SRP06607

SAN PEDRO-SANTA CRUZ PROJECT
ARIZONA

CONCLUDING REPORT

November 1974

This report was prepared pursuant to the Act of June 17, 1902. Publication of the findings and recommendations herein should not be construed as representing either the approval of disapproval of the Secretary of the Interior. The purpose of this report is to provide information and alternatives for further consideration by the Bureau of Reclamation, the Secretary of the Interior, and other Federal agencies.

Gilbert G. Stamm, Commissioner
Edward A. Lundberg, Regional Director, Lower Colorado Region
Bureau of Reclamation

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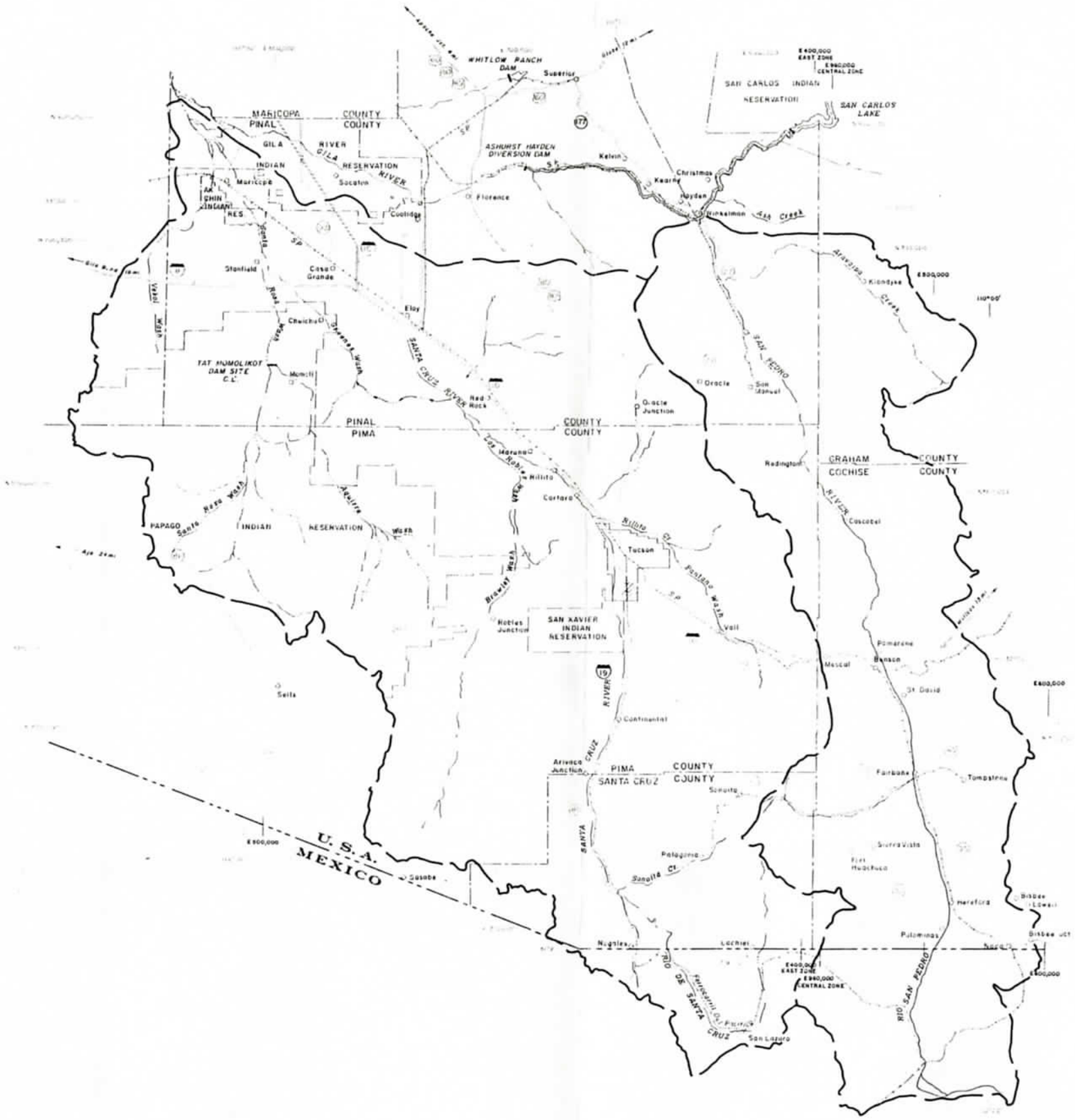
As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering the wisest use of our land and water resources, protecting our fish and wildlife, preserving the environmental and cultural values of our national parks and historical places, and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to assure that their development is in the best interests of all our people. The Department also has a major responsibility for American Indian reservation communities and for people who live in Island Territories under U.S. administration.

LOCATION MAP



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NOTE

Arizona state plane coordinates, east and central zones.

EXPLANATION

Project Investigation Area and Basin Boundaries

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
SAN PEDRO-SANTA CRUZ PROJECT-ARIZONA

GENERAL MAP

10 0 10 20 30
SCALE OF MILES

MAP NO. 1016-314-259
APRIL 1973

PREFACE

The following is the Concluding Report on the San Pedro-Santa Cruz Project. The purpose of the investigation was to evaluate the feasibility of developing the water resources of the San Pedro and Santa Cruz River Basins.

The potential of constructing various surface storage facilities in the Santa Cruz River Basin to provide flood control in the lower Santa Cruz River and to provide supplemental municipal and industrial water supplies to Nogales, Arizona, and Sonora, Mexico, was studied. No potential development was identified in the San Pedro River Basin.

For the most part, there is very little opportunity to economically develop the surface water supplies in either of these basins; hence, ground-water development provides virtually the whole water supply for the area. All development potentials in the Santa Cruz River Basin are flood control oriented. The San Pedro River Basin appears to have sufficient ground-water supplies, and flood control is not now an imperative requirement.

The potential physical developments evaluated in the Santa Cruz River Basin are strongly supported by local interests who in the past have suffered periodic flood or water supply problems. However, it was disclosed as a result of the investigations that, without exception, the proposals evaluated either do not meet standards of feasibility or are not politically viable at this time as full or partial solutions to either water supply or flood control problems.

Due to these conditions, the implementation of the "Water Resources Planning Act" (Public Law 89-80) and the subsequent "Principles and Standards" as specified in the Federal Register of September 10, 1973, would not have contributed to the development of a viable plan or alternative plans. In the event that justification for additional studies should become available, these and any other procedures applicable at that time will be followed.

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APPENDED MATERIAL

Letter from U.S. Bureau of Sport Fisheries and Wildlife dated August 14, 1970, transmitting fish and wildlife benefits for use in Sasco Dam and Reservoir studies.

Letter from Corps of Engineers dated March 3, 1971, transmitting flood control data and benefits for use in Sasco Dam and Reservoir studies.

Last Status Report from Corps of Engineers on Bureau of Reclamation funded flood control studies of Santa Cruz River Basin, dated December 31, 1972.

I. SUMMARY

I. SUMMARY

A. Introduction

The following is the Concluding Report on the San Pedro-Santa Cruz Project investigation. Included are a discussion of problems in the San Pedro and Santa Cruz River Basins and a presentation of the data developed in the investigation. The area investigated includes the portions of the San Pedro and Santa Cruz River Basins lying in the United States in the counties of Pima, Santa Cruz, Graham, and Cochise, Arizona. It also includes a small portion of Pinal County affected by the authorized Central Arizona Project. The frontispiece map, Drawing 1016-314-259, illustrates the extent of the study area.

B. Authority

The report was prepared under the authority of the Federal Reclamation Laws (Act of June 17, 1902, Stat. 388 and Acts amendatory thereof and supplementary thereto). Authorization for feasibility investigations of the project is contained in Public Law 89-561 (80 Stat. 711).

C. Problems and Needs of Area

The San Pedro River Basin includes the Fort Huachuca, Sierra Vista, and Tombstone urban areas and the agricultural communities of Benson, St. David, and Pomerene, Arizona. The lower basin includes the large mining areas in and around San Manuel. Water supplies are obtained from surface flows of the San Pedro River and from the ground-water basin. Although the basin is not yet faced with a critical water problem, population and economic growth pressures within and outside the basin are beginning to create a competitive attitude for the existing water resources.

The prominent cities of Tucson and Nogales, Arizona, and Nogales, Sonora, are located in the Santa Cruz River Basin on or near the Santa Cruz River. These cities are growing steadily and are drawing heavily on the already overdrawn ground-water basin. Agriculture is heaviest in the lower Santa Cruz Valley and is mainly concentrated between Tucson and the Gila River. Heavy competition for the use of ground water exists between agricultural and municipal and industrial interests, and only undependable surface water remains available for development. Flood problems exist throughout but are more pronounced in the Tucson Basin, where the population is concerned about floodwaters

originating from the Santa Catalina Mountains. Flooding has also been a problem in the lower Santa Cruz River near Red Rock, Arizona, where large agricultural areas are periodically flooded.

The San Pedro and Santa Cruz Rivers are international streams not presently covered by treaties. Potential developments of surface water from these rivers will be influenced by any future international allocation of their flows.

D. Scope of Investigation

The Bureau of Reclamation has previously carried out appraisal investigations of the San Pedro River Basin and in fiscal year 1965 initiated similar investigations in the Santa Cruz River Basin. Soon after the latter appraisal investigations were started, it became evident that the municipal and industrial water-supply needs of the Santa Cruz River Basin were of far greater magnitude and urgency than had been previously estimated. Local interests in Pima County urged that Bureau of Reclamation studies be expanded in scope, particularly with respect to ground-water studies, and that they be expedited so that plans suitable for authorization could be formulated at the earliest possible date. This situation was discussed in the Bureau's "Memorandum Report on Status of Investigations, Santa Cruz River Basin, Arizona" (February 1965). Following issuance of this report, the scope of the Bureau's investigations was modified and expanded by combining the San Pedro and Santa Cruz River Basins into a single study of feasibility-grade designated by the Bureau of Reclamation as the "San Pedro-Santa Cruz Project, Arizona." This consolidation was deemed essential because the Bureau's earlier as well as current plans provide for the importation of water from the Colorado River to Tucson as well as for the interbasin transfer of water from the San Pedro River to Tucson.

The subsequent program of feasibility investigations was implemented on the basis of continuous queries and responses from basin interests in regard to needs which require immediate solution.

Inasmuch as portions of the San Pedro and Santa Cruz River Basins will be affected by the earlier proposed and now authorized Central Arizona Project, this investigation was intended to fill the gaps not practically covered by the Central Arizona Project.

Responsibility was divided between the Bureau of Reclamation, which evaluated the developmental potential of the Santa Cruz River Basin's water resources, and the Corps

of Engineers, which evaluated the flood control problems. Other cooperative agencies which contributed significant assistance in the various phases of this investigation include the Bureau of Sport Fisheries and Wildlife, Bureau of Outdoor Recreation, Arizona Game and Fish Department, and various State and local agencies. The U.S. Geological Survey conducted a surface- and ground-water investigation in the Tucson Basin in cooperation with the Bureau of Reclamation, City of Tucson, and University of Arizona.

The program for this investigation was developed by the coordinated efforts of local, city, county, State, and Federal interests in the San Pedro and Santa Cruz River Basins. The Bureau of Reclamation reappraised a number of potential plans for the development of surface waters, many of which had been studied by other agencies. The most promising potential developments were isolated and analyzed in greater detail. These included the Charleston Dam site on the San Pedro River and the Sasco, Sawtooth, and Nogales Dam sites on the Santa Cruz River. The Sawtooth site was evaluated as a possible alternative to the Sasco site. Charleston Dam was authorized as a feature of the Central Arizona Project in 1968 and was subsequently withdrawn from the San Pedro-Santa Cruz Project. However, a large portion of the field investigations for Charleston was accomplished prior to authorization.

E. Investigation History

Early appraisal investigations were made in connection with the Arizona-Colorado River Water Diversion Projects.

F. Cooperative Investigations

1. The Geological Survey prepared a four-part report on stream and ground-water flow in the Santa Cruz River Basin 1/.

2. The Bureau of Reclamation and the Corps of Engineers coordinated studies requiring joint effort in the Santa Cruz River Basin. The Corps of Engineers had the primary responsibility of the flood control studies and provided the necessary flood-benefit data for the potential damsites. Funds for these purposes were transferred to the Corps by the Bureau. The multipurpose aspects of the project were the primary responsibility of the Bureau.

1/ Geological Survey Water-Supply Papers, 1939, A, B, and D.

3. The Bureau of Outdoor Recreation provided data for evaluating the potential recreational impact of the various proposals.

4. The Bureau of Sport Fisheries and Wildlife, in cooperation with the Arizona Department of Game and Fish, provided data to assist in evaluating the fish and wildlife impacts of potential plans.

5. The International Boundary and Water Commission assisted in obtaining and compiling international data and arranged international cooperation.

G. Local Support

Communities, municipalities, and irrigation districts in the San Pedro-Santa Cruz Project study area have indicated support for this study. Funds to expedite the work have been contributed by the State of Arizona. Full cooperation has been extended by the City of Tucson and the University of Arizona, as well as other local, county, State, and Federal agencies, including the International Boundary and Water Commission.

Formal and informal meetings were held with interested groups who responded to 1964 notices regarding the Bureau of Reclamation's initiation of investigations, and subsequent working meetings were conducted with representatives of these groups. With these exceptions, no formal public meetings or hearings were held for these investigations.

H. Water Resources

The primary water resources of the project area consist of the surface-water supplies available from the San Pedro and Santa Cruz Rivers and ground-water supplies available in each of the respective basins. Additional sources of supply include those available from water salvage methods, such as phreatophyte eradication and recycling of reclaimed sewage effluent. Imported water supplies are potential sources not covered in this investigation.

The surface-water supplies in each of the basins are for the most part now fully appropriated. The only surface water remaining to be appropriated is that which occurs during periodic floods from rainstorm activity in the basins.

At the present time, virtually the entire economy of the area is based on the ground-water systems of the two basins. Although the San Pedro River Basin is not in a designated critical ground-water area, it is safe to assume that if present growth trends accelerate as they have in some areas of Arizona, a critical situation could develop in the future. The Santa Cruz River Basin, however, is experiencing a critical period

characterized by earnest competition for the remaining sources of supply. So critical is the mounting problem that the inhabitants of the basin have begun to look to the San Pedro River Basin for water and have already turned to waste water reclamation to satisfy part of the demand.

Except for water supplies currently anticipated from the Central Arizona Project, no economical sources of importation have been identified for use in the San Pedro or Santa Cruz River Basins.

I. Potential Water Resource Developments

An inventory of the resources of the San Pedro and Santa Cruz River Basins indicates that there is little opportunity for developing surface water. Many physical potentials for the development of remaining surface-water supplies were considered, but most were either structurally inferior, not strategically located, or too costly.

No potential water resource development was identified in the San Pedro River Basin, but Charleston Dam and Reservoir which were considered in the studies were authorized by the Colorado River Basin Project Act, P.L. 90-537. However, two project possibilities were identified in the Santa Cruz River Basin, both would conserve the periodic floodwater to fulfill irrigation, municipal, and industrial needs. These are storage near Red Rock, Arizona, and near Nogales, Arizona.

Storage on the Santa Cruz River near Red Rock could be provided by the construction of the potential Sasco or Sawtooth Dams. Floodflows would be detained and then released into the Santa Cruz River channel or into local distribution facilities in such a manner as to either supplement existing irrigation demands or assist in recharging the ground-water basin.

The Sasco site, however, poses potential geologic and flood protection design problems which may preclude its development. A suitable alternative, therefore, was considered at the Sawtooth site, located near the Sawtooth Mountains about 15 miles west of the Sasco site. This offstream site is located approximately at the terminus of the existing Greenes Canal, an old abandoned channel which has diverted floodflows into Santa Rosa Wash since the early 1930's. The plan which was tested has engineering viability, but currently lacks economic justification.

A potential development on the Santa Cruz River mainstem near Nogales, Arizona, appears to be economically justified. This would be a municipal and industrial water-supply development entailing the construction of Nogales Dam approximately 1.5 miles north of the United States-Mexico International Boundary. The development requires an international effort and could be undertaken only at such time as the two countries reach an international treaty on the division of the river's water supply. At the present time, such a potential development appears to have engineering, economic, and financial feasibility, contingent upon the conclusion of an international accord and treaty.

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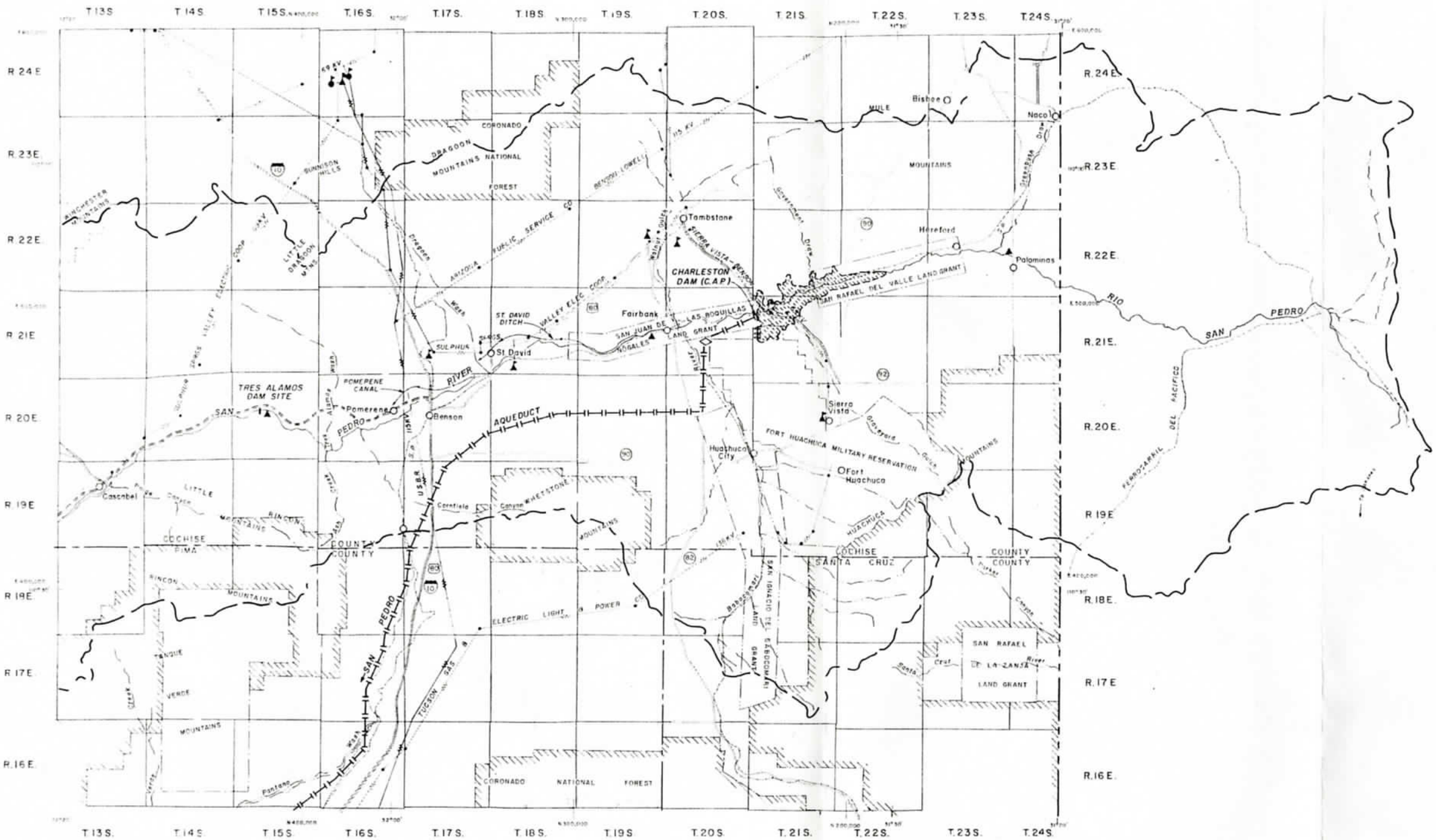

LOCATION MAP

EXPLANATION

San Pedro Basin Boundary

AUTHORIZED FEATURES

Dam and reservoir

Pumping plant

Closed aqueduct

NOTE

Arizona state plane coordinates, east zone.

