UNITED STATES.
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY.
WATER RESOURCES DIVISION

WATER SUPPLY OF THE CENTRAL ARIZONA AREA.

Answers to 24 questions by Mr. J. Richard Queen,
Staff Consultant, Committee on Interior and Insular Affairs,
House of Representatives

Tucson, Arizona

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Introduction

By letter dated May 4, 1951, the Hon. Clair Engle, Member of Congress from California, requested certain data from William E. Wrather, Director, U. S. Geological Survey. The information requested is to consist of answers to 24 questions prepared by Mr. J. Richard Queen, Staff Consultant, Committee on Interior and Insular Affairs, House of Representatives. The questions were written to pertain to the South Coastal Basin, California, and have been replied to, for the South Coastal Basin, by personnel of the Water Resources Division, U. S. Geological Survey, California. Mr. Engle's letter by reference applies the 24 questions to the Phoenix area, Arizona, and more particularly to the Central Arizona Project as defined in H. R. 1500 of the 82d Congress. This report reproduces without change the wording of the 24 questions. To conform with Mr. Engle's distinction between the Phoenix area and the broader definition of the Central Arizona Project, a distinction has been made, where pertinent, between the two areas.

Question I. How many underground reservoir basins have been identified in the South Coastal Basin? (Prepare a map of this area and identify each basin by number and name.)

The "Phoenix area" is interpreted to include Basin 1 (Salt River Valley Basin) and Basin 2 (Lower Santa Cruz Basin) shown on the map, plate 1. The division between Basin 1 and Basin 2, along the channel of the Gila River, is arbitrary and reflects a division of studies made and reports issued by the Geological Survey in the past, rather than a natural barrier. The downstream limit of the area considered is set at Gillespie Dam, near Gila Bend, to conform with the definition of the Central Arizona Project made by the Bureau of Reclamation, U. S. Department of the Interior. Because the combined areas of Basin 1 and Basin 2 occupy about 3 million acres, and extend over most of Pinal and Maricopa Counties, it is thought more suitable to refer to the area as the Maricopa-Pinal area, rather than as the "Phoenix area."

The other basins shown on the map (pl. 1) and included in the overall Central Arizona Project are directly or indirectly tributary to Basins 1 and 2. Moreover, as in the case of the Duncan Basin (Basin 9, pl. 1) and the Lower San Simon-Gila River Basin (Basin 8, pl. 1) for example, upstream basins are tributary to downstream basins in the system. It is not possible therefore simply to sum up figures such as runoff from individual basins and obtain a meaningful total for the entire system. The interrelationship of basin to basin must be taken into account.

Nine ground-water basins are outlined in plate 1 for the purposes of this report. They are as follows:

1. Salt River Valley Basin
    - 1A. Queen Creek Critical Area
    - 1B. Salt River Valley Critical Area
2. Lower Santa Cruz Basin
    - 2A. Eloy Critical Area
    - 2B. Casa Grande-Florence Critical Area

3. Avra-Altar Basin
4. Upper Santa Cruz Basin
5. Upper San Pedro Basin
6. Lower San Pedro Basin
7. Upper San Simon Basin
8. Lower San Simon-Gila River Basin
9. Duncan Basin

Other small ground-water basins are known to exist in the drainage of the Gila River and its tributaries, such as that in the Chino Valley north of Prescott and that in the Verde River Valley near Clarkdale. Data in hand are insufficient to permit even drawing the outlines of such basins, much less to permit discussing their character.

On the map, plate 1, four areas within basins 1 and 2 have been hachured and labeled 1A, 1B, 2A, and 2B. These are ground-water subdivisions that have been designated by the State Land and Water Commissioner as critical ground-water areas. A critical ground-water area is defined as follows in the Arizona Ground-Water Code 1948.

> A "critical ground-water area" is any ground-water basin or any designated subdivision thereof, not having sufficient ground water to provide a reasonably safe supply for irrigation of the cultivated lands in the basin at the then current rate of withdrawal.

In general, the designation of a critical ground-water area restricts the construction of additional irrigation wells in the area and prohibits the cultivation of lands not cultivated prior to the time of designating the area as critical.

Question II. Give the characteristics of each basin, i. e., the size (in acres), shape, depth and capacity of the water-bearing formations to store and transmit water.

The descriptions of ground-water basins included in the overall Central Arizona Project are incomplete in detail. Data do not as yet exist that would permit definitive statements concerning the shape of the rock walls of the basins against which alluvial materials have been deposited, the overall depth of the basins below present ground level, and the capacity of the several formations to store and transmit water. Data are available from well logs, pumping tests, analyses of well cuttings, geologic mapping, and geophysical probes, that permit tentative generalizations. Known conditions in local areas are projected across broad areas in which comparable conditions may be found, but where detailed information is lacking.

In general, each of the ground-water basins shown on the map, occupies an intermontaine trough, probably of structural origin. Detailed drilling connected with mine development, geologic mapping along basin margins, and probing with electrical resistivity apparatus indicate that the mountains bounding the basins are uplifted relative to the basins themselves, on a series of faults essentially parallel to the axis of the individual basin. The alluvial material filling the basins is deepest near the axis, and is progressively shallower toward the sides. The extent to which this pattern is modified by local structures, now buried by basin fill, is unknown.

