[redacted]

UNITED STATES
DEPARTMENT OF THE INTERIOR
U. S. Geological Survey

Geophysical and geological reconnaissance to determine ground-water resources of Chiu Chuischu area Papago Indian Reservation, Arizona

By

Coyd B. Yost, Jr.

Prepared in cooperation with the
Office of Indian Affairs
Sells Agency

Tucson, Arizona
July 1953

53-275

CONTENTS

TABLES

* * * * * * * * * * *

ILLUSTRATIONS

INTRODUCTION

To aid in developing ground water for irrigation in the northern part of the Papago Indian Reservation, Ariz. (fig. 1), the Irrigation Branch of the Office of Indian Affairs requested the Ground Water Branch of the Geological Survey to collect and analyze ground-water data. The area in which the work was done included 30 square miles in parts of Tps. 7 and 8 S., R. 5 E., Pinal County (pl. 1). The field work was done in the spring of 1952 as a continuation of a program started the preceding year (Skibitzke and Yost, 1951). 1/

Field work, consisting of a brief geologic reconnaissance and 30 electrical-resistivity probes, was done by the writer and N. P. Whaley, engineering aid. The work was under the direct supervision of H. N. Wolcott, geologist in charge of the Phoenix area office, who helped in the geologic reconnaissance and provided general information on the geology of the region, and under the general supervision of L. C. Halpenny, district engineer, Tucson, and A. N. Sayre, chief, Ground Water Branch. H. E. Skibitzke, mathematician made valuable suggestions concerning geophysical field methods and interpretations. Data on quality of the ground water were provided by J. D. Hem, district chemist, Quality of Water Branch, Albuquerque, N. Mex.

The cooperation and assistance of Minton Nolan, irrigation engineer, Sells Agency, are gratefully acknowledged.

Location and Extent of Area

The area discussed in this report lies north of the Tat Momoli and Silver Reef Mountains (pl. 1). It is bounded on the east by the line between Rs. 5 and 6 E., and on the north by the boundary of the Papago Indian Reservation. The area is bounded on the west by Santa Rosa Wash, although one probe, near Vaiva Vo, was made west of that wash. Chiu Chuischu, a Papago village within the area, is about 9 miles south of the town of Casa Grande. From Chiu Chuischu, a paved road extends north to Casa Grande, and graded roads extend west to the Indian village of Vaiva Vo and south to the Indian village of Covered Wells. A network of wagon trails provides access to the entire area.

Habitation and Economics of the Indians

Chiu Chuischu, with a population of about 250, is one of the largest villages on the Papago Indian Reservation. The inhabitants of Chiu Chuischu derive their income largely from agriculture and grazing. An area of more than 600 acres, adjoining Chiu Chuischu on the northwest, is irrigated with water from wells at the village. Cotton, grain, hay, and vegetables are raised. An additional farming area is being prepared for irrigation about 3 miles southeast of the village.

The reservation lies just south of a large, intensively farmed area, and many Indians work on these nearby farms. Most of the work is seasonal and is at a maximum during cotton-picking time.

1/ See references at end of report.

Climate

Long, hot summers, warm winters, and scanty rainfall are characteristic of the climate of the region. Precipitation occurs principally during the summer season--generally July and August--and the winter season--generally January and February. Snow seldom falls, and most of the precipitation occurs as rain. The streams of the region flow only for short periods after heavy storms, and occasionally runoff is sufficiently violent to cause damage to roads, communities, and cultivated fields.

The nearest Weather Bureau station is at Casa Grande, where the mean annual precipitation is 7.40 inches. Annual precipitation there has ranged from a minimum of 2.02 inches, in 1883, to a maximum of 19.52 inches, in 1905, during the 62-year period of record. The maximum recorded temperature is 122°F, and the minimum, 17°F. The mean annual temperature is 71°F and the frost-free season averages 253 days.

Topography and Drainage

The area lies along the southwest margin of the Lower Santa Cruz basin and is drained by Quajote and Santa Rosa Washes. Most of the area is a nearly level alluvial plain which slopes gently northwest, and from which rise a few hard-rock hills. The smooth surface of the plain contrasts with the rugged surfaces of the adjacent Tat Momoli and Silver Reef Mountains. This relationship is typical of the topography of the Basin and Range province (Fenneman, 1931, pp. 326-328). The processes that have acted to produce the topography of the region are described by Bryan (1923, pp. 37-65).

Erosion has cut channels as deep as 8 feet in Santa Rosa Wash and to lesser depths in Quajote Wash. Elsewhere, except in the outwash area of the mountains, surface runoff is not sufficiently concentrated to cut gullies in the alluvial plain.

Most of the area is sufficiently level for irrigation, and some parts need only clearing and plowing to be ready for farming. Lands topographically unsuitable for farming are the mountain outwash slopes, the flood plains of the washes, isolated hills, and two sand-dune areas (pl. 1). The larger of the sand-dune areas occupies several square miles in the northwest part of T. 8 S., R. 5 E. There, some of the individual dunes are more than 20 feet high. The smaller area is of less relief and occupies about 1½ square miles immediately west of Chiu Chuischu.

GEOLOGY AND ITS RELATION TO THE OCCURRENCE OF GROUND WATER

The occurrence of ground water in the region is closely related to the character and structure of the rock units. The valleys of the Basin and Range province are partly filled with alluvium. This alluvial fill contains permeable beds and lenses of sand and gravel, which are the principal aquifers of the region.

Hard Rocks

A variety of rock ~~types crop out~~ in the Tat Momoli and Silver Reed Mountains. Quartzite, metamorphosed limestone, granite, basalt, tuff, arkose, and conglomerate, ranging in age from pre-Cambrian to Quaternary, have been identified. The generalized geology of the area is shown on plate 2.

The Casa Grande Mountains, a few miles northeast of the area investigated, are composed principally of metamorphic rocks. Between these mountains and the northeast corner of the reservation, many wells are reported to have encountered impermeable materials at shallow depths.

The isolated hills north of the Tat Momoli and Silver ReefMountains are made up mostly of Tertiary and Quaternary basalt. These hills have a northwest orientation and probably are fault-block remnants. High-angle northwest-trending faults, characteristic of the region, are evident in the volcanic hill north of Chiu Chuischu and in the mountains south of the area.

The irregular surface and variable lithology of the outcrops in and near e area indicate that the hardrock basement probably has an irregular surface and is not composed of a single rock type. Minor irregularities or small hills buried beneath the alluvium ordinarily would not be detected by resistivity probes.