UNITED STATES
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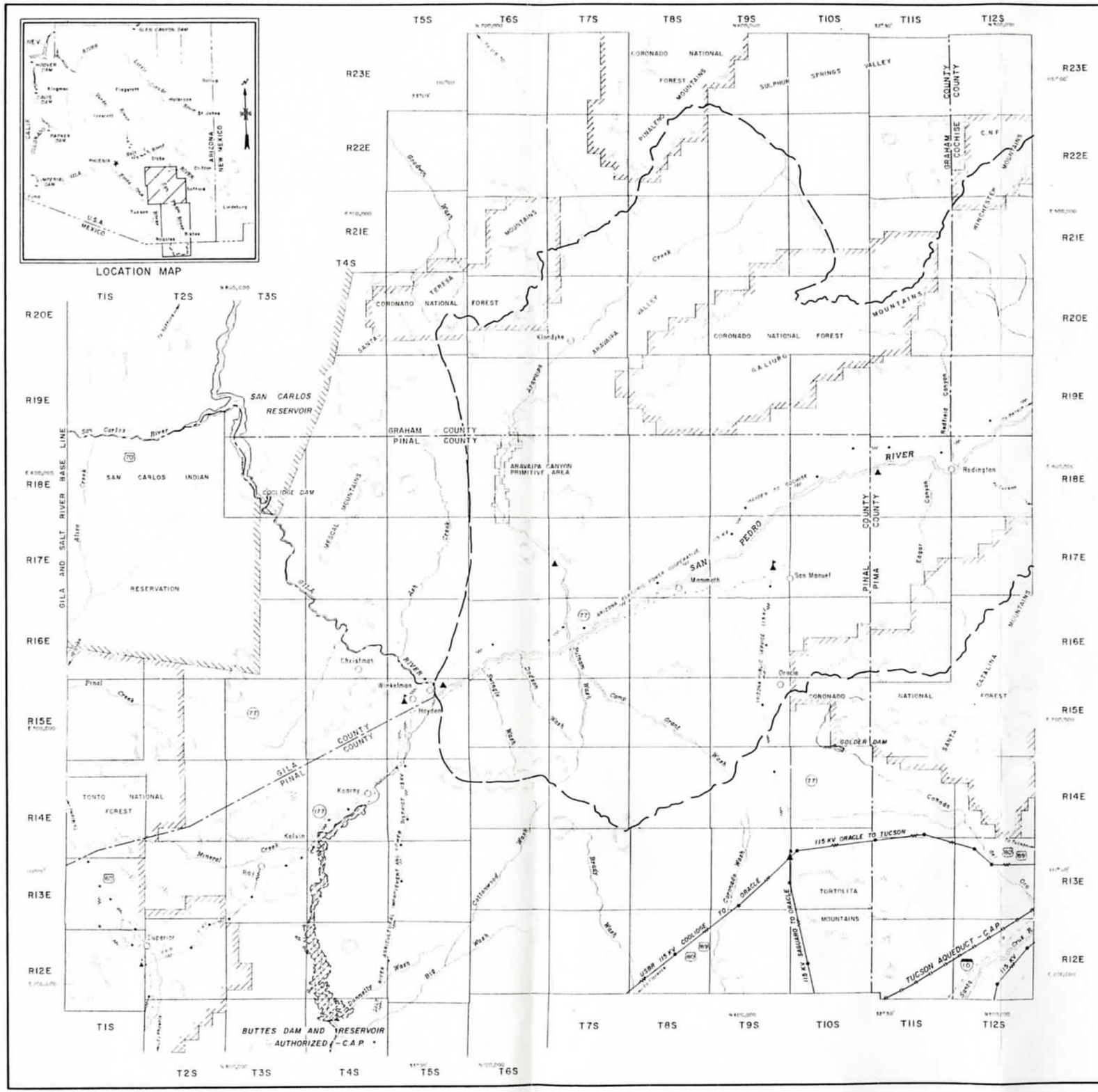
SAN PEDRO-SANTA CRUZ PROJECT

GENERAL MAP
SAN PEDRO UPPER BASIN

4 0 4 8 12
SCALE OF MILES

MAP NO. 1016-314-260

NOVEMBER 1972 SHEET 1 OF 2



EXPLANATION

San Pedro Basin Boundary

AUTHORIZED FEATURES

Dam and reservoir

Supply canal

Closed aqueduct

NOTE

Arizona state plane coordinates, east zone.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
SAN PEDRO-SANTA CRUZ PROJECT

GENERAL MAP
SAN PEDRO LOWER BASIN

SCALE OF MILES

MAP NO. 1016-314-261

JULY 1972 SHEET 2 OF 2

Interior - Reclamation, B.C., Rev. 3-74

II. GENERAL DESCRIPTION--SAN PEDRO RIVER BASIN

II. GENERAL DESCRIPTION–SAN PEDRO RIVER BASIN

A. Location

The San Pedro River Basin is a relatively long and narrow trough formed by the Tortilla, Santa Catalina, Rincon, Whetstone, and Huachuca Mountains on the west and the Galiuro, Winchester, Dragoon, and Mule Mountains on the east. It varies in width from 15 to 30 miles. The basin, originating in the State of Sonora, United Mexican States, extends some 120 miles north into Arizona to the Gila River.

The basin area contains about 4,500 square miles, of which about 3,800 square miles are located in Cochise, Graham, Pima, Santa Cruz, and Pinal Counties in Arizona. The remaining 700 square miles are located in Sonora, Mexico.

The entire San Pedro River Basin lies within the Mexican Highland Section of the Basin and Range Province. The topography is generally characterized by gently sloping valley plains, with foothills near the adjacent mountain ranges. The San Pedro River Basin is generally composed of alluvial deposits encroaching on foothills composed of sedimentary, volcanic, and intrusive igneous rocks. It is incised by a few major and countless minor tributary drainages. The Babocomari River and Aravaipa Creek are the San Pedro River's major tributaries.

The San Pedro River is a part of the Gila-Colorado River drainage system and flows north for a total distance of about 149 miles to its confluence with the Gila River at Winkelman, Arizona. The main channel of the river originates in Mexico at an elevation of about 4,500 feet, drops to about 4,200 feet at Palominas, Arizona, and arrives at its confluence with the Gila River at an elevation of about 1925 feet. The river is well defined, having been variably incised into the alluvium up to 40 feet in some places.

Drawings 1016-314-260 and -261 are general maps illustrating the San Pedro River Basin.

B. Climate

The basin lies within the Sonoran Desert and its climate is typical of much of the southwestern United States. The basin is semiarid with long hot summers and mild winters. Temperatures can exceed 100°F during May through September and drop to well below freezing, particularly at the higher elevations, during the winter. Temperatures average about

62°F annually and vary from a mean in the midforties in January to over 80°F in July. The maximum temperature on record is 116°F at Winkelman, while the low is 1°F at Fort Huachuca.

Precipitation is erratic but typically seasonal. Drought conditions are most common in May and June, followed by a period of summer thunderstorm activity which produces an average of about one-half the annual rainfall. Normally dry conditions then follow in October or November. A second "wet" season extends from December through March. Snow falls occasionally on the basin. Precipitation averages about 12 inches per year at the lower elevations in nearly 30 inches at the highest summits of the Rincon and Santa Catalina Mountains. Summer rains are characterized by afternoon showers and thundershowers, occasionally of great intensity. Winter rains or snow result from extensive storm systems from the Pacific Ocean which produce widespread precipitation sometimes lasting for several days. The frequency of these storms varies greatly from year to year, making them an unreliable source of moisture.

C. Vegetation and Wildlife

The San Pedro River Basin lies in the Chihuahuan Desert subdivision of the Lower Sonoran Life Zone. Typically, it is a shrub desert, and tarbush, white thorn, and creosote bush dominate large portions of the rolling landscape. Interspersed among the dominant stands of desert shrubs are such cacti as ocotillo, mariolla, allthorn, and cholla. Grassland is dominant higher in the basin above Benson, Arizona.

Riparian vegetation along the San Pedro River is well established and, for the most part, considered lush. This includes cottonwood, sycamore, ash, walnut, willow, and associated plants. Mesquite growing in separate stands is generally found between the riparian growth and the higher desert scrub.

Fishery resources are virtually nonexistent on the San Pedro River. If any, they are limited to a few isolated small native nongame species. There is no sport fishing.

The basin abounds with wildlife. The characteristic desert shrubs, grasses, and riparian growth which thrive along the San Pedro River all provide excellent habitat for a wildlife community represented by javelina, deer, rabbit, quail, dove, and many other varieties of ground mammals, birdlife, and southwestern reptiles.

The official "United States List of Endangered Native Fish and Wildlife" 1/ includes several species in the general project area. These are the Gila topminnow (Poeciliopsis occidentalis occidentalis), the masked bobwhite (Colinus virginianus ridgwayi), the Mexican duck (Anusas diazi), the Southern bald eagle (Haliaetus l. leucocephalus), and the American peregrine falcon (Falco peregrinus anatum). In addition to these, the Bureau of Sport Fisheries and Wildlife lists the Mexican wolf (Canis lupus baileyi) as a threatened species 2/.

D. Population

The population of the San Pedro River Basin was estimated to be about 28,000 in 1970. This represents an increase of approximately 44 percent over the 1960 population. Representative cities in the basin having populations over 1,000, as published in the 1960 and 1970 U.S. Census, are shown in the following tabulation. Also included are the estimated populations of communities and areas of less than 1,000.

City or Community	Population (U.S. Census) 1960	1970
Mammoth	1,913	1,953
San Manuel	4,524	4,332
Oracle	100 *	1,000 *
Pomerene	200 *	200 *
Benson	1,494	2,839
St. David	200 *	500 *
Tombstone	1,283	1,241
Huachuca City	1,330	1,233
Fort Huachuca	3,100 *	6,659
Sierra Vista	3,121	6,689
Naco	350 *	400 *
Others **	785 *	954 *
Total	19,400	28,000

* Estimated.

** Farming and ranching communities spread throughout the basin associated with named places on maps which are prominent.

1/ Federal Register, Vol. 35, No. 199 (Tuesday, October 13, 1970), pp. 16047-16048, plus amendments.

2/ Bureau of Sport Fisheries and Wildlife, Threatened Wildlife of the United States, Resource Publication 114 (U.S. Government Printing Office, March 1973).

E. Economy of Area

In order of their importance industry, tourism, and agriculture represent the major sources of income in the San Pedro River Basin.

1. Industry. Industry is principally represented by mining and mining allied operations, limited manufacturing, and commercial and services industries.

Mining in the San Pedro Valley is located primarily in the lower basin and is confined primarily to copper ore and the associated heavy metals recovered in the copper extraction processes. The towns of San Manuel and Mammoth contain the bulk of people associated with the mining industry. The population of these places rises and falls with the demand of copper. There are currently about 2,500 people employed by the San Manual mining and smeltering operations.

Manufacturing is currently limited to explosives, furniture, metal extraction, and some sulphuric acid. According to the Bureau of Census, these industries employ approximately 1,400 people.

The business and service-oriented industries are construction, transportation, utilities, wholesale and retail trade, finance, insurance, business and repair services, professional and related services, educational services, public administration, and other industries. These employ about 4,300 people.

2. Agriculture. Ranching operations comprise the principal agricultural activity in the basin. Irrigated agriculture is oriented to provide forage crops and some cash crops.

About 16,000 acres in the basin have an irrigation history. The most productive area, located in the Benson-St. David-Pomerene area, contains about 8,700 acres of irrigated land.

The principal crops currently grown include permanent irrigated pasture, alfalfa, sorghum, and some cotton. Several small dairy operations provide milk for local consumption, but most production is exported from the basin for commercial processors and distributors.

3. Tourism. The basin is rich in western lore. The famed frontier town of Tombstone and one of Arizona's largest open pit copper mines at Bisbee attract much of the tourism

in the basin. Tourism ranks fourth among the major sources of income in the State; however, it is difficult to say just how much of the $600 million in annual receipts tabulated for the State is generated in the San Pedro River Basin area.

4. Transportation and Utilities. The study area is traversed by the Southern Pacific Railroad, U.S. Highway 80, Interstate 10, and an excellent network of State and county roads. The road system converges near the town of Benson. State Highway 77 and a railroad spur line connecting with the Southern Pacific main line serve the mining areas in the lower basin.

Power utilities serving the basin include the Arizona Public Service Company, Arizona Electric Power Cooperative, and Sulphur Springs Valley Electric Cooperative, Inc.

5. Federal Government. The major military installation employing significant civilian services within the study area is located at Fort Huachuca (a U.S. Army worldwide communication center and proving ground). Most of the people assigned to the base reside at Sierra Vista and Huachuca City. The numbers of civilian and military personnel employed at Fort Huachuca vary with the needs of the military and the size of the operation at Fort Huachuca. During major wars these facilities have been used extensively, and the number of people residing in the area has increased.

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III. LAND UTILIZATION–SAN PEDRO RIVER BASIN

III. LAND UTILIZATION–SAN PEDRO RIVER BASIN

A. General

The 3,800-square-mile San Pedro River Basin is primarily characterized by mining and agricultural activities. Thus, land utilization is oriented toward mineral extraction, irrigated agriculture and livestock grazing, and public use.

The basin contains portions of the extensive Coronado National Forest system, including the Aravaipa Canyon Primitive Area located on Aravaipa Creek, a major tributary of the San Pedro River. Fort Huachuca, located in the southern portions of the San Pedro River Basin, encompasses a vast area for military purposes.

B. Mining

The San Pedro River Basin has a long history of mining activity. Mineral resources, especially low grade copper ores and associated precious metals, are distributed throughout the basin. Estimates on copper ore reserves are not readily available. However, the quantities of undiscovered ore deposits are thought to be extremely high, probably equivalent to currently known deposits.

Magma Copper Company's San Manuel mine is presently the second largest copper mining operation in Arizona and the largest operation in the San Pedro River Basin. On the basis of recent conditions, its ore reserves have been estimated by the Arizona Bureau of Mines to be about 500 million tons, averaging about 0.75 percent copper. New discoveries just northwest of San Manuel have disclosed the possibility of another 500 million tons of ore reserves. This discovery (the Kalamazoo ore body) is being exploited, and Magma has built a 200,000-ton capacity copper refinery to process its ores.

There is also significant mining activity on the San Pedro River Basin's periphery. There are mines and smelters in Hayden, Winkelman, and Ray, all near the Gila River. The Phelps Dodge Lavender Pit mine in Bisbee is located just outside the San Pedro River Basin. This operation was the sixth largest in Arizona in 1966, but is now closing due to mineral depletions at that site. However, low grade ore deposits are located nearby, and operations may again be stimulated if technological advances make it economical to mine.

Mineral exploration within the basin is continuing and new discoveries may lead to more development, withdrawing such areas from other utilization. However, mining activity should level off to a sustained rate unless national and international markets force higher activity throughout the industry.

C. Manufacturing

At the present time manufacturing and allied developments within the basin are very limited. Apache Powder Company is the only large nonmining manufacturing complex known to exist in the area. Current trends have not established specific industrial growth areas or patterns.

D. Agriculture

The principal land use in the area is the raising of livestock on rangeland, and crops are primarily oriented toward forage. The major farming areas are located in the Benson-St. David-Pomerene area.

Farmers adjacent to the river divert a part of their water requirements with small diversion dams and pump the remainder from wells. The irrigated acreage has varied over the years, but as of June 1969 an estimated 12,668 acres of land were irrigated in the basin. An additional 4,035 acres are cleared, but are either idle or not fully developed for irrigation. Table 1 lists a summary of acreages and crops grown in 1969 from the United States-Mexico International Boundary to the Gila River.

A reconnaissance land classification was made in 1963 for inventory purposes and in anticipation of potential development. Approximately 71,110 acres lying along the San Pedro River from the international boundary between the United States and Mexico to the confluence of the San Pedro and Gila Rivers were classified. The classification determined that there were 12,551 acres of Classes 1, 2, and 3 arable lands developed for irrigation and 26,662 acres of Classes 1, 2, and 3 arable lands still undeveloped. Table 2 summarizes the results of the land classification.

E. Phreatophytes

A river vegetative survey conducted in 1969 identified 57,282 acres of mesquite, cottonwood, saltcedar, and other miscellaneous phreatophytic growth. This includes growth densities through 100 percent. The predominant species appear to be mesquite, with about 21,000 of the total acres in relative dense mesquite growth.

Table 1
SAN PEDRO RIVER BASIN ACREAGES DEVELOPED
FOR IRRIGATION AND CROPS GROWN - 1969 1/
San Pedro-Santa Cruz Project, Arizona

Unit: Acres

	Boundary to Charleston Dam Site	Charleston Dam Site to Winkelman	Total San Pedro River Basin
Cropped			
Alfalfa	277	1,688	1,965
Pasture	2,394	3,265	5,659
Small Grains	556	2,049	2,605
Truck Crops	29	15	44
Fruit	10	42	52
Corn	--	127	127
Cotton	--	576	576
Sorghum	--	1,640	1,640
Total Cropped	3,266 2/	9,402	12,668
Not Cropped			
Cleared 3/	79	1,033	1,112
Fallow	26	242	268
Idle	433	2,222	2,755
Total Not Cropped	538	3,497	4,035
Total	3,804	12,899	16,703

1/ Source: San Pedro River land use inventory conducted 1969 by the Bureau of Reclamation.

2/ Includes most of 2,051 acres recently cleared and developed for the use of sprinkling systems. These lands are planted to grasses which should grow well without irrigation.

3/ Not fully developed for irrigation.

Table 2
SUMMARY OF LAND CLASSIFICATION MADE OF THE
DEVELOPED AND UNDEVELOPED ARABLE LAND
IN SAN PEDRO RIVER BASIN
San Pedro-Santa Cruz Project, Arizona

Unit: Acres

Class	Developed for Irrigation	Not Developed	Total
1	8,909	4,840	13,749
2	2,665	19,072	21,737
3	977	2,750	3,727
Total Arable (1-3)	12,551	26,662	39,213
6	97	26,408	26,505
ROW	--	1,520	1,520
Farmstead	--	572	572
"H"	--	3,299	3,299
Total Nonarable	97	31,799	31,896
Total Classified	12,648	58,461	71,109

Source: 1963 Reconnaissance Land Classification.

Although portions of these phreatophytic growths are being cleared for agricultural purposes, the rate of clearing is relatively slow. It has been estimated that for the period of 1963 to 1969 approximately 2,600 acres of phreatophytes have been cleared for agricultural development.

F. National Forests

Approximately 370,000 acres of the Coronado National Forest system lie within the San Pedro River Basin. Portions of the forest are scattered throughout the basin and generally located as part of prominent land-form features. Thus, the forest system covers portions of the Santa Teresa, Galiuro, Winchester, and Dragoon Mountains on the eastern slopes of the basin and the Santa Catalina, Whetstone, and Rincon Mountains on the west. These areas are extensively used for recreation purposes.

G. Urban Growth

The last decade has seen an increase of about 44 percent in the basin population and with it the normal attendant blooming of urban development. The greater portion of the population is presently concentrated in the upper basin. Significant land areas are encompassed by municipalities such as Benson, Tombstone, Sierra Vista, and the Fort Huachuca military reservation. The lower basin contains significant populations in spotted locations primarily along the San Pedro River.

Increased relocations into the basin by many retirees have created an attendant growth of satellite communities. Such evidence may be seen in the San Manuel environs, the Oracle area, Benson, along the river near Charleston, and along the eastern slopes of the Huachuca Mountains.

H. Military Reservation

The U.S. Army maintains and operates the 130-square-mile Fort Huachuca Military Reservation. It appears that this military installation will be maintained in the foreseeable future.