The capacity of water-bearing materials to store and transmit water is imperfectly known. A general pattern infinitely varied in detail is suggested by pumping tests, reconnaissance study of the geology of the basins, and interpretation of well cuttings and drillers' logs.

Two types of valley fill are distinguished, an older fill and a younger fill. The older fill occupies most of the basin from the hard-rock floor upward toward the present land surface. Total thickness of the older alluvium is in most places unknown, but in some basins wells have penetrated at least 2,000 feet of this fill. Typically the older fill is variable in grain size, and is almost invaribly cemented. Fine-grained materials are common in all basins and dominant in those basins where ancient lakes or playas deposited clays, silts, fine sands, and locally limestone, gypsum, and salt. The younger fill overlies the older fill, wholly or in part, and ranges in thickness from a feather-edge at its outer margins to a maximum near the floodplain of contemporary through-draining streams. Maximum thicknesses of the younger fill range from about 100 feet in the San Pedro drainage (Basins 5 and 6, pl. 1) to about 800 feet in the Lower Santa Cruz Basin (Basin 2, pl. 1). The younger alluvium also includes lake bed and playa deposits but is commonly composed of materials ranging in grain-size from silt to gravel.

The water-bearing properties of the older fill and younger fill are markedly different. Because of its cementation and fine-grained texture, the older fill is believed capable of storing large volumes of water but is known to release it relatively slowly to wells. In many places, therefore, successful stock wells can be drilled in older fill, but yields in general are insufficient to permit pumping for irrigation. Local exceptions occur in parts of the San Pedro River Valley (Basins 5 and 6, pl. 1) and parts of the Lower San Simon-Gila River Basin (Basin 8, pl. 1) where artesian aquifers are present in the older fill. The younger fill, in contrast, is in many places uncemented and coarse-grained, yielding water readily to wells. The younger alluvium is the principal aquifer in most basins from which water can be pumped in quantities sufficient for irrigation. Reconnaissance studies of the geology of the basins indicate that in some of the basins such as the Upper Santa Cruz Basin (Basin 4, pl. 1) and the Lower San Simon-Gila River Basin (Basin 8, pl. 1), the younger fill receives water by slow percolation from those parts of the older fill that lie topographically higher than the younger fill.

The outline of each ground-water basin shown on the accompanying map, plate 1, marks the approximate boundary between valley alluvium and mountains or mountain pediment. Mountain pediments are so thinly covered with alluvium that they are ineffective for the storage of ground water, but may be important as recharge areas. Major areas of mountains and pediment that are entirely within some of the ground-water basins, especially in Basins 1 and 2, are shown on the map. The characteristics of the water-bearing formations to store and transmit water in the various basins are summarized in table 1 and discussed more fully in answer to questions III and IV.

Salt River Valley Basin (Basinl)

The Salt River Valley Basin is highly irregular in shape and elongated east and west. Its maximum length is in the order of 90 miles, and the maximum width about 30 miles. The basin includes approximately 1,600,000 acres (2,500 square miles). An additional 154,000 acres (241 square miles) of mountain and pediment areas encompassed by the basin are not included in the figures for basin area.

The younger fill in the basin ranges in thickness from a feather-edge to 600 feet. In areas where irrigation wells are located the younger fill is from 200 to 600 feet thick. Maximum thickness of the older fill is not known. The older alluvium in Basin 1 apparently does not yield water to wells in large quantities.

Part of Basin 1 (see 1A and 1B, pl. 1) has been declared the Queen Creek Critical Ground Water Area and the Salt River Valley Critical Area.

Lower Santa Cruz Basin (Basin 2)

The Lower Santa Cruz Basin is roughly a parallelogram in shape. The longest diagonal extends about 85 miles in a northwest-southeast direction and the maximum width is about 45 miles. The area of the Lower Santa Cruz Basin is 1,500,000 acres (2,350 square miles). About 40,000 acres or 63 square miles of mountain and pediment areas within the basin are excluded from the above figures. The northern limit of the basin is drawn at the Gila River, and is only an arbitrary boundary between this basin and the Salt River Valley Basin. On the south Basin 2 is bounded by the Avra-Altar Basin (Basin 3) and the Upper Santa Cruz Basin (Basin 4). The division between Basins 2 and 3 is an arbitrary one and used for study purposes only, while the division between Basin 2 and Basin 4 is marked by a physiographic narrows, known locally as the Rillito Narrows. Basin 2 is bounded on the east and west by the rock walls of a northwest-southeast trending structural trough.

The younger alluvium ranges in thickness from a feather-edge near the margins to at least 800 feet. Those areas in which irrigation wells have been successful are underlain by 200 to 800 feet of younger alluvium. The thickness of the older alluvium is unknown. A hole drilled to 2,800 feet in this basin did not pass out of valley fill. An electric log of the hole indicated that much fine-grained or cemented material was present below 900 feet and no appreciable increase in production of water could be expected from the hole below that depth. Wells over 1,000 feet deep in other parts of the basin substantiate the belief that the maximum economic depth to which irrigation wells should be drilled in the basin is about 900-1,000 feet.

