Arizona - 8

5. Map showing approximate average change in water levels in developed areas, 1940-68 - 11

6. Map showing potential well production, depth to water, 1968, and change in water level, 1963-68, in selected wells in the southeast part of the Basin and Range lowlands province - 12

7. Graphs showing depth to water in selected wells and estimated annual pumpage in the Duncan and Safford basins - - - - - - 14

8. Graphs showing depth to water in selected wells and estimated annual pumpage in San Simon basin - - - - - - - - - - - - - - - 16

9. Graphs showing depth to water in selected wells in Willcox basin and Aravaipa Valley and estimated annual pumpage in Willcox basin - 18

10. Graphs showing depth to water in selected wells and estimated annual pumpage in Douglas basin - - - - - - - - - - - - - - - - - 21

11. Graphs showing depth to water in selected wells in the San Pedro River valley - 22

12. Map showing potential well production, depth to water, 1968, and change in water level, 1963-68, in selected wells in the south-central part of the Basin and Range lowlands province - 23

Page

Figure 13. Graphs showing depth to water in selected wells and estimated annual pumpage in the upper Santa Cruz basin - - 25

14. Graphs showing depth to water in selected wells in Altar and Avra Valleys and estimated annual pumpage in Avra Valley - 27

15. Graphs showing cumulative average change in water level by areas and estimated annual pumpage in the lower Santa Cruz basin - 30

16. Map showing potential well production, depth to water, 1968, and change in water level, 1963-68, in selected wells in the central part of the Basin and Range lowlands province - 31

17. Graphs showing cumulative average change in water level in the Queen Creek - Higley - Gilbert, Tempe - Mesa - Chandler, and Phoenix-Glendale-Tolleson areas of the Salt River Valley - 32

18. Graphs showing cumulative average change in water level in the Litchfield - Beardsley - Marinette and Liberty-Buckeye - Hassayampa areas and estimated pumpage in the Salt River Valley - 33

19. Graphs showing depth to water in selected wells and estimated annual pumpage in the Waterman Wash area - - - 35

20. Graphs showing depth to water in selected wells and estimated annual pumpage in the Gila Bend basin - - - - - - - 36

21. Map showing potential well production, depth to water, 1968, and change in water level, 1963-68, in selected wells in the southwest part of the Basin and Range lowlands province - 37

22. Graphs showing depth to water in selected wells and estimated annual pumpage in the Harquahala Plains area - - 39

23. Graphs showing depth to water in selected wells and estimated annual pumpage in McMullen Valley - - - - - - - - 40

Page

Figure 24. Graphs showing depth to water in selected wells and estimated annual pumpage in the Gila River drainage from Painted Rock Dam to Texas Hill and in the Ranegras Plain area - 42

25. Graphs showing depth to water in selected wells and estimated annual pumpage in the Yuma area - - - - - - - - - - 44

26. Map showing potential well production, depth to water, 1968, and change in water level, 1963-68, in selected wells in the northwest part of the Basin and Range lowlands province - 45

27. Graphs showing depth to water in selected wells in the northwest part of the Basin and Range lowlands province and estimated annual pumpage in Hualapai and Sacramento Valleys - 47

28. Map showing potential well production, depth to water, 1968, and change in water level, 1963-68, in selected wells in the west part of the Central highlands province and the south-central part of the Plateau uplands province - - - 48

29. Graphs showing depth to water in selected wells and estimated annual pumpage in several areas in the Central highlands province - 49

30. Map showing potential well production, depth to water, 1968, and change in water level, 1963-68, in selected wells in the east part of the Central highlands province and the southeast part of the Plateau uplands province - - - - - - 51

31. Graphs showing depth to water in selected wells in several areas in the Plateau uplands province - - - - - - - - - - - - 52

32. Map showing potential well production and depth to water in selected wells in the north-central part of the Plateau uplands province - 54

TABLES

Page

Table 1. Estimated ground-water pumpage in Arizona, by areas -- 10

ANNUAL REPORT ON GROUND WATER IN ARIZONA, SPRING 1967 TO SPRING 1968

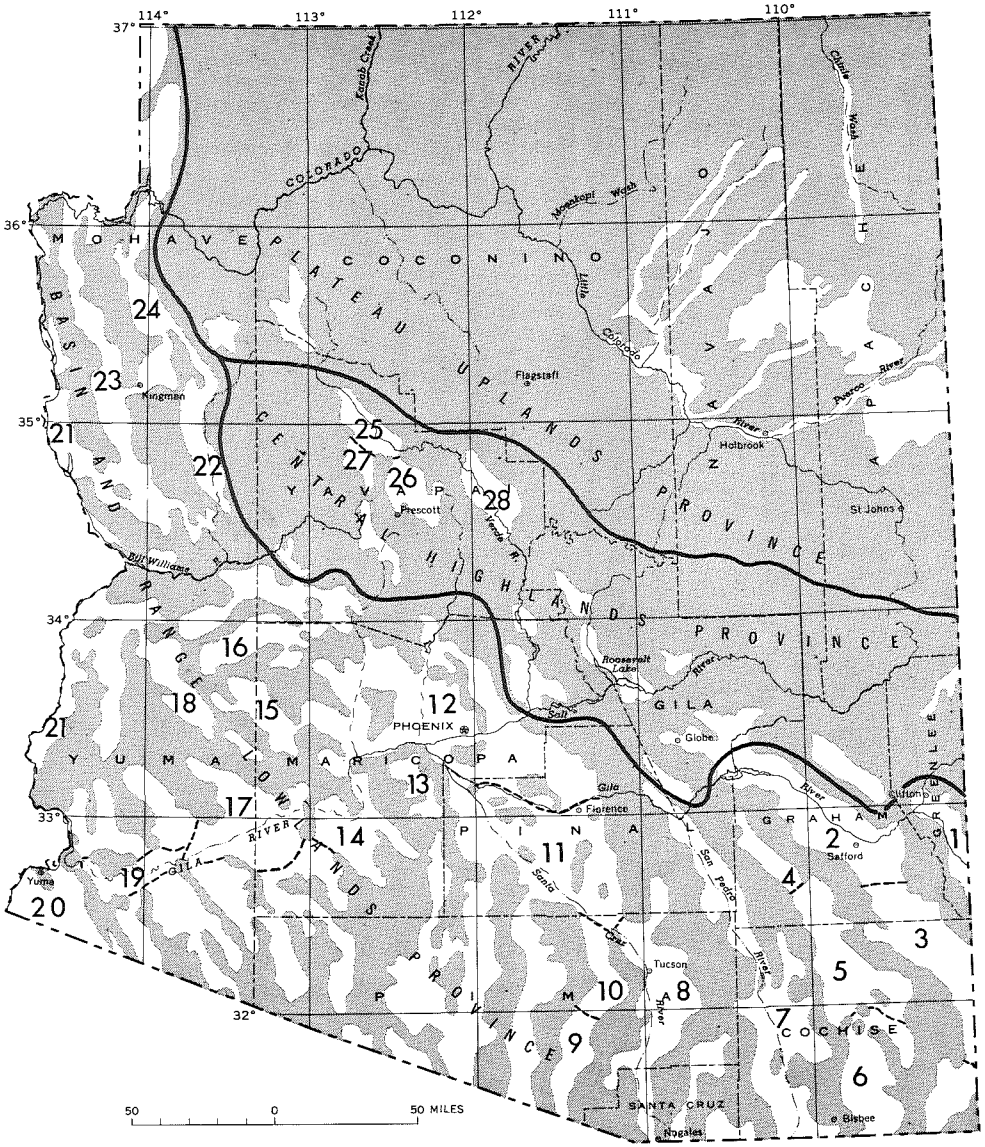
Prepared under the direction of H. M. Babcock,
District Chief, Arizona District, Water Resources Division

INTRODUCTION

The availability of an adequate potable water supply has a greater influence on the economy of arid or semiarid regions, such as Arizona, than any other factor. In a few places in Arizona, some water is obtained directly from streamflow when it is available or from reservoirs that store runoff. The amount of surface water available, however, is not sufficient to meet the constantly increasing demand, and, for many years, nearly two-thirds of Arizona's water supply has been withdrawn from the ground-water reservoirs. In many areas in the State, the present rate of withdrawal far exceeds the rate of replenishment, and the ground-water reservoirs are gradually being depleted. Therefore, it is of prime importance to protect these water supplies through effective management, which requires a comprehensive knowledge of the storage capacity of the aquifers and of the factors that control the transmission of water through them. Research projects, data collection, and comprehensive hydrologic analyses are providing this knowledge.

Since 1939, a planned program of ground-water studies has been conducted by the U.S. Geological Survey in cooperation with the State of Arizona. The State has been represented by the State Land Department since 1942. The program includes the collection and analysis of the geologic and hydrologic data necessary to evaluate the ground-water resources of the State and is under the immediate supervision of H. M. Babcock, district chief of the Water Resources Division of the U.S. Geological Survey in Arizona.

This report is a result of the cooperative program between the U.S. Geological Survey and the State of Arizona. The report contains graphs showing water levels in selected wells and estimated annual ground-water pumpage in most of the developed areas in the State and maps showing (1) depth to water in selected wells in spring 1968, (2) change in water levels in selected wells from 1963 to 1968, and (3) potential well production by areas. Figure 1 shows the areas for which ground-water data are given, and the well-numbering system used in Arizona is explained and illustrated in figure 2.



Alluvial contacts by M. E. Cooley, 1967

EXPLANATION

BASIN AND RANGE LOWLANDS PROVINCE

Ground water mostly from alluvial deposits; small amounts from fractures in consolidated rocks

1. DUNCAN BASIN
2. SAFFORD BASIN
3. SAN SIMON BASIN
4. ARAVAIPA VALLEY
5. WILLCOX BASIN
6. DOUGLAS BASIN
7. SAN PEDRO RIVER VALLEY
8. UPPER SANTA CRUZ BASIN
9. ALTAR VALLEY
10. AVRA VALLEY
11. LOWER SANTA CRUZ BASIN
12. SALT RIVER VALLEY
13. WATERMAN WASH AREA
14. GILA BEND BASIN
15. HARQUAHALA PLAINS AREA
16. McMULLEN VALLEY
17. GILA RIVER DRAINAGE FROM PAINTED ROCK DAM TO TEXAS HILL
18. RANEGRAS PLAIN AREA
19. WELLTON-MOHAWK AREA
20. YUMA AREA
21. COLORADO RIVER FLOOD PLAIN FROM DAVIS DAM TO IMPERIAL DAM
22. BIG SANDY VALLEY
23. SACRAMENTO VALLEY
24. HUALAPAI VALLEY

CENTRAL HIGHLANDS PROVINCE

Ground water from alluvial deposits in a few small valleys and from fractures and joints in consolidated rocks; many springs issue from fractures

25. BIG CHINO VALLEY
26. LITTLE CHINO VALLEY
27. WILLIAMSON VALLEY
28. VERDE VALLEY

PLATEAU UPLANDS PROVINCE

Ground water mostly from fine-grained sandstone units in consolidated rocks; siltstone and claystone layers act as aquicludes; moderate amounts of ground water from narrow alluvial deposits

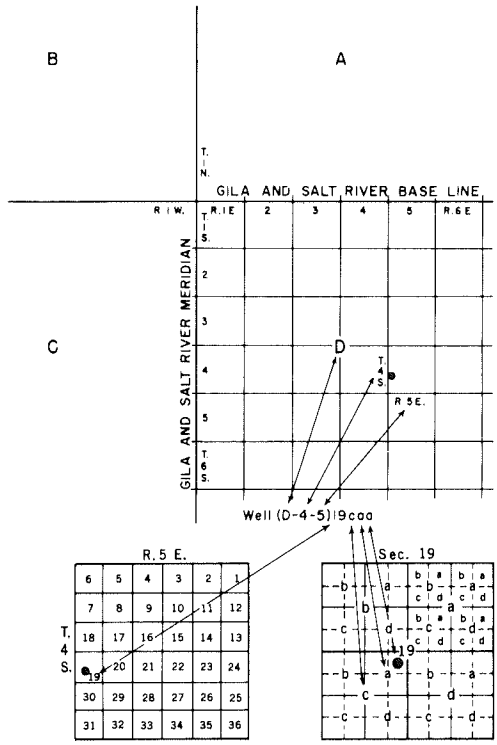
(Discussion of ground-ground-water conditions by counties)

ALLUVIAL DEPOSITS

CONSOLIDATED ROCKS

AREA BOUNDARIES NOT DEFINED BY CONTACT BETWEEN ALLUVIAL DEPOSITS AND CONSOLIDATED ROCKS

FIGURE 1. --AREAS FOR WHICH GROUND-WATER DATA ARE GIVEN.



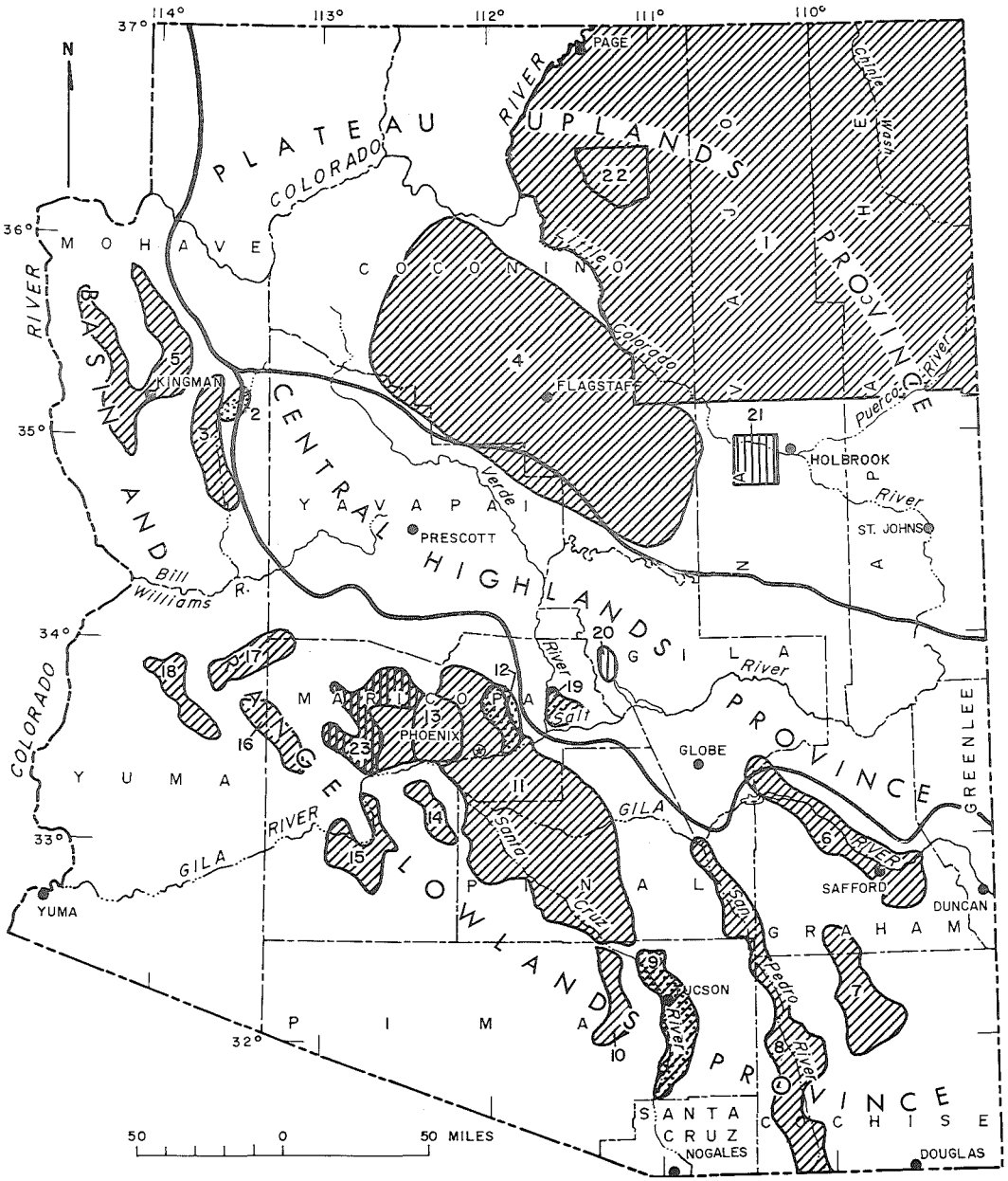
The well numbers used by the Geological Survey in Arizona are in accordance with the Bureau of Land Management's system of land subdivision. The land survey in Arizona is based on the Gila and Salt River meridian and base line, which divide the State into four quadrants. These quadrants are designated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

FIGURE 2. --WELL-NUMBERING SYSTEM IN ARIZONA.

Purpose and Scope of the Ground-Water Programs in Arizona

The overall purpose of the several types of ground-water programs in Arizona is to provide information for the analyses and studies necessary to solve the State's water problems. Investigations are made under the Federal-State cooperative ground-water program and in cooperation with universities, cities, counties, and other Federal agencies. Figure 3 is a pictorial summary of the status of current ground-water work in Arizona.

Federal-State cooperative ground-water program.--The current cooperative ground-water program in Arizona consists of three closely related parts. The first is the statewide ground-water survey, which provides for the collection of the basic hydrologic and geologic information that is necessary for the study and analysis of the ground-water resources of the State. The work includes well inventories, periodic water-level measurements, collection of water samples for chemical analysis, and collection and cataloging of drill cuttings from new wells. The "Annual Report on Ground Water in Arizona" is a result of this part of the cooperative program. The report is published by the State Land Department, and copies are available to the public. Another phase of the statewide ground-water survey provides for the detailed study of ground-water conditions in selected areas on a periodic basis. For the period July 1, 1967, to June 30, 1968, detailed studies were in progress under this phase of the program for McMullen Valley, Waterman Wash area, and Gila Bend basin (reports in review); San Pedro River valley, Harquahala Plains area, and Ranegras Plain area (reports in preparation); and Joseph City area and lower Hassayampa area (fieldwork in progress). The second part of the Federal-State cooperative program includes comprehensive ground-water investigations in areas where ground-water conditions are becoming critical because of over-development, areas where ground-water development is beginning, or areas where there is some special problem or interest. These investigations result in an overall evaluation of the water resources of the area. The third part of the program includes studies related to specific hydrologic problems, such as insufficient supplies, equitable distribution and protection of the available supply, and deterioration in quality of water. Reports in preparation under parts 2 and 3 of the cooperative program include: (1) Ground-water resources of the western part of the Salt River Valley (Beardsley area); (2) Water resources in southern Coconino County; (3) Geohydrology of Hualapai and Sacramento Valleys, Mohave County; (4) Geology and ground-water resources of Big Sandy Valley, Mohave County; (5) Basin potential of Sycamore Creek; (6) Geohydrology and water utilization in the Willcox basin; (7) Electrical-analog analysis of ground-water depletion in central Arizona; (8) Electrical-analog analysis of hydrologic data for Avra Valley, Pima County; and (9) Electrical-analog analysis for the Tuba City area.



EXPLANATION

SUMMARY OF GROUND-WATER PROGRAMS

1. Navajo-Hopi Indian Reservations
2. Cottonwood Wash
3. Big Sandy Valley
4. Southern Coconino County
5. Sacramento and Hualapai Valleys (Kingman area)
6. Arid-lands study (Safford basin)
7. Willcox basin
8. San Pedro River valley
9. Tucson basin
10. Avra Valley (electrical-analog analysis)
11. Part of central Arizona (electrical-analog analysis)
12. Paradise Valley
13. Western part of the Salt River Valley (Beardsley area)
14. Waterman Wash area
15. Gila Bend basin
16. Harquahala Plains area
17. McMullen Valley
18. Ranegras Plain area
19. Sycamore Creek
20. Lower Tonto Creek basin
21. Joseph City area
22. Tuba City area
23. Lower Hassayampa area

Area where field investigation is in progress (As of June 1968)

Area for which a report is in preparation (As of June 1968)

Area for which a report was released (July 1967-June 1968)

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

FIGURE 3. --SUMMARY OF CURRENT GROUND-WATER PROGRAMS.

Programs in cooperation with other agencies. --In 1967 ground-water studies were being conducted in cooperation with the following agencies:

City of Flagstaff
City of Scottsdale
City of Tucson
Maricopa County Municipal Water Conservation District
Navajo Tribe
Salt River Valley Water Users' Association
University of Arizona
U.S. Army
U.S. Bureau of Indian Affairs
U.S. Bureau of Reclamation
U.S. Bureau of Sport Fisheries and Wildlife
U.S. National Park Service.

Current Publications of the Arizona District

The following reports on the water resources and geology of Arizona were published or released to the open file from July 1, 1967, through June 30, 1968.

Arizona highway geologic map, by M. E. Cooley and others: Arizona Geol. Soc. Map, 1967.

Ground water in the Window Rock-Lukachukai area, Navajo Indian Reservation, Arizona and New Mexico, by R. J. Edmonds: New Mexico Geol. Soc. 18th Field Conf., 1967, Guidebook of Defiance-Zuni-Mt. Taylor region, Arizona and New Mexico, 1967. p. 86-91, 1 fig.

Water-resources data for Arizona, 1965—Part 2: Water-quality records, by U.S. Geological Survey: U.S. Geol. Survey open-file report, 1965. 89 p., 1 fig.

Water resources of lower Sycamore Creek, Maricopa County, Arizona, by H. H. Schumann: U.S. Geol. Survey open-file report, 1967. 54 p., 15 figs., 5 tables.

Synopsis of ground-water conditions in the vicinity of T. 11 S., R. 6 E., Pima County, Arizona, by Otto Moosburner: U.S. Geol. Survey open-file report, July 1967. 7 p., 3 figs., 1 table.

Activities of Water Resources Division in Arizona, by U.S. Geological Survey: U.S. Geol. Survey open-file report, 1968. 13 p., 1 fig.

Some notes on the late Cenozoic drainage patterns in southeastern Arizona and southwestern New Mexico, by M. E. Cooley: Arizona Geol. Soc., Southern Arizona Guidebook III, 1968. p. 75-78, 2 figs.

Use of water by riparian vegetation, Cottonwood Wash, Arizona, by J. E. Bowie and William Kam, with a section on Vegetation by F. A. Branson and R. S. Aro: U.S. Geol. Survey Water-Supply Paper 1858, 1968. 62 p., 1 pl., 17 figs., 10 tables.

Water-resources data for Arizona, 1966—Part 1: Surface-water records, by U.S. Geological Survey: U.S. Geol. Survey open-file report, 1967. 230 p., 2 figs.

Error analysis of streamflow data for an alluvial stream, by D. E. Burkham and D. R. Dawdy: U.S. Geol. Survey open-file report, February 1968. 51 p., 15 figs., 3 tables.

Basic ground-water data for southern Coconino County, Arizona, by E. H. McGavock: Arizona State Land Dept. Water-Resources Rept. 33, March 1968. 49 p., 4 figs., 4 tables.

Spring flow into the Colorado River—Lees Ferry to Lake Mead, Arizona, by P. W. Johnson and R. B. Sanderson: Arizona State Land Dept. Water-Resources Rept. 34, April 1968. 26 p., 5 figs., 3 tables.

Annual report on ground water in Arizona, spring 1966 to spring 1967, by C. J. Cox and others: Arizona State Land Dept. Water-Resources Rept. 36, May 1968. 43 p., 30 figs., 1 table.

Ground water in Paradise Valley, Maricopa County, Arizona, by F. E. Arteaga, N. D. White, M. E. Cooley, and A. F. Sutheimer: Arizona State Land Dept. Water-Resources Rept. 35, May 1968. 76 p., 15 figs., 5 tables.