IV. WATER SUPPLY AND UTILIZATION–SAN PEDRO RIVER BASIN

IV. WATER SUPPLY AND UTILIZATION--SAN PEDRO RIVER BASIN

A. The San Pedro River

The San Pedro River rises in Sonora, Mexico, in a basin rimmed with mountains on the east and west, and the watershed divide between Rio San Pedro and Rio de Sonora on the south. It flows generally northeast into the United States, then generally north some 120 miles to join the Gila River near Winkelman, Arizona. The river drains about 4,490 square miles, of which about 696 square miles are in Mexico.

From an elevation of about 5000 feet in the vicinity of Cananea, Sonora, the San Pedro River falls to about 4280 feet at the United States-Mexico International Boundary, then to about 1925 feet at its confluence with the Gila River. Some of the Mexican tributaries drain mountainous areas at elevations of possibly 8000 feet or more.

Aravaipa Creek, with a drainage area of 576 square miles, is the largest tributary on the river. Other prominent tributaries include the Babocomari River, Green Brush Draw, Camp Grant, and Tres Alamos Washes.

1. Streamflow. Arid conditions typical of Arizona prevail over most of the drainage area of the San Pedro River. The river is typical of most of the Sonoran Desert streams, and flow is almost entirely dependent on rainfall. The bulk of the flow is erratic and flash flooding is a common occurrence.

The riverflows have been monitored at Palominas near the U.S.-Mexico International Border, Charleston, Tombstone, Benson, Redington, and Winkelman near the confluence of the Gila River. The locations of gaging stations within the basin are shown on Maps 1016-314-260 and -261. Table 3 summarizes the specific data for the stations.

Flow on the San Pedro River at Palominas has been gaged intermittently between 1930 and 1950 and continuously since 1950. Based on a 28-year period (1930-33, 1935-40, 1950-70), the average annual flow is estimated at about 22,890 acre-feet, or about 30.9 acre-feet per square mile of drainage area. Assuming that this yield rate is representative of the drainage area in Mexico, flow contributions to the United States from the 696 square miles in Mexico are estimated at about 21,500 acre-feet annually. In 1971, the Geological Survey prepared detailed studies in cooperation with the International Boundary and Water Commission to more fully describe flow contributions from Mexico and their relationship to downstream flows.

Table 3
STREAM FLOW RECORDS--SAN PEDRO RIVER
THROUGH WATER YEAR 1971
San Pedro-Santa Cruz Project, Arizona

USGS Gaging Station	Location T.	Location R.	Location S.	Drainage Area (sq mi)	Available Records	Recorded Flow Extremes: Q. Max. (Peak and Date) (ft^3/s)	Q. Min. (Peak and Date) (ft^3/s)	Annual Runoff in 1,000 a.f. Maximum (water year)	Annual Runoff in 1,000 a.f. Minimum (water year)	Annual Runoff in 1,000 a.f. Water Year
San Pedro River at Palominas, Arizona	23S	22E	33	741	May 1930-Oct 1933 May 1935-July 1941 July 1950 to present	22,000 8-14-40	0 Many days	54.9 1954	5.2 1962	23.4 29 years
San Pedro River at Charleston, Arizona	21S	21E	11	1,219	Jan and Feb 1904 (gage ht. only) Mar 1904-Aug 1906 Nov 1910-Dec 1911 (gage ht. only) Sep 1912 to present	98,000 9-28-26	0.5 7-6-66 and 7-11-71	149.3 1915	13.3 1962	44.6 60 years
San Pedro River near Tombstone, Arizona	19S	21E	28	1,740	Apr 1967 to present	9,220 8-10-71	0 Few days	40.7 1971	17.4 1969	29.6 4 years
San Pedro River near Benson, Arizona	15S	20E	15	2,500	Mar 1966 to present	8,200 7-20-70	0 Many days	44.1 1971	10.6 1969	25.8 5 years
San Pedro River near Redington, Arizona	12S	19E	19	2,939	June 1943-June 1947 July 1950 to present	28,600 8-2-51	0 Many days	129.9 1955	7.5 1962	33.8 25 years
San Pedro River near Mammoth, Arizona	8S	17E	18	3,599	May 1931-June 1941	50,000 8-14-40	0 Few days	63.5 1940	15.0 1932	44.6 9 years
Aravaipa Creek near Mammoth, Arizona and Feldman, Arizona	7S	17E	9	541	May 1919-Sep 1921 May 1931-Dec 1942 May 1966 to present	10,500 12-19-67	0.3 8-30-40	57.5 1941	9.5 1939	21.0 16 years
San Pedro River near Winkleman, Arizona	6S	16E	6	4,449	Apr 1962-Dec 1965	16,800 12-22-65	0.3 9-03-63	64.0 1964	16.2 1965	51.3 3.75 years
San Pedro River at Winkleman, Arizona and Dudleyville, Arizona	5S	15E	24	4,471	May to Aug 1890 (mo.only) Jan 1966 to present	15,000 9-30-68	0 Few days	103.5 1966	16.3 1965	45.0 9 years

The 59 years of Geological Survey streamflow gaging at or near Charleston show an average discharge of 44,500 acre-feet annually. Annual flows have varied from 149,300 acre-feet in water year 1915 to 13,280 acre-feet in water year 1962. Ground-water drainage in the narrow canyons near Charleston produces a small base flow throughout the year.

Downstream from Charleston, most of the water occurring during the winter and early spring, October through June, is diverted into the St. David and Pomerene Canals. The erratic and silt-laden nature of the periodic floodflows produced by thunderstorms during July to September precludes significant diversion during this period.

Below Benson the riverflows are intermittent and typically dry at most points, but small local flows do occur from springs or rising ground water. During the summer this area is also subject to intensive rainfall from thunderstorm activity, which produces temporary flows.

Aravaipa Creek is the largest and most important tributary of the San Pedro River and is the only one having a perennial flow. The creek becomes perennial from ground-water drainage in the lower canyon reaches of Aravaipa Valley. The average annual flow at the Aravaipa gaging station, located about 6 miles upstream from the mouth, was 21,740 acre-feet during 15 years of record (1931-42, 1966-70).

The San Pedro River joins the Gila River at Winkelman about 31 miles downstream from Coolidge Dam. The normal flows of the Gila River are diverted for irrigation use on the San Carlos Irrigation Project at the Ashurst-Hayden Diversion Dam located 37 miles downstream from the San Pedro River. A considerable portion of the San Pedro River flows exceeds the diversion capacity of the diversion works and is bypassed. Heavy silting from the diverted flows necessitates frequent sluicing. Buttes Dam and Reservoir would control and regulate the silt-laden floodflows of the San Pedro River.

2. Quality. The Geological Survey, in cooperation with the Bureau of Reclamation, has maintained continuous water quality stations at the Charleston gage since 1964 and at the Winkelman gage since 1966. Parameters measured include specific conductance, water temperatures, and sediment concentrations and volumes.

The quality of San Pedro River water at the Charleston gage is considered excellent for both irrigation and municipal use. Total dissolved solids average about 300 milligrams per liter (mg/l) and have ranged from 150 to 1,000 mg/l. A typical weighted average

chemical analysis based on many samplings and prepared by the University of Arizona follows:

	Milligrams per Liter
Total Soluble Salts	327
Carbonate	0
Bicarbonate	182
Chloride	16
Sulfate	43
Calcium	45
Magnesium	7
Sodium (including potassium)	34
Fluoride	0.5
Hardness (grains per gallon)	8.3

At Winkelman, average total dissolved solids are about 650 mg/l with a range of 200-1,300 mg/l. Sediment yield studies indicate rates of 0.65 acre-foot per square mile at Charleston and 0.37 acre-foot per square mile at Winkelman.

B. Ground Water

The San Pedro River Basin ground-water levels have shown no significant long-term decline, emphasizing that ground-water recharge and discharge are in relative equilibrium. Excellent hydraulic continuity exists between surface and ground water so that local ground-water pumpage is quickly replaced by infiltration of streamflow. Ground-water withdrawals in the basin are estimated to average about 110,000 acre-feet annually. About 70,000 acre-feet of this represent pumpage and the balance is phreatophyte consumptive use.

1. Hydrogeology. The San Pedro Valley is one of several northwest-trending basins contained in the Basin and Range Physiographic Province of Arizona. The basin is further divided structurally and hydrologically at The Narrows (about 10 miles north of Benson) into upper and lower subbasins. Hydrogeologic units in the San Pedro Valley are grouped as follows: (1) a bedrock unit delineating the margins and flooring of the basins including crystalline, metamorphic, volcanic, and older sedimentary rocks; (2) an older basin-fill unit

which contains extensive lakebed sediments including significant evaporites; and (3) the younger alluvial unit which consists of channel and flood plain deposits.

The maximum thickness of the basin-fill and alluvium is estimated to be in excess of 2,000 feet. These constitute the effective ground-water reservoir. The bedrock unit is considered essentially nonwater bearing, although it does contribute water to low yielding stock and domestic wells locally.

2. Occurrence. Ground water in the San Pedro Valley occurs under three conditions: (1) as confined (artesian) water in the older basin-fill unit, (2) as unconfined to semiconfined water in the younger alluvium and in the basin-fill deposits along the basin periphery, and (3) as locally perched or semiperched water associated with the basin-fill deposits along the basin periphery. It is roughly estimated that the alluvial unit may contain from 750,000 to 1,000,000 acre-feet of ground water in storage. There are major artesian developments in the Mammoth, Pomerene-St. David, and Palominas-Hereford areas.

3. Movement. In all hydrogeologic units, the apparent direction of ground-water movement is generally from the mountain fronts toward the San Pedro River, and then in a north to northwesterly direction paralleling the axis of the basin. There is probably local natural movement from the basin-fill deposits into the younger alluvium.

4. Depths. Depths to water in the alluvial unit range from less than 1 foot to about 90 feet and average 30 to 60 feet. Depths to water in the basin-fill unit range from a few feet to about 670 feet. Depths to water in wells penetrating the sedimentary rocks vary from a foot at the mountain fronts to more than 250 feet. Depths to water in the mines near Tombstone are commonly between 400 and 600 feet.

The piezometric surface ranges from a few feet above to as much as 200 feet below the ground surface. Only a few wells in the basin flow perennially, while many flow intermittently.

5. Fluctuations. Many artesian wells with small flows cease flowing during dry months or during periods of heavy pumping. Historic discharge data on drill reports indicate that artesian flows were generally slightly higher than at present. A map of artesian pressure contours in the Benson-St. David area prepared in 1921 compared with present spot data

indicates that throughout much of the area the piezometric surface has declined slightly. Data defining any long-term decline in pressure head throughout the basin are not available.

Unconfined water in the basin-fill usually shows annual fluctuations of less than 5 feet. Scattered well measurements west of the San Pedro River above Charleston indicate a very slight general decline in water levels associated with the Fort Huachuca well field. The maximum annual decline in this area is from 2.5 to 3.0 feet. Scattered measurements elsewhere in the valley indicate that there is no significant long-term trend.

Water levels in the alluvial unit respond rapidly to streamflow. Although annual fluctuations up to 10 feet are common, historic water-level measurements show that there are no long-term declines.

6. Quality. Artesian water from the basin-fill deposits commonly contains from 200 to 600 mg/l total dissolved solids. In the vicinity of Benson and Pomerene, however, the artesian water obtained from about 600 feet has a total dissolved solids content of up to 3,500 mg/l or more. This water and the artesian water south of Mammoth are of the sulfate type, whereas other artesian water in the basin is of the bicarbonate type. Most of the artesian water is high in fluorides usually averaging 3 to 4 mg/l. Unconfined to semiconfined water from the basin-fill is usually of the bicarbonate type and contains between 200 to 500 mg/l total dissolved solids.

Water from the alluvial unit is generally of the bicarbonate type frequently with less than 400 mg/l total dissolved solids. Near the mouth of the San Pedro River the quality deteriorates, having concentrations as high as 1,000 mg/l.

7. Pumpage. Irrigation wells in the alluvial unit range in depth from 25 to 100 feet and average 70 to 90 feet. Usually the pumps have 10- to 20-inch casings and are equipped with 25- to 100-horsepower electric motors or natural gas engines. Discharges range from 400 to 4,000 gallons per minute (gal/min) with specific capacities commonly between 30 and 100 gal/min/foot.

Large diameter artesian irrigation wells in the Palominas-Hereford area range in depth from 260 to 500 feet, with discharges reported up to 1,800 gal/min. In the Pomerene-St. David area some of the deep low-yield artesian wells flow into large tanks which are used for domestic and irrigation supplies when needed. In the vicinity of Pomerene and Benson the wells range in depth from 400 to 1,200 feet with flows of less than 1 to 20 gal/min, while near St. David they are from 90 to 600 feet deep with similar flows.

The average annual gross pumpage in the basin is estimated at about 70,000 acre-feet. Of this, about 41,000 acre-feet represent irrigation pumpage, 22,000 acre-feet industrial pumpage, and about 7,000 acre-feet municipal, domestic, and stock pumpage.

C. Water Utilization

Based on an irrigated acreage and water utilization survey made in 1969, current annual gross water diversion requirements in the basin are estimated at about 79,000 acre-feet. Table 4 shows the estimated utilization in 1969 by reaches in the basin. Agriculture utilized 58 percent of the diverted water supply and industry about 31 percent, with the remainder utilized for municipal, domestic, and stock watering purposes. There have been substantial increases in ground-water withdrawals since the 1969 inventory, and even larger withdrawals are expected in the future. In the hope of securing supplemental municipal and industrial water for the future, water-using entities in the basin have recently submitted expressions of interest for Central Arizona Project water ranging in quantities up to 32,000 acre-feet annually by 2020.

D. Water Rights

There are a large number of surface-water rights filed with the Arizona State Land Department. These filings include applications, permits, and water certificates (current and pending) filed in accordance with the Arizona Water Code of 1919 and "old rights" and "claimed rights" filed in conformance with the earlier territorial Howell Code of 1864. There are also claims filed at county courthouses prior to the enactment of a State code.

In 1947, the City of Tucson filed two applications for permits to construct a reservoir at the Charleston Dam site and to appropriate water for municipal purposes. The City has also filed an application to appropriate approximately 30,000 acre-feet of water for municipal use, such water to be pumped from the San Pedro River Basin in the Cascabel area. As far as is known, these applications have not been acted upon or the permits issued.

According to a preliminary Bureau of Reclamation report on the water rights of the San Pedro River Basin dated May 1965, which was prepared as a supplemental report to the San Pedro River Basin Reconnaissance Report, quantitative water rights are unknown and cannot be determined without considerable State assistance. At that time the State had little knowledge as to the validity of the water rights, especially under

Table 4
ESTIMATED SAN PEDRO RIVER BASIN
ANNUAL WATER UTILIZATION - 1969
San Pedro-Santa Cruz Project, Arizona

Units in 1,000 Acre-Feet

Water Use	Boundary to Charleston Dam Site		Charleston Dam Site to Mouth of San Pedro River		Total San Pedro River Basin	
	Withdrawal	Net Use	Withdrawal	Net Use	Withdrawal	Net Use
Agriculture 1/	12	8	34	19	46	27
Industrial 2/	1	1	23	23	24	24
Municipal & Domestic 3/	3	1.5	3	1.5	6	3
Stock 4/	1	1	2	2	3	3
Subtotal (rounded)	17	12	62	45	79	57
Phreatophytes 5/	3	3	37	37	40	40
Channel Evaporation 6/	4	4	23	23	27	27
Subtotal	7	7	60	60	67	67
TOTAL	24	19	122	105	146	124

Definition: Withdrawal - withdrawn or diverted quantity from ground-water and/or surface supplies.
Net Use - consumed quantity

1/ Based on 12,668 irrigated acres (1969).

2/ Primarily copper industry; return flows are believed minor since most use consists of makeup water or out-of-basin use.

3/ Estimated basin population of 28,000.

4/ Mostly evaporation from stock ponds.

5/ Based on a survey of 57,282 acres of mesquite, cottonwood, and saltcedar (1969).

6/ Nominal use; based on about 5,400 acres of water surface and wetted sands and gravels.

the requirement of existing use. The Water Rights Division of the State Land Department is currently active in bringing old water right records up-to-date and in determining the status of incomplete filings.

Historically, the outflow of the San Pedro River has served as a portion of the surface-water supply for the San Carlos Irrigation and Drainage Project and to some degree as a source of recharge to ground water from the channel of the Gila River. The proposed export of water to Tucson from the authorized Charleston Dam and Reservoir would deplete outflow.

Future water resource developments in the Mexican portion of the San Pedro River Basin could have a considerable impact on the water supply entering the United States and consequently on the inflow to the authorized Charleston Reservoir. An international agreement defining the extent of such development is a necessary requirement in determining the future water supply available.

E. Projected Water Requirements

Future water requirements within the study area will depend upon economic growth, which will probably be based on mineral exploitation, some manufacturing, and general population increases. Although mining and manufacturing are expected to increase somewhat, extensive growth is not anticipated. However, the basin does have a significant potential for growth in this direction based on mineral resources, available land area, and water supply.

There are now approximately 16,700 acres of land developed for irrigation in the San Pedro River Basin, of which about 12,700 acres are cropped annually. The balance is generally left idle in dry pasture and could at some time be placed under full irrigation. Current trends indicate that small amounts of arable land are continuously being cleared for cultivation. It is estimated that by the year 2000 an additional 5,000 acres may be prepared for full irrigation, but that only about 15,000 acres will probably be irrigated annually.

The estimated projected gross water requirements of the San Pedro River Basin through the year 2010 are shown in Table 5.

Table 5
PROJECTION, GROSS WATER REQUIREMENT
San Pedro Basin
San Pedro-Santa Cruz Project

Unit: Acre-Feet

Water Use	1980	1990	2000	2010
Agriculture	50,000	50,000	54,000	54,000
Industrial 1/	26,000	34,000	47,000	49,000
Municipal 2/	7,100	12,000	17,500	21,000
Stock	3,000	3,000	3,000	3,000
TOTAL	86,100	99,000	121,500	127,000

1/ Primarily mining and related industries.

2/ Includes domestic water requirements in basin.

F. Central Arizona Project

Charleston Dam and Reservoir are authorized features of the Central Arizona Project (P.L. 90-537). It is proposed that these facilities provide the necessary conservation storage to assure an annual yield of 12,000 acre-feet for a transbasin diversion to the City of Tucson. The reservoir would also provide flood and sediment control, serve fish and wildlife and recreational purposes, and regulate downstream flows for irrigation diversions. Requests for water from the Central Arizona Project totaled about 32,000 acre-feet per year from the City of Sierra Vista, Fort Huachuca, and the St. David Irrigation District. Wilcox, which lies outside the San Pedro River Basin, has expressed an interest in about 2,700 acre-feet per year of Central Arizona Project water.

G. Potential Supplemental Water Supplies

At the present time the San Pedro River Basin is not experiencing a critical water-supply problem. The basin, however, is growing in economic importance, and additional water supplies will eventually be necessary if this growth is to continue.

The existing ground-water basin appears to have sufficient quantities for the basin's near future economic growth. Thus, at this time the potential supplemental surface-water supplies which could ultimately be developed from river regulation and water salvage are less attractive than ground-water development. Nevertheless, these two sources represent significant quantities of supplemental water which would improve the usable water supply of the basin.

For the most part, the surface flows of the San Pedro River which are not fully utilized for irrigation or municipal and industrial purposes infiltrate into the ground-water basin. The normal flows are fully appropriated and are generally used to provide a supplemental supply for the demands met primarily by ground-water pumping. The only surface water left for possible development is that which is in the form of periodic floodflows from rainstorm activity in the basin.

Ground water appears to be the most viable source in the basin at this time and should be developed first as needed. Other sources of water which the basin may eventually consider seriously are as follows:

1. River Regulation. Construction of storage facilities strategically located on the main stem of this river could provide the surface-water control necessary for a more

effective distribution of the present water supply to the downstream water users. It could also provide flood control and recreation benefits. However, since the ground-water basin is currently adequate for the needs of the downstream users, surface storage will not become important until ground-water supplies approach critical conditions. Under the anticipated near future conditions of development, no strategic storage sites are available, other than the Charleston Dam site.

Other physically potential storage sites studied on the San Pedro River mainstream were the Tres Alamos and Cascabel sites, neither of which offer attractive storage possibilities.