The hard rocks do not yield appreciable quantities of water and therefore are of no value as a source for irrigation.

Alluvial Fill

The alluvial fill of the region includes gravel, sand, silt, clay, and caliche. The thickness of the alluvium in the Lower Santa Cruz basin ranges from a few inches near the mountains to at least 2,700 feet in a well about 13 miles east of Chiu Chuischu. As the alluvial fill yields water readily to wells in areas where a sufficient thickness of sand and gravel lies below the water table, one of the principal problems of the investigation was to determine the thickness of alluvium. Data from the 30 electrical-resistivity probes, together with inferences drawn from the geology of the area, were used to determine the depth-to-bedrock outlines shown on plate 3. These outlines indicate areas where the depth to bedrock is likely to be less than 200 feet, from 200 to 300 feet, from 300 to 600 feet, and more than 600 feet.

The wells at Chiu Chuischu and all the wells in the areas adjacent to the reservation (table 1) are withdrawing ground water from a common reservoir. The slope of the water table and the depth to water are shown on plate 2. The ground-water contours indicate that the direction of movement is generally northwest through the gap between the Silver Reef and Casa Grande Mountains. Although development of the ground-water supplies in the area investigated has been negligible, the lands outside the reservation have been irrigated heavily with ground water for several years. Cushman (Halpenny and others, 1952, p. 130), shows that withdrawals in the Lower Santa Cruz basin increased from about 344,000 acre-feet in 1941 to 1,110,000 acre-feet in 1951. The decline of the water table (pl. 1) shows that ground-water withdrawals have exceeded recharge. The decline shown is only approximate for the reservation area because it is based mainly upon data from wells outside the reservation. The map indicates that the amount of unwatering since the spring of 1942 within the area investigated ranges from less than 10 feet to slightly less than 50 feet.

The decline for the period 1952-53 (pl. 1) was about 4 feet or more at the reservation boundary. Farther north the decline was greater. In the area of greatest decline, about 5 miles northwest of the reservation, the water table lowered more than 15 feet during the year.

It has been stated that the sand and gravel of the alluvial fill yield water readily to wells. Within 2 miles north of the northern boundary of the reservation, one or two of the irrigation wells yield as much as 1,200 gallons per minute. Generally, the wells along the reservation boundary are progressively more productive from east to west (table 1). Figure 2 is a cross section based on data from wells just north of the reservation boundary, and shows a westward increase of 100 feet in depth to water. It also indicates, however, a westward thickening of more than 100 feet in the saturated permeable portions of the fill (table 2). Thus, although the depth to water is greater on the west side of the area, the total saturated portion of the water-bearing materials also is greater.

Pumping in areas adjacent to the reservation has already unwatered some of the permeable materials. This unwatering has been reflected in a gradual reduction in well yields. It is to be expected, therefore, that if irrigation wells are developed on the reservation within the 30-square-mile area investigated, their rate of discharge will decrease as a result of the continued decline of the water table.

QUALITY OF WATER

Analyses of water samples collected from wells near the reservation indicate that ground water within the area investigated is likely to have a relatively low content of dissolved mineral matter. Water from these wells generally has a content of less than 500 parts per million of dissolved solids. The average temperature of water from wells near the reservation is approximately 80°F. Analyses of water from typical wells are given in table 3.

West of Casa Grande and about 7 miles north of Chiu Chuischu is a narrow area of highly mineralized ground water containing more than 4,000 parts per million of dissolved solids; water from wells near the center of this area has nearly 5,000 parts per million. This area is about 10 miles in length and trends northwest, parallel both to the regional structure and to the direction of ground-water movement. It has been suggested (Turner and others, 1943, p. 80) that this zone of high mineralization is a result of an upward movement of highly mineralized water along faults. It has also been suggested (Skibitzke, H. E., oral communication, 1953) that evaporation of irrigation water brought in from the Gila River by the Casa Grande-Florence canal has contributed to the increase of total solids in the ground water. This highly mineralized area is downgradient from the Papago Reservation and therefore is not likely to spread far enough south to have an adverse effect upon the quality of ground water in the area investigated.

Two of the well samples listed in table 3 have dissolved solids concentrations of more than 800 parts per million. One of the wells is deep and has a relatively high fluoride and nitrate content. The other well was drilled to granite and the nitrate content was also high.

GEOPHYSICAL DETERMINING OF DEPTH TO BEDROCK

Principles of the Method

Electrical-resistivity probing, one of the indirect geophysical methods used to obtain subsurface geologic information, measures the resistivity of subsurface materials. Different rock types, in many cases, have different resistivities. Thus, with a prior knowledge of the various types of rocks likely to be present within an area, and with a knowledge of their respective resistivities, it is possible to interpret resistivity information in terms of geology.

The resistivity apparatus measures commutated direct current which is caused to flow through the ground between two copper-coated steel stakes used as current electrodes, and also measures the difference in potential between two additional stakes used as potential electrodes. By measuring the current input, the potential, and the electrode separation, a figure for the apparent resistivity of the subsurface material can be obtained. The formula used to compute apparent resistivity is:

$$\rho = C4\pi A \quad V/I$$

where ρ = apparent resistivity, in ohm-centimeters
C = constant for conversion from feet to centimeters
A = stake separation, in feet
V = potential, in millivolts
I = current, in milliamperes
π = 3.1416

Resistivity curves are obtained by plotting the apparent resistivity against stake separation on logarithmic paper (fig. 3). Interpretation of the curves is done in two operations. The curves are first compared to theoretically determined type curves (Wetzel and McMurry, 1937). This comparison indicates the resistivity, number, and thickness of the subsurface layers having measurably different resistivity. These layers, defined by their individual characteristics of electrical resistivity, are called resistivity layers and do not necessarily conform to geologically defined layers. On the basis of a general knowledge of the geologic formations in the area and their respective resistivities, the resistivity layers are interpreted in terms of geology.

In order to provide an interpretable resistivity curve, a geologic unit must have a resistivity which contrasts with that of adjacent units; otherwise, its boundaries are not determinable by this method. Other factors remaining the same, shallow bodies have more influence on the shape of the curve than do deep ones, and massive bodies are more influential than thin ones. A single thin layer ordinarily will have no recognizable influence on the curve unless it is near the surface. Alternating thin layers are not individually recognizable on the resistivity curve.