Most of Basin 2 has been declared a critical ground-water area (see pl. 1, areas 2A and 2B) and part of the remainder is under consideration for declaration as being a critical ground-water area.

Avra-Altar Basin (Basin 3)

The Avra-Altar Basin is about 70 miles long, approximately 15 miles wide, and contains about 540,000 acres (840 square miles). In general, the axis of the basin trends north. The northern boundary of the basin is an arbitrary one established for study purposes only, and the southern or upper limit of the basin is defined by a topographic or surface drainage divide. The entire basin is tributary to Basin 2.

The lack of deep drilling in Basin 3 prevents a definite statement regarding thickness and composition of the older alluvium. Younger valley fill ranges in thickness from a feather-edge to a known thickness of 700 feet. About 300 feet is the maximum thickness of younger material known to yield water in quantities sufficient for irrigation.

During 1950 and 1951, extensive development of irrigation has taken place in the northern half of the basin. This pumping for irrigation will lower the water levels in Avra-Altar Valley and diminish the underflow to Basin 2. The geology and hydrology of the upper (southern) half of the basin is little known. A reconnaissance investigation by Andrews (1937) suggests that ground-water supplies are limited.

An application has been filed by the land owners to have a part of the Avra-Altar Basin declared a critical ground-water area, and a hearing will probably be held during the fall of 1951.

Upper Santa Cruz Basin (Basin 4)

The Upper Santa Cruz Basin, a north-south trending basin, is about 80 miles long and averages about 11 miles wide. The basin includes approximately 570,000 acres (900 square miles). The southern limit of the basin is set at the International Boundary between the United States and Mexico. The northern limit is taken at a natural ground-water barrier and narrows near the town of Rillito. The barrier is a subsurface structure that maintains the water table about 80 feet higher south (upstream) than north (downstream) of the barrier. The decline occurs in a distance of less than one mile. South of the International Boundary at Nogales, the Santa Cruz River swings in an arc about 40 miles long and returns to its headwaters in Arizona approximately half way between Nogales and Bisbee, not far from longitude 110° 30' West. That part of the Santa Cruz River drainage south of the International Boundary and its small headwater area in Arizona are not included in the Upper Santa Cruz Basin of this report.

The younger alluvium in the Upper Santa Cruz Basin is confined to a belt between half a mile and two miles wide near the axis of the basin. The greatest thickness of alluvium identifiable as younger alluvium amounts to about 300 feet. The younger fill is the principal aquifer in the basin.

Wells have reaches a maximum depth of about 2,000 feet. On the basis of logs of deep wells and on reconaissance geological study of the basin, it is believed that the older alluvium in most areas of the basin will yield water in quantities sufficient for stock wells and in some places yield up to 400 or 500 gallons per minute in properly constructed and developed wells. The maximum thickness of the older alluvium is not known, but in some places it exceeds 1,500 feet.

Upper San Pedro Basin (Basin 5)

The Upper San Pedro Basin, a north-south trending basin, is approximately 55 miles long and averages about 15 miles wide. The area of the Upper San Pedr Basin is about 535,000 acres (840 square miles). The basin is irregular in shape and extends from the International Boundary northward to a natural ground-water barrier located about half way between the towns of Pomerene and Cascabel. The headwaters of the basin are about 50 miles south of the International Boundary in Mexico, and data are unavailable for that area.

The maximum depth of valley fill penetrated by drilling in the basin is 1,505 feet of which only about 100 feet is younger alluvium. Most of the young alluvium is confined to a relatively narrow belt along the San Pedro River. Several irrigation wells have been developed in the younger fill. Much of the total thickness of valley fill in this basin consists of ancient lake-bed and playa deposits, including gypsum and gypsiferous silts. Artesian acuifers in the older fill supply water to many wells in the basin. Yields from the artesian aquifers are small.

Lower San Pedro Basin (Basin 6)

The lower San Pedro Basin is about 70 miles long, and averages about 8 miles wide. The total area of the basin is about 370,000 acres (575 square miles). The southern upstream limit of the basin is at a natural ground-water barrier separating this basin from Basin 5. The northern or downstream limit is arbitrarily drawn at the Gila River.

The deepest drilling in the basin bottomed in valley fill at 1,485 feet. This well encountered about 100 feet of younger fill, predominantly sands and gravels, and about 1,400 feet of older fill consisting of about 500 feet of clays and silts below which were about 900 feet of clays and sands containing some water under artesian pressure.

Upper San Simon Basin (Basin 7)

The Upper San Simon Basin extends from the vicinity of Rodeo, New Mexico, northwestward into Arizona to an arbitrary line between townships 9 and 10 south. For the purpose of this report the southeastern limit of the basin is drawn at the Arizona-New Mexico State Line. The Upper San Simon Basin is about 60 miles long and about 15 wide. The Upper San Simon Basin includes about 640,000 acres (1,000 square miles). That part of the basin within New Mexico probably contributes little water to Arizona. A generalized log near the central axis of the basin would show that the alluvial cover of younger fill consists of sands and gravels to a depth of about 200 feet underlain by older fill consisting of 400 feet of clay, below which are silts, clay, sands and gravels to a depth of 2,800 feet. Artesian aquifers occur at depths between 400 and 2,300 feet.