2. Improvement of Irrigation Facilities. Improving local irrigation conveyance facilities would provide an increase in the efficiency of water deliveries. Lining primary canals and distribution works in the St. David-Pomerene area could result in smaller transmission losses. However, the increase in efficiency is not economically justified on the current scales of agricultural operations. It does not appear that agricultural activity in the future will increase significantly enough to warrant the rehabilitation of existing works.

3. Water Salvage

a. Phreatophyte Control. An estimated 57,300 acres of mixed phreatophytic growth along the San Pedro River consume an estimated 40,000 acre-feet of ground water per year. Total or selective eradication of such phreatophytes from the San Pedro River, which could save up to 40,000 acre-feet, is not justified in view of the availability of sufficient ground water which can be obtained at reasonable cost. Further, the phreatophytes offer a certain amount of flood control protection for the adjacent river bottom lands and provide excellent wildlife habitat. At this time, phreatophytes in the San Pedro River Basin are considered a beneficial resource and should be preserved as such.

b. Waste Water Reclamation. At the present time there is very little potential for consolidated waste water reclamation in the basin. The approximate 24,000 acre-feet of water diverted each year for industrial purposes are wholly consumed. Current industrial processes, primarily involving mining extraction, fully utilize the diverted supplies in recycling processes.

Of the 6,000 acre-feet of annual municipal and domestic diversions, it is estimated that about 3,000 acre-feet are consumed, suggesting a return to the ground-water system of approximately 3,000 acre-feet. This may be viewed as a recycling process since the water becomes available for repumping. Such quantities should be accounted for in projecting future supplies. Inasmuch as the basin does not at this time face a serious problem of water shortages or a problem of disposing of large quantities of effluent, waste water reclamation in the sense of treatment and recycling is not a serious consideration for potential development.

H. Hydrologic Data Developed

Flood hydrology studies on the San Pedro River were limited to design flood studies associated with the authorized Charleston Dam and Reservoir. These were initiated prior to authorization of the Central Arizona Project and while Charleston Dam and Reservoir were still features of the San Pedro-Santa Cruz Project. The studies were completed in 1969 and yielded the following peak discharges and runoff volumes which could be expected to occur at the Charleston Dam site:

Flood Frequency	Peak Discharge (ft^3/s)	3-Day Volume (acre-feet)
Design Flood	323,000	272,000
100-year	83,000	82,000
50-year	56,000	56,000
25-year	37,400	38,000
10-year	21,100	21,000
5-year	13,200	14,000

Sedimentation studies for the San Pedro River at Charleston indicate that sediment volumes of about 790 acre-feet per year will occur in the proposed Charleston Reservoir.

V. GENERAL DESCRIPTION--SANTA CRUZ RIVER BASIN

V. GENERAL DESCRIPTION–SANTA CRUZ RIVER BASIN

A. Location

The Santa Cruz River Basin contains about 8,600 square miles of arid and semiarid land in southern Arizona and northern Sonora, Mexico. It extends from northern Sonora, Mexico, to the confluence of the Santa Cruz and Gila Rivers southwest of Phoenix, Arizona. The Santa Cruz River, which drains the basin, originates in the Canello Hills area of the Huachuca Mountains in Arizona, flows southward into Mexico, and enters Arizona again about 5-1/2 miles east of Nogales. The river then flows generally north through Santa Cruz, Pima, and Pinal Counties to its confluence with the Gila River.

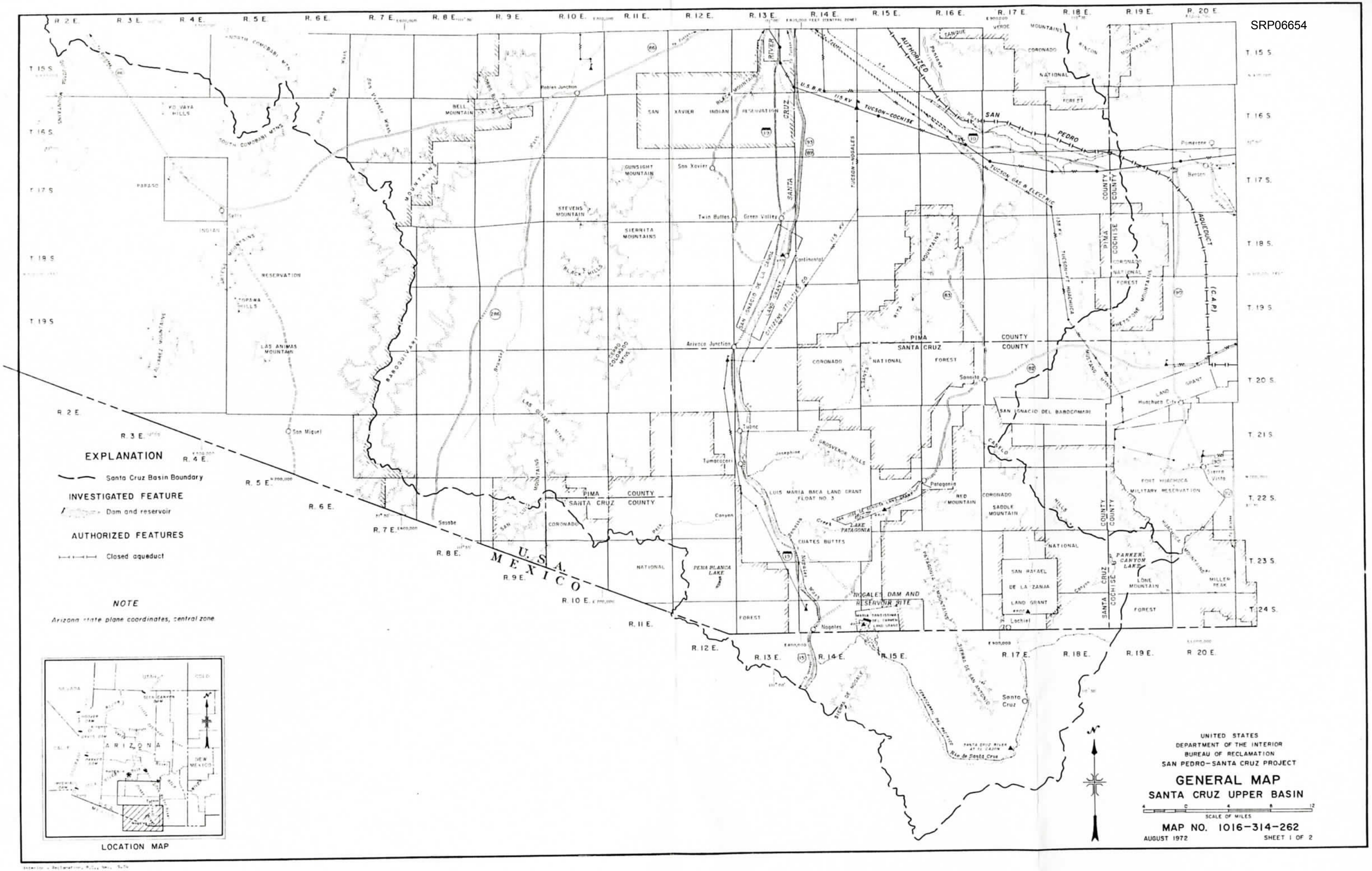
North of the international boundary, the Atasco-Tumacacori and Patagonia Mountains confine the river to the narrow Santa Cruz Valley. Further north, the valley begins to open into the expansive area of the Tucson Basin. Below Tucson the lower Santa Cruz River Basin is mostly an alluvial desert plain having only scattered low mountain ranges.

Major tributaries to the Santa Cruz River within the study area include Sonoita and Rillito Creeks and Los Robles, Brawley, and Santa Rosa Washes. Santa Rosa Wash located on the west edge of the project area, heads in the Papago Indian Reservation and flows generally north to its confluence with the Santa Cruz River channel in Pinal County.

The Santa Cruz River drops about 3,000 feet by the time it reaches Tucson. From Tucson to about Red Rock, Arizona, the river drops more than 600 feet and loses almost all of its natural channel characteristics due to the flatness of the topography in Pinal County. Over the years the lower channel has been confined by local flood dikes built to protect agricultural areas.

The Tucson Basin is a broad 1,000-square-mile area in the upper Santa Cruz River drainage basin. It is considered to be the economic and urban nucleus of the study area. All roads routing through the Santa Cruz River Basin converge in this area and serve most of southern Arizona. The twin cities of Nogales, Arizona, and Sonora, located at the United States-Mexico International Boundary, represent the basin's second busiest commercial center, a point where international traffic takes place, and the second largest urban growth area within the study area. Drawings 1016-314-262 and -263 are general maps illustrating the Santa Cruz River Basin.

SRP06654


EXPLANATION
Santa Cruz Basin Boundary
INVESTIGATED FEATURE
Dam and reservoir
AUTHORIZED FEATURES
Closed aqueduct
NOTE
Arizona state plane coordinates, central zone
LOCATION MAP
ARIZONA
NEW MEXICO
U.S.A.
MEXICO
SAN PEDRO AQUEDUCT (C.A.P.)
TUCSON-COCHISE
TUCSON GAS & ELECTRIC
TUCSON-NOGALES
SANTA CRUZ RIVER
SAN XAVIER INDIAN RESERVATION
BELL MOUNTAIN
GUNSIGHT MOUNTAIN
STEVENS MOUNTAIN
SIERRITA MOUNTAINS
LAS ANIMAS MOUNTAIN
BABOQUIVARI MOUNTAINS
CORONADO NATIONAL FOREST
SAN IGNACIO DEL BABOCOMARI
LUIS MARIA BACA LAND GRANT FLOAT NO. 3
LAKE PATAGONIA
CUATES BUTTES
PENA BLANCA LAKE
NOGALES DAM AND RESERVOIR SITE
SAN RAFAEL DE LA ZANJA LAND GRANT
PARKER CANYON LAKE
FORT HUACHUCA MILITARY RESERVATION
PIMA COUNTY
SANTA CRUZ COUNTY
COCHISE COUNTY
Santa Cruz
Nogales
Patagonia
Sonoita
Arivaca Junction
Tubac
Tumacacori
Continental
Green Valley
Twin Buttes
San Xavier
Sasabe
San Miguel
Pomerene
Benson
Huachuca City
Sierra Vista
Lochiel
Santa Cruz
Rio de Santa Cruz
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
SAN PEDRO-SANTA CRUZ PROJECT
GENERAL MAP
SANTA CRUZ UPPER BASIN
SCALE OF MILES
MAP NO. 1016-314-262
AUGUST 1972
SHEET 1 OF 2

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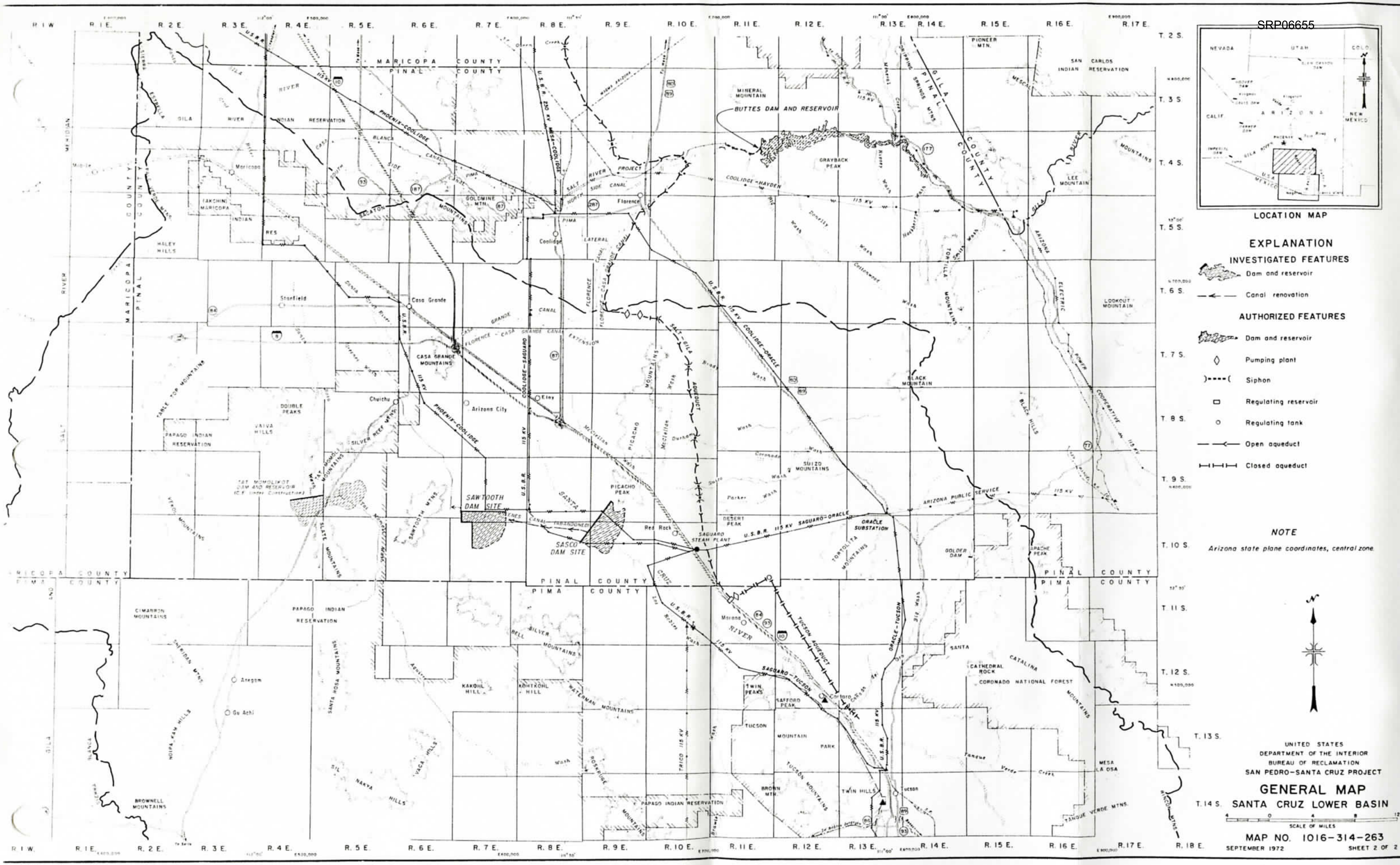
LOCATION MAP
NEVADA
UTAH
COLO.
CALIF.
ARIZONA
NEW MEXICO
USA
MEXICO
EXPLANATION
INVESTIGATED FEATURES
Dam and reservoir
Canal renovation
AUTHORIZED FEATURES
Dam and reservoir
Pumping plant
Siphon
Regulating reservoir
Regulating tank
Open aqueduct
Closed aqueduct
NOTE
Arizona state plane coordinates, central zone
R. I W.
R. I E.
R. 2 E.
R. 3 E.
R. 4 E.
R. 5 E.
R. 6 E.
R. 7 E.
R. 8 E.
R. 9 E.
R. 10 E.
R. 11 E.
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R. 17 E.
R. 18 E.
T. 2 S.
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T. 9 S.
T. 10 S.
T. 11 S.
T. 12 S.
T. 13 S.
T. 14 S.
MARICOPA COUNTY
PINAL COUNTY
PIMA COUNTY
GILA COUNTY
GILA RIVER INDIAN RESERVATION
SAN CARLOS INDIAN RESERVATION
AK CHIN MARICOPA INDIAN RES
PAPAGO INDIAN RESERVATION
BUTTES DAM AND RESERVOIR
MINERAL MOUNTAIN
GRAYBACK PEAK
PIONEER MTN.
LEE MOUNTAIN
LOOKOUT MOUNTAIN
BLACK MOUNTAIN
DRIPPING SPRINGS MTNS
TORTILLA MOUNTAINS
BLACK HILLS
SALT RIVER PROJECT
NORTH SIDE CANAL
PIMA LATERAL
PIMA CANAL
FLORENCE - CASA GRANDE CANAL
FLORENCE - CASA GRANDE CANAL EXTENSION
CASA GRANDE CANAL
SOUTH SIDE CANAL
CASA BLANCA CANAL
SALT-GILA AQUEDUCT
TUCSON AQUEDUCT
PHOENIX-COOLIDGE
U.S.B.R. 115 KV
U.S.B.R. 230 KV MESA-COOLIDGE
COOLIDGE-HAYDEN
COOLIDGE-ORACLE
COOLIDGE-SAGUARO
SAGUARO-ORACLE
SAGUARO-TUCSON
ORACLE-TUCSON
ORACLE SUBSTATION
SAGUARO STEAM PLANT
ARIZONA ELECTRIC POWER COOPERATIVE 115 KV
ARIZONA PUBLIC SERVICE 115 KV
TRICO 115 KV
Maricopa
Florence
Coolidge
Casa Grande
Stanfield
Chuichu
Arizona City
Eloy
Red Rock
Marana
Cortaro
Tucson
Anegam
Gu Achi
GOLDMINE MTN.
SACATON MOUNTAINS
CASA GRANDE MOUNTAINS
HALEY HILLS
DOUBLE PEAKS
VAIVA HILLS
TABLE TOP MOUNTAINS
SILVER REEF MTNS
TAT MOMOLI MOUNTAINS
TAT MOMOLIKOT DAM AND RESERVOIR (C.E. Under Construction)
SAWTOOTH DAM SITE
SASCO DAM SITE
SAWTOOTH MTNS
SLATE MOUNTAINS
VEKOL MOUNTAINS
PICACHO PEAK
PICACHO MOUNTAINS
SUIZO MOUNTAINS
DESERT PEAK
TORTOLITA MOUNTAINS
GOLDER DAM
APACHE PEAK
SANTA CRUZ RIVER
CIMARRON MOUNTAINS
SHERIDAN MTNS.
NOIPA KAM HILLS
SANTA ROSA MOUNTAINS
SIL NAKYA HILLS
VACA HILLS
BROWNELL MOUNTAINS
KAKOHL HILL
KOHTKOHL HILL
SILVER BELL MOUNTAINS
WATERMAN MOUNTAINS
ROSKRUGE MOUNTAINS
TWIN PEAKS
SAFFORD PEAK
TUCSON MOUNTAIN PARK
TUCSON MOUNTAINS
BROWN MTN.
TWIN HILLS
SANTA CATALINA MOUNTAINS
CATHEDRAL ROCK
CORONADO NATIONAL FOREST
MESA LA OSA
TANQUE VERDE MTNS.
RINCON MTNS.
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
SAN PEDRO-SANTA CRUZ PROJECT
GENERAL MAP
SANTA CRUZ LOWER BASIN
SCALE OF MILES
MAP NO. 1016-314-263
SEPTEMBER 1972
SHEET 2 OF 2

B. Climate

The climate in the Santa Cruz River Basin is typical of areas of the arid southwest and is characterized by mild winters and hot summers. Maximum summer temperatures on the valley floor frequently exceed 105°F. Average daily winter temperatures are generally above freezing. Average annual temperatures range from about 62°F at Nogales near the international boundary to about 70°F near the Pima-Pinal County line.

Annual precipitation in the basin is erratic, ranging from less than 10 inches near Tucson to over 30 inches in the Santa Catalina Mountains. The basin as a whole has an average annual precipitation of about 13 inches. About one-half of the average rainfall is provided by short-duration, high-intensity summer storms generally occurring in July, August, and September.

C. Vegetation and Wildlife

Vegetation in the basin is largely characterized by typical lower Sonoran Desert shrubs. The growths are typically sparse, but become more dense near water courses. Phreatophytic growth is prominent along the Santa Cruz River channel and all its major and minor tributaries. Vegetative species include small stands of trees of cottonwood and sycamore associations. Ironwood and paloverde are also represented. Typical shrubs include mesquite, creosote bush, etc., with a wide variety of cacti dispersed throughout the basin.

Except for areas of human development, animal life appears to be abundant within the basin. Wildlife now is mainly confined to the smaller species represented by deer, coyote, rabbits, and other lower rodent and reptile varieties and a large variety of birds such as quail, dove, hawks, and songbirds. Endangered or threatened species in the general area are listed on page 9.

Agricultural activities within the basin include livestock grazing operations, with cattle introduced throughout the basin. The livestock are now in direct competition for range grazing with the larger wildlife of the basin.