Riverbed degradation below dams [a discussion], by M. E. Moss: Am. Soc. Civil Engineers Proc., Hydraulics Div., v. 94, no. HY3, May 1968. p. 757-759, 1 table.

SUMMARY OF GROUND-WATER CONDITIONS

The ground-water reservoirs are the source of nearly two-thirds of Arizona's water supply; for about the last 15 years, the withdrawal of ground water in the State has been more than 4 million acre-feet per year. The greatest use of water is for the cultivation of crops. Figure 4 shows the amount of ground water pumped and the cultivated acreage for each year from 1940-67.

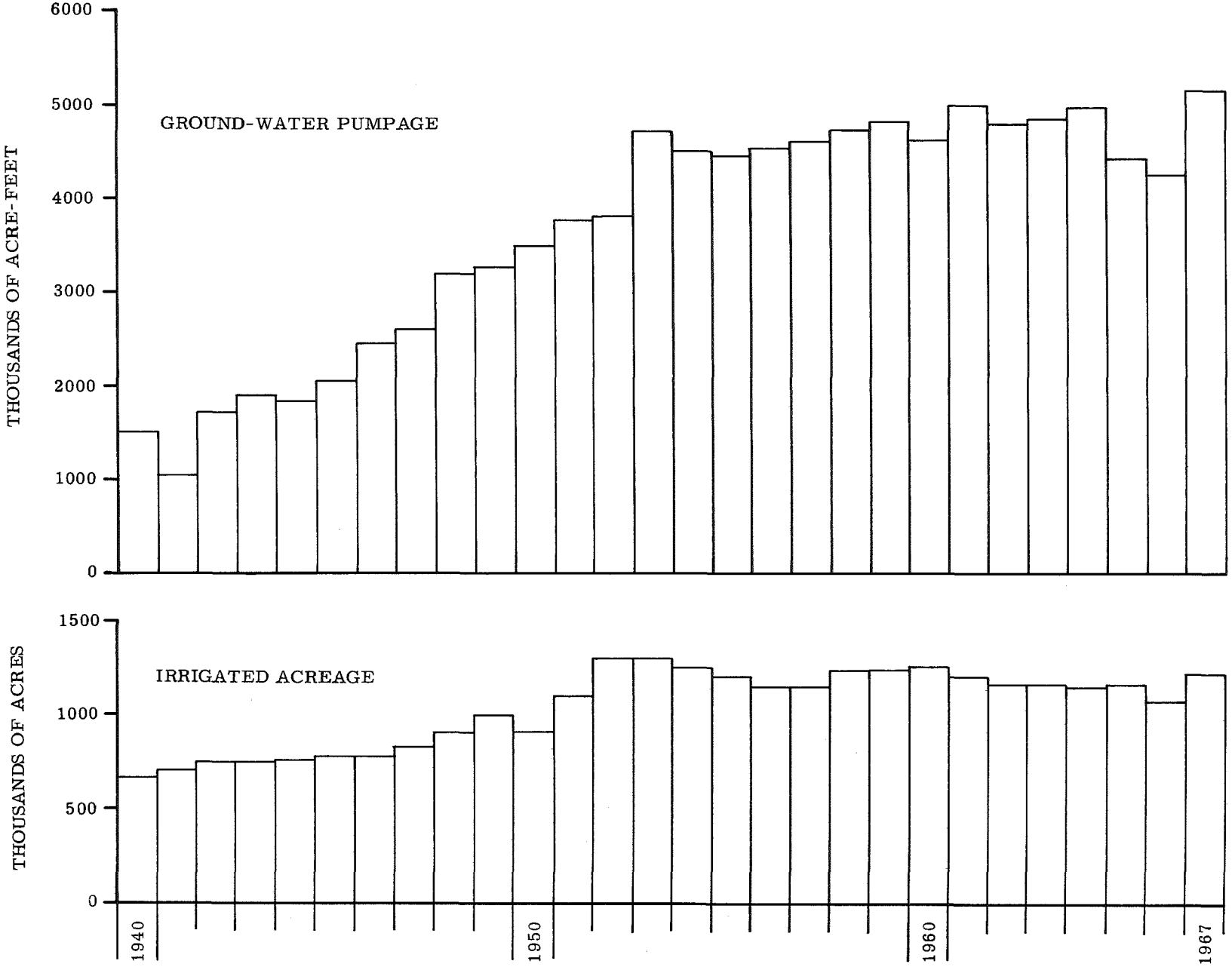


FIGURE 4. --ESTIMATED ANNUAL GROUND-WATER PUMPAGE AND IRRIGATED ACREAGE IN ARIZONA.

In 1967 nearly 5.2 million acre-feet of ground water was withdrawn from the ground-water reservoirs in Arizona—the largest amount for any year to the present time. Table 1 shows the amount of water pumped in each of the major developed areas in the State in 1967 and the accumulated total since the beginning of record. The large withdrawal of ground water has resulted in the decline of water levels in many areas in the State. Figure 5 shows the approximate average change in water levels in the developed areas in the State from 1940 through 1968; the greatest water-level declines are in the areas of greatest ground-water withdrawal.

Ground water occurs under different conditions in each of the three water provinces in Arizona (fig. 1)—the Basin and Range lowlands province, the Central highlands province, and the Plateau uplands province. In the Basin and Range lowlands the unconsolidated or weakly consolidated deposits in the basins store large amounts of ground water and yield the water readily to wells. In the Central highlands the igneous and metamorphic rocks and the well-consolidated sedimentary rocks contain only small amounts of space for the storage of ground water. In the Plateau uplands, water-bearing sandstone constitutes a large storage reservoir for ground water, but well yields generally are small. The use of ground water and current ground-water conditions in each of the three provinces are discussed separately.

Basin and Range Lowlands Province

The Basin and Range lowlands province (fig. 1) comprises about 45 percent of the State, but it contains more than 90 percent of the cultivated land and more than 80 percent of the population; therefore, the demand for water is great. The extensive development of the ground-water supply has resulted in a decline in water levels in a large part of the province. The following paragraphs give brief discussions of ground-water conditions in most of the developed areas in the province.

Duncan and Safford basins.--Although the Duncan and Safford basins (fig. 1, Nos. 1 and 2) are separated topographically and by a ground-water divide, the occurrence of ground water and current ground-water conditions are similar in the two areas. The alluvium that underlies the flood plain of the Gila River and its tributaries constitutes the principal developed aquifer. The alluvium is from about 40 to 100 feet thick and, in general, is capable of yielding from 50 to more than 2,500 gpm (gallons per minute) of water to wells (fig. 6). Most irrigation wells drilled in the alluvium produce from about 100 to 1,500 gpm, but a few wells produce as much as 2,000 gpm. The water in the alluvium is unconfined. Some artesian water is available from deep aquifers in the basins, but it is not used extensively for irrigation because of the high dissolved-solids content.

Table 1.--Estimated ground-water pumpage in Arizona, by areas

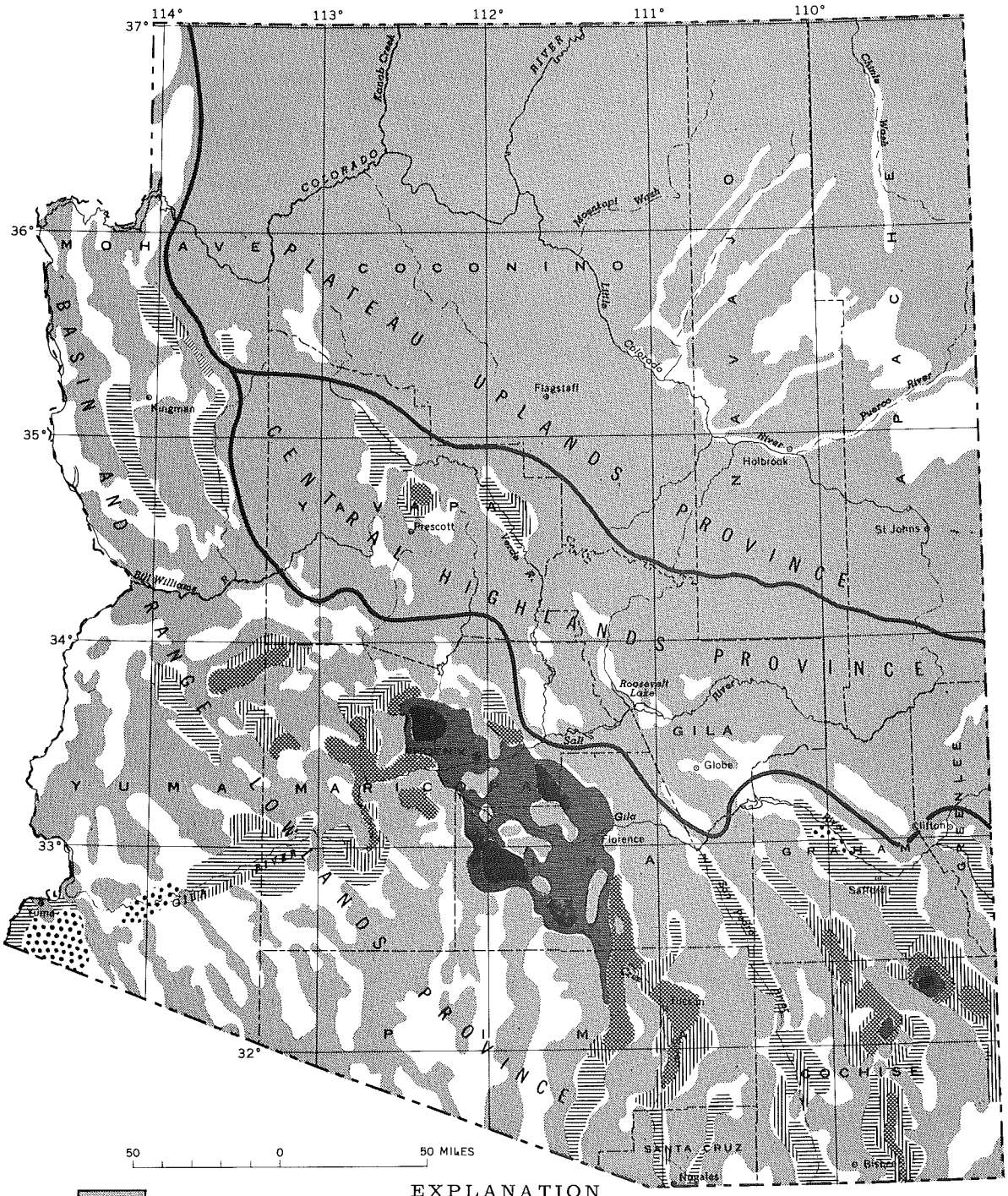
[Numbers rounded to nearest thousand acre-feet. Area: See figure 1 for location. Other areas: Aravaipa Valley, Big Sandy Valley, Date Creek area, Peeples Valley, Skull Valley, Verde Valley, Little Colorado River basin, areas in the Plateau uplands, and small areas not identifiable with any particular basin]

Area	Pumpage, in thousands of acre-feet	
	In 1967	Accumulated total through 1967
Duncan basin	25	543
Safford basin	145	2,430
San Simon basin	76	1,028
Willcox basin	300	2,903
Douglas basin	120	1,241
San Pedro River valley	63	1/
Upper Santa Cruz basin	200	5,207
Avra Valley	121	2,178
Lower Santa Cruz basin	1,120	31,202
Salt River Valley	1,763	58,817
Waterman Wash area	52	724
Gila Bend basin	198	3,183
Harquahala Plains area	170	1,715
McMullen Valley	98	818
Gila River drainage from Painted Rock Dam to Texas Hill	100	891
Ranegras Plain area	12	211
Wellton-Mohawk area	2/213	2,250
Yuma area 3/	224	2,714
Colorado River flood plain from Davis Dam to Imperial Dam	20	115
Sacramento Valley	4	12
Hualapai Valley	4	14
Big Chino Valley	9	349
Little Chino Valley	12	325
Williamson Valley	2	36
Other areas	100	1,780
Total	5,151	120,686

1/ Pumpage for San Pedro River valley was not computed prior to 1966; estimated pumpage before 1966 is included under other areas.

2/ Withdrawal for drainage purposes only.

3/ Yuma area includes South Gila Valley, Yuma Mesa, and Yuma Valley. Beginning in 1947 in Yuma Valley and in 1961 in South Gila Valley, part of the pumpage was for drainage of waterlogged lands.



EXPLANATION

CONSOLIDATED ROCKS

CHANGE IN WATER LEVEL IN ALLUVIAL DEPOSITS, IN FEET

RISE

GENERALLY LESS THAN 10

DECLINE

LESS THAN 10

10-25

26-75

76-125

MORE THAN 125

NO DATA
OR NOT ANALYZED
(SEE NOTE)

NOTE: IN THE PLATEAU UPLANDS AND PART OF THE CENTRAL HIGHLANDS, WATER LEVELS IN THE CONSOLIDATED ROCKS AND ALLUVIAL DEPOSITS FLUCTUATE ERRATICALLY IN RESPONSE TO INTERMITTENT RECHARGE AND PUMPING; THEREFORE, NO LONG-TERM TRENDS HAVE BEEN ESTABLISHED

FIGURE 5. --APPROXIMATE AVERAGE CHANGE IN WATER LEVELS IN DEVELOPED AREAS, 1940-68.

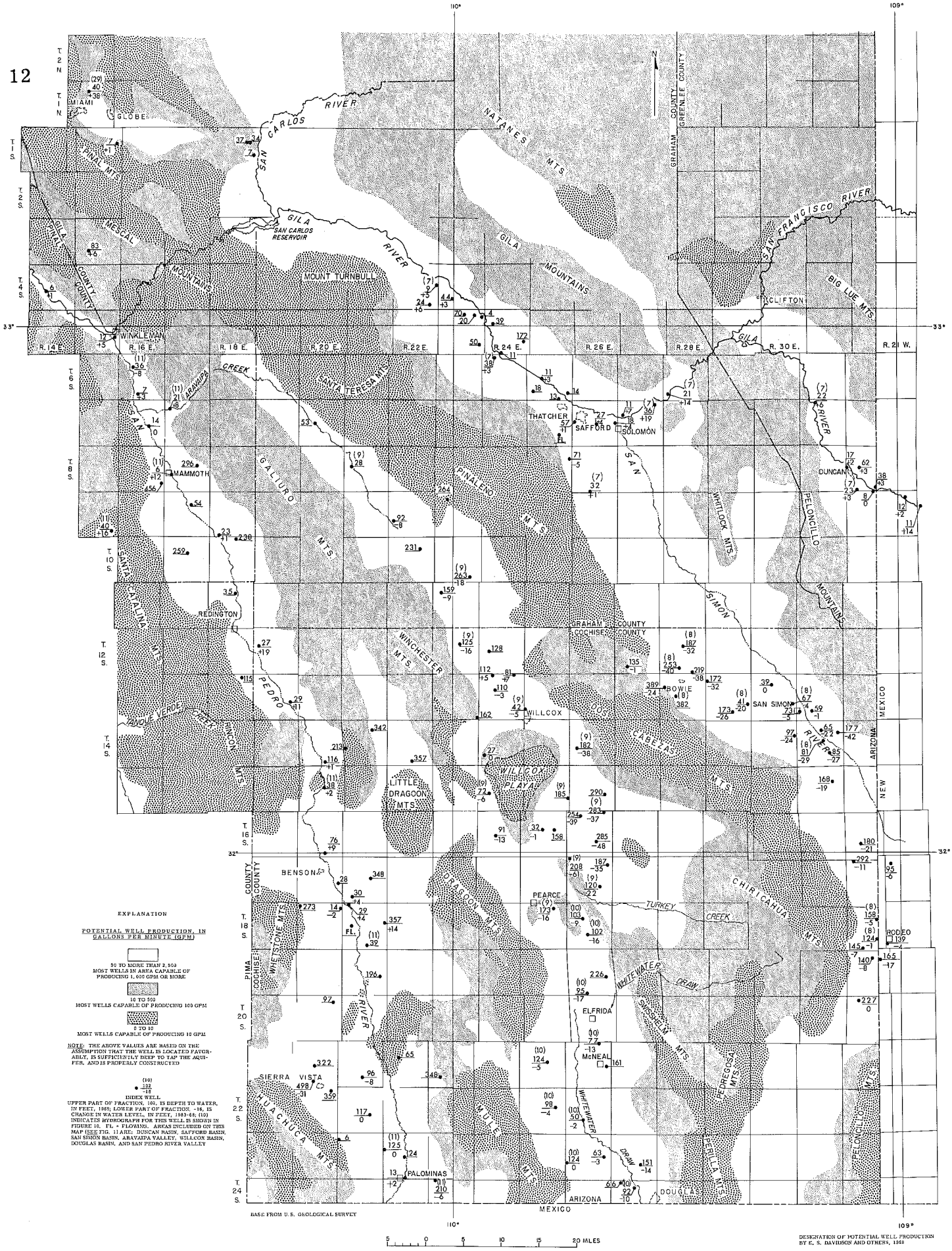


FIGURE 6.--POTENTIAL WELL PRODUCTION, DEPTH TO WATER, 1968, AND CHANGE IN WATER LEVEL, 1963-68, IN SELECTED WELLS IN THE SOUTHEAST PART OF THE BASIN AND RANGE LOWLANDS PROVINCE.

In the Duncan and Safford basins ground water is used to supplement surface water from the Gila River for the irrigation of a specified amount of acreage decreed by law. Therefore, the amount of ground water pumped in any given year depends upon the availability of surface water. In 1967 no surface water was diverted into the Arizona part of the Duncan basin, and ground-water pumpage was about 25,000 acre-feet. In the Safford basin about 145,000 acre-feet of ground water was pumped in 1967 to supplement slightly more than 90,000 acre-feet of surface water. The total withdrawal of ground water through 1967 was about 543,000 acre-feet in the Duncan basin and 2,430,000 acre-feet in the Safford basin (table 1).

Water levels in the flood-plain alluvium in the basins fluctuate with pumping cycles and with the flow in the river. Water levels in the basins generally rose from 1967 to 1968 and from 1963 to 1968. Figure 6 shows the depth to water in spring 1968 and the change in water levels from 1963 to 1968 in selected wells in the basins. Graphs showing the depth to water in selected wells and estimated annual pumpage in each of the basins are given in figure 7.

San Simon basin. --In the southern part of the San Simon basin ground water occurs in a single unconfined aquifer. In the rest of the basin (fig. 1, No. 3) ground water occurs under artesian conditions in a lower aquifer and under water-table conditions in an upper aquifer. The upper and lower aquifers are separated by an extensive clay unit, which forms an aquiclude, except in a marginal zone along the mountain fronts where ground water is under water-table conditions. In general, the aquifer materials in the basin are capable of yielding from 50 to more than 2,500 gpm of water to wells (fig. 6). Individual well yields differ, however, depending on the aquifer penetrated and on the location of the well in the basin. Wells completed in the artesian aquifer yield from about 100 to 2,500 gpm; the higher yields are from wells in the Bowie area. Wells completed in the water-table aquifer yield from about 200 to 400 gpm in the San Simon area; the upper materials are dry in the Bowie area. South of Bowie, wells in the marginal zone yield from about 1,000 to 3,000 gpm; southeast of San Simon, two wells in the marginal zone yield only 100 to 300 gpm. In the Rodeo area, well yields range from about 200 to 1,500 gpm.

In 1967 about 76,000 acre-feet of ground water was pumped in the San Simon basin; total withdrawal since 1915, when pumping began, has been more than a million acre-feet (table 1). Nearly all the water is used for the irrigation of crops; in 1967 slightly less than 32,000 acres was cultivated, all of which was irrigated with ground water.

The extensive pumping has caused a continuing decline in water levels in the basin. The largest declines have been in the Bowie area, where the average decline was about 29 feet from 1963 to 1968 and about 5 feet from 1967

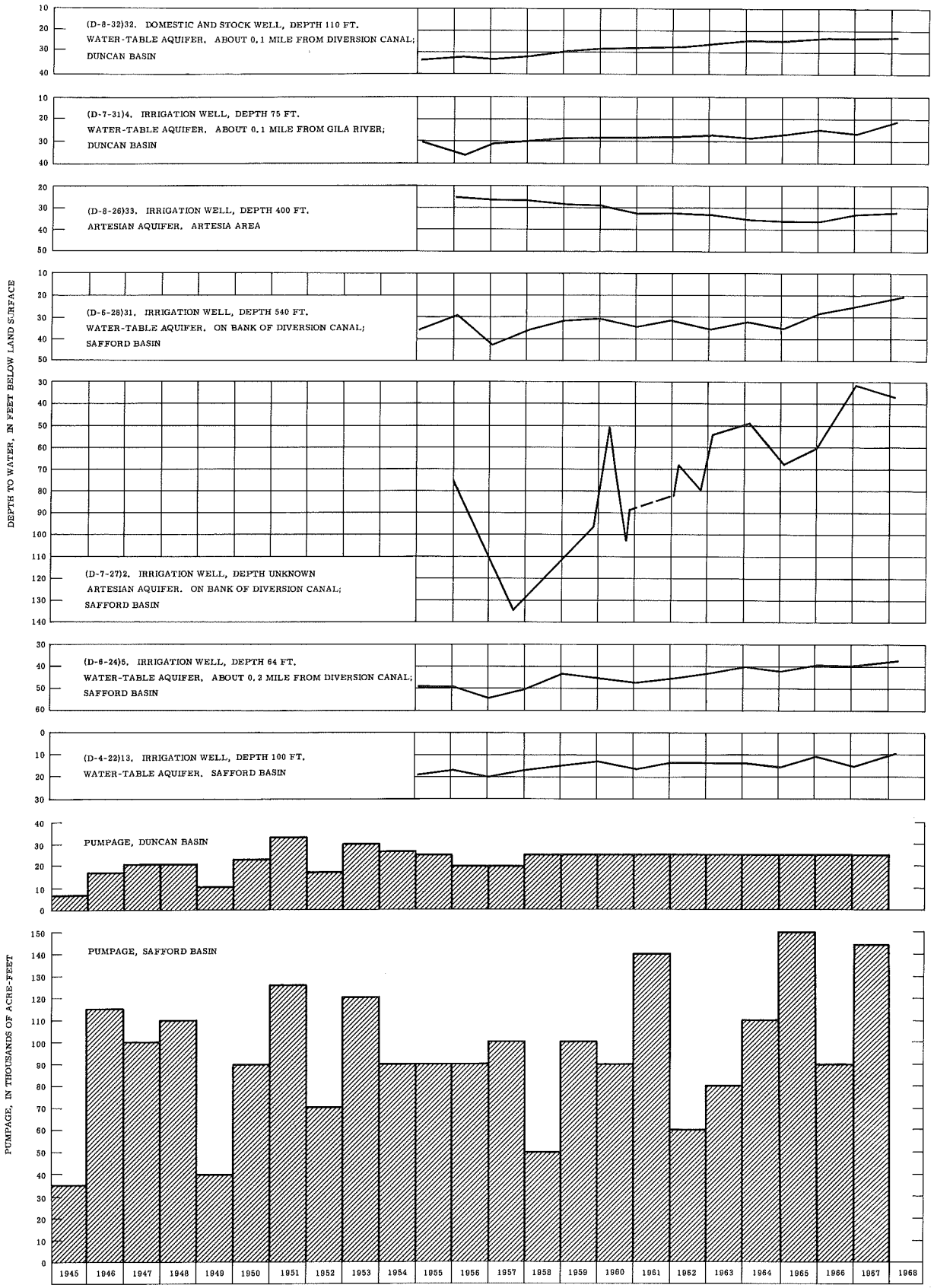


FIGURE 7.--DEPTH TO WATER IN SELECTED WELLS AND ESTIMATED ANNUAL PUMPAGE IN THE DUNCAN AND SAFFORD BASINS.

to 1968, based on measurements in 14 wells. In the San Simon area the average decline in water level was about 17 feet for the 5-year period, based on measurements in 17 wells; in the Rodeo area the average decline was about 6 feet, based on measurements in 13 wells. In the San Simon and Rodeo areas the average change in water level from 1967 to 1968 was zero, although water-level changes ranged from rises of about 8 feet to declines of about 8 feet. The depth to water in the San Simon basin varies greatly, depending on the aquifer penetrated and the location of the well (figs. 6 and 8).