Lower San Simon-Gila River Basin (Basin 8)

The Lower San Simon-Gila River Basin extends northwest from the northern boundary of the Upper San Simon Basin. The lower basin is about 70 miles long, and averages about 25 miles wide. The area contains about 735,000 acres (1, 150 square miles). The valley fill is about 2,700 feet thick. The younger fill is not over 100 feet thick and contains the aquifers which supply most of the ground waters used in the basin. Artesian aquifers in the older fill between 200 to 1,200 feet below land surface, yield highly mineralized water to wells.

Duncan Basin (Basin 9)

The Duncan Basin is the Arizona portion of a larger basin that extends from the vicinity of Lordsburg, New Mexico northwestward to the vicinity of Clifton, Arizona. The Duncan Basin is a relatively small area about 30 miles long and averages less than 10 miles wide. The basin contains about 175,000 acres or 275 square miles. The New Mexico portion of the large basin contributes an appreciable quantity of water to the Duncan Basin.

The deepest well drilled in the basin bottomed in valley fill at 750 feet. The younger valley fill which is not over 100 feet thick contains aquifers that supply most of the ground water used in the basin.

Question III. What is your Department's estimate in acre-feet of the storage capacity of each identifiable basin? What is your Department's estimate in acre-feet of the total storage capacity for all of the underground basins?

In estimating the storage capacity of a subsurface reservoir, it is necessary to consider the volume of the reservoir and the average specific yield of the materials comprising the reservoir. The term "storage capacity" in this report is restricted to that part of the capacity of the reservoir containing water available for use. The estimates are made in terms of "available water."

The volume of a reservoir is determined by three factors:

1. The upper limit. For the purposes of this report the water table of 1950 is selected as the upper limit. Ordinarily the upper limit is that level to which a basin can be filled with water before it rejects additional water. This limit can not be considered applicable to most of the basins of the Central Arizona area because the supply of water reaching them is insufficient to fill them to that level.
2. The lower limit. For the purposes of this report, a lower limit is arbitrarily set at 100 feet below the water table in 1950.
3. The average area of the reservoir

Specific yield is the ratio , expressed as percent, of the volume of water that can be drained by gravity to the total volume of water-bearing material from which it was drained. Data regarding specific yields are meager and determinations of yields on materials in other states are cited to show general accordance with yields obtained in Arizona.

The following table summarizes data on determinations of specific yield.

Area and reference	Type of material	Specific yield (Percent)
Eloy district, Arizona (Smith, 1940)	No data	8.86 - 13.36
Florence-Casa Grande area, Arizona (White, 1935)	Sands and gravels	20 - 25
Bill Williams River, Arizona (Unpublished data, U. S. Geol. Survey, Ground Water Branch, Tucson, Arizona)	Sands and gravels	9.8 - 30.9
Escalante Valley, Utah (White, 1932)	Clays, clay-loams, silts and fine grained sands	1.3 - 5.5
Grand Island, Nebraska (Wenzel, 1936)	Coarse sands	22 - 23
Mokelumne area, California (Stearns, Robinson and Taylor, 1930)	Hard, sandy clay to medium-grained sand	0.3 - 20
Mokelumne area, California (Piper, Gale, Thomas, and Robinson, 1939)	Very fine sand, silt and clay	3.5
	Medium and fine sand	22.6
	Gravel and coarse sand	35
	All materials	12.8

Area and reference	Type of material	Specific yield (Percent)
Santa Clara Valley, California (Estimate made by Clark, cited in Piper, Gale, Thomas, and Robinson, 1939)		12
Safford Valley, Arizona (Gatewood and others, 1950)	Floodplain materials	16
Phoenix area, Arizona (Turner, McDonald and Cushman, 1946)	Silt, sand and gravel	15
Verde River, Arizona (McDonald and Padgett, 1945)	Sands and gravels Average	3.7 - 30.3 16

Average specific yields for individual basins in the table below are based on the above data and on knowledge of the geology of each basin. It is estimated that 60,770,000 acre-feet of water are stored in the combined areas of the basins treated in this report. The values for the individual basins are shown in the table below.

Basin	Reservoir area (acres)	Depth of reservoir (feet)	Specific yield (percent)	Volume of available water in storage (acre-feet)
1. Salt River Valley	1,600,000	100	12	19,200,000
2. Lower Santa Cruz	1,500,000	100	10	15,000,000
3. Avra-Altar	540,000	100	8	4,320,000
4. Upper Santa Cruz	570,000	100	10	5,700,000
5. Upper San Pedro	535,000	100	6	3,210,000
6. Lower San Pedro	370,000	100	6	2,220,000
7. Upper San Simon	640,000	100	6	3,840,000
8. Lower San Simon-Gila River	735,000	100	8	5,880,000
9. Duncan	175,000	100	8	1,400,000
TOTAL				60,770,000

Question IV. What is your Department's estimate of the safe yield in acre-feet of all the underground reservoirs of this basin?

Question V. For the last 10 years of record give in acre-feet the average annual surplus or overdraft for the South Coastal Basin.

The estimate of the safe yield of all the basins in Arizona and the averag annual surplus or overdraft are interrelated and are discussed together. Estimates of safe annual yield are made only for Basins 1, 2, 3, and 4 and are tabulated below.