D. Population

According to the 1970 U.S. Census there are approximately 372,000 people within the study area, a 37 percent increase over the 1960 population.

The bulk of the population is located in the Tucson Basin which contains about 300,000 people (U.S. Census). If it continues to grow at about the same rate as in the last decade, the population may reach 550,000 by 1980.

E. Economy of Area

1. Agriculture. With approximately 220,000 acres of irrigated land, agriculture is a large factor in the economy of the basin. The greater part of the acreage is located in the lower portion of the basin in Pinal County. Crops grown include cotton, grains, alfalfa, and vegetables. Approximately $206 million of produce were grown in 1971. In addition, Pinal County is the second largest cattle raising county in the State. In the upper half of the basin, expecially in Pima and Santa Cruz Counties, agriculture plays a smaller role in the economy compared to industry, education, tourism, and transportation.

2. Industry. Industry in the Santa Cruz River Basin includes many types of commerce. These include mining, manufacturing, construction, transportation, utilities, wholesale and retail businesses, financial services, and Government activities.

3. Education. Educational institutions in the study area include the University of Arizona and Pima College, both located in Tucson. The two institutions had a combined enrollment of about 34,500 in 1971. Central Arizona College, located in Coolidge just outside the study area, has an enrollment of about 4,450.

4. Tourism. Warm winters, historical sites, the proximity of the international boundary, and the natural southwestern desert setting attract many tourists to the area. Some of the historical areas in the basin include the City of Tucson, San Xavier Mission, Casa Grande Ruins National Monument, and Tumacacori Mission National Monument. In addition, outdoor recreational activities are available through the extensive Coronado National Forest system, and Indian cultures embodied in the basin's Indian reservations offer educational enlightenment. The basin is also Arizona's gateway to Old Mexico. In 1971 over 9 million persons crossed the border at Nogales, Arizona.

5. Transportation. The Santa Cruz River Basin has an excellent transportation network, including highways, a railroad, an international airport, and many smaller airports. Interstate Highways 10 and 19 are the main transportation arteries through the basin. Arizona State Highways 82, 83, 86, and 87, as well as numerous county roads, interconnect

the whole basin. The Southern Pacific Railroad traverses the river basin from the Mexico border at Nogales to the population centers of central Arizona.

F. Land Utilization

The Santa Cruz River Basin has a variety of economic activity including mining, agriculture, manufacturing, tourism, and military facilities. The rapidly growing Tucson Basin supports municipal growth, agriculture, and military activity. The upper Avra, Aguirre, and Altar Valleys west of Tucson are primarily agricultural areas. Avra Valley leads this activity with approximately 24,800 acres under cultivation. The upper basin in the general vicinity of Nogales is largely in a transformation to urban development. Portions of the vast Coronado National Forest system dot the basin. Numerous mining districts are located in the basin and many copper mines are currently under full production. The general trend in the basin is the transformation of undeveloped desert areas to mining and urban development to accommodate the growing population.

1. Mining. Mineral resources, generally consisting of low-grade copper ores and associated precious metals, are distributed throughout the basin. Estimates on copper ore reserves are not readily available. However, quantities of undiscovered ore deposits are thought to be extremely high, probably exceeding the ranges of currently known deposits.

Judging from recent increases in mining activity throughout the basin, it would appear that mining will withdraw significant quantities of land areas from other uses. Mining companies presently operating within the basin include the American Smelting and Refining Company in the Silver Bell and Mission mining areas, Anaconda and the Duvall Corporation in the Sierrita Mountain area, and Hecla Mining Company developing portions of the Papago Indian Reservation.

2. Agriculture. Due to a declining water table and the present economic conditions, the development of additional agriculture lands has nearly stopped in the Santa Cruz River Basin. The drilling of wells for irrigation is regulated by the State of Arizona. The State has classified most of the Santa Cruz River Basin a critical ground-water area and has closed most of it to new ground-water drilling except for replacement purposes. The only area now left open to ground-water exploitation is part of Aguirre Valley where some new lands and new wells are presently being developed. Some of the water from the new wells is being applied on lands within the critical ground-water area. Further

development of private lands in Aguirre Valley is limited due to its proximity to the Papago Indian Reservation. A large area of undeveloped lands in Avra and Aguirre Valleys could be developed for irrigation if additional water could be provided.

The lands currently being irrigated are generally located on the old flood plains of the Santa Cruz River, Rillito Creek, and Brawley Wash in Avra Valley. They vary in width from less than a mile to several miles and are several miles long. These lands have good topography and, with few exceptions, are smooth and level. The soils are generally deep but stratified and vary from coarse to medium textures. They appear to be well drained and only in a few small localized areas are there any indications of high water tables. There is no evidence of harmful salts or alkalies in the soil.

A field inventory made in 1964 along the Santa Cruz River from the Pima-Pinal County line to Nogales, Arizona, including Avra Valley and Rillito Creek, revealed that there were then about 74,000 acres irrigated or developed for irrigation. Table 6 shows the 1970 estimated acreage developed for irrigation along the Santa Cruz River by counties based on the 1964 field inventory. Although some acreage has since been taken out of production, the relative magnitude of the acreage still developed for irrigation remains about the same.

A subsequent modified detailed land classification conducted in 1965 and updated in 1970 on approximately 57,000 acres from Tucson to the Pima-Pinal County line and Avra Valley south to Robles Junction, revealed that 53,000 acres of Classes 1, 2, and 3 arable land were developed for irrigation. Of this total, 51,563 acres were classified as Class 1. A draft report on the land classification study is on file in the Arizona Projects Office.

3. National Forests. Approximately 845,000 acres of the Coronado National Forest system lie within the Santa Cruz River Basin. For the most part, the forest areas are located along the mountain ranges on the eastern and southern portions of the basin.

4. Urban Growth. The most rapid population growth in the basin is in the metropolitan area of Tucson. Studies show that the area population has grown approximately 550 percent in the 20-year period between 1950 and 1970. Encompassing vast areas of desert land, the expansion of Tucson has absorbed some developed irrigated

Table 6
ESTIMATED ACREAGE DEVELOPED FOR IRRIGATION IN
THE SANTA CRUZ RIVER BASIN STUDY AREA-1970
San Pedro-Santa Cruz Project, Arizona

	Acres		Total
	Irrigated	Not Cropped	Acres
Santa Cruz River			
Santa Cruz County	6,500	300	6,800
Pima County	36,500	1,700	38,200
Green Valley Estates-Farms	1,090	-	1,090
Subtotal	44,090	2,000	46,090
Avra Valley	24,800	980	25,780
Rillito Creek	1,600	370	1,970
Survey Acreage Total	70,490	3,350	73,840

Based on updated 1964 field inventory of irrigated land from Pima-Pinal County line to Nogales, Arizona, including Avra Valley and Rillito Creek area.

land adjacent to the Santa Cruz River. The metropolitan area now encompasses approximately 100 square miles of area within the Tucson Basin.

Arizona City, located north of Tucson below the Sasco Dam site, is a typical example of urban growth encompassing previously irrigated lands. Typical growth trends indicate that the area may encompass approximately 7 square miles by 1980.

Approximately 20 miles north of Nogales on the Santa Cruz River, the Gulf American Corporation has begun its 55,000-acre Rio Rico Community development. The developers envision a population of about 100,000 under full development. The corporation also plans to develop the 60,000-acre Empire Sonoita holdings located southeast of Tucson.

5. Indian Lands. The study area of the Santa Cruz River Basin includes significant portions of the 4,300-square-mile Papago Reservation and all of the 111-square-mile San Xavier Reservation. Together, they comprise a significant land area in southern Arizona. Land-use trends on the reservations are not definite, but significant land portions of the Papago Reservation are being opened to mineral development.

VI. PROBLEMS AND NEEDS OF SANTA CRUZ RIVER BASIN

VI. PROBLEMS AND NEEDS OF SANTA CRUZ RIVER BASIN

A. Water Supply

The greatest problems in the Santa Cruz River Basin are the increased ground-water depletions and the damages caused by periodic floods. If the basin continued to experience what may be considered the high population growth of the last decade, the already critical water supply problem will be increased in the near future and flood damages in developed flood plain areas will persist.

1. Municipal and Industrial Water. The City of Tucson is deeply concerned about meeting future demands from local water supplies. Local ground-water supplies are diminishing at a rapid rate, and the city has had to purchase farmland in Avra Valley in order to obtain the right to divert ground water into the Tucson Basin. Areas in which the city has acquired property for the purpose of pumping ground water include the Brawley Wash area and sections in the San Pedro River Basin. It is possible, however, that the inhabitants of the San Pedro River Basin may resist any exportation of water supplies for this purpose. To offset the expected water shortage, the City of Tucson has expressed an interest in the Central Arizona Project and has applied for 100,000 acre-feet per year.

The water problem is further complicated by the new urban developments which are occurring everywhere in the basin. While some of these developments are now taking place on agricultural land, the net result will be an increasing depletion of ground-water storage as the developments expand to incorporate desert lands not previously irrigated.

The growth of the twin cities of Nogales, Arizona, and Nogales, Sonora, has reached the point where a critical ground-water situation is being created. While the City of Nogales, Sonora, has had a 73 percent population increase in the last decade (a 1970 population of 65,000), Nogales, Arizona, has increased only 23 percent in the same period (a 1970 population of about 8,950). Both communities are dependent on ground-water to supply municipal demands. The effect of ground-water pumpage in the Nogales well field in Mexico on the Nogales well field in Arizona is considered negligible. The total capacity of the wells being drawn upon decreases seasonally, creating severe water shortages in months

when riverflows are at a minimum or have ceased for extended periods. The cities are now searching for new water sources to meet present and future demands. So critical has the water supply problem been that in 1965 the City of Nogales, Sonora, requested a supplemental supply from Nogales, Arizona, to meet its needs that year.

Just north of Nogales and below the confluence of Sonoita Creek, the Gulf American Corporation is developing a 55,000-acre community called Rio Rico. The developers anticipate a 1980 population of about 15,000 and optimistically envision an ultimate population of about 180,000. In addition, it appears that the Gulf American Corporation has plans to develop its 60,000-acre Empire-Sonoita holdings 35 miles southeast of Tucson. The developers and some officials of Pima and Santa Cruz Counties envision possible populations ranging from 60,000 to 180,000 in 100 years. Population increases from these two major developments alone would burden the water supply with an ultimate estimated demand of approximately 60,000 acre-feet per year. Many similar developments on a smaller scale are occurring throughout the basin.

The growing industrial water requirement in the basin is currently estimated at about 32,000 acre-feet per year, about triple the 1965 water requirement, and is expected to fluctuate significantly with changing mining activity. The mining industry uses an estimated 30,000 acre-feet of this supply each year for the mining and processing of about 300,000 tons of copper and allied metals. Table 7 shows the projected water requirements estimated for municipal and industrial uses in the study area.

Table 7
ESTIMATED MUNICIPAL AND INDUSTRIAL GROSS WATER REQUIREMENTS FOR SANTA CRUZ RIVER BASIN STUDY AREA, 1980-2020
San Pedro-Santa Cruz Project, Arizona

Unit: Acre-Feet

	1980	1990	2000	2020
Municipal	100,000	155,000	253,000	420,000
Industrial	40,000	46,000	52,000	60,000
Total	140,000	201,000	305,000	480,000

2. Irrigation Water. Agriculture in the Santa Cruz River Basin has always played an important role in the State's economy and will need a stabilized water supply if economic productivity is to continue at the current levels. In 1970, there were approximately 64,000 acres of irrigated land within the study area utilizing about 330,000 acre-feet of ground water. This is about 6,500 acres less than was irrigated in 1964. The reduction represents nonagricultural development encroaching along the upper reaches of the Santa Cruz River.

Current urban and suburban growth trends are making heavy demands on the land and the ground water of the basin. Agriculture is now in direct competition with M&I uses for the remaining water supply and, with the ground water already at or near the point of marginal pumping, is slowly but surely yielding to the pressures of an expanding population. To alleviate the heavy ground-water overdraft in the basin, the Central Arizona Project will import portions of Arizona's Colorado River entitlement. This, however, will provide only temporary relief in reducing the rates of ground-water depletion. Additional sources of water must be found if the basin's agricultural productivity is to be maintained.

B. Flood Control

Flooding has always been a problem in the Santa Cruz River Basin. Although large direct damages occur to agricultural, commercial, and industrial lands, the serious impairment of the basin's transportation networks might be considered the greatest damage.

Notable past floods include those from the September 1962 storms, which caused an estimated $11 million 1/ in damages in the basin. Though the flooding was widespread, floodflows of considerable significance concentrated in the lower Santa Cruz River Basin. Floodflows occurred along the Santa Cruz River north of Tucson, on Brawley Wash east of Santa Rosa Wash, and on Greenes Wash, a tributary of the Santa Rosa Wash whose confluence is downstream from the Tat Momolikot Dam site. The flow in Greenes Wash originated in the Santa Cruz River. Discharges on Santa Rosa Wash above the Greenes Wash confluence reached an estimated peak of 53,000 cubic feet per second, and flows along Greenes Wash were estimated at about 16,000 cubic feet per second.

1/ Interim Report on Survey for Flood Control, Santa Rosa Wash, Arizona, USCE, August 1963.

In September of 1964 the Santa Cruz River Basin experienced flood damages amounting to an estimated $2.5 million 1/ from a general storm which caused flooding all along the Santa Cruz River mainstem and its major tributaries. The major flooding occurred in the Tucson Basin. The following month another rainstorm occurred in the Tucson area which produced flood damages estimated at between $4 and $6 million. Significant flooding also occurred in 1967, 1968, and 1972.

To alleviate the flooding problem, the Corps of Engineers is constructing the Tat Momolikot Dam on Santa Rosa Wash (authorized by the Flood Control Act of 1965). The project plans provide for a multipurpose reservoir about 6-1/2 miles upstream from the village of Vaiva Vo and for the development of 1,640 acres of cultivated land on the Papago Indian Reservation downstream from the dam. Plans are also being developed for channel improvements and flood plain management on Rillito Creek to facilitate passing floodwaters on the creek through the Tucson metropolitan area. In addition, the Corps of Engineers is conducting flood hazard information programs to assist communities in the basin in their zoning problems relative to construction on or near hazardous flood plains.

The Soil Conservation Service is conducting programs to control flood runoff on small watersheds.

C. Recreation

There are very few water-oriented outdoor recreation developments available to residents of the basin. Most are small isolated ponds under 50 acres in extent which are inadequate to meet recreational needs, and local residents desiring to participate in water-oriented sports must travel at least 150 miles to reach larger bodies of water where such opportunities are available. In the last decade, only one significant body of water has been constructed in the basin. This is Lake Patagonia, located on Sonoita Creek approximately 12 miles upstream from its confluence with the Santa Cruz River. The reservoir provides approximately 260 surface acres for recreation purposes.

The need of providing water to meet higher use demands within the study area may preclude any dedication of future water supplies for purely recreational uses.

1/ Flood Damage Report on Storm and Flood of September 1964, Upper Santa Cruz River, Southern Arizona, USCE, December 1964.

D. International Aspects

The Santa Cruz River is an international stream not covered by treaty. As Nogales, Sonora, continues to grow or if water use in Sonora increases, there will be a decrease in the supply coming into the United States. The greatest effect will be felt in Santa Cruz County. This depletion is inevitable. The United States and Mexico are currently preparing the groundwork for negotiations of a possible treaty on the division of the flows of the Santa Cruz River.

SRP06668

VII. WATER SUPPLY AND UTILIZATION–SANTA CRUZ RIVER BASIN

VII. WATER SUPPLY AND UTILIZATION–SANTA CRUZ RIVER BASIN

A. The Santa Cruz River

Draining approximately 8,600 square miles of arid and semiarid land, the Santa Cruz River is an intermittent stream flowing only 10 to 15 percent of the time. The streamflow results directly from precipitation and, except for very large floodflows, largely infiltrates into the ground-water basin. Floodflows generally result from high intensity precipitation during thunderstorms in July and August. The river's tributaries are also intermittent and subject to large infiltration losses.

1. Streamflow. The river originates in the United States in the Canello Hills and flows into Sonora, Mexico, making a 42-mile loop before reentering the United States 5-1/2 miles east of Nogales, Arizona. Above Nogales, the stream drains approximately 545 square miles. Streamflow records have been maintained for gaging stations located at Lochiel, Arizona, where the river first crosses into Mexico, and El Cajon, Sonora, within Mexico and near Nogales, Arizona.

At Lochiel, a Geological Survey gaging station measures the flow from approximately 82 square miles of drainage originating in the United States. Riverflows at this point have been recorded since 1949. A maximum annual flow of 12,200 acre-feet was recorded in 1955. Records show extensive periods of no flows.

The El Cajon Gaging Station was established in 1954 by the Mexican Section of the International Boundary and Water Commission. It measures flows from a drainage area of 305 square miles, of which 182 square miles lie in the United States. A 12-year average annual flow of about 8,600 acre-feet is estimated for this gage.

The Nogales Gaging Station, located about 5-1/2 miles east of Nogales, Arizona, and three-fourths of a mile north of the international boundary, was established by the Geological Survey in 1907. Flow records were maintained intermittently between 1907 and 1935 and have been kept continuously since 1935. The maximum recorded annual flow was 68,900 acre-feet, which occurred in 1966. Records show extensive periods of little or no flow.

Other gaging stations located below the Nogales Gage include a Geological Survey gage at Continental and below Tucson at Cortaro.

The Santa Cruz River at the Sasco Dam site drains about 5,230 square miles of arid and semiarid desertland. Its flows are erratic and silt laden, for the most part generated by local and intense summer rainstorms of short durations and by winter rainstorms of long durations. Since gaging stations cannot be economically established on the Santa Cruz channel at or near the Sasco Dam site, estimates of monthly runoff for the damsite were made using correlation with the Cortaro gage. These data were checked and adjusted to reflect the results of recent studies published by the Geological Survey concerning streamflow in the Santa Cruz River Basin. The 30-year average annual flow for the Sasco Dam site was estimated at about 11,400 acre-feet. This water supply was used in evaluating the potential Sasco and Sawtooth storage alternatives. Table 8 shows the estimated historical net flows arriving at the Sasco Dam site, and Table 9 shows the historical and estimated flows at Cortaro. Table 10 is included to show the average annual infiltration characteristics affecting surface flows of the river. Table 11 lists the various Geological Survey streamflow measuring gages along the Santa Cruz River.

2. Water Quality. The general chemical quality of the Santa Cruz River surface water is good. Flows, however, do carry heavy silt loads.

B. Ground Water

The Santa Cruz Valley has been divided into upper and lower basins by previous ground-water investigations. The upper basin extends from northern Sonora, Mexico, to Rillito, Arizona. The lower basin extends from Rillito to the confluence of the Santa Cruz and Gila Rivers southwest of Phoenix, Arizona. This section discusses the ground-water resources of the upper basin and the extreme southern end of the lower basin, known as the Marana area. The lower basin in Pinal County is part of the Central Arizona Project service area, and the ground water has been comprehensively studied as part of the Central Arizona Project investigations.