Willcox basin.--In most of Willcox basin (fig. 1, No. 5) ground water is under water-table conditions, although, in a few places, lake-bed deposits act as a confining layer and cause local artesian conditions near the Willcox Playa. Figure 6 shows the general potential well production from the aquifer materials in the Willcox basin; however, individual well yields vary greatly. Although most irrigation wells yield from 750 to 1,200 gpm of water, some yield only about 400 to 500 gpm, and a few are reported to yield more than 2,000 gpm. In general, wells east of the Willcox Playa and south of Willcox have the highest yields, and the lowest yields are from wells near the playa.

In 1967 about 106,000 acres of land was cultivated in the basin, and about 300,000 acre-feet of ground water was pumped—an increase in pumpage of about 25 percent since 1966. A part of the increase was the result of extensive preplanting irrigation necessitated by the extremely dry weather conditions in winter 1966-67. However, some of the increase in pumpage was because of the development of new land, mostly in the Sierra Bonita Ranch and Turkey Creek areas. The total withdrawal of ground water through 1967 was more than 2.9 million acre-feet in the Willcox basin (table 1).

Water levels in most of the basin have continued to decline. The greatest declines are in the developed area southeast of the Willcox Playa, but immediately adjacent to the playa water-level declines are small. Northwest of Willcox, the area of water-level decline has extended farther northward (figs. 6 and 9).

Douglas basin.--The ground water in the alluvial deposits, which are the principal aquifers in Douglas basin (fig. 1, No. 6), is generally unconfined; however, in a few places wells yield water under artesian pressure. The alluvium is capable of yielding from 50 to more than 2,500 gpm of water to wells (fig. 6). Most of the irrigation wells in the basin produce from 200 to 1,200 gpm of water.

Most of the ground water pumped in the Douglas basin is used for irrigation, although some is used for industrial (smelting) and municipal purposes. In 1967 about 120,000 acre-feet of ground water was withdrawn, of which slightly

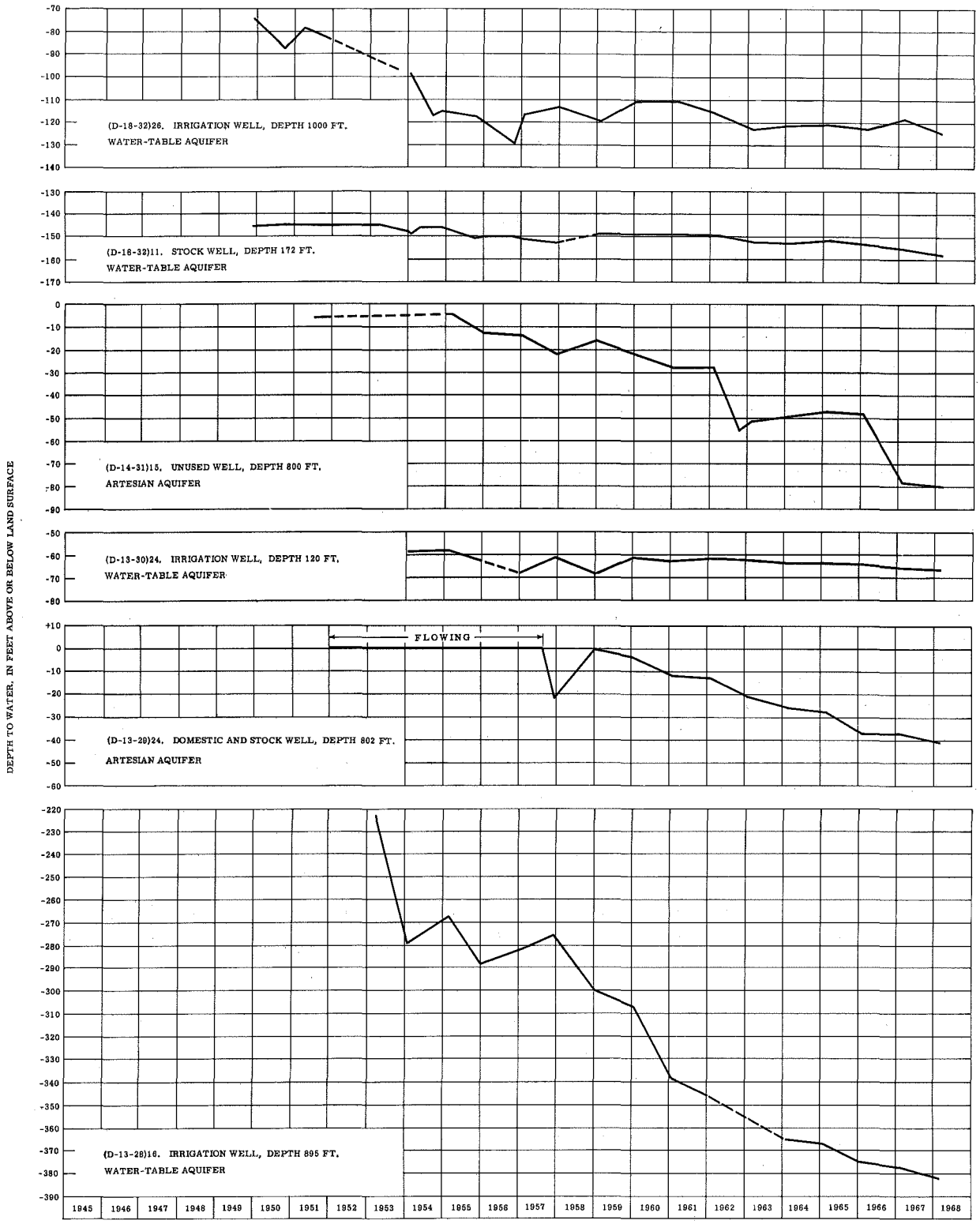


FIGURE 8.--DEPTH TO WATER IN SELECTED WELLS AND ESTIMATED ANNUAL PUMPAGE IN SAN SIMON BASIN. (IN TWO SHEETS.)
SHEET 1 OF FIGURE 8

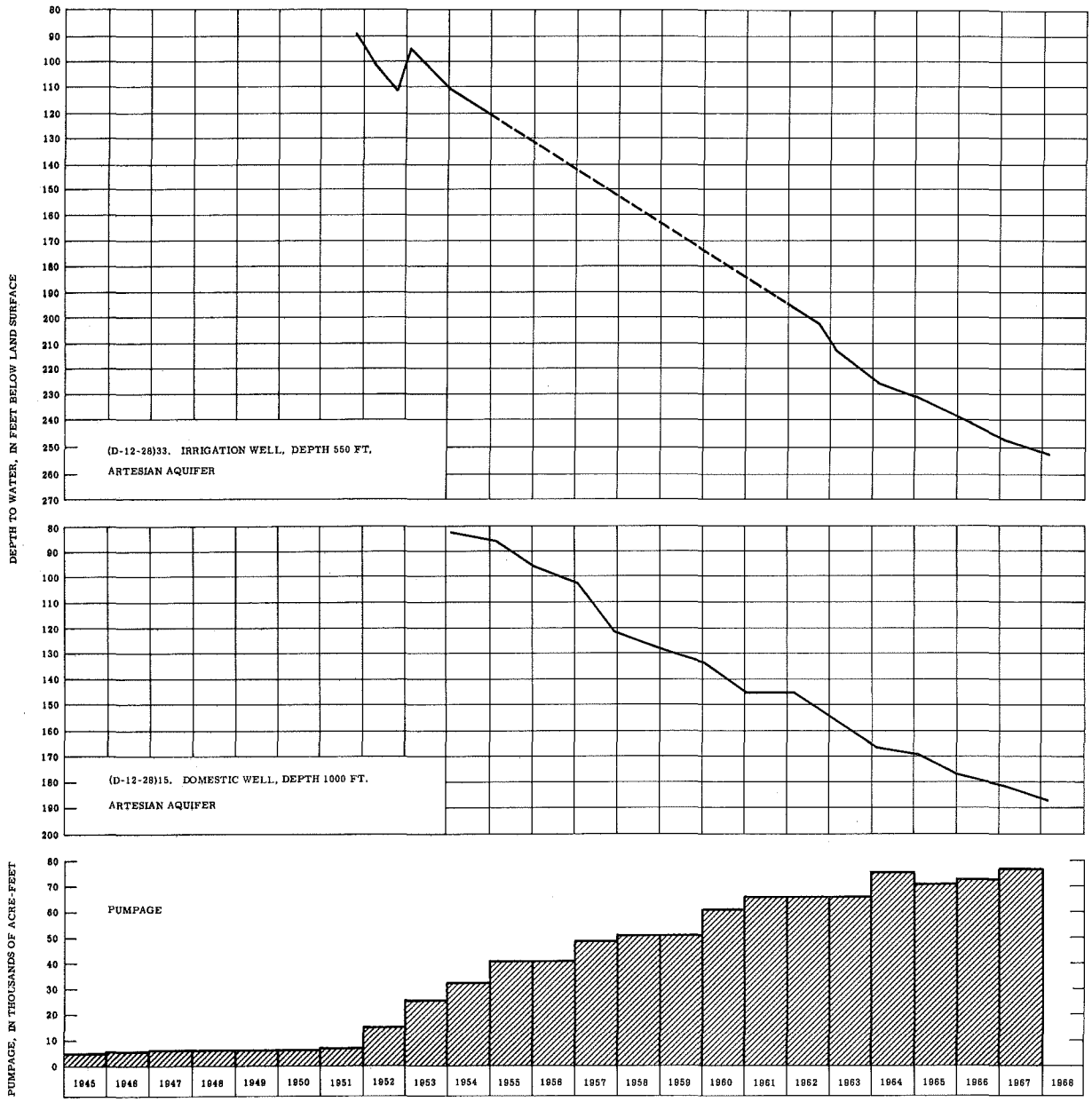


FIGURE 8.--DEPTH TO WATER IN SELECTED WELLS AND ESTIMATED ANNUAL PUMPAGE IN SAN SIMON BASIN. (IN TWO SHEETS.)
SHEET 2 OF FIGURE 8

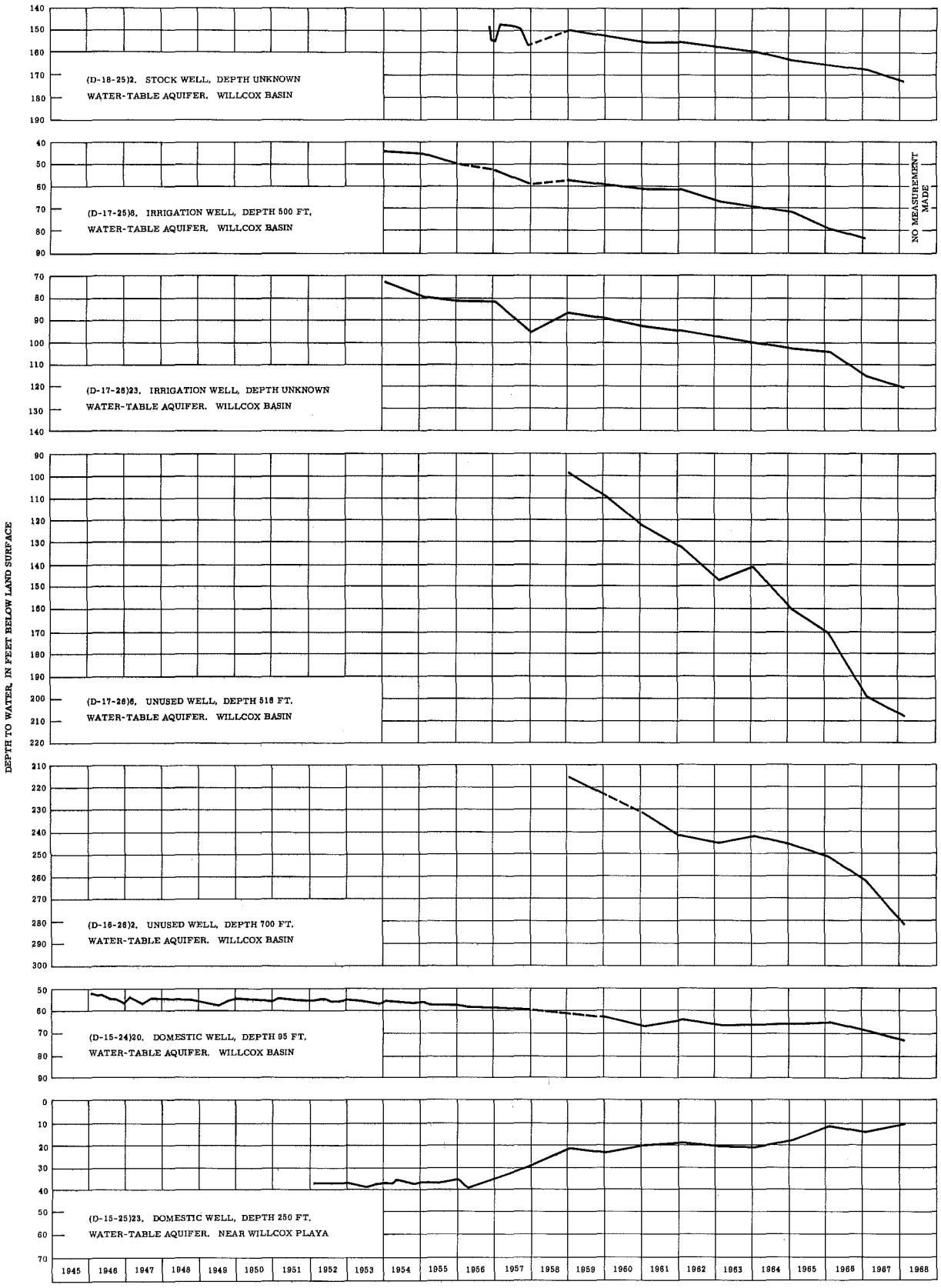


FIGURE 9.--DEPTH TO WATER IN SELECTED WELLS IN WILLCOX BASIN AND ARAVAIPA VALLEY AND ESTIMATED ANNUAL PUMPAGE IN WILLCOX BASIN. (IN TWO SHEETS.)

SHEET 1 OF FIGURE 9

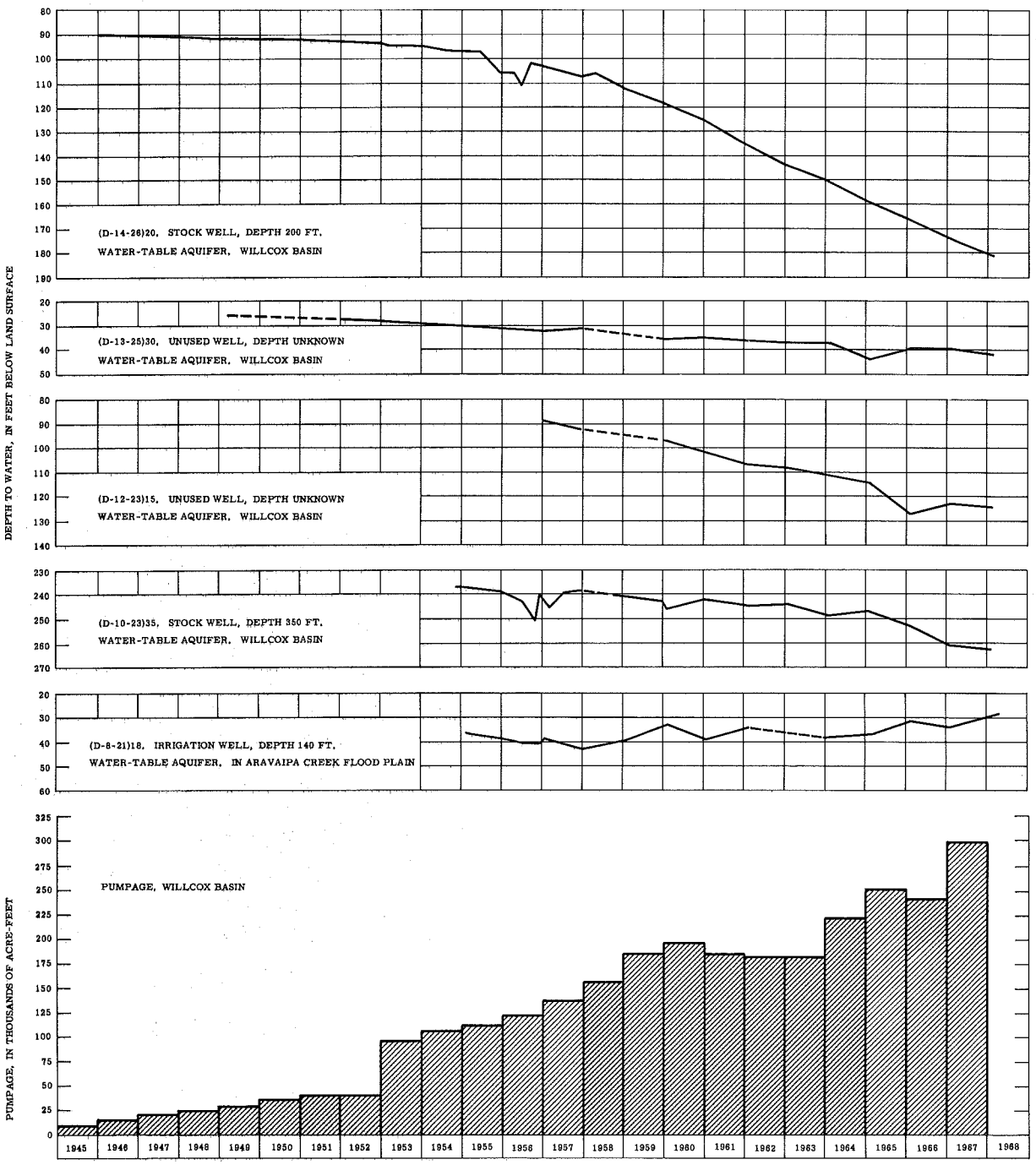


FIGURE 9.--DEPTH TO WATER IN SELECTED WELLS IN WILLCOX BASIN AND ARAVAIPA VALLEY AND ESTIMATED ANNUAL PUMPAGE IN WILLCOX BASIN. (IN TWO SHEETS.)

SHEET 2 OF FIGURE 9

more than 116,000 acre-feet was used to irrigate crops. Through 1967 more than 1.2 million acre-feet of ground water had been withdrawn from the aquifers in Douglas basin.

Water levels in the Douglas basin generally continued to decline from spring 1967 to spring 1968; the average decline for the year was about 1 foot, slightly less than during the last few years. From 1963 to 1968, the average decline was about 8 feet. Depth to water is least along the center of the basin and greatest near the mountain fronts (figs. 6 and 10).

San Pedro River valley. --In the San Pedro River valley (fig. 1, No. 7) the valley-fill deposits, which have been divided into three principal units, contain ground water under water-table and artesian conditions. In places the artesian pressure is sufficient to cause wells to flow, but in other places the artesian pressure has been reduced by nearby pumping and wells have ceased to flow. Figure 6 shows the general potential well production from the valley fill; individual well yields vary greatly and range from about 5 to as much as 2,000 gpm.

In 1967 about 63,000 acre-feet of ground water was pumped in the San Pedro River valley. About 38,000 acre-feet of water was used to irrigate crops, and the remainder was used for municipal and industrial purposes. Ground-water withdrawal was not computed prior to 1967 because the necessary data were not available; therefore, the total withdrawal from the aquifers is not known (table 1).

In general, ground water is in transit along the flood plains of the San Pedro River and its tributaries—that is, the aquifer is being recharged at a rate that is about equivalent to the rate of discharge. The water levels in wells along the flood plain fluctuate with pumping schedules and recharge from flow in the river. From 1963 to 1968 and from 1967 to 1968, water levels generally rose in this area. The water levels in deep wells along the flanks of the valley showed no pattern of rise or decline in these periods. In the Fort Huachuca-Sierra Vista area water levels are declining (figs. 6 and 11).

Upper Santa Cruz basin. --The water-bearing alluvial materials in most of the upper Santa Cruz basin (fig. 1, No. 8) are interconnected, and ground water occurs under water-table conditions. Figure 12 shows the general potential well production from the alluvium; however, individual well yields vary greatly depending on well location, depth, and construction.

In 1967 about 200,000 acre-feet of ground water was withdrawn from the alluvial aquifers in the upper Santa Cruz basin; of this amount about 118,000 was used to irrigate crops. Ground-water withdrawal by the City of Tucson

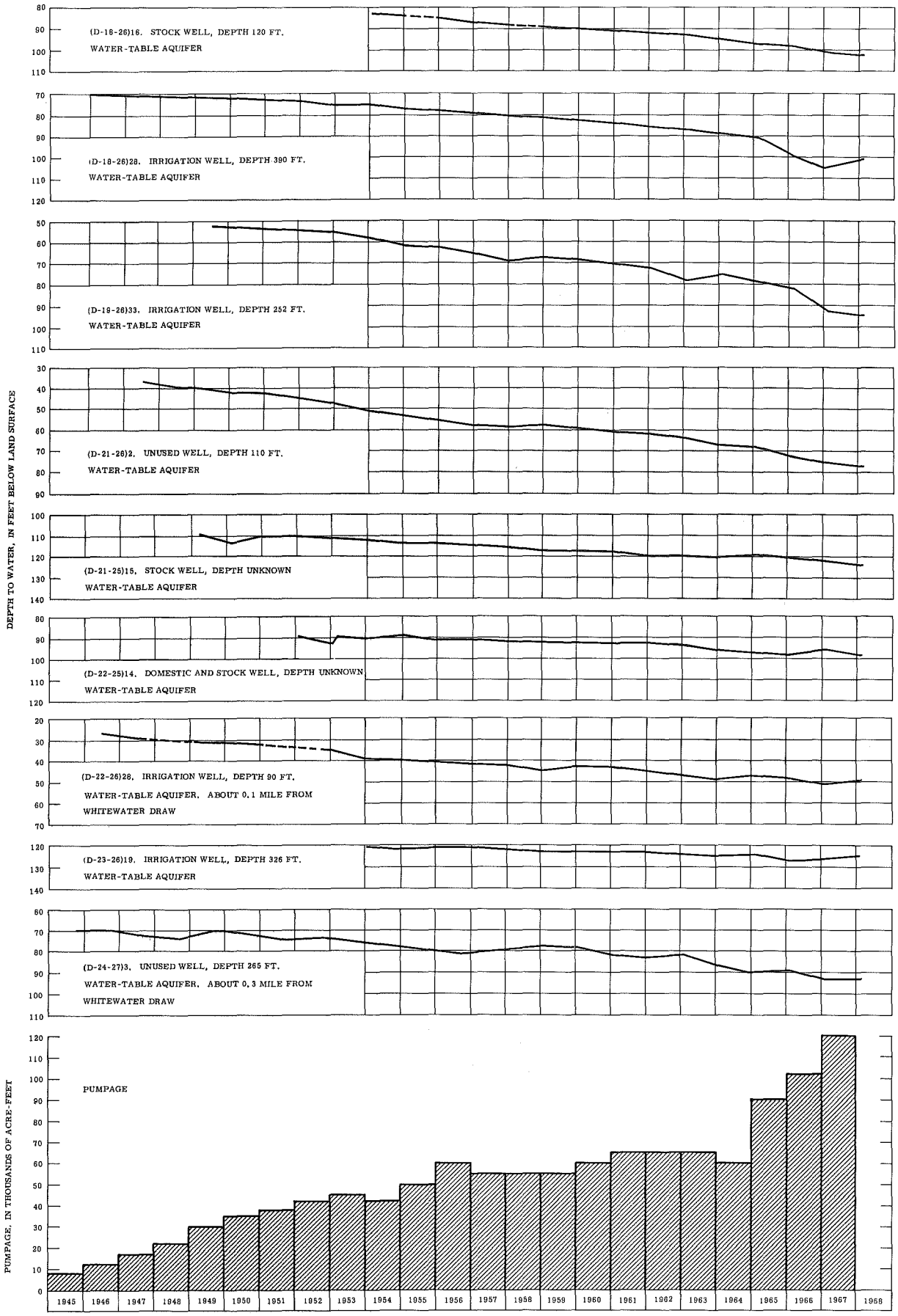


FIGURE 10.--DEPTH TO WATER IN SELECTED WELLS AND ESTIMATED ANNUAL PUMPAGE IN DOUGLAS BASIN.