The resistivity of a rock unit is controlled in large part by the distribution and resistivity of the contained moisture. Absolutely pure water is a poor conductor, but a salt solution is an excellent conductor. Water within the different rock formations contains varying amounts of dissolved minerals. Thus, the quality of the contained water affects the conductivity and hence, the resistivity of the rocks.

Solid rock, such as granite, containing very little moisture, ordinarily has high resistivity. The same type of rock has a lower resistivity if joints or other openings containing moisture are present. The resistivity of alluvium is generally lower than that of granitic rocks.

In selecting a well site it is desirable to know the thickness of the saturated portion of the alluvium. To determine this thickness it is necessary to know the depth to the water table and to bedrock. The position of the water table changes gradually from place to place, and it is possible to make fairly accurate estimates of depth to water by interpolation or extrapolation of data from nearby wells. In the Basin and Range portion of Arizona, estimating the depth to bedrock by interpolation or extrapolation from known points ordinarily does not give accurate results because irregularities in the bedrock surface are common. Therefore, to obtain depth to bedrock at a particular point, it is necessary to measure it by drilling or by geophysical means.

As the approximate position of the water table in the area can be determined from well data, the determination of the thickness of saturated alluvium resolves into finding the depth to bedrock. The resistivity surveys of the area provided data on the approximate depth to bedrock at several points. The bedrock at any point in the area probably is volcanic, granitic, or metamorphic, similar to the rocks cropping out in the mountains to the south or in the isolated hills. It has been learned from previous surveys in southern Arizona that these three general rock types ordinarily have a resistivity much higher than that of the overlying alluvium. In interpreting the resistivity curves obtained during the survey, it was assumed that there is a contrast between the resistivity of the alluvium and that of the underlying bedrock. Future drilling will furnish definite geologic information that can be correlated with the resistivity curves and may provide more specific information.

Field Procedures

During the geophysical survey a variation of the double equidistant electrode configuration was used in locating the four electrodes. For the configuration used, three stakes are driven in a straight line, spaced equal distances apart. The center stake is not moved during the probe and is the point where the depth determination is being made. The instruments are set up at this stake. The fourth electrode is driven at a distance of 2 miles or more from the probe site, preferably in a direction either along or perpendicular to the straight line through the other three stakes. This electrode is referred to as the infinite stake. Commutated direct current is caused to flow through the earth between the infinite stake and one of the outer stakes on the straight line through the probe site; these two stakes are called current stakes. The stake at the probe site and the remaining stake on the straight line are the potential stakes and are used in measuring the potential distribution about the nearby current stake. Only the two outer stakes on the straight line are moved during the probing operation; by locating these two stakes at successively greater but equal distances from the center stake, the apparent resistivity of the rock material at increasingly greater depths can be obtained.

A five-man field party was used. The equipment used consists of a modified Gish-Rooney-type instrument, a portable generator-motor unit to operate the commutator, 45-volt B batteries for current, two 3,000-foot reels of lightweight copper wire to connect the movable stakes to the instrument, 6 miles of double-strand military field wire to connect the distant current electrode to the instrument, and a truck-mounted gasoline-powered winch for laying and retrieving the field wire.

Two readings are made for each stake separation. For both readings the center stake is used as a potential stake and the infinite stake is used as a current stake. During the first reading, one of the outer stakes is used as a potential stake and the other as a current stake; during the second reading this relationship is reversed. By averaging these two readings a truer depth-resistivity determination is obtained for material vertically below the probe site.

In order to obtain a maximum of information with a minimum expenditure of time and labor, most of the probes were made along lines from south to north. By extending the lines northward from the hard-rock outcrops of the mountains to the reservation boundary, north of which well-log information is available, the best possible geologic control was obtained. When probing along a profile line, it is not necessary to locate a new infinite stake for each succeeding probe. Time and labor is saved by simply extending the length of the infinite wire to each additional probe location.

Three lines of probes were made, extending northward from the Silver Reef and the Tat Momoli Mountains to the reservation boundary. The locations of all the probes made are shown on plate 3. Two of the lines were approximately 6 miles long and consisted of twelve and nine probes, respectively. A similar but shorter profile was desired, to extend from the north end of the Tat Momoli Mountains to the reservation boundary, but the land surface in the intermediate part of the line is excessively rough, making it impracticable to make probes there. These lines of probes provided data for plotting profiles at a large angle to the regional northwest structural trend and can be expected to indicate any important subsurface structural features that conform to the trend.

Several isolated probes were made to obtain information at specific points. Probe 23, near Vaiva Vo, generally indicates the depth of the subsurface channel of this part of Santa Rosa Wash. Probes 29 and 30, in sec. 34, T. 7 S., R. 5 E., were made to determine the resistivity of the volcanic rock outcrop and to confirm the suspected rapid increase in depth to bedrock toward the north.

Interpretation

Interpretation of the results of the probes indicates that, in the area investigated, the depth to bedrock ranges from a few inches to 600 feet or more. The results of the interpretation are shown on the depth-to-bedrock map (pl. 3). This map shows the areas underlain by bedrock lying within several arbitrarily selected depth limits. At distances of more than half a mile from a probe or outcrop, it is possible that the uneven basement surface will cause depths in limited areas to be greater or less than these limits.

Until more is known about the transmissibility and the saturated thickness of the alluvium, determination of the depth to bedrock is the most reliable criteri for the location of test holes and water wells in the area. Such being the case, the depth-to-bedrock map generally indicates the relative possibility of developing ground-water supplies in various portions of the area. As drilling proceeds and as more is learned about the aquifers, the data from wells already drilled will help in the location and drilling of each new well.

Two areas shown on the map as having a depth to bedrock of 300 to 600 feet and greater than 600 feet are considered favorable for ground-water prospecting. The larger of these areas is along the northern edge of the reservation, and the smaller is along the line of probes 24, 14, 15, 16, and 17 (pl. 3).

Considering the well data available, it is probable that wells drilled in secs. 28, 29, or 30, T. 7 S., R. 5 E. will be more productive than those drilled farther east, where the alluvium has a lower transmissibility. It is believed that test holes should precede the drilling of irrigation wells anywhere in this area.

Bedrock depths of 300 to 600 feet are indicated by probes in an elongated area about half a mile wide extending 3 miles north from the northeast part of sec. 29, T. 8 S., R. 5 E. Because of the sandy soil in this area, it was difficult to obtain or maintain a good electrode-to-ground contact. This condition resulted in irregular resistivity curves. None of these curves provided conclusive results, but all gave varying degrees of indication that bedrock lies below 300 feet. Individually, these probes would not be considered reliable as a basis for regarding this area as favorable for ground-water development. Collectively, however, they indicate that bedrock is at a sufficiently great depth to warrant drilling a test hole. The borders of this area have been arbitrarily limited to a distance of not more than half a mile from the line of probes. When additional information is available, it may be found that the area extends farther east or west than is shown on the map.