Because of the relationship of the Tucson Basin to both the Santa Cruz and the Central Arizona Project investigations, a comprehensive ground-water study was conducted by the Geological Survey in cooperation with the Bureau of Reclamation, City of Tucson, and University of Arizona. Each contributed financial support or services, or both. The Bureau of Reclamation drilled six deep test holes, contributed $100,000, and stationed

Table 8
ESTIMATED FLOW OF SANTA CRUZ RIVER AT SASCO DAM SITE
San Pedro-Santa Cruz Project, Arizona

Unit: 1,000 Acre-Feet

Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Total
1940	0	0	0	0.1	0	0	0	0	0.1	0.3	13.1	0.3	13.9
41	0	0.2	6.9	0.8	0.6	0.9	0	0	0	0	0.9	0.6	10.9
42	0	0	0	0	0	0	0	0	0	0	0.3	0.1	0.4
43	0	0	0	0	0	0	0	0	0	0.1	3.3	2.7	6.1
44	0	0	0	0	0	0	0	0	0	0.2	6.4	1.3	7.9
1945	0	0	0	0	0	0	0	0	0	3.1	10.8	0	13.9
46	0	0	0	0	0	0	0	0	0	1.0	4.3	0.7	6.0
47	1.4	0	0	0	0	0	0	0	0	0	2.0	0.1	3.5
48	0	0	0	0	0	0	0	0	0	0.1	1.9	0.1	2.1
49	0	0	0	0.1	0	0	0	0	0	0	2.2	1.4	3.7
1950	0	0	0	0	0	0	0	0	0.1	20.6	0.6	0	21.3
51	0	0	0	0	0	0	0	0	0	1.3	3.2	0	4.5
52	0.6	0.2	0.2	0.2	0	0.3	0	0	0	0	1.6	0.1	3.2
53	0	0.1	0	0	0	0	0	0	0	7.3	0	0	7.4
54	0	0	0	0	0	3.6	0	0	0.5	13.8	8.3	1.8	28.0
1955	0	0	0	0	0	0	0	0	0	8.5	32.8	0	41.3
56	0	0	0	0	0	0	0	0	0	0.4	0	0	0.4
57	0	0	0	0.8	0	0	0	0	0	0	0.1	0.3	1.2
58	0	0	0	0	0	1.0	0	0	0	3.0	2.9	0	6.9
59	0	0	0	0	0	0	0	0	0	1.1	3.9	0	5.0
1960	0.1	0	0.7	9.4	0	0	0	0	0	0	1.9	0.1	12.2
61	0.7	0	0	0	0	0	0	0	0	1.1	9.3	0	11.1
62	0	0	1.2	1.3	0	0	0	0	0	0	0	4.6	7.1
63	0	0	0	0	0.9	0	0	0	0	1.9	4.7	0.4	7.9
64	0	0	0	0	0	0	0	0	0	2.9	4.2	14.8	21.9
1965	0	0	0	0	0	0	0	0	0	0.1	0	0	0.1
66	0	0	38.5	0	5.0	0	0	0	0	0.6	6.4	2.5	53.0
67	0	0	0	0	0	0	0	0	0	4.1	0	0	4.1
68	0.3	0	33.1	0	2.0	0.7	0	0	0	0	0.6	0	36.7
69	0	0	0	0	0	0	0	0	0	0	1.4	0.2	1.6
1970													
1940-69 Total	3.1	0.5	80.6	12.7	8.5	6.5	0	0	0.7	71.5	127.1	32.1	343.3

30-Year Mean

Oct. 1939-June 1947 and July 1950-Sept. 1970, from correlation with historic Santa Cruz River at Cortaro.

July 1947-June 1950 from correlation with estimated Santa Cruz River at Cortaro.

Table 9
RECORDED AND ESTIMATED HISTORICAL FLOW OF SANTA CRUZ RIVER AT CORTARO, ARIZONA
San Pedro-Santa Cruz Project, Arizona

Unit: 1,000 Acre-Feet

Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Total
1940	0	0	0	0	0.7	0	0	0	0.6	1.5	16.3	1.1	20.2
41	0	0.7	10.4	2.3	2.2	2.6	0	0	0	0.6	3.4	2.2	24.4
42	0	0	0.3	0.1	0.3	0.2	0.1	0	0	0.5	1.5	0.9	3.9
43	0	0	0	0	0	0.4	0	0	0.1	1.6	10.2	5.3	17.6
44	0	0	0	0	0	0	0	0	0	0.9	11.0	2.4	14.3
1945	0.4	0.4	0	0	0	0	0	0	0	6.0	17.2	0.1	24.1
46	0.5	0	0	0.3	0	0	0	0	0	3.8	9.8	2.4	16.8
47	2.4	0.1	0	0	0	0	0	0	0	0.3	5.5	0.7	9.0
48	0	0	0	0	0	0	0	0	0	1.1	5.8	0.8	7.7
49	0	0	0.4	1.0	0	0	0	0	0	1.1	4.8	3.8	11.1
1950	0	0	0	0	0	0	0	0	0.7	31.9	1.9	0.4	34.9
51	0	0	0	0	0	0	0.1	0	0.1	4.4	6.9	0.1	11.6
52	1.7	0.9	0.8	1.6	0	1.6	0.3	0	0	1.1	4.4	1.1	13.5
53	0	0.5	0	0	0	0	0	0	0	14.2	0.2	0	14.9
54	0	0	0	0	0	6.2	0	0	1.7	24.2	16.8	4.3	53.2
1955	0.2	0	0	0.1	0	0	0	0	0	13.7	53.3	0.1	67.4
56	0.1	0	0	0.1	0	0	0	0	0	1.4	0.2	0	1.8
57	0	0	0	1.7	0	0	0	0	0	0.3	1.9	0.9	4.8
58	0.5	0.2	0	0	0.3	3.8	0	0	0	6.7	8.2	0.8	20.5
59	0.1	0	0	0	0	0	0	0	0	3.8	9.7	0.1	13.7
1960	0.8	0	2.0	15.1	0	0	0	0	0	0.1	4.4	0.4	22.8
61	1.5	0	0.1	0.2	0	0	0	0	0	2.2	13.3	0.5	17.8
62	0	0	2.8	2.8	0	0	0	0	0	0.1	0.1	6.9	12.7
63	0	0	0	0	1.9	0	0	0	0	4.1	12.0	2.3	20.3
64	0	0.4	0	0	0	0	0	0	0.2	6.6	10.1	21.3	38.6
1965	0.1	0	0.4	0.3	0.3	0	0	0	0	1.0	0.1	0.2	2.4
66	0	0	52.3	0	10.6	0	0	0	0	2.2	13.0	5.2	83.3
67	0.1	0	0	0	0	0	0	0.1	0	7.6	0.3	0.1	8.2
68	0.9	0	42.3	0	4.8	2.4	0	0	0	0.1	2.7	0	53.2
69	0	0.2	0	0	0	0	0	0	0	0.4	4.3	0.9	5.8
1970													
1940-69 Total	9.3	3.4	111.8	25.6	21.1	17.2	0.5	0.1	3.4	143.5	249.3	65.3	650.5
30-Year Mean													

Oct. 1939-June 1947 and July 1950-Sept. 1970, from Geological Survey Water-Supply Papers.

July 1947-June 1950, from correlation with Santa Cruz River and Rillito Creek at Tucson, Arizona.

Table 10
SUMMARY OF ESTIMATED ANNUAL INFILTRATION FOR THE
MAIN CHANNELS OF THE TUCSON BASIN (1936-1963)
San Pedro-Santa Cruz Project, Arizona

Reach	Coefficient[1] (C) per Mile of Channel	Reach Length (miles)	Avg. Ann. Inflow Acre-Feet	Avg. Ann. Inflow a.f./Sq. Mi.	Avg. Ann. Infiltration Acre-Feet	Avg. Ann. Infiltration % of Inflow	Avg. Ann. Infiltration a.f./mile of Channel
1 Santa Cruz, Continental to Tucson	0.06	28.5	22,450	10.1	9,030	40	320
2 Tanque Verde Creek	0.18[2]	17.5[5]	16,740	75.8	7,540	45	430
3 Rincon Creek	0.32	7.8	3,790	46.6	3,500	92	450
4 Pantano Wash	0.11	21.5	7,150	11.8	5,160	72	240
5 Rillito Creek	0.18	9.5	13,990	15.3	7,780	56	820
6 Canada del Oro	0.18[3] 0.06[4]	36.1[6]	9,940	38.8	5,940	60	160
7 Santa Cruz, Tucson to Cortaro	0.11	16.6	26,850	7.7	8,030	30	480

1/ Where footnoted, data were inadequate to establish inflow-infiltration relation.
2/ Assumed to about the same as Reach 5.
3/ Similar to Reach 5 upstream from the mouth of Big Wash.
4/ Similar to Reach 1 downstream from the mouth of Big Wash.
5/ Includes 3 miles of Sabino Creek and 4 miles of Agua Caliente Wash.
6/ Includes 12 miles of Big Wash.

Table 11
STREAMFLOW RECORDS--SANTA CRUZ RIVER
THROUGH WATER YEAR 1971
San Pedro-Santa Cruz Project, Arizona

USGS Gaging Station	Location T.	Location R.	Location S.	Drainage Area (sq mi)	Available Records	Recorded Flow Extremes: Q. Max. (Peak and Date) (ft^3/s)	Recorded Flow Extremes: Q. Min. (Peak and Date) (ft^3/s)	Recorded Flow Extremes: Annual Runoff in 1,000 a.f. Maximum (water year)	Recorded Flow Extremes: Annual Runoff in 1,000 a.f. Minimum (water year)	Annual Runoff in 1,000 a.f. Water Year
Santa Cruz River near Lochiel, Arizona	24S	17E	11	82	Jan 1949 to present	4,810 9-12-65	0 Few days	12.2 1955	0.2 1962	2.4 22 years
Santa Cruz River near Nogales, Arizona	24S	15E	18	533	Mar-Nov 1907 Apr 1909-Dec 1912 (partial records) Jan 1913-June 1922 May 1930-Dec. 1933 July 1935 to present	15,200 12-20-67	0 Few days	75.0 1915	0.5 1960	17.0 52 years (1912-22, 1929-71)
Santa Cruz River at Continental, Arizona	18S	13E	23	1,662	May 1940-Dec 1946 Oct 1951 to present	18,000 12-20-67	0 Most of year	64.4 1966	0.2 1965	14.1 26 years
Santa Cruz River at Tucson, Arizona	14S	13E	14	2,222	Oct 1905 to present	16,600 8-23-61	0 Most of year	80.9 1915	0.9 1965	15.9 66 years
Santa Cruz River at Cortaro, Arizona (Rillito, Arizona)	12S	12E	35	3,503	Oct 1939-June 1947 July 1950 to present	17,000 8-14-40	0 Most of year	83.3 1966	1.9 1956	23.6 28 years
Santa Cruz River at Laveen, Arizona	2S	2E	29	8,581	Jan 1940-Sep 1946 Dec 1947 to present	9,200 9-29-62	0 Most of year	45.2 1955	0.7 1969	15.2 29 years

one man in Tucson to assist the University of Arizona personnel in collecting data. The Geological Survey completed the study in 1968 and subsequently published technical reports on the Tucson Basin. 1/ In May 1970 the Geological Survey released an open-file report 2/ which correlated the published technical reports and emphasized the geohydrology and water budget of the basin. Much of the material presented herein is derived from this report and from other publications of the Geological Survey.

1. Upper Santa Cruz River Basin

a. Hydrogeology. The upper basin is primarily a north-south trending, structurally controlled depression typical of other basins in south and central Arizona. From the Pima-Santa Cruz County line south to the international boundary it is formed by a narrow valley of about a mile in width, mainly comprising the channel and flood plain of the Santa Cruz River. North of the Pima-Santa Cruz County line the basin widens to a maximum of about 20 miles south of Tucson. There are three hydrogeologic units in the basin: (1) a bedrock unit delineating the margins and floor of the basin which includes cyrstalline, metamorphic, volcanic, and older sedimentary rocks; (2) a thick and extensive basin-fill unit which in the Tucson Basin the Geological Survey subdivided into the Pantano Formation, Tinaja beds, and Fort Powell Formation; and (3) young, areally limited, and relatively thin alluvial units comprising channel and flood plain, terrace, and alluvial-fan deposits. The basin fill and alluvium, which constitute the ground-water reservoir, have an estimated aggregate thickness of over 3,000 feet. The bedrock unit is considered to be essentially nonwater bearing, although it does contribute water to low yielding stock and domestic wells locally.

b. Occurrence. Ground water in the upper Santa Cruz River Basin occurs primarily as unconfined or semiconfined water in the basin-fill and alluvial units. Confined (artesian) water occurs locally within the basin fill because of lithologic variations and also occurs in local conglomerates at significant depths. There are no reported occurrences of perched or semiperched water bodies.

1/ Geological Survey Water-Supply Papers, 1939, A, B, and D.

2/ Geohydrology and Water Resources of the Tucson Basin, Arizona. Geological Survey Open-File Report, May 1970.

c. Movement. In all hydrogeologic units the apparent direction of ground-water movement is generally from the mountain fronts toward the Santa Cruz River and then in a general northerly direction paralleling the river channel. There are areas where pumping has created ground-water troughs, but these are limited to the local concentrations of pumping for municipal or industrial purposes in the Tucson Basin.

d. Depths. Depths to ground water range from about 1 foot to more than 500 feet in the upper Santa Cruz River Basin. Along the river and its major tributaries, depths are commonly 25 to 100 feet, with minimal depths within 1 foot of channel grade. Depths to water in the basin-fill deposits commonly range from 100 to 500 feet.

e. Fluctuations. Substantial parts of the upper basin, primarily in the Tucson Basin, are experiencing long-term water-level declines. During the 1940-1965 period declines in the Tucson Basin reached a maximum of about 70 feet. The most severe declines occurred in the Continental-Sahuarita area and in the Tucson metropolitan area. There have been prolonged periods of water-level declines between the Tucson Basin and the international boundary during dry years, but water levels have consistently recovered to near original levels during wet years.

f. Quality. The ground water is commonly of the bicarbonate type and concentrations of total dissolved solids are generally less than 500 mg/l. At depths exceeding 1,000 feet in the Tucson Basin, fluoride concentrations are above the recommended public health limits for municipal use.

g. Pumpage. Irrigation and municipal wells in the alluvium range in depth from 50 to 150 feet. They usually have 10- to 20-inch casing and are equipped with 25- to 100-horsepower electric motors or natural gas engines. Discharges range to more than 3,000 gallons per minute (gal/min) with specific capacities commonly between 20 to 50 gal/min/ft. Irrigation and municipal wells in the basin-fill deposits range up to 2,500 feet in depth, with capacities of up to more than 2,500 gal/min. Specific capacities commonly range between 10 and 40 gal/min/ft.

Transmissibility values computed from aquifer tests range from less than 5,000 to about 500,000 gallons per day (gal/d) per foot. The transmissibility of most of the materials is less than 50,000 gal/d per foot.

There are about 300 high-capacity irrigation, municipal, and industrial wells in the upper Santa Cruz River Basin. Most of the municipal and industrial wells are in the Tucson Basin. Gross pumpage in the upper Santa Cruz River Basin was estimated by the Geological Survey to be about 240,000 acre-feet in 1970. This consisted of an estimated 150,000 acre-feet pumped for irrigation and about 90,000 acre-feet pumped for municipal, industrial, and recreation purposes. Approximately 30,000 acre-feet were pumped by the mining industry. Estimates reported in 1972 by the Agricultural Experiment Station of the University of Arizona generally agree with the Geological Survey estimates of gross pumpage, but vary somewhat with respect to the distribution.

h. Quantitative Analysis

(1) Tucson Basin. The Geological Survey prepared a water budget in its Tucson Basin report covering the 1936-1963 period. This budget is presented below. All quantities are mean annual.

Surface Water	Acre-Feet
Inflow	68,000
Outflow	17,000
Infiltration	51,000
Ground Water	
Inflow	
Subsurface	17,800
Mountain front recharge	31,000
Infiltration	51,000
Sewage effluent return	7,000
Total	106,800
Outflow	
Subsurface	10,000
Evapotranspiration	15,500
Net pumpage	161,500
Total	187,000
Inflow minus Outflow (Ground-water depletion)	80,200

The Geological Survey estimates that in recent years the ground-water depletion has ranged from 30,000 to 100,000 acre-feet per year. With projected future increases in pumpage, depletions will probably increase proportionately. Current Central Arizona Project planning contemplates a delivery of about 100,000 acre-feet annually to the Tucson metropolitan area for municipal and industrial use. With proper management of the imported water and with the reuse of its return flows, the occurrence of short-term ground-water depletions in the future could be eliminated. Due to concentrated pumping, however, there will probably still be local areas of ground-water depletion.

(2) South of the Pima-Santa Cruz County Line to the International Boundary. Available data indicate that this area is nearly in a hydrologic balance. Although severe depletions in ground-water storage occur during dry periods, primarily in the Otero-Calabasas and Nogales areas, subsequent wet periods commonly replace most, if not all, of the past declines. Infiltration of surface water and recharge on the mountain fronts supply much of the recharge to both this area and the Tucson Basin.

2. Marana Area

a. Hydrogeology. Although the Marana area lies astride the Santa Cruz channel and flood plain, it is more geologically related to Avra Valley, a north-south trending, structurally controlled depression drained by Brawley Wash. The valley is underlain by basin-fill deposits composed of permeable lenses of gravel and sand interbedded with clay and silt. The maximum thickness of the deposits is estimated at about 2,000 feet. No detailed subdivision of the materials has been made.

b. Occurrence. According to the Geological Survey, there is a single unconfined body of water to a depth of about 700 feet. There is some evidence that below about 1,100 feet a confined water body occurs below a sequence of primarily fine-grained materials.

The ground water is recharged by infiltration from floodflows and sewage effluent from the City of Tucson and by subsurface inflow from the Upper Santa Cruz River Basin and Avra Valley. Although wet periods temporarily slow or halt the annual water-level declines, the area is already overdeveloped and overdrafts will continue over the long term.

c. Movement. Ground water in Avra Valley moves from the adjacent mountain areas toward the center of the valley and then in a northerly direction to merge with

the northward movement of water along the Santa Cruz River channel. The Marana area lies roughly at the confluence of this dual ground-water movement.

d. Depths. As of 1965, depths to water ranged from about 225 to 300 feet in the Marana area. The minimal depths to water occurred along the Pima-Pinal County line.

e. Pumpage. Extensive ground-water development in the Marana area began in about 1950. There are currently about 80 high-capacity wells in the area, generally ranging in depth from about 350 to 850 feet. The wells usually have 16- to 20-inch casing and are equipped with 50- to 125-horsepower electric motors or natural gas engines. Discharges range up to 3,200 gallons per minute, with specific capacities commonly between 60 and 125 gal/min/ft. Transmissibility values computed from aquifer tests range from about 70,000 to more than 200,000 gal/d/ft. Gross annual pumpage for irrigation in the Avra-Marana area is estimated to range between 120,000 and 160,000 acre-feet.

f. Fluctuations. Avra Valley and the Marana area are experiencing long-term water-level declines. During the 1955-1965 period, water levels declined from 40 to 60 feet.

g. Quality. Ground-water quality is excellent in the Marana area. The water is a calcium-sodium bicarbonate type with total dissolved solids concentrations of less than 500 mg/l.

C. Land Subsidence

Land subsidence has not, as yet, been documented by surveys. However, because of the direct historic correlation of subsidence to substantial water-level declines in Pinal and Maricopa Counties, there is good reason to infer that it is also occurring in the upper Santa Cruz River Basin. The Geological Survey estimates that land subsidence of from 1 to 3 feet has occurred, based upon the maximum water-level declines of 60 to 70 feet during the 1940-1964 period.

D. Water Utilization

From 1961 to 1970, approximately 1.5 million acre-feet of water were utilized annually within the United States portion of the Santa Cruz River Basin. This included about 215,000 acre-feet of surface water diverted from the Gila River at Ashurst-Hayden Diversion Dam for use on portions of the San Carlos Project lands located within the

lower Santa Cruz River Basin. Except for these diversions, the water supply was wholly obtained from ground-water sources.

Table 12 outlines the utilization of water within the Santa Cruz River Basin for the period of 1940 to 1970. As shown, the annual withdrawals of water in the area have remained relatively constant in total since 1949. However, a dramatic shift in the type of use has taken place as urban populations have continued to grow within the basin. For example, Table 13 shows that while irrigated acreage in Santa Cruz, Pima, and Pinal Counties declined from over 346,000 acres in 1960 to 290,600 acres in 1970, the population in the basin increased from 300,000 to nearly 400,000 in the same period. Most of the loss of agricultural acreage has been in the heavily pumped lower Santa Cruz area in Pinal County. The population increases are occurring mostly in Pima County, principally in the Tucson metropolitan area. Table 14 shows the estimated 1970 distribution of ground-water utilization in Santa Cruz Valley from the Cortaro area to the international boundary.