The determination of safe annual yield of the Salt River Valley (Basin 1, pl. 1) is complicated by the large, and yet undetermined, volume of water that must be allowed to flow out of the basin in order to maintain the salt balance. Consequently, the estimate of safe annual yield for Basin 1 is stated as being between probable upper and lower limits.

The Upper and Lower Santa Cruz Basins and the Avra-Altar Basin (Basins 4, 2 and 3, pl. 1) have been studied (S. F. Turner and others, 1943) in some deta and figures for safe annual yield of these basins are quoted from the report. The safe annual yield of Basin 3 is included in the figure for Basin 2.

The problem of safe annual yield in the Lower San Simon-Gila River Basin and in the Duncan Basin (Basins 8 and 9, pl. 1) is involved with legal problems related to prior rights to water in the Gila River (S. F. Turner and others, 1946; L. C. Halpenny and others, 1946). This complication precludes the possibility of establishing a figure for safe annual yield on hydrologic grounds.

The other basins included in the overall Central Arizona project are too imperfectly known geologically and hydrologically to permit estimating their safe annual yield.

Estimates of the safe annual yield and average annual overdraft in Basins 1, 2, 3, and 4 are given in the table below.

Basin	Safe annual yield	Average annual overdraft 1941-50
1. Salt River Valley	500,000 - 1,000,000	265,000 - 765,000
2 and 3. Lower Santa Cruz and Avra-Altar	135,000	520,000
Sub-total Maricopa-Pinal area	635,000 - 1,135,000	785,000 - 1,285,000
4. Upper Santa Cruz	80,000	65,000

The overdraft has greatly increased during recent years and for compariso the table below is presented.

Basin	Safe annual yield (acre-feet)	Average annual overdraft 1946-50 (acre-feet)
1. Salt River Valley	500,000 - 1,000,000	595,000 - 1,095,00(
2 and 3. Lower Santa Cruz and Avra-Altar	135,000	750,000
Sub-total Maricopa-Pinal area		1,340,000 - 1,840,00C
4. Upper Santa Cruz		100,000

Question VI. Give in acre-feet for this basin an estimate of the average annual water loss due to transpiration from swampy areas overgrown with water-loving vegetation?

The annual use of water by water-loving vegetation (phreatophytes) in Arizona has been estimated by Turner (S. F. Turner and others, 1951). Data adapted from that estimate are reproduced below for the basins included in the present report. Between 274,000 and 354,000 acre-feet of water is lost annually through transpiration of phreatophytes in the nine basins.

Basin	Area occupied by phreatophytes	Annual use (acre-feet)
1. Salt River Valley	22,500	75,000
2. Lower Santa Cruz	25,000	100,000 - 150,000
3. Avra-Altar	No data	Probably negligible
Sub-total, Maricopa-Pinal area	47,500	175,000 - 225,000
4. Upper Santa Cruz	No data	Probably small
5 and 6. Upper and Lower San Pedro	10,000 - 20,000	30,000 - 60,000
7. Upper San Simon	No data	Probably negligible
8. Lower San Simon-Gila River	12,500	60,000
9. Duncan	1,800	9,400
TOTAL	72,000 - 82,000	275,000 - 350,000

Question VII. Of the total amount of precipitation on the combined watershed what is the best estimate in acre-feet of the amount returned to the atmosphere by (a) evaporation and (b) transpiration?

Preparation of an accurate answer to this question would require additional basic research regarding precipitation, runoff, diversion of surface flow for irrigation, recharge; research regarding evaporation from water surfaces, from wetted sand in stream bottoms, from irrigated lands, from the land-surface immediately following rains, from mountain snows during the winter and during spring melt; and research regarding use of water by plants, both those using perennial water and desert plants using near-surface water immediately following rains. Many of these data are not available.

From those data that are available it is tentatively estimated that 37,500,000 acre-feet of the total precipitation falling on the drainage basin of the Gila River upstream from Gillespie Dam is lost by evapo-transpiration.

Question VIII. How many pumps are now operated in this basin for the purpose of withdrawing water from the underground by
(a) Individuals for agricultural or domestic use?
(b) Industrial plants?
(c) Municipalities?

The following tabulation is based on counts by the U. S. Geological Survey of irrigation pumping plants operated in the basins on data furnished the Survey by municipalities and industrial establishments, and on estimates prepared using 1950 Census figures.

Basin Number	Basin	Number of pumps operated for Agriculture	Industry	Municipal	Private Domestic
1.	Salt River Valley	1,500	25	40	No data
2.	Lower Santa Cruz	1,300	20	7	No data
3.	Avra-Altar	35	5	None	40
4.	Upper Santa Cruz	800	50	100	400
5.	Upper San Pedro	50	10	10	No data
6.	Lower San Pedro	55	5	2	230
7.	Upper San Simon	40	5	2	No data
8.	Lower San Simon-Gila River	400	10	2	No data
9.	Duncan	50	5	1	No data

Question IX. Give an annual average estimate in acre-feet of the water pumped from various underground reservoirs that is used by
(a) Individuals for agricultural or domestic uses
(b) Industrial plants
(c) Municipalities

The following data were compiled in 1950 for a report on ground-water conditions and problems in Arizona. This report was made at the request of the President's Water Resources Policy Commission. Data are not available for 1951

Basin Number	Basin	Average annual withdrawal of ground water in acre-feet: Agriculture	Industry	Municipal
1.	Salt River Valley	1,650,000	5,500	17,900
2.	Lower Santa Cruz	1,000,000	450	3,000
3.	Avra-Altar	7,500	100	None
4.	Upper Santa Cruz	160,000	1,350	13,400
5.	Upper San Pedro	3,000	650	180
6.	Lower San Pedro	10,000	5,000*	1,000*
7.	Upper San Simon	6,000	250	60
8.	Lower San Simon-Gila River	47,000	200	100
9.	Duncan	10,000	No data	80

* Pumped from mines.

