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ARIZONA STREAM NAVIGABILITY STUDY
for the
SANTA CRUZ RIVER
Gila River Confluence to the Headwaters

Final Report

Prepared by:

SFC Engineering Company

In Association with
George V. Sabol Consulting Engineers, Inc.,
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SWCA, Inc. Environmental Consultants,
University of Arizona Water Resources Research Center,
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November 1996

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Santa Cruz River
03-002-NAV 019

SANTA CRUZ RIVER FINAL REPORT

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PREFACE

This report was prepared under contract to the Arizona State Land Department Drainage & Engineering Section. The report summarizes factual information relating to the navigability of the Santa Cruz River as of the time of statehood, from its confluence with the Gila River to its headwaters. Information presented in this report is intended to provide data to the Arizona Navigable Stream Adjudication Commission (ANSAC) from which ANSAC will make a decision regarding the navigability of the Santa Cruz River. This report does not make a recommendation or conclusion regarding title navigability of the Santa Cruz River.

The report consists of several related parts. First, archaeological information for the Santa Cruz River Valley relating to river uses is presented to set the long-term context of river conditions and river uses. Second, historical information from the periods prior to and including statehood are discussed with respect to river uses, modes of transportation, and river conditions. Oral history information for the river is also presented. Third, a review of geologic influences on stream flow and river conditions is also presented. Fourth, historical and current land use information are described and presented in a GIS format. Fifth, historical and modern hydrologic data are summarized to illustrate past and potential flow conditions in the river.

The 1997 Santa Cruz River Navigability Study was performed by a project team consisting of SFC Engineering Company (SFC) in association with George V. Sabol Consulting Engineers, Inc. (GVSCE), JE Fuller/ Hydrology & Geomorphology, Inc. (JEF, Inc.), SWCA, Inc., Environmental Consultants (SWCA), the Arizona Geological Survey (AZGS), and the University of Arizona Water Resources Research Center (U of A WRRC). This study was completed on behalf of the ASLD (Contract # A5-0092) as directed by Arizona Revised Statutes §37-1124. Project staff included V. Ottozawa-Chatupron, ASLD, Project Manager; George V. Sabol, SFC, Project Principal; P. Deschamps, SFC, Project Co-Manager; J. Fuller, JEF, Inc., Project Co-Manager; R. Borkan, SWCA, team leader; D. Gilpin, SWCA, historian; D. Greenwald, SWCA, archaeologist; M. Cederholm, SWCA, GIS specialist; P. Pearthree, AZGS, team leader and geomorphologist; M. L. Wood, AZGS, geomorphologist; P. K. House, AZGS, geomorphologist; B. Tellman, U of A WRRC, historian;

and R. Yarde, U of A WRRC, historian. This report was revised in 2004 by JE Fuller/Hydrology & Geomorphology, Inc. under contract # LDA-04-0564.

EXECUTIVE SUMMARY

The State of Arizona received sovereign title to the beds of navigable rivers located within state boundaries, as of statehood on 14 February 1912, under the Equal Footing Doctrine. From statehood until the mid-1980's, Arizona claimed only the bed of the east half of the Colorado River, and failed to act on all other claims of streambed ownership. In early 1994, House Bill 2589, amending Arizona Revised Statutes §§37-1101 through 37-1156, was adopted. HB 2589 sets the criteria to be used for determinations of navigability and non-navigability. HB 2589 requires the Arizona Navigable Stream Adjudication Commission (ANSAC) to set priorities for investigating and conducting hearings on watercourses within this state and then to report its recommendations as to which watercourses or reaches of watercourses were navigable or non-navigable as of statehood to the Legislature. The Legislature then makes a finding upon consideration of the ANSAC recommendation and enacts appropriate legislation in response to the determination.

A.R.S. §37-1101 (6) sets out the definition of "navigable" or "navigable watercourse" to be used to address the ownership of streambeds. That definition is:

> "Navigable" or "navigable watercourse" means a watercourse, or a portion or reach
> of a watercourse, that was in existence on February 14, 1912, and at that time was used or was susceptible to being used, in its ordinary and natural condition, as a highway for commerce, over which trade and travel were or could have been conducted in the customary modes of trade and travel on water."

The data collection effort for this study provides information that will assist ANSAC in determining if a given river meets the criteria of the statutory definition.

The following is a summary of the key findings of the following sections of this report addressing the archaeology, history, hydrology, hydraulics, geomorphology, and land use of the Santa Cruz River from the confluence with the Gila River to the headwaters. Refer to Figure 1 for a map of the Santa Cruz River basin showing the location of the place names mentioned in the text. The most pertinent findings relative to the legislatively mandated evidence of navigation or evidence of susceptibility to navigation are compiled to provide information to support a determination by others of navigability or non-navigability of the Santa Cruz River. This report does not make a recommendation or conclusion regarding title navigability of the Santa Cruz River.

Evidence of Navigation

Archaeological Evidence

Archaeological data augment the historical record of potential river uses at statehood by providing an extended record of river conditions, use of river water, climatic variability, and cultural history along the river. The investigation of the archaeological record focused on prehistoric uses of the river as evidenced by settlement patterns, the presence of canals for irrigated agriculture, and transportation and/or trade routes on or along the river.

Settlement Patterns - The archaeological literature documents prehistoric settlements distributed both temporally and spatially throughout the Santa Cruz River valley. Late Archaic sites (2000 - ca. 100 B.C.) were located in floodplains, areas adjacent to floodplains, or alluvial fans. During the Archaic-Hohokam transitional stage (ca. 50 B.C.- A.D. 425), settlement patterns, consisting of agricultural hamlets in floodplain settings and camps in bajada areas, reflected a subsistence strategy based on floodwater farming of maize, hunting, and foraging in the bajada and upland zones. During the Hohokam Pioneer period/late Early Formative period (A.D. 425 - 750), the Hohokam emerged as a regional culture with the Tucson Basin becoming a local node in the Hohokam regional system.

Shifts in settlement patterns through time are evident. By the end of the Hohokam Colonial period (A.D. 750 - 950), an expanding population settled most villages along secondary rather than primary drainages of the Santa Cruz River in the Tucson Basin. Settlement locations further shifted away from floodplains during the late Hohokam Sedentary period (A.D. 950 - 1150) partly due to entrenchment - progressive degradation of the streambed - and cienega - marsh - formation. As a result, non-riverine agricultural features began to appear on terraces and bajadas. There was continued use of non-riverine agricultural systems as well as floodwater farming during the Hohokam Classic period (A.D. 1150 - 1400).

Irrigated Agriculture - Prehistoric populations took advantage of potential agricultural areas as conditions allowed, partly because the floodplain environment of the river was highly variable. Arroyo fan deltas and discontinuous gully fan environments had floodwater agricultural potential and Hohokam settlers appeared to locate in those areas for the purpose of optimizing farming conditions.

Certain archaeological investigators suggest that the floodplain environment and surface hydrology of the river was not conducive to canal irrigation, but limited canal or ditch irrigation would have been feasible near cienega environments. Others believe that canals may have been present on a small scale, possibly in association with the primary villages. In fact, recent archaeological findings indicate farming villages near Tucson were using surface water to irrigate crops as long as 2000 to 3000 years ago. These same people supplemented their diet with fish caught from the river. More recently, 300 to 400 years ago, Indians were still irrigating crops with surface water near Tucson, San Xavier, and Tubac. This practice continued during the period of the development of the Spanish missions of southern Arizona and well into the period of Anglo settlement.

Transportation and Trade - The archaeological record indicates that the Tucson Basin became a local node in the Hohokam regional trade system. Interregional exchange is evident by the presence of Mogollon ceramics from the mountainous regions to the east and by shell artifacts from the Sea of Cortez. Further, the Santa Cruz River was the line of communication for the dissemination of new types of pottery, notably, Rincon polychrome vessels among others. Vessels of this type were found at the north and south extremities of the river. The river valley functioned as a communication, transportation, and trade corridor in prehistoric times. No evidence was found to suggest that the early inhabitants of the valley used boats on the river.

Historical Summary

Historical data provide information on actual river uses at the time of statehood, and also provide information on whether river conditions would have supported navigation. The historical investigation focused on use of the river and adjacent areas in historic times, with special emphasis on the establishment, growth, and development of towns, irrigation systems, commercial activities, and developments.

During the historical period, the Santa Cruz River was an important transportation route for Native Americans, missionaries and Spanish explorers, colonizers and wanderers, miners and cattlemen, and new residents. It provided a well established route from the south and the east into present-day Arizona as far as Tucson, providing water, forage, and food for the traveler. The river also provided water, wood, food, and shelter for the people who lived near it. Farmers diverted the surface water of the river. Millers, both of flour and ore, powered their grinders with Santa Cruz water. Entrepreneurs dammed the river, and the lakes that were created were used by the public for fishing, boating, picnicking, and swimming. Much of the settlement in southern Arizona, to date, is within the valley of the Santa Cruz River.

Probable Condition of the River in 1912 - At the time of statehood, the river was probably still perennial - flowing year round - in some of the reaches that had historic surface flow, but intermittent - flowing only during portions of the year - in more areas than previously. An important difference was that the vegetative structure of the valley was much different, and the entrenchment - the progressive degradation of the streambed - of the river meant that surface waters visible in 1912 were much lower than 25 years earlier. In many areas riparian vegetation had been cut for wood or lumber, and farms or homes used much of the water riparian trees had formerly used.

The U.S. Geological Survey Streamgage Summaries report that essentially the entire flow of surface waters from the river were diverted both at the Nogles and Tucson gaging stations by irrigation ditches (USGS 1907, 1912). Agricultural water use in the Tubac, Tucson, and San Xavier areas used most of the available surface water and also intercepted groundwater and subsurface flow. Diversions and pumping also diminished flows on tributaries, especially the Rillito River. In 1910, the University of Arizona

Agricultural Experiment Station estimated that flow from the Rillito River reached the Gila River 1 in 15 years (Smith, 1910).

The upper reach of the Santa Cruz River, located in Santa Cruz County, has its headwaters in the San Rafael Valley of southeastern Arizona. Historically, the river consisted of shallow flows similar to present conditions. The river through Mexico still flowed dependably. From the border downstream to the Sonoita Creek confluence, the Santa Cruz River was dry much of the time because of diversions. With the addition of Sonoita Creek waters downstream of the confluence, there was again surface flow visible in the river. Much of that water was diverted for agriculture along the river downstream of Calabasas to the north.

The middle Santa Cruz River reach is defined as that portion of the river located in Pima County. In this reach, the springs were drying up in the San Xavier area and diversions and pumping took most, if not all, the flow. A high water table still supported a lush mesquite bosque south of the mission. The City of Tucson and many others had dug wells in numerous locations, some as far south as San Xavier, which intercepted flow and lowered the groundwater table. In 1915, the first year such measurements were systematically taken, the Santa Cruz River and the Rillito River flowed less than half the year. Through Tucson the deeply entrenched channel carried some flows, but all of the low flow was diverted before the Congress Street bridge. Springs and groundwater still supported some agriculture downstream of Tucson, but there was little perennial flow.

The lower Santa Cruz River, in Pinal County downstream of Marana, continued to have little flowing water except in years of high rainfall.

Navigation Accounts - Although the river valley was an important transportation route, it was not normally used for navigation except for the following accounts found in the literature:

- A land speculator portrayed the river at Calabasas (downstream of Nogales) as capable of floating steamboats in the 1880s. This, however, was pure fiction but gave rise to the belief that surfaces, occasionally even today, that the river was navigated by large ships.

- During the 1880s, Silver Lake (a manmade lake just south of downtown Tucson on the Santa Cruz River) was a popular recreation area, featuring boating, fishing and swimming. A paddle boat on the lake was a major attraction. Boating both by rowing and sail was popular in the lake and upstream. Silver Lake was damaged by a combination of floods in the late 1880's, and finally destroyed in 1890. The dam itself was reported standing until the floods of 1900. Based on the limited information available, other conditions (possibly the increase in other water diversions) made the existence of a reservoir behind the dam impossible.

- In December 1914, during a flood period, a group of adventurers attempted to float the Upper Santa Cruz River, but were grounded. The boat was later located buried in mud. Also in the 1914 flood, numerous people were stranded on rooftops and windmills near Sahuarita. The Arizona National Guard went to rescue them with an inflatable boat, but the current was too strong and the effort was unsuccessful. Later the people were rescued with horses.

- Occasionally, in recent times, a canoer or rafter has floated the river during flood time. Tubers floated the Santa Cruz River in the 1970s during flood time. The Tucson Weekly featured a canoer traveling the effluent-dominated stretch in July 1990, a trip which he repeated during flood time for the Tucson Weekly photographer. The Tucson Citizen reported canoes on the Rillito River during the 1990 flood. The same canoers have also traveled on the Santa Cruz and Agua Caliente at various times in the 1990s. These canoers stated that when they also traveled the river during the winter of 1989-90, it was "a reasonable canoeing river", but when they made the trip in the summer, it was "more like the Grand Canyon" in terms of difficulty. They are knowledgable with regard to local boating groups, but are unaware of any attempts to boat the upper Santa Cruz River, although they state that it is certainly feasible. Canoers state that the Santa Cruz is just barely navigable by canoe with 4" of water, but that the channel topography is a limiting factor as sand bars are frequent.

- There are no stories of boating at any time on the lower Santa Cruz, although during one high flood event Tucsonan Sam Hughes expressed, in his opinion, that the river was "big enough to float a steamboat all the way to the sea."

- There are no records of ferry service anywhere on the river. Fords and crossable washes are marked on numerous maps. When the bridges went out during floods, people were stranded and had to wait until the river could be crossed by horse. No evidence of boats being used to cross the river at flood time were found.

- No evidence was found of the river being used to transport goods such as logs.

- John Spring recorded in his diary that there was an old Mexican settler who had carved a canoe to cross the upper Santa Cruz River when flooding made it too high to cross on the road. According to Spring, this is the origin of the name for that area of the Santa Cruz Valley, "La Canoa."

Changes in the River - The three distinct sections of the river had very different histories. The upper and middle reaches, located in Santa Cruz and Pima Counties respectively, were used extensively by native peoples, Spaniards, and later Americans. The lower reach, located in Pinal County, had much less dependable water and was used much less. Because of underlying geology and the fact that population eventually centered in the Tucson area, the middle Santa Cruz experienced much more extreme changes than either the upper or lower sections in terms of location of perennial flow.

Some portions of the river remain perennial to this day. Other reaches north of Nogales and Tucson have more water now than they did at the time of statehood due to wastewater effluent flow. Many of the perennial sections of the river, however, have been lost. The perennial waters near San Xavier persisted until 1949, and supported native fish until at least 1937. The section of the river near Tucson probably had some perennial flow in 1912, but at this time the river was deeply entrenched. Therefore, the water table was already lower than it was before entrenchment began after the floods of 1890. The United States Geological Survey kept data on streamflow at certain measuring points on the Santa Cruz River. By 1910, it was reported that the entire base flow of the river at both the Mexican border, and near the Congress St. Bridge in Tucson, was diverted for agriculture.

The upper Santa Cruz River in Santa Cruz County, including the headwaters in the San Rafael Valley, has been relatively stable. Perennial flow existed in many places here, as well as some cienegas. The geology changes north of Tubac, and the river frequently went subsurface there throughout history, as it presently does. However, the historical perennial reaches at San Xavier and Tucson are gone.

The lower Santa Cruz River in Pinal County never supported perennial flow. In fact, it was only during rare flood events that water from the upper Santa Cruz River reached the confluence with the Gila River. Early explorers said that the river through

Pinal County had a nearly indistinguishable channel, and maps showed a discontinuous channel there. This section of the river remains relatively unchanged in terms of the absence of perennial flow. The lower Santa Cruz River flows only in response to precipitation events.

The biggest changes in the valley have been along the middle Santa Cruz River, especially from Tucson to Tubac, because of population growth, mining, and agriculture. This combination of events has led to loss of perennial water, an increase in groundwater withdrawal, and an extensive change in the vegetative structure there.

Evidence of Susceptibility to Navigation

The hydrology and geomorphology of the Santa Cruz River have experienced both subtle and dramatic changes in their character since the time of Statehood. These changes have resulted from a combination of climate change, human activities, and geomorphologic processes.

<u>Hydrology</u>

Historically (circa the 1890s), the Santa Cruz River was perennial from its source to Tubac. Climate change since the turn of the century, combined with the extensive groundwater pumping for irrigation and the flow diversion for municipal use that began near the international border during the 1930 to 1950 drought period, has resulted in no flow in the channel in Sonora, Mexico, and discontinuous flow in the channel near Nogales, Arizona. The 1913 gage record at Nogales, the earliest in that region, indicated that by the time of statehood, the Santa Cruz River near Nogales was no longer perennial, but instead had continuous flow during the winter and occasional flow during the spring, summer and fall. The 1913 winter discharge averaged about 15 cubic feet per second (cfs), except for an increase caused by a rainfall event that ranged from 35 to 174 cfs. A survey of the daily data for the rest of the Nogales record indicated that, during wet years, there were only a few days of no-flow conditions. During dry years, there were entire months that passed with no flow recorded in the channel. At present, naturally occurring perennial reaches occur only in the uppermost part of the river in the San Rafael Valley. The perennial reach north of Nogales results from the discharge of sewage effluent from the Nogales International Wastewater Treatment Plant that began in 1972.

The Santa Cruz River historically had several springs and cienegas within its channel from Tubac to Tucson, and a marsh at its confluence with the Gila River near Laveen. Even in the historical record, only the very largest floods were sustained from the headwaters to the confluence with the Gila River. A review of the daily discharge record indicated that there was some semblance of baseflow, with an average of about 12 cfs during the fall and winter of 1912-1913, at the Tucson gage. Such continuous flow for months at a time was not seen again in the years that followed, though there were periods of several weeks that experienced continuous or nearly continuous flow during very wet winter seasons. The Laveen gage recorded nearly year-round flow from its beginning date in 1940 until June of 1956, when it began to measure zero flow for weeks at a time. During the 1940 to 1956 period, the daily flow averaged about 3 cfs during low flow conditions, and had peaks as high as 5060 cfs during wet periods. By 1960, the Santa Cruz at Laveen was also experiencing no flow conditions for months at a time.

Not only have the locations of surface flows changed since the time of statehood, but also the seasonality and magnitude of flows in the Santa Cruz River have changed in response to shifts in the hydroclimatology of the region. Though the majority of flow events occur during the summer season, the magnitude and number of annual peak discharges that occurred in the fall and winter were higher before 1930 and after 1960 than during the 1931-1959 period. For example, six of the seven largest floods at Tucson occurred after 1960, indicating that the magnitude of flood peaks has increased in the past few decades.

In evaluating the susceptability of the Santa Cruz River to navigation in historic times, it is important to be cognizant of the significant changes that have occurred in the river. The current condition of the river is not representative of the conditions that existed at statehood. Human activities, as well as climate change, have had notable effects on the peak flows of the Santa Cruz River, especially in the lower basin. Since 1962, the construction of flood control channels in the washes of the lower Santa Cruz River basin has resulted in the reduction of floodplain storage and infiltration losses, therefore reducing the attenuation - the downstream decrease of the flood peak - of peak discharges. For example, the attenuation of peak flows was greater during the 1962 floods than during the 1983 floods because water was able to spread out over the broad flow zones in the lower reaches of the Santa Rosa and Santa Cruz washes. In contrast, much of the floodwater during the 1983 floods was efficiently transmitted downstream by the flood-control channels.

Geomorphology

The geomorphology of the Santa Cruz River upstream of Marana is quite different from that of the lower Santa Cruz River downstream of Marana. The river has a well-defined, often entrenched, channel in its upper reaches that contrasts strongly to the ill-defined system of braided channels that exist north of Rillito Peak at the northern end of the Tucson Mountains. Both the upper and lower reaches of the Santa Cruz River have experienced dramatic changes resulting from a combination of both natural geomorphic processes and human activities. Three types of lateral change - 1) meander migration, 2) avulsion and meander cutoff, and 3) channel widening - and two types of vertical change - aggradation and degradation of the channel bed - have occurred. While arroyo development is the most obvious type of channel change to occur since the 1890s in the upper Santa Cruz River, most of the initial channel incision occurred before the time of statehood. Since 1912, various reaches of the upper Santa Cruz River have been dominated by such processes and activities as: meander migration and cutoff, channel widening, arroyo widening, channelization, and the vegetational effects of sewage effluent discharge. The channel locations in different reaches have changed spatially on the order of a few feet to a few thousand feet, depending on the processes that resulted in the change, and often change could be detected from one year to the next.

The lower Santa Cruz River, downstream of Marana, experienced changes of a completely different magnitude from the upper Santa Cruz River. Changes in the location of the channel in the lower basin can be measured in miles, and, due to the nature of the causes of the changes, the timing spans decades. Before the construction of Greene's Canal in 1910, the river transformed from a relatively deep, well-defined channel to a broad, flat, extensive alluvial plain at a point in the Marana area. Now that transition point occurs near Chuichu, Arizona. The construction and subsequent flood damage of Greene's Canal has resulted in other dramatic geomorphic changes. Prior to and during the floods of 1914-1915, flood flow had the opportunity to follow routes down the North Branch of the Santa Cruz Wash and McClellan Wash. After the development of the arroyo in Greene's Canal, the bulk of subsequent flood flows have had westerly paths.

Land Use

Land use data were compiled for the Santa Cruz River and entered into a GIS database. Land use data includes existing title owner records from county assessors offices; and state and federal land leasing records from ASLD, the Bureau of Land Management, and the U.S. Forest Service. Existing improvements, commercial activities, and present use of lands were identified from land use mapping and reports, aerial photographs, and in some cases, by field visits. Other data collected for the Santa Cruz River, such as floodplain limits, were also entered into the GIS database. The GIS map work product is contained in the Appendix.

The statistics provided by the analysis of the land use data is useful in informing ANSAC and others about the breakdown by categories of land use and land ownership. The land use dataset and GIS work product are provided to inform the State with regard to impacted lands as findings of navigability or non-navigability are made by the Legislature.

History of Navigation

Could the river have been navigated in 1912 or before? A few instances of boating on the river are reported, but the perennial flow that existed on the river historically was such that it was never regularly navigated. It was, however, a very important transportation corridor for travelers going from the eastern United States to the west, or from Mexico to the Gila River. Without its waters, forage and food travelers would often probably not have survived.

There is no evidence that the Hohokam or O'odham people had boats at any time in the past. The river was much too shallow most of the time for small boats, even in the perennial stretches. Entrenchment of the river and development of a deeper channel from San Xavier to Tucson, might have made navigation possible if there had been a dependable supply of water. By 1912, the U.S. Geological Survey reported that the entire low flow of the river was diverted at both the Nogales and Tucson gages, making navigability highly unlikely in low flow conditions. There is no evidence of commercial trade on the river.

In more recent times, some people have attempted to navigate the river. Canoers report that boating is feasible, especially in the effluent-dominated areas. The Tucson Citizen, a local newspaper, reported on canoers who boated on both the effluent-dominated section in the upper reach of the river, on the Rillito River, and on other portions of the Santa Cruz during floods in 1990.

Boating, then, has occurred on rare occasions on portions of the Santa Cruz River. The river has also provided other benefits including: fish for human consumption, water for crop irrigation, recreation, and necessary relief for early travelers. At least one major travel route followed the course of the river, and communities have existed along the river for thousands of years.

Refer to the Summary provided in Section 6 of this report for the study findings relative to the criteria contained in A.R.S. 37-1128 to be used in determining the navigabiliby or non-navigability of the Santa Cruz River.

ARIZONA STATE LAND DEPARTMENT

Section 1

ARIZONA STREAM NAVIGABILITY STUDY
for the
SANTA CRUZ RIVER
Gila River Confluence to the Headwaters

Final Report

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November 1996

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SANTA CRUZ RIVER FINAL REPORT
SECTION 1

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APPENDIX
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INTRODUCTION

SFC Engineering Company (SFC)1, in association with George V. Sabol Consulting Engineers, Inc. (GVSCE), JE Fuller/ Hydrology & Geomorphology, Inc. (JEF, Inc.), SWCA, Inc., Environmental Consultants (SWCA), the Arizona Geological Survey (AZGS), and the University of Arizona Water Resources Research Center (WRRC); was retained by the Arizona State Land Department (ASLD) to provide information to the Arizona Navigable Stream Adjudication Commission (ANSAC). ANSAC will use the data and evidence provided by the SFC project team to make findings as to the navigability or non-navigability of the Santa Cruz River as of the time of statehood.

This report documents information relating to the Santa Cruz River from the confluence with the Gila River to the headwaters. No recommendation or conclusion regarding title navigability of the Santa Cruz River is made in this report. The report consists of several related sections:

Section 1 - General information is provided by SFC as to the project background, the definition of navigability, the study reach limits, the objectives of the project, and the method of approach;

Section 2 - An archaeological overview of the Santa Cruz River valley prepared by SWCA relates to river uses and sets the long-term context of river conditions;

Section 3 - A historical review by the WRRC addresses the periods prior to and including statehood with respect to river uses, modes of transportation, and river conditions;

Section 4 - The historical geomorphology and hydrology of the Santa Cruz River evaluated by AZGS estimate past and potential flow conditions in the river;

Section 5 - Historical and current land use information compiled by SWCA is described and presented in a GIS format;

Section 6 - The results of the Santa Cruz River study most pertinent to navigability or non-navigability criteria are summarized.

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1 SFC is now known as Stantec Consulting, Inc.

A list of references cited, as well as an extended bibliography where appropriate, is included in each section. Appendices contain supporting documentation and the GIS work products. A glossary of terms and a list of acronyms are provided.

Project Background

Public Trust principles date back to English Common Law when the King held the beds of rivers affected by tides in Trust for the general public and for the public good. This provision was founded on the principle that there is a public need to use the waterways for commerce. When the United States gained independence from the British Crown, Public Trust principles were recognized so that the lands beneath navigable waters within the original thirteen states became the sovereign property of those states. The Equal Footing Doctrine provided that future states were entitled to sovereign ownership of riverbeds located within those new states on an "equal footing" with the original thirteen states.

At the time of statehood on 14 February 1912, the State of Arizona received sovereign title to the beds of navigable rivers located within state boundaries. Under the Equal Footing Doctrine, the United States government previously held these lands in Trust pending the creation and admission of the State of Arizona to the Union. Although the State owned the land, in order to perfect title to the navigable streambeds, the State was required to make its claim of ownership. From statehood until the mid-1980's, Arizona claimed only the bed of the east half of the Colorado River. The State failed to act on all other claims of streambed ownership and other parties asserted title to certain streambeds lands. In assuming ownership of lands located in or near these streambeds, many of the current record title holders constructed projects and improvements to the land, paid property taxes, and altered the stream ecosystems and riparian habitat.

During recent years, the State, as well as a number of private and public entities, asserted claims of ownership of streambeds throughout Arizona. These claims turned on whether or not the streams were navigable or susceptible to being navigable at the time of statehood. The titles held by land owners whose property includes all or a portion of the streambed of potentially navigable streams are clouded. As a result of litigation addressing in-stream sand and gravel mining activities in the Verde River, the Arizona Legislature recognized the economic hardships created by the uncertainty of the State's potential future claims on streambed lands. In 1987, House Bill (HB) 2017 was passed outlining a procedure to quit claim any interest of the State in the beds of the Salt, Gila, and Verde Rivers for a nominal fee, reaffirming the State's claim to the Colorado River, and waiving any claim to all of the other streambeds in the State. A lawsuit challenging the constitutionality of HB 2017 was successful in 1991 and the Court found that one flaw in the bill was that it did not provide for an evaluation of the validity and value of the State's Public Trust interest on the individual watercourses.

In 1992, the Governor signed HB 2594 which repealed HB 2017 and established a systematic administrative procedure for gathering information and determining the extent of the State's ownership of streambeds. The main purpose of the legislation was to confirm State ownership in Public Trust lands located in the beds of streams determined to have been navigable at statehood. HB 2594 also created the Arizona Navigable Stream Adjudication Commission (ANSAC), a five member board appointed by the Governor. ANSAC was directed to establish administrative procedures, hold public hearings, and make determinations of navigability. The legislation also directed the Arizona State Land Department (ASLD) to facilitate determination of navigability and to act as support staff for the ANSAC.

In 1994, after ANSAC had made an initial classification that the Lower Salt River had characteristics of possible navigability as of the time of statehood, and had scheduled public hearings to receive evidence of navigability or non-navigability, the Arizona Legislature passed HB 2589. HB 2589 (ARS 37:1101-1156) revised and defined the criteria to be used to determine whether a stream was navigable or non-navigable, established an ombudsman office to represent the interests of private property owners, amended the powers of ANSAC to an advisory role, and made decisions of navigability subject to judicial review and action by the Arizona Legislature. The 1996 Santa Cruz River report prepared by SFC reflected changes in the definition of navigability made under HB 2589.

In 1999, after the Arizona Legislature ratified ANSAC's recommendations that the Salt River and other Arizona rivers be found non-navigable using the criteria of HB 2589, lawsuits were filed challenging the constitutionality of certain provisions in HB 2589. In response to the subsequent

Arizona Court of Appeals decision, the Arizona Legislature enacted SB 1275, which removed the unconstitutional presumptions of non-navigability and limitations on information to be considered by ANSAC, and restored the applicable burden of proof in line with the so-called "federal test" of navigability. The 2004 revision of the original SFC Santa Cruz River report was prepared to reflect changes in the navigability statutes made under SB 1275.

Definition of Navigability

A.R.S. §37-1101 (6) set out the definition of "navigable" or "navigable watercourse" to be used to address the ownership of streambeds. That definition is:

> "Navigable" or "navigable watercourse" means a watercourse, or a portion or reach of a watercourse, that was in existence on February 14, 1912, and at that time was used or was susceptible to being used, in its ordinary and natural condition, as a highway for commerce, over which trade and travel were or could have been conducted in the customary modes of trade and travel on water."

The data collection effort for this study provides information that will assist ANSAC in determining if a given river meets the criteria of the statutory definition.

Project Limits

The project team is to collect data and information relevant to the navigability or non-navigability and, hence, to title to the streambeds of the Santa Cruz River from the confluence with the Gila River to its headwaters, as shown in Figure 1.

Study Reach Lengths

The lengths of the study reaches were estimated using data reduced from the Arizona Land Information System (ALRIS) GIS database. Those data were converted to an AutoCad drawing file and the lengths of the subreaches determined using that program. The resulting total lengths of the study reaches are shown in Table 1.

TABLE 1

Study Reach Lengths

River Study Reach	**Length**	
	kilometers	**miles**
Santa Cruz River	325	202

Lateral Study Limits

The maximum lateral extent of the study limits for each study reach is the 100-year floodplain boundary. The identification of the lateral limits of the study reaches was conducted in two steps. First, a set of key maps was developed for all study reaches indicating sources of floodplain maps, topographic information, aerial coverage, and other pertinent information. The primary source of floodplain boundary delineations is the Federal Emergency Management Agency (FEMA) Flood Insurance Rate Maps (FIRM). Then, a GIS map layer was developed for each study reach showing the 100-year floodplain to establish the maximum lateral extent of the study limits for the purpose of information and data collection in subsequent work tasks. For those subreaches mapped by FEMA, the 100-year floodplain boundary was digitized in GIS format directly from the FIRM maps. No FEMA maps are available for those portions of the study reaches which are on Federally-owned or Indian reservation lands. New mapping was not part of the scope of services for this project.

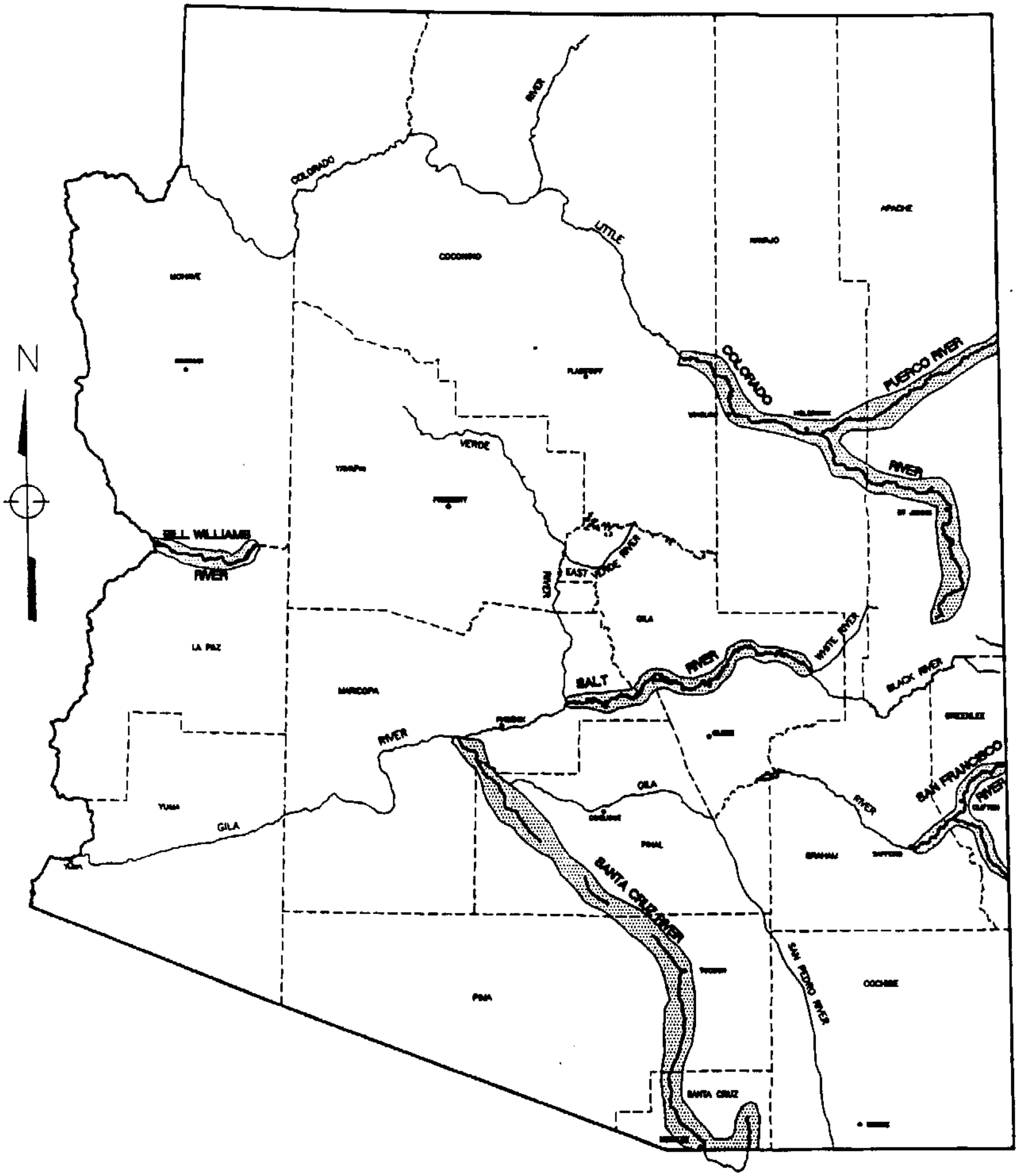

FIGURE 1

General Location Map for Arizona Stream Navigability Studies

Study Objectives

The primary objective of the project is to provide information concerning the factors addressing navigability set forth in A.R.S. §37-1101 *et seq.* to assist in the determination of navigability or susceptibility to being navigable as of statehood. Specific technical goals include the following:

- Perform a literature search to identify and catalog existing historical, archaeological, hydrologic, hydraulic, geomorphic, and land use information.
- Review existing historical, archaeological, and land use information to identify and evaluate evidence of navigable uses of the study areas.
- Review existing hydrologic, hydraulic, and geomorphic materials to identify and evaluate discharge characteristics of the study reaches.
- Identify title owners, lessees, improvements, and current uses of land located in or near the study reaches using existing information.
- Prepare reports, maps, and other information describing the results of the archaeological, historical, hydrologic, hydraulic, geomorphic, and land use investigations.
- Participate at public hearings and other public forums, as required.

PROJECT METHODOLOGY

The basic approach to the stream navigability studies is to develop a database of information to be used by ANSAC in making navigability determinations. To that end, the scope of services for this study includes five main tasks:

- Agency Contact
- Literature Search
- Data Summaries
- Land Use
- Final Report

Because the legislative definition of navigable watercourse includes both actual navigation and susceptibility to navigation, the data collection effort was focused in two areas:

- Historical Uses of the River - Data describing actual uses of the river at the time of statehood were collected. Specific tasks include agency contact and literature search.

- Potential Uses of the River - Data describing river conditions at the time of statehood were collected. Specific tasks include agency contact, literature search, and hydrologic, hydraulic and geomorphologic assessments.

Agency Contact

The objectives of the agency contact task were to inform community officials of the studies, to obtain information on historical and potential river uses, and to obtain access to data collected by agency personnel in regard to the five study reaches. For the latter task, public officials from communities, towns, cities, and counties located along the Santa Cruz River study area were contacted. Contact consisted of an initial letter describing the stream navigability study, its potential impacts on the community, and requesting information to be used in the study. Each community official was then contacted by telephone to answer questions about the study and to provide a second opportunity to provide information for the study. In addition, officials from most local, state, and federal agencies with jurisdiction or interest in the river study areas were contacted by letter and telephone.

Historians, librarians, and archivists from public and private museums, libraries, and other collections were also contacted. Letters requesting summaries of information pertaining to historical stream uses or conditions were sent to each institution, with follow-up telephone contact. Other contacts included letter and telephone requests for information to clubs, professional organizations, special interest groups, and environmental groups. In most cases, contacts led to other persons thought to have information pertinent to the study.

Literature Search

The objective of the literature search was to obtain published and unpublished documentation of historical river uses and river conditions. Information collected from agency contact was supplemented by published information from public and private collections. Literature search focused on the following main categories:

- Archaeology
- History
- Hydrology
- Hydraulics
- Geomorphology

Historical literature searches were conducted to obtain information on the historical uses of the rivers and adjacent lands. Library research identified books, professional journals, magazine and newspaper articles, and unpublished materials that provide information on the history of the use of the rivers. City directories, Sanborne fire insurance maps, and General Land Office maps were also consulted to identify businesses located near the rivers. Literature searches in archaeology provided data on prehistoric and historic settlement patterns along the river, including evidence on paleoenvironment and irrigation agriculture. This research included published books and articles and "gray literature" or technical reports. Hydrologic, hydraulic, and geomorphic studies relating to historic navigability of each stream reach were also collected from city, county, state, and federal agencies. Published journal articles, books, and reports available from public library collections were also consulted. Bibliographies of documents and resources for each area of expertise are included in the corresponding report sections.

Data Summaries

Data collected from the agency contact and literature search tasks was organized and synthesized by these subject areas: archaeology, history, hydrology, hydraulics, geomorphology, and land use.

<u>Archaeology</u>

Archaeological data augment the historical record of potential river uses at statehood by providing an extended record of river conditions, use of river water, climatic variability, and cultural history along the rivers. SWCA archaeologists reviewed literature and other information collected during the literature search and agency contact tasks. An overview summarizing previous archaeological work in the area, paleoenvironment, the culture history, settlement patterns, and evidence relevant to navigability of the river is presented in Section 2.

History

Historical data provide information on actual river uses at the time of statehood, and also provide information on whether river conditions would have supported navigation. WRRC historians prepared a report summarizing use of the river and adjacent area in historic times, with special emphasis on the establishment, growth, and development of towns, irrigation systems, commercial activities, and developments. The historical overview is presented in Section 3 of this report.