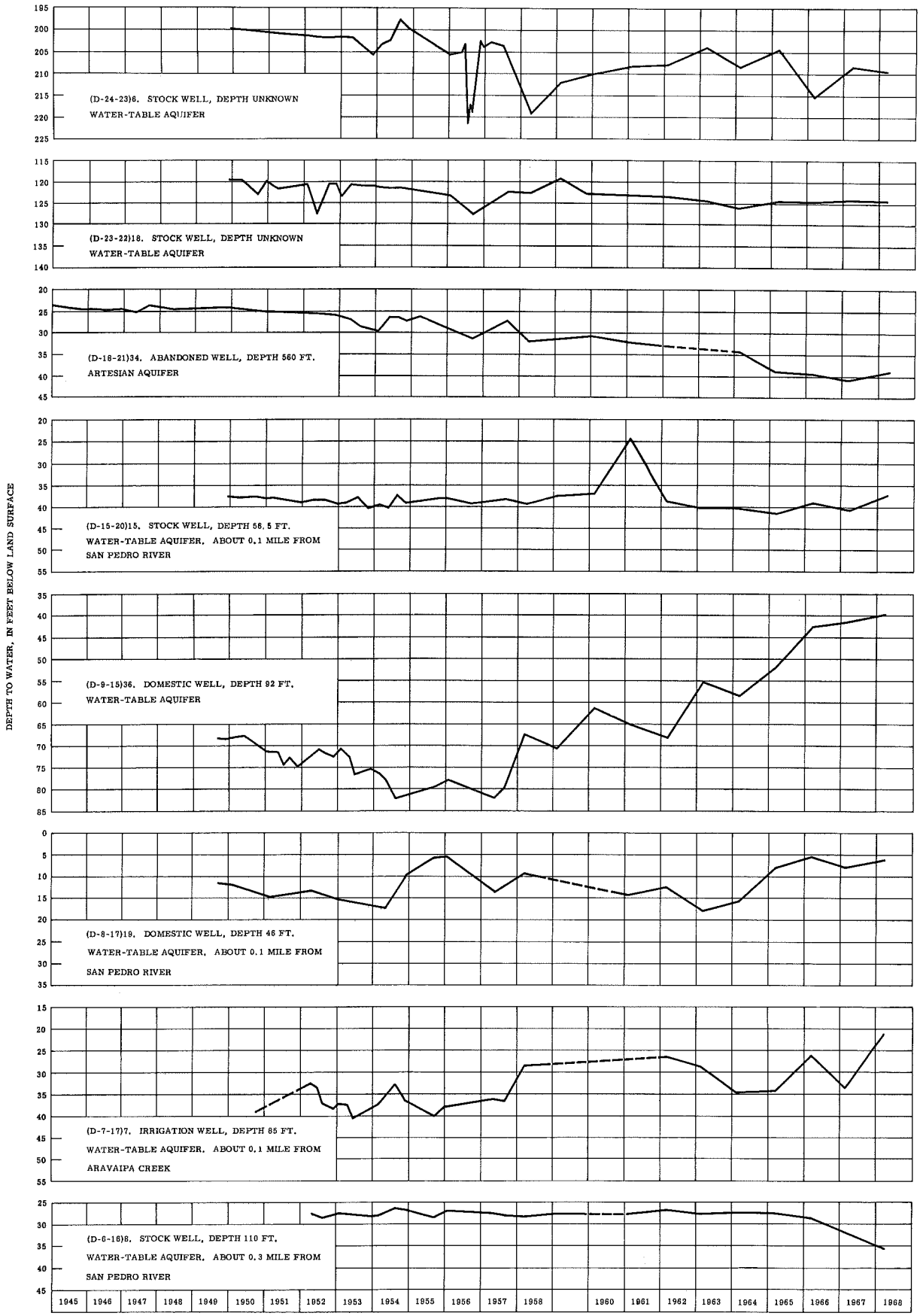


FIGURE 11.--DEPTH TO WATER IN SELECTED WELLS IN THE SAN PEDRO RIVER VALLEY.

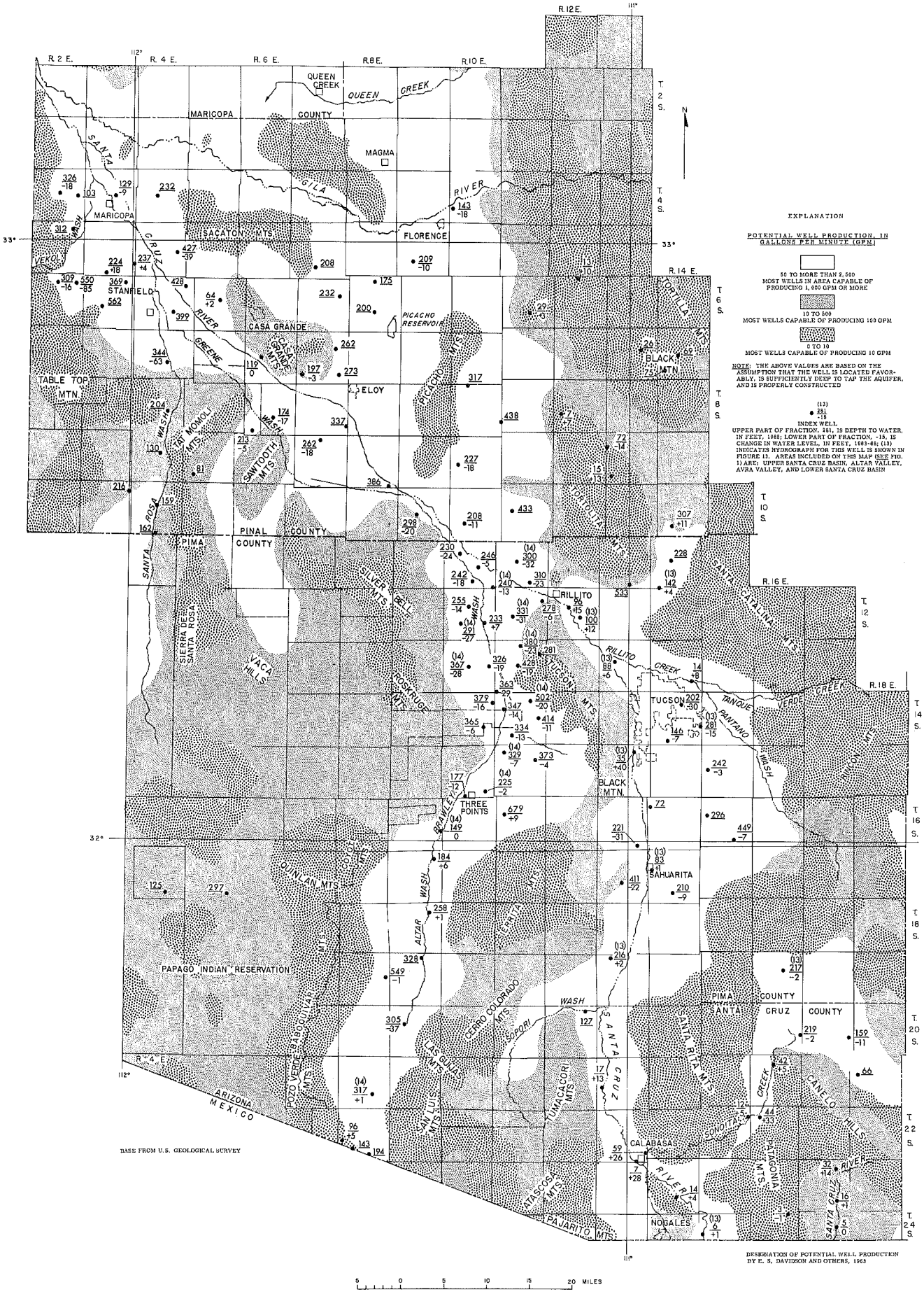


FIGURE 12. --POTENTIAL WELL PRODUCTION, DEPTH TO WATER, 1968, AND CHANGE IN WATER LEVEL, 1963-68, IN SELECTED WELLS IN THE SOUTH-CENTRAL PART OF THE BASIN AND RANGE LOWLANDS PROVINCE.

Water Utility has increased steadily because of increasing population, and in 1967 about 61,000 acre-feet of ground water was pumped for municipal use. Large-scale pumping in the upper Santa Cruz basin began in about 1940, and, through 1967, about 5.2 million acre-feet of ground water had been withdrawn (table 1).

Water levels in wells near the Santa Cruz River and near Sonoita and Rillito Creeks generally rose from 1967 to 1968 and from 1963 to 1968. Excessive runoff in the main streams in December 1967 may have provided some recharge to the ground-water reservoir. Water levels in wells farther from the main drainages, especially in the central part of Tucson and west of Sahuarita, declined from 1963 to 1968 (figs. 12 and 13).

Altar and Avra Valleys. --In general, the water-bearing materials in Altar and Avra Valleys (fig. 1, Nos. 9 and 10) are interconnected to a depth of at least 700 feet, and they form a single water-table aquifer. Below a depth of about 1,100 feet, however, there is some evidence that the water is confined beneath less permeable materials and that it may rise above the regional water table in places. Data are insufficient to determine the extent of the confined aquifer. Figure 12 shows the general potential well production from the saturated materials in the area. Individual well yields vary greatly; most irrigation wells in Avra Valley produce more than 1,000 gpm, and a few produce as much as 3,000 gpm. Most of the wells in Altar Valley are equipped to produce only small amounts of water.

In Altar Valley ground water is used mainly for domestic and stock purposes, and a small amount is used for irrigation; the amount of ground-water pumpage has not been calculated. In Avra Valley the main use of ground water is for the irrigation of crops. In 1967 about 34,000 acres of land was irrigated using about 121,000 acre-feet of ground water; the total amount of ground-water withdrawal through 1967 was slightly less than 2.2 million acre-feet (table 1).

Water-level changes in Altar Valley are minor, and no pattern of rise or decline is discernible. Water levels in Avra Valley are declining in response to the withdrawal of ground water in excess of the rate of replenishment. From 1963 to 1968, the average decline in water level in Avra Valley was about 16 feet, based on measurements in 26 wells; the largest declines are in the northern part of the area, where the withdrawal of ground water is greatest (figs. 12 and 14).

Lower Santa Cruz basin. --Three units of unconsolidated alluvium form the principal aquifers in the lower Santa Cruz basin (fig. 1, No. 11). In places the units combine hydrologically to form a single aquifer system in which ground water is under water-table conditions. In other places, however, the units are

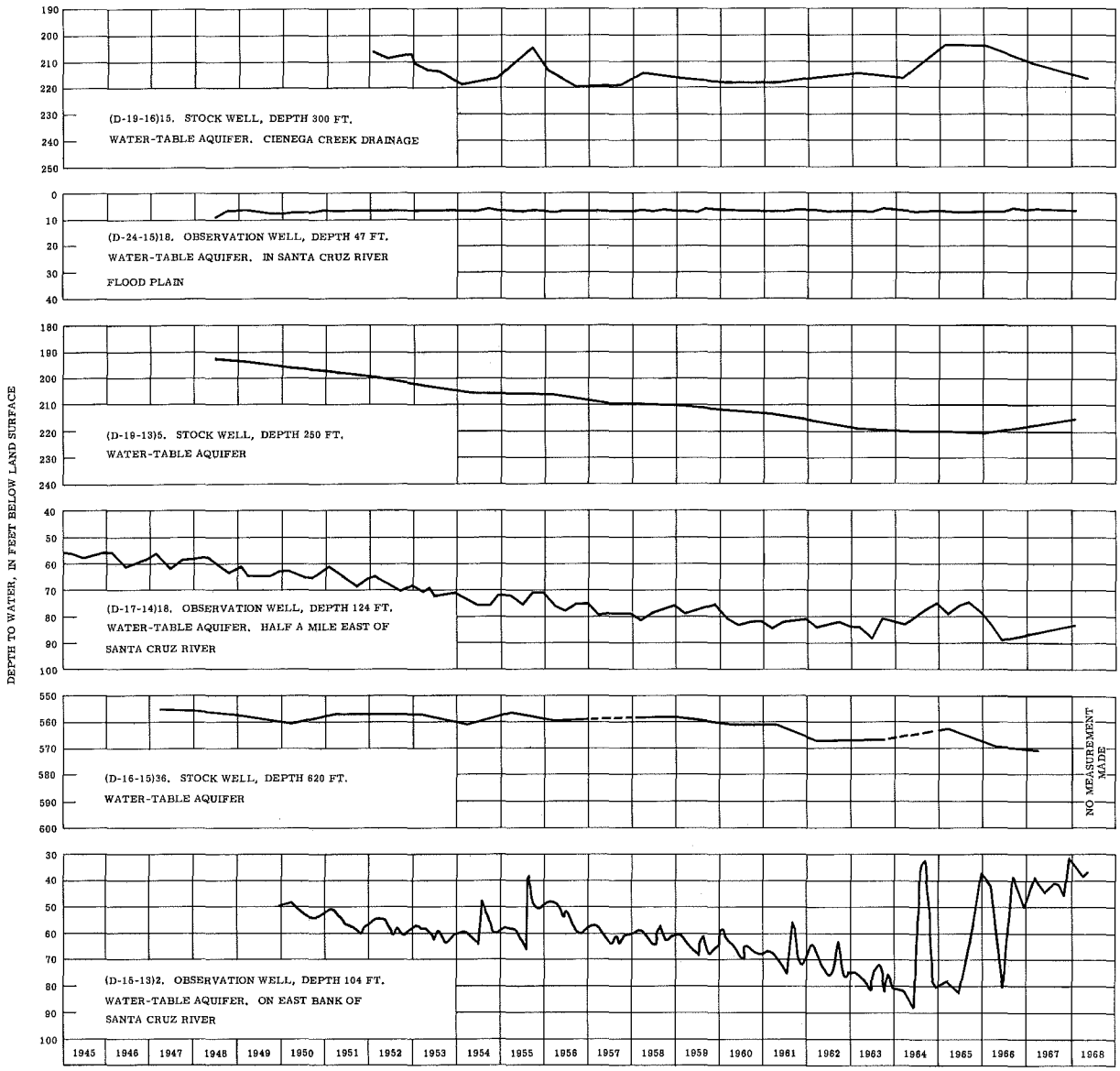


FIGURE 13.--DEPTH TO WATER IN SELECTED WELLS AND ESTIMATED ANNUAL PUMPAGE IN THE UPPER SANTA CRUZ BASIN. (IN TWO SHEETS.)
SHEET 1 OF FIGURE 13

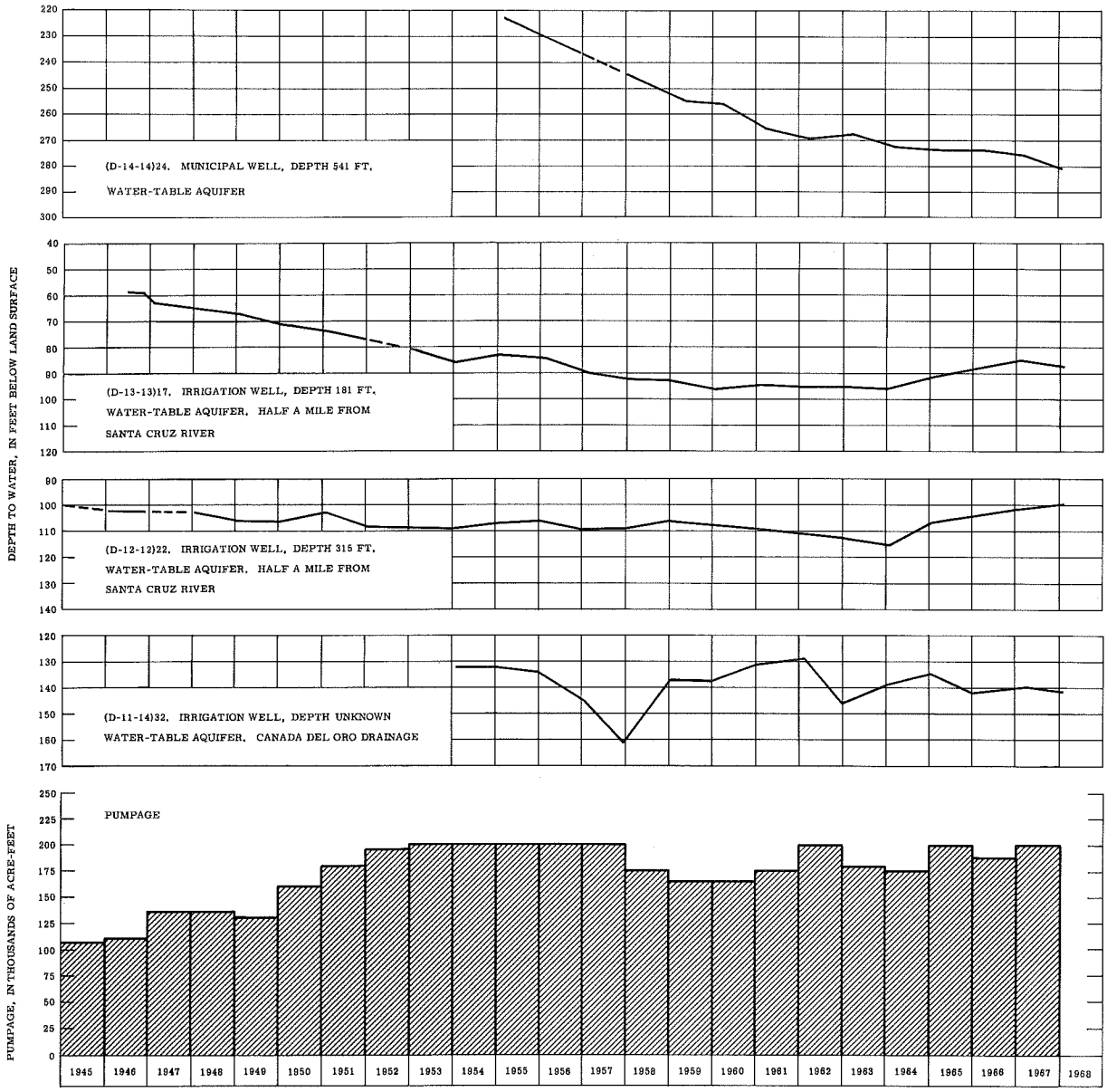


FIGURE 13.--DEPTH TO WATER IN SELECTED WELLS AND ESTIMATED ANNUAL PUMPAGE IN THE UPPER SANTA CRUZ BASIN. (IN TWO SHEETS.)
SHEET 2 OF FIGURE 13

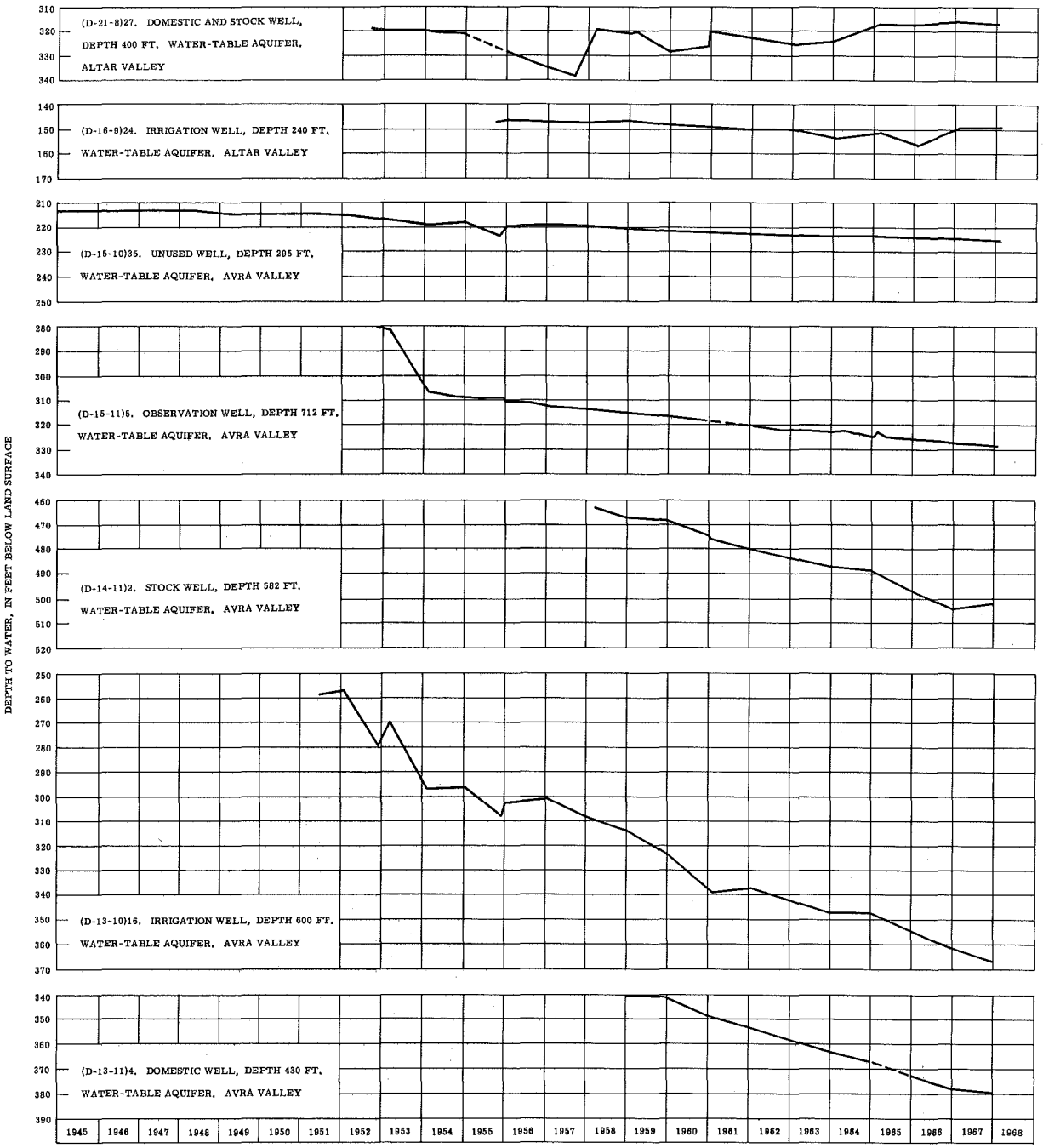


FIGURE 14.--DEPTH TO WATER IN SELECTED WELLS IN ALTAR AND AVRA VALLEYS AND ESTIMATED ANNUAL PUMPAGE IN AVRA VALLEY. (IN TWO SHEETS.)