Question X. How much useful water in acre-feet furnished by nature not presently utilized can be made available to the inhabitants of this area by proper engineering investments other than aqueducts to import water?

Three sources other than importation of water from outside the basins migh contribute to total water available for use. Construction of additional upland storage reservoirs might add to water made available for use of man. Elimination of phreatophytes would reduce transpiration losses. Diversion of mineralized waters from salt springs in the Salt and Gila River drainages and evapor: tion of the salty water would favorably affect the salt balance in Basins 1 and 2, thus reducing the volume of water that currently must flow out of the basins to maintain a salt balance. Additional water might be made available to the Central Arizona area by development of springs along the Mogollon Rim on the headwaters of the Gila, Salt, and Verde Rivers. Construction of temporary impoundment reservoirs on selected washes would slow down the runoff of flood waters and would allow a greater volume of these flood waters to recharge the subsurface reservoirs.

A highly tentative estimate of 500,000 acre-feet per year is made for the amount of water it might be possible to salvage by the methods indicated above. The research needed to determine better values has not been done owing to lack of money and personnel.

The cost of developing the several possibilities suggested has not been calculated, hence there is no knowledge as to their economic feasibility.

Question XI. Give an average annual estimate in acre-feet of the amount of water consumed by the vegetative cover in (a) the mountain and foothill areas tributary to valley floors, and (b) valley floor area.

Reference is made to Question VII, which is in part equivalent to Question XI.

Data are not available showing the amount of water used by evapo-transpiration in the mountain and foothill areas. Studies of the water use by crops and by non-beneficial phreatophytes have been made in some valley floor areas. The tabulations appearing below summarize the available information about the average annual use of water by crops in irrigated areas 1/.

Basin	Water use (acre-feet)
1. Salt River Valley Basin	1,350,000
2. Lower Santa Cruz Basin	500,000
Sub-total for Maricopa-Pinal area	1,850,000
4. Upper Santa Cruz Basin	90,000
8. Lower San Simon-Gila River Basin	70,000
9. Duncan Basin	8,500
Total use in 5 basins	2,018,500

1/ Acreages available in: Barr, (1948 and 1949); duty of water for various crops from: Gatewood and others, (1950); Turville and Hitch, (1944); Ross and others, (1931); Marr, (1927).

No data are available for the other basins but it is believed that the combined acreages of the other areas would be small in comparison with the five basins cited. The use by non-beneficial phreatophytes in all of the basins was given in Question VI as between 275,000 and 350,000 acre-feet.

Question XII. For the last 10 years of record give in acre-feet the average amount of water that has wasted to the ocean.

This question is interpreted to mean the amount of water flowing from the basin at Gillespie Dam other than diversions at the dam. In 1941 flow past the dam was unusually large owing to the heavy precipitation of that year. Flow in

Gila River below Gillespie Dam was as follows:

Year		Acre-feet
1941		1,036,000
1942		17,700
1943		14,170
1944		13,490
1945		7,380
1946		29,510
1947		12,650
1948		936
1949		10,560
1950		4,120
	Average 1941-50	114,700
	Average 1942-50	11,000

Question XIII. Give in acre-feet for the last 10 years of record the average annual mountain and foothill runoff.

It is estimated that the average annual runoff from the mountain and foothill areas for the 10-year period 1941-50, amounted to about 2,600,000 acre-feet.

Question XIV. According to your records, how much water in acre-feet has been available and utilized on an average annual basis for the past 10 years of record from all surface and ground water sources?

The average annual use of water for the past ten years is shown in the table below.

		Water use (acre-feet)
Maricopa-Pinal area (Basins 1 and 2)		
From surface water		1,293,000
From ground water		1,926,000
	Total	3,219,000
All Central Arizona area including Basins 1 and 2		
From surface water		1,454,000
From ground water		2,190,000
	Total	3,644,000

The expansion in use of ground water is shown by the following data i the year 1949.

		Water use (acre-feet)
Maricopa-Pinal area (Basins 1 and 2)		
From surface water		1,206,000
From ground water		2,784,000
	Total	3,990,000
All Central Arizona area including Basins 1 and 2		
From surface water		1,430,000
From ground water		3,050,000
	Total	4,480,000

Question XV. Give an estimate in acre-feet of the average annual amount of precipitation that is unrecoverable. Explain.

Unrecoverable precipitation is considered that part of the total precipitation on the drainage area that is not or cannot be (a) used as surface water, or (b) added to recharge of subsurface reservoirs.