Hydrology/Hydraulics

Hydrologic/hydraulic information is a key source of information regarding susceptibility to navigation. These data include estimates of flow depths, width, velocity, and average flow conditions at statehood, based on the available records. AZGS evaluated information collected during agency contact and literature search tasks. Literature, stream gage records, topographic maps, aerial photographs, and other data were used to develop an estimate of natural stream conditions at statehood, as well as for existing stream conditions. Depth, velocity, and topwidth rating curves for existing and (circa) statehood channel conditions were developed from historical gaging records. Estimates of 2-, 5-, 10-, 50-, 100-year, and average annual flow rates were obtained from gage data. Flow duration curves and average monthly flow rates were also summarized.

Geomorphology

Geomorphic data provide information on river stability, river conditions at statehood, and the nature of river changes since statehood. A summary of the geology and geomorphology of the Santa Cruz River was prepared by AZGS. These summaries were based on literature and other information collected during agency contact and the literature search. The objectives of these summaries were to estimate channel positions at the time of statehood, assess the possibility of and mechanism for historical channel movement from its current position, provide evidence of geologic control of flow rates, and to estimate the location of the ordinary high and low watermarks. The hydrologic, hydraulic, and geomorphologic summaries are presented in Section 4.

Land Use

Land use data were compiled for the Santa Cruz River and entered in a GIS database. Land use data included existing title owner records from county assessors offices, state and federal land leasing records from ASLD, the Bureau of Land Management, and the U.S. Forest Service. Existing improvements, commercial activities, and present use of lands were identified from land use mapping and reports, aerial photographs, and in some cases, by field visits. Other data collected for the Santa Cruz River, such as floodplain limits, were also entered in the GIS. The land use data summary description is presented in Section 5; the GIS work product is contained in Appendix A.

SUMMARY

A comprehensive summary is presented in Section 6 of this report which itemizes the key findings of the preceding archaeological, historical, hydrologic, hydraulic, geomorphologic and land use sections. The most pertinent findings relative to evidence of navigability or non-navigability, or evidence of susceptibility to navigation, are summarized to provide information to support a determination by others of navigability or non-navigability for each study reach. This report does not make a recommendation or conclusion regarding title navigability of the Santa Cruz River.

ARIZONA STATE LAND DEPARTMENT

Section 2

ARIZONA STREAM NAVIGABILITY STUDY
for the
SANTA CRUZ RIVER
Gila River Confluence to the Headwaters

Final Report

Prepared by:

SFC Engineering Company

In Association with
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SWCA, Inc. Environmental Consultants,
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November 1996

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January 12, 2004

ARCHAEOLOGICAL OVERVIEW OF THE SANTA CRUZ RIVER VALLEY

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November 6, 1996

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Dawn M. Greenwald
Dennis Gilpin

Archaeology along most of the Santa Cruz River, particularly the middle Santa Cruz in the Tucson Basin, has received much attention, especially since the 1970s (Table 1). However, the upper Santa Cruz River, designated here as the portion that originates in the Canelo Hills and continues through the San Rafael Valley to Nogales, Arizona, is an exception. This area is not well known archaeologically, and what little is known indicates that it was occupied prehistorically by people who were part of a different cultural system than the inhabitants of the lower and middle Santa Cruz River valleys.

ARCHAEOLOGICAL PROJECTS

Early Investigations

A large portion of the lower Santa Cruz River valley (from north of the Tucson Mountains to the confluence with the Gila River) was surveyed in the 1920s by Gila Pueblo (Gladwin and Gladwin 1929a, 1929b, 1930). The surveys covered an area east-west from Florence to the Sierra Estrella Mountains and north-south from the Phoenix Mountains to Chuichu. These reconnaissance surveys were conducted to determine the boundaries of the culture (later designated Hohokam) associated with red-on-buff pottery. In 1925 Dr. Byron Cummings directed another reconnaissance along the southwestern slopes of Tanque Verde ridge in the eastern Tucson Basin. This survey led to the excavation of about half of the Tanque Verde Ruin in 1927 by E. J. Hands. Haury (1927, 1928a, 1928b) discussed the findings on house types, and Fraps (1935) summarized the investigations.

A number of large, important sites were excavated in the 1930s. In the Tucson Basin, Cummings examined the Martinez Hill site, which was partially excavated by Gabel (1931) and partially restored. The site was located at the foot of Martinez Hill and about one-half mile east of the Santa Cruz River. It contained contiguous-room surface structures with thick adobe walls. Three of seven

Table 1. Major Archaeological Projects along the Santa Cruz River

Sponsor	Type of Project	Areal Extent	No. of Sites	References
Gila Pueblo	reconnaissance	E-W from Florence to the Estrella Mtns., N-S from the Phoenix Mtns. to Chuichu	>200	Gladwin and Gladwin 1929a, 1929b, 1930
Gila Pueblo	excavation	Snaketown	1	Gladwin et al. 1937
Gila Pueblo	excavation	Hodges Ruin	1	Kelly 1978
?	survey	70 miles along the Upper Santa Cruz River	ca. 140	Danson 1946
?	survey	Pantano and Rillito drainages	?	Rogers 1958
NPS and U. of Arizona	excavation	University Indian Ruin	1	Hayden 1957
	survey	From Tubac to Sahuarita along the Santa Cruz River		Frick 1954
?	excavation	Black Mountain	1	Fontana, Greenleaf, and Cassidy 1959
AZ State Highway Dept.	excavation	Punta de Agua	10	Greenleaf 1975
Amerind Foundation	excavation	Palo Parado	1	Di Peso 1956
City of Tucson	inventory and survey	Survey: Santa Cruz Riverpark, Tucson (ca. 22 km linear distance); Inventory: Tucson Basin	63 487	Betancourt 1978a, 1978b
AZ SHPO, NSF, ASM, BOR, AZ State Lands Dept.	survey - northern Tucson Basin	707,200 acres, N-S from northern Tucson Mtns. to north of the Picacho Mtns., E-W from the Tortolita Mtns. to approximately Casa Grande	ca. 50	Fish, Fish, and Madsen 1992
	survey - southern Tucson Basin			Doelle, Dart, and Wallace 1985
BOR	survey - Tucson Aqueduct, Central Arizona Project	Phase A: ca. 14,540 acres, Picacho Reservoir to Rillito Phase B: 11,898.8 acres, Rillito to SW corner of San Xavier Indian Reservation	89 57	Czaplicki 1984; Herron and Ciolek-Torrello 1988 Downum, Rankin, and Czaplicki 1986; Seymour 1989
BOR	excavation - Picacho Reservoir	Between the Picacho Mtns. and Picacho Reservoir	21	Bayham, Morris, and Shackley 1986
BOR	excavation - Tucson Aqueduct, Phase A	Around the Picacho Mtns.	ca. 35	Ciolek-Torrello 1988; Ciolek-Torrello, Callahan, and Greenwald 1988; Ciolek-Torrello and Wilcox 1988
BOR	excavation - Tucson Aqueduct, Phase B	N-S from Rillito to south of Martinez Hill and west of the Tucson Mtns.	13	Czaplicki and Ravesloot 1989a, 1989b, 1989c
ANAMAX Mining Co.	survey - ANAMAX-Rosemont	16,000 acres, around the Santa Rita Mtns.	89	Debowski 1980

Sponsor	Type of Project	Areal Extent	No. of Sites	References
ANAMAX Mining Co.	excavation - ANAMAX-Rosemont		32	Ferg et al. 1984; Huckell 1984a
BOR	survey - Santa Cruz Flats	951.2 acres, Santa Cruz Flats	15	Halbirt and Henderson 1993; Henderson 1988a, 1988b
BOR	excavation - Santa Cruz Flats	Santa Cruz Flats	16	Halbirt and Henderson 1993; Henderson and Martynec 1993
BOR	survey - Santa Rosa Canal	2689 acres, S of Maricopa through Santa Cruz Flats to S of Picacho Reservoir	85	Marmaduke 1993
BOR	excavation - Santa Rosa Canal		60	Marmaduke 1993; Marmaduke and Martynec 1993
BOR	survey - Chuichu	3408 acres, Chuichu District of the Papago Indian Reservation	50	Marmaduke and Robinson 1983
BOR	sample survey - Gila River Indian Reservation	ca. 1400 acres	?	Marmaduke and Conway 1984
Pepper Tree Ranch and U. of Arizona Foundation	excavation	Los Morteros	1	Lange and Deaver 1989
American Continental Corp.	excavation	Los Morteros	1	Bernard-Shaw 1989a
Pima Co. Dept. of Trans.	excavation	West Branch	1	Huntington 1986
City of Tucson	excavation	Valencia	1	Doelle 1985a
	excavation	Lonetree	1	Bernard-Shaw 1989b
NSF	excavation	Dairy Site	1	Fish et al. 1992
AZ Dept. of Transportation	excavation	San Xavier Bridge	1	Ravesloot 1987
Pima Co. Dept. of Trans. and Flood Control District	excavation	Houghton Road	1	Ciolek-Torrello 1995
American Continental Corp.	excavation	Redtail	1	Bernard-Shaw 1990

?=report does not specify
NPS = National Park Service; SHPO = State Historic Preservation Office; NSF = National Science Foundation; ASM = Arizona State Museum; BOR = Bureau of Reclamation

room blocks were excavated. University Indian Ruin, on the upper eastern terrace of Pantano Wash, was excavated first under the direction of Cummings (Kelly 1936), then during the late 1930s by Haury. Hayden investigated the site more intensively in 1940 (Hayden 1957), excavating two groups of contiguous rooms with thick adobe walls. Excavations at Hodges Ruin commenced in 1936 under the direction of Carl Miller and were continued by Isabel Kelly in 1937. However, Kelly's employment with Gila Pueblo ended in 1938, and her work at the site was not reported (Betancourt 1978a:7). James Officer, a graduate student at the University of Arizona, worked on a report but never finished it, and a compilation of the data was finally completed in the 1970s by Kelly and Gayle Hartmann (Kelly 1978).

Between 1934 and 1935, Gila Pueblo excavated the large Hohokam village site of Snaketown (Gladwin et al. 1937), located on the north side of the Gila River about three miles west of Gila Butte. This work was a milestone in Hohokam archaeology, providing expanded and systematized knowledge on Hohokam material culture. Architecture, ballcourts, and canals were investigated, and the chronological sequence that the Gladwins developed is the basis for the chronology used today (Figure 1).

In 1941 Danson (1946) surveyed the Santa Cruz River from its headwaters in the San Rafael Valley to Tubac, and from 1937 to 1939 Mitalsky conducted an informal reconnaissance in the Tucson area. Another survey, by Frick (1954), completed in the early 1950s, covered the Santa Cruz Valley from Tubac to Sahuarita. In 1958 Malcolm J. Rogers surveyed the Pantano and Rillito drainages for pre-Hohokam occupation of the Tucson Basin (Rogers 1958).

The first work on the San Xavier Indian Reservation was undertaken in the late 1950s and 1960s. Investigations at San Xavier del Bac Mission started in 1958 (Robinson 1963), and Fontana, Greenleaf, and Cassidy (1959) documented features on Black Mountain, including rock walls, terraces (trincheras), petroglyphs, and circular stone enclosures, similar to feature assemblages found on top of Martinez Hill and Tumamoc Hill (Betancourt 1978a:10). In 1965-1966 excavations were carried out on four prehistoric sites on the Punta de Agua Ranch, funded by the state for the

Highway Salvage Program of the Arizona State Museum (Greenleaf 1975). Important data gathered during this project led to the seriation of Rincon phase pottery into early, middle, and late variants (Huntington 1986:6).

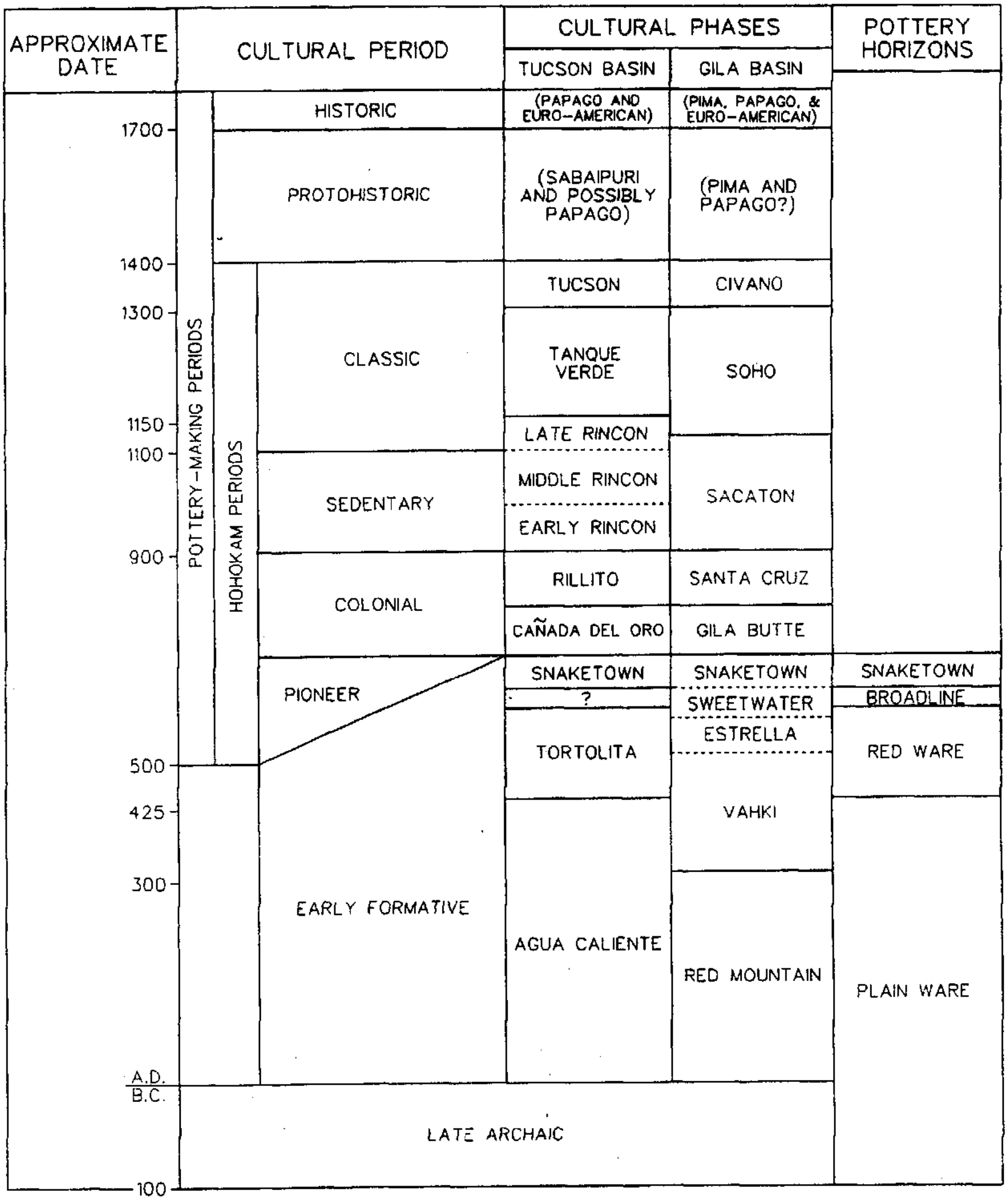

Figure 1. Cultural periods and phase sequences for sites along the Santa Cruz River (adapted from Deaver and Ciolek-Torrello 1995 and Wallace, Heidke, and Doelle 1995).

Other significant excavations took place prior to the 1970s. Di Peso (1956) reported on extensive excavations he conducted at the Paloparado (Palo Parado) site, a major southern outpost of the Hohokam. The Rabid Ruin, located on a terrace about 3 km upstream from the confluence of the Rillito with the Santa Cruz River, was excavated as a salvage operation by Laurens Hammack. Two Tanque Verde phase pit houses were excavated, and a cremation area was documented. Excavations on the Whiptail site began in 1966 and extended to 1971. The 20-60 acre site was located on a bajada at the foot of the Agua Caliente Hills. Fifty of the 100 houses identified were excavated, revealing a settlement pattern of dispersed house clusters and isolated houses. No report of this work has ever been published.

Investigations since 1970

Since 1970 the amount of work conducted along the Santa Cruz River, particularly in the Tucson Basin, has substantially increased. One important project was the Santa Cruz Riverpark survey and management study by Julio Betancourt (1978a, 1978b). Betancourt documented and re-evaluated previous research in the Tucson Basin and established the existence of some important sites within highly developed areas in the City of Tucson. Other large surveys have included the Northern Tucson Basin (Fish, Fish, and Madsen 1984, 1992; Skibo 1988), the Southern Tucson Basin (Doelle, Dart, and Wallace 1985), the San Xavier Project (Doelle and Wallace 1986), Saguaro National Monument (Simpson and Wells 1983, 1984), the ANAMAX-Rosemont Project (Debowski 1980), the Tucson Aqueduct Project (Czaplicki 1984; Czaplicki and Mayberry 1983; Czaplicki and Rankin 1985; Downum, Rankin, and Czaplicki 1986; McCarthy 1982), the Santa Cruz Flats (Halbirt and Henderson 1993; Henderson and Martynec 1993), the Santa Rosa Canal Alignment (Marmaduke 1993; Marmaduke and Martynec 1993), the Chuichu District of the Papago Indian Reservation (Marmaduke and Robinson 1983), the Papago Water Supply Project (Dart 1987), and the Gila River Indian Reservation Sample Survey (Marmaduke and Conway 1984) (Figure 2). Most of these large surveys were the result of an increase in contract work due to the implementation of federal legislation to mitigate the effects of development.

In addition to the surveys, there has also been an increase in the number of sites that have been excavated, often due to their identification during survey and documentation as significant sources of archaeological data (i.e., eligibility to the National Register of Historic Places). Some major excavated sites include Los Morteros (Bernard-Shaw 1989a; Lange and Deaver 1989), West Branch (Huntington 1986), Valencia (Doelle 1985a), Lonetree (Bernard-Shaw 1989b), Redtail (Bernard-Shaw 1990), the Dairy Site (Fish et al. 1992), Tator Hills (Halbirt and Henderson 1993), Picacho Pass (Greenwald and Ciolek-Torrello 1988), McClellan Wash (Herron and Ciolek-Torrello 1988), the San Xavier Bridge Site (Ravesloot 1987), ANAMAX-Rosemont (Ferg et al. 1984), and Shelltown and the Hind Site (Marmaduke and Martynec 1993) (Figure 3). In many cases, these and similar sites filled in gaps in the culture history of the Santa Cruz River valley and contributed data that illuminated settlement structure, intra- and interregional interactions, the subsistence base, and changes in social and economic structures through time.

CULTURE HISTORY

The Paleoindian and Archaic Traditions

The Paleoindian tradition and the early stages of the subsequent cultural tradition, the Archaic period, are not well represented along the Santa Cruz River or in the Southwest in general. Chronologically sensitive diagnostic artifacts or features are often lacking for these time periods. Dart (1987:21) has postulated that there are two reasons for this: (1) surfaces containing evidence of early prehistoric activity are very eroded, and (2) if surfaces have remained intact, they probably are deeply buried. In fact, none of the Paleoindian artifacts known so far along the Santa Cruz were found in a context that is unarguably Paleoindian (i.e., they are all surface finds, with the exception of the Clovis point recovered from a Hohokam pit house at the Valencia Road site). The situation along the Santa Cruz therefore contrasts sharply with that in the San Pedro River valley, where buried Clovis kill sites have yielded evidence that continues to be remarkable in the context of New World prehistory. Paleoindian period occupations were adaptations to climatic conditions of the last Ice Age, which contributed to the availability of water sources and overall moist conditions. Between the Paleoindian and Archaic periods, there was a reduction in the available moisture, resulting in variations in water sources and a drier climate. After approximately 2050 B.C., available

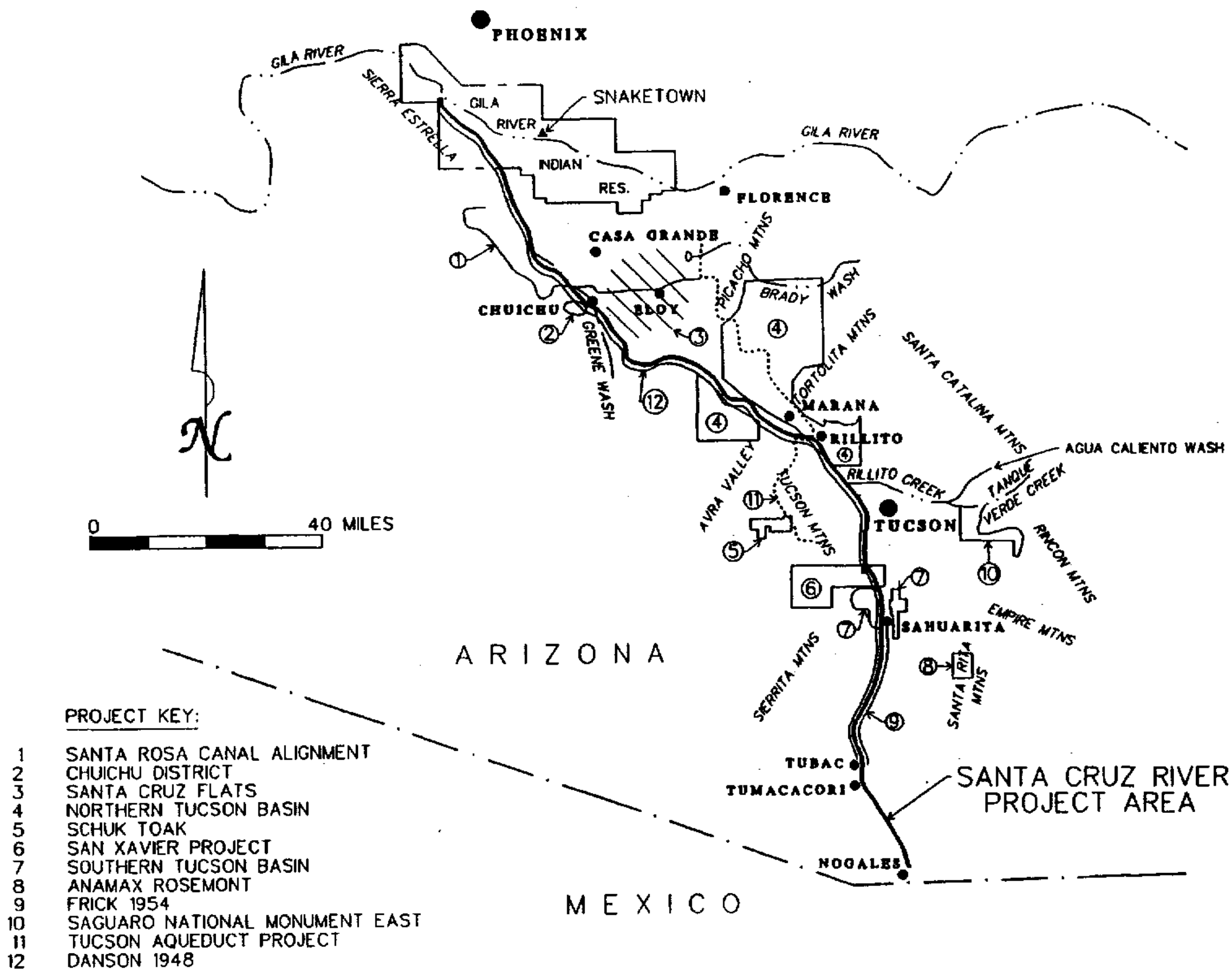

Figure 2. Recent archaeological investigations along the Santa Cruz River.

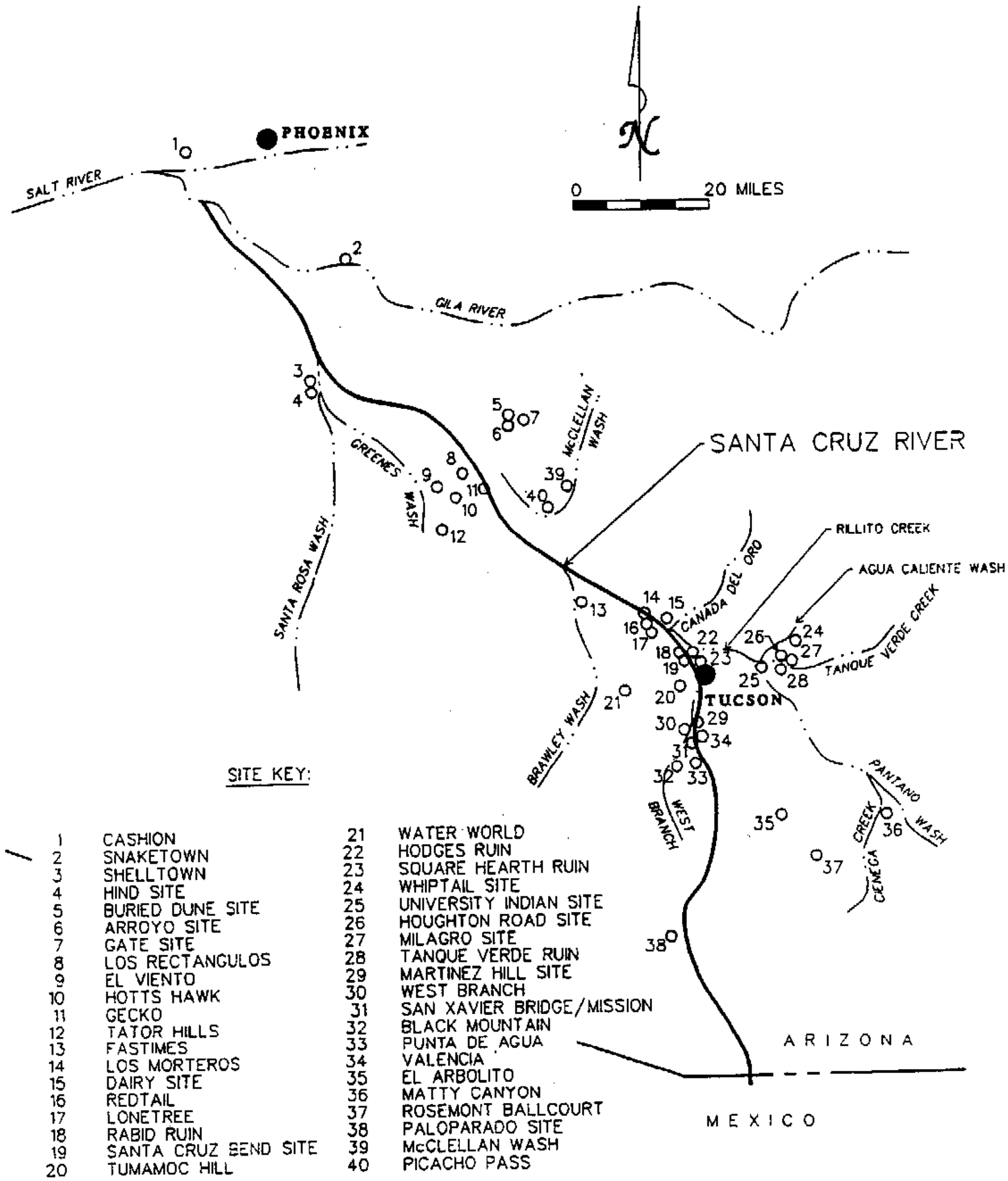

Figure 3. Excavated Sites along the Santa Cruz River.

moisture increased. These climatic patterns contributed to fluctuating patterns in faunal and vegetal resources and thus to changes in human adaptations during these early periods.

The Paleoindian tradition in North America is characterized by large spear points, flake blades and scrapers, and other flaked stone tools, and sometimes the associated remains of large late-Pleistocene mammals, such as bison and mammoth. Because well-produced, specialized spear points dominate Paleoindian assemblages, and known sites consist of camps and kill/butcher sites, archaeologists believe that Paleoindian subsistence was based primarily on hunting now-extinct megafauna. The earliest evidence of the Paleoindian tradition along the Santa Cruz River is termed the Llano Culture and is characterized by fluted Clovis points. It may date as early as 9500 B.C., and points diagnostic of this culture have been documented from the Rattlesnake Pass area of the Tucson Mountains (Agenbroad 1967:118), from the Avra Valley (Huckell 1982:15-19), near the southwest corner of San Xavier Indian Reservation (Betancourt 1978a:35), in the Santa Catalina Mountains (Huckell 1984b:134), and in the Tucson Basin (Doelle 1985a:181). Later Paleoindian occupations, the Plano Culture, are represented by lanceolate, unfluted knives and spear points and are associated with either modern species of fauna or an overlap of modern and extinct species (Jennings 1968:111-112). The Plainview projectile point is from the Plano complex and dates sometime between 8350 and 7850 B.C. (Huckell 1984b:135). Examples of this point type have been found in the Tortolita and Santa Catalina mountains (Dart 1987:19) and on the west edge of the Picacho Mountains (Wallace and Holmlund 1986:14).

The Archaic period, representing the Cochise culture, has been divided into three stages: Sulphur Spring (7500-3500 B.C.), Chiricahua (3500-1500 B.C.), and San Pedro (1500-ca. 100 B.C.). Tool assemblages from the Early and Middle Archaic, or Sulphur Spring and Chiricahua stages, exhibit a predominance of ground stone associated with plant food gathering and processing rather than the emphasis on hunting technology seen earlier. The Early Archaic is poorly documented (Huckell 1984a), but there is evidence for Middle Archaic sites along the Santa Cruz River. Near the Picacho Mountains, three sites have been dated to the Middle Archaic period. Two of these sites, the Buried Dune Site, a short-term field camp, and the Arroyo Site, a long-term base camp, were located in old dune deposits (Bayham, Morris, and Shackley 1986:368-369). The third site, the Gate Site, a hunting and gathering base camp, was in the lower bajada of the Picacho Mountains (Bayham, Morris, and Shackley 1986:98). In the Santa Cruz Flats project area, 17 sites contained Middle Archaic remains. Most of these sites were thermal features, such as roasting pits and fire-cracked rock concentrations, indicating that the primary activity at the sites was to gather and prepare food (Henderson 1993:382-383). Three sites contained structures, which appeared to be no more than temporary brush shelters. Henderson (1993:384) interprets the Middle Archaic occupation as comprising small, mobile groups moving seasonally in response to resource availability over extensive distances. Middle Archaic sites in the Tucson Basin included large base camps, small specialized activity areas, quarry sites, and possibly burials (Huckell 1984a:139). Sites in the Avra Valley represented short-term occupations for food gathering and processing activities.

Mobility patterns and subsistence practices changed dramatically, particularly in the Tucson Basin, between the Middle and Late Archaic. Late Archaic sites investigated in and around the Tucson Basin and Santa Cruz Flats, such as the Milagro Site (Huckell, Tagg, and Huckell 1987), Matty Canyon (Eddy and Cooley 1983), and the Tator Hills Site (Halbirt and Henderson 1993), were located in floodplains, areas adjacent to floodplains, or alluvial fans. Similarities among these sites are a relatively permanent water supply, an abundance of maize, small, informal pit houses, large intramural and extramural storage pits, many roasting pits and fire-cracked rock concentrations, middens, and overlapping inhumation and cremation areas (Ciolek-Torrello 1995:535). Houses averaged only 6 m^2 in area; they were built into shallow, basin-shaped pits with a pole framework covered with brush, hides, or grass (Halbirt and Copus 1993:44). Pit houses lacked hearths or entryways, but large storage pits were common internal features. Because much of the small space inside of pit houses was used for storage, it has been postulated that they were used primarily for storage and only secondarily as shelters (Ciolek-Torrello 1995:535). Recent excavations at the Santa Cruz Bend site have documented almost 200 houses dating between 400 and 200 B.C., with features and house types following this general pattern, although houses were larger and more variable in size (3-5 m in diameter) (Ciolek-Torrello 1995:537). Although this large settlement suggests that Late Archaic populations were aggregating during the maize-growing and harvesting seasons, there is evidence that such occupation was relatively short-term (Ciolek-Torrello 1995:537). Base camps located in bajada environments indicate that seasonal exploitation of resources still took place during the Late Archaic, so that full-time sedentism did not occur until the early Formative period. Food-processing equipment, such as milling stones, hand grinding tools, and projectile points, remained the same throughout the Archaic, suggesting both a continued reliance on wild seed plants and hunting practices and that maize cultivation, although important in the new diet, had not changed the Archaic subsistence pattern significantly enough to affect the technological system.

The Archaic-Hohokam Transition

Recent investigations in the Tucson Basin have lent support to the theory that the Hohokam culture developed out of the Archaic tradition in Southern Arizona. The Late Archaic period showed the beginnings of sedentism while retaining the technological characteristics related to seasonal mobility. The Agua Caliente phase (ca. 50 B.C. - A.D. 425), represents a transitional stage between the Archaic and Hohokam traditions that saw the development of maize dependence, sedentism, a new ceramic and lithic technology, and large, permanent houses. Sites dating to this transitional period occur in a variety of environments, including the river floodplain and terraces, and are represented by the Houghton Road site (Ciolek-Torrello 1995), El Arbolito (Huckell 1987), and the Square Hearth site (Mabry and Clark 1994). Settlement patterns consisting of agricultural hamlets in floodplain settings and camps in bajada areas reflected a subsistence strategy based on floodwater farming of maize, garden hunting, and foraging in the bajada and upland zones (Ciolek-Torrello 1995:561). Late Archaic projectile point styles, bifacial reduction technology, and food-processing technology (milling stones and cobble handstones) remained the same; however, a new expedient flaked stone technology developed as well as a ceramic technology producing plainwares, smudged brownwares, and incipient redwares (Ciolek-Torrello 1995:561). Burials were a mixture of inhumations and cremations, and houses were circular, oval, or rectangular pits, averaging 8.9 m^2 in area, with well-defined entryways. Small, informal Archaic style houses with interior storage pits continued, and new bean-shaped communal houses appeared.

The Prehistoric Ceramic Periods

The prehistoric ceramic periods are usually interpreted within the context of the Hohokam cultural sequence, which is divided into four periods: Pioneer (A.D. 425-750), Colonial (A.D. 750-950), Sedentary (A.D. 950-1150), and Classic (A.D. 1150-1400). Distinctions between the periods are based on diagnostic ceramic types and variations in architecture and other material culture.

Pioneer Period/Early Formative Period

Along the lower Santa Cruz River, Pioneer period occupation resembles Hohokam cultural patterns. In the middle Santa Cruz River valley, the Pioneer period occupation has been argued to be more reflective of the Mogollon culture (Deaver and Ciolek-Torrello 1995:483) and has been termed the Early Formative. Little is known of the Pioneer period in the upper Santa Cruz River valley.

Lower Santa Cruz

During the Pioneer period, the first pottery vessels appear. The Hohokam lived in pit houses of various shapes and sizes, with clay-lined hearths, entryways, and a roof-support configuration of 2-4 posts, arranged in small clusters. A biseasonal settlement pattern is postulated, based on excavations along the Salt River valley, in which permanent winter villages and temporary summer hamlets co-occurred. The winter villages had formalized pit house architecture, and the summer hamlets contained ephemeral, informal structures (Cable and Doyel 1984:266-269). Interregional exchange is evident by the presence of Mogollon ceramics from the mountainous regions to the east and shell from the Sea of Cortez.

Early Pioneer period sites are lacking along the lower reach of the Santa Cruz River (Marmaduke and Conway 1984; Wilcox 1979); however, seven late Pioneer period sites are known along the Gila River where its course brings it close to the Santa Cruz River (Wilcox 1979:Figure 25). Sites were an average of 4.9 km apart (including the sites north of the Gila along the same river stretch) and fell into three size classes: one site was 0.025-35 acres in size; three sites were 50-165 acres in size; and three sites were 180-550 acres in size (Wilcox 1979:99, Figure 25). No Pioneer period sites have been identified in the Santa Cruz Flats (Halbirt and Henderson 1993; Henderson and Martynec 1993; Marmaduke 1993).

Middle Santa Cruz

The Early Formative period in the middle Santa Cruz Valley includes three ceramic horizons, two of which are correlated with phase names (Figure 1). The earliest is the Red Ware horizon, also known as the Tortolita phase, and it is represented by the Lonetree (Bernard-Shaw 1989b), Rabid Ruin (Slawson 1990), and Valencia (Huckell 1993) sites. This phase is marked by the addition of a slipped and polished redware, a greater variety of vessel forms, larger houses (ca. 16.2 m^2), a preference for semiflexed inhumations, and the emergence of a permanent and cohesive settlement structure (Bernard-Shaw 1990; Ciolek-Torrello 1995:543; Whittlesey 1995:471). Following the Tortolita phase is the Early Broadline horizon, identified by the appearance of red-on-brown pottery with broadline geometric patterns. Isolated sherds of this type have been found at the Dairy site

(Fish et al. 1992), the Hodges Ruin (Kelly 1978), Paloparado (Di Peso 1956), and Valencia Road (Heidke 1993). One structure at Redtail Village has been assigned to this Early Broadline horizon (Deaver and Ciolek-Torrello 1995:486). It was a rectangular structure, 11.2 m^2 in area, with an entryway and thinly plastered walls and floor. Corn and agave remains were found on the floor (Bernard-Shaw 1989c:26-28). The late Early Formative period is the Snaketown phase and is concurrent with the Snaketown horizon. It is characterized by red-on-brown pottery with a hachure decorative style and some incising or scoring on the exterior of vessels. Ceramic technology reflected increasing influence from the Gila Basin, and some pottery may have been imported from the Gila Basin during this time (Deaver 1989:53). The lithic assemblages reflect typical ceramic period technologies, including corn-grinding equipment and expedient flaked stone tools. Structures of the Snaketown phase come from the Hodges Ruin, Redtail Village, and Hawk's Nest (Gardiner 1989:17-19) sites. Structures in the Tucson Basin were square to rectangular with long vestibule entryways. The structures at Hawk's Nest, in the Santa Rita Mountains to the southeast, were small and less formal; they were circular or oblong with vestibule entries. During the Snaketown phase,

> the Tucson Basin pottery tradition adopted many aspects of the Gila Basin Hohokam tradition that became even more strongly expressed in the Colonial period. It was probably at this time that the Hohokam emerged as a regional culture (Wilcox 1988:251; Cable and Doyel 1987; Doyel 1991; Fish 1989:28) with the Tucson Basin becoming a local node in the Hohokam regional system [Deaver and Ciolek-Torrello 1995:487-488].

Colonial Period

The Colonial period is separated into two phases in the Tucson Basin: Cañada del Oro (A.D. 750-850), and Rillito (A.D. 850-950). During the Colonial period there is evidence for continuing village development, and the ballcourt system was in place. The ballcourt at Los Morteros probably dates to the Rillito phase. Ballcourt villages appear to be evenly spaced along the southern drainage (Doelle 1985a, 1985b; Doelle and Wallace 1986). By the end of the Colonial period, an expanding population saw most villages along secondary rather than primary drainages of the Santa Cruz in the Tucson Basin (Betancourt 1978a:18). Sites with components dating to the Colonial period included Redtail Village, Hodges Ruin, the Dairy Site, Rosemont Ballcourt, Fastimes, and Water World (Deaver and Ciolek-Torrello 1995).

Evidence from Water World and Fastimes indicated that houses were clustered into groups sharing common areas or courtyards (Czaplicki and Ravesloot 1989a:13-14) and that cremation areas were separated from the habitation areas. At Fastimes, five separate house groups or farmsteads were identified; seven house groups were documented at Water World. One of the latter house groups represented a permanent occupation, and the other six appeared to represent winter occupation (Czaplicki and Ravesloot 1989c:13). Occupants of these sites, which were located along the bajada on the western slopes of the Tucson Mountains, practiced seasonal floodwater farming using the natural runoff from gullies or arroyos that spread out over gully-mouth fan surfaces. It is postulated that these sites were eventually abandoned when headcutting of the fan surfaces limited or destroyed ideal farming conditions (Czaplicki and Ravesloot 1989a:16-17).