SHEET 1 OF FIGURE 14

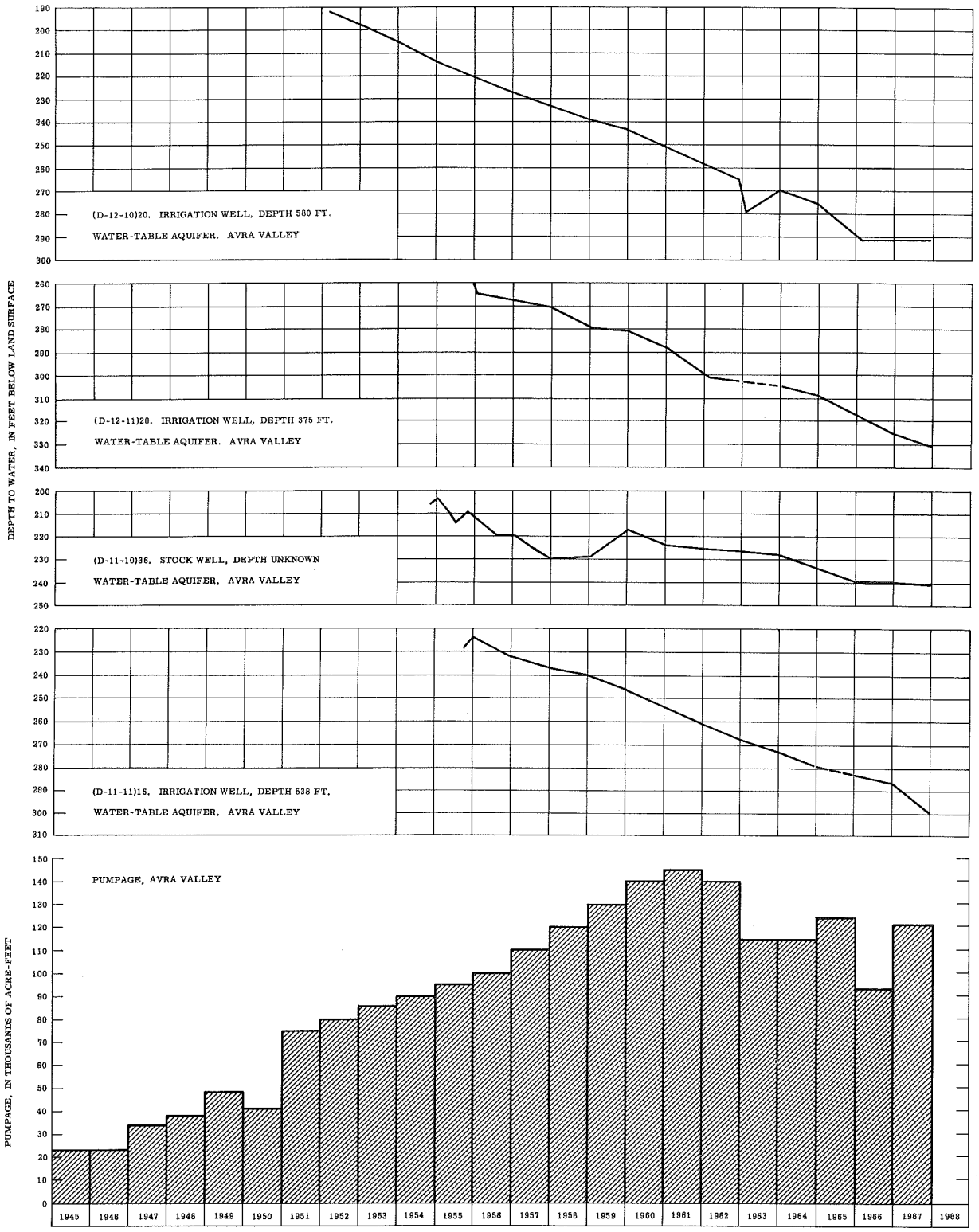


FIGURE 14.--DEPTH TO WATER IN SELECTED WELLS IN ALTAR AND AVRA VALLEYS AND ESTIMATED ANNUAL PUMPAGE IN AVRA VALLEY. (IN TWO SHEETS.)

SHEET 2 OF FIGURE 14

separated by confining beds, and water in the underlying aquifer is under artesian pressure. Figure 12 shows the general potential well production from the aquifers. Individual well yields vary greatly in the area and depend not only on the aquifer or aquifers penetrated but also on well construction. Most irrigation wells produce from 750 to 2,000 gpm of water, but some produce more than 3,000 gpm.

The lower Santa Cruz basin is one of the most highly developed areas in the State, and it is second only to the Salt River Valley in the amount of ground water used and in irrigated acreage. In 1967 about 1,120,000 acre-feet of ground water was pumped from the alluvial aquifers in the basin; the total amount withdrawn through 1967 was about 31.2 million acre-feet (table 1).

Water levels are declining in most of the area. From 1940 through 1967, the average water-level decline was about 160, 112, and 185 feet in the Eloy, Casa Grande-Florence, and Stanfield-Maricopa areas, respectively (fig. 15). Figure 12 shows the depth to water in spring 1968 and the change in water level from 1963 to 1968 in selected wells in the basin.

Salt River Valley. --In the Salt River Valley (fig. 1, No. 12) ground water is under water-table conditions where the units of the unconsolidated alluvium combine hydrologically to form a single aquifer system; where the units are separated by confining beds, water in the underlying aquifer is under artesian conditions. Figure 16 shows the general potential well production from the aquifers in the area.

The Salt River Valley is the most highly developed area in the State and contains the most cultivated acreage, the greatest concentration of people, and the most industry. Therefore, it is in this area that the demand for water is greatest. The surface-water supply is not adequate to meet the needs and large amounts of ground water are pumped each year—more than in any other area. In 1967 about 1,763,000 acre-feet of ground water was pumped, and the total withdrawal through 1967 was more than 58.8 million acre-feet (table 1).

The general trend of water-level changes in the Salt River Valley is a decline, although the rate of decline has lessened during the last few years (figs. 17 and 18). From 1967 to 1968, water levels in most wells declined 0-6 feet, although in some wells the water levels rose druing the year. In December 1967 Cave Creek, New River, Skunk Creek, and the Agua Fria River had surface flow, and some water was released into the normally dry Salt River from Granite Reef Dam. Most of the rises in water level occurred in wells near these streams (fig. 16).

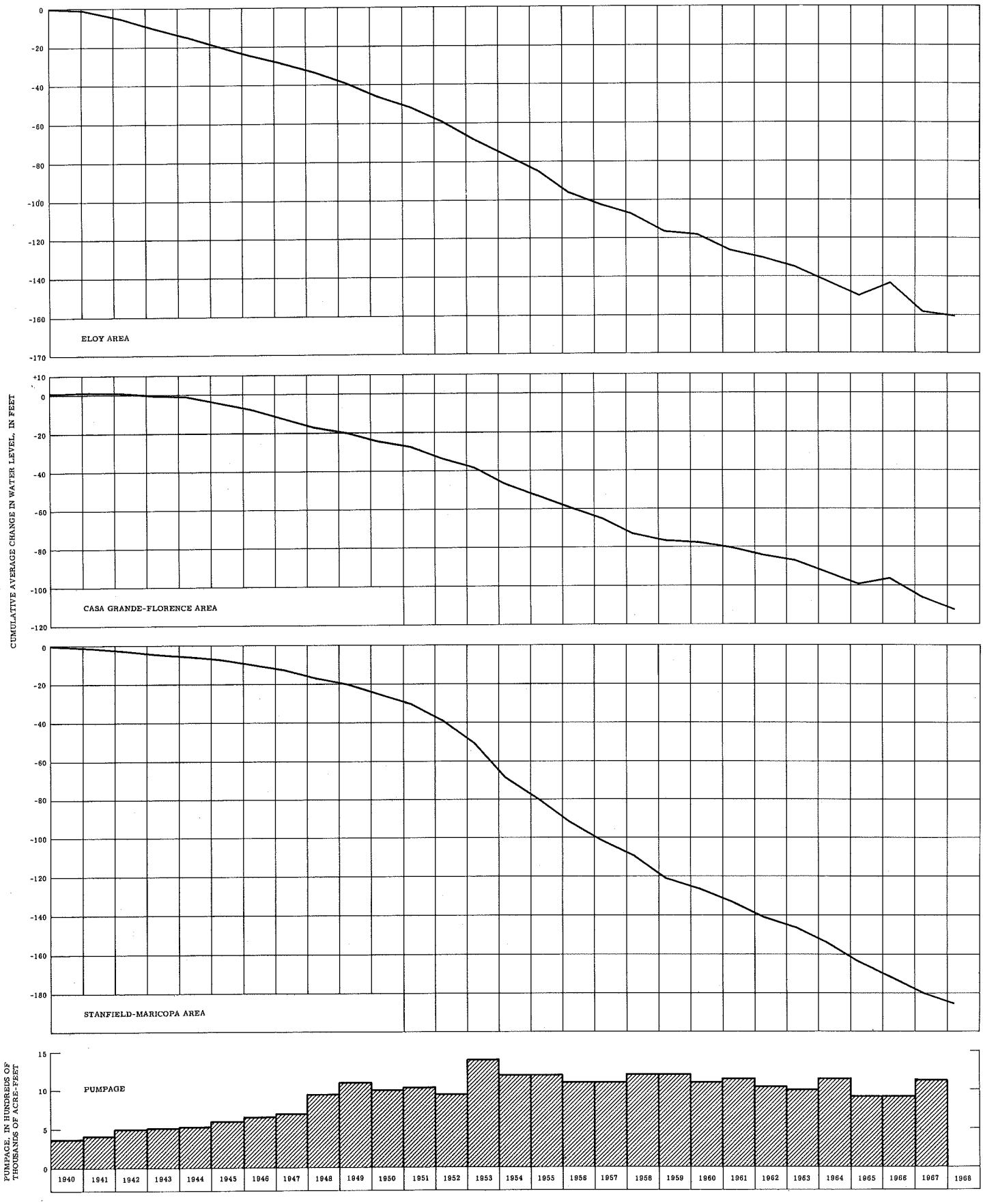


FIGURE 15.--CUMULATIVE AVERAGE CHANGE IN WATER LEVEL BY AREAS AND ESTIMATED ANNUAL PUMPAGE IN THE LOWER SANTA CRUZ BASIN.

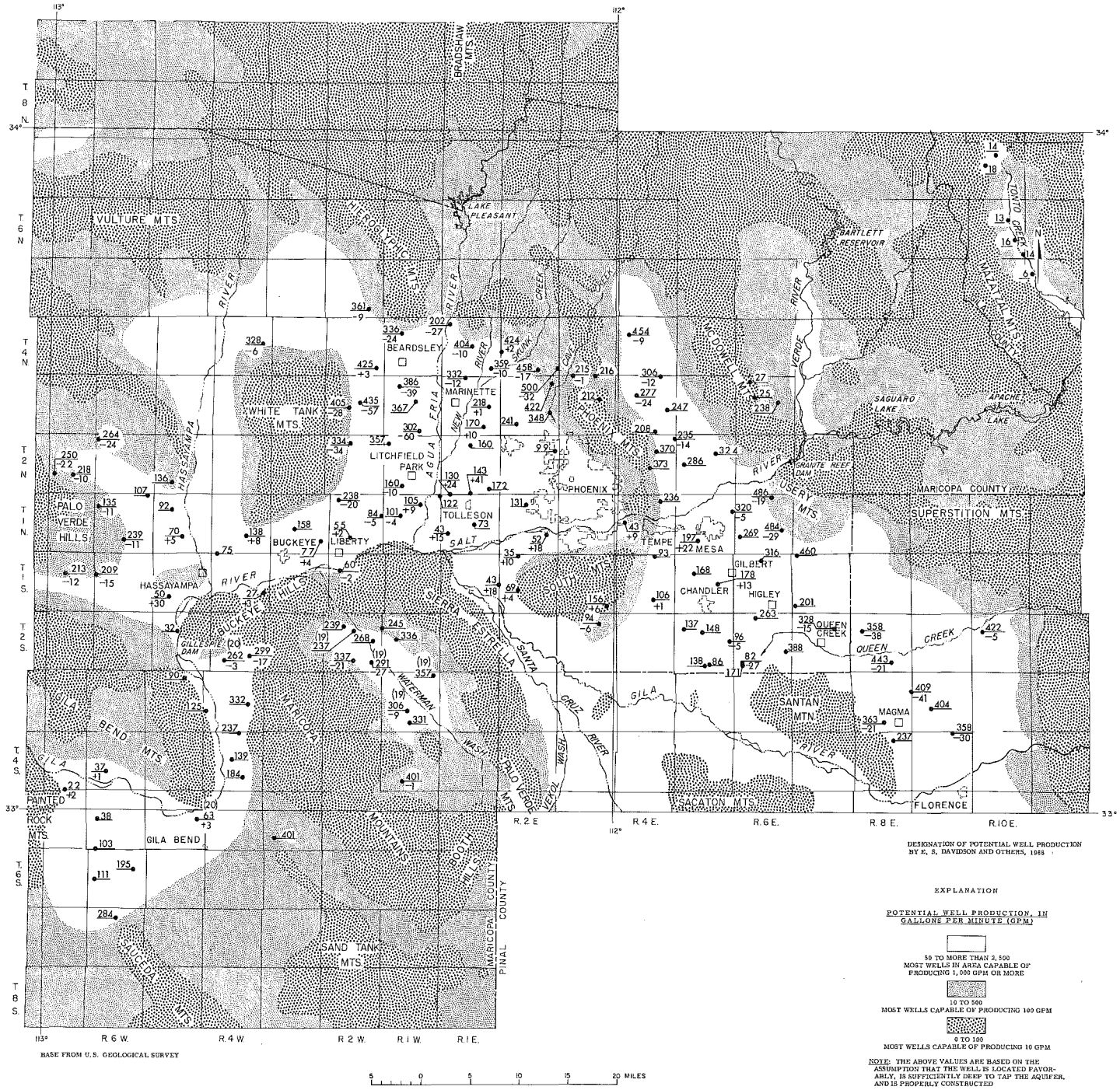


FIGURE 16. --POTENTIAL WELL PRODUCTION, DEPTH TO WATER, 1968, AND CHANGE IN WATER LEVEL, 1963-68, IN SELECTED WELLS IN THE CENTRAL PART OF THE BASIN AND RANGE LOWLANDS PROVINCE.

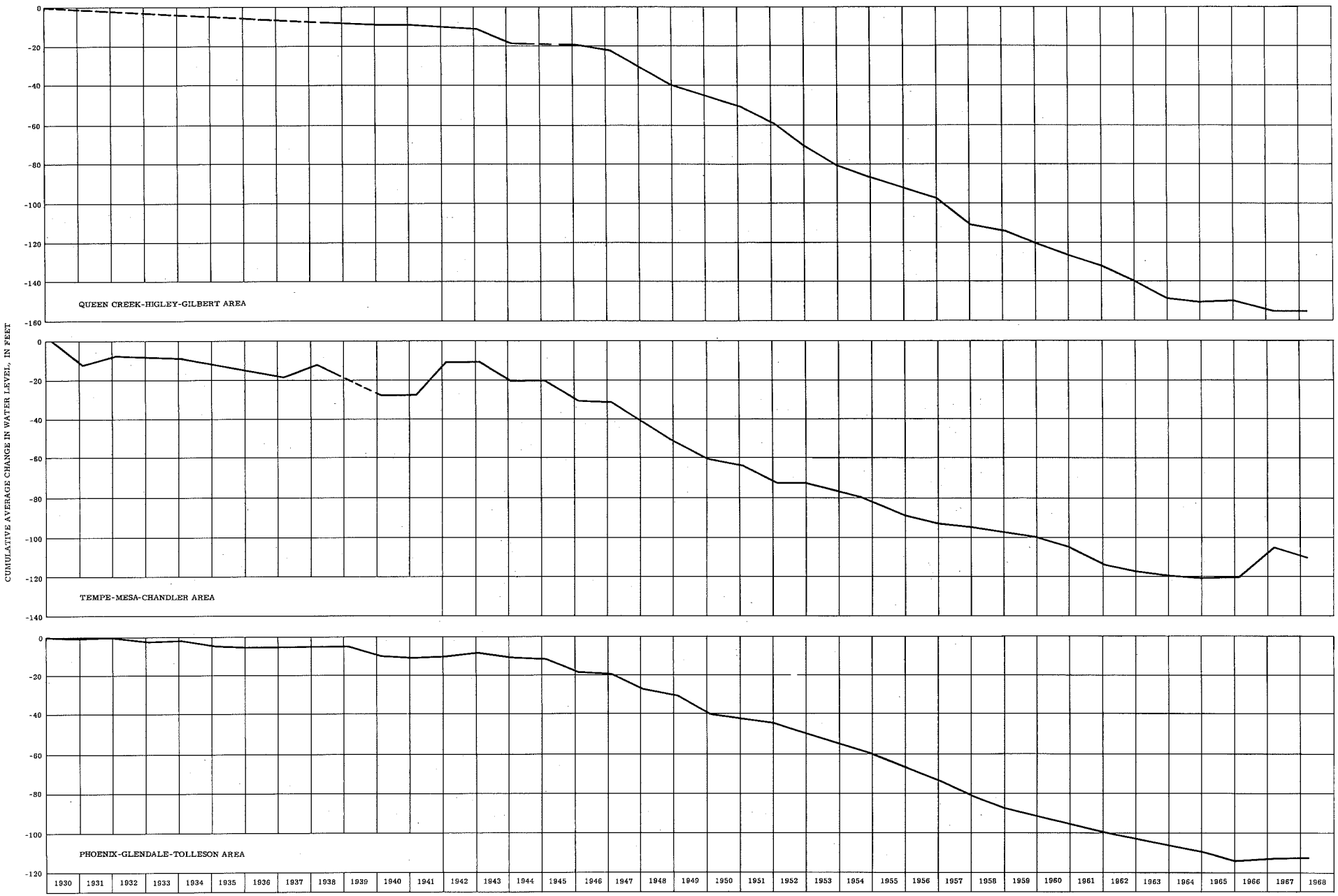


FIGURE 17.--CUMULATIVE AVERAGE CHANGE IN WATER LEVEL IN THE QUEEN CREEK-HIGLEY-GILBERT, TEMPE-MESA-CHANDLER, AND PHOENIX-GLENDALE-TOLLESON AREAS OF THE SALT RIVER VALLEY.

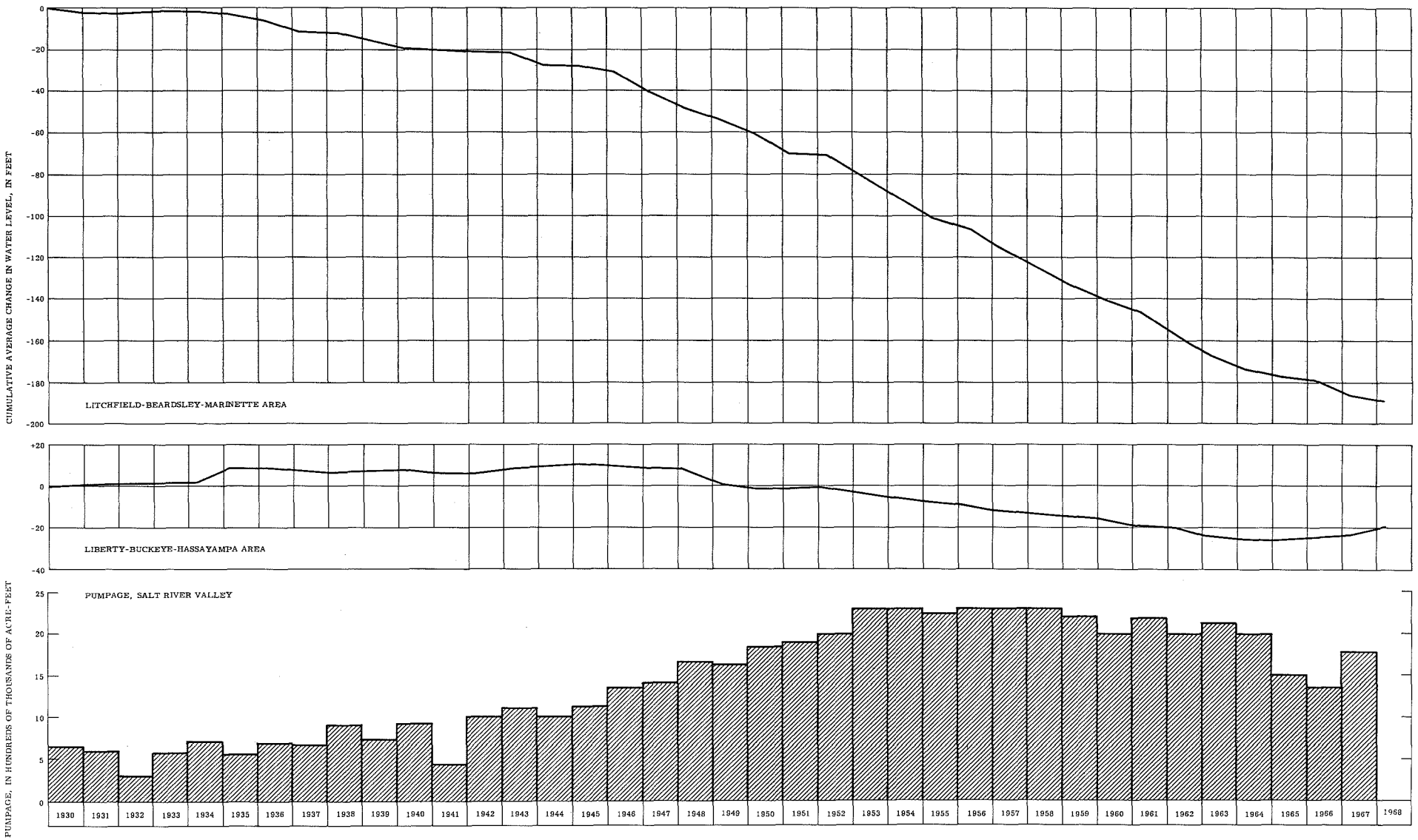


FIGURE 18.--CUMULATIVE AVERAGE CHANGE IN WATER LEVEL IN THE LITCHFIELD-BEARDSLEY-MARINETTE AND LIBERTY-BUCKEYE-HASSAYAMPA AREAS AND ESTIMATED ANNUAL PUMPAGE IN THE SALT RIVER VALLEY.

Waterman Wash area. --The alluvial materials in the Waterman Wash area (fig. 1, No. 13) are hydrologically interconnected and act as a single aquifer; generally, ground water in the area is under water-table conditions, although some water may be under artesian pressure in places. Figure 16 shows the general potential well production from the permeable materials in the area. Individual well yields vary depending on the depth of aquifer penetrated and on the well construction. Nearly all the irrigated land is in the northern part of the area, where most irrigation wells produce 1,000 gpm or more of water, and some produce more than 2,000 gpm. Only a few wells have been drilled in the southern part of the area, and well yields generally are small.