An additional factor that makes this area favorable for exploration is that it is sufficiently in line with the channels of Silver Reef and Santa Rosa Washes to make it logical that such a bedrock channel might formerly have been occupied by a larger, ancestral Silver Reef Wash capable of depositing sand and gravel that would yield water readily to wells. This hypothesis is supported by the presence of large gravel and boulder deposits 4 miles southeast, adjacent to Silver Reef Wash. As these materials are well rounded and made up of rocks not common to the area, they must have been deposited by a stream much larger than the present Silver Reef Wash.

The area designated on plate 3 as having a depth to bedrock of 200 to 300 feet is transitional between the areas considered favorable and unfavorable for drilling. Portions of this area may be capable of yielding sufficient water for irrigation. After the possibilities of the more favorable areas have been exhausted it might prove worth while to explore the area further with test holes or additional resistivity probes. A well drilled in this area half a mile west of Chiu Chuischu in 1950 penetrated to a depth of 230 feet without reaching bedrock. It did, however, encounter a "red oxide" at 192 feet which apparently is relatively impermeable. A pumping test showed that this well produced 125 gallons per minute.

Relatively great risk is involved in trying to develop ground water in the area shown on plate 3 as having bedrock at depths of less than 200 feet. This shallow bedrock is probably a continuation of the rock found in the adjacent outcrops

SUMMARY AND CONCLUSIONS

To assist the Office of Indian Affairs in developing ground water for irrigation in the alluvial plain of the Lower Santa Cruz basin, near the northern boundary of the Papago Indian Reservation, a geologic, hydrologic, and geophysical reconnaissance was made in 1951 and 1952. Electrical-resistivity probing in a 30-square mile area indicates that most of the area is underlain by bedrock at depths of less than 300 feet. An area having depths to bedrock of as much as 600 feet lies northeast of a nearly straight line extending northwest from Chiu Chuischu past the north edge of three groups of volcanic hills. Apparently a fault with the downthrown side to the north is responsible for this northward increase in the depth to bedrock. Southwest of this assumed fault, bedrock is relatively shallow except in an elongated area extending northward from the pass between the Tat Momoli and Silver Reef Mountains. It is believed that bedrock lies at depths of approximately 300 feet or more in that area. Bedrock lies at depths of less than 200 feet near the bases of the mountains and volcanic hills.

Along the north boundary of the reservation, water-table and aquifer data are available from nearby wells. The depth to the water table increases from about 75 feet at the east side of T. 7 S., R. 5 E., to about 175 feet at the west side. Most of the ground water withdrawn from the alluvium in the heavily developed area north of the reservation comes from a zone of unconsolidated, saturated sand and gravel immediately below the water table. This saturated permeable zone increases in thickness westward along the reservation boundary, from less than 100 feet at the east side to more than 200 feet near the west side. Below the sand and gravel is a zone of clay and cemented material. Production from individual irrigation wells within a mile or two north of the reservation also increases westward, from an average of about 500 gallons per minute to more than 1,000 gallons per minute. The general westerly increase in well yield is undoubtedly related to the increased thickness and permeability of the aquifer.

Farther south, in the area of shallower bedrock (pl. 3), no drilling has been done except at Chiu Chuischu and therefore little is known of the permeability the alluvium.

In developing the ground-water resources of the area wells can be drilled, possibly to depths of 600 feet, without encountering bedrock in the northern half of secs. 25, 26, 27, and 28, T. 7 S., R. 5 E. However, the layers of permeable sand and gravel in these sections are thinner, and wells are likely to be less productive than those drilled farther west. In the north part of secs. 29 and 30 the risk of encountering shallower bedrock is greater, but it is probable that the aquifer is thicker and, therefore, more productive. It is suggested that development should be initiated by test drilling.

Test drilling is considered to be warranted in the elongated area immediately north of the pass between the Silver Reef and the Tat Momoli Mountains.

Developing at any place within the area can be successful only if it is systematic. Additional information obtained from the drilling of test holes, irrigation wells, and additional probes should be correlated with the results of the present survey, thereby furnishing the maximum amount of data for the location of each succeeding well or probe site.

From a study of water samples from wells near the reservation, it is believed that the ground water of the reservation is probably relatively low in content of dissolved mineral matter. The ground water should be suitable for irrigation purposes.

Table 1.--Records of representative wells near Chiu Chuischu, Papago Indian Reservation, Pinal County, Ariz.

Well No. a/	Depth of well (feet)	Diameter of well (inches)	Water level: Depth below land surface (feet) b/	Water level: Date of measurement	Use of water c/	Type of lift d/	Discharge: Gallons per minute e/	Discharge: Date of measurement	Remarks f/
Wells outside reservation									
(D-7-4)									
24baa	480	20	-	-	I	T,E	1560 M	6-22-49	-
24cdd	550	20	175.17	2-12-52	I	T,G	1880 M	9-6-50	L.
25bd	400	20	-	-	I	T,G	1230 M	9-15-41	C.
25ddd	525	20	188.19	2-17-53	I	T,D	2800 R	1947	L.
26bb	900	24	-	-	-	-	-	-	C.
36ddd	850	18	168.00	2-17-53	I	T	-	-	-
(D-7-5)									
15ddd	650	20	-	-	I	T,G	650 M	1-22-53	Cemented sand and gravel at 650 Ft.
16aaa	200	20	147.73	2-16-53	I	T,G	715 M	4-22-46	Rock at 195 Ft.
18add	695	20	193.04	2-6-51	I	-	-	-	-
18ddd	500	20	-	-	I	T,D	2220 M	9-15-41	C.
19cdd	632	20	192.43	2-16-53	I	T,G	1460 M	6-16-49	L. Conglomerate at 616 feet.
21daa	325	12	167.51	1-22-53	I	T,G	380 N	4-13-50	-
22ddd	-	12	76.56	3-12-42	I	T,G	350 M	5-21-51	C.
23ccd	250	20	114.04	2-16-53	I	T,G	500 M	6-15-49	Rock at 200 to 250 feet.
24dad	475	20	80.43	2-16-53	I	-	-	-	L. Hard red shale at 450 feet.
24ddd	130	12	-	-	I	T,G	470 M	1-22-53	-
(D-7-6)									
19ddd	316	20	-	-	I	T,G	610 M	1-22-53	Very hard shell at 314 feet.
29ddd	260	20	99.81	2-18-53	I	T,G	1430 M	8-11-48	C.
31adc	186	20	90.44	2-18-53	I	T,E	450 M	8-11-48	C. Granite at 184 feet.