Sedentary Period

The Sedentary period is represented by the Sacaton phase in the lower Santa Cruz River/Gila Basin area and by the Rincon phase in the Tucson Basin, although some archaeologists perceive the late Rincon phase as part of the Classic period (Bernard-Shaw 1989c). This was a period of population growth and expansion. Villages were located along primary and secondary drainages, with large villages associated with smaller hamlets and farmsteads. Most known sites in the lower Santa Cruz Valley have only been surveyed; sites in the Tucson Basin are better known because many have undergone excavation. Sites dating to this period include Valencia, West Branch, Hodges Ruin, Tanque Verde Wash, and Punta de Agua. During the Sedentary period, there was a reduction in Phoenix–Tucson Basin contact, an expansion of local ceramic traditions (Bernard-Shaw 1989c:7), and a preference for inhumations. Greenleaf (1975) believes that the Santa Cruz River was the line of communication for the dissemination of a new type of pottery, Rincon Polychrome. Vessels of this type "were found at the north and south extremities--one near Cashion where the Santa Cruz joins the Gila, and the other at Paloparado" (Greenleaf 1975:109).

Houses at the Punta de Agua site changed from a variety of shapes (oval, square, or subrectangular) in the Rillito phase to oval or subrectangular in the early Rincon phase, to usually subrectangular during the middle and late Rincon phases (Greenleaf 1975:36). The shape of the entry also changed from short and straight sided during the early Rincon to large and bulbous during the late Rincon. At the West Branch site, Rincon habitation structures were quite variable in size. In the Wyoming Street precinct, domestic structures were divided into four size classes: less than 10 m^2; 10-15 m^2; 15.5-20 m^2; and more than 20 m^2.

Doelle, Huntington, and Wallace (1987) have found similarities in community organization during early and middle phases of the Sedentary period and a reorganization or shift in settlement pattern by the late Rincon phase. Part of this shift in settlement location (away from the floodplain) was due to floodplain entrenchment and cienega formation (Waters 1987a:60). Nonriverine agricultural features, such as rock piles, check dams, terraces, and large roasting pits, began to appear on terraces and bajadas. Settlement-pattern shifts have been documented in the San Xavier Project area, at Ventana Wash, and in the ANAMAX Project area (Doelle, Huntington, and Wallace 1987:81).

Classic Period

The Classic period is represented in the Tucson Basin by the Tanque Verde phase (A.D. 1150-1300) and the Tucson phase (A.D. 1300-1400). During the Tanque Verde phase, the size of sites along primary drainages increased, but the number of sites declined. House styles changed to rectangular structures with free-standing adobe walls. There was continued use of nonriverine agricultural systems as well as floodwater farming. Large Classic period sites were documented in the Santa Cruz Flats, where the occupational focus extended from the alluvial plain near Greene Wash to the Santa Cruz River (Henderson and Martynec 1993:591). At Santa Cruz Flats the primary habitation zones—represented by large villages such as El Viento (256 hectares), Gecko (16 hectares), and Los Rectángulos (60 hectares)—appeared to be associated with a zone of secondary habitation sites, such as the Hotts Hawk farmstead (Henderson and Martynec 1993:583).

During the Tucson phase, contiguous pueblo structures appeared that were surrounded by compound walls. Other traits included platform mounds, inhumations, and intrusive polychrome ceramic types from the Tonto Basin area. The number of sites continued to decrease as their size continued to grow. Sites representing this time period include Martinez Hill, Tumamoc Hill, and Black Mountain (Betancourt 1978a:20). At the culmination of the Tucson phase, these sites appear to have been abandoned.

The Protohistoric Period

The protohistoric period is the transition between the prehistoric and historic periods, from approximately A.D. 1400 to 1700. The Paloparado Ruin was identified by Di Peso (1956) as a site containing a short Hohokam occupation followed by an "Upper Pima" occupation from around A.D. 1250 through 1751. Di Peso's interpretation has been the subject of considerable debate, with most archaeologists arguing that there was no protohistoric component at all.

Doyel (1977) has attributed the England Ranch Ruin, near Calabasas, to an Upper Pima phase (A.D. 1500-1700) based on similarities with excavated sites in the San Pedro Valley (Betancourt 1978a), although no evidence for Spanish contact was found (Ravesloot and Whittlesey 1987:90). Isolated artifacts and a burial have been identified as "Sobaipuri" (Ravesloot and Whittlesey 1987:90-91), a general term used for the protohistoric culture(s) of southern Arizona.

The Historic Period

A considerable amount of historical archaeology has been done along the Santa Cruz River, most of it focusing on Spanish missions and presidios and historic Tucson. A few homesteads, rancherías, and mining sites have also been investigated. Barnes (1984) and Whittlesey, Ciolek-Torrello, and Sterner (1994) provide good overviews of the historical archaeology in the region. In addition, Ayres (1981, 1983, 1987, 1988a, 1988b, 1988c, 1989, 1990a, 1991, 1992a, 1992b, 1992c, 1993a, 1993b, 1993c, 1995) has summarized ongoing research in the Santa Cruz River valley and has presented some information on a number of projects that have not been published. A common approach of historical archaeologists working in the Santa Cruz River valley has been to use archival data to identify the ethnicity, occupation, social class, and gender of particular sites, then to see how these various social statuses and roles are reflected in artifact assemblages. Ultimately, the objective is to reconstruct the daily lives of different groups of people during this period.

Spanish Colonial Archaeology

Spanish colonial archaeology has focused on the Spanish missions at Guevavi, Tumacacori, San Xavier del Bac, and San Agustín (at Tucson) and the presidios at Tubac and Tucson. Between 1964 and 1966, William J. Robinson conducted excavations in the convento at Guevavi, a Spanish mission on the Santa Cruz just north of the international border (Robinson 1976). The mission was established in 1701 by Father Kino at a Sobaipuri community he had observed in 1691, but the structures excavated by Robinson dated to the mid to late eighteenth century. After Guevavi was acquired by the Archaeological Conservancy, National Park Service archaeologists mapped and this site and nearby Calabazas (Burton 1992a) and conducted excavations at Guevavi. The site was then made an outlying component of Tumacacori National Monument (Burton 1992b). From September 8 to October 24, 1980, Lee Fratt and Maurice Montgomery of the National Park Service Western Archeological and Conservation Center conducted excavations at the convento at Tumacacori National Monument (Ayres 1981:37-38; Fratt 1981, 1986; Shenk 1976), a Spanish mission established in 1691 and abandoned in 1844.

In 1963 archaeology students from the University of Arizona and avocational archaeologists from the Arizona Archaeological and Historical Society conducted excavations at Mission San Xavier del Bac, established in 1691 and still in use (Robinson 1963). Although the purpose of the excavations was to try to find evidence of occupation of the Santa Cruz River valley between about 1450 and 1540, nothing was found that could be dated prior to the eighteenth century. Cheek's (1974) dissertation is on the historical archaeology of Mission San Xavier del Bac. The Arizona State Museum conducted additional work at the site in conjunction with the U.S. Bicentennial in 1976 (Ciolek-Torrello and Brew 1976). More recently, Jack S. Williams excavated inside a room adjacent to the nave of the mission church and identified a series of floors and related artifacts dating between about 1700 and 1900 (Ayres 1988a:35).

Excavations at the Presidio of San Ignacio de Tubac by the Arizona State Museum are described by Shenk and Teague (1975). Excavations at Tubac by Williams and Ivonne De La Cruz of the

Center for Spanish Colonial Archaeology have not yet been published, but Ayres (1988b, 1988c, 1989, 1992a, 1993b) has summarized these studies. According to Ayres (1988b:39), "Tubac was the location of a mission visita/farm (1732-1751), and later of Spanish (1752-1776; 1787-1821) and Mexican (1821-1849) presidios (military bases) as well as two Apache Peace settlements (1790-1848; 1851-1854), a major mining camp (1855-1860), and a Mexican military colony (1851-1854)." Ayres (1992a:31) also states, "Between 1856 and 1861, the settlement was the largest mining and commercial center in what would become Arizona Territory. During the later nineteenth century, Tubac continued as a relatively small agricultural and ranching village. Ethnic groups present at Tubac prior to 1900 include Pimans, Opatas, Yaquis, Apaches, Piros, Chinese, Mexicanos, Africans, other Hispanos, Germans and Anglo-Americans." Ayres (1989:38) mentions that by 1989, research was focusing on identifying specific buildings shown on a 1766 map by Josef de Urrutia. Fifteen to 25 mounds had been recognized in the southern half of the site, and the total number of buildings was estimated at between 100 and 150. Ayres (1992a:31) reported on the continuation of this project, stating that by 1991, 150 to 200 structures had been identified in this area, and excavations had been conducted in the south end of the Captain's house and in the Otero residence, two adobe structures that were occupied in the second half of the eighteenth century. In 1991 Williams and De La Cruz excavated a group of adobe houses around a small plaza. In 1993 excavations in a segment of an eighteenth century acequia (aqueduct) exposed a structure of upright poles that dated to the initial period of occupation (1732-1751)(Ayres 1993b:27). Excavations have also been conducted in the east midden and at the site of the Luis Lim Mercantile (ca. 1900-1920), where evidence of earlier structures was found, "including a Spanish period house not shown on the 1766 Urrutia plan" (Ayres 1993b:27).

Mission San Agustín, on the west side of the Santa Cruz River south of Congress Street in Tucson, is designated Site AZ BB:13:6(ASM). Established in 1757 as a visita (a mission where church services were provided by a visiting priest who resided at another mission) on the site of an earlier village and consisting at one time of "a Pima village, a chapel, a large two-storied structure (the convento), a granary, and an orchard" (Betancourt 1978:68), Mission San Agustín was studied in 1949-1950 and 1956, before its destruction by development (Betancourt 1978b:68-70). The first excavations were conducted in 1949-1950, when three areas, including two cemeteries, were excavated prior to expansion of a brickyard. In 1956 excavations were conducted in the mission buildings and the compound wall before the area was turned into a landfill. More recently, excavations at the site have identified some outlying features and recovered additional artifacts (Ayres 1988b; Ciolek-Torrello and Whittlesey 1991; Deaver and Albright 1992; Elson and Doelle 1987; Williams 1986). Williams (1986) identified a stone-lined acequia that possibly dated to the colonial period, although it was probably later reused by Solomon Warner as a millrace in the 1870s (Ciolek-Torrello and Whittlesey 1991). In the summer of 1988, and De La Cruz conducted excavations at the Mission Gardens/Castañeda site at the base of Sentinel Peak ("A" Mountain) and identified orchards and related outbuildings and granaries of the Mission Visita de San Agustín (Ayres 1988b:39-40). A portion of the San Agustín Mission complex south-southeast of the two-story convento and east of the Carillo house was tested by Statistical Research, and few intact deposits were found (Ayres 1992b:21-22; Ciolek-Torrello and Whittlesey 1991).

The Presidio of San Agustín del Tucson was first archaeologically investigated by Emil Haury and Edward Danson (Haury and Fathauer 1974; Olson 1985). In 1987 Williams conducted excavations at the Tucson Metropolitan Library site, located outside the boundaries of the Spanish presidio, and recovered artifacts dating between 1775 and 1900 (Ayres 1987:41; Williams 1988). Portions of the Presidio wall were identified during 1992 excavations conducted by Homer Thiel in the courtyard of the 1919 Pima County Courthouse (Ayres 1993a:22; Thiel, Faught, and Bayman 1993). The original wall of the Tucson Presidio was built between 1776 and 1783, but extensions and repairs may have been made later. The wall fell into disrepair in the 1850s. At the Spanish Presidio Cemetery, which dated from the 1770s to the 1860s, 19 complete burials of Caucasians and

Native Americans were relocated to make way for a gas line, and dozens of other graves were identified (Faught 1992; Thiel, Faught, and Bayman 1993).

The Santa Cruz River at Tucson

Studies of the San Agustín Mission have already been described, but other archaeological studies along the Santa Cruz River at Tucson have identified more recent historic sites. The survey of the proposed Santa Cruz Riverpark Archaeological District in Tucson (Betancourt 1978b), from Camino del Cerro to Los Reales Road, resulted in the identification of 19 historic sites, including four Sobaipuri or Piman burials, San Agustín Mission, Warner's Mill, the Pioneer Mill, two homesteads, a foundation and brick cistern, two irrigation systems (the Crosscut water recovery and distribution system and Farmer's Ditch), a lime kiln, a dump, and five artifact scatters. Two of the burials were thought to be associated with San Agustín del Oiur (or Oyaut), a Sobaipuri village shown on Kino's 1695-1696 map (Bolton 1936:272). One of the artifact scatters may be associated with the Silver Lake Hotel.

Ayres (1981:38) reported that the 1980 Pima College survey of Midvale Farms, on the West Branch of the Santa Cruz River at the southwestern edge of Tucson, recorded two late-nineteenth century rancherías that were scheduled to be excavated in 1981. In 1979, Bruce Huckell excavated a three-room structure at the late-nineteenth century community of Los Reales on the east side of the Santa Cruz (Ayres 1984:228). David Stephen, J. R. Billings, and Douglas Craig of Pima College excavated three houses at Los Reales (Ayres 1983:41).

Downtown Tucson

In addition to archaeological research on the Presidio of Tucson, a number of archaeological projects have been conducted in downtown Tucson that have investigated numerous sites dating to the territorial period and modern development of the city. Motsinger, Bierer, and Stein (1993) summarize historic sites within the City of Tucson Downtown Heritage Incentive District and provide a bibliography of previous work conducted within the district.

The Tucson Urban Renewal Project ran from 1967 to 1972 and investigated sites dating from 1776 to 1920. Although a number of specialized studies (Anderson 1968, 1970; Ayres 1978, 1990b; Barnes 1983, 1984; Clonts 1983; Lister and Lister 1989; Olsen 1978; Renk 1969; Roubicek 1969) came out of this research, the project is largely unreported.

Excavations just outside the walls of the Tucson Presidio identified over 90 historic and prehistoric features, most of which dated between about 1870 and 1920. These included 31 foundations, 1 well, 4 privies, 3 refuse deposits, and a grave (Ayres 1990b:44). The work was conducted by Richard Ciolek-Torrello of Statistical Research, Inc. (SRI).

Ciolek-Torrello and Mark Swanson of SRI conducted excavations in an area of downtown Tucson adjacent to the location of previous excavations that had exposed portions of the presidio of San Agustín del Tucson (AZ BB:13:9[ASM]). Ciolek-Torrello and Swanson found over 100 prehistoric and historic features, most dating from 1880 to 1912. Included were "three large trash-filled borrow pits, seven privies, and two wells" (Ayres 1991:33). Ciolek-Torrello and Swanson identified 116 features, including "numerous adobe and masonry house foundations, privies, wells, septic tanks, and small trash deposits dating to the late nineteenth and early twentieth centuries" (Ayres 1993a:21).

In 1990, Jonathan Mabry of Desert Archaeology, Inc., excavated a city block (Block 83) in downtown Tucson, identifying 32 features, primarily "foundations, trash piles, latrines, and well shafts" (Ayres 1993a:21; Mabry 1991). Desert Archaeology also conducted excavations at the Hotel Catalina Site (AZ BB:13:405[ASM]), the DeLong House, the Presidio Wall, and the Presidio Cemetery (AZ BB:13:13[ASM]). Excavations by Mabry and Lisa Eppley at the Hotel Catalina Site, first occupied between 1889 and 1896, identified mostly foundation remains, although a privy and trash pit were also found and excavated (Ayres 1993a:21). The DeLong House site (excavated by Jim Bayman) consisted of the adobe foundations of two structures: a house built between 1862 and 1886, and a house built over the earlier foundations sometime prior to 1886, when the DeLongs purchased it. The DeLong House was demolished in 1929 to make way for the third Pima County

Courthouse (Ayres 1993a:21-22). Excavations conducted by Homer Thiel in 1992 in the courtyard of the 1919 Pima County Courthouse resulted in the identification of the Presidio wall and "portions of the 1881 County Jail, the 1883 Pioneer Hose firehouse, the 1883 City Jail, a shortlived fountain dating to 1929, and an early twentieth century privy" (Ayres 1993a:22; Thiel, Faught, and Bayman 1993). In 1992 Danielle Desruisseaux conducted excavations in Tucson Block 138 in the Barrio Libre, the historic Mexican neighborhood of Tucson, and found 50 features dating from the 1880s to 1990, including foundations for houses and outbuildings, as well as wells, privies, and bottle dumps. These features were associated with "the Soto (Yaqui Indian), Torres (Mexican), and Ransom (Afro-American/Mexican) families" (Ayres 1993a:22). Research on these sites focused on the study of ethnicity, gender, and social class and how they are reflected in artifact assemblages and faunal remains.

Mining

In 1982 the Arizona State Museum and Archaeological Research Services conducted excavations at 30 historic sites in the Helvetia-Rosemont Mining District in the Santa Rita Mountains east of the Santa Cruz River (Ayres 1984). The sites included the town of old Rosemont (1894-1910), new Rosemont (1915-1921), the Rosemont school, 12 mining-related sites, five ranches, a Forest Service facility (1904-1937) comprising two sites, and seven sites of indeterminate or miscellaneous function.

In 1992 Laurie V. Slawson and Ronald P. Maldonado of Cultural and Environmental Systems, Inc., (CES) conducted excavations at a historic mining camp near the San Xavier Mine southwest of Tucson. The site (AZ DD:4:202[ASM]) consisted of a possible habitation area and associated artifacts dating between about 1900 and 1930 (Ayres 1992c:36). Slawson and Ayres (Ayres 1993c) also conducted research on the Vulcan Mine and an associated mining camp in the Pima Mining District south of Tucson. The Vulcan Mine was in operation from 1896 to 1923 (Ayres 1993c:33). Whittlesey, Ciolek-Torrello, and Sterner (1994:333) summarize excavations conducted by CES at four sites in the Silver Bell Mining District southwest of the Santa Cruz River and northwest of Tucson. The Tin House Well site (AZ AA:10:5[ASM]) was a large mine and associated camp, the

Happy Hour site (AZ AA:10:3[ASM]) was a small mining camp, and sites AZ AA:10:12(ASM) and AZ AA:10:26(ASM) were two cemeteries associated with the town of Silver Bell.

Farming and Ranching

McGuire (1979) reports on excavations at the Punta de Agua ranch on the Santa Cruz River south of San Xavier. The site was established by Fritz Contzen in 1855 and occupied by him until 1867, when it passed into the hands of Juan Elias, who lived there until it was included in the San Xavier Indian Reservation in 1877. McGuire studied the relationship between economic and social status of the occupants of the site and the ways ethnicity is reflected in the archaeological record.

In an archaeological survey along the Santa Cruz River northeast of Tucson, Stein (1993) recorded a number of homesteads dating from the 1880s to the 1900s and twentieth-century farms operated by the Pima Farm Company and Cortaro Farms. In 1978 archaeologists from the National Park Service excavated the Lewis-Weber site, a homestead dating from 1882 to 1910 that is now within the City of Tucson (Curriden 1981).

Other Studies

Whittlesey, Ciolek-Torrello, and Sterner (1994:339) summarize unsuccessful attempts to archaeologically identify several historically documented stage stations that have been archaeologically documented along the Santa Cruz River northwest of Tucson. Stein (1990) hypothesized that the oldest of these, the Point of the Mountain Butterfield Stage Station (1858), which later became the Ruelas Ranch (1876-1898), had been destroyed by a trailer court.

The Upper Santa Cruz River

So little of the culture history of this portion of the Santa Cruz River is known that it is appropriate to describe the scant evidence separately. The occupation of this portion of the river valley has been described only in old survey or reconnaissance data (Danson 1946; Frick 1954; Sauer and Brand 1931). Most of this information indicates that cultural affiliations and settlement patterns were quite different in the upper Santa Cruz valley than in the middle and lower portions (Wilcox 1987:241).

The earliest dated sites are from the Colonial period (Danson 1946:39), although there were many campsites and other temporary sites that (1) did not contain ceramics and could represent either preceramic cultures or short-term ceramic period occupations, or (2) contained mostly plainwares, which are not generally temporally diagnostic. Campsites were found along the entire length of the upper Santa Cruz, with the majority occurring in the San Rafael Valley near the headwaters of the river. Most were located on the bluffs overlooking the river, and some of these sites, according to Danson (1946:10), represent Papago occupation. Large campsites with numerous sherds, mostly plainware, and some ground stone were found throughout the upper Santa Cruz on the edge of low bluffs and terraces above the valley floor. These were early ceramic period sites, although they could not be assigned dates. "Late Sherd Areas" were all found north of the international border. These sites contained more pottery, including decorated wares, and the ground stone assemblage was dominated by trough metates, indicating a corn-based diet. Many of these sites were associated with permanent village sites, suggesting that they represented hamlets or farmsteads of the Colonial or Sedentary periods.

Classic period sites are identified as "Compound Sites" (Danson 1946:18) and terraced hill, or trincheras, sites. After re-analyzing the data from Di Peso's excavations at the Paloparado site, Wilcox (1987:239) determined that the Classic component of the site was strikingly different from the Colonial-Sedentary period Hohokam occupation. The Classic period occupation consisted of a closely aggregated series of more than 15 domestic compounds, each composed of 3-8 houses with entryways facing a common courtyard that contained work and burial areas (Wilcox 1987:246). According to Wilcox,

> Other sites similar to the Classic component at Palo Parado exist in the Rio Rico area, and sites as far up the Santa Cruz as the San Rafael Valley exhibit analogously aggregated compound site structure (Sauer and Brand 1931; Danson 1946; personal observation). The structure of these sites contrasts with that in the Tucson Basin (Wallace and Holmlund 1984),

> and the local ceramics are different. Palo Parado Ruin thus appears to lie near the northern end of a settlement system different from the one in the Tucson Basin [Wilcox 1987:241].

Danson (1946:18) found two of six compound sites north of the international border; four were found in Sonora.

Another site type was the "house ring," circular or oval rings of rock with cleared areas in the center. Danson (1946:12) attributes this type of site to the protohistoric period.

ENVIRONMENTAL RECONSTRUCTIONS

Interpretations of Holocene vegetation and climate have engendered much debate, but the generally accepted view is the sequence developed by Antevs (1955, 1962) and Sayles and Antevs (1941) with three basic periods: the Anathermal, the Altithermal, and the Medithermal. The subhumid Anathermal occurred circa 9000-5500 B.C.. The arid, hot Altithermal (ca. 5500-2000 B.C.) followed, to be succeeded by a semi-arid Medithermal with a moist initial phase and drought oscillations (Gish 1993:204). This scenario represents a general regional trend, with more variable local depositional histories dependent on the nature of a particular fluvial system, such as the size and character of the watershed and local floodplain dynamics. In fact, Waters (1989:Figure 3.7) shows that periods of channel downcutting and filling were specific to different water systems (e.g., the San Pedro River, Cienega Creek, Whitewater Draw, the Santa Cruz River).

Generally, data indicate that, prior to 1890, large segments of the Santa Cruz floodplain were not entrenched:

> The Santa Cruz River flowed intermittently through a broad, flat, grassy valley within a narrow, shallow channel. The river was surrounded by numerous mesquite thickets and occasional cottonwood groves, and was supported by a shallow water table. Discharge was normally confined to the small channel, and only during infrequent storms did water overtop the banks and spread over the floodplain. These stretches of the river were punctuated by wet marshlands or cienegas at a few locations where groundwater was forced upward to the surface [Waters 1987a:42].

Prehistoric environmental conditions along the Santa Cruz River have been reconstructed from archaeological studies using paleobotanical, paleofaunal, and geomorphological investigations. Perhaps the most intriguing studies have been the reconstructions of the depositional environments and hydrologic conditions in the middle Santa Cruz Valley (Haynes and Huckell 1986; Waters 1987a, 1987b, 1989). Haynes and Huckell (1986) developed a general stratigraphic sequence for the Santa Cruz River based on exposures 5-12 km south of the San Xavier Bridge site. The sequence suggested that the alluvial history of the river was relatively stable until approximately 550 B.C., when floodplain aggradation occurred. Haynes and Huckell defined five major episodes of alluvial downcutting and filling.

Other stratigraphic investigations were conducted at the San Xavier Bridge site (Waters 1987b), with correlations made to natural exposures upstream and downstream of the site. Seven major geologic units were defined, and dates were derived from radiocarbon and archaeomagnetic samples. Waters determined that the alluvial environment along the Santa Cruz was used by Late Archaic, Hohokam, and Postclassic populations. Channel erosion and widening occurred during Paleoindian through Middle Archaic times (Figure 4), followed generally by channel filling during the Late Archaic. During the Pioneer and early Colonial periods, the floodplain was entrenched, which "would have made farming impossible on the upper floodplain or in the river bottom; only after filling would farming be possible" (Waters 1987b:57). Waters believes that the floodplain would have been suitable for farming during the Rillito and early Rincon phases, with additional floodwater farming possible on the discontinuous channel fans that composed the lower bajada (ak chin farming) (Waters 1987b:59). This period corresponded to intensive occupation on the floodplain. During the middle Rincon phase, prehistoric settlement shifted to the north. Waters believes that the shift may have been related to the development of dunes and the entrenchment of the southern floodplain, as well as the cutting of a discontinuous gully in the southern portion of the reservation (Waters 1987b:59). Another shift in settlement, from the west to the east side of the river during the late Rincon phase, corresponded to continued headcutting of the discontinuous gully, which probably destroyed arable land, and to the emergence of a cienega environment to the north. The cienega near

Martinez Hill apparently attracted settlement during the Tanque Verde phase, as the number of sites continued to increase on the east side of the river, particularly around Martinez Hill. The river channel in the southern portion of the reservation stabilized and began to fill at this time. These conditions continued through the Tucson phase, after which sites were abandoned, at about the same time that major entrenchment of the Santa Cruz floodplain was taking place (Waters 1987b:59). The channel filled again during protohistoric occupation of the San Xavier Bridge site.

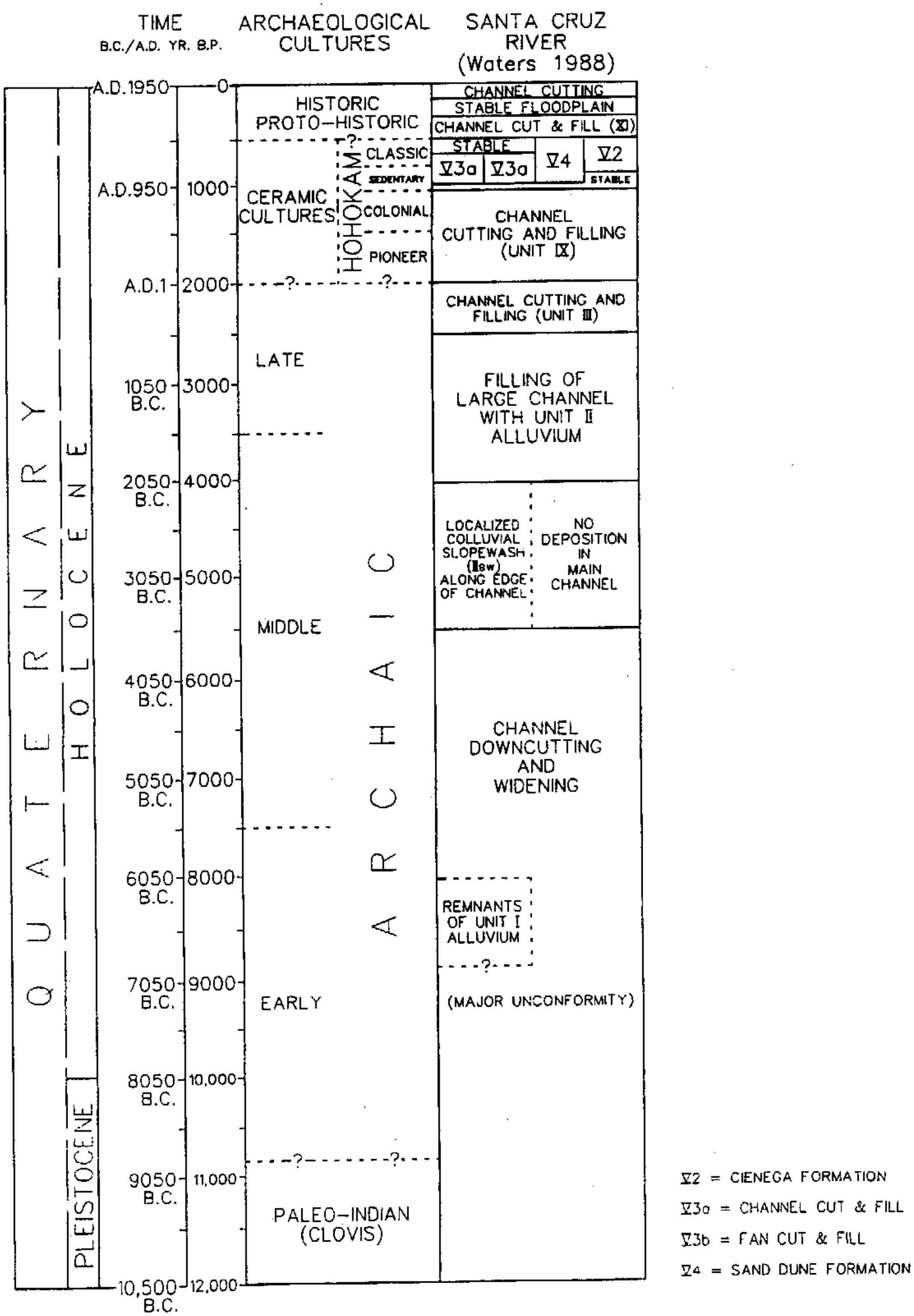

Figure 4. Alluvial sequence for the Santa Cruz River along the San Xavier reach (from Waters 1989:Figure 3.

In the Avra Valley, Waters (1987a) found that late Holocene deposition primarily occurred in arroyo fan deltas and discontinuous gully fan environments. These areas had floodwater agriculture potential, and Hohokam settlers appeared to locate there for the purpose of optimizing farming conditions. Field (1992) found that floodwater farming on alluvial fans in the northern Tucson Basin promoted settlement primarily on the bajadas below the Tortolita Mountains and the Tucson Mountains. Prehistoric populations took advantage of these potential agricultural areas as conditions allowed, perhaps partly because the floodplain environment of the river was highly variable (Waters 1987b:59). Although Waters suggests that the floodplain environment and surface hydrology of the river were not conducive to canal irrigation, he believes that limited canal or ditch irrigation would have been suitable near cienega environments. Others believe that canals may have been present on a small scale, possibly in association with primary ballcourt villages (Doelle 1985b; Doyel 1984). In fact, a few canals have been documented during archaeological excavations. About 1 mile from the Hodges Ruin, on the east side of the river, 1 or 2 canal segments were found (Kinkade and Fritz 1975), and canals associated with the Sedentary period have been found at Los Morteros on the first terrace and on the floodplain on the west side of the river (Bernard-Shaw 1988).

CONCLUSIONS

Archaeological studies along the Santa Cruz River are of interest for three reasons: (1) they document the natural conditions of the river prior to the advent of groundwater pumping; (2) they indicate what changes occurred in the river in its natural condition; and (3) they show how the river has been used throughout human history.

Environmental reconstructions, particularly that of Waters (1989), suggest that prior to 1890, the Santa Cruz River was an intermittent stream with occasional marshlands or cienegas. Large segments of the floodplain were unentrenched and supported mesquite and cottonwood bosques. Although sequences of stream aggradation and erosion varied according to specific geographical location, the only areas that were consistently conducive to irrigation agriculture were around the cienegas.

Archaeological studies have demonstrated long-term (11,500 years) occupation of the Santa Cruz River valley generally, but there have been clear differences in the cultural history of the upper, middle, and lower stretches of the valley. Some of this variability has resulted from changes in the condition of the river, which in turn resulted in different farming practices.

The archaeology of the upper Santa Cruz River valley is not well known, but it appears to contrast with the archaeology of the middle and lower valleys. The most distinctive sites date to the Classic Period (A.D. 1150-1400) and consist of compounds of 3-8 houses constructed around courtyards. This type of site seems to be the northernmost manifestation of a settlement pattern that is centered in northern Mexico. By about A.D. 1450, however, settlement had shifted to the ranchería pattern (dispersed hamlets and farmsteads) that characterized the area when the Spaniards arrived in the 1690s.

The middle Santa Cruz River valley has been occupied almost continuously since the Archaic period, and early farming communities appeared along this reach of the river as early as 400 B.C. Some of these communities appear to have been repeatedly occupied on a seasonal basis for at least 200 years. By the Pioneer Period (A.D. 1-750), some communities along the middle Santa Cruz River were occupied year-round. Colonial Period (A.D. 750-950) farmers practiced floodwater farming on bajadas and alluvial fans until headcutting of arroyos occurred. Sedentary period (A.D. 950-1150) entrenchment and cienega formation led to movement away from the floodplains. In the Classic period, populations aggregated into fewer larger sites and farmed both floodplains and uplands. After about A.D. 1400, settlement shifted to the ranchería pattern described above. Throughout the prehistoric agricultural periods, irrigation from the Santa Cruz River was limited.

The lower Santa Cruz River valley was apparently never occupied as intensively as the middle portion of the valley, and most sites that have been recorded in this area are associated with the Gila River rather than the Santa Cruz.

Historical archaeology in the Santa Cruz River valley has been as extensive as in any other area of Arizona and has confirmed locations of historic sites and identified colonial, United States territorial, and twentieth century farms and irrigation systems. It is noteworthy that water wells were commonly found in archaeological excavations in historic Tucson, a testament to high groundwater levels during the colonial and territorial periods.

Thus, the archaeological record suggests that the Santa Cruz River was marginal for irrigation agriculture using prehistoric agricultural technologies and that the most extensive use of the river for irrigation occurred in historic times. The prehistoric peoples of the Santa Cruz River valley traded in shell, ceramics, and presumably other items. The well-documented use of the river as a transportation and settlement corridor in historic times is materially manifest in the chain of missions, presidios, and other communities along the river that have been investigated by historical archaeologists. Despite all of this archaeological work, however, no archaeological evidence of navigation along the Santa Cruz River has been found.

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ARIZONA STATE LAND DEPARTMENT

Section 3

ARIZONA STREAM NAVIGABILITY STUDY
for the
SANTA CRUZ RIVER
Gila River Confluence to the Headwaters

Final Report

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January 12, 2004

A Historical Study of the Santa Cruz River

Background Information for Determination of Navigability of the River at the Time of Arizona Statehood, 1912

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November 1996

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EXECUTIVE SUMMARY

The purpose of this document is to provide relevant historic information that will help to answer the question: was any portion of the Santa Cruz River navigable at the time of statehood in 1912? In order to ensure a reasonably comprehensive analysis, many factors must be considered. The determination of where and how much perennial water there was in the river at any given time probably cannot be accurately determined; however, it is certainly not the only consideration. The Santa Cruz River Valley has been a center of travel, commerce, settlement, and agricultural activities for thousands of years.

To describe these impacts more clearly, the information is presented by sections: the upper Santa Cruz River (Santa Cruz County); the middle Santa Cruz River (Pima County); and, the lower Santa Cruz River (Pinal County).

The Santa Cruz River supported communities long before Anglo settlement. According to recent archaeological findings, people in farming villages near Tucson were using surface water to irrigate crops as long as 2000 to 3000 years ago. These same people supplemented their diet with fish caught from the river. More recently, 300 to 400 years ago, Indians were still irrigating crops with surface water near Tucson, San Xavier, and Tubac. This practice continued throughout the Spanish missionization of the southern Arizona and well into the period of Anglo settlement. No evidence was found to suggest that the early inhabitants of the valley used boats on the river. However, according to the journals of an early Anglo traveler, the place called "La Canoa" (just south of Green Valley) is named after an early Mexican settler who used a canoe to cross the river during times of high water. Other sources, however, explain the origin of the name differently.

During Anglo settlement of the Tucson valley, perennial water was used for irrigation. Two dams were constructed near Tucson to provide water for grain and ore mills. The lakes behind the dams also provided the community with recreation for swimming, boating, and fishing. Around this time, a land speculator reported that the river near Calabasas (Rio Rico) was large enough for steamboats, but this was found to be only false advertising to promote the sale of land. A group of men left from Nogales to try to bring a boat all the way to Tucson on a

good-will trip around the time of statehood. The launch was successful for some miles, but never made it beyond Tubac because of low water. No other known instances of boating on the Santa Cruz River during this time period were discovered.

Some portions of the river remain perennial to this day. Other parts of the river north of Nogales and Tucson have more water now than they did at the time of statehood due to wastewater effluent flow. Many perennial sections of the river have been lost: The perennial waters near San Xavier persisted until 1949, and supported native fish until at least 1937; and, the perennial section of the river near Tucson probably had some perennial flow in 1912, but by that time the river was deeply entrenched. Therefore, the water table was already lower than it was before entrenchment began after the floods of 1890. The United States Geological Survey kept data on streamflow at certain measuring points on the Santa Cruz River, and by 1910, it was reported that the entire base flow of the river, at both the Mexican border and near the Congress St. Bridge in Tucson, was diverted for agriculture.

The upper Santa Cruz River in Santa Cruz County, including the headwaters in the San Rafael Valley, is relatively stable. Perennial flow exists in many places here, as well as some cienegas. The geology changes north of Tubac, and the river frequently went subsurface here throughout history, as it does today. However, the perennial reaches at San Xavier and Tucson are gone. The lower Santa Cruz River in Pinal County never supported perennial flow. In fact, it was only during rare flood events that water from the Santa Cruz River reached the Gila confluence. Early explorers said that the river through Pinal County had a nearly indistinguishable channel, and maps showed a discontinuous channel there. This section of the river remains relatively unchanged.

The biggest changes in the valley have been along the middle Santa Cruz River, especially from Tucson to Tubac, because of population growth, mining and agriculture. This combination of events has led to loss of perennial water, an increase in groundwater withdrawal, and an extensive change in the vegetative structure there.

In more recent times, some people have attempted to navigate the river. These canoers report that boating is feasible, especially in the effluent-dominated areas. The *Tucson Citizen*, a local newspaper, reported on canoers who boated on both the effluent-dominated section in the upper portion of the river, on the Rillito River, and on other portions of the Santa Cruz during floods in 1990.

Boating, then, has occurred on rare occasions on portions of the Santa Cruz River. The river has also provided other benefits, including fish for human consumption, water for crop irrigation, recreation and necessary relief for early travelers. At least one major travel route followed the course of the river, and communities have existed along the river for thousands of years.

SANTA CRUZ RIVER HISTORY

I. THE HISTORIC SETTING

The Santa Cruz River Basin encompasses about 8,200 square miles. All of the streams in the watershed have a collective length of approximately 9,720 miles. Of those 9,720 miles of streams in the Arizona portion of the Santa Cruz River Basin, only 73 miles are perennial (Arizona Department of Environmental Quality 1994). The river crosses the international boundary twice, with a generally northward course after the loop it makes in Mexico. It is convenient for organizational purposes to study three sections: Santa Cruz County; Pima County; and Pinal County. It is also useful to study three periods of history: the Spanish/Mexican Period through the 1840s; the Territorial Period, from the 1840s until statehood in 1912; and, the Modern Period, from statehood to the present (Figure 1).

Upper Santa Cruz River - Santa Cruz County

The Santa Cruz River originates in numerous springs and creeks in the upper San Rafael Valley in extreme south-central Arizona, between the Huachuca Mountains, the Canelo Hills, and the Patagonia Mountains. The river flows south from this valley for about 8 miles, where it enters Sonora, Mexico. After a 32-mile loop into Mexico, it curves northward and re-enters Arizona five miles east of Nogales. The river then runs north past Rio Rico, which was once known as Calabasas, then winds toward Tumacacori National Historic Park and Tubac Presidio State Park.