Natural water losses resulting from wetted streambeds, consumption by riparian vegetation, etc., are not considered to be large. Most streams in the basin flow only 10 to 15 percent of the time, are normally dry during the periods of maximum potential evapotranspiration, and have high infiltration rates. All these factors tend to minimize the time during which streamflow is exposed to diminishment by evapotranspiration. It is estimated that water losses in the Santa Cruz River Basin associated with phreatophytes, lakes, and ponds may range from 5,000 to 7,000 acre-feet per year. These uses occur at widely scattered locations, but are confined primarily to the main channels upstream from Tucson.

E. Water Rights

Rights to the use of surface waters in the Santa Cruz River Basin are of little significance in the development of resources. Since the river has only a limited streamflow, development within the basin has been based on local ground-water supplies. In accordance with provisions of the Arizona ground-water code, most of the developed portions of the area have been designated as critical ground-water areas. Such a declaration places severe limitations on the drilling of new wells in the area, but does not restrict or regulate the pumping of existing wells.

Table 12
ESTIMATED ANNUAL WATER UTILIZATION
IN THE SANTA CRUZ RIVER BASIN
San Pedro-Santa Cruz Project, Arizona

Unit: 1,000 Acre-Feet

Year 1/	Upper 2/ Santa Cruz GW Pumpage 4/	Avra Valley GW Pumpage 4/	Lower 3/ Santa Cruz GW Pumpage 4/	SW Diversions 5/	Total
1940	62	12	372	155	601
41	70	10	421	296	797
42	94	6	500	382	982
43	95	20	515	364	994
44	100	19	530	291	940
1945	106	23	610	202	941
46	109	23	660	85	877
47	136	34	700	69	939
48	135	38	950	73	1,196
49	132	48	1,100	263	1,543
1950	160	41	1,000	117	1,318
51	180	75	1,030	47	1,332
52	195	80	950	230	1,455
53	200	85	1,400	54	1,739
54	200	90	1,200	125	1,615
1955	200	95	1,200	115	1,610
56	200	100	1,100	74	1,474
57	200	110	1,100	79	1,489
58	175	120	1,200	273	1,768
59	165	130	1,200	160	1,655
1960	165	140	1,100	251	1,656
61	175	145	1,150	62	1,532
62	200	140	1,050	226	1,616
63	180	115	1,000	191	1,486
64	175	115	1,150	123	1,563
1965	200	125	910	138	1,373
66	190	95	915	305	1,505
67	200	121	1,120	264	1,705
68	210	134	910	314	1,568
69	236	155	1,043	307	1,741
1970	240	157	890	245	1,532
1961-70 Avg. 6/	200	130	1,015	215	1,560

1/ Ground-water pumpage on irrigation year, surface-water diversions on calendar year.

2/ Upper Santa Cruz area includes all United States upstream from near Rillito, Arizona; excludes all uses within Mexico.

3/ Lower Santa Cruz area includes all Santa Cruz River Basin below Rillito, Arizona, plus the southside Gila River drainage from Ashurst-Hayden Diversion Dam to the confluence of the Santa Cruz River with the Gila River.

4/ From "Annual Reports on Ground Water in Arizona," prepared by the Geological Survey, Phoenix, Arizona

5/ Diversions of water from the Gila River at Ashurst-Hayden Diversion Dam, from annual reports, "Water Resources Data for Arizona," Geological Survey.

6/ Averages rounded to nearest 5,000 acre-feet.

Table 13
COMPARATIVE POPULATION AND IRRIGATED ACREAGE
IN THE SANTA CRUZ RIVER BASIN
San Pedro-Santa Cruz Project, Arizona

	1960		1970	
	Population 1/	Irrigated Acres 2/	Population 1/	Irrigated Acres 2/
Santa Cruz County				
Nogales	7,286		8,946	
Other	3,522		5,020	
Subtotal	10,808	8,120	13,966	3,620
Pima County (excluding Ajo and Papago Divisions)				
Tucson	212,892		262,933	
Other	41,267		77,582	
Subtotal	254,159	52,100	340,515	55,500
Pinal County (excluding Florence, San Manuel, and Superior-Ray Divisions)				
Casa Grande	8,311		10,536	
Coolidge	4,990		4,651	
Other	23,228		22,327	
Subtotal	36,529	285,900	37,514	231,450
Santa Cruz Basin Totals	301,500	346,100	392,000	290,600

1/ Based on United States Census data divisions which lie wholly or mostly within the Santa Cruz River Basin.

2/ From "Arizona Agriculture," annual reports by the Arizona Crop and Livestock Reporting Service.

Table 14
ESTIMATED GROUND-WATER USE BY AREAS
IN SANTA CRUZ VALLEY IN 1970
San Pedro-Santa Cruz Project, Arizona

Unit: Acre-Feet

	Canada del Oro	Tucson & Environs	Sahuarita	Santa Cruz County	Total
Industrial	500	13,000	22,000	500	36,000
Municipal	2,000	71,000	14,000	1,700	88,700
Irrigation	34,500	13,000	43,000	17,000	107,500
Recreation	2,000	3,000	1,000	800	6,800
Total	39,000	100,000	81,000	20,000	239,000

Source: Agricultural Experiment Station Technical Bulletin 194, University of Arizona.

The City of Tucson, in its quest for added municipal supplies, attempted in 1971 to import ground water from the nearby Avra Valley into the Tucson Basin. This amounted to a transfer of water from one critical basin to another and was challenged in court by the water users of the Avra Valley. The litigation eventually reached the Arizona Supreme Court (Arizona Supreme Court Case #9488) which ruled in favor of Tucson, with the stipulation that Tucson purchase land in Avra Valley with an irrigation history and retire it prior to pumping. By 1972, the City of Tucson purchased 320 acres of which 307 had an irrigation history and acquired the right to pump up to 1,220 acre-feet per year from these lands. An additional 2,000 acres were subsequently purchased and a petition for the associated water right is currently under consideration.

F. Central Arizona Project

The Santa Cruz River Basin upstream from Tucson will be unaffected by the Central Arizona Project. Present plans call for a Central Arizona Project aqueduct to terminate just north of the City of Tucson, delivering approximately 100,000 acre-feet of Colorado River water per year. Plans also include diverting approximately 12,000 acre-feet annually via the Tucson Aqueduct from the authorized Charleston Dam on the San Pedro River.

Imports to Tucson will undoubtedly increase the ground-water inflow into the basin above the potential Sasco Reservoir as a result of return flows originating from supplemental Central Arizona Project water use. The greatest impact of the Central Arizona Project on the Santa Cruz River Basin will be the periodic replacement of former ground-water pumping with imported surface waters, thus reducing ground-water overdrafts and the resulting water-level declines.

G. Developable Water Supply

The only remaining developable surface-water supply left in the Santa Cruz River Basin occurs as periodic stormflows. The erratic nature of this type of runoff with its high sediment content and large channel infiltration losses, together with a lack of economic storage sites, makes the development of this water very costly and unattractive. However, controlling these flows could result in a reduction of losses en route to the ground-water basin.

Another potential source of supplemental water occurs in the populated areas of the Tucson Basin, where sewage effluent may be readily consolidated, treated, and reused.

This effluent is already being applied to certain uses. The international communities of Nogales, Arizona and Sonora, produce significant quantities of consolidated sewage effluent which may provide a further opportunity to satisfy portions of future demands. Currently, most of such treated water is returned to the ground-water basin, although some is probably lost to recovery.

1. Storage in the Red Rock Area. The construction of storage facilities at either the Sasco or Sawtooth sites could control the Santa Cruz River sufficiently to develop portions of the estimated 11,400 acre-feet per year of floodflows which occur on the river near Red Rock. Although portions of the floodflows in this area normally recharge the ground-water basin, significant amounts are lost either to evaporation or transpiration. In addition, not all of the water which recharges the ground-water basin can be practically recovered.

2. Storage near Nogales. The construction of a dam and reservoir across the Santa Cruz River on the United States side of the international boundary could control periodic flooding to conserve an estimated long-term annual average of 12,000 acre-feet of water. This water supply could be used in meeting the future municipal and industrial demands of the growing communities of Nogales, Arizona and Sonora. Here, also, uncontrolled floodwaters normally infiltrate the Santa Cruz ground-water basin and are partially used downstream.

The development of a Nogales Dam and Reservoir on the United States side would require an international endeavor. It would be particularly beneficial to the United States because Nogales, Sonora, will draw on greater quantities of its ground-water supplies as it grows, thus reducing underground and surface flow into the United States. Presumably, there will be a point in time when Mexico will wholly deplete the underground flow for its own use. It is also possible that Mexico could, in some future time, construct a dam and reservoir on the Mexican portion of the Santa Cruz River Basin to develop the remaining floodflows which occur. This would intercept virtually all flows into the United States, whether surface or underground. Therefore, each Nation's right to the Santa Cruz River must be established by an international agreement before more serious studies on Nogales Dam can be undertaken.

3. Sewage Effluent Reuse. As urban populations in the Santa Cruz River Basin have grown, the centralized handling and treatment of sewage have increased. During the 5-year period of 1966 through 1970, the volume of sewage effluent from the City of Tucson increased from about 22,000 to over 30,000 acre-feet per year. Estimates of projected population growth and water requirements indicate that by 1980 this volume will increase to about 47,000 acre-feet, and will more than double that by the year 2000.

In perspective, 30,000 acre-feet per year could support nearly 50 percent more people in Tucson without additional pumping from ground-water sources. If all this effluent could be put back into the local aquifer, the annual overdraft could be reduced by about 30 percent. However, the recycling of effluent for human consumption, although technically possible through tertiary treatment, desalting, etc., would be very expensive and is not readily acceptable to the consuming public at large.

Currently, the most practical approach attempted by Tucson is to achieve an exchange with irrigation pumping with sewage piped to irrigated areas and ground water substituted for M&I use. This type of exchange is a concept which deserves much more study and application throughout Arizona. Treated sewage effluent offers a satisfactory source for numerous industrial and agricultural water supplies, potentially freeing better qualities of water for municipal consumption. However, the cost of new conveyance facilities to effect the exchange may restrict the extent to which this can take place.

The effluent from the international communities of Nogales is being treated in a new international waste water treatment plant located in Arizona and designed to provide secondary treatment for about 9,200 acre-feet of effluent annually. The operation currently treats sewage from about 75,000 people. Projections indicate that the plant should suffice until about 1980. All treated effluent is released to the Santa Cruz River channel for infiltration downstream.

VIII. PLANS AND ESTIMATES–SANTA CRUZ RIVER BASIN

A. General

Because of the nature of the available surface water in the Santa Cruz River Basin, there is very little opportunity to economically develop the resources. Two areas were identified for possible development of the floodflows. These consist of potential storage facilities located near Red Rock in Pinal County or east of Nogales on the Santa Cruz River in Santa Cruz County.

B. Development Considered

1. Storage near Red Rock. Floodflows on the Santa Cruz River near Red Rock have affected lands within the Maricopa-Stanfield Irrigation and Drainage District and the Central Arizona Irrigation and Drainage District. Landowners in the historically flooded portions of these districts, recognizing the need for control measure, have formed the Greenes Reservoir Flood Control District and the Midway Flood Control District. Floods have also affected portions of the Maricopa Indian Reservation which lie within the boundaries of the Maricopa-Stanfield Irrigation and Drainage District.

In addition to spending sums of private money on channel and diking work, these districts have requested Federal emergency funds from the Corps of Engineers to assist their independently constructed flood protective works. There has also been a constant hope on the part of the districts that either the Corps of Engineers or the Bureau of Reclamation would construct a flood detention reservoir in the Red Rock area.

Several methods of partially controlling the recurring and destructive floodflows in the area are evaluated in this study. The alternatives examined involve the detention and orderly routing of floodwaters, utilizing the potential Sasco or Sawtooth Reservoir sites or both, as well as the possibility of diverting flows into the Corps of Engineers Tat Momolikot Reservoir on Santa Rosa Wash (currently under construction).

Proposals for controlling the flows of the river at Sasco or for diverting them into Santa Rosa Wash have been studied in the past by the Corps of Engineers. These earlier studies concluded that flood control development as then proposed was not economically justified.

The alternatives which were considered are briefly described in the following paragraphs. Each represents about the same scale of development in relation to flood protection and water supply developed.

a. Sasco Dam and Reservoir. This facility would be constructed across the Santa Cruz River just west of Red Rock, Arizona, at an estimated cost of about $20,352,000. The proposed 27,000-foot-long embankment would create a storage capacity of about 60,000 acre-feet allocated to conservation and flood control. Floodwaters would be stored in the conservation pool for later use, and flows in excess of this would be directed into the Greenes Wash area. The facility could provide protection against floods of up to the 100-year frequency. The reservoir, if empty at the beginning of the 100-year flood, could regulate it to a nondamaging discharge. If already full to the conservation level, the reservoir would suppress the 100-year flood peak of 91,800 ft^3/s to 24,000 ft^3/s. The magnitude of the 100-year occurrence would be characterized by a peak flow of about 91,800 ft^3/s and a volume of about 75,000 acre-feet. The flood study for Sasco Dam and Reservoir was approved by the letter from the E&R Center dated August 9, 1972.

The high cost of protection for the dam against a flood of severe proportions, as well as possible geological conditions in the form of local settlement cracks downstream from the right abutment area, are two areas which indicate the difficult engineering problems of this development.

b. Sawtooth Dam and Reservoir. This plan considers the construction of an 8-mile-long earthfill embankment near the Sawtooth Mountains in the Greenes Wash area. The facility would create an 80,000 acre-foot reservoir with storage allocated to conservation and flood control. A training dike would be required across the Santa Cruz River, and Greenes Canal would be modified to a capacity of about 50,000 ft^3/s to carry the flows to the Sawtooth Reservoir. The reservoir could be operated to control the 50-year frequency flood to a nondamaging flow of 7,000 ft^3/s. The 50-year flood developed for the Sasco Dam was used for the Sawtooth Dam and Reservoir flood evaluation. The 50-year flood had a peak of about 52,000 ft^3/s.

The cost of this plan is estimated at about $16,867,000.

c. Combined Plan. This plan would be a combination of a. and b. with any desired capacity in conveyance facilities. Floodflows would be routed through Sasco then through Sawtooth via Greenes Canal, and into Greenes Wash for disposition. With a combined system capacity of about 140,000 acre-feet, the complex would protect the area against a flood exceeding a 100-year frequency. The cost of this plan is estimated at $37,219,000.

d. Diversion Into Tat Momolikot Reservoir. The cost of diverting Santa Cruz River floodflows into the Corps of Engineers Tat Momolikot Reservoir (under construction) is estimated at about $10,555,000.

This scheme was considered with the construction of a 30,000 ft^3/s, 20-mile-long channel from the Santa Cruz River near the Sasco Dam site.

This plan could function only if capacity were available in Tat Momolikot Reservoir. For the most part floodflows in Santa Rosa Wash coincide with those in the Santa Cruz River only during major storms. Minor flooding could be handled with this scheme, but major floods would require the construction of added storage in Tat Momolikot which may not be economically justified.

2. Nogales Storage. The development of an international storage facility across the Santa Cruz River could provide about 12,000 acre-feet of floodwater annually for municipal and industrial uses in the area of Nogales, Arizona and Sonora. The earthfill dam would be constructed about 2-1/2 miles downstream from the international border, and the 50,000 acre-foot reservoir would extend into Sonora.

C. Project Facilities and Their Functions

1. Sasco and Sawtooth Facilities. These facilities (including their combined development) could provide water conservation, flood control, wildlife propagation, and recreation.

a. Water Conservation. The storage facilities would serve to regulate floodflows of the Santa Cruz River for their orderly disposition to the ground-water basin or for later use in direct irrigation diversions. It is estimated that a long-term annual average of 11,000 acre-feet could be available for diversion from Sasco or Sawtooth Reservoirs, effecting a like reduction in ground-water and pumping costs.

b. Flood Control. The potential storage facilities could significantly reduce flood damages within the project area. Either facility could contain nearly all of the predicted 25-year flood and significantly suppress the 100-year floodflow to an outflow of about 25 percent of the peak.

In combination, the storage facilities could suppress the 100-year floodflow peak of 92,000 ft^3/s to an outflow of about 7,000 to 10,000 ft^3/s.

In evaluating this function, Bureau of Reclamation flood hydrology was utilized, rather than Corps of Engineers' data, because higher order flood hydrology data were already available from the Bureau's "Sasco Design Flood Study."

c. Wildlife Propagation. Operation of either facility could provide opportunities for developing wildlife habitat. The peripheral areas of the reservoir could be allowed to develop the vegetative growth that normally accompanies shallow, periodically flooded areas.

d. Recreation. Recreation would be available in various forms. Upland game hunting could be enhanced by the increase in habitat along the shore of the reservoir. Because of the nature of the water supply and the type of reservoir operations, opportunities for traditional water-oriented recreation would be very limited, if not totally precluded.

2. Nogales Dam and Reservoir

a. Municipal and Industrial. The primary function of the potential Nogales facility would be to regulate the flows of the Santa Cruz River for the development of surface water for Nogales, Arizona, and Nogales, Sonora. Table 15 shows the estimated gross M&I water requirement for the twin cities through the year 2000. It is estimated that the operation of the potential Nogales Dam and Reservoir could provide a long-term average annual water supply of about 12,000 acre-feet to fulfill a portion of the future demand. The water supply, however, would not provide a sustained yield.

Table 15
ESTIMATED MUNICIPAL AND INDUSTRIAL WATER
REQUIREMENTS FOR THE CITIES OF NOGALES, ARIZONA-SONORA
San Pedro-Santa Cruz Project, Arizona

Unit: Acre-Feet

Year	Nogales Arizona	Nogales Sonora	Total
1980	2,200	7,600	9,800
1990	2,800	12,000	14,800
2000	3,400	19,000	22,400

b. Flood Control. Flood control would be incidental to the primary function. However, some minor benefits would be derived.

c. Fish, Wildlife, and Recreation. These functions would be minor due to the operation of the reservoir.

D. Designs and Estimates

The following presents a brief statistical data summary on each of the proposals selected for evaluation.

1. Sasco Dam and Reservoir

Dam:

Type	Earthfill Embankment
Length	27,600 feet
Approx. Height (max. section)	45 feet
Outlets Capacity	11,000 ft^3/s
Spillway Capacity	14,000 ft^3/s
Emergency Spillway	Fuse Plug Section

Reservoir Storage:

Storage Assignment	Allocation (acre-feet)	Accumulation (acre-feet)	Approximate Elevation (feet)
Inactive	5,000	5,000	1,743
Conservation	35,000	40,000	1,760
Flood Control	20,000	60,000	1,765
Surcharge	27,000		1,772

2. Sawtooth Dam and Reservoir

Dam:

Type	Earthfill Embankment
Length	41,000 feet
Approx. Height (max. section)	45 feet
Outlet Capacity	11,000 ft^3/s
Spillway Capacity	14,000 ft^3/s
Emergency Spillway	Fuse Plug Section

Reservoir Storage:

Storage Assignment	Allocation (acre-feet)	Accumulation (acre-feet)	Approximate Elevation (feet)
Inactive	5,000	5,000	1,600
Conservation	30,000	35,000	1,615
Flood Control	45,000	80,000	1,627
Surcharge			1,630

Greenes Canal Modification 50,000 ft^3/s

3. Santa Cruz River–Tat Momolikot Channel

10,000 ft^3/s System 1/
30,000 ft^3/s System 2/

Component:

Training Dike	2 miles
Greenes Canal Modification	10 miles
New Channel Construction Greenes Canal–Tat Momolikot Valley	10 miles
Structure Protective Device	Fuse Plug Section

1/ Capacity sufficient to divert all floods up to 5-year frequency magnitude, if storage available in Tat Momolikot Reservoir.

2/ Capacity sufficient to divert all floods up to 25-year frequency magnitude, if storage available in Tat Momolikot Reservoir.