a/ Well number describes location; for example, the first well listed is in the NE$\frac{1}{4}$ NE$\frac{1}{4}$ NW$\frac{1}{4}$ sec. 24, T. 7 S., R. 4 E.
b/ Depth was adjusted to land-surface datum from measuring point.
c/ I, irrigation; D, domestic; S, stock; E, exploratory test; P, plan to use for irrigation.
d/ T, turbine; C, cylinder; E, electric; G, natural gas; D, diesel; W, windmill; N, none.
e/ M, measured by Geological Survey; R, reported.
f/ L, see log, table 2; C, see chemical analysis, table 3; D, drill cuttings collected, examined, and filed. Remarks about depth of rock units are based on driller's log.

Table 1.--Records of representative wells near Chiu Chuischu, Papago Indian Reservation, Pinal County--continued.

Well No. a/	Depth of well (feet)	Diameter of well (inches)	Water level: Depth below land surface (feet) b/	Water level: Date of measurement	Use of water c/	Type of lift d/	Discharge: Gallons per minute e/	Discharge: Date of measurement	Remarks f/
(D-7-6)									
31bda	176	20	87.19	2-5-52	I	T,E	950 M	8-11-48	C, L. Granite at 172 feet.
32ddd	335	20	95.10	1-22-53	I	T,E	3000 R	1952	Hard rock at 335 feet.
33cdd	487	20	104.14	2-17-53	I	T,E	800 M	8-19-48	Rock at 487 feet.
33ddd	600	18	114.12	2-17-53	I	T,G	2170 M	8-13-48	C.
34ddd	611	16	-	-	I	T,G	3000 M	8-3-48	Water temperature 91° F. Solid rock at 611 feet.
(D-8-6)									
3add	800	18	129.03	2-18-53	I	T,G	2100 M	7-29-48	-
3ddd	785	18	132.81	2-18-53	I	T,G	2580 M	7-29-48	Hard sand and rock at 779 feet.
10add	600	20	116.82	2-5-52	I	T,G	2000 M	7-29-48	C.
14ddd	750	20	140.68	2-18-53	I	T,G	1860 M	7-30-48	Conglomerate at 690 feet.
15ddd	450	20	95.41	8-25-48	I	T,G	840 M	5-1-52	C.
17ddd	610	20	-	-	I	-	-	-	C.
22cdd	450	20	89.11	2-4-49	I	T,E	765 M	7-10-52	C. Pumping level 133.8 feet.
29ddd	358	20	109.00	2-18-53	I	T,E	1020 M	1-22-53	C, L. Rock at 340 feet.
30dad	296	20	109.29	7-28-48	I	T,E	560 M	8-3-44	L. Black rock at 290 feet.
30ddd	440	20	-	-	I	T,E	730 M	6-15-44	C.
32acc	306	20	126.20	2-14-52	I	T,E	495 M	7-28-48	Black rock at 302 feet.
32ccb	400	20	-	-	I	T,E	610 M	7-28-48	C.
Wells within reservation									
(D-8-4)									
23(unsurv)	196	6	152.56	1-22-53	D,S	C,W	-	-	-
(D-8-5)									
1(unsurv)	228	20	-	-	D,I	T,E	570 M	1-23-53	L, C. At Chiu Chuischu.
do.	220	20	-	-	D,I	T,E	-	-	Do.
2(unsurv)	103	20	-	-	E	N	-	-	L. Drilled in 1950. Casing removed Well drilled 4,000 feet west of Chiu Chuischu.
do.	230	20	70 R	May,1950	E	N	300 R	June,1950	L, D. Well drilled 4,000 feet west of Chiu Chuischu

Table 1.--Records of representative wells near Chiu Chuischu, Papago Indian Reservation, Pinal County--continued.

Well No. a/	Depth of well (feet)	Diameter of well (inches)	Water level: Depth below land surface (feet) b/	Water level: Date of measurement	Use of water c/	Type of lift d/	Discharge: Gallons per minute e/	Discharge: Date of measurement	Remarks f/
(D-8-6)									
17aaa	500	20	87.42	1-23-53	P	N	410 925 1520 35'dd 51'dd 65'dd	July, 1952	L, D, C.
17add	475	20	90.20	1-23-53	P	N	-	-	L, D, C.
17dcb	305	6	92.94	1-23-53	E	N	-	-	L, D. C.
17dcc	504	20	91.74	1-23-53	P	N	565 R	June, 1952	L. Drawdown, 118 feet.
17ddd	610	20	92.67	1-23-53	P	N	1020 R	Aug., 1952	L, D, C. Drawdown 130 feet.

Table 2.--Logs of representative irrigation wells near Chiu Chuischu, Papago Indian Reservation, Arizona

	Thickness (feet)	Depth (feet)
(D-7-4)14cdd		
Top soil	2	2
Sand and gravel up to 3"	32	34
Sandy clay	36	70
Tight gravel	8	78
Clay	42	120
Soft clay	30	150
Clay	100	250
Tight gravel in clay	8	258
Clay	8	266
Tight gravel in clay	42	308
Soft sandy clay	22	330
Sand in clay	220	550
TOTAL DEPTH		550
(D-7-4)25ddd		
Valley silt	10	10
Yellow clay	6	16
Rock	4	20
Sand and gravel	20	40
Sand and gravel	44	84
Yellow clay	16	100
Gravel	4	104
Sand	16	120
Clay and broken rock	8	128
Cement gravel	4	132
Clay and gravel	16	148
Cemented sand and gravel	18	166
Sand and gravel - water	18	184
Yellow clay	60	244
Cemented sand	6	250
Red rock and clay	86	336
Gravel large - water	4	340
Cemented gravel	8	348
Rock	16	364
Red rock and clay cemented	161	525
TOTAL DEPTH		525

	Thickness (feet)	Depth (feet)
(D-7-5)19cdd		
Surface soil	8	8
Sandy clay	47	55
Sand and boulders	30	85
Hard caliche	5	90
Clay	60	150
Sand, some water	2	152
Clay	20	172
Sand and gravel, good	16	188
Clay	17	205
Sand and gravel, good	15	220
Clay	36	256
Gravel	3	259
Clay and gravel	27	286
Sand and gravel	7	293
Cemented sand	10	303
Sand and gravel	9	312
Cemented sand	7	319
Sand and gravel, good	13	332
Cemented sand	8	340
Sand and gravel	8	348
Cemented sand	8	356
Clay and gravel	8	364
Sand and gravel	7	371
Cemented sand	9	380
Sand and gravel	9	389
Clay	33	422
Cemented sand	6	428
Conglomerate	128	556
Gravel	9	565
Hard clay	51	616
Conglomerated rock	16	632
TOTAL DEPTH		632
(D-7-5)24dad		
Surface, sand, gravel, rocks	58	58
Clay	16	74

Table 2.--Logs of representative irrigation wells near Chiu Chuischu continued.