Nearly all the ground water pumped in the Waterman Wash area is used for the irrigation of crops. In 1967 about 52,000 acre-feet of ground water was pumped from 48 wells in the area. Agricultural development has been comparatively recent, and the total amount of ground water withdrawn through 1967 was only about 724,000 acre-feet (table 1).

Large water-level declines have taken place in the developed part of the area—as much as 7 feet from 1967 to 1968 and as much as 27 feet from 1963 to 1968. In the undeveloped south end of the area there has been essentially no change in the water level (figs. 16 and 19).

Gila Bend basin. --The older and younger alluvial-fill deposits in the Gila Bend basin (fig. 1, No. 14) are interconnected and form a continuous ground-water reservoir. In general, ground water occurs under water-table conditions. Figure 16 shows the general potential well production from the alluvium.

In the Gila Bend basin some surface water is available for irrigation from diversions into canals at Gillespie Dam; however, the amount available is not adequate to meet all irrigation needs, and large amounts of ground water are pumped each year. In 1967 about 198,000 acre-feet of ground water was withdrawn from the aquifers, and the total amount withdrawn through 1967 was about 3,183,000 acre-feet (table 1).

Although there has been a general decline in the water table in the Gila Bend basin, the decline has been slight in places (figs. 16 and 20). From 1967 to 1968 water levels in most wells in and near the flood plain of the Gila River rose as a result of greater than average flow. Data are insufficient to determine the average change in water level for the 5-year period 1963-68.

Harquahala Plains area. --The principal aquifers in the Harquahala Plains area (fig. 1, No. 15) are sand and gravel lenses in the alluvium; the aquifers are hydrologically interconnected, and ground water occurs under water-table conditions. Figure 21 shows the general potential well production from

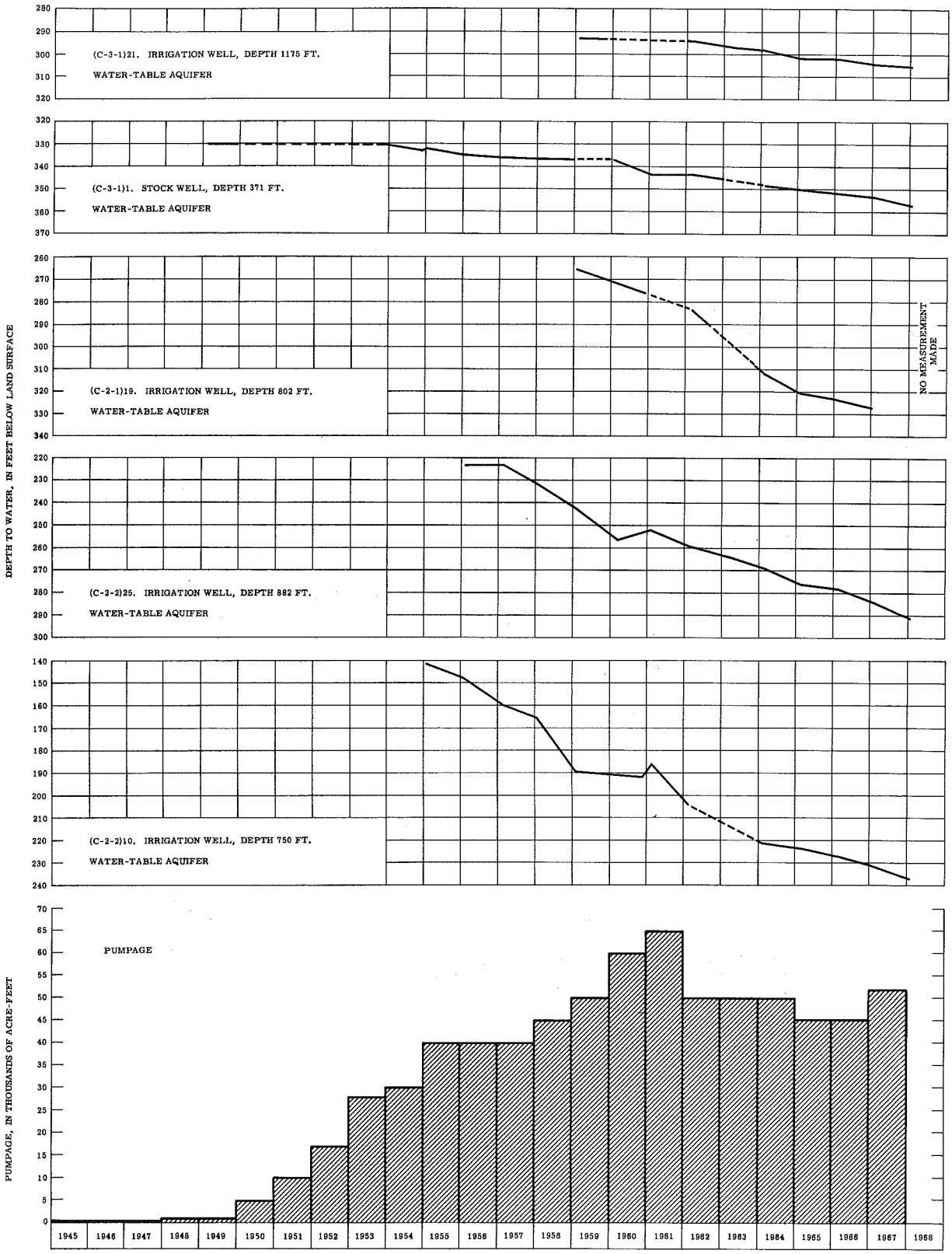


FIGURE 19.--DEPTH TO WATER IN SELECTED WELLS AND ESTIMATED ANNUAL PUMPAGE IN THE WATERMAN WASH AREA.

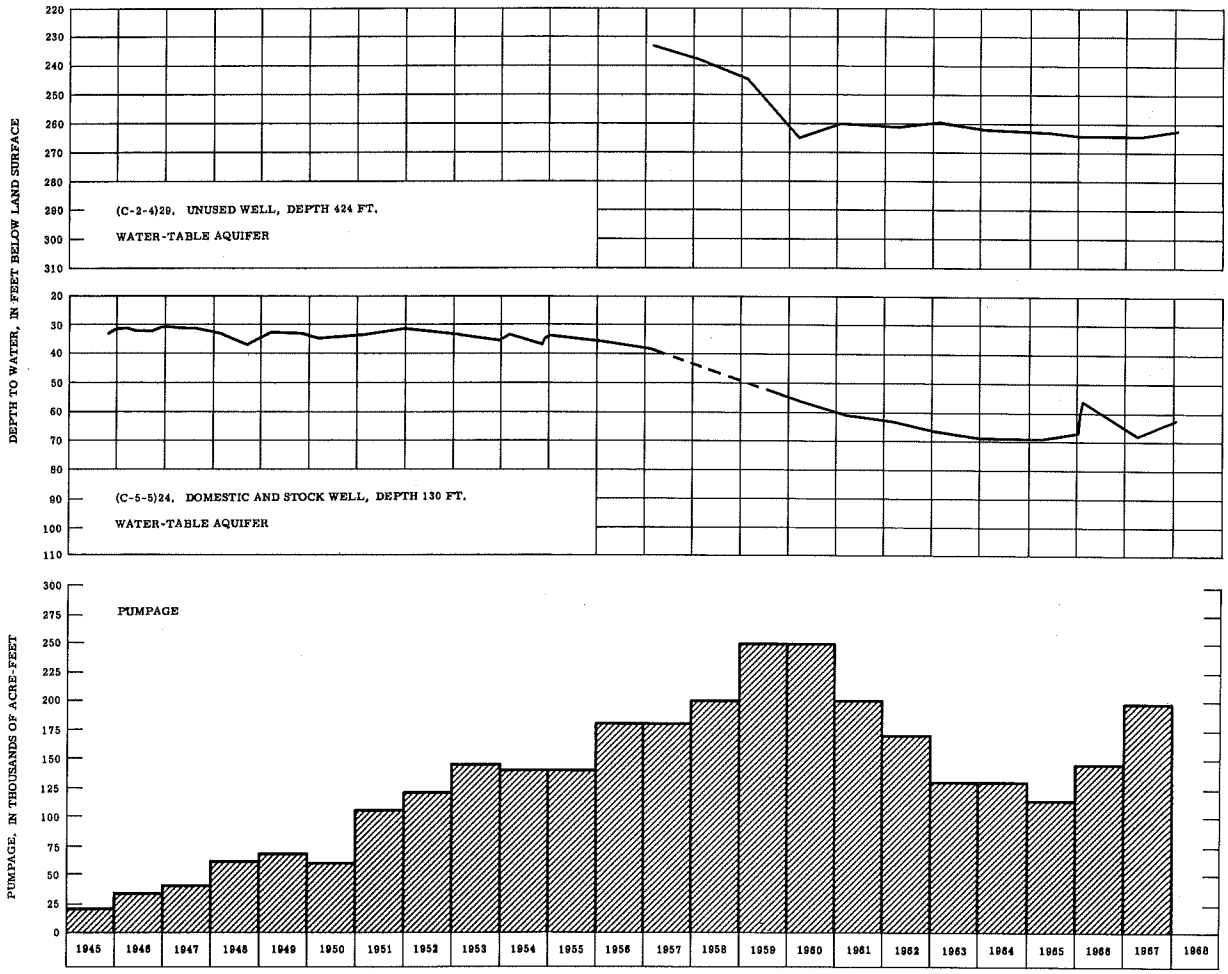


FIGURE 20.--DEPTH TO WATER IN SELECTED WELLS AND ESTIMATED ANNUAL PUMPAGE IN THE GILA BEND BASIN.

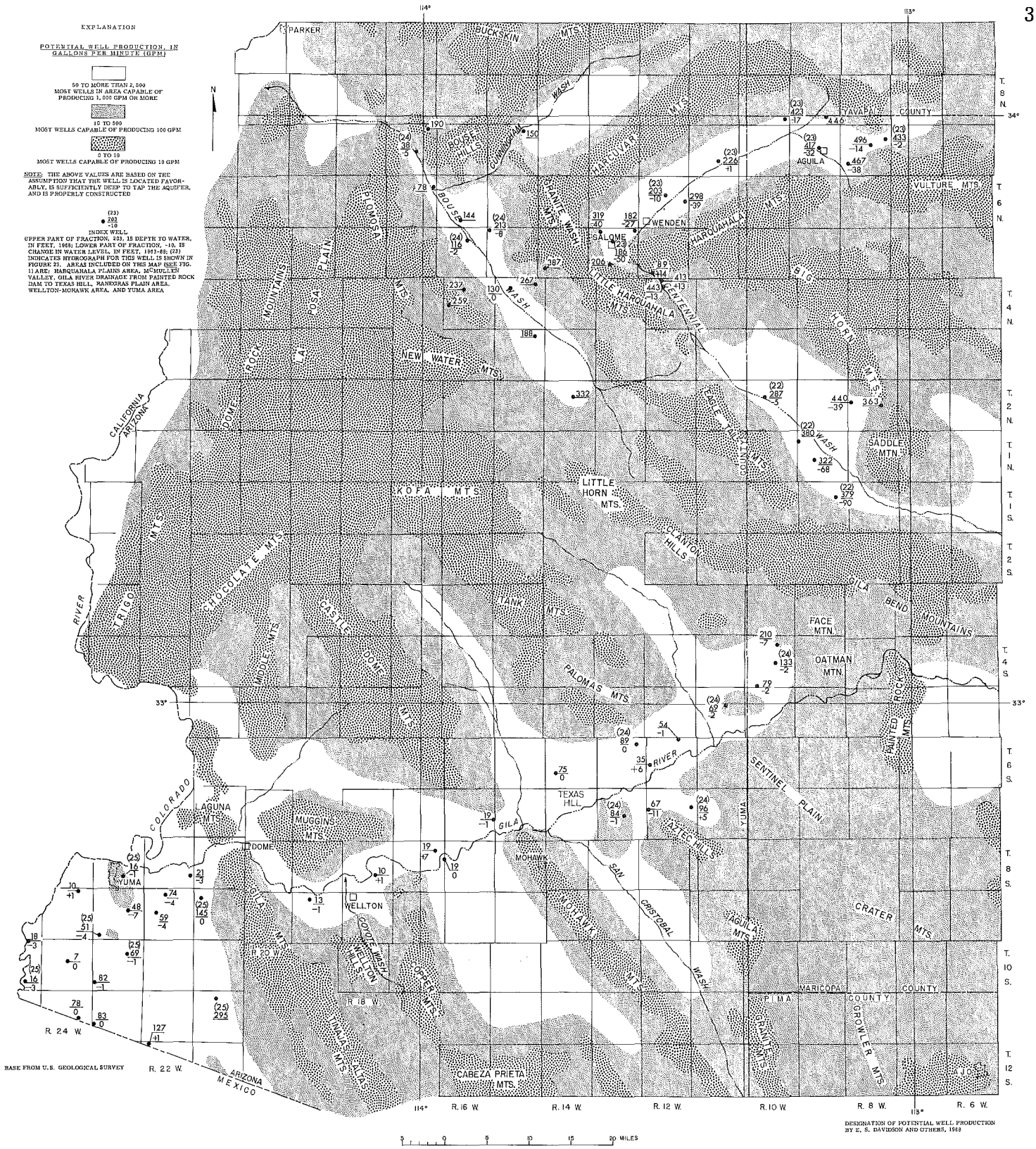


FIGURE 21.--POTENTIAL WELL PRODUCTION, DEPTH TO WATER, 1968, AND CHANGE IN WATER LEVEL, 1963-68, IN SELECTED WELLS IN THE SOUTHWEST PART OF THE BASIN AND RANGE LOWLANDS PROVINCE.

the alluvium in the area. Individual well yields vary greatly; in the south-central part of the area, many irrigation wells produce from slightly less than 1,000 to more than 2,000 gpm of water. At the southeast end of the area, wells generally produce less water.

Nearly all the ground water pumped in the Harquahala Plains area is used for the irrigation of crops. Although agricultural development in the area has been comparatively recent, it has taken place rapidly, and large amounts of ground water have been pumped during the last several years. In 1967 about 170,000 acre-feet of ground water was pumped from about 130 irrigation wells; the total withdrawal through 1967 was about 1,715,000 acre-feet (table 1).

Water levels are declining in most of the area, but the amount of decline varies greatly. The largest water-level declines have taken place in the lower or southeast part of the area, where ground-water withdrawal has been greatest. In the upper or northwest part of the area along Centennial Wash water-level declines have been less (figs. 21 and 22).

McMullen Valley. --The four units of the valley-fill deposits that constitute the principal ground-water reservoir in McMullen Valley (fig. 1, No. 16) are interconnected, and water occurs chiefly under water-table conditions. In places, however, fine-grained deposits retard the downward movement of ground water, and a perched water table overlies the deposits. Figure 21 shows the general potential well production from the valley fill. The amount of water produced by wells depends on the unit or units penetrated and on the well construction.

Most of the water pumped in McMullen Valley is used for irrigation. Agricultural development has been comparatively recent, and ground-water withdrawals have not been large. In 1967 about 98,000 acre-feet of ground water was pumped in the area, and the total withdrawal through 1967 was about 818,000 acre-feet (table 1).

Water-level declines in McMullen Valley are greatest in the areas where ground-water development has been concentrated—one area near the northeast end and one area at the southwest end of the valley. On the fringes of the area and in shallow wells along Centennial Wash, water-level declines are less (figs. 21 and 23).

Gila River drainage from Painted Rock Dam to Texas Hill. --The area includes the flood plain of the Gila River and the extensive alluvial-filled valleys and plains north and south of the river from Painted Rock Dam to Texas Hill. Ground-water data, however, are available for only a part of the area (fig. 1, No. 17). The valleys to the north and south are hydraulically connected along

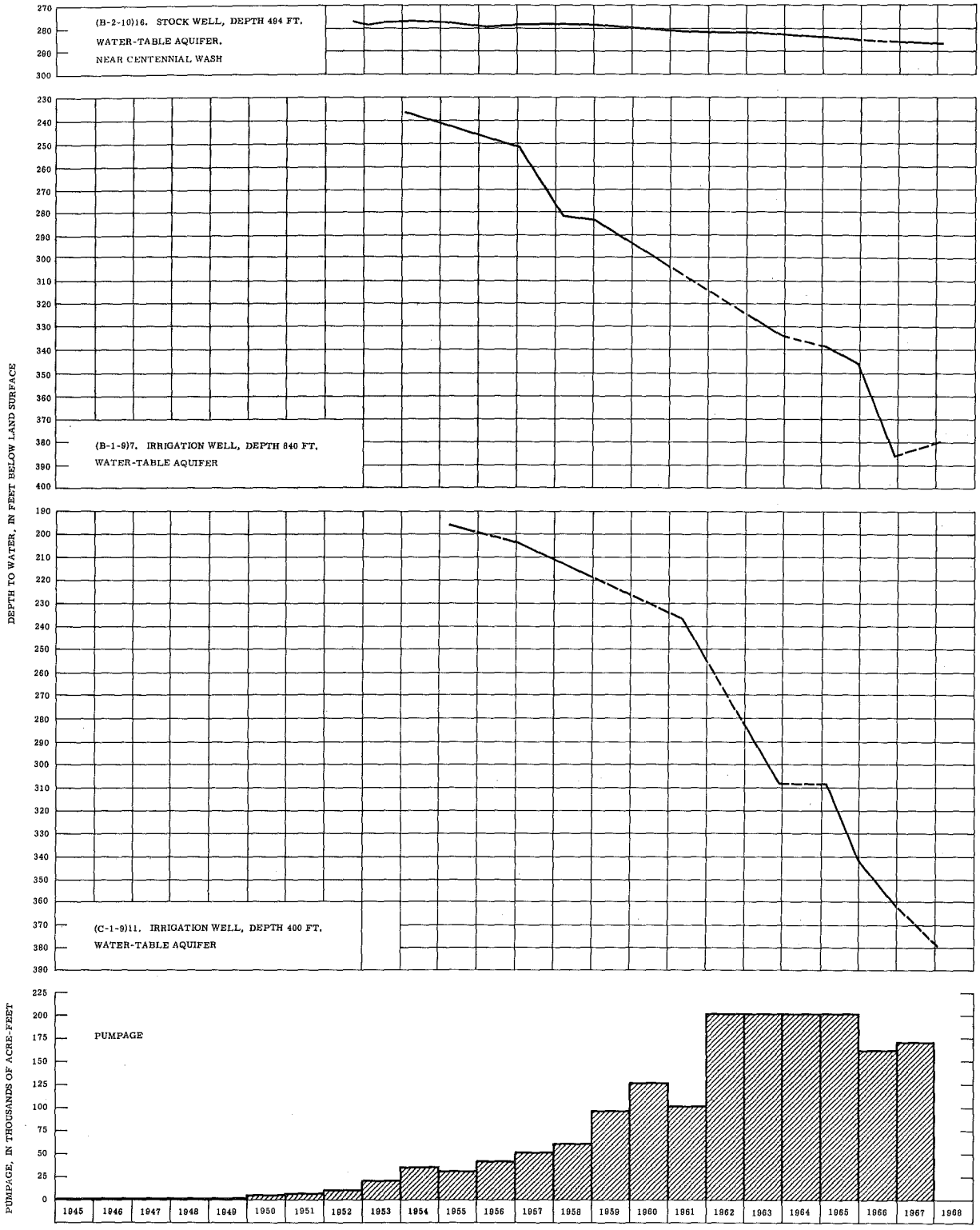


FIGURE 22.--DEPTH TO WATER IN SELECTED WELLS AND ESTIMATED ANNUAL PUMPAGE IN THE HARQUAHALA PLAINS AREA.

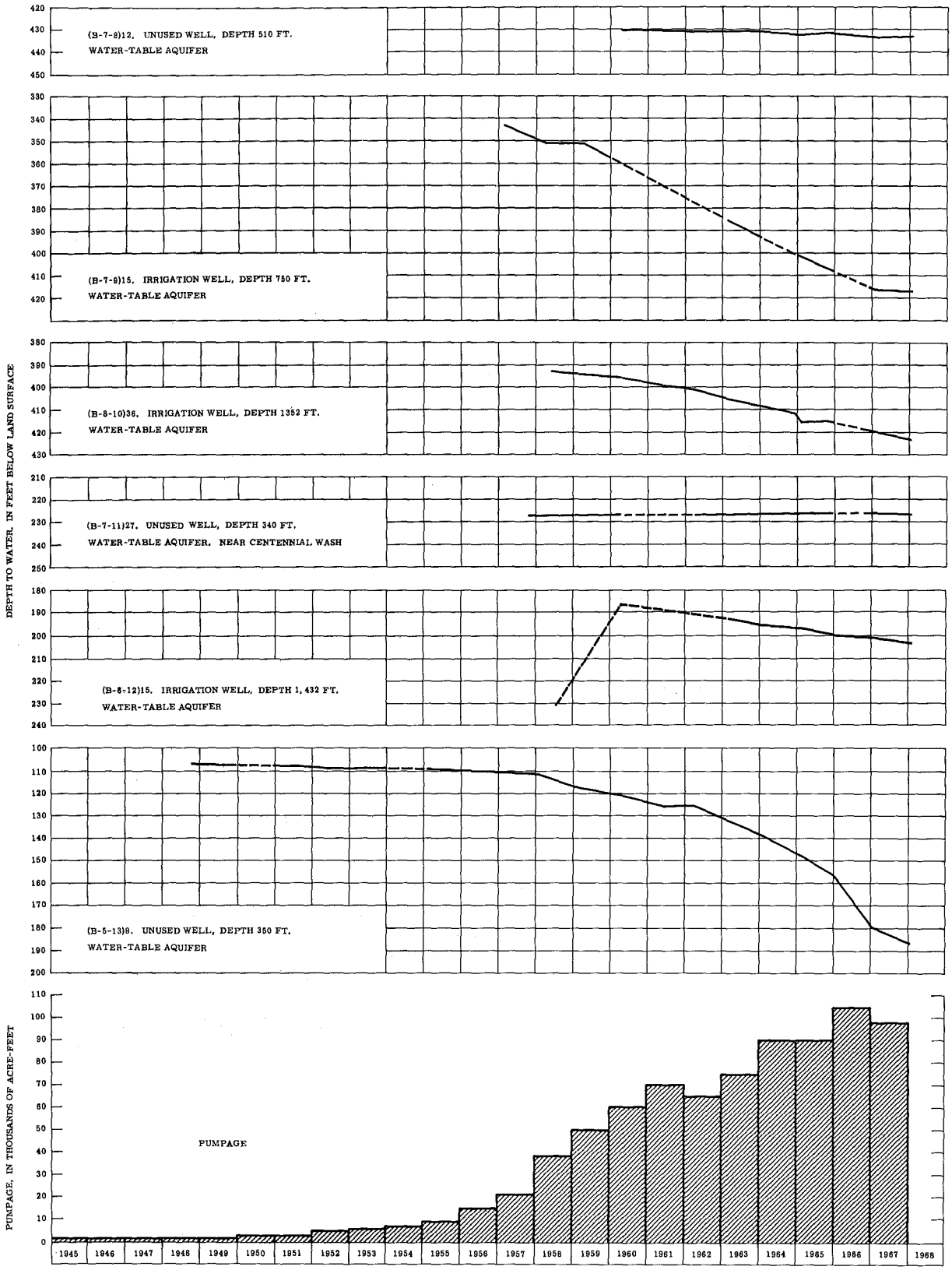


FIGURE 23. --DEPTH TO WATER IN SELECTED WELLS AND ESTIMATED ANNUAL PUMPAGE IN MCMULLEN VALLEY.

the course of the river, although in places the underflow along the river is constricted by narrow openings between the mountains that extend along both sides of the river. In general, the alluvial deposits constitute the main aquifer, although small amounts of water may be obtained from the volcanic rocks. Figure 21 shows the general potential well production from the aquifer materials in the area. Well yields vary greatly, but, in general, the largest yields are from wells nearest the flood plain of the river.