According to most historical accounts, the Santa Cruz was largely perennial, from its headwaters south into Mexico, and then back into Arizona just north of Tubac. The headwaters area had numerous marshy areas, especially a large one north of the town of Santa Cruz. Near the Santa Cruz/Pima County line, the geology changes from a high bedrock situation to a deep alluvial system, and the river usually sinks below the surface.

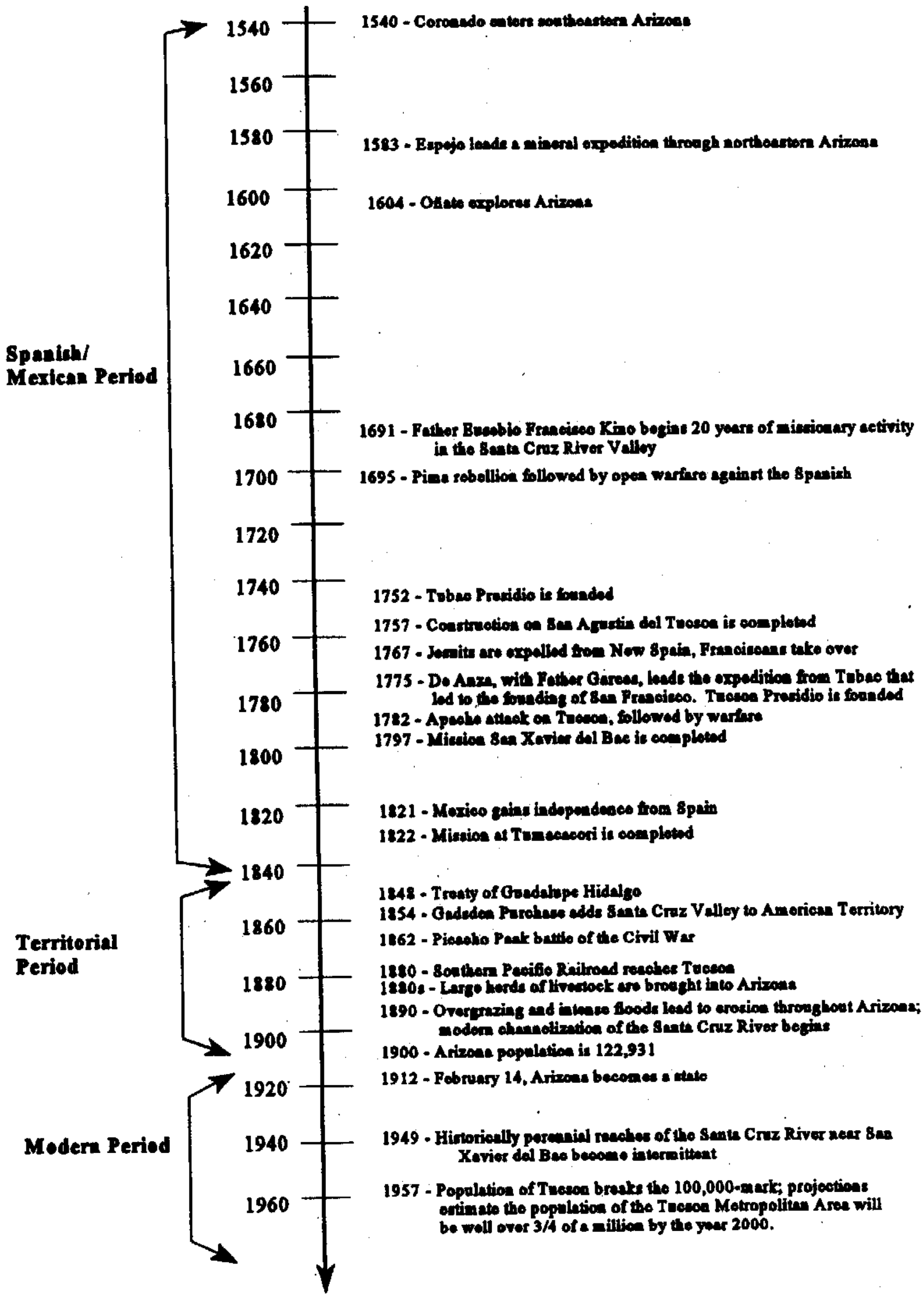

Figure 1. Chronology of Important Events in the Santa Cruz River Valley, 1540 – Present.

This part of the Santa Cruz River Valley is broad and flat, and bounded on both sides by mountains. Historically this entire stretch of the river was lined with riparian vegetation. The river may also have gone underground in at least one other location near Tubac during low-water periods. (Halpenny, personal communication, 1996).

Middle Santa Cruz River - Pima County

The river, running north into Pima County, passes Green Valley, enters the San Xavier Indian Reservation, and comes within sight of the Mission San Xavier del Bac. Historically the river went underground just north of Tubac, and did not have perennial surface flow again until it reached the San Xavier Mission. It was no coincidence that the Mission was located near the river. Until the 20th century, this portion was perennial, and in fact supported early Indian agriculture for hundreds of years.

The river then went underground just north of the Mission, and again came to the surface near Sentinel Hill, or "A" Mountain, in Tucson. Numerous springs contributed to the surface flow that existed both at San Xavier and near Sentinel Hill. Other springs present in the area were often used by early travelers as stopping points to replenish water supplies and water livestock (see Betancourt and Turner 1990: p. 50; Page 1954: pp. 63, 69). Nine-mile waterhole, shortly before the confluence with the Rillito, was traditionally the last dependable watering place on the trail to the Gila River. Just north of Tucson, south of the Pinal County line, the surface water disappeared again.

Lower Santa Cruz River - Pinal County

From Tucson the river turns to a north-northwest course, and at the Pinal County line it generally disappears. Since the river is cryptic in this region, very little has been written about it, except as a route of travel that was known to be lacking in water. The river runs through the desert in Pinal County until it meets the Gila River near Phoenix, 222 channel miles from its origin (Holub and Bufkin 1987). Some maps show the river as discontinuous, with the main stem emptying into playa. Waters from Santa Rosa Wash form a new channel to the Gila. Only during flood times was the river continuous to the Gila.

Tributaries

The major tributaries of the Santa Cruz River from south to north are Nogales Wash, Sonoita Creek, Rillito Creek, Cañada del Oro and the Altar-Brawley Wash.

Nogales Wash flows from Mexico, through Nogales and northward to the Santa Cruz River. This wash, together with a number of swampy areas around Nogales, made the area, according to an 1883 article in the *Phoenix Herald*, "a swamp dangerous for both man and beasts to cross." Malaria was rampant, so to deal with this problem, and reclaim land for human use, some of the swamps were drained.

Sonoita Creek flows perennially from its origin on the east side of the Santa Rita Mountains, through a Nature Conservancy Preserve to Patagonia Lake (a manmade lake and State Park), and from there, ephemerally, through lush riparian vegetation to the Santa Cruz River at Rio Rico.

The Rillito River is the largest tributary of the Santa Cruz River. One of its branches, Cienega Creek, starts high in the Santa Rita Mountains, and much of it is perennial today. It becomes Pantano Wash until the confluence with Tanque Verde Wash at Craycroft Road in Tucson, after which the river is called "Rillito Creek." Pantano Wash tends to be a summer stream with little underflow beyond the Cienega Creek stretch. The other branch, Tanque Verde Wash, is primarily a winter-flowing stream, carrying water from Sabino Creek which starts at the top of Mt. Lemmon at about 10,000' elevation. Bear Canyon and Agua Caliente are two other mountain streams tributary to the Tanque Verde Wash, which has a strong underflow to the confluence, and even today has perennial flow for most of its length.

The Cañada del Oro Wash flows from the northwest side of the Santa Catalina Mountains through the town of Oro Valley to its confluence with the Santa Cruz River north of Tucson. One of its tributaries in Oro Valley, Honeybee Canyon, flows most of the time.

The Altar-Brawley Wash, west of the Tucson Mountains, also collects waters which flow into the Santa Cruz River north of Marana. A marsh at Arivaca has water perennially, but the remainder of the area is ephemeral today. This Wash is deeply incised south of Ajo Way.

Santa Rosa Wash is an ephemeral stream which contributes to the flow of the Santa Cruz River near the Gila confluence. Many small ephemeral washes in the surrounding mountains contribute to the Santa Cruz River's flow at certain times of year.

II. HISTORIC VEGETATION, WILDLIFE AND CLIMATE

Vegetation

In the early days of exploration and settlement, the upper and middle Santa Cruz River valleys were consistently described as lush or fertile valleys with excellent grazing grounds, abundant grass, occasional forests of huge mesquite trees, and a river lined with giant cottonwoods, walnuts, willows and other riparian species. The lower Santa Cruz was considered dry with undependable water and grass. Kino (Bolton 1919) praised the richness of the valley and its potential, and he believed it had sufficient water, grass and wood to support a community of several thousand people and cattle. Many nineteenth century travelers described the river including: Bartlett (1965) in the early 1850s, Durivage (1937) in 1849, Parke (1857) in 1857, Aldrich (1950) in 1849, Reid (1858) in 1858, Froebel (1859) in 1859, Browne (1974) in 1864, Spring (in Gustafson 1966) in 1881, Couts (1961) in 1848 and '49, Cooke (1854) in 1854, Powell (1931) in 1849-52, Way (in Duffen 1960) in 1858, Clarke (1988) in 1851, Zuniga (in Hammond 1931) in 1795, and Bell (1854). Cadastral surveys conducted in the late 1800s are summarized in Betancourt and Turner (1990) and provide useful information. Some sample quotes follow.

Upper Santa Cruz

Travelers were welcomed upon reaching the town of Santa Cruz, which had orchards and farms providing fresh food. However, some found the town unappealing and the inhabitants sickly (apparently from malaria). Those who came through after Apache depredations found little to praise except the river. For many years it was the largest town between El Paso and California.

"The right, or West bank of the stream, on which we now are, is highly picturesque, not being as usual, a long unsightly bluff, but rises to the Mountains in a thousand little swells and undulations...The soil of the valley is rich and the grasses (grama and others) grow here luxuriantly.... Between 3 and 4 miles brought us to Santa Cruz. The corn fields come so close to the West side of the valley at places that it threw our wagons on the side hill; one large one canted and turned over the water which flooded it...." Powell (1931) in 1852.

"Our journey down the valley of the Santa Cruz was one of the most agreeable in our entire tour. We were accompanied by Señor Commodoran, an intelligent Mexican, whose friendship toward Americans traveling through the country has long been proverbial. . . . After passing through the canyon of the San Lazaro we entered a valley which opens out onto a magnificent grazing range, extending nearly 20 miles to the foot-hills of the Pinitos Mountains. Groves of cotton-wood of gigantic size fringe the stream at intervals of every few miles; the grass is wonderfully luxuriant, covering the valley and hill-sides as far as the eye can reach with a rich gold-colored carpeting . . . Our camp for the night was under a fine grove of cotton-wood, where the grass, shaded from the crisping rays of the sun, grew up in luxuriant masses high over our heads. Here we cut and slashed at the tufts, and burned out broad spaces for our fires, of which there was constant danger, till our camp was secure from conflagration; and then the venison and wild-ducks were quickly placed in the frying-pans, and their savory odors mingled with the pleasant fumes of the coffee-pot, and the creature-comforts of earth were ours in perfection." Browne, J. Ross (1974) [first published in 1864]**(pages 212-213).**

"The soil in the valley of the river is exceedingly rich, the best I have seen in Mexico. ... On the river's banks are cotton and musketi [mesquite] *trees...At sunset we halted for the night, with excellent wood and water at hand....*[Tubac area] *...we encamped for the night by the side of a running stream, about one mile from the town of Tucson."* Aldrich, Lorenzo (1950) in October, 1849.

"...at Santa Cruz, and further down, the banks of the river, and the valley itself, are covered with poplars and willows, ash-trees and plantains, oaks and walnut trees... Some portions of the valley are of such grand, rich, and simple beauty, as for instance Tumacacori and San Xavier del Bac, that they would be remarkable in any part of the world..." Froebel, Julius (1859).

"If you will portray in your imagination a bottom covered with tall, golden colored grass, hedged by mountains whose sands glitter like metal, divided by a meandering stream a dozen yards wide and as many inches deep, this shaded by cotton-woods, willows, and musquites, then a few hundred yards higher up another stream, a creek with less volume pouring in from the right, and in the fork an elevated rolling surface, you will have a view of Calabasas (Pumpkin, so called from an old yellow adobe house, named from its color, which stands on the right bank of the river near the above noticed junction.) Then picture to your mind's-eye this bottom dotted with shanties of straw and cloth, and the fork covered with military tents, and you have the tenements belonging to Calabasas, which were occupied by several hundred citizens, and four companies of the 1st Dragoons at the time or our arrival." page 187-188. February 8, 1857. Reid, John C. (1858).

"The valley continued about half a mile wide, thickly covered with mesquite trees of a large size. The bottom-lands resembled meadows, being covered with luxuriant grass, and but few trees. The immediate banks of the river, which is here [near the mouth of Sonoita creek] as diminutive as near Tucson, are lined with cotton-wood trees of a gigantic size. ... In some places there are large groves of these trees, rendering this part of the valley the most picturesque and beautiful we had seen." Bartlett, J.R. (1965), in July, 1852 [first published in 1854] (Vol. 2, page 307).

Middle Santa Cruz

"Leaving San Xavier, we followed the course of the Santa Cruz Valley for two days, making only one camp at Rhodes's ranch [near Tucson]. *I had supposed, previous to our entrance into this region that Arizona was nearly a continuous desert, as indeed it is from Fort Yuma to Tucson; but nothing can be a greater mistake than to form a general opinion of the country from a journey up the Gila. The valley of the Santa Cruz is one of the richest and most beautiful grazing and agricultural regions I have ever seen. Occasionally the river sinks, but even at these points the grass is abundant and luxuriant. We traveled, league after league, through waving fields of grass, from two to four feet high, and this at a season when cattle were dying of starvation all over the middle and southern parts of California. Mesquite and cotton-wood are abundant, and there is no lack of water most of the way to Santa Cruz."* (pages 143-144) Browne, J. Ross (1974), in late January, 1864 [first published in 1864].

"[From San Xavier to Tubac] *The bottoms in places, are several miles wide and highly fertile. Cotton-wood and musquite, of good size, are abundant in them. The river runs in the middle of a valley that varies in width, from a few to several miles, of surpassing beauty. The valley, table-land and mountain sides here, as elsewhere in the Purchase, are covered with a luxuriant coating of gramma grass which is the staff of life for every four-footed animal throughout the country. The mountain tops are white, till late in the spring, with snow."* page 185. February, 1857. Reid, John C. (1858).

"...It passes through one of the most beautiful and fertile valleys in the world, once inhabited by Mexicans, but now presenting a melancholy spectacle of deserted ranchos and fields running to waste. We procured water, in places from zeqjias [acequias] which were used to irrigate the land...[Tubac area] Clarke, A.B. (1988), on May 27, 1849 [first published in 1849].

[several miles south of Tucson] *"A rapid brook, clear as crystal, and full of aquatic plants, fish and tortoises of various kinds, flowed through a small meadow covered with shrubs... We had hitherto been following the course of the river of Santa Cruz, which although its channel was found dry in several places, constantly re-appeared. But below Tucson it loses itself in the desert..."* Froebel, Julius (1859), in July, 1855.

"Starting early from Tucson, the first day's noon will generally find a traveler at one of the sinks of the Santa Cruz, where the water disappears in a shallow bed of gravel and quicksand. The stream has here a fall of 75 feet to the mile, and there is an abundance

of grass for feed.... The great peaks of the Sierra Santa Rita now loom grandly before one through the trees." Hinton (1970), in 1878.

Lower Santa Cruz

This stretch of the Gila Trail has been known as the "Ninety Mile Desert" and was feared for its lack of water during most times of year.

"...we came in sight of the Presidio of Teuson [Tucson] *and finding good water and grass we camped. Learning that there is no water beyond two miles from Teuson, to the river Gila, about one hundred miles..."* Clarke, A.B. (1988), in 1849.

"Hence to the Gila River was a desert plain without water" (Harris 1960), in the mid-1800s.

" We left our Camp between the Mountains after breakfast. It is just at the top of a divide; the water, when there is any, runs all ways from here. The ground is perfectly bare and the larrea, mesquite, or some scattering weeds spring up solitary. Once in a way at long intervals there is a bunch or two of grass. .... There was neither water nor grass for the cattle... The road was very dusty..." Powell (1931), in 1852.

"During some seasons it flows further than others, so that the length of the stream above ground is subject to considerable variation; but it never succeeds in reaching the Rio Gila on the surface, although I believe it flows over the bedrock and under the drift which covers it for the remaining one hundred miles from Tucson to Maricopa Wells, where a large spring, the waters of the Rio Santa Cruz, it is believed - comes to the surface and flows to the Gila. ..." Bell (1869).

"Today we passed through Tucson. ... Here we heard some awful tales of the route ahead of us [from Tucson to the Gila], *dead animals strewing the road, wagons forsaken, human skeletons, who had famished for want of water etc."* (Hunter no date) in 1849.

"...the Sierra Tucson, near the town of that name, and along beyond the base of which it flows northward for miles, when it sinks and is lost sight of permanently. It is supposed to enter the Gila by some subterranean channel near Florence... ." Hinton (1970), in 1878.

The Tributaries

Early travelers found a series of cienegas along many parts of the Cienega Creek, Pantano Wash (both of which mean "swampy area") and Rillito River watershed. A long stretch of the river, probably all the way to the confluence with the Santa Cruz, was called "Cienegas Las Pimas." The entire lower valley was described as:

> *"...an unbroken forest, principally of mesquite, with a good growth of gramma and other grasses between the trees. The river course was indefinite - a continuous grove of tall cottonwood, ash, willow and walnut trees with underbrush and sacaton and galleta grass, and it was further obstructed by beaver dams...Such portion of rainfall as found its way to the river channel was retarded and controlled in its flow, and perhaps not oftener than once in a century did a master flood erode and sweep the river channel... ."* Smith (1910).

> *"The water was in marshes, coming from springs and a little brackish... The grass, or rather cane, was some 6 feet high... ."* Eccleston (*In* Hammond and Howes 1950), in November, 1849.

Similar marshy areas were described in the headwaters area, in Nogales, in nearby locations as far north as Tubac, Patagonia, Arivaca (in the Altar-Avra Valley basin), and at the Gila River/Santa Rosa Wash confluence. Irwin, a medical officer at Fort Buchanan in 1859, believed the marshy areas around the Fort, near present-day Patagonia, were responsible for the persistent malaria infecting the troops. His description follows:

> *"This cienega consists of alluvial deposits and extensive beds of decaying organic matter, the result of the rank, forced vegetation of the hot season. Here several warm and cold springs pour forth their contents, which run over the surrounding level surface, forming a peat marsh of considerable extent, wherein there are several stagnant filthy pools, in which vast herds of swine may be seen constantly basking in the mud or rooting up the foetid and miasmatic soil of the adjacent quagmires... ."* Irwin (in Betancourt and Turner 1990) in 1859.

Historic Changes in Vegetation

Very few of the historic vegetation features described by early travelers are recognizable in the valley today: the water table has dropped significantly; the loss of surface water and water table decline resulted in loss of vegetation and increased erosion; and the lush native grasses that early explorers described are virtually nonexistent. Cottonwoods exist only in isolated remnant forests, most notably where effluent flows, and a few scattered individual trees exist in other areas. Only a few remnant cienegas remain. Groundwater pumping led to the loss of a very large and old mesquite bosque and cottonwood forest in the San Xavier District in the 1960s. (Halpenny 1962). Some cienegas were drained to control malaria. Arroyo formation discussed below radically changed the nature of much of the area. Sabino Creek, Sonoita Creek, Arivaca Cienega, Honeybee Canyon and Cienega Creek are remnants of these former riparian areas and cienegas.

Wildlife

Early travelers described wildlife not found or rare in the area today and other wildlife still common in specific areas. Julius Froebel described the river near Tucson in 1855 as: *"A rapid brook, clear as crystal, and full of aquatic plants, fish, and tortoises of various kinds..."* (Froebel 1859: p. 503). It is not clear what kind of fish or tortoises he spoke of, but it is clear that the dry bed of the Santa Cruz River near Tucson has no such wildlife today, except some aquatic species that survive in wastewater effluent flows. Beaver were described on the Rillito, at Ft. Buchanan, and possibly near Tucson. Muskrat were described near Tucson and elsewhere by early settlers. Some samples of descriptions follow:

Upper and Middle Santa Cruz

> *"Near Santa Cruz in Sonora, we found this animal* [wolf] *more common than we had observed it elsewhere on our route. It, as well as the coyote, were often destructive to the flocks... .*
> *"These animals* [grizzlies] *were observed by us in greater or less numbers in the San Luis mountains, the Sierra Madre, and at Los Nogales; being particularly numerous at the first and last named localities.*
> *"During our stay at Los Nogales in the month of June, particularly the latter part, the heat during the day was quite oppressive; and the valleys of the streams, with their thick undergrowth affording a good protection from the rays of the sun, were the favorite places of resort for these animals... ."* Kennerly, C.B.R. (1856) in 1855.

> *"Like the flora, the fauna of this vicinity is of a highly diversified and interesting description. The following have been noticed: the panther, leopard* [jaguar?], *wild cat, lynx, grey wolf, coyote, red fox, grey fox, grizzly bear, brown or cinnamon bear, badger, pole cat, weasel, raccoon, beaver, rat, mouse, prairie dog, gopher, grey squirrel, brown squirrel, ground squirrel, antelope, white-tailed deer, black-tailed deer, peccary or Mexican hog, and the mustang or wild horse which roams over the plain in vast herds."*

"Much might be written about the rare and beautiful birds that abound in this country, many of which are remarkable for the gorgeous beauty of their plumage. The following have been met with: wild turkey..swan, brent, mallard duck, greenwinged teal, bluewinged teal, diver, blue crane, white crane, white heron, grey heron... ." Irwin, B.J.D. (in Davis 1986) in 1857 on Sonoita Creek.

"Mr. Fuller had killed a tiger in my absence and he and Grosvenor had quite a chase after a bear that ventured near the camp...Bears are very numerous here of these species, the black bear, the brown or as it is called the cinnamon bear and the fierce and dreaded grizzly... ." Way, Phocian (in Duffen 1960) at Tubac in June, 1858.

"Panthers [mountain lions] *are found in greater or less numbers throughout the entire country traversed by the Boundary Commission... it... was observed by us as far* [west] *as Los Nogales in Sonora; in which State the Mexicans, who call it Leon, wage against it an unceasing warfare, on account of the ravages which it commits among the cattle.... Near Los Nogales, in the month of June, we pursued a female panther, which we succeeded in wounding very severely..."* Baird, S.F. (1859).

"...he told me that there were some twenty turkeys a short distance off in the trees...[near Tubac].
"A white and black crane was killed today, cooked for supper and was quite palatable... [wood ibis?]." Bell, James G. (1932) in 1854.

"Wild game in abundance could be procured in the immediate vicinity, and by Christmas we had such a store of bear meat, deer, antelope, and fat wild turkeys, that no apprehension of short rations disturbed our enjoyment.... [Tubac]" Poston, Charles (1854).

Lower Santa Cruz

"We saw numbers of very large rabbits and also some very large Tarantulas..." Powell (1931) in 1852.

Change in Wildlife

The relationship between changes in the river and changes in faunal distribution in the valley are not always conspicuous. Notable examples are the grizzly bear and the wolf. These large predators were described extensively by early explorers in the region. A list of other wildlife species noted by various explorers in the 1800s is compiled in Table 1.

Animals like shorebirds, waterfowl, fish, muskrat and beavers, which are dependant on water, as well as large predators like wolves and bears, have essentially been eliminated from the Santa Cruz Valley. Exceptions exist in some of the areas fed by effluent, where there is still a rich diversity of bird species, as there is in the perennial tributaries. The corridor created by the Santa Cruz River is used by migrating wildlife and many local species. Some species of State or Federally threatened or endangered wildlife and plants are currently found within the Santa Cruz Valley (United States Fish and Wildlife Service 1991). The number of listed species that can be found in the valley is approximately 50, as shown in Table 2.

Table 1. Wildlife Mentioned by Some 19th Century Explorers in the Santa Cruz River Valley

Some of the explorers that traveled in the Santa Cruz River Valley in the 1800s kept journals in which they noted wildlife. The names that the explorers used are sometimes outdated, local terms, or even guesses. The bracketed names ...[ ]... are explanations proposed by the editors. The numbers following the animal coincide with the sources at the end of the list.

Birds

Wild turkey 1, 2,
Black and white crane [Wood Ibis?] 1
Swan 4
Brent [Brandt?] 4
Mallard duck 4, 8
Greenwinged teal 4, 8
Bluewinged teal 4
Redwinged teal 8
Diver 4
Blue crane 4
White crane 4
White heron 4
Grey heron 4
Pisano or Prairie pheasant [road runner] 4
Massena partridge [Mearns' quail] 4
Black-crested quail [Gambel's quail] 4
Speckled quail [Scaled quail?] 4
Dove 4
Ringdove 4
Wild pigeon 4
Gray duck 8
Spoonbill duck 8
Canvass back 8
Widgeon 8
Spring tail 8
Butter 8
Fish duck [? merganser] 8
Snipe 8
Curlew 8
Plover 8

Fish

Carp 10
Fish and Tortoises of various kinds 9

Mammals

Bear 2, 5
Brown or cinnamon bear 4, 5
Black bear 5
Grizzly bear 3, 4, 5, 7
Antelope 2, 4
Deer 2
White-tailed deer 4
Black-tailed deer 4
Wolf 3
Coyote 3, 4
Panther [Mountain lion, Leon] 4, 6
Leopard [jaguar?] 4
Wild cat 4
Lynx 4
Grey wolf 4
Red fox 4
Grey fox 4
Badger 4
Pole cat 4
Weasel 4
Raccoon 4
Beaver 4
Rat 4
Mouse 4
Prairie dog 4
Gopher 4
Grey squirrel 4
Brown squirrel 4
Ground squirrel 4
Peccary or Mexican hog 4
Mustang or wild horse 4
Tiger 5

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1. **Bell, James G. 1854**
2. **Poston, Charles. 1854**
3. **Kennerly, C.B.R. 1856**
4. **Irwin, B.J.D. 1857**
5. **Way, Phocian. 1858**
6. **Baird. 1859**
7. **Clarke, A.B. 1849**
8. **Arizona Weekly Citizen. Nov. 17, 1883**
9. **Warner, Solomon. 1884 [see: Hayden no date-b]**
10. **Arizona Weekly Citizen. March 15, 1884.**

Table 2. Special Status Species, Santa Cruz River Valley*

COMMON NAME	SCIENTIFIC NAME	STATUS
Mammals		
Black Mountain rock pocket mouse	*Chaetodipus intermedius nigrimontis*	C2
California leaf-nosed bat	*Macrotus californicus*	C2, SC, S
Cave myotis	*Myotis velifer*	C2, S
Greater Western mastiff-bat	*Eumops perotis californicus*	C2, S
Lesser long-nosed bat	*Leptonycteris curasoae verbabuenae*	LE, SE, S
Mexican free-tailed bat	*Tadarida brasiliensis*	S
Yellow-nosed cotton rat	*Sigmodon ochrognathus*	C2
Birds		
Fulvous whistling duck	*Dendrocygna bicolor*	C2
Northern beardless-tyrannulet	*Camptostoma imberbe*	S
Northern gray hawk	*Buteo nitidus maximus*	C2, ST, S
Rose-throated becard	*Pachyramphus aglaiae*	SC, S
Thick-billed kingbird	*Tyrannus crassirostris*	CS, S
Tropical kingbird	*Tyrannus melancholicus*	SC, S
Yellow-billed cuckoo	*Coccyzus americanus*	ST, S
Zone-tailed hawk	*Buteo albonotatus*	S
Reptiles/Amphibians		
Chiricahua leopard frog	*Rana chiricahuensis*	C1, ST, S
Gila monster	*Heloderma suspectum*	S
Great Plains narrow-mouthed toad	*Gastrophryne olivacea*	SC, S
Mexican garter snake	*Thamnophis eques megalops*	C2, SC, S
Fish		
Desert pupfish	*Cyprinodon macularius macularius*	LE, SE, S
Desert sucker	*Catostomus clarki*	C2
Gila topminnow	*Poeciliopsis occidentalis occidentalis*	LE, ST, S
Longfin dace	*Agosia chrysogaster*	C2
Plants		
Chiltepin	*Capsicum annuum glabriusculum*	S
Crested coral root	*Hexalectris spicata*	SR
Goodding ash	*Fraxinus gooddingii*	S
Large-flowered blue star	*Amsonia grandiflora*	C2, S
Lemmon cloak fern	*Notholaena lemmonii*	C2, S
Lyre-leaved twistflower	*Streptanthus carinatus*	S
Pima Indian mallow	*Abutilon parishii*	C2, S, SR
Pima pineapple cactus	*Coryphantha scheeri robustispina*	LE, S, HS
Pringle lip fern	*Cheilanthes pringlei*	S
Santa Cruz beehive cactus	*Coryphantha recurvata*	C1, S, HS
Santa Cruz star leaf	*Choisya mollis*	C2, S
Sonoran desert tortoise	*Gopherus agassizii*	C2, SC, S
Sonoran green toad	*Bufo retiformis*	S
Southern yellow bat	*Lasiurus ega*	SC, S
Speckled dace	*Rhinichthys osculus*	C2, S
Spotted bat	*Euderma maculatum*	C2, SC, S
Supine bean	*Macroptilum supinum*	C2, S, SR
Thornber fishhook cactus	*Mammillaria thornberi*	SR
Tumamoc globeberry	*Tumamoca mcdougalii*	S, SR

STATUS CODES: LE - Listed Endangered; PE - Proposed Endangered; PT - Proposed Threatened; C1 - Category 1 Candidate; C2 - Category 2 Candidate; 3C - Category 3 Candidate; SE - State Endangered; ST - State Threatened; SC - State Candidate; S - Sensitive; HS - Highly Safeguarded; SR - Salvage Restricted.

******Note*: **Compiled from information provided by the Arizona Game & Fish Department, Heritage Data Management System; the species listed are documented as occurring within a 10-mile corridor centered over the Santa Cruz River; the information is current on November 20, 1995, and is subject to change at any time.**

Climate

Droughts

Droughts and floods have significant impacts on the flow of the Santa Cruz River. The weather patterns of the Arizona desert can be extreme in either situation. Early travelers described landscapes very differently from year to year depending on the amount of rain the region had. J. Ross Browne, on his travels through Arizona in 1864, noted the effects of a drought in southern California and Arizona:

> *The country through which we travelled for several days was not altogether new to me. I had passed through it before during a tour of exploration among the Southern Indians in 1860. But how different was it now! In former years the magnificent valleys, stretching all the way from Los Angeles to the borders of the Colorado Desert, were clothed in the richest verdure. Vast herds of cattle roamed over them rampant with life. ... Now, after two years of drought, all was parched, grim, and melancholy. The pastures scarcely showed the first faint tinge of green, and the higher grounds were barren as the road over which we travelled. For hundreds of miles the country was desolated for want of rain. ... Thousands of cattle lay dead around the black, muddy pools. ... No more pitiable sight ever disturbed the eye of a traveller in this lovely region than the dreary waste of dead and dying animals* (Browne 1974: 42).

This is one of the periods of drought noted by Meko et al. (1995), whose study reconstructed tree-ring histories to identify droughts in the West and Southwest. Other droughts identified by the study include the periods ending in 1624, 1670, 1686, 1709, 1778, 1789, 1824, [1864], 1881, 1894, 1900, and 1956. One particularly intense period of drought from 1573-1592 apparently affected the entire western United States.

The effects of these droughts on the structure of the Santa Cruz River are hard to quantify. Other factors coupled with loss of vegetation due to low rainfall may lead to erosion and arroyo cutting (Betancourt 1990). Once the soil is exposed by vegetation loss, it is vulnerable to the heavy rains that often come in the monsoon season. This was probably the case in southern Arizona in 1880, according to Dobyns (1981):

> *Thus, intensity of rainfall perhaps interacted with parched soil conditions to magnify the erosive results. Still, the amount of channel entrenchment recorded in the summer rains of 1880 emphasizes that man's degradation of the environment*

was directly responsible for triggering massive erosion during a drought year (p. 179).

Similar conditions were present when the drought/flood cycles in the 1880s led to the starvation of the majority of cattle in southern Arizona (see "Livestock in the Santa Cruz Valley"), and preceded the beginning of the entrenchment of the Santa Cruz River during the floods of 1890.

Floods

Although the Santa Cruz River Valley is sometimes scorched by drought, it is at other times washed with floods. Precipitation in southern Arizona typically falls in short, sporadic and intense sessions, especially during the summer monsoon season. Winter rains tend to be more regional and last longer. Occasional intense fall storms (margins of Pacific hurricanes) bring a great deal of rain over a period of days or weeks. Because of these conditions, flooding of the river is not uncommon. Heavy rains contribute to surface flow in otherwise dry stretches of the river, and it is during flooding events that the normally dry lower Santa Cruz River in Pinal County carries any surface flow. The *Arizona Daily Star* recorded a conversation with Tucson pioneer Samuel Hughes during the floods of 1891. Hughes was reminiscing about some past floods:

> *The Santa Cruz and other rivers which empty into the Gila were all running high, and so great was the snow and rainfall during that season and the two years following that the Santa Cruz flowed a surface stream from its source to the Gila during* [18] *'68, '69 and '70, something unheard of since, as the stream is subterranean more than three fourths of the length of the valley through which it flows* (28 February, 1891).

The monsoon season in Arizona is often so intense that flooding on the Santa Cruz River is not uncommon. Some floods are notable for the extent of the damage they created. It has already been stated that the floods of 1890 were the beginning of the entrenchment of the Santa Cruz River. Other extraordinary floods in the vicinity between 1870 and the early 1980s occurred in 1887, 1891, 1898, 1907, 1908, 1912, 1914, 1916, 1919, 1926, 1930, 1931, 1932, 1936, 1945, 1947, 1950, 1951, 1957, 1959, 1961, 1964, 1965, 1966, 1970, 1972-73, 1976, 1977-78, 1979, 1982 and 1983 (Brazel and Evans 1984).

The December flood of 1914 lasted less than a week, but resulted in loss of life and property. A dam below San Xavier was swept out, city wells damaged, the University farm on the Rillito damaged, and many houses lost. A dramatic rescue near Sahuarita featured the National Guard, which headed toward the area with a collapsible boat. They found, however, that the current was too strong and ultimately rescued stranded people by horseback, using ropes. (*Arizona Daily Star* and *Tucson Citizen*, Dec. 19-21, 1914).

In the same flood, the first recorded attempt at floating a boat down the Santa Cruz River took place. A small wooden boat, the "Nogales," left Nogales during particularly high water level on the Santa Cruz, hoping to reach Tucson. The three sailors expected it would take two days to make the trip, but the boat went aground south of Tubac, and the trip was never completed (*Arizona Daily Star* 30 December 1914; Holub and Bufkin 1987).

During most of the major floods, bridges were damaged or destroyed, stranding people. Since flood water seldom persisted for more than a few days, people waited out the floods until they could cross the river on horseback or wagon.

The loss of vegetation, the drop of the groundwater table, the cementing of the banks, construction of impervious surfaces such as roads, and the channelization of the Santa Cruz River all undoubtedly contribute to the increased severity of floods. Six of the seven largest floods ever recorded at Tucson have occurred after 1960 (Webb and Betancourt 1990). The floods of 1983 displaced about 10,000 people, destroyed crops, roads and homes, and caused damage of more than $200 million dollars (Brazel and Evans 1984).

III. SPANISH/MEXICAN PERIOD TO THE 1840s

Early Exploration

The exploration by the Spanish of the area that is now Arizona began in the 16th century. Over the ensuing 300 years, the influence of these explorers, and especially the Jesuit and Franciscan missionaries, played an important role in developing the structure that would promote travel through the area, and finally colonization. A concise history, as well as a map, of the journeys of Spanish explorers into what is now Arizona, may be found in Walker and Bufkin (1986).

The first Spanish to enter were Alvar Nuñez Cabeza de Vaca and three others who, rather accidentally, ventured through the extreme southeastern portion of the modern state of Arizona in 1536. Because of the tales of rich Indian cities further north, or the "Seven Cities of Cíbola," the viceroy of New Spain, Don Antonio de Mendoza, sent Fray Marcos de Niza to explore the region (Hanna and Kupel 1987). The following year de Niza returned on another expedition with a small group of Spanish explorers led by Don Francisco Vasquez de Coronado.

De Niza and Coronado did not venture up the Santa Cruz Valley, though Coronado may have gone through the San Rafael Valley (Hadley and Sheridan 1995). Nor did subsequent journeys by Don Antonio de Espejo (on a mineral expedition in 1583) or Don Juan de Oñate (in 1604-1605) bring them into southern Arizona. It was not until 1691 that the Santa Cruz Valley had its first *entrada* by a Spanish (actually Austrian by birth) explorer, the Jesuit missionary Father Eusebio Francisco Kino. In 1774 and 1775, Fray Francisco Garcés accompanied Captain Juan Bautista de Anza on two journeys down the Santa Cruz Valley. On the second journey, in 1775, Garcés and de Anza led approximately 300 people on a settlement trip to the Coast of California. De Anza started at the presidio of Terrenate, in Mexico, and collected settlers and supplies as he slowly moved up the Santa Cruz River to "his presidio" at Tubac (Garate 1995). Their successful expedition resulted in a new colony at what would become the city of San Francisco. Later, de Anza led two expeditions from Mexico, north along the Santa Cruz River toward the Gila. His letters reveal the premier importance of water in an area where it is often scarce:

> *Well, although there is a road more free of Apaches and with a savings of more than thirty leagues [between Tubac and Tucson], we are unable to use it for lack of*

watering places. I have affirmed this in previous reports, saying that I have taken this route through the Papago Nation between here and the said river. Because of their poverty I will not travel through their country again, so that we will not end up in their situation. (Garate 1995).

What might have contributed to the poverty of the Papago Nation (the Indians at San Xavier del Bac) is discussed below, i.e., diseases introduced by the Spanish, and fighting with the Apaches.

Development of Missions

The impact that Father Kino had on the Santa Cruz Valley, either directly or indirectly, should not be underestimated. Probably the first large settlement in the area was the Jesuit mission of Santa Maria Soamca, later known as Santa Cruz (Mexico), which was established by Father Kino. The valley was used extensively by the priest as a travel route into the northern portion of *Pimería Alta*. Kino's missionary efforts in the 20 years between his first entrance in 1691 and his death in 1711 also led to the establishment of missions at San Xavier del Bac and Guevavi. The mission at Tumacacori was not finished until 1822, well after Kino's death, but his influence certainly played a role in its construction. Some smaller missionary posts, or *visitas*, were established at Tubac and San Agustín del Tucson. Perhaps the greatest impact Kino and subsequent missionaries had on the Santa Cruz Valley, though, was the introduction of new technologies, crops, domestic animals, and disease (Sheridan 1988).

The headwaters region of the Santa Cruz River, in the San Rafael Valley, is primarily grasslands; in fact, because of the extensive pasturage, grazing has been perhaps the most important activity in the area since the time of Father Kino. He brought livestock into many areas along the Santa Cruz River Valley, promoting the idea of grazing. In the San Rafael Valley, the San Rafael de la Zanja Land Grant was contested before the Court of Private Land Claims (see below: Land Grants). The grant was awarded, and this officially established the valley as a range for the grazing of livestock for many years to come (Hadley and Sheridan 1995).