	Thickness (feet)	Depth (feet)
Sand	8	82
Caliche	8	90
Sand (water)	12	102
Sand gravel	12	114
Hard brown clay (end of pipe)	92	206
Shale	54	260
Hard rock malapai (reduced hole, 10")	20	280
Hard red shale	20	300
Muddy	15	315
Hard shell	10	325
Red shale, muddy	115	440
Hard shell	10	450
Hard red shale	25	475
TOTAL DEPTH		475

(D-7-6)31bda

	Thickness (feet)	Depth (feet)
Clay	24	24
Fine sand	4	28
Coarse sand	28	56
Sand and big rocks	8	64
Boulders	4	68
Coarse sand and gravel	4	72
Pea gravel	4	76
Sand and gravel	20	96
Clay	20	116
Sandy clay	28	144
Sand, little gravel	8	152
Clay	12	164
Hard clay	8	172
Granite rock	4	176
TOTAL DEPTH		176

(D-8-5)1 (unsurveyed at Chiu Chuischu.

	Thickness (feet)	Depth (feet)
Silt and sand	18	18
Sand	4	22
Coarse gravel	26	48
Caliche	22	70
Coarse gravel	18	88
Indurated clay	2	90
Coarse gravel	4	94
Caliche	18	112
Soft, sandy clay	42	154
Granitic gravel	66	220
Decomposed granite	8	228
Granite		228
TOTAL DEPTH		228

Cased, 0-220; perforated, 70-95 and 150-220.

(D-8-5)1 (unsurveyed) at Chiu Chuischu.

	Thickness (feet)	Depth (feet)
Silty soil	18	18
Sand and gravel	2	20
Coarse gravel	25	45
Clay and gravel	9	54
Sand and gravel	4	58
Caliche and clay	12	70
Coarse gravel and boulders, water	22	92
Clay	6	98
Clay and caliche	15	113
Sand and gravel	2	115
Sandy clay and gravel	30	145
Decomposed granite	15	160
Decomposed granite and clay	56	216
Granite	4	220
TOTAL DEPTH		220

Cased, 0-200; perforated 56-176

(D-8-5)2 (unsurveyed)

	Thickness (feet)	Depth (feet)
Surface soil and sandy loam	24	24
Gravel, up to 6"	36	60
Sandy clay	4	64

Table 2.--Logs of representative irrigation wells near Chiu Chuischu continued.

	Thickness (feet)	Depth (feet)
Sharp gravel in red iron oxide - - - - - - - -	6	70
Same material, set hard	31	101
Same material, cemented	2	103
TOTAL DEPTH		103

(D-8-5)2 (unsurveyed)

	Thickness (feet)	Depth (feet)
Surface soil - - - - -	4	4
Gray sand and silt - -	21	25
Gravel, up to 8 inches	35	60
Same, with layer of clay	13	73
Clay and small sharp gravel	22	95
Sharp gravel in iron oxide	53	148
Sharp gravel and clay	7	155
Small gravel - - - - -	3	158
Sharp gravel in iron oxide	34	192
Sharp gravel cemented in iron oxide - - - -	38	230
TOTAL DEPTH		230
20-inch casing, 0-230; perforated 72-220.		

(D-8-6)17aaa

	Thickness (feet)	Depth (feet)
Brown clay - - - - - -	15	15
Brown sandy clay - -	20	35
Sand - - - - - - - - - -	27	62
Brown sandy clay - -	56	118
Sand - - - - - - - - - - -	3	121
Sand and gravel - - -	4	125
Brown sandy clay - -	77	202
Sand and gravel- - - -	5	207
Brown sticky clay - -	21	228
Brown clay with gravel	9	237
Conglomerate - - - -	15	252
Brown sticky clay with gravel - - - - - - -	218	470
Conglomerate - - - -	30	500
TOTAL DEPTH		500
20-inch casing, 0-466; perforated 89-454.		

(D-8-6)17add

	Thickness (feet)	Depth (feet)
Sandy loam - - - - - -	4	4
Clay and gravel - - -	81	85
Sand, gravel up to 3"	35	120
Fine sand and clay - -	35	155
Light-brown clay with gravel - - - - - - -	85	240
Packed sand - - - - -	5	245
Red clay and gravel -	30	275
Brown clay - - - - - -	30	305
Hard red clay and gravel	15	320
Gray clay- - - - - - -	5	325
Hard red clay - - - -	30	355
Hard sandy clay - - -	30	385
Hard, packed, red gravel	5	390
Sandy clay - - - - - -	5	395
Hard, packed, sharp gravel - - - - - - -	19	414
No record - - - - - -	61	475
TOTAL DEPTH		475
20-inch casing, 0-412; perforated top to bottom.		

(D-8-6)17dcb

	Thickness (feet)	Depth (feet)
Soil, clay- - - - - - -	10	10
Sticky clay - - - - - -	25	35
White clay - - - - - -	5	40
Clay and sand - - - -	24	64
Coarse gravel - - - -	1	65
Clay and gravel - - -	5	70
Soft clay - - - - - - -	10	80
Coarse gravel, caving	7	87
Fine sandy clay - - -	17	104
Coarse gravel - - - -	43	147
Sand, clay, caving - -	28	175
Soft clay, sand - - - -	10	185
Clay and coarse gravel	5	190
Sticky clay and sand -	40	230
Clay and fine sand - -	45	275
Fine sand, clay - - -	15	290
Sticky clay and sand -	5	295

Table 2. --Logs of representative irrigation wells near Chiu Chuischu continued.