It is estimated that about 37,000,000 acre-feet is unrecoverable from the total annual precipitation of 40,000,000 acre-feet on the drainage basins of the Gila River and its tributaries upstream from Gillespie Dam. The 3,000,000 acre-feet of water estimated as recoverable includes the diversions of surface water, present recharge to subsurface reservoirs, and the additional savings mentioned in Question X.

Question XVI. Give a brief summary of the results obtained in this basin as a result of your sedimentation surveys and studies.

The Geological Survey has not conducted sedimentation studies or surveys in the basins of Gila River and its tributaries.

Question XVII. Give an estimation in dollars and cents of the average yearly damage to reservoirs, bottom land, and water yield generally as a result of the sediments derived from various types of erosion.

The Geological Survey has no data in the drainage basins of Gila River and its tributaries that are pertinent to this question.

Question XVII. What is your department's estimate of the annual amount of water in acre-feet in this basin that is presently not used that could be made available by artificial recharge?

A research project is being planned with the Geological Survey and the Soil Conservation Service cooperating with local agencies, that is intended to define the answer to this question in quantitative terms.

An estimate is made based on studies by Babcock and Cushing (1942) in the Queen Creek area of Basin 1, and S. F. Turner and others (1943) in Basin 4. Additional recharge that might be obtained by temporary storage, controlled flood runoff, and artificial water spreading, is estimated as 285,000 to 300,000 acre-feet per year.

Question XIX. For the South Coastal Basin give an estimation per acre-foot of the cost of maintaining an adequate water supply through
(a) Artificial recharge
(b) Importation through the Owens Valley and Colorado River Aqueducts.

This question lies outside the scope of activity of the Geological Survey.

Question XX. What is your Department's estimate of the amount of water in acre-feet that could be saved annually from the runoff through stable waterways and temporary detention of such runoff in small upland storage basins?

As stated under Question X, it is estimated that not more than 100,000 acre-feet of water per year could be made available for use by additional upland storage and by establishment of stable waterways.

Question XXI. What is your Department's estimate in acre-feet of the amount of water that is lost by evaporation and transpiration that could be saved by methods more practical and economical than importation?

The present development of ground-water resources in central Arizona has in many places so lowered the water table that transpiration losses from non-beneficial phreatophytes have been reduced. Additional saving of water could be effected by further eradication of phreatophytes, and an estimate of the amount that could be saved is included under Question X.

The comparison of cost of salvaging water lost to evapo-transpiration with the cost of importing water lies outside the scope of activity of the Geological Survey.

Question XXII. What is your Department's estimate in acre-feet of the average annual amount of flood waters presently salvaged in the South Coastal Basin by various methods, such as intentionally leaking reservoirs, etc.?

It is estimated that since 1938 all flood waters in the 9 basins of the Central Arizona Project area have been salvaged by impoundment in reservoirs or by addition to recharge of ground-water reservoirs, except (a) during 1941 when exceptional flood conditions prevailed, (b) for losses to evaporation and transpiration, and (c) for limited amounts passing Gillespie Dam during normal years. It should be noted under (c) that water must pass Gillespie Dam in normal years so that excess salts accumulated in ground water in Basins 1 and 2 may be removed from the Maricopa-Pinal area in order to maintain a salt balance.

Question XXIII. What is your Department's estimate in acre-feet of the average annual amount of flood waters that presently waste to the sea?

In terms of the central Arizona area, this question is identical with Question XII.

Question XXIV. How much of the flood water (in acre-feet) presently wasted to the ocean could be salvaged by various engineering methods?

The question is answered by the answers to Questions IV, V, X, and XXII.

Table 1.--A summary of size, storage capacity, safe annual yield, and overdraft of basins in the Central Arizona area

Basin Number	Basin	Area (acres)	Storage capacity (acre-feet)	Safe annual yield (acre-feet)	10-year average annual overdraft (acre-feet)
1.	Salt River Valley	1,600,000	19,200,000	500,000-1,000,000	265,000- 765,000
2.	Lower Santa Cruz	1,500,000	15,000,000	135,000	520,000
Sub-total for Maricopa-Pinal area		3,100,000	34,200,000	635,000-1,135,000	785,000-1,285,000
3.	Avra-Altar	540,000	4,320,000	Included with Basin 2	
4.	Upper Santa Cruz	570,000	5,700,000	80,000	65,000
5.	Upper San Pedro	535,000	3,210,000	No data	
6.	Lower San Pedro	370,000	2,220,000	Insufficient data	
7.	Upper San Simon	640,000	3,340,000	do.	
8.	Lower San Simon-Gila River	735,000	5,380,000	Not determined because of legal problems.	
9.	Duncan	175,000	1,400,000	do.	