Father Kino also brought new information and new crop species to the Piman Indians in the Santa Cruz Valley, which led to the expansion of farming. As Hohokam agriculture had hundreds of years earlier, the crops of the missions relied on irrigation from Santa Cruz River surface waters flowing through irrigation canals. Kino brought cattle, sheep, and goats into the area from the herds he maintained further south in Mexico. According to Wagoner (1952), Kino viewed the possession of cattle as the most important tool in converting the natives. In a letter to Father Visitor Antonio Leal, April 2, 1702, Kino wrote:

> *There are already many cattle, sheep, and goats and horses...for although in the past year I have given more than 700 cattle to the four fathers who entered this Pimeria, I have for the new conversions and mission, which by the favor of heaven it may be desired to establish, more than 3,500 more cattle...* (quoting from Bolton 1919, pp. 357-358).

By the time Captain Juan Bautista de Anza began his journey down the Santa Cruz Valley in 1775, the missions were under many pressures. The Apaches were continually attacking travelers on the road that followed the Santa Cruz River, as well as the missions themselves, and taking food, livestock, and other goods. The *visita* at San Agustín del Tucson was established in 1757, and the Tubac Presidio was formed in 1751 - though it was defended only intermittently. The Jesuits had been expelled from New Spain in 1767, and Franciscans entered the area to take charge of a seriously deteriorated mission system. Although construction on the churches at San Xavier and Tumacacori was not completed until 1797 and 1822, respectively, they were still centers of missionary activity. Because of frequent fighting with Apaches, Tumacacori often had a population as intermittent as Tubac in its inhabitance.

Another European import, disease, had a devastating effect on Indian populations in the valley. Baldonado (1959), reported the census figures taken by Fray Antonio Ramos in 1774 for the missions and *visitas* in the Santa Cruz Valley. Mission San Jose de Tumacacori, at that time, had 98 Piman Indians, as well as 19 Spaniards; its *visita*, San Cayetano de Calabazas (Calabasas, or present-day Rio Rico), had 138 Pimas (many of which had migrated there from other pueblos abandoned because of Apache raids). The Mission San Xavier del Bac had 160 Pimas, and its *visita*, San Agustín del Tucson, 239. Although the introduction of new crop species and new agricultural technology provided more food per capita than at any other previous time in history, the European diseases introduced into the Santa Cruz River Valley by Spanish explorers and missionaries very nearly led to the complete destruction of communities of native Indians. According to Dobyns (1963), the Indian population in the Santa Cruz River Valley from 1700 to 1800 may have decreased by as much as 95% or more.

Agriculture

The valley of the Santa Cruz River was one of the earliest and most widely farmed valleys in Arizona. Agriculture has been practiced in the Santa Cruz Valley since at least 1200 B.C., with farming communities established by 600 B.C. (Mabry 1995). The method for farming at this time was occasional dry farming during the rainy season, and irrigation by diversion of surface flows through complex systems of ditches. Agriculture and grazing introduced by Kino and others are described above.

One of the places where agriculture was practiced, by diverting surface flow of the Santa Cruz River into diversion ditches, was near Tubac, which has been continually irrigated for more than 400 years (Halpenny, personal communication, 1995). San Xavier has been almost continuously farmed from prehistoric times to the present.

Mining

Mining in the Santa Cruz River Valley was practiced for centuries by Indians, primarily in small silver mines in the Santa Rita Mountains. After the arrival of the Spanish, moderate attempts at mining silver and gold were made. At this time the mechanics of the process made any large-scale attempt at mining unlikely. Not only was it difficult to haul the ore over the rugged terrain of the mountains, but the common Apache raids made it dangerous. Furthermore, the Jesuit missionaries of Pimería Alta looked unfavorably upon mining, mainly because of the questionable behavior of miners. Captain Manje, a Spanish soldier who frequently escorted and guarded Father Kino, found what appeared to be a large piece of silver ore at San Xavier del Bac in 1697. However, Fathers Luis Velarde and Jacobo Sedelmayr informed Manje that no mining had been done in Pimería Alta in the first twenty years of the missionary activities there (Wilson 1987).

Land Grants

In the territory of New Spain in the 17th and 18th centuries, prior to United States acquisition of what is now southern Arizona, the Spanish government wanted to encourage settlement into Pimería Alta. Northward expansion by ranchers led to a process through which the Spanish government auctioned off land grants for the purpose of encouraging settlement and providing grazing land for livestock. A grant was to be four *sitios*, or four square leagues (17,350 acres); however, if a claimant later demonstrated a need for more land for his livestock, he could purchase "overplus," or an indeterminate amount of adjoining land, at the original auction price. When Mexico gained independence in 1821, its new government continued the practice. Many acres of land in the fertile river valleys in what is now southern Arizona and New Mexico were sold to the ranchers. This area was to become a part of the United States through the Gadsden Purchase in 1853, and the U.S. government had to decide how to deal with the claims.

It was decided that if evidence of title could be located in Mexican archives, the surveyor general of the territory must report on the validity of the claim, submit the information to the Secretary of the Interior, who then would give the information to Congress. This process was slow and Congress had not acted on any of the 13 claims by 1888; so, after many years of being pressured, they established the Court of Private Land Claims (CPLC) in 1891. The duty of the Court would be to examine and act on the claims. By 1904, when the Court disbanded, they had confirmed title to 116,540 acres of land out of 837,680 acres claimed (not including the famous and fraudulent Peralta-Reavis claim of 13,000,000 acres, which was submitted to the New Mexico Territory; the land included the Gila River Valley from the Arizona-New Mexico border, nearly to its confluence with the Salt River).

The grants had been located in areas with good grass forage for livestock; therefore, the properties were centered right over rivers and streams, including almost the entire Santa Cruz River and its tributaries, as well as some in the San Pedro River Valley. Following is a short list of facts regarding the land grants that were located on the Santa Cruz River:

<u>Tumacacori/Calabasas</u>

- Oldest land grant
- Requested by Indians at Tumacacori in 1806, full grant in 1807
- Sold several times until C.P. Sykes and John Curry requested sanction from the CPLC in 1880s, who denied the claim - the decision was upheld by the Supreme Court.

La Canoa

- Described in 1775 as being five leagues north-northwest of the Presidio of Tubac (de Anza expedition's first stop)
- In 1820, Tomas and Ignacio Ortiz requested four *sitios* known as "La Canoa", five leagues north of Tubac
- In July, 1821, the surveyor reported that the Santa Cruz runs through the land, but that it only runs water after rains
- Maish & Driscoll acquired half interest from the Ortiz heirs, and the CPLC was petitioned in 1893; the Court awarded title of 46,696.2 acres
- The government appealed, and the Supreme Court awarded title of 17,203 acres

Buena Vista, or Rancho de Maria Santissima del Carmen

- Jose Tuvera petitioned for the grant in 1826, on behalf of his father-in-law, Don Josefa Morales
- Requested four square leagues of "ancient abandoned place of Maria Santissima Carmen," partially in Arizona and partially in Sonora, Mexico
- Sold several times and finally purchased by Maish & Driscoll; petitioned CPLC in 1880s and were awarded 5,733 of 17,354 acres claimed

San Jose de Sonoita

- Title issued to Don Leon Herreras for 1.75 *sitios* in 1825 at Sonoita
- Sold several times; Matias Alsna submitted request to CPLC, Supreme Court allowed the claim after establishment of true boundaries; claim totalled 5,123 acres

El Sopori

- Adjacent to La Canoa and south of Mission San Xavier del Bac
- The Court rejected a claim for 141,722 acres in 1893

San Rafael de la Sanja (Zanga)

- Don Manuel Bustillo petitioned for four *sitios* in 1821, most within the boundary of Santa Cruz Presidio
- Supreme Court in 1902 maintained lower court's allowance of four square leagues

Aribaca (Arivaca)

- Ortiz brothers (of La Canoa) were awarded two square leagues in 1833 at Arivaca, which was 10 leagues northwest of Guevavi
- Charles D. Poston eventually became owner of the land, and he sold it to Arivaca Land and Cattle Company, who petitioned for title in 1893
- Supreme Court denied the claim

Los Nogales de Elias

- Don Jose Elias and his parents Don Francisco Gonzales and Dona Babanera Redondo petitioned for 7.5 *sitios* on the western side of Tumacacori grant
- Camou brothers obtained the claim and petitioned for 32,763 acres in 1892
- Supreme Court ruled against the claim

The Mexican Period

The pressures of disease and Apache raids were not the only instabilities in the region at this time. Mexico went to war with Spain to gain independence, and achieved it in 1821. In 1846, Mexico again went to war, this time with the United States. With the Treaty of Guadalupe Hidalgo in 1848, the war ended and the United States gained possession of all of Arizona north of the Gila River. The U.S. was interested in expanding its frontier to the west and found that Mexico still controlled some important land; especially important so soon after the California Gold Rush. Therefore, through the Gadsden Purchase of 1854, all of Arizona south of the Gila River was added to the United States. This addition of land to the area of the U.S. was an important precursor to the completion of the railroad, which would finally connect the extreme Southwest with the East, ending the isolation of the region, bringing the settlers, and initiating the Territorial Period.

At various times during this period, and up to the 1870s, there was a great deal of instability because of Apache raids, and some areas were depopulated temporarily. Agriculture and grazing were less feasible during this period than they were in later periods.

Spanish/Mexican Period Summary

In summary, the Santa Cruz River at this time probably remained much as it was before the Spanish arrived. It had perennial reaches from its headwaters to just north of Tubac, where it sunk into the sand only to rise again near Martinez Hill and through the grounds of Mission San Xavier del Bac. The waters would sink again and rise around the marshy cienegas at the base of Sentinel Hill, or "A" Mountain, at Tucson. Finally, it would disappear again north of Tucson, near what is now the Pima/Pinal County line and become virtually indistinguishable in the desert all the way to its confluence at the Gila River. The perennial reaches of the river supported the Spanish missions, as well as communities of Indians, much as it had probably done for millennia. It had no deep channel, but at least south of Tucson, and along the tributaries, it was frequently marked by gigantic cottonwoods that followed its channel winding through the broad and fertile Santa Cruz Valley, spoken of time and again by early explorers.

Upper and Middle Santa Cruz River

There was much activity around the river in Santa Cruz County during the Spanish/Mexican Period. Father Kino established the first significant missionary structure in the upper Santa Cruz River Valley in the 1690s and early 1700s. Among other things, he introduced new agricultural technologies and livestock. Most of Kino's activities were between Mission Soamca in Mexico and Mission San Xavier del Bac (Tucson at this time being a relatively insignificant *visita*). Although Kino introduced ideas and technologies that would lead to many changes in the future of the Santa Cruz, the river probably remained relatively unchanged through this period. The perennial reaches near the mission, and at Tucson, still supported surface flows, and no channelization had yet occurred.

Lower Santa Cruz River

The missionary activity of this period, and the later northward settlement, essentially bypassed Pinal County. Kino did not often travel beyond Tucson, and expeditions to the northern frontier proceeded to the Gila River and beyond it. The river, between Tucson and its confluence with the Gila, never supported perennial flow, or even much ephemeral flow, and this is how it remained throughout the Spanish/Mexican Period.

IV. TERRITORIAL PERIOD 1850-1912

Trappers Enter Arizona

In 1824, James Ohio Pattie and thirteen other men entered Arizona from the east on a beaver trapping expedition and started moving down the Gila River, which was at that time unexplored territory as far as the fur trappers were concerned. They explored tributaries such as the San Pedro and Salt Rivers, where they expected to find beaver. There is no indication that Pattie or any other trappers entered the Santa Cruz River Valley. From their vantage point on the Gila, it was undoubtedly (as it is today) beyond the marshes at the confluence a dry and barely distinguishable river bed to the south (and therefore not good beaver habitat). There are isolated accounts of beaver on Sonoita Creek, Pantano Wash and possibly the Santa Cruz River, but apparently beaver were not numerous in the area.

Arizona Enters the Union

Since trapping did not have the allure to bring settlers into the area after the 1830s, it was another decade or more before more American settlers began to enter Arizona. The Treaty of Guadalupe Hidalgo in 1848 came at the end of the U.S. war with Mexico, and added all of modern Arizona north of the Gila River to the United States as part of the Territory of New Mexico. Almost immediately after the Treaty, gold was discovered in California, and a huge number of argonauts began passing through Arizona on their way to expected riches (Harris 1960). Reports by Couts (1961) in 1848, Evans (1945) in 1849, Forsythe (no date), Pancoast (1930), Hunter (no date), Powell (1931) in 1852, Hayes (1929), Durivage (1937) in 1849, and others, provide information about this period.

Once the territory joined the United States, a survey of the boundary was conducted in 1851 in anticipation of the Gadsden Purchase of 1854. Gray conducted a survey for the railroad in 1854, with another boundary survey led by Emory in 1893, both of which provided valuable information about the river and its environs.

In anticipation of the immigration of pioneers, some entrepreneurs began to set up businesses in important locations along major routes of travel. One of these locations was Tucson, along the Gila Trail (Walker and Bufkin 1986: Figure 40). At this time, however, Tucson was still a part of Mexico and certain instabilities in the region, including Apache raids and the fact that the area was isolated from either Mexican or United States protection, hindered expansion. It was not until well after the Gadsden Purchase was ratified in 1854, that Tucson held an active military presence. In fact, it was only with the conclusion of the Civil War in 1865 that a cohesive military presence, and the subsequent defeat of the Apaches, brought a relative stability to the region and led to the expansion of population and enterprise. The first notable enterprise that took place in the region was ranching.

A Route for Travelers

The Santa Cruz River provided a useful route for many early travelers and explorers. For the Spaniards coming north from Sonora, the river was an ideal route, providing both water and food for animals and people. For people coming from the east, there were three feasible ways to enter the state: north of the White Mountains along the Little Colorado River; south of those mountains along the Gila River (approximately the present I-10 route); and, south of the Chiricahua Mountains. For many early travelers the Gila Trail, or southern route, was the safest, as Apaches controlled much of the middle route and mountainous conditions made the northern route less attractive. By the end of the 19th century, more travelers took the middle route once the Apaches were subdued. The Butterfield stage, and later the railroad and highway, all came this way.

Using the southern route, or the Gila Trail, travelers crossed the mountains at Guadalupe Pass, headed west toward the San Pedro River, and then usually turned south to the town of Santa Cruz and followed the Santa Cruz River all the way to the Gila River. Parties without wagons might take a shortcut along Sonoita Creek. This route and slight variations on it were used for exploration, travel to the California gold fields, prospecting, cattle drives, and many other purposes. The traveler could count on grass for the animals as far as about present-day Marana, as well as water and game. Some of those who took this route were the Mormon Battalion in 1846, Bartlett (1965) in 1852, Gray (1855) in 1854, and Emory (1857) in 1855.

One of the early travelers on the upper Santa Cruz River was John Spring (Gustafson 1960). In his diary, Spring gives one explanation of the origin of the name "La Canoa" (now Canoa, just south of Continental), and it is one of the few allusions to navigation on the river found in the literature:

> *A number of the newly-arrived squatters* [post-gold rush settlers] *followed the Santa Cruz River upward as far as Calabazas and Huebabe and settled there, while a party of about eighteen, including women and children, stayed at a place named then, as now, "La Canoa," so called because a Mexican settler already there had built a large canoe, or flat-bottomed boat, upon which he crossed the river whenever the lower, or western, road leading to Tubac became flooded by the summer rains, in which case the eastern road was chosen, as it led over the high ground along the ever-present foothills.* (Gustafson 1966: 53).

The portion of the route north of Tucson, however, usually offered the traveler little in the way of either food or water. Many travelers complained of lack of water and lack of forage all the way from the 9-mile waterhole north of Tucson to the confluence with the Gila River: "An Indian came into camp last night and reported 'no water until we get to the Gila' and as proof drank until he made himself sick; he stated that he had been two days without..."[camp just north of Tucson] (Bell 1932); "...we pushed on in order to procure water, and after driving till ten o'clock without breakfast, found some, but it was almost impossible to use it, being covered with a thick green scum" [about 22 miles north of Tucson] (Aldrich 1950); and, "Hence [from Tucson] to the Gila River was a desert plain without water. To have the advantage of the coolness of the night and shade, we started at sunset, traveling without order and camping in small squads. By sunrise we had mastered 30 miles; by sunset, 40 more. We rested till morning and at 10 or 11 a.m. reached water at the Gila River" (Harris 1960).

With the arrival of stagecoaches in 1858, and suppression of the Apaches by the 1870s, the more northern route became popular and the southern route fell into disuse. This route somewhat paralleled present I-10 highway and entered the Santa Cruz Valley along Cienega Creek-Pantano Wash. The railroad later also followed this alignment.

Livestock in the Santa Cruz Valley

The area had been grazed periodically during the Spanish and Mexican periods and wild cattle were encountered by travelers, but the numbers of cattle in the late 19th century probably far surpassed earlier numbers.

The Southern Pacific Railroad was completed as far as Tucson in 1881, opening southern Arizona to commerce with the East. Furthermore, droughts in the ranges of California and Texas were forcing many ranchers there to move their cattle. A combination of these, and perhaps other forces, led to a huge immigration of ranchers with their cattle into Arizona. In the early 1880s, two ranches along Pantano Wash near Tucson, Empire and Vail, had an estimated total of 6,000 cattle and 23,000 sheep (Wagoner 1961). Between 1825 and 1843, there were from 2,000 to 5,000 head of cattle grazed in the San Rafael Valley annually (Hadley and Sheridan 1995).

When the livestock industry moved into southern Arizona in the 1880s, the economy of the region grew at an unprecedented rate. Much of the growth could reasonably be attributed to the completion of the railroad, the growth of the livestock industry, and the development of groundwater-pumping technology. Samuel Hughes, an early pioneer of Tucson, gives a concise description of Tucson in 1885:

> *Tucson now has a population of 9000, about 1/3 Americans. We have 1 Catholic church, 5 Protestant churches, 3 public schools, "one large brick school house," 9 teachers and 500 scholars... . We also have glass works, water works, electric light, 2 ice factories, two wagon manufacturies, 2 breweries, a sash door and blind factory and R. R. repair shops, a fine brick Court House, 5 hotels, about 20 restaurants. ... There are good mines all around Tucson from 3 ½ to 75 miles which will pay when properly developed. Good cattle ranges from edge of town. Pima Co. has about 10,000 head of cattle on ranges* (Page 1954: 64).

There were a large number of livestock grazing in the Santa Cruz Valley when severe weather patterns moved into the area in 1885. A series of very dry summers and very wet falls, coupled with the overgrazing of livestock, created a decade of dramatic change on the middle Santa Cruz River. Cattle and sheep grazed until much of the valley was denuded; short heavy rains in the fall months did not encourage new growth, but instead washed away much of the exposed soil. In early 1890, the previous four years of very dry summers, coupled with flooding in the fall and winter, culminated with the most damaging and extensive floods that had yet been recorded in the valley. The flood waters wrecked buildings, washed out dams (see below: <u>Warner and Silver Lakes</u>), and initiated the deep entrenchment of the Santa Cruz River that is characteristic today. The cattle industry peaked within a year; an official census showed 721,000 head of cattle in Arizona in 1890, although many estimated the count to be twice that. But a year later 50%-75% of the cattle were dead of starvation, and many more were being moved out of state or sold for beef (Wagoner 1961). The lush grasslands that existed for millennia, and that were written about with enthusiasm by explorers, have never recovered.

Grazing and the Arroyo Debate

The role that grazing played in arroyo cutting in the southwest has been debated for years (Bryan 1925 and 1940, Antevs 1952, Hastings 1959, Cooke and Reeves 1976, Dobyns 1981, Betancourt and Turner 1990, Bahre 1991, and others). Some have argued that climatic change best accounts for arroyo cutting, some have argued that arroyo cutting and filling are natural processes that preceded cattle, and others have argued that a combination of factors best explains the fact that in many places in the southwest arroyos formed in the late 19th century. They further argue that the presence of too many cattle served as a trigger for arroyo cutting in the presence of a drought-flood cycle. Betancourt and Turner (1990) discuss the role that other human activities played in cutting the Santa Cruz River channel - poorly designed ditches, diversion dams and other activities.

Agriculture

During the late 1800s and early 1900s, agriculture in the valley changed because of the introduction of new technologies, including relatively efficient groundwater pumping devices. Some major areas of agricultural development at this time were between Tucson and Tubac. This was undoubtedly due to the availability of the water supply and the broad, fertile flatlands.

Even though water was relatively plentiful, it was not always strictly reliable, as this quote from Bartlett (1965) shows:

> *The preceding fall* [of 1851] *after the place has been again occupied, a party of Mormons, in passing through on their way to California, was induced to stop there* [Tubac] *by the representations of the Mexican commandante. He offered them lands in the rich valley, where acequias were already dug, if they would remain and cultivate it; assuring them that they would find a ready market for all the corn, wheat and vegetables they could raise, from the troops and from passing emigrants. The offer was so good and the prospects were so flattering that they consented to remain. They, therefore, set to work, plowed and sowed their lands, in which they expended all their means, anticipating an abundant harvest. But the spring and summer came without*

rain; the river dried up; their fields could not be irrigated; and their labor, time, and money was lost. They abandoned the place, and, though reduced to the greatest extremities, succeeded in reaching Santa Isabel in California, where we fell in with them.

Once Anglos began migrating into the Santa Cruz River Valley, some new technologies and techniques came with them. Agriculture in the mid- to late-1800s was characterized still by the diversion of surface flows. When the groundwater table began to drop, cross-cut ditches were dug across the river to intercept shallow subsurface waters. Sam Hughes' ditch was one that diverted subsurface waters to fields in and around Tucson. During the floods of 1890, it was probably at this cross-cut that the entrenchment of the Santa Cruz River began (Betancourt and Turner 1990).

Even before the arrival of groundwater pumping technology, large tracts of land were devoted to agriculture either through the diversion of surface waters or simply by dry farming. The extent of pre-pump farming in the valley is illustrated by the following quote:

> *That portion of the valley which is generally watered (for the Santa Cruz is much like your eccentric streams of Southern California, which sink out of sight sometimes for many miles) produces, like southern California two crops a year. Last year there were 40,000 acres of land in cultivation in Santa Cruz Valley proper, and nearly 45,000 acres in the net-work of valleys and canyons adjacent* (Bulletin 1879).

By 1890, pump technology arrived in southern Arizona. The pumping of groundwater changed the nature of agriculture in the Santa Cruz River Valley forever. New crops were introduced into the area, new land was devoted to agriculture, and the water table began to drop significantly. Wheat, alfalfa, citrus and pecan trees were all water-intensive crops introduced into the Santa Cruz Valley after the arrival of groundwater pump technology. Another interesting attempt at agriculture occurred near Continental soon after statehood. In 1914, the Continental Rubber Company began growing guayule (*Parthenium tomentosum* X *P. argentatum*) for production of synthetic rubber. When World War I ended, the price of rubber dropped and the company was out of business. At its peak in 1920, 450 ha, or approximately 1100 acres, were in guayule production (Betancourt and Turner 1990).

Calabasas Development Site

Another interesting historical event around this time was that of the Calabasas development site. In 1878, Col. Charles Sykes bought the Tumacacori, Calabasas, and Guevavi land grants (see: <u>Spanish/Mexican Period, Land Grants</u>), which totaled about 80,000 acres of the river valley near the Sonoita Creek confluence. He published a pamphlet with artwork showing a lush, thriving city on the banks of the Santa Cruz River, including a fleet of steamboats at the waterfront. This may be one reason for the historical perception of a large, perennial river. The pamphlet was soon found to be a ridiculous exaggeration, and Sykes' land claim was found to be invalid by the Court of Private Land Claims (Holub and Bufkin 1987). Development around Calabasas had to await the Rio Rico subdivision in the 20th century.

Mining

It was not until after the Gadsden Purchase that large-scale mining started in the Santa Cruz Valley, perhaps for two reasons: the entrance of the territory into the United States allowed for a solid military presence in the area for the first time; and, coincidentally, the Gadsden Purchase was ratified at a time shortly after the 1849 gold rush which inspired a huge migration of prospectors to the West, and quickly led to a scarcity of mineral resources and an excess of miners in California. The mining that took place prior to the Gadsden Purchase was centered in the Santa Cruz Valley because of the natural abundance of ore and the presence of other necessities. The valley in the 1800s,

> *in addition to all its mineral wealth, contained large areas of agricultural land with permanent water, wood and grass, contained twenty-five silver mines or openings which were worked by the Mexicans before the Apache war, and became famous for their rich ore. The best known mines were San Jose, Santa Margarita, Basura, Blanca, Azonias, Tafitos, Amado, and La Purisima.* (Blake 1901: 4).

The "era of modern mining" in Arizona, according to Wilson, began in the Santa Cruz Valley in 1857 with the purchase of the Sopori and Arivaca land grants (Wilson 1987). The purchasers of the grants, including Charles D. Poston, formed the Sonora Exploring and Mining Company, and later the subsidiary Santa Rita Silver Mining Company. Despite considerable optimism about the richness of the mines, the operations never produced a significant profit. The status of major mining activity in the Santa Cruz River Valley at the turn of the century is described by Blake (1901), who laments the absence of adequate railway transportation as hindering the development of significant deposits of mineral wealth.

Woodcutting

Woodcutting played an important role in changing the river environment. Not only was wood used to fuel pumps, it was used in increasingly large amounts for building houses, cooking, fueling mining operations, powering various kinds of engines, building and fueling the railroads, and warmth. Trees were cut to make way for agricultural fields, homes, and businesses. The trees closest at hand were usually cut first, followed by trees farther and farther out. By 1875 it was estimated that there were only 3 trees growing within Tucson city limits. Major tree planting efforts began in 1880, and the local water company provided free water for trees on city streets in 1888. While beautification efforts proceeded into the early 20th century, the riparian forests were rapidly being lost due to wood harvesting, lowering of the water table, and damaging floods. (McPherson and Haip 1988). The loss of riparian vegetation further contributed to degradation of the channel of the Santa Cruz River.

The Railroad

During the 1870s and 1880s, the railroad slowly made its way across Arizona. Casa Grande was originally a temporary terminus of the Southern Pacific Railroad in 1879 (and was called "Terminus" for postal purposes for more than a year). Initially, water for the railroad community was brought by train from Maricopa, farther west until wells could be dug. After a year, enough railway ties and other equipment had been brought to finish the railroad to Tucson. This was the only real community along the Upper Santa Cruz, except for Maricopa Wells at the confluence with the Gila.

The railroad not only influenced grazing as described above, but also the growth of towns. Goods and people could be brought easily, and relatively cheaply, across the continent. Railway construction itself had an impact on Cienega Creek. The original track was along the creek and was washed out several times before being moved to the ridges above the creek where they remain. Two bridges span the creek. Construction of this section of the railroad was considered the most difficult portion of the track across southern Arizona.

Railroads also connected Nogales with the San Pedro Valley and Guaymas (traveling along Sonoita Creek). Another railroad connected Nogales with Tucson, paralleling the Santa Cruz. Nogales grew in size and importance because of the railroad.

Water Management in the Tucson Area

Irrigation Ditches

Farming was intensive in the San Xavier region. Maps from the 1880s and 1890s show the river being basically diverted fully into agricultural ditches (see Appendix A). A survey of the Martinez property about that time (between Martinez Hill and the mission) showed no river, only an agricultural ditch, although the river must have crossed this property (Arizona Historical Society, Martinez file).

The Manning and Farmers ditches diverted most of the low flow south of downtown Tucson by the turn of the century. Agricultural ditches watered some 140 acres north of the Mexican border and diverted most of the low flow. Greene's ditch north of the end of the Tucson Mountains diverted any existing flow west to Avra Valley.

Warner's and Silver Lake

Tucson in the 1880s, then, was a growing community with a need for new industry and recreation. This need was partially fulfilled in the development of two lakes on the Santa Cruz River near downtown Tucson.

Silver Lake was built in the 1860s by putting a dam across the Santa Cruz River about a mile south of Sentinel Hill, or "A" Mountain. In 1863, James Lee built a mill near the lake, grinding flour with power supplied by water from the lake. Warner Lake was built about one half mile north of Silver Lake by Solomon Warner in 1883-1884. Since all of the water from the Santa Cruz was impounded and diverted by James Lee, Warner built his dam far enough north to catch the waters seeping from the cienegas around the base of Sentinel Hill. Both of these mills ground grains to supply flour to the nearby community. Warner was fairly successful, so he added a three stamp mill to grind ore from local mines he was operating (Arizona Weekly Star 26 December, 1878).

These lakes became popular areas for a number of reasons. First, local people began to picnic by the waters, and then to swim. Also, the lakes were large enough that at least one flat-bottomed boat was launched on Warner's Lake for recreation both on the lake and "up the river" (Betancourt 1978). The water attracted a lot of waterfowl to the area, and some hunters obtained the right to hunt the ducks (Arizona Weekly Citizen 17 November, 1883). In 1888, Frank and Warren Allison had possession of the lake, and were harvesting over 500 pounds of the fish every day to sell in Tucson (Arizona Daily Star 7 June, 1888). Bath-houses were built on the lakeshores, and for some time the lakes near Sentinel Hill were probably the focal point of recreation for the community. Betancourt (1978) includes a detailed account of both Silver and Warner's Lakes. Portions of this account, as well as other sources that describe the lakes from their constructions to their demise follow, taken from Betancourt:

> *"The head of the millrace* [to Warner's Mill] *was a short distance below the ford on the Santa Cruz, near James Lee's water mill and pond. Its total length was about 1.5 km. The race crossed church lands southeast of the present intersection of Mission Lane and Grande Avenue, a tract then occupied by the mission garden (not to be confused with the older mission orchard which was north of Mission Land and the mission buildings). The tailrace (the ditch that takes water away from the water wheel) also crossed church lands, apparently passing between the old convento structure and Mission Lane. It followed the mission fence to the east where it emptied into the old ditch or "Acequia Madre" from which the lands on the eastern side of the valley were irrigated. It may seem a discrepancy that the tailrace did not empty into the river; however, there was no stream below the dam at Lee's pond. Rather, the water from the dam had long been diverted to follow a system of acequias which irrigated the level bottomlands on either side of the valley."* Page 71.
>
> Quoting the Arizona Citizen 30 October, 1875...*"The driving force* [of Warner's Mill] *is some six hundred cubic feet of water with an average fall of eleven and a half feet. To get this force Mr. Warner had to construct a ditch...which is quite a piece of engineering, but as Mr. Warner says, the only badly constructed thing about the mill."* Page 72.
>
> *"Successful in his initial venture, in 1878 Warner added a three stamp mill to process ore from small mines he was working; to be run by borrowed power from the existing grist mill."* Quoting Arizona Weekly Star 26 December, 1878...page 72.
>
> *"Warner's discontent with the millrace led him to explore other alternatives. In 1881, the Tucson Water Company, headed by Silvester Watts, dug a trench in the riverbed near the present location of the Valencia Road bridge about 10 km south of the mill (Schwalen and Shaw 1957: 89). During the following two years, the water level at Lee's*

pond dropped considerably due to the water development upstream. Because of this, Warner then considered damming the cienegas fringing the eastern slopes of the Tucson Mountains between San Xavier and Tucson (the present West Branch). He began buying sufficient land south of 'A' Mountain to serve his purpose. In the summer of 1883, he began building an earthen dam to impound the water from the cienegas (The Arizona Citizen 11/17/1883). The dam started where the millrace first touched the hill and ran for 400 m along the side of the race towards Silver Lake (by 1880s Lee's Pond had changed its name), ending at a point of ground high enough to hold all the water needed. The top of the dam was wide enough for a roadway to connect with the road (the present Mission Road south of the mill) by the millrace. At the base of 'A' Mountain was a bulkhead (a wall or partition built to hold back water) ten feet wide and equipped with strong gates which were opened in case of flooding." Page 72.

Warner, Solomon, 1884 "Personal Notes and Narratives" [see Hayden no date-b]...*"The watershed that supplies the cienega is quite extensive. It commences on the west side of the Sierritas...In some seasons the quantity of water running from the cienega is equal to from one quarter to one-half enough to run the mill several months a year...Tullies [cattail] and water grasses grew on all of the land and the pond covers with the exception of three or four acres on the south and east side...There were other depressions where the water remained all the time."* Page 73.

"The lake attracted a variety of wild ducks and soon the area became a favorite of hunters. The lake was also stocked with carp obtained from the government (the Arizona Citizen 3/15/1884)."

In July 1884, [Warner] received legal notice from Hereford Lowell, attorney for the Water Overseer and landowners below Warner's Lake:

"You are hereby notified that you are interfering with the water in the Santa Cruz and obstructing the free and continuous passage of the same at your mill and lake and water being taken from and prevented from flowing in the public acequia without the consent of the water overseer and to the damage of the landowners thereto.

You are also notified that unless you desist from interfering with and using said water in the manner you are now doing that you will be proceeded against in accordance with the law (letter of July 8, 1884, Solomon Warner Biographical File, on file at archives of Arizona Historical Society, Tucson)." Page 74.

"Lucas and McCandless have a way of making visitors at Warner's Lake feel as if they were at a picnic. The lake itself is picturesque, being a large sheet of water, with wild ducks floating at a distance and white cranes perching on the shore. The waters contain good size carp, and an abundance of smaller fish of good quality. The leasees propose to put in a wharf at the landing, and launch a small steamboat on its waters." (Arizona Mining Index, 24 Apr 1886).

"According to Solomon Warner (1884), Lees' Pond (Silver Lake) was first built in 1856 and consisted of a low earthen dam south of present Silverlake Road. Originally, it had been built as a flood-control device to minimize damage to cultivated fields downstream and provide an easily-managed water supply from which to irrigate these same fields. Other uses came into being in 1857 when Alfred and William Rowlett

(formerly of Virginia) built Tucson's first flour mill powered by a millrace which began at the pond. In 1859, they advertised that '...Those wishing to have their wheat ground into flour could take it to Rowlett's Mill ...having purchased in San Francisco the most improved milling stone and bolt, we defy competition' (The Weekly Arizonian 10/27/1859)." Page 81.

"*In 1880, a man by the name of Smith was proprietor of George J. Roskruge's boating, swimming and bathing facilities at Silver Lake* (Arizona Daily Star 6/10/1880).

Around 1881, James Lee leased 20 acres to J. F. Ricky and J. O. Bailey for the purpose of setting up a resort along the shores of Silver Lake. The 1881 City of Tucson Directory describes the resort and lake in the following manner:

...lake is caused by a dam of masonry in the Santa Cruz River and extends over several acres. Several boats for sailing and rowing up the river beyond the lake...A row of commodious bath houses for bathers and a stout rope extends across a portion of the lake for the convenience of persons learning how to swim. The hotel, bath houses, pavilion, lake, and grove occupy a space of 20 acres, leased and controlled by Ricky and Bailey, who also own the mile racetrack [presently Cottonwood Road] adjacent thereto and where the annual races are held. This is the only race track near Tucson and only swimming baths in Arizona (Barter 1881)." Page 86.

"*By 1885, the Silver Lake area was dotted with Chinese truck gardens* (Tom 1938)." Page 86.

Other descriptions of the lake and irrigation in the area follow:

"*...To illustrate how every gulch surround the Santa Cruz Valley contains a 'mine of wealth', let the case of Messrs. Miller and Warner's be cited. Finding that the 'rawhide' or pioneer method of dividing the water in the irrigating ditches in the Santa Cruz prevented them from running their flour and quartz mills with any certainty or regularity, they cast about for other help. On the south side of Picket Post butte (or Sentinel hill) there is a small gulch running around the hill. In this gulch were certain small springs, as indicated by the cienegas. These gentlemen went to work last November and built an earthen dam a quarter of a mile wide across the mouth of the gulch. The effect was that in a very few days they had a pond of water covering sixty acres, and that averaged eight feet in depth. They now have sufficient water on hand to not only guarantee a continuous run of their mills, but also to irrigate and render valuable many hitherto unused acres below them. They also procured a lot of carp from the Government and put in their pond. From the well known breeding character of these fish these gentlemen will soon have one of the finest fish farms in America."*
Quoting Arizona Citizen, daily, 3/15/1884, 1-5.

"*Warner's Work. . . .The result of this big dam [Warner's Lake] has already been wonderful. The waters of the many springs of the different cienegas on the Warner land have been held back by the dam, and have risen till they have covered some twenty acres of land, creating a sheet of water that is beautiful to look upon. Already the wild* *fowl have made it their resort, and an organization of hunters have obtained the exclusive right to shoot upon its waters. A flat-bottomed boat sails over its surface. The different kinds of ducks killed there are the gray and spoonbill, the green and red winged teal, mallard, canvass back, widgeon, spring tail, the butter and a new kind never seen before called the fish duck. It has saw-shaped teeth. The snipe, curlew and plover appear abundantly.*

When the dam is completed and the waters have occupied all their space, about fifty acres will be covered. . . . None of the water of this big pond comes from the Santa Cruz river. It is all from the land owned by Mr. Warner, and the economical measures he hast taken to save this water for his own use first, and after that for the farmers below him is to be commended. . . . The waters of the Santa Cruz river still flow in the old ditches undisturbed by this new and great improvement by Mr. Warner." Arizona Weekly Citizen, Tucson, 11/17/1883 3:3. Warner, Solomon (Hayden no date-a).

"Mrs. Moss Sees 50-year Change"...[Mrs. Moss is the daughter of James Lee] *"You probably never heard of the old flour mill out at Silver Lake,' she said, 'but my father owned and ran that for years. You see, there was one built and run there before the Civil War in order that Tucson might have white flour and a place for the grinding of grain...Silver Lake was formed south of Tucson by putting a dam across the Santa Cruz. That supplied power for the mill which father rebuilt in 1863. He operated it until 1880, the year the railroad came, and he also opened certain amusement concessions on the lake. After his sale to Maish & Driscoll, they put in more facilities for boating and swimming..."* clipping from Arizona Star, Lee, James (see Hayden no date-a).

The same drought and flood cycles that confounded the overgrazing of cattle in southern Arizona in the late 1880s also affected Warner's and Silver Lake. The dams that created both lakes were periodically washed out and rebuilt during this period. It was the intense flooding of February, 1890, that dealt the final blow to Tucson's only boating, fishing and bathing ponds. The floods washed out the dams, and the entrenchment that occurred at the same time necessarily meant that the hydrology of the Santa Cruz River was very much different than it had ever been in recorded history, so neither the dams nor the lakes were rebuilt.

Groundwater Pump Technology

The entrenchment that occurred in the riverbed near Tucson radically changed the hydrology of the river. The development of pump technology that first became available in 1891 (Holub and Bufkin 1987), initiated the extensive groundwater pumping that excluded any reasonable chance of recovery by natural processes.

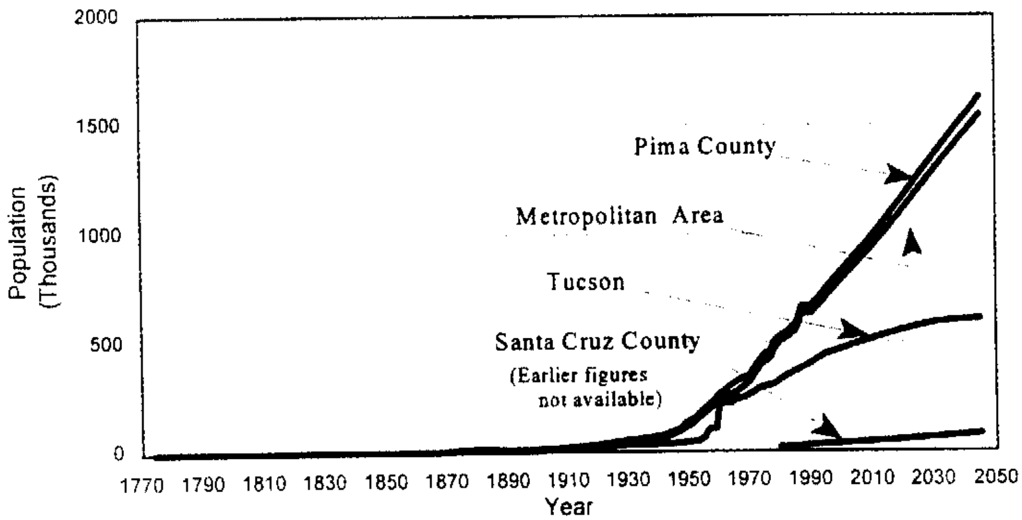
Pumping also affected the tributaries of the Santa Cruz River. The part of Rillito Creek that is today near Craycroft Road was chosen as the site for Fort Lowell in 1871 because of its water supply and its plentiful supply of grass for the livestock. Although at first the fort had a steady water supply, demands soon rendered the supply inadequate. In 1873 windmills were constructed, but these were also unsatisfactory. Acequias were then dug to bring water to the fort, but by 1885 these too were inadequate. Wells to a depth of 150' were dug without success, and a plan to bring water from Sabino Canyon seven miles north also did not work out. Finally in 1887, a new steam pump was procured along with large new water tanks (Smith 1910). The water delivery problem was solved, but de-watering of the river proceeded quickly.