	Thickness (feet)	Depth (feet)
Hard clay and sand - -	5	300
Sticky clay and fine sand	5	305
TOTAL DEPTH		305
(D-8-6)17dcc		
Brown clay - - - - - -	24	24
Brown clay and gravel	64	88
Fine sand - - - - - - -	5	93
Coarse sand - - - - -	32	125
Brown sandy clay - - -	75	200
Brown clay with gravel streaks - - - - - - -	190	390
Brown clay - - - - - -	3	393
Tight gravel, up to 4"	17	410
Conglomerate - - - - -	65	475
Red clay with gravel -	29	504
TOTAL DEPTH		504
20-inch casing, 0-446; perforated 88-428.		
(D-8-6)17ddd		
Gravel and clay - - - -	60	60
Gravel, up to 2 inches	15	75
Clay and gravel - - - -	10	85
Unknown - - - - - - - -	5	90
Sand, gravel up to 5"	25	115
Gravel and clay - - - -	60	175

	Thickness (feet)	Depth (feet)
Clay, gravel, and sandy clay	35	210
Hard clay and gravel -	90	300
Clay, gravel, and caliche	100	400
Decomposed granite -	15	415
Sand and boulders up to 9" - - - - - - - -	20	435
Cemented boulders - -	17	452
Loose gravel - - - - -	8	460
Cemented gravel - - -	40	500
Sand, clay, and gravel	15	515
Cemented gravel - - -	50	565
Clay and gravel - - - -	10	575
Cemented sand and gravel - - - - - - -	35	610
TOTAL DEPTH		610
20-inch casing, 0-460; perforated 429-460.		
(D-8-6)29ddd		
Silt - - - - - - - - - -	19	19
Sand and gravel - - - -	38	57
Clay - - - - - - - - - -	21	78
Sand and gravel 6" - -	10	88
Clay - - - - - - - - - -	164	252
Hard clay and sharp gravel - - - - - - -	88	340
Rock - - - - - - - - - -	18	358
TOTAL DEPTH		358

Table 3.--Analyses of water from representative wells near Chiu Chuischu, Papago Indian Reservation, Ariz.

Well no.	Date of collection	Depth of well (feet)	Temperature (°F.)	Parts per million: Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Total hardness as $CaCO_3$	Percent sodium	Specific conductance (micromhos at 25° C.)
(D-7-4)																
25bd	9-15-41	400	78	-	32	7.2	80	176	72	39	1.7	5.3	324	109	61	543
26bb	do.	900	79	-	23	16	286	335	172	190	3.4	17	872	123	83	1470
(D-7-5)																
18ddd	9-12-41	500	78	-	-	-	-	178	-	25	-	-	-	-	-	473
22ddd	9-8-41	-	77	-	-	-	-	176	-	26	-	-	-	-	-	495
(D-7-6)																
29ddd	8-11-48	260	79	-	39	6.9	63	183	72	22	1.0	4.7	299	126	52	504
31adc	do.	186	80	-	130	22	123	170	195	230	.9	17	802	415	39	1370
31bda	do.	176	79	-	58	12	117	180	154	92	.7	9.8	532	194	57	881
33ddd	8-13-48	600	87	30	9.3	2.2	88	145	56	28	1.0	5.1	291	32	86	441
(D-8-5)																
1	9-15-48	228	80	36	33	7.4	77	193	67	33	1.0	5.5	355	113	60	546
(D-8-6)																
10add	8-6-48	600	82	-	-	-	-	156	-	24	-	-	-	-	-	446
17dcb	1-24-51	240a/	-	40	40	8.3	67	192	74	28	1.0	4.7	358	134	52	543
22cdd	9-12-41	450	81	-	27	5.9	85	163	102	24	-	3.2	327	92	67	466
29ddd	do.	358	83	-	-	-	-	168	-	33	-	-	-	-	-	510
32ccb	7-28-48	400	80	39	23	6.2	105	181	81	50	1.6	4.2	399	83	73	625

a/ Sampled during drilling.

Chiu Chuischu Report

REFERENCES

Bryan, Kirk, 1923, Erosion and sedimentation in the Papago country, Ariz., with a sketch of the geology: U. S. Geol. Survey Bull. 730-B, pp. 19-90.

Fenneman, N. M., 1931, Physiography of western United States: McGraw-Hill Book Co., 1st. Ed., 534 pp.

Halpenny, L. C., and others, 1952, Ground water in the Gila River basin and adjacent areas, Ariz.--a summary: U. S. Geol. Survey open-file report, 224 pp.

Skibitzke, H. E., and Yost, C. B., Jr., 1951, Results of a geophysical survey of subsurface geology as related to ground water in the vicinity of Chiu Chuischu, Papago Indian Reservation, Pinal County, Ariz.: U. S. Geol. Survey unpublished report in open file.

Turner, S. F., and others, 1943, Ground-water resources of the Santa Cruz basin, Ariz.: U. S. Geol. Survey mimeographed, 84 pp.

Wetzel, W. W., and McMurry, H. V., 1937, A set of type curves to assist in the interpretation of the three-layer resistivity problem: Geophysics, vol. 2, no. 4, pp. 329-341, Oct. 1937.