4. Nogales Dam and Reservoir

Dam:

Type	Earthfill Embankment
Length	1,350 feet
Approx. Height (max. section)	95 feet
Operating Outlet	20 ft^3/s
Spillway	152,000 ft^3/s

Reservoir Storage:

Storage Assignment	Allocation (acre-feet)	Accumulation (acre-feet)	Approximate Elevation (feet)
Inactive (min.)	1,500	1,500	3,708
Conservation	23,500	25,000	3,753
Surcharge	25,000	50,000	3,773

E. Benefits

1. Conservation. Water developed in either Sasco, Sawtooth, or Tat Momolikot Reservoirs by the control of Santa Cruz River floodflows would have the same value as that assigned by the Central Arizona Project. However, since it can be viewed that this water would eventually enter the ground-water basin (except for an undetermined amount not recoverable due to losses, etc.), the cost of pumping may be considered to be the value of each acre-foot made available at the respective reservoirs. The current cost of pumping in the Central Arizona Project area is estimated at about 6 cents per acre-foot of lift. Assuming our average lift of 200 feet, the cost of pumping an acre-foot is estimated at about $12. The assignable annual benefits to any of the Red Rock storage alternatives are calculated at about $115,000.

2. Flood Control. The Corps of Engineers prepared preliminary flood hydrology and benefit estimates for application to Red Rock storage (Sasco and Sawtooth) and for the Nogales Dam site. These benefits were adjusted by the Bureau of Reclamation to reflect a lower "Standard Project Flood" base (a lower level of protection) for Sasco and Sawtooth. With protection against magnitudes of the 100-year and 50-year floods at Sasco and Sawtooth, respectively, computed annual equivalent benefits were estimated at $209,000 for Sasco Reservoir and $412,000 for Sawtooth Reservoir.

Flood control at the Nogales Dam is considered incidental. There are no significant areas below the dam subject to extensive flood damages. Preliminary Corps estimates indicate that about $5,000 in annual flood benefits could accrue from the operation of a reservoir.

3. Municipal and Industrial Water. Municipal and industrial benefits would accrue to Nogales Dam and Reservoir. Benefits are based on alternative non-Federal development and non-Federal financing over a 30-year period at 7 percent interest. The M&I benefits are calculated to be $898,000 as follows:

Construction Cost	$10,293,000
Interest During Construction	719,000
Investment Cost	$10,992,000
Annual Equivalent Cost, 30 years at 7.0 percent (.08059)	$ 886,000
Annual OM&R Cost	12,000
Total Annual Cost	$ 898,000 1/

1/ Annual benefits equal annual cost.

4. Wildlife. It was determined that the water supply for the three storage alternatives would not be sufficient for the propagation of fish. However, benefits would accrue from the enhancement of habitat for native wildlife. The Bureau of Sport Fisheries and Wildlife estimated wildlife benefits for Sasco, Sawtooth, and Nogales at $14,000, $65,000, and $25,000, respectively.

5. Recreation. Recreation benefits were not evaluated.

F. Economics

Table 16 presents economic analyses of each of the plans studied. The economic evaluation is based on a 100-year period of analysis and 6-7/8 percent interest. Cost allocation or repayment studies were not made.

The construction and operation of a Nogales Dam and Reservoir would probably be an international development with reimbursable cost obligations assignable to both the United States and Mexico. Feasibility investigations are not warranted until progress is made on an international agreement on division of the water of the Santa Cruz River.

Table 16
ECONOMIC ANALYSES OF VARIOUS PLANS EVALUATED
San Pedro-Santa Cruz Project, Arizona

	Sasco Dam and Reservoir	Sawtooth Dam and Reservoir	Santa Cruz River Tat Momolikot Channel	Nogales Dam and Reservoir
Costs: (1973 level)				
Construction Cost	$20,352,000	$16,867,000	$10,555,000 1/	$10,273,000
I.D.C.	1,425,000	1,181,000	739,000	719,000
Total Federal Cost	$21,777,000	$18,048,000	$11,294,000	$10,992,000
Annual Equivalents:				
Annual Cost				
Cost amortized 100 yrs @ 6-7/8%	$ 1,498,000	$ 1,241,000	$ 777,000	$ 756,000
Operation and Maintenance	12,000	18,000	16,000	12,000
Total Annual Cost	$ 1,510,000	$ 1,259,000	$ 793,000	$ 768,000
Annual Benefits				
Conservation	$ 115,000	$ 115,000		
Flood Control	209,000	412,000	$ 289,000 2/	$ 5,000
Wildlife and Recreation	14,000	65,000	Undetermined 3/	25,000
M&I Water			3/	898,000
Total Annual Benefits	$ 338,000	$ 592,000	$ 289,000	$ 928,000
Benefit-Cost Ratio	0.22:1.00	0.47:1.00	0.36:1.00	1.14:1.00

1/ Understated as cost of incremental storage required in Tat Momolikot Reservoir is not included.
2/ Bureau of Reclamation estimate based on Corps of Engineers' data.
3/ As may accrue from Tat Momolikot.

IX. ENVIRONMENTAL ASPECTS

IX. ENVIRONMENTAL ASPECTS

A. General

The proposed project areas would include the Sonoran Desert and mountain ranges. The environment and climate of the San Pedro and Santa Cruz River Basins are similar and contain comparable biota. Detailed environmental impact studies have not been conducted in these basins. Additional environmental studies would be part of any future planning in the area.

The proposed Charleston Dam and Reservoir on the San Pedro River were authorized as a part of the Central Arizona Project. The construction, operation, and maintenance of these facilities will have impacts on the environment of the basins.

B. Beneficial and Adverse Effects

1. Water Quality. The water quality of the San Pedro River Basin is considered excellent with an average total dissolved solids of about 300 mg/l. The chemical quality of the water in the Santa Cruz River Basin is good but carries high silt loads during periods of high flow. River control facilities would contain the silt loads and have little effect on the chemical quality of the water.

2. Streamflow Regimen. Major changes in the river systems would result from the operation of river control works. On the Santa Cruz River, storage facilities at either Red Rock or Nogales would significantly reduce the periodic uncontrolled flooding of vast agricultural areas, and facilitate the infiltration of surface flows into the ground-water basin. The river channel below the potential dams would be dry for longer periods than under present conditions. This would adversely affect the riparian vegetation in the area which now depends upon periodic flooding.

3. Impacts on Plant and Animal Life. Storage facilities on the Santa Cruz River near Red Rock would enhance wildlife populations, since riparian habitat could be established. No significant impact on the native biota below the facilities is anticipated, since the lands are agricultural areas and no change in land use is anticipated.

The potential Nogales Dam and Reservoir, however, would have adverse effects on the downstream biota because the reduced flows below the dam would result in the loss

of riparian vegetation now dependent upon periodic floodflows. The small wildlife inhabiting the vegetation would consequently be displaced or lost.

There are several species in the area that are on the official "United States List of Endangered Native Fish and Wildlife." 1/ These species are the Gila topminnow, the masked bobwhite, the Mexican duck, the Southern bald eagle, and the American peregrine falcon. The actual use of the area by these species and the possible effect the proposed project would have on them are unknown. More data would be collected if additional studies are made.

The inundation of the river channel by the potential reservoirs would destroy riparian habitat and cause the displacement of animals. The lakes formed by the project could provide potential sport fishing in an area that presently has none.

4. Archeological Sites. The Arizona State Museum, University of Arizona, conducted an archeological survey in part of the San Pedro River Basin in connection with the investigations of the Central Arizona Project. This study identified numerous sites in the area. It is probable that the Santa Cruz River Basin also contains many archeological sites. These sites indicate a long and diverse use by man. Complete archeological surveys would be conducted as required as part of any future studies.

5. Esthetics and Construction Scars. Clearing, blasting, and earthmoving would be required during construction of project features and would adversely affect the esthetic quality of the area. After completion of construction, all supplies and equipment not required for operation would be removed and roads not required for operation and maintenance would be returned to as near preconstruction condition as practicable. Any borrow or fill areas required for construction would be contoured to blend with the surrounding area.

The esthetics of the area would be changed by the addition of dams and lakes.

6. Human Environment and Economy. There is very little water-oriented recreation available within these basins. The project would provide a limited amount of water-oriented recreation and fishing. The economy of the area would benefit through increased tourism. The flood control features of the project would be beneficial to both the ecology and

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1/ Federal Register, Vol. 35, No. 199 (Tuesday, October 13, 1970), pp. 16047-16048, plus amendments.

the economy of the area. The ecology would benefit by less disruptions to the habitat from flooding, and the economy would save expenses for cleanup and replacement caused by floods. The water storage features of the project could help reduce the overdraft of ground water pumped in the Santa Cruz River Basin.

C. Draft Environmental Statement

Should additional studies be authorized, there would be coordination with Federal, State, and local agencies which have delegated jurisdiction and environmental expertise. A draft environmental statement would be prepared in accordance with the National Environmental Policy Act.

X. CONCLUSIONS

X. CONCLUSIONS

A. San Pedro River Basin

There are no immediate water-related problems in the San Pedro River Basin other than those associated with the division of the San Pedro River flows between the United States and Mexico. A treaty with Mexico would be required to establish a limitation on the depletion of the San Pedro River in Mexico. The current ground-water supplies appear to be of sufficient quantity to sustain the basin's estimated short-term growth and offer the most economic future water source. Alternative water supplies are available and may be developed as the more economic supplies dwindle.

Currently only minor flood damage occurs along the San Pedro River and flood control does not appear imperative. Charleston Dam and Reservoir, authorized as part of the Central Arizona Project, will remove much of the remaining flood threat.

B. Santa Cruz River Basin

Although the potential features investigated in this basin have some merit, they are currently unjustified.

The Nogales Dam and Reservoir, on the other hand, offer the most optimistic development potential, lacking only political accord as a joint international development. Underwritten by both countries, the development could feasibly develop supplemental municipal and industrial water supplies for the sister communities of Nogales.

This report does not recommend any of the developments for the Santa Cruz River Basin at this time. Since the surface water resources of the basin are almost wholly used, it appears that the best course of action would be to improve resources management practices and to concentrate on import possibilities.

APPENDED MATERIAL

SRP06703

UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
BUREAU OF SPORT FISHERIES AND WILDLIFE
522 North Central Avenue - Room 247A
Phoenix, Arizona 85004

August 14, 1970

Memorandum

To: Assistant Regional Director, Bureau of Reclamation
Phoenix Development Office, Phoenix, Arizona

From: Acting Field Supervisor, Division of River Basin Studies

Subject: San Pedro-Santa Cruz Project, Arizona--Sasco Reservoir

The Arizona Game and Fish Department and this office have reviewed the project plans for a proposed Sasco Reservoir as a potential development in conjunction with the subject project.

From information contained in your May 6, 1970 memorandum, transmitting a map and area-capacity curve, along with information received from Messrs. Hong Wong and David Creighton of your office, the following preliminary evaluation benefits have been derived.

Man-day and benefit figures are maximum, assuming optimum conditions. It is expected that it may be 20 years after construction that the maximum potential will be reached. The man-day figures, estimated by the Arizona Game and Fish Department, are for the total reservoir area, with about 2,000 surface acres within the 1,750 feet elevation being assumed as prime dove and quail habitat.

The total reservoir area is expected to produce 250,000 doves annually, providing 8,000 man-days of hunting per year, with an annual benefit of $12,000. Resultant habitat for quail would be expected to provide 500 man-days of quail hunting annually, with a benefit of $1,000.

Borrow pits excavated within the reservoir area's flood pool, up to 5,000 acre-feet of potential water, should provide habitat for waterfowl, providing 300 man-days of hunting, resulting in an average annual benefit of $900.

When and if the plans for Sasco Reservoir are modified or finalized, the Arizona Game and Fish Department and this office would be pleased to furnish reevaluated estimates. The cooperation of your office is appreciated.

Donald W. Welch

DEPARTMENT OF THE ARMY
LOS ANGELES DISTRICT, CORPS OF ENGINEERS
P. O. BOX 2711
LOS ANGELES, CALIFORNIA 90053

SPLED-PB

3 March 1971

Mr. C. A. Pugh
Projects Manager
Phoenix Development Office - Region 3
U. S. Bureau of Reclamation
135 N. Second Avenue
Phoenix, Arizona 85003

Dear Mr. Pugh:

In reply to your letter of 12 January 1971 file 314-730/123.8b, the information on the Sasco (Red Rock) Dam is provided.

The overflow areas considered extend from the confluence of the Santa Cruz River and Greene Canal to the Santa Cruz Wash, about 2 miles downstream of the town of Maricopa, Arizona. The estimated nondamaging discharge is 7,000 cubic feet per second.

The projected future values of property were based on the Office of Business Economics and Economic Research Service (OBERS) regional annual increase of personal income. For residential, commercial, and public property values, a projected increase of 2.6 percent per year was applied for the first 50 years (1970-2020) and a projected increase of 1.3 percent per year was applied for the second 50 years (2020-2070). For industrial property values, a projected increase of 3.0 percent per year (1970-2020) and 1.5 percent per year (2020-2070) were used. No escalations were used for crops, utilities, railroads, highways and bridges.

Damage-discharge curves are shown on plate 1 (inclosure 2). The damage-discharge and damage-frequency curves for 1970, and an outlet release of 10,000 cubic feet per second at Sasco Dam are drawn on plate 2 (inclosure 2). The areas under the damage-frequency curves represent the estimated flood damages undiscounted - column 4 in table 2 (inclosure 1).

SPLED-PB
Mr. C. A. Pugh

3 March 1971

The equivalent average annual benefits for each outlet release were determined by bringing the estimated average annual benefits back to present worth (1970) at the interest rate of 5-1/8 percent, and are given in table 7.

The estimated average annual benefits and the equivalent average annual benefits for two outlet releases are shown on plate 3 (inclosure 2).

Table 7

Estimated equivalent annual benefits under average future condition for various flood releases - Sasco Dam, Arizona.

Flood releases cfs	Average equivalent annual benefits
7,000	$690,000
10,000	550,000
15,000	350,000
32,000	100,000
45,000	55,000
55,000	23,000

We are also inclosing the preliminary data for the standard project flood hydrograph of the Sasco (Red Rock) Dam (inclosure 3). If you desire further information, please contact Mr. Claude Wong (213) 688-5449.

Sincerely yours,

EDWARD KOEHM
Chief, Engineering Division

3 Incls
As stated

ATTN: DAEN-CW

STATUS REPORT - SURVEYS
(Reports Control Symbol ENGCW-P-6 (R-1))

Name of Study: Santa Cruz River Basin, Gila River, Arizona and New Mexico (Interim Report)

Effective Date: 31 Dec 1972

Class: Flood Control Studies
District: Los Angeles

Division: South Pacific

1. Authorization. Survey on Gila River and Tributaries, Arizona and New Mexico, authorized by the Flood Control Act of 28 June 1938.

2. Public Contacts. The initial public hearing and an environmental public hearing were held in Tucson, Arizona, on 25 May 1966 and 11 June 1970, respectively.

3. Inter-Agency Coordination. A meeting was held in Phoenix, Arizona, on 20 July 1966 between members of the Corps of Engineers and U.S. Bureau of Reclamation (USBR). A plan of investigation was agreed upon which indicated the studies to be undertaken by the Corps of Engineers and those to be undertaken by the USBR in order to avoid duplication of studies and to coordinate studies requiring joint efforts. The study of detention basins, channels, etc., requested by local interests at the public hearing, would be the primary responsibility of the Corps of Engineers; the multipurpose project in the Red Rock area would be the primary responsibility of USBR.

4. Problems and Solutions.

a. The Santa Cruz River basin has an area of about 8,600 square miles. The major part of it lies in Pinal, Pima, and Santa Cruz Counties in southern Arizona, and a small part lies in the State of Sonora, Mexico. The primary problems are water conservation and flood control. The area as a whole is drawing on the underground water supply considerably faster than the supply is being replaced. Recent floods occurring in 1955, 1962, 1964, 1965, and 1967 have caused large damages to agricultural property, crops, transportation facilities, and business property throughout the basin. Urban development of high value has recently been constructed in areas previously used for agriculture in the flood plain of the Santa Cruz River and its tributaries, and the indications are that this will continue to happen thereby increasing the flood hazard.

b. Local interests request the construction of (1) channel improvements on Rillito Creek or detention dams on its tributaries - Tanque Verde, Pantano Wash, and Sabino Canyon; (2) a dam on the Santa

REPORT DEFERRED UNTIL FUNDED UNDER GILA RIVER AND TRIBUTARIES, ARIZONA AND NEW MEXICO STUDY

Name of Study: Santa Cruz River Basin, Gila River, Arizona and New Mexico (Cont'd)

Cruz River south of Tucson; (3) a dam at Sasco (Red Rock); (4) channel improvements on Canada Del Oro and on Santa Cruz River in Tucson; and (5) multipurpose and flood control dams in Santa Cruz County on the main stem of the Santa Cruz and its tributaries. In addition, a study for a dam at Three Points on Brawley Wash and a dam on McClellan Wash will be made.

5. Progress to Date on Field and Office Studies.

a. Plan of survey was submitted to SPD in February 1968 and approved by OCE on 3 October 1968. Alternative plans for Rillito Creek consisting of dams and channels improvements were presented to the Pima County Board of Supervisors and City Council of Tucson at a meeting held on 12 December 1967. Flood-hazard information on Rillito Creek was developed and supplied to Pima County Engineer on 11 June 1968. Alinement of an earth-bottom channel for Rillito Creek to contain a 50-year flood and flood plain management for a 100-year flood was favorably received by the Pima County Board of Supervisors at a meeting held on 29 January 1969 in Tucson. Phase I conference for Rillito Creek and the Santa Cruz River at Tucson was held on 5 February 1969. The Pima County Board of Supervisors were informed in a letter dated 17 September 1969 that LAD could see no advantage to an interim report and that the Rillito Creek study would be included as part of the Santa Cruz River basin report. Hydrology study for Rillito Creek was approved by SPD on 23 March 1970.

b. Phase I conference for the Santa Cruz River basin was held on 8 October 1969. Phase I studies concluded that channel improvement and dams located on tributaries of the Santa Cruz River are not economically justified. The cooperative study for a multipurpose reservoir on the Santa Cruz River at Red Rock (Sasco) was coordinated with USBR. Preliminary flood control benefits and hydrological data were furnished to USBR on 4 June 1960 and preliminary economics and hydrology for Nogales Dam on the Santa Cruz River on 18 March 1970. Channel improvements for the lower Ephriam Canyon, Nogales, Arizona, would appear qualified under Section 205 of the 1948 Flood Control Act as amended. However, local interests are not able to provide the local assurances at the present time. A meeting was held on 9 January 1970 in Tucson with local interests to consider channel improvements for about 4.0 miles of the Santa Cruz River through the model neighborhood. Phase II conference on Rillito Creek and review of tangible benefits for the Santa Cruz River through the model neighborhood at Tucson was held on 17 March 1970. Hydrology study for Santa Cruz River at Tucson was approved by SPD on 27 January 1971. Flood control benefits based on partial control of the standard project flood at the Sasco (Red Rock) Dam was provided to USBR on 3 March 1971.

c. A program along Rillito Creek providing a 50-year channel and flood plain management between the 50-and 100-year flood levels appears the optimum plan for that stream. The Pima County Board of Supervisors adopted a resolution on 3 April 1972 supporting the program and agreeing to the items of local cooperation.

6. Proposed Schedule of Operations. Funds for this study are exhausted. Up to now, such funds were received from USBR as part of their San Pedro-Santa Cruz study. USBR program is being terminated and no funds are programmed for the Corps. Los Angeles District is
* requesting capability funds to continue the interim report on Rillito Creek under the Gila River and Tributaries, Arizona and New Mexico study in FY 1974. Required work will include finalizing plan and preparation of draft report and environmental impact statement.

7. Presently Approved Schedule of Submission by District and Division Engineers.

	Dates of Submission	
	Scheduled	Actual
District	Indefinite 1/	
Division	Indefinite 1/	

1/ See paragraph 6, above.

8. Other Matters. This investigation is being conducted concurrently with and coordinated with the feasibility study for San Pedro-Santa Cruz Rivers now under preparation by Region 3, USBR.

9. Fiscal Status.

Total Study	
Approved Federal cost estimate	$456,800
Allowance to date	456,800
Balance to complete	$ 0
Current Fiscal Year	
Available for obligation	$ 910 1/
Obligations, fiscal year to date	0
Contracts awards included above	($0)
Estimated unobligated balance 30 June 1972 . .	$ 0
Suggested Funding Adjustment	
Revocation	$ 0
Additional work allowance required	$ 0

1/ U.S. Bureau of Reclamation funds.