At this time the population of Tucson was growing, and it is difficult to say, now, if pump technology led to an increase in the population or if the expanding population accelerated development of new pump technology. In the first decade of the 20th century, the first full decade after the introduction of pump technology to the area, the population of Tucson nearly doubled (Figure 2). On the eve of the new century in the late 1890s, Tucson was for the first time dependent on groundwater, and likewise on the wood for fueling the pumps, and it was in shortage of both. The water table at the San Xavier District was dropping, as reported by the superintendent of the Tucson Water Company in June, 1895:

> *This fact is determined by the well from which the city supply of water comes. Originally the well was but 18 feet deep and the process of sinking is still going on. Formerly the city supply came through submerged sluices in the river bed and to some extent these still furnish all that is necessary, but the company has been obliged to run their pump 27 months in the last two and a half years. To do this it required 1,782 cords of wood at an expense of $4500. Tucson uses an average of 13 million gallons of water per month* (Arizona Daily Star 13 June, 1895).

Papago Indians furnished most of this wood (Arizona Daily Star 17 November, 1895), presumably from what they gathered in the surrounding area. A cord of wood is a stack four feet high, four feet wide, and eight feet long, or 128 cubic feet. Also, as a matter of comparison, Tucson Active Management Area used an average of well over 9.2 billion gallons of water per month in 1990 (Eden and Wallace 1992), and average depth to the water table within the Tucson Active Management Area in 1985 was 240 feet (Arizona Department of Water Resources 1991).

Figure 2. Population from 1774-2045
Santa Cruz River Valley



Territorial Period Summary

In summary, the Territorial Period in the Santa Cruz River Valley was a time of significant change. The river was put under tremendous pressures from a new population of settlers in the area. The completion of the railroad in 1881 opened up the previously isolated southwest to both settlement and commerce. A period of heavy grazing in the 1880s, along with extreme weather patterns, culminated in the beginning of the entrenchment of the Santa Cruz River during the extraordinary floods of early 1890. The introduction of pump technology in the 1890s led to the first era of groundwater dependence in the valley, and perhaps played a part in the near doubling of the population in Tucson from 1900 - 1910. This period, immediately before statehood in 1912, marked the beginning of the changing vegetative structure, erosion of the channel, and drop of the water table that is now characteristic of the modern river.

At the end of the Territorial Period, in 1912, the Santa Cruz River was a very different river, but it was probably still perennial in many of the same reaches that historically had surface flow, from the headwaters to just north of Tubac, near Mission San Xavier del Bac, and again near

Sentinel Hill at Tucson; albeit a surface flow that was, at least at the latter location, somewhat lower due to water use and the entrenchment of the river that occurred during this period.

Upper Santa Cruz River

The upper Santa Cruz River, in Santa Cruz County, was historically perennial from the headwaters into Mexico and back again to Tubac. In addition to a surface flow, the river here frequently diffused into broad cienegas, especially near the mouths of some tributaries like Potrero Creek, Sonoita Creek, Nogales Wash, and others. In fact, the marshy areas near Calabasas were reported to be the cause of a problematic outbreak of malaria in the 1870s (Hendrickson and Minckley 1984). Some were drained.

The river in Santa Cruz County, although exposed to many human impacts in the Territorial Period, probably remained relatively unchanged - all of the perennial reaches and many of the cienegas remained intact at least until the early 1900s.

Halpenny (1988) summarizes historical references to where the upper Santa Cruz River went subsurface. This information is reproduced in Table 3-3.

Table 3. Historical References to Where the River Went Underground
***Source*: Halpenny 1988: pp. 5-6**

Year of Travel	Name of Observer	Source Reference	Where River Ceased to Flow
1775	Pedro Font	Bolton 1931	South of campsite, which was 7.8 miles downstream from La Canoa
1804	Manuel de Leon	McCarty 1976	At Tubac
1804	Jose de Zuniga	McCarty 1976	5 miles downstream from Tubac
1821	Ignacio Elias Gonzales	Surveryor General 1880	1.3 miles downstream from Tubac
1848	Cave Couts	Couts 1961	Shortly downstream from Tubac
1848	John Durivage	Durivage 1937	8 miles downstream from Tubac
1849	H.M.T. Powell	Powell 1931	9 miles downstream from Tubac
1852	J.R. Bartlett	Barlett 1854	9 miles downstream from Tubac
1856-57	W.R. Emory	Emory 1857	Shortly downstream from Tubac
1867	W.A. Bell	Bell 1869	At Canoa (Ranch)
1872	T. White	White 1872	Present Canoa Ranch Headquarters

Middle Santa Cruz River

In Pima County, the middle section of the Santa Cruz River experienced perhaps the most dramatic changes of any other portion of the river during the Territorial Period. The river was always ephemeral from Tubac to San Xavier del Bac, and then again between the mission and Sentinel Hill at Tucson. The perennial reaches at the mission and near Tucson probably continued to flow supersurface beyond statehood.

However, this was an important period of change in the river. The settlement of Tucson and subsequent demands put on the river's flow became unsustainable in the late 1800s. For the first time the population became dependent on groundwater. The river was dammed and deep diversion structures were built to capture shallow subsurface flows. A combination of these and other impacts led to the beginning of the entrenchment of the Santa Cruz River near Tucson, which quickly worked its way upstream. By the time of statehood in 1912, the river was channelized as much as 10 meters all the way from Tucson to Mission San Xavier del Bac (Betancourt and Turner 1990).

Lower Santa Cruz River

The river through Pinal County was depicted on several old maps as discontinuous, stopping entirely, then starting again with the influx of some minor tributaries shortly before the confluence with the Gila River near Maricopa Wells. At this location marshes abounded and extensive agriculture was practiced by the Pimas and Maricopas, and later by Anglos. Maricopa Wells became an important stopping point for travelers, stagecoaches, the Butterfield route, and later the railroad. Little water was available for travelers or for settlers until pump technology was developed.

The "Ninety-Mile Desert" through which the Santa Cruz River flows from Tucson to its confluence with the Gila River has never had regular surface flow. Travelers who used this route often found it a long and miserable journey.

Elsewhere in Pinal County settlement was based on the Gila River, rather than the Santa Cruz River (both prehistorically and historically).

V. THE MODERN PERIOD, 1912 TO THE PRESENT

Some citizens had become discontented with being a part of the Territory of New Mexico. Yuma residents, for example, had to travel over 700 miles to visit the capitol at Santa Fe. So President Lincoln signed the Arizona Organic Act in 1863, which created a separate Arizona Territory (Dreyfuss 1972). It was not until February 14, 1912, that Arizona finally became the 48th State in the Union.

Mining

Thousands of small mining operations were established in the area, but only a small portion of those have yielded significant amounts of minerals. The major mining efforts along the Santa Cruz River Valley have been in copper, sand & gravel, and molybdenum, with some extraction of silver, gold, cement, lead, clays, gypsum and perlite. Since water is necessary to process the minerals, mining was historically near sources of water. Groundwater pumping and water transport have allowed an expansion of this industry. Today, open pit copper mining predominates. By 1962, groundwater pumping between San Xavier and Tubac had lowered the water table there some 70 feet (Halpenny 1962). Annual pumping for these large open pit copper mines was 20,000 acre feet in 1994, down considerably from its peak in the 1950s-70s.

Population Growth

The population in the vicinity of Tucson at statehood in 1912 was probably around 14,000. A graph of the population growth in the region indicates the beginnings of exponential growth at about the same time that some perennial reaches of the river dried up, around 1940 (Figure 1). In 1995, there are about 700,000 people in the Tucson metropolitan area, and projections by the Pima Association of Governments (PAG) and the SouthEastern Arizona Governments Organization (SEAGO) project the population in Pima and Santa Cruz Counties to be approximately 1.7 million by the year 2045 (Pima Association of Governments 1995; SouthEastern Arizona Governments Organization 1995).

The population of Nogales, Arizona increased dramatically after the arrival of the railroads. Nogales, Sonora is several times the population of Nogales, Arizona (population figures conjectural) and continues to impact both water supply on the river and water quality. A major wellfield along the Santa Cruz River south of the border effectively eliminates surface flow for over 10 miles.

Tubac, Carmen and Tumacacori remain small towns, but urban development is encroaching upon them. Green Valley has grown rapidly since its beginnings in the 1960s. Incorporated areas within Pima County include Sahuarita, Tucson, South Tucson, Oro Valley, and Marana. In Pinal County, Casa Grande is the largest Santa Cruz River town. It was a very small railroad community with limited agriculture until 1940 when high-powered pumping technology made modern agriculture (primarily cotton) in the area feasible. In 1910 the population of the town was only 250. Between 1940 and 1950 the population jumped to 4,181. Casa Grande is growing rapidly with the advent of industry and regional shopping centers. Smaller towns include Eloy, Picacho, and Maricopa.

Agriculture

Agriculture has been the major water user throughout the basin since the 1880s. Today agriculture is still an important industry in Arizona, although of decreasing importance with the expansion of urban areas and increased costs of water. The three counties that the Santa Cruz River passes through in Arizona, Pima, Pinal and Santa Cruz, had nearly 225,000 acres of land in irrigated crops in 1987 (some of which were in the Gila drainage, not the Santa Cruz drainage). The primary crops have been cotton, alfalfa and wheat, with pecan groves in the Green Valley area. Irrigation of these acres is partially through groundwater pumping of aquifers in the Santa Cruz River Valley.

The groundwater overdraft in the Tucson Active Management Area (AMA), which comprises most of the Santa Cruz Valley, is 207,000 acre-feet per year (Eden and Wallace 1992). The Tucson and Santa Cruz AMAs are operated with a goal of "safe yield" while the Pinal AMA is not, since the groundwater supply is so depleted. Because of the increased cost of pumping water, agriculture in the Pinal AMA has declined, although the Central Arizona Project (CAP) has brought in new water supplies for those that can afford it. Agriculture on the Ak-Chin and Salt River Pima Reservations is thriving, thanks to CAP water. Very little agriculture is possible now in the San Xavier District because of the presence of hundreds of sinkholes in the former agricultural areas. The cause of these sinkholes is under study and may be related to the decline of the water table, the loss of the mesquite bosque, the agricultural use of the area, or other causes.

Water Management and Use

The Modern Period in the Santa Cruz River Valley, beginning with statehood in 1912 and continuing to the present, has been both a time of change and of expectations met. The receding water table, reliance on groundwater, and eroded river channel mostly devoid of vegetation were now, regardless of sentiment, an accepted standard. The pump technology that had been discovered and introduced into the region in 1891 was becoming more advanced. The pumps no longer relied on wood-fired steam power, wells were sunk deeper and deeper, and the water table continued to drop. The entrenched river appears to have acted as a drain, moving waters downstream.

It is not entirely clear when some perennial sections of the river went subsurface. Although some have proposed that in certain places the Santa Cruz River went subsurface due to groundwater pumping in the 1890s (Ohmart 1982: 356), it is very likely that the portions of the river that were historically perennial flowed until the early 1900s. Halpenny (1962) proposes that the river near San Xavier Indian Reservation was perennial until World War II, despite increasing groundwater pumping. Studies by Robert Rush Miller, an ichthyologist, support Halpenny's theory. In his investigation of the state of the fish fauna near Mission San Xavier del Bac, he found that:

For many years the Santa Cruz River, intermittent from near Nogales almost to Tucson, rose to the surface shortly above San Xavier Mission, about 8 miles south of Tucson. Here, in March 29, 1904, Chamberlain obtained 5 species: Agosia chrysogaster, Gila robusta intermedia, Catostomus insignis, Pantosteus clarki, *and* Poeciliopsis occidentalis. *By April 25, 1937, when Allan R. Philips sampled this perennial flow, only the resistant Agosia remained, and this is the only species that I found there on July 12, 1939. By April 13, 1950, the flow had disappeared, and I was informed by Raymond Hock (then of the University of Arizona) that it went dry for the first time during the previous winter. Even in early historic time, the Santa Cruz ordinarily had no surface flow from some distance below Tucson to its confluence with Gila River. It formerly maintained a permanent flow in the headwaters, near Lochiel, but pumping in the San Rafael Valley eliminated this surface water and its fishes* (Gila, Agosia, Poeciliopsis) *between 1950 and 1956.* (Miller 1961: 379).

The water table at San Xavier was high enough to support a great old mesquite bosque, described by Brandt in the 1940s:

"Ten miles south of Tucson in the broad intermountain valley of the Santa Cruz River, and just beyond the ancient twin-towered mission of famed San Xavier, there once flourished a noble woodland of mighty mesquite trees. This virgin forest bordered both banks of the Santa Cruz at its broadest part, tapering back to the river on either side. Here we enjoyed the only important trace of semitropical forest cover that we encountered in southeastern Arizona. It reminded me very much of a semiarid, hotland Sinaloa jungle, with its lively community of strange animals and plants.... In 1935 many a grand old patriarch still ruled here that had evidently already looked down on several centuries of desert droughts and savage storms. .... Here, there are, indeed, trees of heroic dimensions; the bole of one stately specimen that we measured reached a girth of 13 feet 6 inches, and a diameter of more than 4 feet, 3 inches; while the height of another capitol-domed giant was calculated to be 72 feet... " (Brandt 1951).

Brandt goes on to say that, when he revisited the bosque in 1945, the big trees had been hacked away for firewood. The bosque had its final demise in the 1960s when the water table dropped below the root zone (Halpenny 1962).

After the 1940s, highly efficient pumps and a population explosion both contributed to groundwater depletion. Between 1940 and 1965, over 4 billion cubic meters (over 1 trillion gallons) of water were pumped from the Tucson Basin aquifer (Betancourt and Turner 1990).

Floods continue to affect the river, leading to increasing entrenchment south of the mission where the river goes through a veritable badlands of eroded lands. In order to reduce erosion near the San Xavier Mission, the entire flow of the West Branch of the Santa Cruz River was diverted through a man-made channel into the East Branch in 1914 (Cooke and Reeves 1976). Efforts to control the river have continued to present times. Erosion since construction of I-19 is exacerbated by the bridge which funnels flood waters directly towards the mission and a curve of the river.

Changed Water Supply in the River

The U.S. Geological Survey "Streamgage Summaries" report that essentially the entire flow of surface waters from the river were diverted both at Nogales and Tucson gaging stations by irrigation ditches (United States Geological Survey 1907, 1912). The first gages in the area were set up in 1905 at the Congress Street Bridge and in 1907 five miles north of the Mexican border.

The University of Arizona Agricultural Extension office set up more elaborate gaging stations and by 1915 had seasonal information on flows on the Rillito and the Santa Cruz to Maricopa (Table 4).

The conclusion reached from their studies of 1916 (an average rainfall year) was:

> *It will be seen from the table that practically all of the Santa Cruz run-off was absorbed into the ground and the residual flow that reached the Gila River was a small percentage of the total. The sum of the Santa Cruz and Rillito discharges near Tucson in 1916 was 90,500 acre feet. Of this amount 64,900 acre-feet sank into the river bed between the Tucson gauging stations and Sasco, a distance of 32 miles, while the remaining 25,600 acre-feet passed Sasco. Just west of Sasco the stream divides, part flowing northwest to Eloy and part west to an abandoned reservoir and thence northwesterly to Maricopa. Of the former portion the amount that reached Eloy was 4500 acre-feet. This amount is again subdivided and probably less than one-third of it reaches the Gila. Of the second portion only 2200 acre-feet reached Maricopa.* (Agricultural Experiment Station 1916).

Table 4. Santa Cruz River Flow in 1916
(condensed from Agricultural Experiment Station, 1917).

Month	Santa Cruz/ Tucson	Rillito River/ Tucson	Santa Cruz/ Red Rock	Santa Cruz/ Maricopa
	ACRE-FEET	ACRE-FEET	ACRE-FEET	ACRE-FEET
January	24700	37400	20690	1800
February	600	2220	0	310
March	0	3630	0	0
April	0	58	0	0
May	0	0	0	0
June	0	0	0	0
July	2720	920	720	0
August	8210	7840	4040	170
September	1340	690	130	560
October	140	28	0	0
November	0	0	0	0
December	0	0	0	0
TOTAL	37700	52800	25580	2840

Modern Period Summary

A brief review of the status of the Santa Cruz River in the Modern Period shows that the changes that face the river now are related to the pressures of population growth. The population of the Santa Cruz River Valley has grown exponentially since World War II, which when combined with the development of efficient groundwater pumping technology has led to an immense annual overdraft of water.

In two locations, the Santa Cruz River has once again come to life: downstream of the Nogales wastewater treatment plant for about 15 miles, and downstream of the Roger Road and Ina Road wastewater treatment plants in Tucson for about 15 miles. The Nogales section probably contains more water today than it has for many years and supports a lush cottonwood-willow forest, home to many species of birds and aquatic creatures. This flow stops at about the same spot the flow did historically because of the underlying geology. The Tucson section does not provide nearly as good a wildlife habitat because the stream is so entrenched and because portions of it have been soil-cemented for flood control purposes. The water flow, however, is probably greater than it was 100 years ago. A small effluent flow at Casa Grande supports a saltcedar forest.

Upper Santa Cruz River

The headwaters of the river in the San Rafael Valley have remained relatively pristine, although most of the cienegas have disappeared and the origins of the headwaters have often moved downstream. Although Miller (1961) reports that the native fish fauna had disappeared in the 1950s in the San Rafael Valley, some perennial waters persist. The river usually flows much of the way from the headwaters into Mexico and almost back to the border at Arizona, although at a lessened level. A Nogales wellfield south of the border takes most of the flow at that point, and much of the surface flow downstream of the Nogales Wastewater Plant is now effluent. Water quality has become an issue, especially with regard to untreated flows from Mexico in Nogales Wash. The effluent flow goes underground at about the same location that the river went underground historically.

Two perennial streams remain in the Nogales area: Sonoita Creek and Sycamore Creek. A natural cienega still exists near Nogales. Important parts of Sonoita Creek today are owned by the Nature Conservancy and Arizona State Parks (including a recreational manmade lake in the river).

Middle Santa Cruz River

The historically perennial reaches of the river, at Mission San Xavier del Bac and at Sentinel Hill in Tucson, no longer flow under normal circumstances. Miller (1961) showed that the perennial water at San Xavier flowed until 1949-50, and that at least one species of native fish was present there until later than 1939.

The springs have all stopped flowing near the river, although a few remain in outlying areas. Three perennial streams still flow near the Tucson area: Sabino Creek, Cienega Creek, and Honeybee Canyon. The river, which was once slow and shallow through Tucson, has become a deeply entrenched channel with no surface flow except during unusual flooding events. The banks have been cemented or otherwise altered in an effort to prevent erosion and damages from floods like those suffered in 1983, which amounted to perhaps more than $200 million dollars. The average water table has been lowered over 400 feet in the valley, with cones of depression near Green Valley (mines and agricultural pumping), and San Xavier (mines and City of Tucson pumping). Effluent flows from the Pima County treatment plants have kept the water table relatively high in the Marana area, where water is extracted for agriculture.

Lower Santa Cruz River

The lower Santa Cruz River in Pinal County, again, was the sight of relatively little historical activity until the arrival of the railroad and later efficient pumping technology. This stretch of the river never supported much flow, and it still does not. Agricultural activity arose here during the Modern Period, one of the most important communities being Casa Grande. Currently the water table is highly overdrafted and subsidence has caused numerous changes, including influencing the direction of water flow in at least one case.

VI. SUMMARY

The Santa Cruz River has long been an important transportation route for Native Americans, missionaries and Spanish explorers, colonizers and wanderers, miners and cattlemen, and new residents. It was an easy route as far as Tucson, providing water, forage and food for the traveler. For people who lived near it, the river provided water, wood, food and shelter. Farmers diverted the surface water of the river for millennia. Millers, both of flour and ore, powered their grinders with Santa Cruz water and entrepreneurs dammed the river, and the lakes that were created were used by the public for fishing, boating, picnicking and swimming. Much of the settlement in southern Arizona, to this day, is within the valley of the Santa Cruz River.

Changes in the River

The three distinct sections of the river have had very different histories. The upper and middle sections were used extensively by native peoples, Spaniards and later Americans, and the lower section, having much less dependable water was used much less. Because of underlying geology, and the fact that population eventually centered in the Tucson area, the middle Santa Cruz suffered much more extreme changes than either the Upper or Lower sections.

Upper Santa Cruz River

The Upper Santa Cruz has lost most of its marshes and has been affected by groundwater pumping near Nogales, but because of effluent flow it still supports a lush cottonwood-willow forest from Rio Rico to Tubac. The streams of the headwaters are much as they were for centuries, despite a history of mining in the 19th century and ranching up to the present. While mining, agriculture, grazing, urbanization and other influences had major impacts on downstream stretches of the river, the San Rafael Valley remained relatively undisturbed. Some of these impacts, especially mining, grazing and woodcutting, did impact the valley. The ranchers that dominated the valley did not relinquish their ownership of large tracts of land for development, and therefore, "The San Rafael Valley has largely escaped the transformations that have changed the economic, cultural and physical landscapes of so many other rural areas of Arizona since World War II." (Hadley and Sheridan 1995)

The areas settled early by the Spanish and later the Americans from the Mexican border to the Santa Cruz County line have been changed by agriculture (with its pumping and water diversion) and the development of Nogales, Tubac and Green Valley. By 1912 enough water was being diverted near the border to take up all the low flow of the river. (United States Geological Survey 1910). The river was replenished by springs and runoff from tributaries. Agriculture and small communities, however, began to divert and pump more and more groundwater. Groundwater pumping from City of Nogales, Sonora wellfields have depleted the river flow drastically, so that no low flow leaves the wellfield area and the river is mostly dry (with the addition of some spring-fed waters north of the border) until it reaches the wastewater treatment plant. The construction of a wastewater plant upstream from Calabasas (Rio Rico) allowed the river to flow once again, and the healthy cottonwood forest developed and flourishes to this day.

Middle Santa Cruz River

The Middle Santa Cruz has changed from a shallow, wide meandering stream fed by numerous springs to a dry, deeply entrenched channel constrained by flood control structures through much of the metropolitan area. The river near San Xavier is nothing like its former self and the ancient mesquite bosque is gone. Groundwater pumping for agriculture, mining and urban use has driven the water table far below a level which can support trees. Sink holes of uncertain (but definitely manmade) origin have rendered many acres of land unusable there. Farther downstream, the river is dry with little vegetation until the wastewater discharge is reached at Sweetwater Drive, on the north side of Tucson. From there through Marana the river flows again, with a more dependable supply of water than it ever had historically. All the historic springs are gone.

The year 1890 was a turning point in the structure of the middle Santa Cruz River. Until then, the river structure had remained relatively stable - perennial reaches from its headwaters in the San Rafael Valley through Mexico and again into Arizona just north of Tubac, sinking there for the first time below the sand to rise again near Mission San Xavier del Bac and again at Tucson. It was a shallow river, with large trees marking the ill-defined channel of the river, which lay in a broad and fertile valley. After the unprecedented grazing in the valley in the 1880s left it exposed and vulnerable to erosion, manmade structural changes (dams and diversion ditches) were built. Extreme weather patterns peaked in early 1890. Years of plentiful rain were followed by years of drought and followed once again by huge amounts of rain. The dams and ditches on the river near Tucson were washed out, and the re-routing and entrenchment of the river from north of Green Valley through Tucson had begun.

Every year that the monsoon rains fell in southern Arizona, the entrenchment worked further upstream. By the time of statehood in 1912, there was a deep channel, perhaps more than 20 feet deep, well into what is now the San Xavier Indian Reservation. Pump technology had been developed in the 1890s, but at this time the primitive state of the science made it difficult to extract much water. Diversions, however, had taken all the low flow from both north of the Mexico border and south of Congress Street in Tucson.

It was not until around World War II that the population in the valley exploded and groundwater pumping led to the disappearance of the Santa Cruz River's perennial flow at Tucson and San Xavier.

Lower Santa Cruz River

The Lower Santa Cruz is still a dry channel at all but flood times. Before the days of modern pumps agriculture was largely by floodwater irrigation or centered around the much more dependable Gila River to the north. In modern times, extensive groundwater pumping has lowered the water table throughout central Pinal County and in some places long subsidence fissures opened. Only at flood time can the river's course be easily discerned and only at high flood time does it discharge to the Gila River. This is probably somewhat different from previous times, but that section of the river has long been ephemeral and offered little to the traveler who might have had to travel for days without fresh water. Any underflow that once carried waters regularly to the Gila River is no longer possible. The cienegas that once existed at the confluence with the Gila River no longer support wildlife.

The Tributaries

The tributaries have very different histories. A few streams, including Sabino Creek, Sonoita Creek, Cienega Creek, Honeybee Canyon and some mountain streams still flow most of the year and support diverse wildlife, others, however, especially Rillito Creek, Pantano Wash, the Cañada del Oro, and Altar-Brawley washes are greatly changed and seldom flow. Through the urban areas flood control structures predominate, especially along entrenched reaches. In rural areas, Patagonia Lake impounds waters from Sonoita Creek for recreational purposes such as boating, and Parker Lake, also a recreational lake where boating is popular, impounds tributary waters in Parker Canyon.

Wildlife

The corridor created by the Santa Cruz River is used by migrating wildlife, and habitats of some state and federal threatened and endangered species are within the Santa Cruz Valley. Some animals that are now extirpated from Arizona were once found there, and others that were once common, such as the wild turkey, are no longer found in the region. The beavers that once built dams along the Rillito River clearly can no longer survive in the dry streambed. In some of the areas fed by effluent, however, there is still a rich diversity of species, as there is in the perennial tributaries. Manmade lakes, a Nature Conservancy Preserve, a Pima County Preserve on Cienega Creek and Forest Service riparian areas (most notably Sabino Canyon) still provide excellent habitat for some wildlife.

The History of Navigation

Probable Condition of the River in 1912

At the time of statehood, the river was probably still perennial in some of the reaches that had historic surface flow, but intermittent in more areas than previously. An important difference was that the vegetative structure of the valley was much different and the entrenchment of the river meant that surface waters visible in 1912 were much lower than 25 years earlier. In many areas, riparian vegetation had been cut for wood or lumber and farms or homes used much of the water riparian trees had formerly used. Diversions, at both the Mexican border area and south of Tucson, were said to have taken all the low flow of the river. Agricultural water use in the Tubac, Tucson, and San Xavier areas used most of the available surface water and also intercepted groundwater and subsurface flow. Diversions and pumping also diminished flows on tributaries, especially the Rillito. It was estimated in 1910, that flow from the Rillito reached the Gila River one year in 15 (Smith 1910).

The San Rafael Valley headwaters were shallow flows, much as they are today, although there were more cienegas then there are today. The river through Mexico probably still flowed dependably. From the border to the Sonoita Creek confluence, the river may have been dry much of the time because of diversions. With the addition of Sonoita Creek waters, the river again came to life, but much of that water was diverted for agriculture along the river from Calabasas to the north. The springs were drying up in the San Xavier area, and diversions and pumping took most if not all the flow, but a high water table still supported a lush mesquite bosque south of the mission. The City of Tucson and many others had dug wells in numerous locations, some as far south as San Xavier which intercepted flow and lowered the groundwater table. In 1915, the first year such measurements were systematically taken, the Santa Cruz River and Rillito flowed less than half the year. The deeply entrenched channel carried some flows through Tucson, but all the low flow was diverted before the Congress Street bridge. Springs and groundwater still supported some agriculture downstream of Tucson, but there was little perennial flow.

By 1912, the Rillito, too, had largely dried up and pumping was necessary to support agriculture though the water table remained high and shallow wells were possible. Cienega

Creek still was perennial, as were Sonoita Creek, Sabino Creek and most of the other small tributaries.

The lower Santa Cruz continued to have little flowing water except in years of high rainfall.

Summary of Recorded Navigation Incidents

Although the river was an important transportation route, it was not normally used for navigation except for the following accounts found in the literature:

1. A land speculator portrayed the river at Calabasas (west of Nogales) as capable of floating steamboats in the 1880s. This was pure fiction, but gave rise to the belief, that surfaces occasionally even today, that the river was navigated by large ships.

2. During the 1880s, Silver Lake (a manmade lake just south of downtown Tucson on the Santa Cruz River) was a popular recreation area, featuring boating, fishing and swimming. A paddle boat on the lake was a major attraction. Boating both by rowing and sail was popular in the lake and upstream. This lake was washed out in the 1891 flood and not rebuilt.

3. In December 1914, during a flood period, a group of adventurers attempted to float the Upper Santa Cruz River, but were grounded. The boat was later located buried in mud. Also in the 1914 flood, numerous people were stranded on rooftops and windmills near Sahuarita. The Arizona National Guard went to rescue them with an inflatable boat, but the current was too strong and the effort was unsuccessful. Later, the people were rescued with horses.

4. Occasionally in recent times a canoer or rafter has floated the river during flood time. Tubers floated the Santa Cruz River in the 1970s during flood time. The Tucson Weekly featured a canoer traveling the effluent-dominated stretch in July 1990, a trip which he repeated during flood time for the Tucson Weekly photographer (Malusa 1990). The Citizen reported travelers in canoers on the Rillito during the 1990 flood (Tucson Citizen, July 25, 1990). The same canoers have also traveled on the Santa Cruz and Agua Caliente at various times in the 1990s. These canoers, Wayne Van Vorhees and his wife, stated that when they also traveled the river during the winter of 1989-90 it was "a reasonable canoeing river," but when they made the trip in the summer, it was "more like the Grand Canyon" in terms of difficulty. They are

deeply involved with local boating groups, but are unaware of any attempts to boat the upper Santa Cruz River, although they state that it is certainly feasible. Mr. Malusa believes that the Santa Cruz can just barely be navigated by canoe with 4" of water, but that the channel topography is a limiting factor as sand bars are frequent. (Jim Malusa and Wayne Van Vorhees, personal communications, 1996).

5. There are no stories of boating at any time on the lower Santa Cruz, although during one high flood event Tucsonan Sam Hughes said that, in his opinion, the river was "big enough to float a steamboat all the way to the sea."

6. There are no records of ferry service anywhere on the river. Fords and crossable washes are marked on numerous maps. When the bridges went out during floods, people were stranded and had to wait until the river could be crossed by horse. No evidence was found of boats being used to cross the river at flood time.

7. No evidence was found of the river being used to transport goods such as logs.

8. John Spring recorded in his diary that there was an old Mexican settler who had carved a canoe to cross the upper Santa Cruz River when flooding made it too high to cross on the road. According to Spring, this is the origin of the name for that area of the Santa Cruz Valley, "La Canoa."

There were a few instances of boating on the river, but the perennial flow that existed on the river historically was such that it was never regularly navigated. It was, however, a very important transportation corridor for travelers going from the eastern U.S. west, or from Mexico to the Gila River. Without its waters, forage, and food, travelers would often probably not have survived.

There is no evidence that the Hohokam or O'odham people had boats at any time in the past. The river was much too shallow most of the time for small boats, even in the perennial stretches. The river from San Xavier to Tucson could have potentially been navigable, if there had been been a dependable supply of water because of the much deeper channel. By 1912, however, the U.S. Geological Survey reported that the entire low flow of the river was diverted at both the Nogales and Tucson gages making navigation highly unlikely. The only times one might be able to navigate the waters of the Santa Cruz now are during unusual high water, i.e. during flooding events.

VII. CHRONOLOGY AND POPULATION FIGURES

CHRONOLOGY

1539 - Fray Marcos de Niza probably reached the headwaters of the Santa Cruz.
1687 - Kino starts missions in Sonora.
1689 - Kino starts missions at three sites along the Santa Cruz in present Sonora.
1690s - Warfare between Apaches and Pimas.
1691 - Missions established at Guevavi and Tumacacori. Indian population estimated at 30,000.
1695 - Pima rebellion followed by open warfare against the Spanish in Sonora which lasted many years.
1697 - Manje counts 900 Indians at Bac and 800 at Tucson.
1701 - Founding of San Xavier, south of Tucson - abandoned then restaffed in 1732. Present mission started in 1779, finished in 1797.
1736 - Silver discovered south of Nogales, starting mining boom.
1752 - Presidio of Tubac founded.
1762 - Spanish move Sobaipuris from the San Pedro River to the Santa Cruz, settling them at Tucson, leading to increased Apache depredations as there was no longer a good line of defense away from the Santa Cruz River.
1767 - Jesuits expelled.
1771 - Fortified walls and church built at Tucson.
1775 - De Anza leads group from Tubac to San Francisco Bay.
1775 - Relocation of presidio of Tubac 40 miles father north to Tucson. Founding of Tucson.
1782 - Major Apache attack on Tucson, repelled by Spanish, but followed by frequent warfare.
1787 - Presidio founded at Santa Cruz, Sonora.
1820-30s - Sonoran ranchers start to colonize grasslands of SE Arizona using the Land Grant.
1821 - Mexico wins independence from Spain; Canoa Land Grant awarded.
1823 - First Anglo trappers reach Arizona, but probably did not reach the Santa Cruz.
1826-1831 - Five major Spanish land grants awarded.
1836-1847 - War between U.S. and Mexico, resulting in Treaty of Guadalupe de Hidalgo.
1843 - Apaches drive settlers out of San Rafael Valley.
1844 - Tumacacori declared abandoned by Mexico and land auctioned off, driving off what few Pimas remained.
1846 - Dec. 17 - Lt. Col. Phillip St. George Cooke's Mormon Battalion takes possession of Tucson and raises the American flag in Tucson without encountering Mexican garrison. [Pres. Polk declared war with Mexico on May 13, 1846]
1846 - Kearny passes through Tucson on military expedition to the Pacific, laying out wagon road.
1848 - Oct. 25 - U.S. First dragoons reach Tucson en route to California.
1848 - Treaty of Guadalupe Hidalgo.
1848 - Lt. Couts with military expedition from Mexico to California, describes Santa Cruz Valley.
1849 - California gold rush begins. For next several years, Santa Cruz River is on the route of would-be miners going to California. Numerous cattle drives from Texas to the gold fields passed along the Santa Cruz through Tucson and on to the Gila River.
1850 - Sep. 9 - Congress passes the "Omnibus Bill" making Arizona and New Mexico one territory, with the proviso, "Nothing in this act shall be construed to inhibit the United States from dividing said Territory into two or more territories."
1852 - John Bartlett describes the Santa Cruz Valley.
1853 - Dec. 30 - Under terms of the Gadsden Purchase the United States agrees to pay Mexico ten million dollars for 45,535 acres of land below the Gila River from the Rio Grande to the

Colorado. Of this land, 31,535 square miles are eventually included in the Territory of Arizona.

1854 - Gadsden Purchase ratified.

1856 - Feb. 28 - Solomon Warner reaches Tucson from Yuma at head of train of 13 mules loaded with merchandise for first Arizona general store.

1856 - Mar. 10 - U.S. Army quarters four companies of dragoons in Tucson.

1856 - Mar. 24 - Charles D. Poston organizes the Sonora Exploring and Mining Co. With Maj. S. P. Heintzelman as president, he purchases the Arivaca Ranch west of Tubac and begins operation of mines.

1856 - Americans establish fort at Calabasas.

1857 - Jun. 22 - U.S. government signs contract with James E. Birch for semimonthly mail and passenger service from San Antonio to San Diego, via Tucson. Became known as the 'Jackass Mail' because passengers frequently had to ride a mule between Fort Yuma and the coast.

1857 - John Reid describes the Santa Cruz Valley.

1858 - Oct. 10 - First Butterfield Overland Mail coach enters Arizona through Stein's Pass; reaches Tucson.
Oct. 2, 6:15 p.m. and crosses into California on Jaegers' ferry, Oct. 5, 6:15 a.m.

1858 - William S. Oury introduces first herd of fine cattle to Arizona, pasturing 100 heifers and four bulls in the Santa Cruz Valley near Tucson.

1858 - Phocian Way describes the Santa Cruz Valley.

1859 - Mar. 3 - *Weekly Arizonian*, first Arizona newspaper printed in Tubac. Vol I. No. One, reports 19 acts of murder and robbery by Indians between Jan. 1 and Feb. 21.

1859 - Aug. 4 - Lieut. Sylvester Mowry buys *Weekly Arizonian* and publishes it in Tucson.

1859 - Nov. 12 - Forty-six thousand sheep pass through Tucson en route to California.

1860 - Lieut. Sylvester Mowry buys the Patagonia Mine east of the Santa Cruz Valley and renames it the Mowry Mine.

1860s - Silver Lake constructed by damming the Santa Cruz.

1860s-1880s - Large numbers of cattle introduced in the area during unusually rainy period.

1862 - Jan. 18 - Confederate Congress passes enabling act, making Arizona and New Mexico Confederate Territories; Jefferson Davis signs, Feb. 14.

1863 - Feb. 20 - Congress passes Arizona Territorial Bill which becomes law Feb. 24.

1863 - Lee builds water-powered flour mill near lake.

1864 - May 8 - Governor John N. Goodwin proclaims Tucson and incorporated city and appoints officials.

1864 - J. Ross Browne describes the Santa Cruz Valley.

1866- Oct. 3 - Third Territorial Legislature convenes in Prescott under Governor McCormick. Governor makes gloomy report; Territory is deep in debt; there are no stagecoach lines; roads are extremely poor; Apaches are very active; total amount of taxes collected, $355.

1867 - Mar. 18 - Military headquarters in the Territory are moved from Prescott to Tucson.

1867 - Nov. 1 - Tucson becomes the Capital of the Territory.

1871 - May 17 - Village of Tucson buys two sections of land from federal government and begins to sell lots and issue deeds.

1873 - Jan. 6 - Seventh Territorial Legislature convenes in Tucson. . . . Gov. A.P.K. Safford ... asks Congress to promote sinking of artesian wells.

1873 - Mar. 19 - Tucson garrison is moved to site on Rillito Creek, and important permanent post is built and named Fort Lowell. Abandoned April 10, 1891.

1874 - Sep. 28 - *Tucson Citizen* announces first cotton grown near Tucson by Steven Ochoa.

1875 - Jan. 6 - Eighth Legislature convenes in Tucson under Governor Safford. Reward of $3,000 offered for discovery of first artesian water; net profits of mines taxed; Pinal County created.

1877 - Feb. 7 - City of Tucson incorporated by legislative enactment.

1877 - Mar. 9 - Congress passes Desert Land Act which permits settler to get title to 640 acres of desert land, provided that he irrigates it within three years and pays small sum per acre.