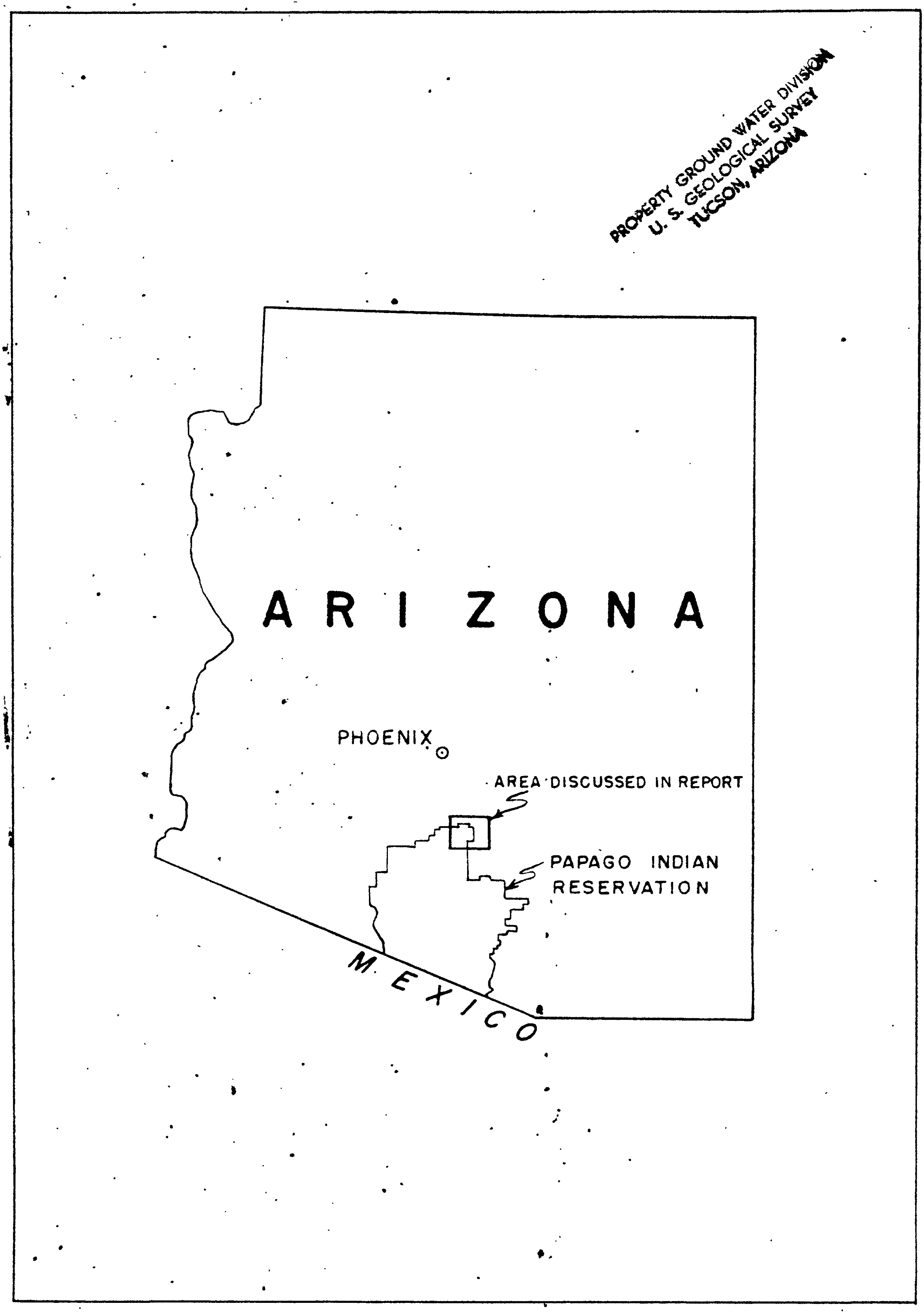

Figure 1.– Map of Arizona showing area discussed in this report.

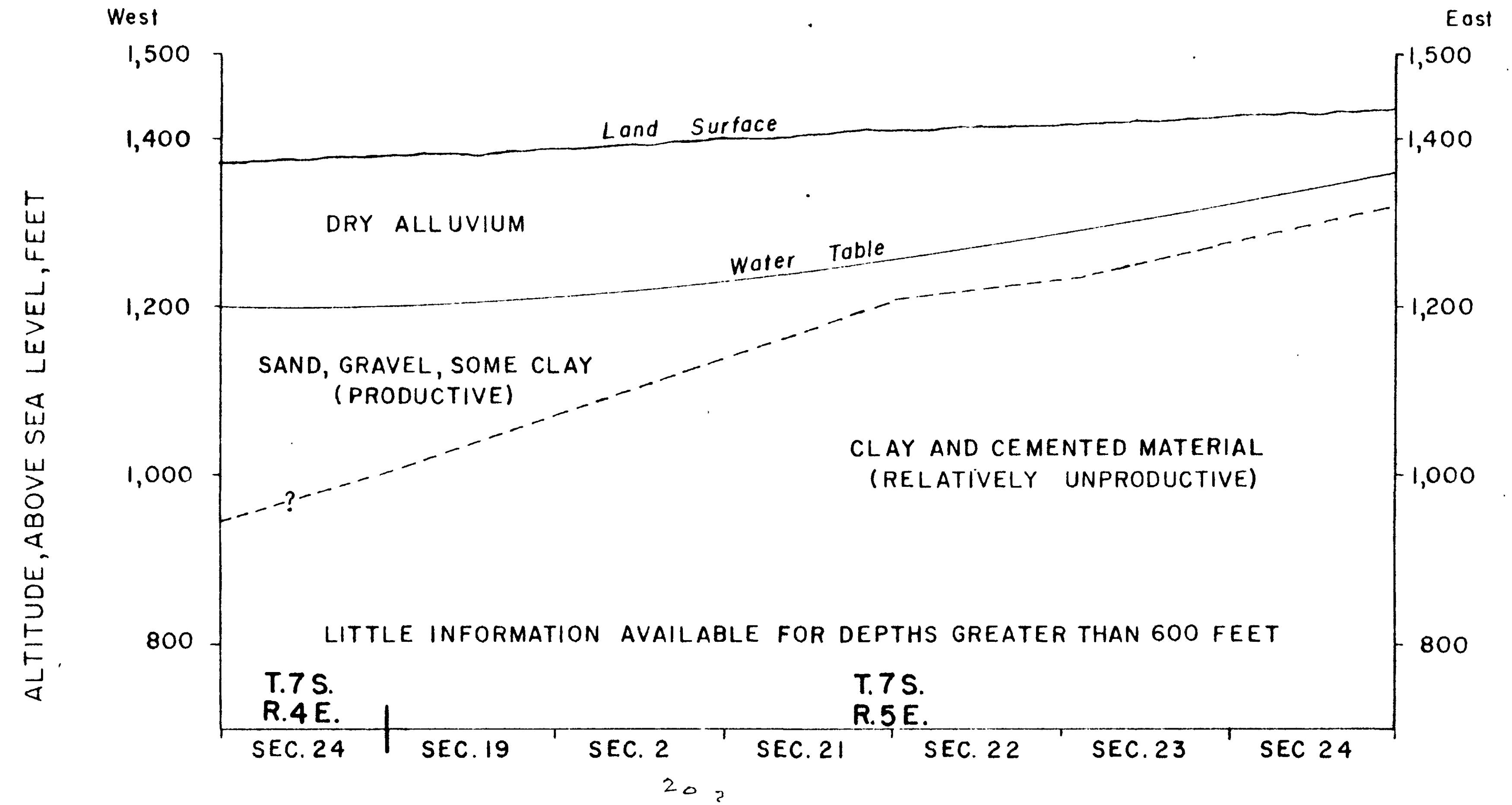

Figure 2.- Generalized cross section along northern boundary of Papago Indian Reservation.