Although the area is large, agricultural development and ground-water withdrawal have been minor, and development has been confined to a few small areas, mostly near the Gila River. Agricultural development is increasing, however, and in spring 1968 about 19,000 acres of land was under cultivation. The only water supply available is from the ground-water reservoir, and about 100,000 acre-feet of ground water was withdrawn in 1967. Through 1967 about 891,000 acre-feet of ground water had been withdrawn in the area (table 1).

Water-level changes have been minor in this area. From 1967 to 1968, water-level rises and declines occurred in wells in the area (figs. 21 and 24).

Ranegras Plain area. --Ground water occurs in the older and younger alluvium in the Ranegras Plain area (fig. 1, No. 18), but the best aquifers are the sand and gravel lenses in the younger alluvium. Figure 21 shows the general potential well production from the alluvium in the area.

The withdrawal of ground water in the Ranegras Plain area has been small, and only a few irrigation wells are in operation. In 1967 about 12,000 acre-feet of ground water was pumped, and the total withdrawal through 1967 was only about 211,000 acre-feet (table 1). Water levels in most wells in the area have changed very little since the beginning of record (figs. 21 and 24).

Wellton-Mohawk area. --The unconsolidated flood-plain alluvium constitutes the principal aquifer in the Wellton-Mohawk area (fig. 1, No. 19), and ground water generally occurs under water-table conditions. Figure 21 shows the general potential well production from the alluvium in the area.

Pumping of ground water for irrigation began in the early 1900's and increased steadily until 1952, when surface water from the Colorado River became available and ground-water pumping was curtailed. The application of large amounts of surface water to cultivated lands and the small amount of ground-water withdrawal have caused water levels to rise, which has created a water-logging problem. Since 1961, the pumping of ground water has been for drainage purposes only, and in 1967 about 213,000 acre-feet of ground water was withdrawn to drain the land. The total withdrawal of ground water through 1967 was about 2,250,000 acre-feet (table 1).

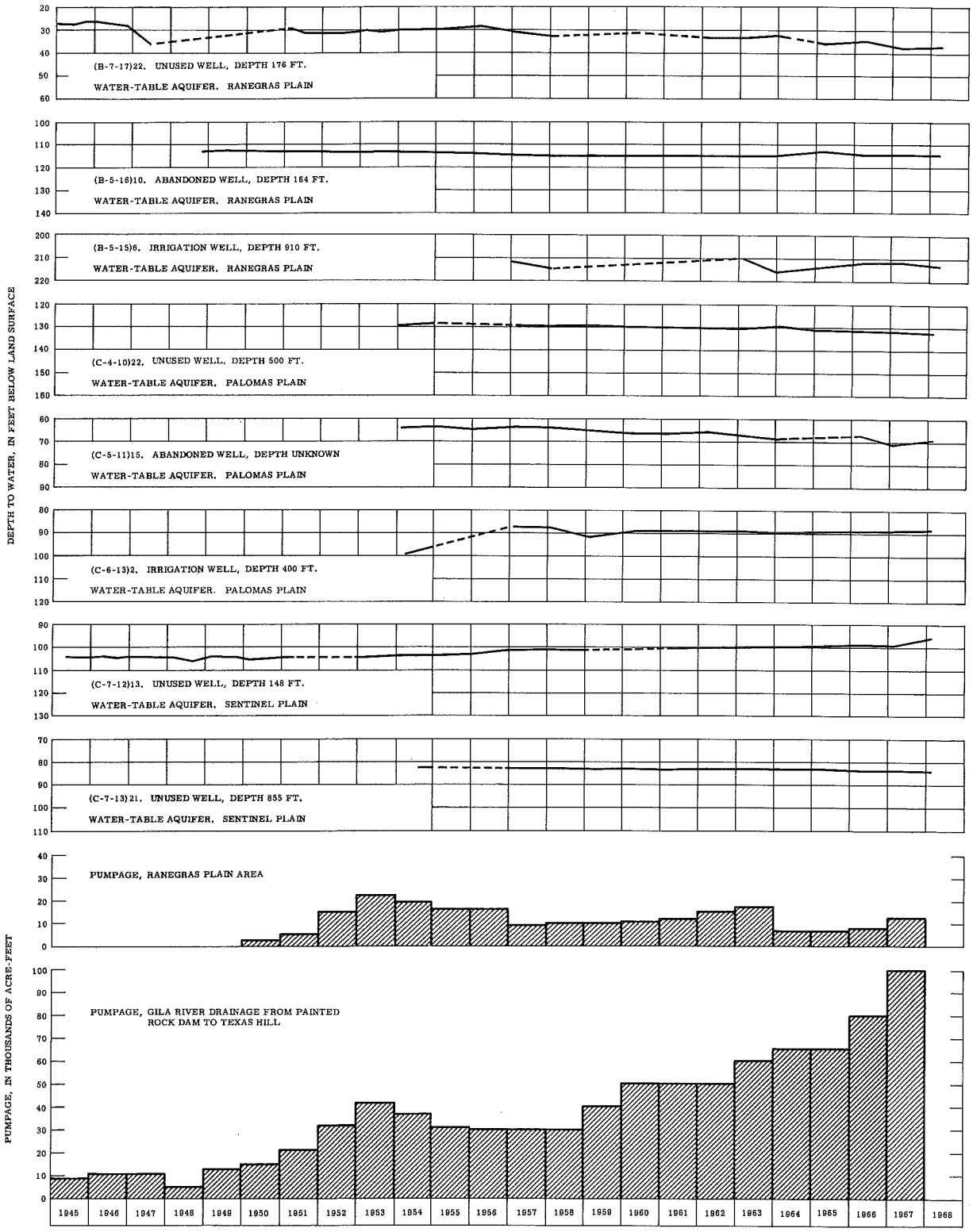


FIGURE 24.--DEPTH TO WATER IN SELECTED WELLS AND ESTIMATED ANNUAL PUMPAGE IN THE GILA RIVER DRAINAGE FROM PAINTED ROCK DAM TO TEXAS HILL AND IN THE RANEGRAS PLAIN AREA.

Yuma area. --Most of the ground water in the Yuma area is from wells drilled in the younger and older alluvium. The coarse gravel aquifer in the basal part of the younger alluvium supplies most of the water to the wells in the flood plains of the Gila and Colorado Rivers. The older alluvium, which is exposed in the mesas adjacent to the flood plains and underlies the coarse gravel in the flood plains, also contains a large volume of ground water. The general potential well production from the alluvium is shown in figure 21.

In parts of the Yuma area surface water from the Colorado River is supplemented by ground water for irrigation. In other parts of the area ground water is pumped for drainage purposes. The use of the surface water and ground water differs in three subareas—South Gila Valley, Yuma Mesa, and Yuma Valley (fig. 21). In the South Gila Valley ground water was pumped for irrigation use beginning in the early 1900's. Since 1961, some ground water also has been pumped for drainage purposes. Since 1965, some surface water has been available for irrigation use, and the amount of ground water pumped for irrigation has decreased. In Yuma Mesa most of the cultivated land is irrigated with surface water, and only a small amount of ground water is pumped, although the amount is increasing. In Yuma Valley ground water has been pumped for drainage purposes since about 1947; some ground water also is pumped for irrigation. In 1967 the total withdrawal of ground water in the Yuma area was about 224,000 acre-feet; of this amount, about 128,000 acre-feet was pumped for drainage purposes. Prior to 1967, data were not available to distinguish the amount of water pumped for drainage from the amount pumped for irrigation. The total withdrawal of ground water through 1967 was more than 2,714,000 acre-feet (table 1).

In the Yuma area, water levels fluctuate with the application of surface water for irrigation, pumping of irrigation and drainage wells, and flow of the Colorado River. In the South Gila Valley, water levels are controlled by a system of drainage wells, and changes are minor; the depth to water is generally from 15 to 20 feet below the land surface. In Yuma Mesa water levels fluctuate in response to the application of surface water for irrigation; the overall trend is a rise in water level. In Yuma Valley, water levels are controlled by a system of surface drains and drainage wells. The depth to water generally is from 5 to 15 feet below the land surface, and changes in water level are minor (figs. 21 and 25).

Sacramento and Hualapai Valleys. --The older alluvium is the principal aquifer in Sacramento and Hualapai Valleys (fig. 1, Nos. 23 and 24); in a few places the older volcanic rocks yield small amounts of water to wells, and the younger volcanic rocks form an important aquifer near Kingman. Figure 26 shows the general potential well production from the aquifer materials.

Development of ground water in Sacramento and Hualapai Valleys has been slight, and in 1967 about 4,000 acre-feet of ground water was withdrawn

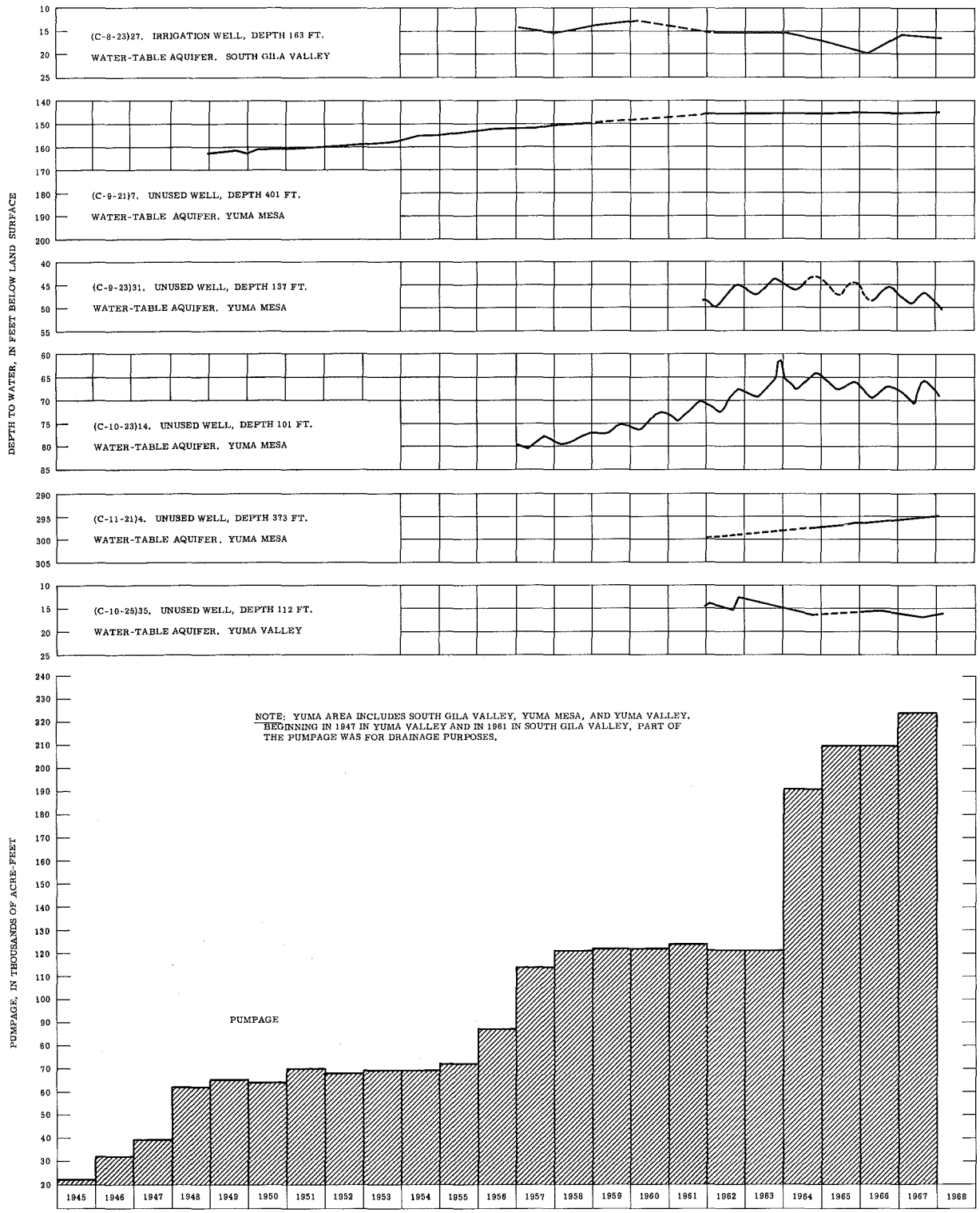


FIGURE 25.--DEPTH TO WATER IN SELECTED WELLS AND ESTIMATED ANNUAL PUMPAGE IN THE YUMA AREA.

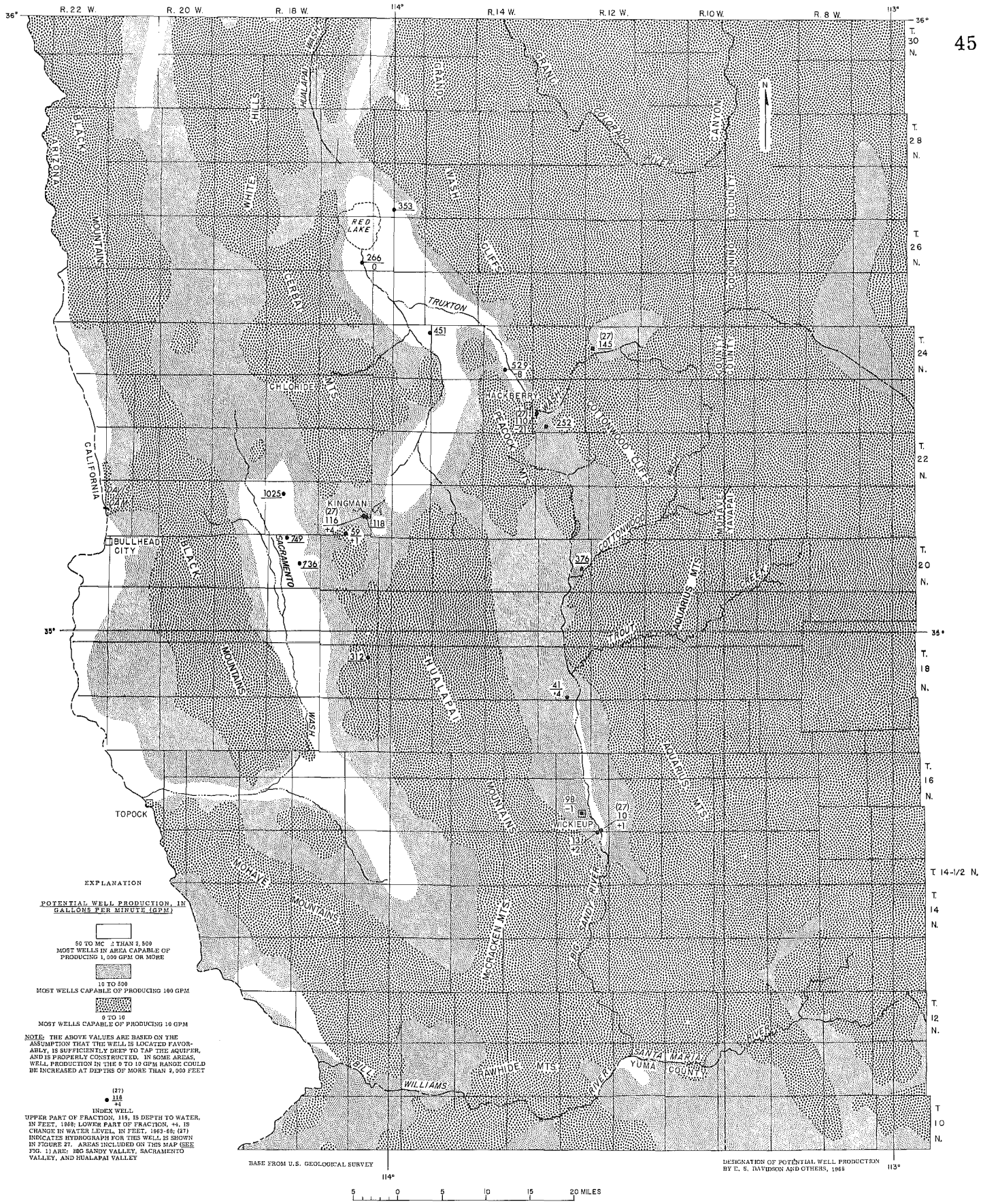


FIGURE 26. --POTENTIAL WELL PRODUCTION, DEPTH TO WATER, 1968, AND CHANGE IN WATER LEVEL, 1963-68, IN SELECTED WELLS IN THE NORTHWEST PART OF THE BASIN AND RANGE LOWLANDS PROVINCE.

in each of the valleys. The total withdrawal through 1967 was only 12,000 and 14,000 acre-feet in Sacramento and Hualapai Valleys, respectively.

No large regional water-level declines have occurred in these valleys, but in a few small areas of concentrated pumping some water-level declines have taken place. The depth to water in the area varies greatly (figs. 26 and 27).

Central Highlands Province

The Central highlands province is the smallest of the three water provinces in Arizona; only a few thousand acres of land is under cultivation, and the amount of ground water pumped is small. Ground water is withdrawn in a few small alluvial valleys between the mountains, and the largest and most developed of these are Big Chino, Little Chino, Williamson, and Verde Valleys (fig. 1). Ground water occurs under similar conditions in Big Chino, Little Chino, and Williamson Valleys and under slightly different conditions in Verde Valley.

Big Chino, Little Chino, and Williamson Valleys.--Ground water occurs under water-table conditions in the alluvium and under artesian conditions in the buried lava flows in Big Chino, Little Chino, and Williamson Valleys (fig. 1, Nos. 25, 26, and 27). In many places the lava flows are interbedded with volcanic ash, cinders, and alluvial deposits, and in other places they are interbedded with layers of clay, sand, and gravel. The general potential well production from the aquifers in the valleys is shown in figure 28. Individual well yields vary greatly, depending on the aquifer penetrated and the construction of the well. Some small wells produce less than 10 gpm of water, mostly for domestic and stock use, and a few irrigation wells produce more than 1,000 gpm.

Ground-water withdrawal in these valleys has been slight. In 1967 about 9,000 acre-feet of ground water was pumped in Big Chino Valley, 12,000 acre-feet in Little Chino Valley, and only 2,000 acre-feet in Williamson Valley. Most of the water is used for irrigation in Little Chino Valley; about 2,000 acre-feet of the total withdrawal was for municipal use by the city of Prescott. The total withdrawal of ground water through 1967 was 349,000, 325,000, and 36,000 acre-feet in Big Chino, Little Chino, and Williamson Valleys, respectively.

Water-level changes in the valleys are minor (figs. 28 and 29). In Big Chino and Williamson Valleys, slight rises in water level have occurred in the last few years. In Little Chino Valley water levels continued to decline slightly.

Verde Valley.--In Verde Valley (fig. 1, No. 28) ground water is present in the Verde Formation, Supai Formation, and streamwash deposits. The limestone beds in the Verde Formation are the chief aquifer in the area, and most

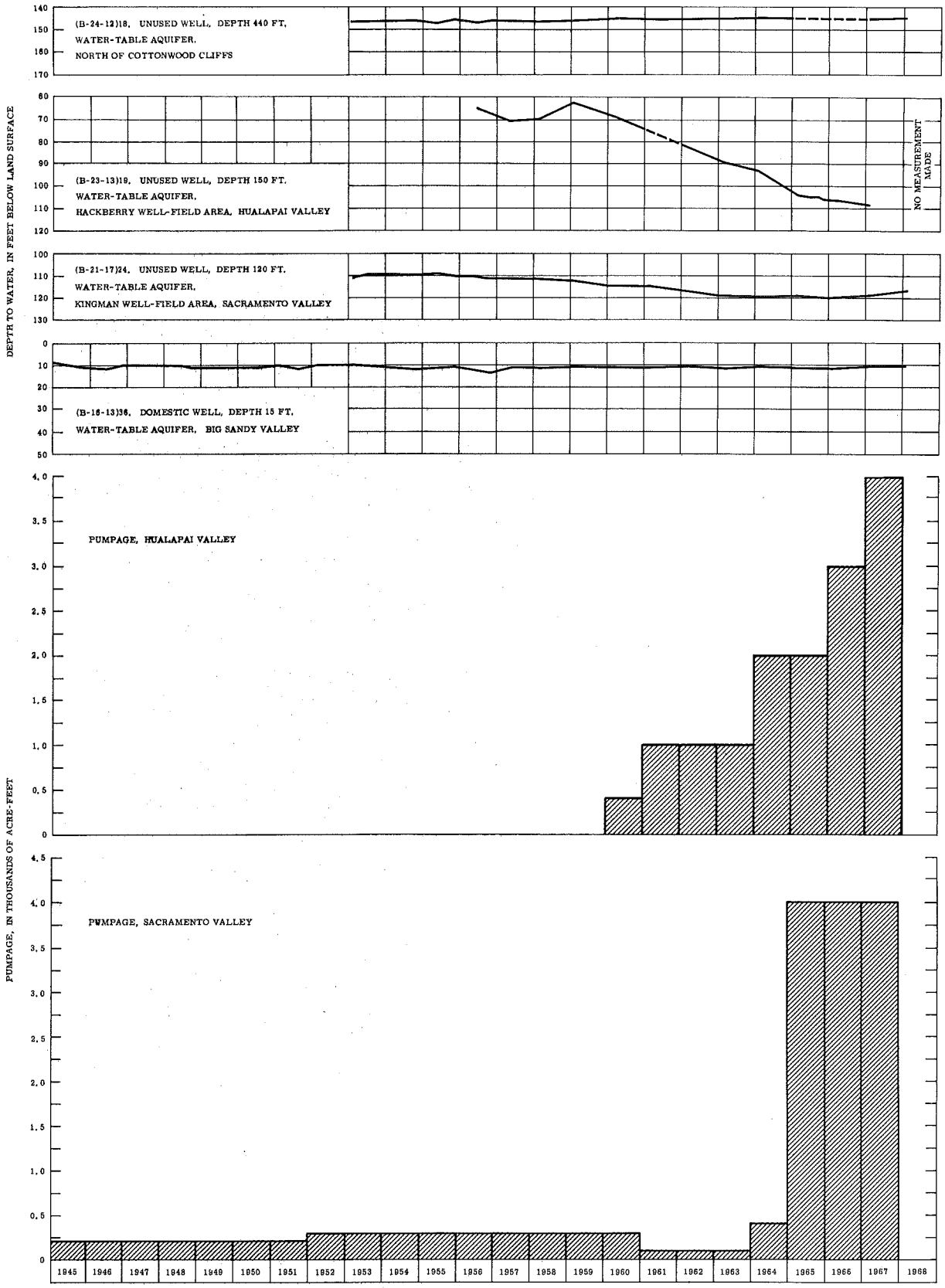


FIGURE 27.--DEPTH TO WATER IN SELECTED WELLS IN THE NORTHWEST PART OF THE BASIN AND RANGE LOWLANDS PROVINCE AND ESTIMATED ANNUAL PUMPAGE IN HUALAPAI AND SACRAMENTO VALLEYS.