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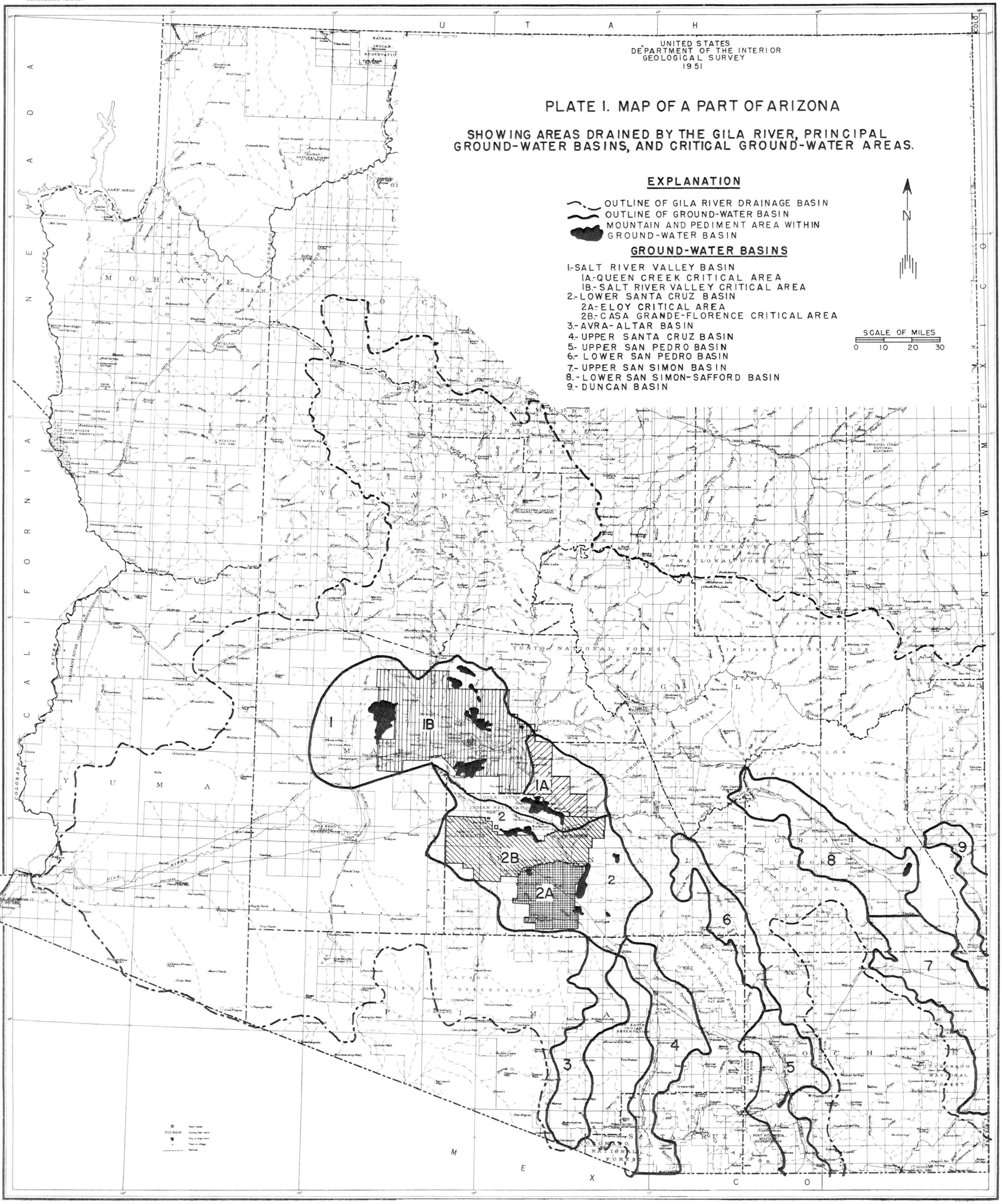
UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
1951
PLATE I. MAP OF A PART OF ARIZONA
SHOWING AREAS DRAINED BY THE GILA RIVER, PRINCIPAL GROUND-WATER BASINS, AND CRITICAL GROUND-WATER AREAS.
EXPLANATION
OUTLINE OF GILA RIVER DRAINAGE BASIN
OUTLINE OF GROUND-WATER BASIN
MOUNTAIN AND PEDIMENT AREA WITHIN GROUND-WATER BASIN
GROUND-WATER BASINS
1-SALT RIVER VALLEY BASIN
1A.-QUEEN CREEK CRITICAL AREA
1B.-SALT RIVER VALLEY CRITICAL AREA
2.-LOWER SANTA CRUZ BASIN
2A.-ELOY CRITICAL AREA
2B.-CASA GRANDE-FLORENCE CRITICAL AREA
3.-AVRA-ALTAR BASIN
4.-UPPER SANTA CRUZ BASIN
5.-UPPER SAN PEDRO BASIN
6.-LOWER SAN PEDRO BASIN
7.-UPPER SAN SIMON BASIN
8.-LOWER SAN SIMON-SAFFORD BASIN
9.-DUNCAN BASIN
N
SCALE OF MILES
0 10 20 30
U T A H
NEVADA
CALIFORNIA
NEW MEXICO
COLO
M E X I C O
MOHAVE
YUMA
PIMA
GRAHAM
COCHISE
TONTO NATIONAL FOREST
CROOK NATIONAL FOREST
CORONADO NATIONAL FOREST
FORT APACHE INDIAN RESERVATION
PAPAGO INDIAN RESERVATION
GILA RIVER INDIAN RESERVATION
LAKE MEAD
1
1B
1A
2
2B
2A
3
4
5
6
7
8
9