1878 - Land speculator promotes Calabasas development with brochure showing steamboats docked at the busy river. Tombstone Epitaph reveals hoax. Area not developed until 1960s.
1879 - Founding of Casa Grande, aka Terminus.
1880 - Mar. 20 - First train over Southern Pacific reaches Tucson and is greeted by roar of cannon and a wild celebration.
1880 - Railroad arrives in Tucson.
1881 - Tucson Water Co. Builds water distribution system starting at Valencia Road in river bed.
1882 - Railroad completed from Benson to Sonora through Calabasas.
1883 - Warner's Lake constructed, followed by construction of flour mill and stamping mill. Reaches 37 acres in size.
1885 - Chinese truck gardens established in Tucson.
1886-1890 - Very rainy period. Santa Cruz is more than a mile wide and deep enough to float a steamboat.
1887 - Jan. 17 - Speaking at the first council meeting of the year Mayor Stevens of Tucson warns members that they must be prepared to do something about watering the city streets in the summer months.
1887 - Jan. 17 - First Pullman train rolls into Tucson and citizens turn out to marvel at the wonder.
1888 - Sam Hughes builds diversion ditch which begins to erode that summer.
1890 - Jan. 31 - Empire Ranch starts driving 1,000 head of cattle to California to escape excessive freight rates.
1890 - Major floods wash out the dams that created Silver and Warner's Lakes, and Hughes ditch, and change river from shallow meandering stream to incised channel.
1890-1904 - Drought sets in and many cattle die. Tucson's population declines by 2000 down to 5000 people.
1891 - Jan. 16 - Herd of 2,000 steers passes Tucson as cattlemen continue drives to coast to avoid railroad charge of $7 a head.
1891 - Feb. 8 - T. A. Gulley, director of University's Experiment Station, proves practicability of pumping underground water for irrigation on UA campus.
1891 - Sep. 6 - Tucson sprinkles 17,000 gallons of water daily on down-town streets to lay the dust.
1891 - Pump well technology reaches Arizona. Hartt develops farm depending on water pumped from underground.
1893 - Plagued by a long drought and the effects of overgrazing the ranges, cattlemen of Southern Arizona experience a 50 to 75 per cent mortality among their stock and ship 200,000 head of all classes out of the state.
1894 - Mar. 30 - Court of Private Land Claims voids Spanish land grants along the border. Nogales, Huachuca, and Tombstone hold all night celebration with bonfires and salutes.
1895 - Jul. 14 - Indians of the Pima villages go to court and charge Arizona Canal Company with stealing water guaranteed Pimas under contract.
1898 - Major improvements to the Nogales Water Works.
1899 - Nogales-Tucson rail link completed.
1899 - Jan. 16 - Governor Murphy meets with Twentieth Territorial Legislature. Fifteen year tax exemption granted for water development...
1901 - Nogales water supply report says Nogales Water Company has "an inexhaustible supply from 3 wells, tapping the underground flow of Potrero Creek."
1901 - Aug. 2 - Director of U.S. Census reports that Arizona has 5,800 farms covering 1,935,287 acres of which 254,521 acres are improved land.
1905 - Tucson gets 24" of rain (twice normal) mostly in winter.
1907 - Jan. 17 - Santa Cruz River runs full to the bank and races through Tucson at eight miles an hour.
1910 - Tucson Farms Company formed (became Flowing Wells Irrigation District in 1912).
1910 - 1920 - Mexican revolution spreads and more than a million people are killed in Mexico. Pancho Villa seizes Nogales, then retreats in 1916.
1911 - Aug. 8 - U.S. Senate passes resolution granting statehood to both New Mexico and Arizona.

1911 - New water lines built in Nogales and the first well is sunk near the Santa Cruz.
1911 - Aug. 9 - House concurs in Senate statehood resolution.
1912 - Feb. 14 - President Taft signs necessary proclamation making Arizona a state. George W. P. Hunt is inaugurated as governor and entire state celebrates wildly.
1913 - May 2 - Great Western Power Co's. government permit to water rights in Sabino Canyon expires. City of Tucson sends officials to file claim at midnight if the Power Company's claim is not extended.
1914 - Feb. 15 - Tucson sinks a new well and gets a flow of one million gallons a day.
1914 - Dec. 23 - Swollen by week of rain the Santa Cruz River floods valley and runs one and one-half miles wide at Amado where destruction is heavy.
1914 - During flood period, sailors attempted to sail a boat from Nogales to Tucson, but boat got stuck near Tubac. Claim is that this is the first time in 28 years that there has been enough water to float a boat.
1916 - Dec. 27 - Phoenix, Tucson, Douglas, and Bisbee plagued by intense cold weather and coal shortage. Demand for mesquite is heavy.
1917 - First Border fence erected in Arizona.
1917 - Nov. 7 - U.S. Council of defense report shows 491,867 acres of land under cultivation in Arizona.
1919 - Mar. 26 - Legislature appropriates $100,000 to co-operate with U.S. Dept. of Interior on surveys and preliminary studies for construction of storage or diversion dams, etc., to increase productivity of the land.
1920 - Jun. 23 - Board of Health urges all citizens of Tucson to boil drinking water 10 minutes. Contaminated well has filled the mains.
1920 - Jul. 11 - Tucson suffers from a water famine. Irrigation of lawns barred in daytime.
1920 - Jul. 13 - Special committee reports to the city council that all Tucson wells are either contaminated or subject to contamination.

NOTE: This chronology draws extensively from Martin 1963, 1966.

POPULATION FIGURES

A Short List of Historical Population Figures

1790s - Non-Indian population, 300-500 people in Tucson, 300-400 at Tubac and 100 at Tumacacori.

1831 - Census lists 465 Mexican inhabitants in Tucson.

1835 - Census lists 486 individuals in Tucson.

1860 - U.S. decennial census of Arizona population given as approximately 6,482.

1864 - May 24 - U.S. Marshal Milton B. Duffield completes the first census of Arizona and reports to Governor Goodwin that the population totals 4,573, including U.S. soldiers. Arizona had sworn to Congress that the population was 6,500.

1866 - Oct. 3 - Territorial census shows population is 5,526.

1870 - U.S. Census report Arizona population as 9,658.

1875 - Jan. 6 - County assessors' reports place population at 11,480.

1880 - U.S. Census reports Arizona population as 40,440, a gain of 318.7 percent in 10 years.

1890 - Dec. 31 - U.S. Census reports Arizona population as 88,243; a gain of 118.2 per cent. U.S. Census credits Arizona with 1,526 farms and 104,128 acres of improved land.

1898 - Ambos Nogales population estimated at 2000 in Arizona and 2500 in Mexico.

1900 - U.S. Census reports Arizona population as 122,931, a gain of 39.3 percent.

1901 - Nogales, Arizona population estimated at 5300.

1909 - Census figures show population for Nogales, Arizona 2503.

1910 - U.S. Census reports Arizona population as 204,354, a gain of 66.2 per cent in 10 years.

VIII. NOTE ON SOURCES

A rich variety of resources regarding the history of the Santa Cruz River Valley is available, especially in Tucson. The University of Arizona Main and Science Libraries have most of the general reading documents listed in the bibliography, such as books, journal articles, and bulletins. The University's Special Collections Library keeps an extensive collection of historic and rare documents. Some of the manuscripts, journals, diaries, and hard-to-find documents used in this report are housed in Special Collections. Another extremely valuable library is that of the Arizona Historical Society in Tucson. Manuscripts, journals, and old or rare newspaper articles and photographs are more likely to be found at the Arizona Historical Society Library, both because of its extensive collection and an admirable cataloguing system. Another historical society library, Pimeria Alta, is in Nogales, Arizona, and was found to have few materials relating to the history of the river and very little indexing. However, the library may have some information regarding the upper Santa Cruz River, and should not be entirely overlooked.

Some general works on the history of the Santa Cruz River were particularly useful in preparing this document. Holub and Bufkin (1987) speak of the navigability question specifically. Betancourt and Turner (1990) provide background on the question of arroyo cutting on the Santa Cruz River in Pima County; however, the information provided could be considered a comprehensive history of the river in Pima County, and is extremely useful in deciphering the complex history of the Tucson area. Another work by Betancourt (1978) presents archaeological evidence of prehistoric and early-historic inhabitance along the river in the Tucson area. The Halpennys have studied the hydrology of the river, especially as it concerns historic irrigation in the Santa Cruz Valley. Several of their works, including those from 1962 and 1988, are of general interest. Hadley and Sheridan (1995) provide a comprehensive history of the headwaters of the Santa Cruz River in the San Rafael Valley.

Walker and Bufkin (1986) is an excellent resource for general information about historical influences across Arizona and in the Santa Cruz Valley. Other general works that include useful information on the Santa Cruz River are Wilson (1987), Bahre (1991), and Dobyns (1981).

Parker (1993) is an analysis of channel change on the Santa Cruz River, and provides general information about the river's perennial flow through time.

Hendrickson and Minckley (1984) review the cienegas in southern Arizona, including those on the Santa Cruz River and its tributaries. This publication is an important source of comparative maps showing historical and recent status of surface waters.

Meko et al. (1995) uses tree-ring analysis to construct a long-term climatic history of the southwest. Betancourt and Turner (1990) present climatological data for the Santa Cruz River Valley in order to determine the impact of drought/flood cycles on arroyo cutting.

A number of books have been written about the Spanish/Mexican period of history in the Southwest. Because his primary work was in the Santa Cruz Valley, Father Kino's memoirs are particularly useful; Bolton (1919) presents these memoirs. Hammond (see 1929, 1931, 1940, and Hammond and Howes 1950, Hammond and Rey 1953) has studied the history of the Spanish and Mexican period through analyses of Kino, Zuniga, Coronado, and Oñate, as well as the history of the gold rush in 1849.

A map of land grants in the Santa Cruz Valley is available in Walker and Bufkin (1986). Mattison (1967 and no date) provides a description of some of these land grants, as well as a general history of the topic.

Many early explorers, pioneers, and travelers described the vegetation and wildlife of the Santa Cruz River in their journals and diaries, some of which are now published. Bahre (1991) describes historic human impact on vegetation in southern Arizona.

Davis (1986) compiles information about many of the old pioneers' manuscripts and is a useful index to the occurrence of wildlife in Arizona in the 1800s. Brandt (1951) has information about the birds in the Santa Cruz Valley, as well as some description of related vegetation. The occurrence of fish in the Santa Cruz River and its tributaries is an important factor in determining the status of perennial water. Miller (1961) is interested in the changing fish fauna of southwestern rivers, and provides information about perennial water in the Santa Cruz River near San Xavier, Tucson, and in the San Rafael Valley. Minckley is the premier fish biologist of Arizona's rivers, and his 1973 book is generally considered a classic work.

The beginning of Anglo settlement in Arizona and the Santa Cruz Valley is chronicled through the journals of early settlers. Among these see Spring (1966), Couts (1961), Evans (1945), Gustafson (1966), Forsythe (no date), Pancoast (1930), Hunter (no date), Powell (1931), Hayes (1929), and Durivage (1937). Harris (1960) describes the gold rush migration along the Gila Trail, which included the Santa Cruz Valley. These descriptions may be some of the most important documents in attempting to determine the status of the river in 1912. Other important documents are U.S. Geological Survey reports (streamgage summaries that list annual streamflow at measuring stations) and some of the University of Arizona's early Agricultural Experiment Station Bulletins.

Wilson (1987) talks about the sky islands of southern Arizona, and presents a history of land use. Bell (1932) and Loomis (1962) talk about the early cattle industry in southern Arizona. Dunning (1959) is a comprehensive history of the early mining industry.

Betancourt and Turner (1990) and Hadley and Sheridan (1995) describe the impact of livestock grazing on the river near Tucson and in the San Rafael Valley.

The modern status of the river is described in some of the general works listed above. Also useful are Eden and Wallace (1992) who present data on water use in the Tucson Active Management Area. Halpenny (1962) and Halpenny (1988) review the hydrology of the river near Tubac and the San Xavier Indian Reservation. The Tucson Active Management Area occasionally presents summary information on the status of water use in the Tucson area and related groundwater information. General information about the extent of the watershed and the recent status of perennial waters is available in Arizona Department of Environmental Quality (1994).

Population growth is directly related to water use in the Santa Cruz Valley, and information on population growth there can be obtained from government organizations. The Pima Association of Governments (PAG) and the SouthEastern Arizona Governments Organization (SEAGO) both keep historic population information and periodically project population growth.

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X. APPENDICES

APPENDIX A -- HISTORIC MAPS

Listed below are some of the many maps available. Most are in published form and easily accessible as indicated. In addition the three major nineteenth century surveys, Bartlett, Gray and Emory contain useful maps . Finally, the Arizona Game and Fish Department mapped perennial streams in 1994 and has maps of the perennial sections of the river and tributaries, showing vegetation and other features.

Betancourt 1990

- A-I Page 30 - "Figure 3. Map of the Santa Cruz River Valley, with places mentioned in the text."
- A-II Page 75 - "Figure 11. Map of the northeast portion of the San Xavier Indian Reservation in 1882 (after Roskruge, 1882). In this map, and on later ones (Figs. 12-13), the course of the Santa Cruz north of Martinez Hill is not indicated, suggesting that the channel had long been replaced by ditches in carrying floodflows."
- A-III Page 76 - "Figure 12. Map of the San Xavier Indian Reservation in 1888 (Chillson, 1888)."
- A-IV Page 77 - "Figure 13. Map of San Xavier Indian Reservation in 1891 (Surveyor General's Office, 1891)." [shows Santa Cruz River being diverted into ditches around the Reservation]
- A-V Page 100 - "Figure 21. Map of northern Sonora and southern Arizona, showing hydrological effects of the 1887 earthquake (after Dubois and Smith 1980)."
- A-VI Page 136 - "Figure 40. Plan of the Tucson Farms Company Crosscut and distribution system (Hinderlider 1913)."
- A-VII Page 142 - "Figure 47. Map of Greene's Canal and lower Santa Cruz River."

Bolton

- A-VIII Map of Pimeria Alta 1687-1711. Shows Kino's routes, etc.

Carleton 1864

- A-IX Military Map of New Mexico. Shows a discontinuous Santa Cruz River north of Tucson.

Cooke and Reeves 1976

- A-X Page 52 - "Figure II.9 Santa Cruz Valley: data from Olberg and Schanck (1913)" [shows man-made channel being constructed to join the West and East Branches of the Santa Cruz River south of Mission San Xavier del Bac]

Eckhoff, E.A. 1880

- A-XI Official Map of the Territory of Arizona. Shows "supposed underground passage of the Santa Cruz River" north of Tucson.

Emory 1857

A-XII Leaflet on back page - sketch of the Gila River Basin, including the Santa Cruz River.

Fergusson 1862

A-XIII "Cultivated Fields in and about Tucson" - at Arizona Historical Society

Hadley and Sheridan 1995

A-XIV Page 2 - "Figure 1. San Rafael Valley Area."
A-XV Page 29 - "Figure 2. Early Trails and Roads." [in San Rafael Valley]
A-XVI Page 45 - "Figure 5. Major Mines of the San Rafael/Lone Mountain Study Area."
A-XVII Page 110 - "Figure 12. Forest Service Ranges, 1917." [in San Rafael Valley]
A-XVIII Page 111 - "Figure 13. Forest Reserve Grazing Allotments, 1940's." [in San Rafael Valley]
A-XIX Page 207 - "Figure 20. Homesteads In the study area." [in San Rafael Valley, circa 1913-1930]

Halpenny 1962

Numerous maps throughout of the San Xavier District.

Halpenny 1988

A-XX Page 16 - "Figure 5. Water-level changes, 1953-1982, southern Santa Cruz River Valley."

Hendrickson and Minckley 1984

A-XXI Page 135 - "Figure 3. Sketch map of southeastern Arizona, with some place names mentioned in the text. Historical and present status of surface streamflows are indicated as adapted from Brown, Carmony, and Turner (1981)."
A-XXII Page 150 - "Figure 12. Sketch map of the Santa Cruz Valley, Arizona, with some place names mentioned in the text and some present-day aquatic and semiaquatic habitats (excluding stock tanks)."
A-XXIII Page 151 - "Figure 13. Sketch map of the Santa Cruz Valley, with aquatic and semiaquatic habitats before 1890 as inferred from historic records."

Mattison 1946

A-XXIV Inset - "Spanish and Mexican Land Grants in Arizona...Photostat of General Land Office Map of 1887."

Parker 1993

A-XXV Page 10 - "Figure 3. Santa Cruz River in 1988, perennial and intermittent reaches in 1890, and location of headcuts in relation to marshes in the late 19th century."

Walker and Bufkin 1986

Historical Atlas of Arizona - various maps illustrating travel routes, land grants, Spanish exploration, military forts and presidios, missions, and others.

APPENDIX B -- HISTORIC PHOTOS

The Arizona Historical Society and Special Collections at the University of Arizona Library have a wealth of photos relating to the Santa Cruz River. Unfortunately, many of these photos are inadequately labeled. For example, one may say "person crossing Santa Cruz River" without giving date or place. A series of photos of the Santa Cruz County portion of the river was made by a surveyor, but the exact locations are unknown. Recently the Buehman Collection was made available at the AHS Library, consisting of some one million photos. Only about a fourth have been cataloged, however, and few have dates or locations. Other AHS collections of value include the Roskruge file, Arizona-places-Santa Cruz River, Arizona-Santa Cruz River-floods and Arizona-places-ranches. A fine collection of photos is available at the Tumamoc Hill office of the U.S. Geological Survey, the collection from which the photos in The Changing Mile are drawn. The Turner photos listed below are from that collection.

Most of the photos listed below are available at the AHS as well as in their published form which is the one listed if applicable.

Betancourt 1990

- B-I Page 32 - "Figure 4. Aerial view of Tucson reach of the Santa Cruz River, Looking southeast on October 9, 1983."
- B-II Page 49 - "Figure 7. Upstream view in 1912 of Acequia de Punta de Agua, a streambed spring along the Santa Cruz River south of the San Xavier Mission (from Olberg and Schanck, 1913)."
- B-III Page 53 - "Figure 8. Looking west across Silver Lake in the 1880s. Structure on the right was a hotel."
- B-IV Page 53 - "Figure 9. Same view as Figure 8, taken on December 16, 1981."
- B-V Page 83 - "Figure 14. Solomon Warner's house and mill in 1880, looking southeast from lower slope of Sentinel Peak, with the Santa Cruz Valley in the background."
- B-VI Page 84 - "Figure 15. The Santa Cruz Valley from the base of Sentinel Peak looking east ca. 1880. Warner's Mill is the structure at left margin of photograph. White structure at center right is Leopoldo Carrillo's ice house, which was cooled by water from the mill's tail race."
- B-VII Page 84 - "Figure 16. Same view as Figure 15 on December 1, 1981."
- B-VIII Page 85 - "Figure 17. East view of Santa Cruz Valley and Tucson from Sentinel Peak in 1882, showing the San Agustin Mission (center) and Warner's Mill Complex at lower left. The Acequia Madre, which was fed by Silver lake, runs from right to left across center of photograph. The Acequia may have followed the mainstem of the Santa Cruz River, which at that time had no discernible channel."
- B-IX Page 85 - "Figure 18. Same view as Figure 17 on December 1, 1981."
- B-X Page 93 - "Figure 19. Southeast view of Warner's Lake in 1883. The shallow channel of the Santa Cruz River is visible downstream of the dam at extreme left of the photograph."
- B-XI Page 93 - "Figure 20. Approximately the same view as Figure 19 on December 31, 1988."
- B-XII Page 105 - "Figure 22. Upstream view of the heading of Sam Hughes' intercept ditch at the St. Mary's Road crossing in October 1889."
- B-XIII Page 105 - "Figure 23. Taken on the same day, a slightly different view of the headcut in Figure 22, with Sentinel Peak at upper right."

B-XIV <u>Page</u> 111 - "Figure 25. View looking directly west across the St. Mary's Road crossing in August 1890, with newly formed arroyo threatening homestead on opposite bank."

B-XV <u>Page</u> 111 - "Figure 26. Same view as Figure 25 on February 4, 1982."

B-XVI <u>Page</u> 112 - "Figure 27. Downstream view of the Santa Cruz river during the flood of August 1890, taken from east bank at the St. Mary's road crossing."

B-XVII <u>Page</u> 112 - "Figure 28. Upstream view of the Santa Cruz River on the same day and from same location as Figures 26 and 27."

B-XVIII <u>Page</u> 116 - "Figure 29. View looking upstream at Congress Street in 1902. The deep arroyo that eroded in 1890 and 1891 made river crossings more difficult."

B-XIX <u>Page</u> 116 - "Figure 30. Downstream view of the Santa Cruz river in 1902."

B-XX <u>Page</u> 118 - "Figure 32. The San Agustin Mission or Convento Ruins as sketched by John Spring in 1871, looking west across the Acequia Madre."

B-XXI <u>Page</u> 118 - "Figure 33. The San Agustin Mission in 1903, looking across to the west bank of the Santa Cruz River."

B-XXII <u>Page</u> 119 - "Figure 34. The San Agustin Mission, most likely in the 1910s, from roughly the same vantage point as Figures 32 and 33."

B-XXIII <u>Page</u> 120 - "Figure 35. Downstream view of the confluence of the West Branch and the Santa Cruz River, looking northeast from the lower slope of Sentinel Peak in 1904."

B-XXIV <u>Page</u> 120 - "Figure 36. Same view as Figure 35 on December 17, 1981."

B-XXV <u>Page</u> 131 - "Figure 37. Head of the Manning Ditch in 1907, with the Santa Cruz River and Sentinel Peak in the background."

B-XXVI <u>Page</u> 132 - "Figure 38. Same view as Figure 37 on February 4, 1982."

B-XXVII <u>Page</u> 137 - "Figure 41. East view of the Crosscut in 1913, with trenching for concrete conduit in progress and well casing in foreground."

B-XXVIII <u>Page</u> 137 - "Figure 42. West view of the Crosscut under construction in 1912."

B-XXIX <u>Page</u> 138 - "Figure 43. Outlet from the Crosscut in the streambed of the West Branch in 1913."

B-XXX <u>Page</u> 139 - "Figure 44. Same view as Figure 43 on February 4, 1982."

B-XXXI <u>Page 140</u> - "Figure 45. Diversion point for water developed by the Crosscut, about 3 km downstream along the bed of the Santa Cruz River, in 1912."

B-XXXII <u>Page</u> 140 - "Figure 46. Sector of finished concrete lined canal inside the east bank of the Santa Cruz River in 1913."

B-XXXIII <u>Page</u> 145 - "Figure 48. Upstream view from Martinez Hill in 1912, with dense mesquite growth in the valley bottom. By this date, a channel 9m deep marked the course of the Spring Branch, with a steep headcut terminating just below the dam in the center of the photograph."

B-XXXIV <u>Page</u> 145 - "Figure 49. Similar view as Figure 48 on December 15, 1981."

B-XXXV <u>Page</u> 150 - "Figure 50. The Santa Cruz River in flood at Congress Street on December 23, 1914."

B-XXXVI <u>Page</u> 151 - "Figure 51. Upstream view of the Congress Street Bridge on the morning of January 31, 1915, as the east approach to the bridge began to give way."

B-XXXVII <u>Page</u> 151 - "Figure 52. In this northwest (downstream) view of the 1915 flood, onlookers stand perilously close to the eroding east bank of the Santa Cruz River, just downstream of the Congress Street Bridge."

B-XXXVIII <u>Page</u> 152 - "Figure 53. Southwest (upstream) view of Santa Cruz River in flood in February 1915."

B-XXXIX Page 153 - "Figure 54. The Congress Street Bridge after erosion of east bank in January 1915, looking northwest."

B-XL Page 153 - "Figure 55. A similar view as Figure 54 in July 1915."

B-XLI Page 154 - "Figure 56. North (downstream) view of the Santa Cruz River from the Congress Street Bridge in November 1907. Note narrow channel."

B-XLII Page 154 - "Figure 57. Similar view as Figure 56 on July 29, 1916 after the 1915 flood widened the Santa Cruz River Channel."

B-XLIII Page 156 - "Figure 58. In March 12, 1910, Ellsworth Huntington, the noted geographer, took this photograph..."

B-XLIV Page 156 - "Figure 59. Same view as Figure 58 taken on November 30, 1983."

B-XLV Page 160 - "Figure 60. Santa Cruz River in flood, November 1926, showing road embankment on the east approach from Congress Street."

B-XLVI Page 160 - "Figure 61. Same view as Figure 60 taken on September 12, 1983."

B-XLVII Page 162 - "Figure 62. View south from summit of Sentinel Peak in 1919, looking upstream along the Santa Cruz River."

B-XLVIII Page 162 - "Figure 63. Same view as Figure 62 on January 6, 1988."

B-XLIX Page 163 - "Figure 64. View from Sentinel Peak on May 30, 1927, looking east across Santa Cruz River."

B-LPage 163 - "Figure 65. Same view as Figure 64 taken on October 6, 1987."

B-LI Page 164 - "Figure 66. View east-northeast from Sentinel Peak on May 30, 1927, with Santa Cruz River in foreground."

B-LII Page 164 - "Figure 67. Same view as Figure 66 on October 6, 1987."

B-LIII Page 165 - "Figure 68. View northeast from Sentinel Peak on May 30, 1927 with Santa Cruz River running from right to left."

B-LIV Page 165 - "Figure 69. Same view as Figure 68 on October 6, 1987."

B-LV Page 168 - "Figure 70. In 1935, the Works Projects Administration (WPA) constructed several flood control features along the Santa Cruz River. In the reach just south of Sentinel Peak (left), the river's flow was deflected into pilot channels by means of revetments, in this case fashioned from old automobile frames."

B-LVI Page 168 - "Figure 71. Same view as Figure 71 on May 11, 1982. The WPA measures were largely effective in eliminating the sharp meanders."

B-LVII Page 172 - "Figure 72. South view from Martinez Hill in June 1942."

B-LVIII Page 172 - "Figure 73. Same view as Figure 72 on May 29, 1981. Note the broad river bottom and badly denuded bottomlands."

B-LIX Page 173 - "Figure 74. Upstream view of the Santa Cruz River bridge at Continental on June 4, 1940."

B-LX Page 174 - "Figure 75. Same view as Figure 74 on November 16, 1978, showing deepening of the channel by ca. 1 m."

B-LXI Page 175 - "Figure 76. East view of the Santa Cruz River Valley and Tucson from Sentinel Peak in 1932."

B-LXII Page 175 - "Figure 77. Same view as Figure 76 on July 8, 1981."

B-LXIII Page 176 - "Figure 78. Southeast view of the Santa Cruz River, looking upstream from a point just south of the Congress Street Bridge."

B-LXIV Page 176 - "Figure 79. Same view as Figure 78 on February 26, 1982."

B-LXV Page 177 - "Figure 80. Downstream view of the Rillito-Santa Cruz confluence, looking north in 1939."

B-LXVI Page 177 - "Figure 81. Same view as figure 80 on November 9, 1983."

B-LXVII <u>Page</u> 178 - "Figure 82. East view of Congress Street and the then active floodplain of the Santa Cruz River, taken from West Congress Terrace in the 1890s."
B-LXVIII <u>Page</u> 178 - "Figure 83. Approximate view as Figure 82 in the 1930s."
B-LXIX <u>Page</u> 179 - "Figure 84. Same view as Figure 83 on February 26, 1982."

Betancourt 1978
B-LXX <u>Page</u> 67 - "Figure 13. Confluence of the West Branch and the Santa Cruz in 1904."
B-LXXI <u>Page</u> 67 - "Figure 14. The new confluence of the West Branch and the Santa Cruz."
B-LXXII <u>Page</u> 69 - "Figure 15. The Convento structure of the San Augustin Mission (Arizona Historical Society)." [no date]
B-LXXIII <u>Page</u> 70 - "Figure 16. Warner's Mill around 1880 (Arizona Historical Society)."
B-LXXIV <u>Page</u> 85 - "Figure 23. Silver Lake, the Silver Lake Hotel, and the residence of a Mr. Kelley to the left. Photograph (taken in 1880) looks west across the lake toward the Tucson Mountains in the background (Arizona Historical Society)."

Hadley and Sheridan 1995
B-LXXV <u>Page</u> 41 - "Figure 3. San Rafael Valley during the drought of 1892-93. From the 1893 U.S. Border Report Survey."
B-LXXVI <u>Page</u> 140 - "Figure 18. San Rafael Valley, looking east from Monument 110. From the 1893 U.S. Boundary Survey Report."
B-LXXVII <u>Page</u> 141 - "Figure 19. San Rafael Valley, 1917. U.S. Forest Service. Exact location unknown, probably north end of study area, near Meadow Valley."

Halpenny 1962
B-LXXVIII <u>Page</u> 21 - "Figure 2. -- Photographs of river channel and of desert vegetation."
B-LXXIX <u>Page</u> 28 - "Figure 3. -- Photographs of bottom lands taken from the air."
B-LXXX <u>Page</u> 38 - "Figure 4. -- Photographs of dead mesquite."
B-LXXXI <u>Page</u> 40 - "Figure 5. -- Photographs of dead mesquite."

Photo Files from Arizona Historical Society, Tucson
Pictures - Places - Tucson - Businesses - Milling Companies
[photos of Warner's Mill]
Pictures - Places - Tucson - Santa Cruz River
[photos of Santa Cruz River, most during floods of unspecified date]
Picture - Places - Tucson - Warner's Lake
[a few photos of Warner's Lake circa 1880s]

X. APPENDICES

APPENDIX A -- HISTORIC MAPS

Listed below are some of the many maps available. Most are in published form and easily accessible as indicated. In addition the three major nineteenth century surveys, Bartlett, Gray and Emory contain useful maps . Finally, the Arizona Game and Fish Department mapped perennial streams in 1994 and has maps of the perennial sections of the river and tributaries, showing vegetation and other features.

Betancourt 1990

A-I	<u>Page</u> 30 - "Figure 3. Map of the Santa Cruz River Valley, with places mentioned in the text."
A-II	<u>Page</u> 75 - "Figure 11. Map of the northeast portion of the San Xavier Indian Reservation in 1882 (after Roskruge, 1882). In this map, and on later ones (Figs. 12-13), the course of the Santa Cruz north of Martinez Hill is not indicated, suggesting that the channel had long been replaced by ditches in carrying floodflows."
A-III	<u>Page</u> 76 - "Figure 12. Map of the San Xavier Indian Reservation in 1888 (Chillson, 1888)."
A-IV	<u>Page</u> 77 - "Figure 13. Map of San Xavier Indian Reservation in 1891 (Surveyor General's Office, 1891)." [shows Santa Cruz River being diverted into ditches around the Reservation]
A-V	<u>Page</u> 100 - "Figure 21. Map of northern Sonora and southern Arizona, showing hydrological effects of the 1887 earthquake (after Dubois and Smith 1980)."
A-VI	<u>Page</u> 136 - "Figure 40. Plan of the Tucson Farms Company Crosscut and distribution system (Hinderlider 1913)."
A-VII	<u>Page</u> 142 - "Figure 47. Map of Greene's Canal and lower Santa Cruz River."

Bolton

A-VIII	Map of Pimeria Alta 1687-1711. Shows Kino's routes, etc.

Carleton 1864

A-IX	Military Map of New Mexico. Shows a discontinuous Santa Cruz River north of Tucson.

Cooke and Reeves 1976

A-X	<u>Page</u> 52 - "Figure II.9 Santa Cruz Valley: data from Olberg and Schanck (1913)" [shows man-made channel being constructed to join the West and East Branches of the Santa Cruz River south of Mission San Xavier del Bac]

Eckhoff, E.A. 1880

A-XI	Official Map of the Territory of Arizona. Shows "supposed underground passage of the Santa Cruz River" north of Tucson.

Emory 1857

A-XII Leaflet on back page - sketch of the Gila River Basin, including the Santa Cruz River.

Fergusson 1862

A-XIII "Cultivated Fields in and about Tucson" - at Arizona Historical Society

Hadley and Sheridan 1995

A-XIV Page 2 - "Figure 1. San Rafael Valley Area."

A-XV Page 29 - "Figure 2. Early Trails and Roads." [in San Rafael Valley]

A-XVI Page 45 - "Figure 5. Major Mines of the San Rafael/Lone Mountain Study Area."

A-XVII Page 110 - "Figure 12. Forest Service Ranges, 1917." [in San Rafael Valley]

A-XVIII Page 111 - "Figure 13. Forest Reserve Grazing Allotments, 1940's." [in San Rafael Valley]

A-XIX Page 207 - "Figure 20. Homesteads in the study area." [in San Rafael Valley, circa 1913-1930]

Halpenny 1962

Numerous maps throughout of the San Xavier District.

Halpenny 1988

A-XX Page 16 - "Figure 5. Water-level changes, 1953-1982, southern Santa Cruz River Valley."

Hendrickson and Minckley 1984

A-XXI Page 135 - "Figure 3. Sketch map of southeastern Arizona, with some place names mentioned in the text. Historical and present status of surface streamflows are indicated as adapted from Brown, Carmony, and Turner (1981)."

A-XXII Page 150 - "Figure 12. Sketch map of the Santa Cruz Valley, Arizona, with some place names mentioned in the text and some present-day aquatic and semiaquatic habitats (excluding stock tanks)."

A-XXIII Page 151 - "Figure 13. Sketch map of the Santa Cruz Valley, with aquatic and semiaquatic habitats before 1890 as inferred from historic records."

Mattison 1946

A-XXIV Inset - "Spanish and Mexican Land Grants in Arizona...Photostat of General Land Office Map of 1887."

Parker 1993

A-XXV Page 10 - "Figure 3. Santa Cruz River in 1988, perennial and intermittent reaches in 1890, and location of headcuts in relation to marshes in the late 19th century."

Walker and Bufkin 1986

Historical Atlas of Arizona - various maps illustrating travel routes, land grants, Spanish exploration, military forts and presidios, missions, and others.

Betancourt 1990

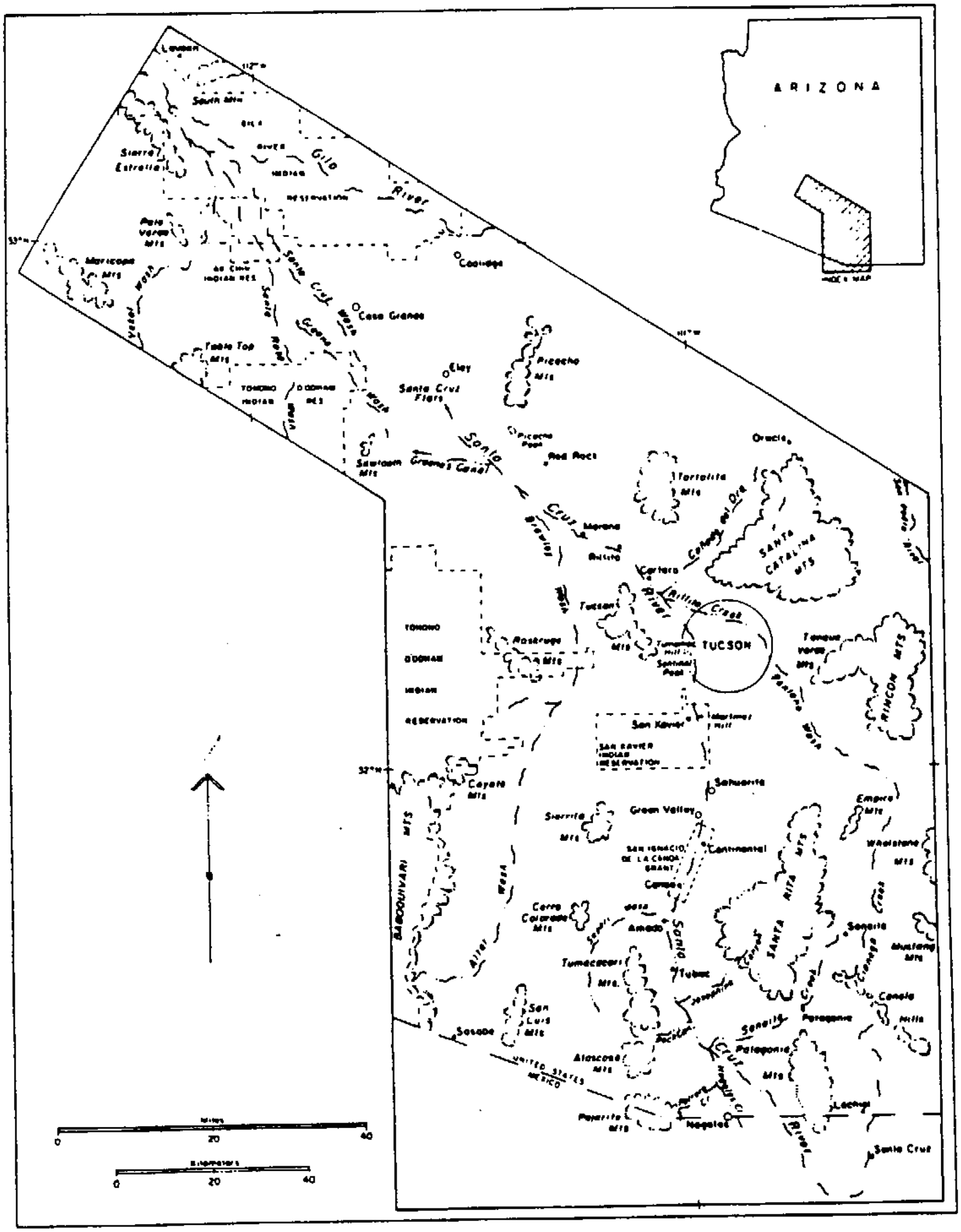


Figure 3. Map of the Santa Cruz River valley, with places mentioned in the text.

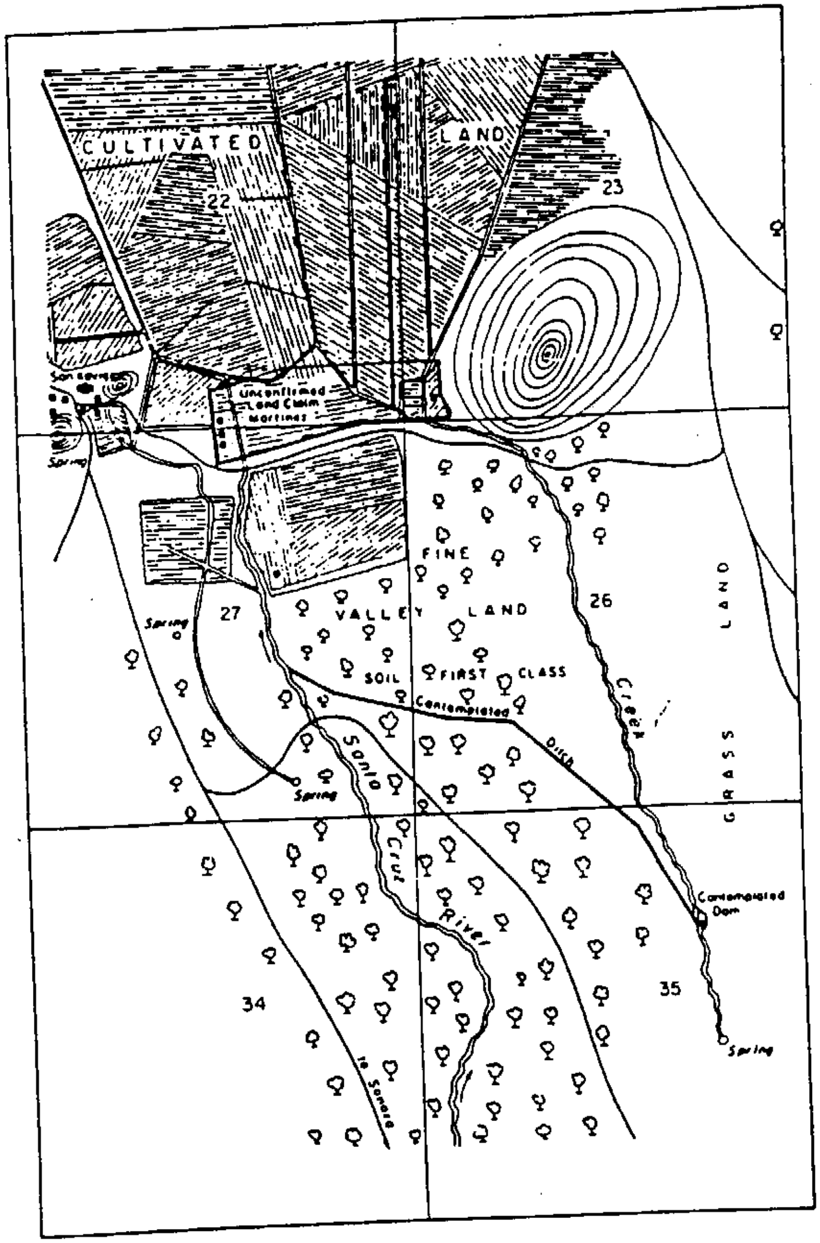


Figure 11. Map of the northeast portion of the San Xavier Indian Reservation in 1882 (after Roskruge, 1882). In this map, and on later ones (Figs. 12-13), the course of the Santa Cruz north of Martinez Hill is not indicated, suggesting that the channel had long been replaced by ditches in carrying floodflows.