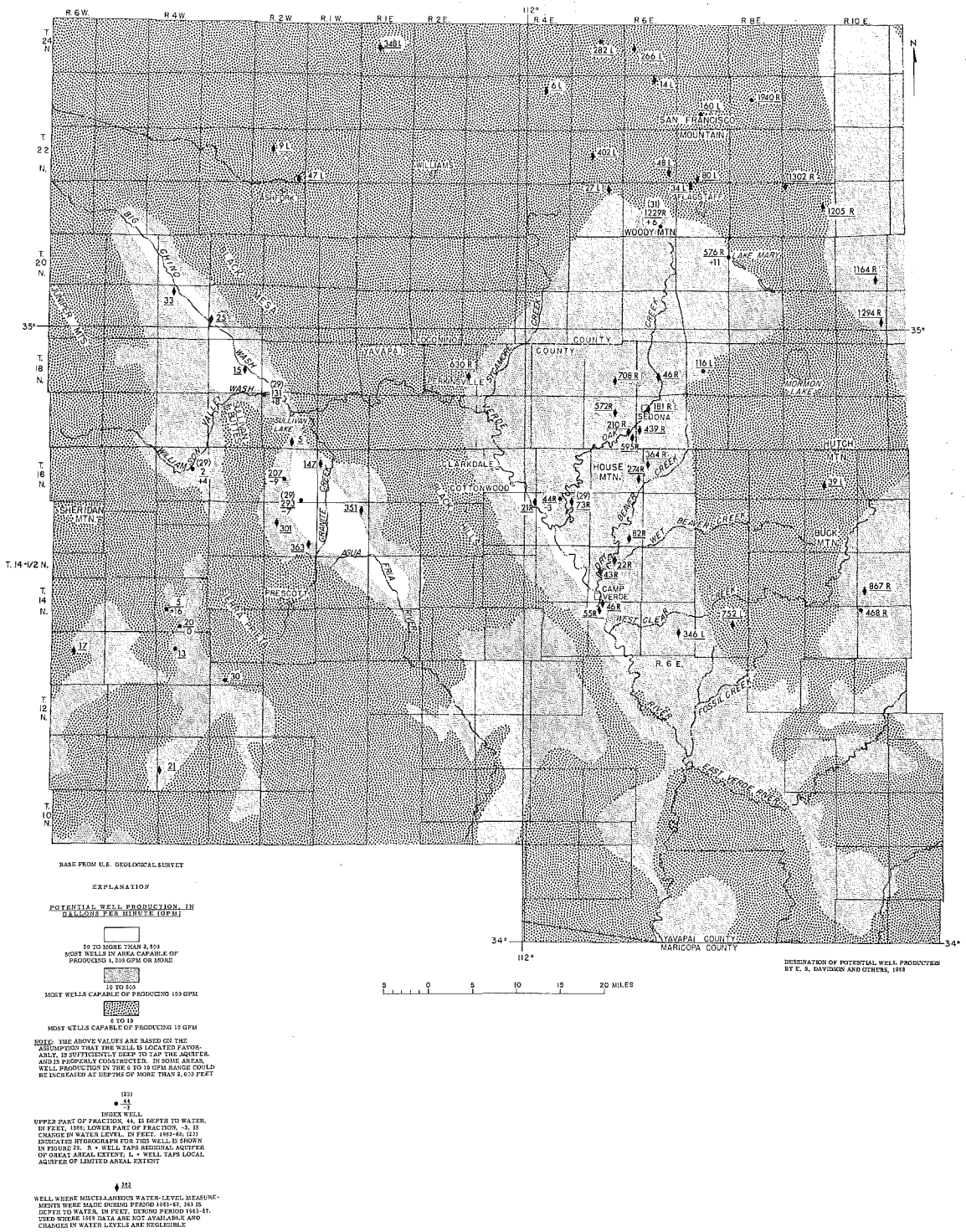


FIGURE 28. --POTENTIAL WELL PRODUCTION, DEPTH TO WATER, 1968, AND CHANGE IN WATER LEVEL, 1963-68, IN SELECTED WELLS IN THE WEST PART OF THE CENTRAL HIGHLANDS PROVINCE AND THE SOUTH-CENTRAL PART OF THE PLATEAU UPLANDS PROVINCE.

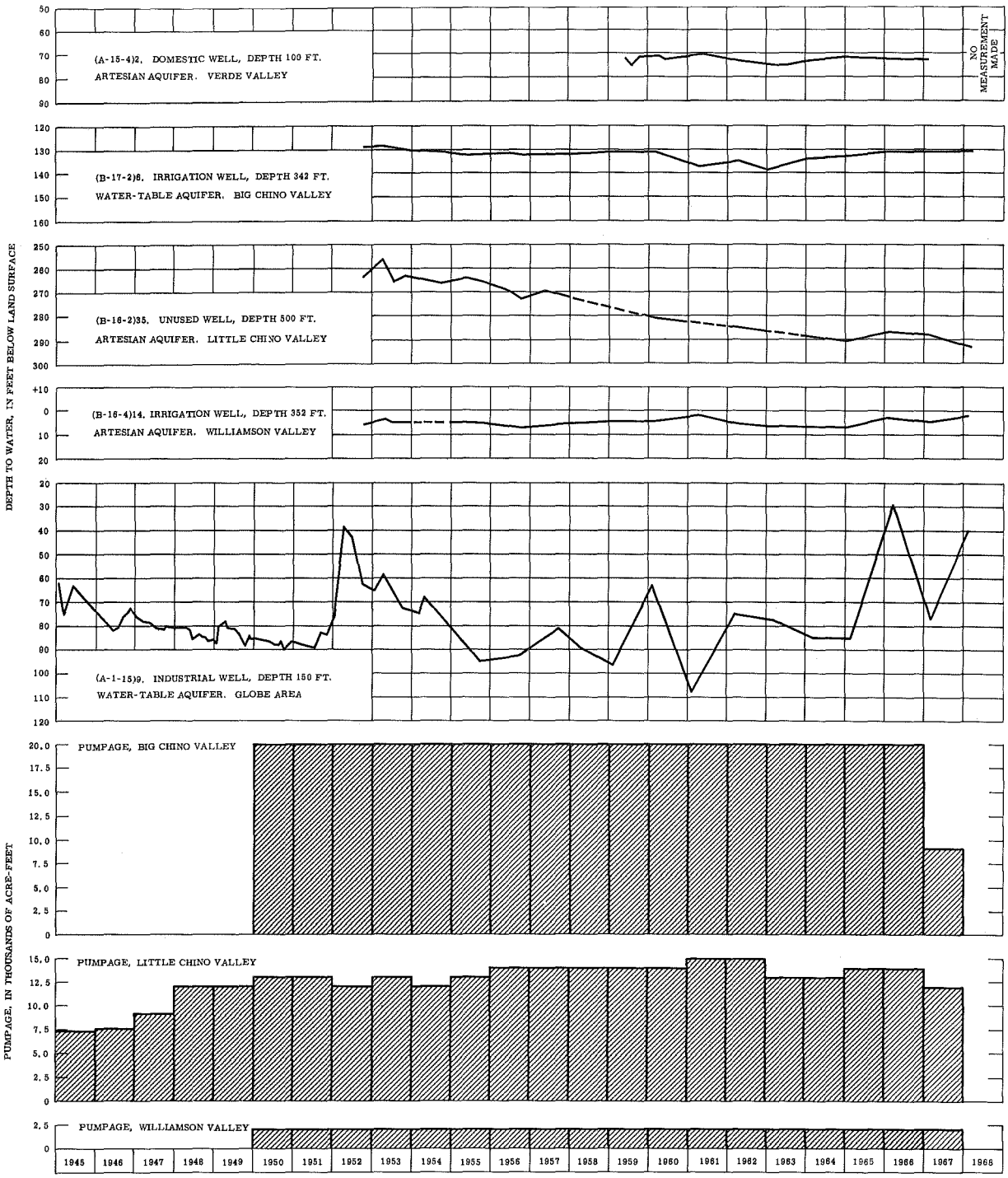


FIGURE 29.--DEPTH TO WATER IN SELECTED WELLS AND ESTIMATED ANNUAL PUMPAGE IN SEVERAL AREAS IN THE CENTRAL HIGHLANDS PROVINCE.

of the water occurs under artesian conditions. Sandstone beds in the Supai Formation are permeable and yield water under artesian pressure to wells and springs. The sand and gravel in the streamwash deposits form a good water-table aquifer in and near the channels of streams. Figure 28 shows the general potential well production from the aquifers in the area.

In Verde Valley ground water is used to supplement surface water for irrigation; ground water also is used for industrial, domestic, and stock purposes. Most of the ground water used in the valley is from springs, although the use of ground water from wells is increasing. The amount of ground water pumped each year is not known. Water-level changes in the area have been slight (figs. 28 and 29), and recharge to the aquifers probably is about equal to the discharge.

Plateau Uplands Province

Ground-water development in the Plateau uplands province (fig. 1) is small compared to that in the Basin and Range lowlands, but it is somewhat greater than that in the Central highlands. Only about 35,000 acres of land is under cultivation in the Plateau uplands province. Except for the few population centers, such as Flagstaff, Holbrook, and the White Mountain recreation areas, the use of ground water is confined to scattered farms and homesites. The Navajo and Hopi Indian Reservations make up a large part of the province. As there are no large areas of concentrated pumping in the Plateau uplands, the ground-water conditions in this province are discussed by counties.

Apache County. --Ground water in Apache County (fig. 1) is under water-table and artesian conditions in the consolidated sedimentary rocks and under water-table conditions in the weakly consolidated alluvial fill. The main water-yielding units are the Coconino Sandstone and the gravel that underlies the volcanic rocks in the southern part of the area and the De Chelly and Navajo Sandstones in the northern part of the area. Water is withdrawn from the alluvium in several places; well yields range from 100 to more than 900 gpm. Figure 30 shows the general potential well production from the aquifers in the Hunt-St. Johns area. Most wells in Apache County produce water for stock and domestic purposes, and the yields range from 5 to 50 gpm. Some irrigation wells in the Hunt-St. Johns area, however, yield from 800 to 2,000 gpm from the Coconino Sandstone aquifer system.

In most of Apache County ground-water withdrawal is small and has not caused any significant long-term declines in water levels (figs. 30 and 31). The water levels in many irrigation wells decline in the summer because of heavy pumping, but they generally recover during the winter.

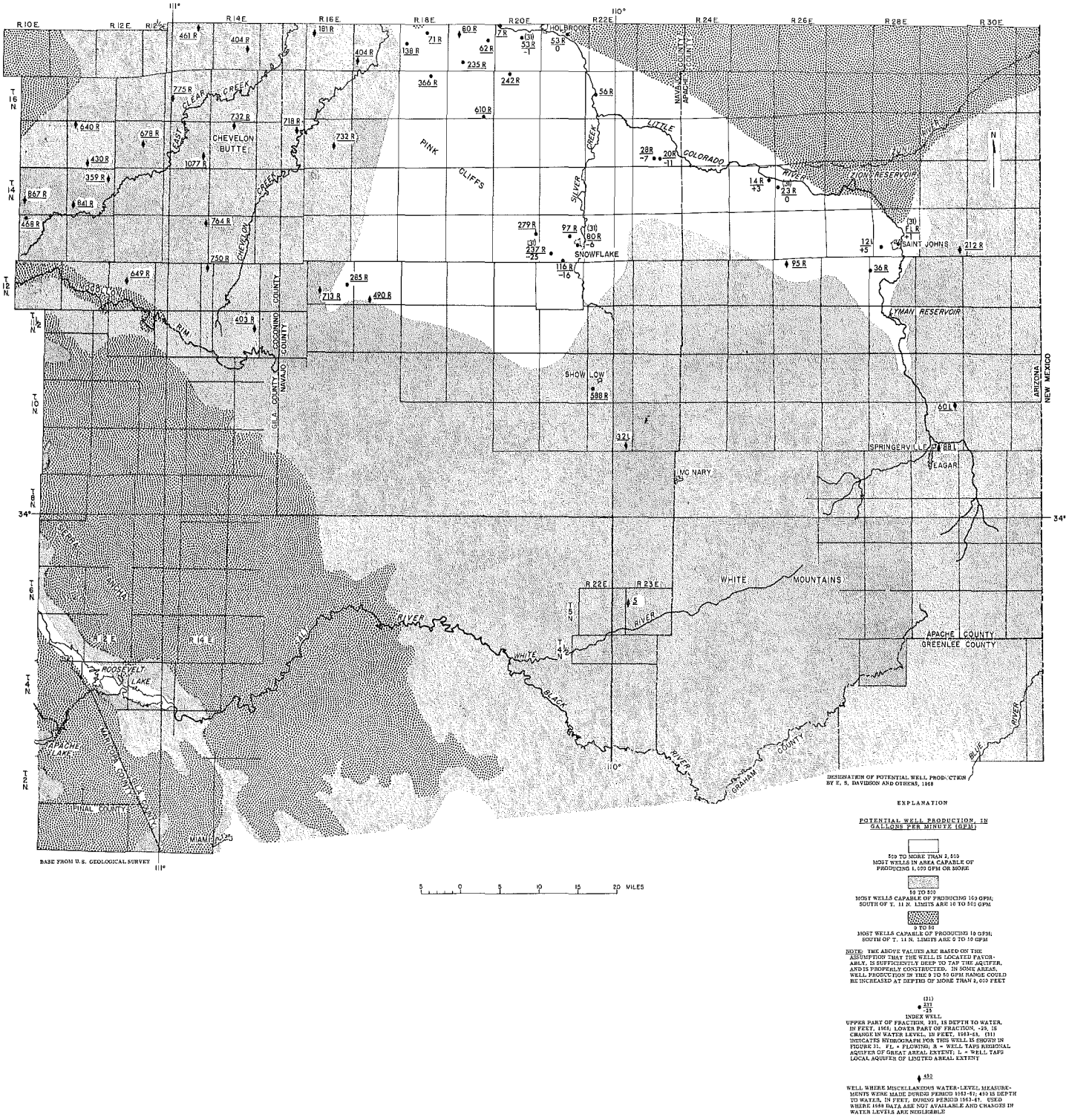


FIGURE 30. --POTENTIAL WELL PRODUCTION, DEPTH TO WATER, 1968, AND CHANGE IN WATER LEVEL, 1963-68, IN SELECTED WELLS IN THE EAST PART OF THE CENTRAL HIGHLANDS PROVINCE AND THE SOUTHEAST PART OF THE PLATEAU UPLANDS PROVINCE.

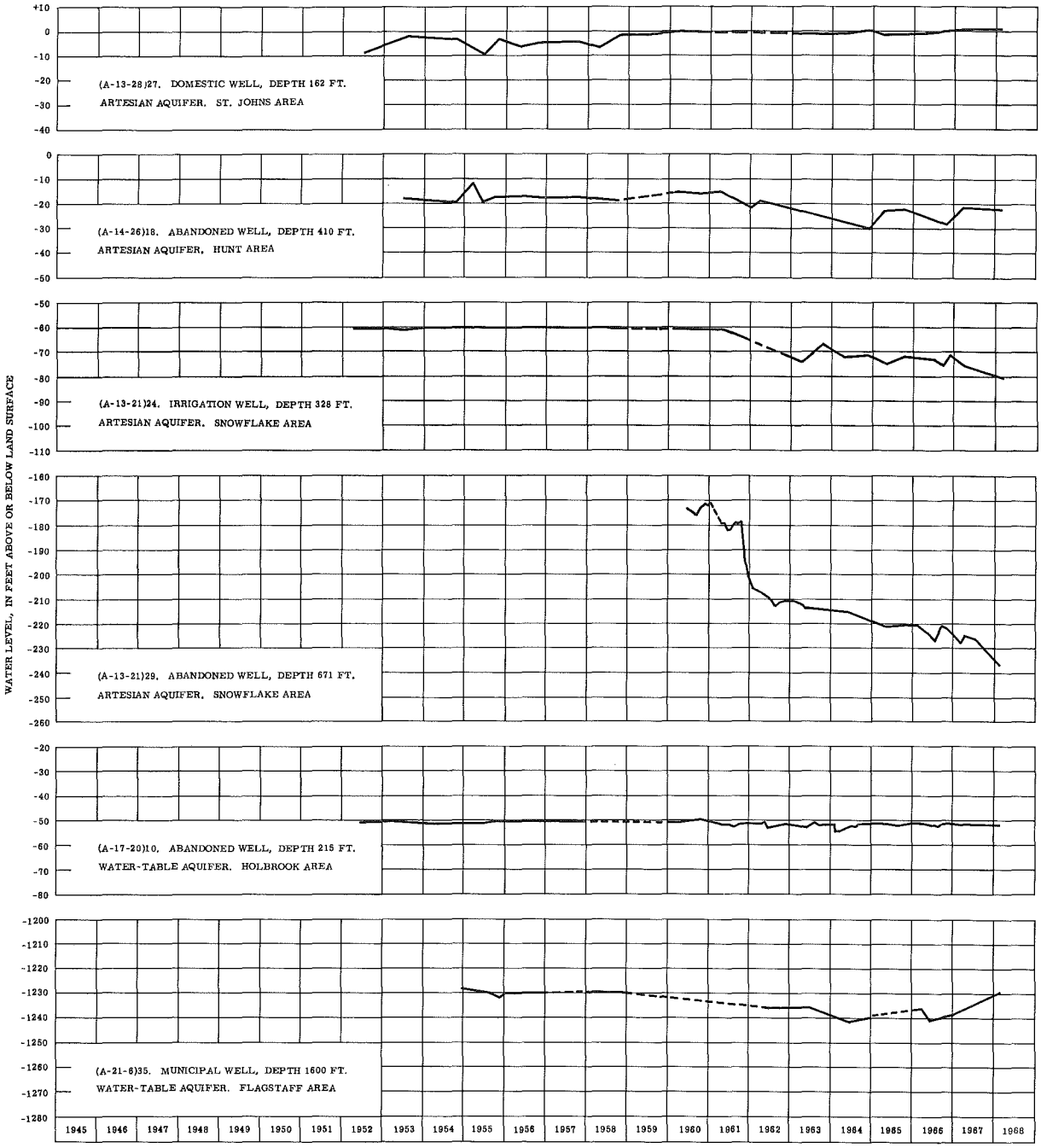


FIGURE 31.--DEPTH TO WATER IN SELECTED WELLS IN SEVERAL AREAS IN THE PLATEAU UPLANDS PROVINCE.

Navajo County.--The Coconino Sandstone is the principal aquifer south of the Little Colorado River in Navajo County (fig. 1). The Navajo Sandstone, which yields 50 to 400 gpm of water, is the major aquifer in the northern two-thirds of the county. The Dakota Sandstone and the Toreva Formation yield small amounts of water to many wells in the area. South of the Little Colorado River ground water is under water-table and artesian conditions, and north of the river it is under artesian conditions. Figure 30 shows the general potential well production for the southern part of the county.

The major development of ground-water supplies in Navajo County has been in the area between the Little Colorado River and the Mogollon Rim. Most of the withdrawal has been concentrated in the Holbrook-Joseph City and the Snowflake-Taylor areas, where water is withdrawn for irrigation and industrial use. Wells throughout the county produce water for domestic and stock use. Most water-level declines are seasonal, except near Snowflake where the water level declined about 25 feet from 1963 to 1968 (figs. 30 and 31).

Coconino County. --The chief aquifer in Coconino County (fig. 1) is the Coconino Sandstone, which is present in the subsurface in most of the area. Well yields from the Coconino Sandstone generally range from less than 5 to about 600 gpm; the yield is dependent mainly on the amount of fracturing in the rocks. Figures 28, 30, and 32 show the general potential well production in parts of the county.

Most of the ground-water withdrawal in Coconino County is from the municipal well fields near Winslow and Flagstaff. Wells throughout the county produce water for stock and domestic use. Water levels in the county have remained relatively stable except for seasonal fluctuations (figs. 28, 30, 31, and 32).

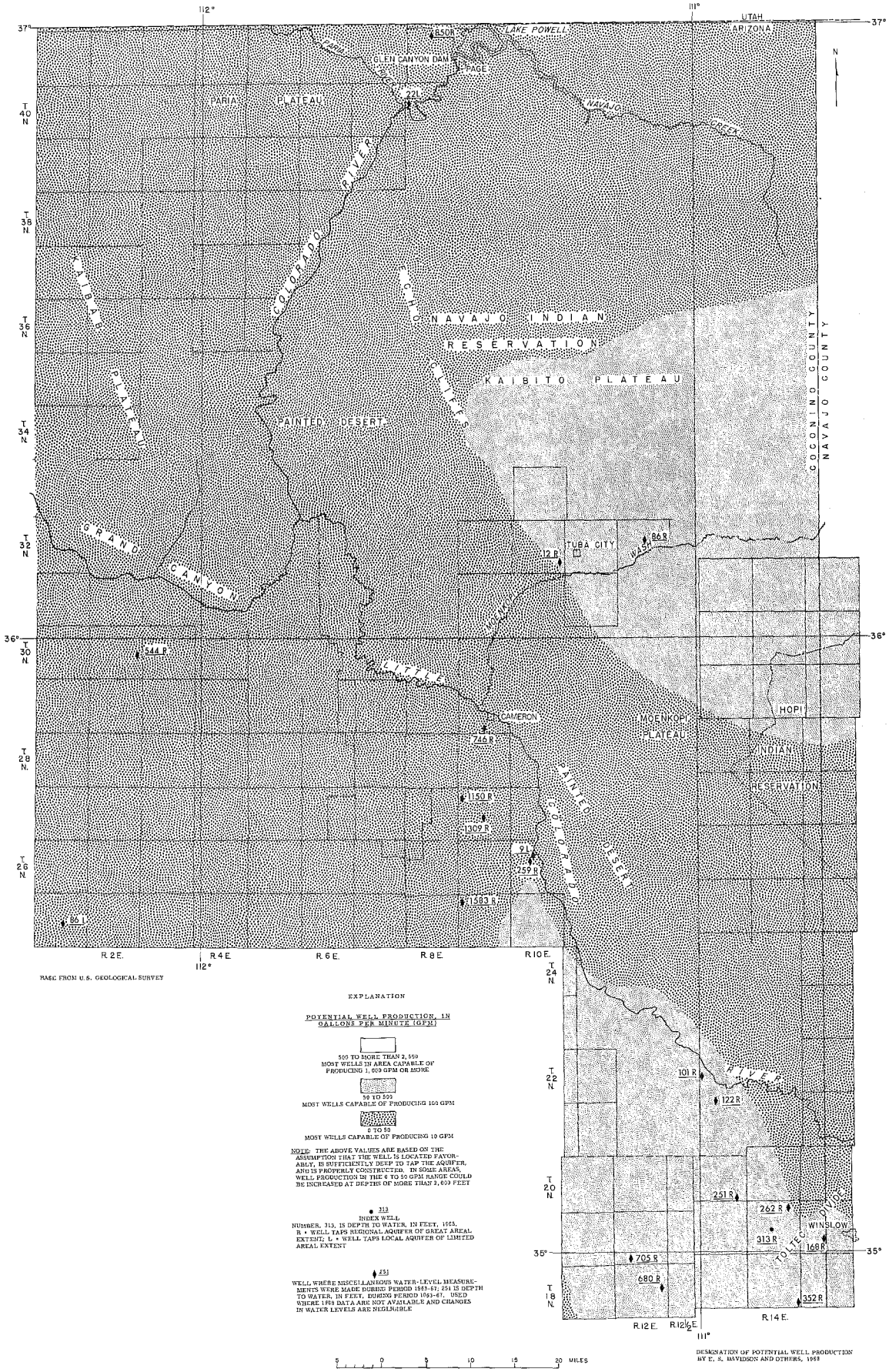


FIGURE 32. --POTENTIAL WELL PRODUCTION AND DEPTH TO WATER IN SELECTED WELLS IN THE NORTH-CENTRAL PART OF THE PLATEAU UPLANDS PROVINCE.