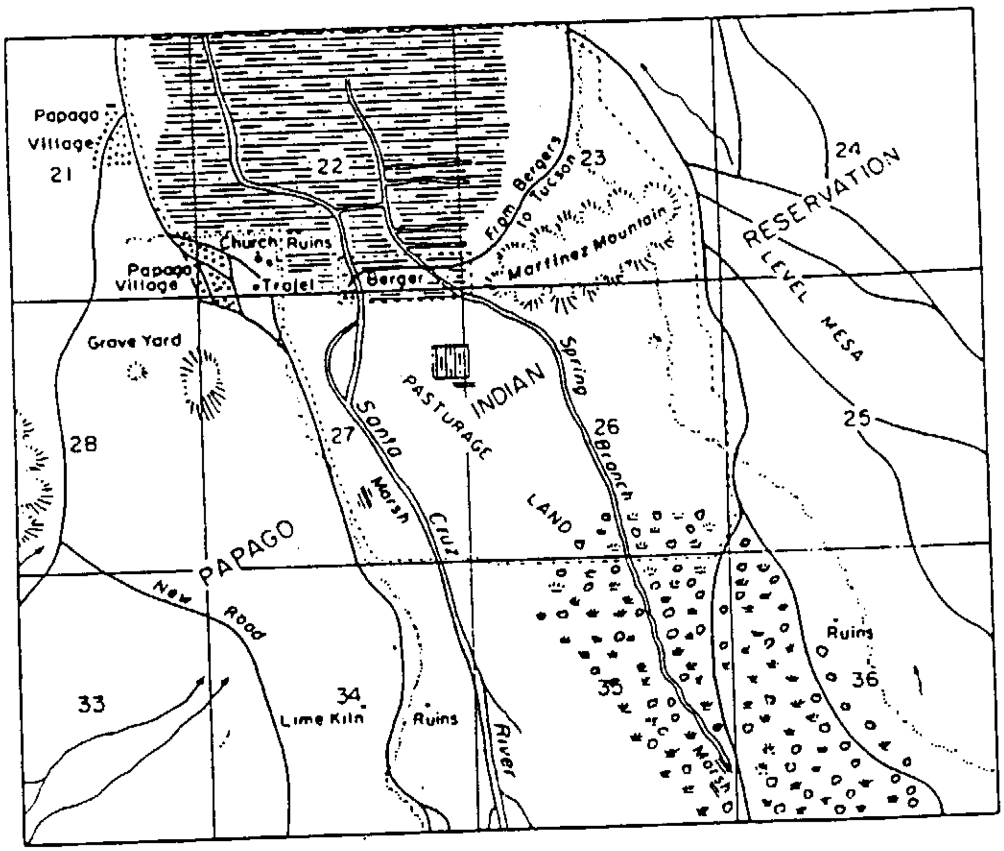


Figure 12. Map of the San Xavier Indian Reservation in 1888 (Chillson, 1888).

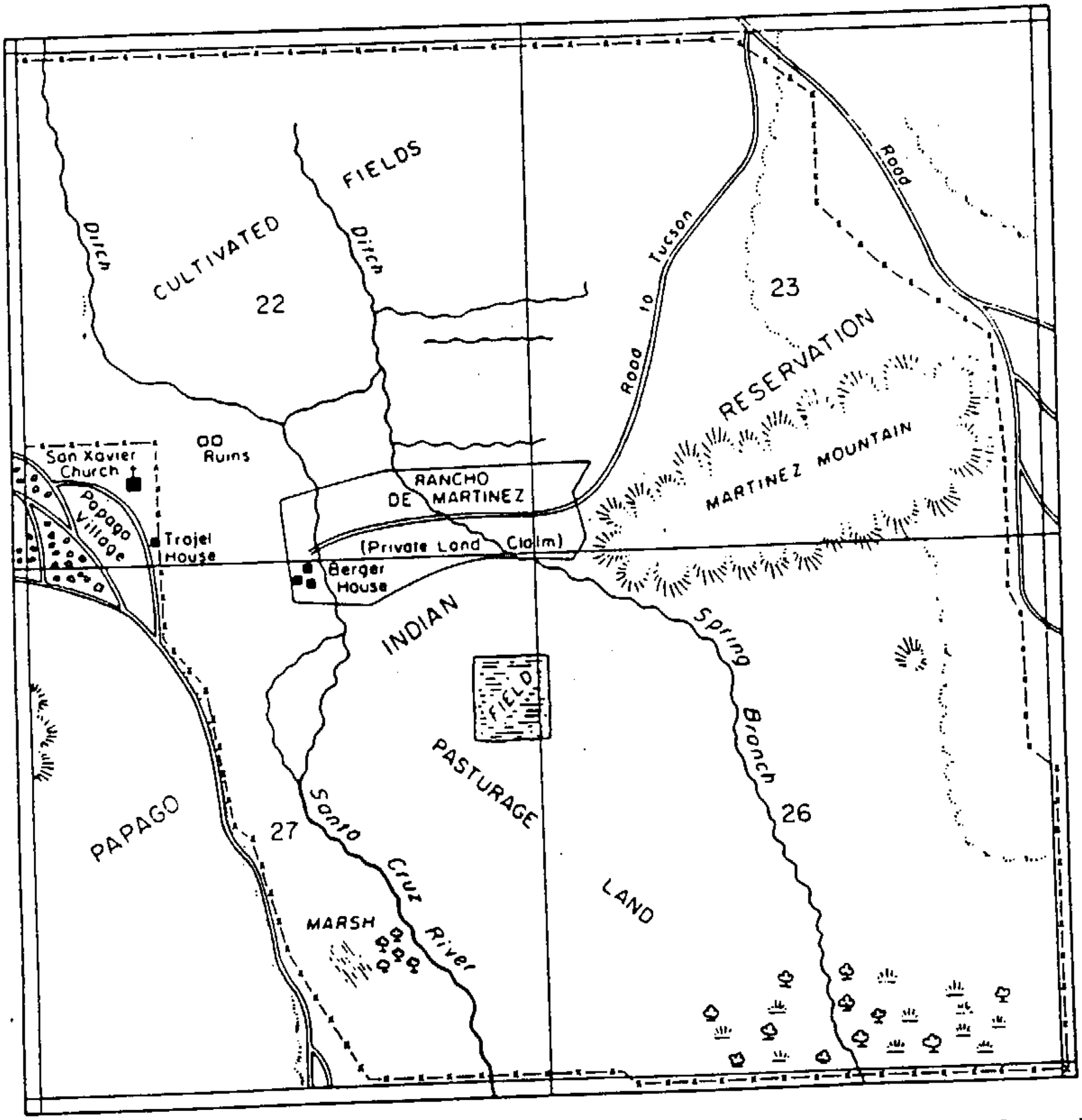


Figure 13. Map of San Xavier Indian Reservation in 1891 (Surveyor General's Office, 1891).

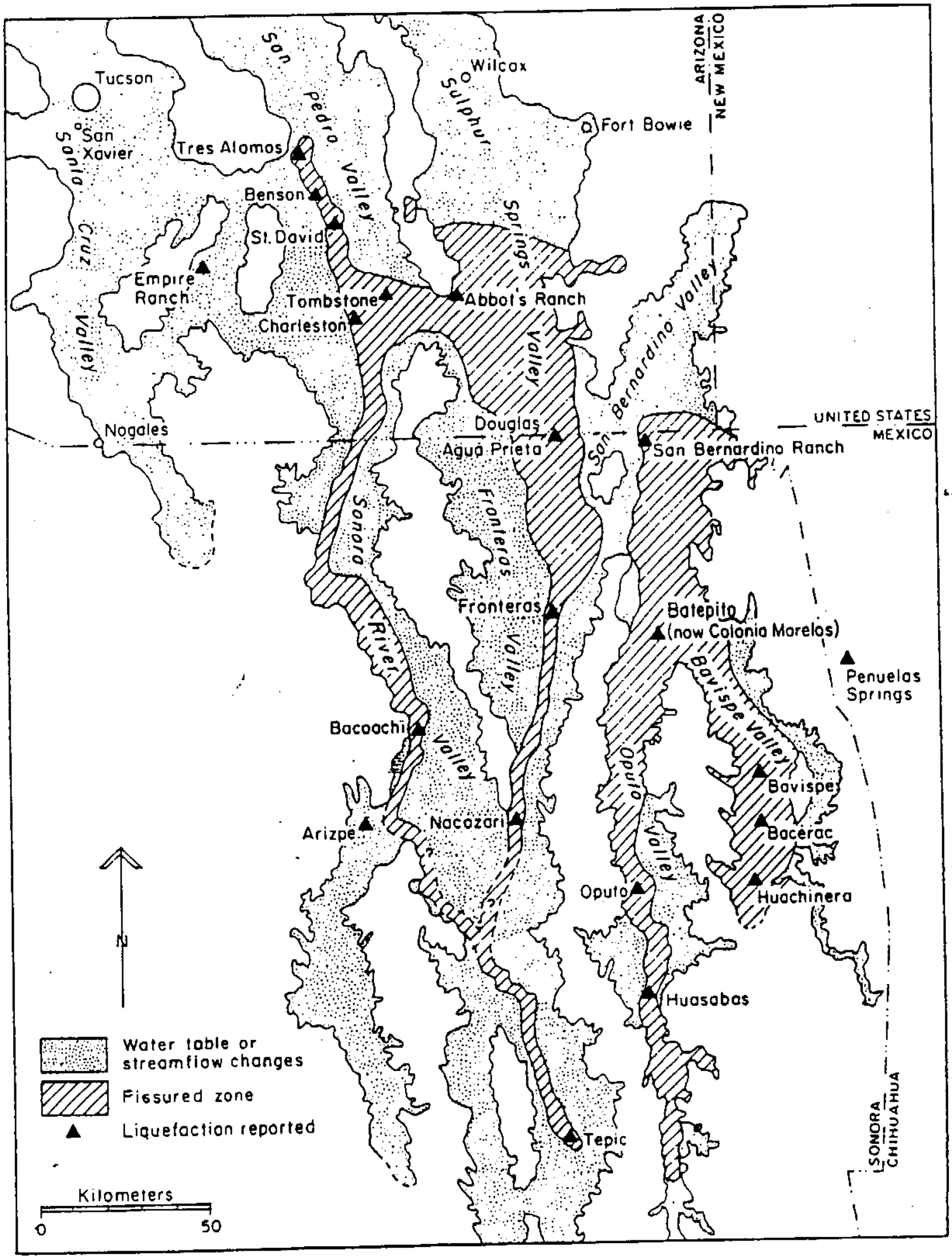


Figure 21. Map of northern Sonora and southern Arizona, showing hydrological effects of the 1887 earthquake (after Dubois and Smith 1980).

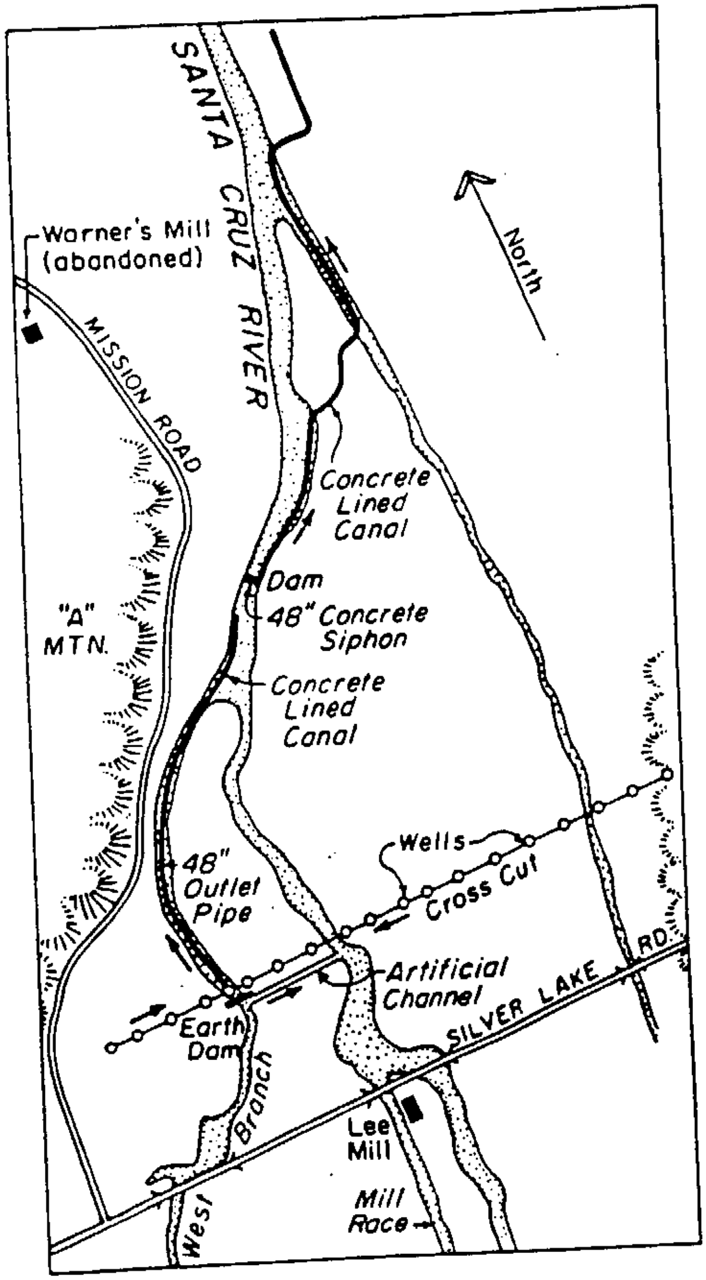
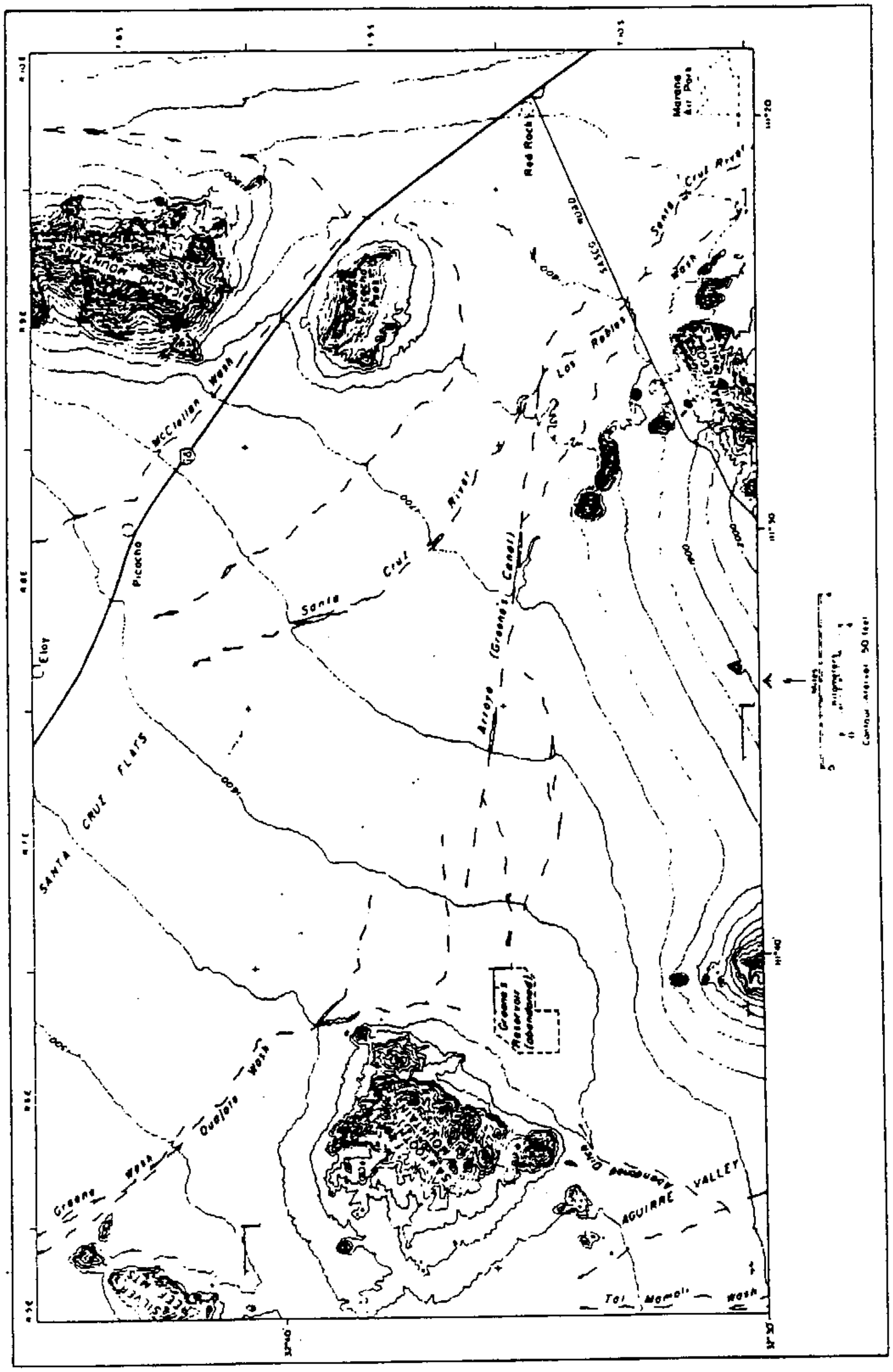


Figure 40. Plan of the Tucson Farms Company Crosscut and distribution system (Hinderlider 1913).

Figure 47. Map of Greene's Canal and lower Santa Cruz River, based on U.S.G.S. 15' Quadrangles.



Cocke + Reeves 1976

A-X

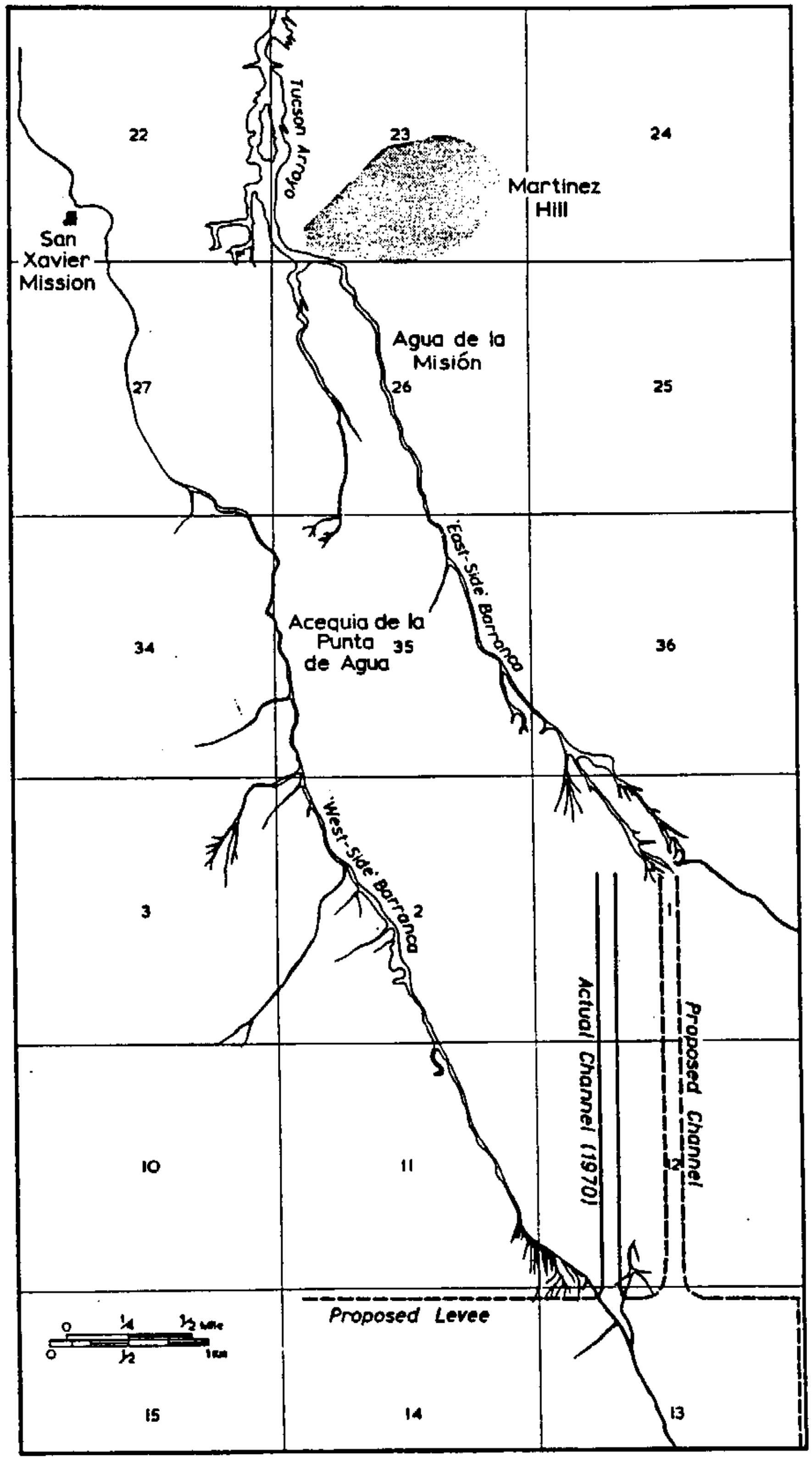


Figure II.9 Santa Cruz Valley: data from Olberg and Schanck (1913)

Hadley & Sheridan 1995

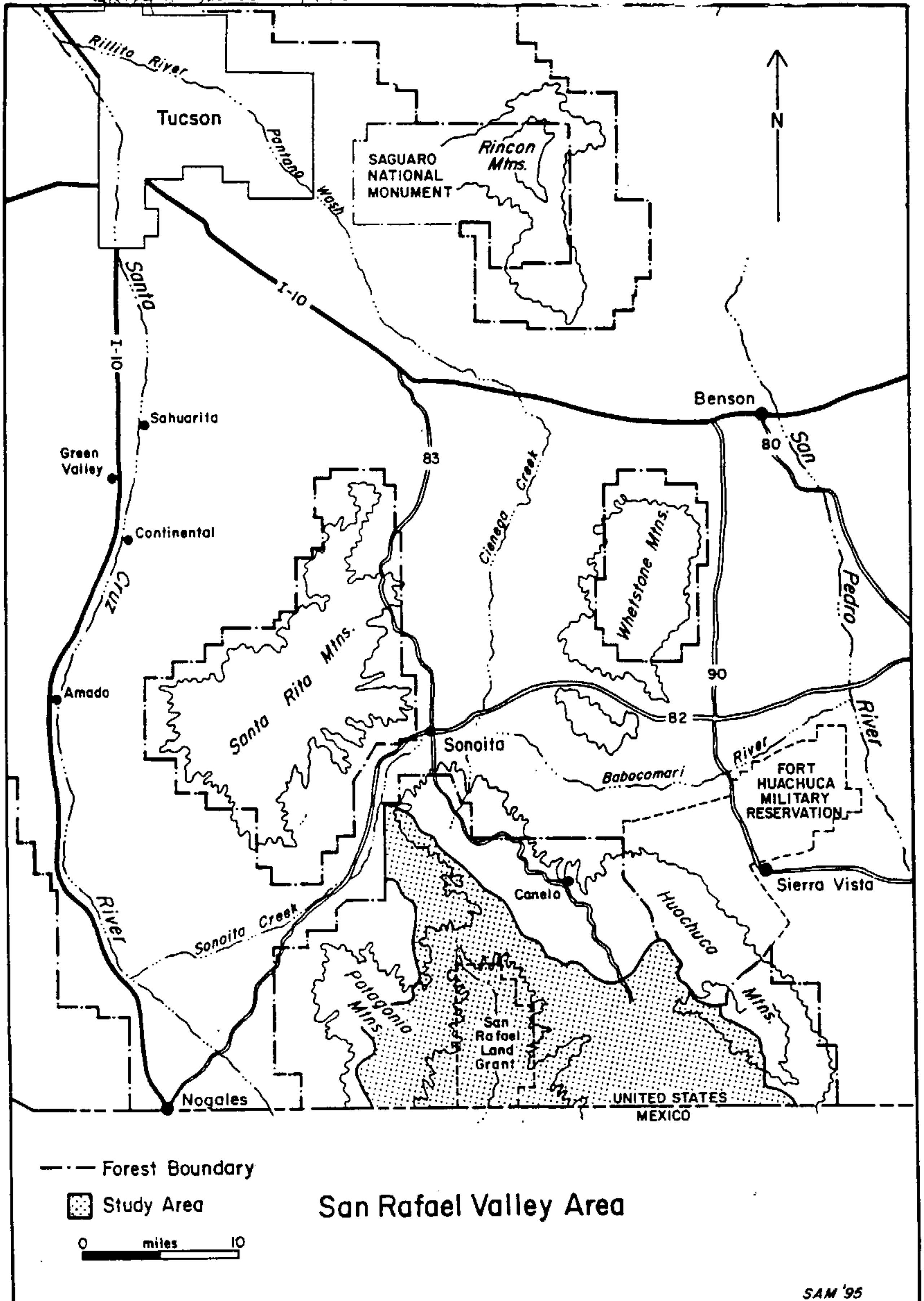


Figure 1

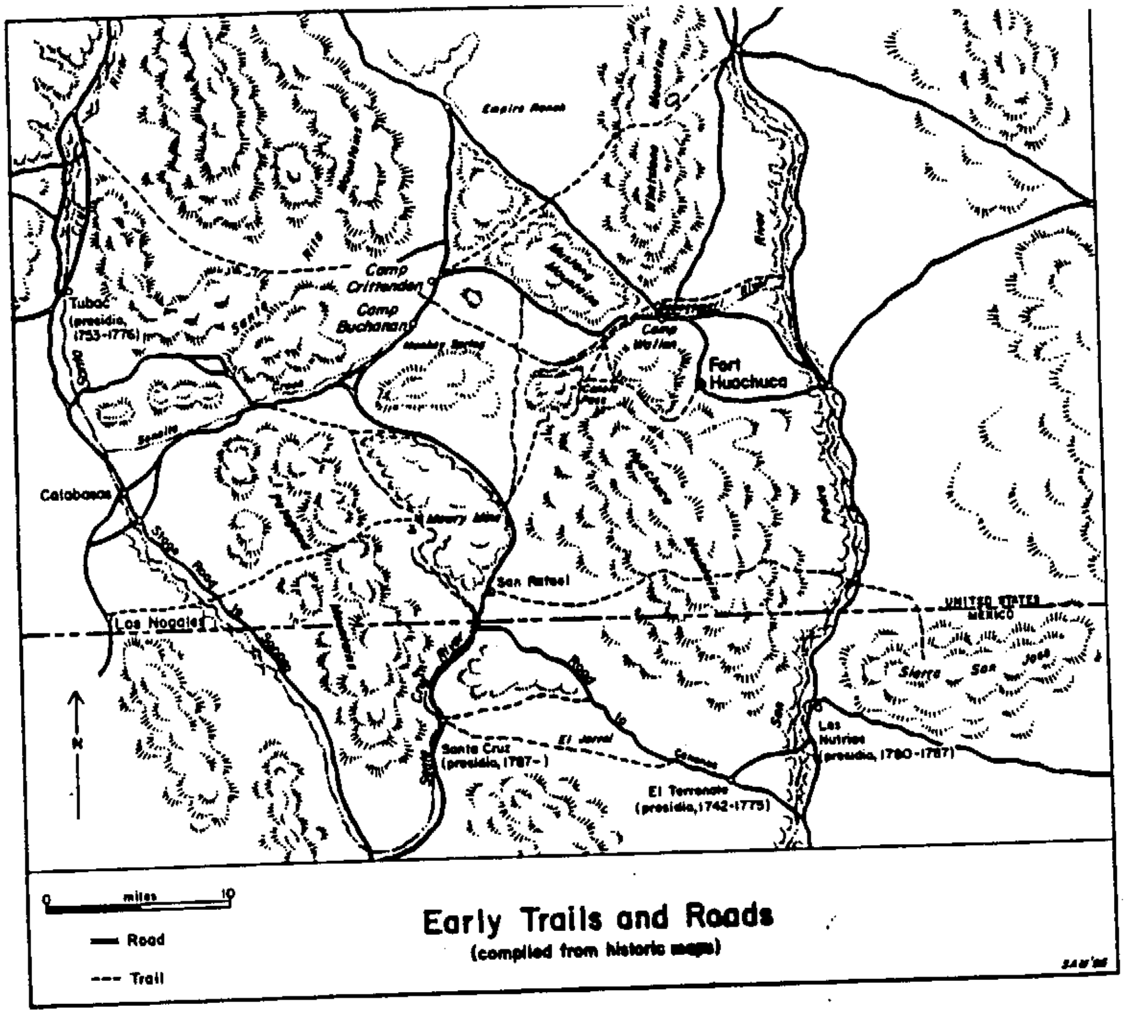


Figure 2

leans *Daily Picayune*, went to Santa Cruz, Major Graham's tracks were still fresh. Durivage's party followed Graham's mistaken first attempt to find a route over the steep slopes until they reached the place where "it was evident that Major Graham had turned back" (Bieber 1937:206). His party also turned back, subsequently found the wagon road, and reached Santa Cruz with ease.

On August 12, after a heavy rain, George W. B. Evans and the Ohio Company took the shorter route to Santa Cruz. They departed from Colonel Cooke's trail and made what Evans described as a "very steep" ascent up a rocky road into unnamed mountains. On the descent, his party had gone only two miles when they were forced to camp near the highest peak of the mountains. Departing from this camp in the morning, they reached Santa Cruz by 3:00 p.m., stopping to repair a broken wheel en route. After reaching Santa Cruz by the shorter, steeper trail, several members of the Ohio Company abandoned their wagons and continued to California as a pack train (Dumke 1945:145–46).

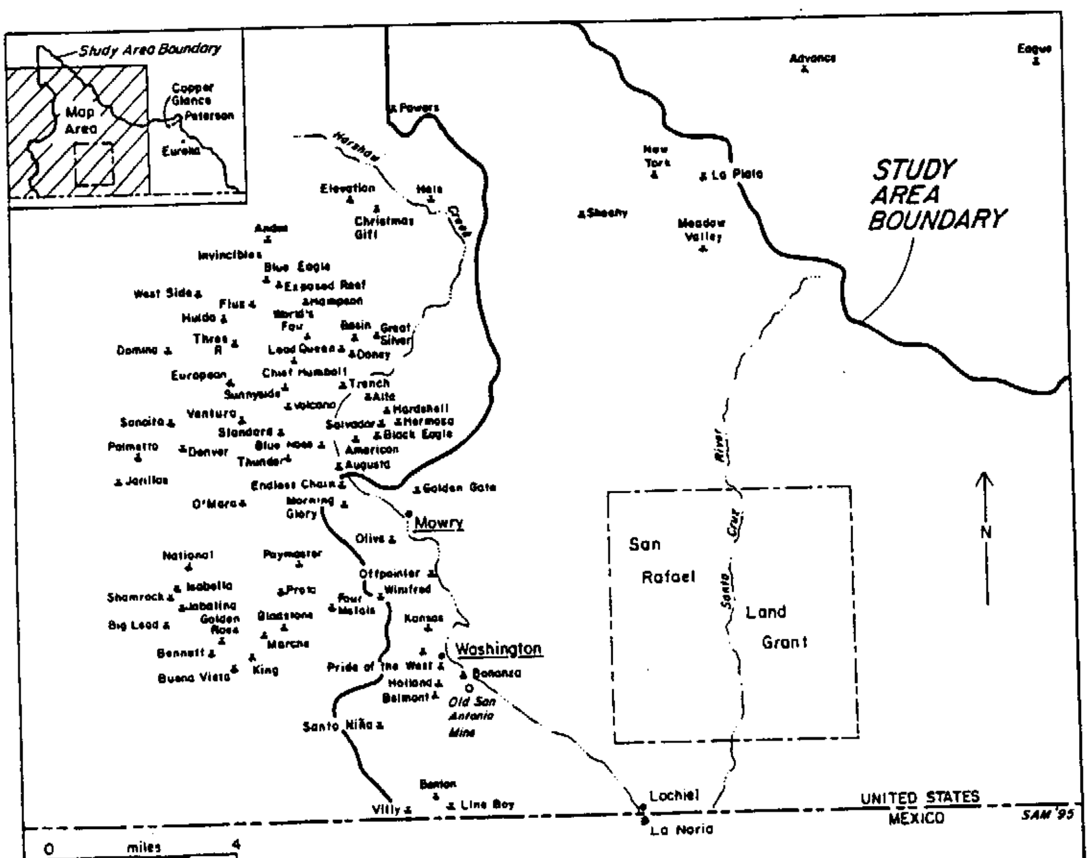
In early September, John Robert Forsyth of the Peoria Company took the shorter route to Santa Cruz. He noted that the road began at "three deserted Ranches some of the walls still in a good state of preservation & at one of them large piles of melted metal resembling lead or silver" [Terrenate or Las Nutrias]. The descent of the road into the southern portion of the San Rafael Valley passed through a canyon where "there was not six Inches more room than was required by the Wagons." He noted that the rocks on this portion of the road were 300 to 400 feet perpendicular and overhung the valley below. The road continued through a "fine rich valley" which had the appearance of an "English Landscape" (Forsyth ms:69–70). Charles Pancoast, who traveled with the same company, recalled a "steep descent of about fifty feet where we had to lower our wagons with ropes" (Hannum 1930:233). Since Pancoast wrote his memoir many years after his journey, his recollections are unreliable. However, it is possible that the descent required braking with ropes. Although these two diarists do not state which trail they had taken, it is

Chapter 5

Mining and Settlement

Scattered throughout the mountainous parts of the study area are the remains of old mines, prospects, primitive adobe smelters, and timeworn slag piles. Mining has taken place within the study area since the Spanish and Mexican periods (see Appendix 5.2). However, impacts from mining and the many subsidiary activities associated with mining became intense during the late 1870s and lasted until the 1960s (see Appendix 5.3). The study area contains three significant mining areas: Mowry and Washington Camp/Duquesne in the Patagonia Mountains, and Sunnyside on the western slopes of the Huachucas (Fig. 5). Located slightly north of the study area is Harshaw, the largest of the nearby mining camps and the only location in this part of Santa Cruz County that experienced a true mining boom. Because of its proximity to the study area and the important influences that its mining activity had on the study area, Harshaw is included in this report.

Although the activity of mining itself may be restricted to a specific location, subsidiary activities associated with mining produce a web of ecological impacts that extend far beyond the mining site itself. These associated activities include: road construction; fuelwood cutting, particularly during the period when smelting relied on charcoal and machinery operated from steam boilers; the development of mining camps and nearby towns; extraction of water from surface and underground water courses; the creation of waste dumps; chemical and mineral leakage from tailing and slag piles; removal and relocation of earth from mine shafts and workings; and the



Major Mines of the San Rafael / Lone Mountain Study Area.
(from Robert Lenon Map, 1950)

Figure 5

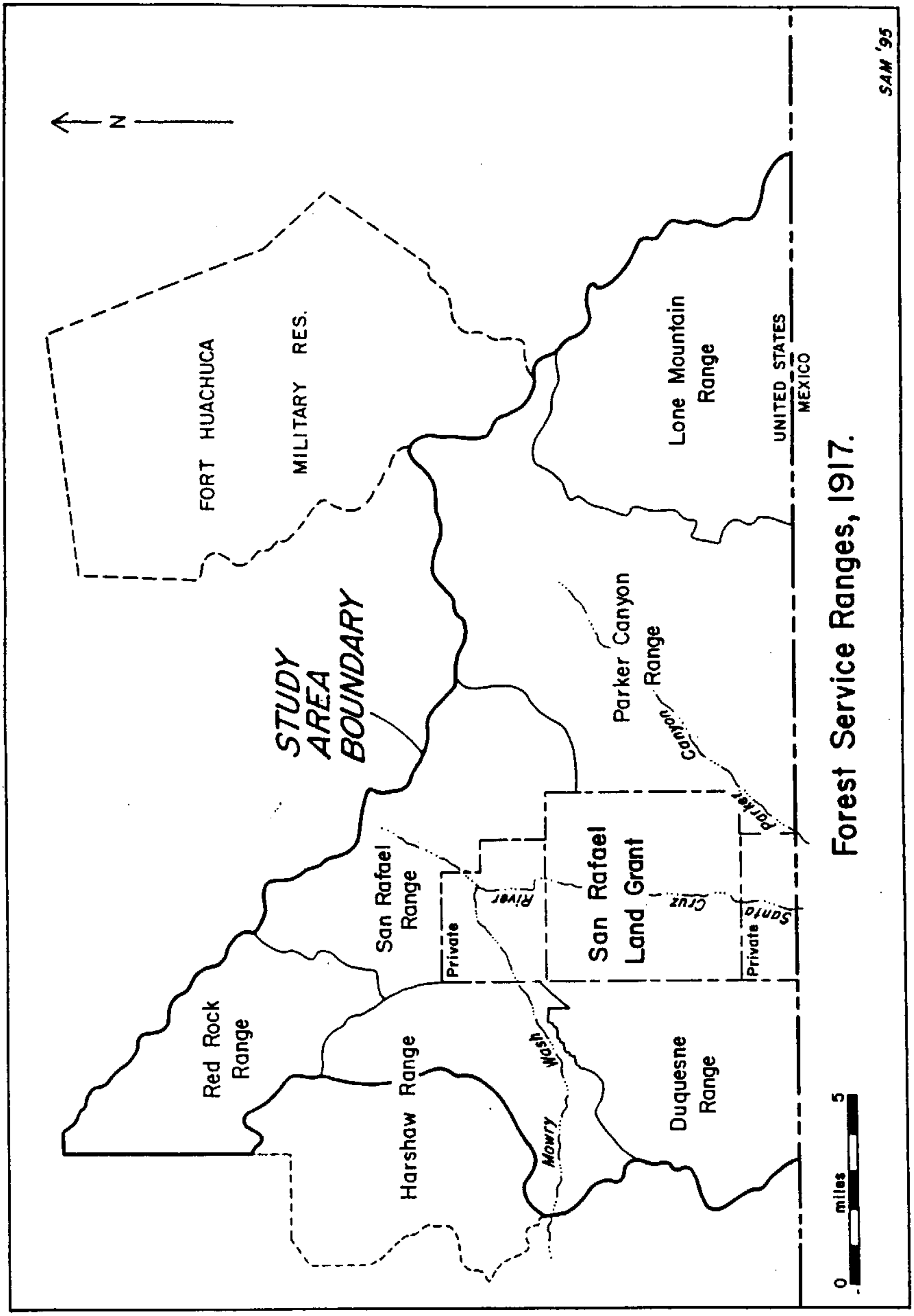
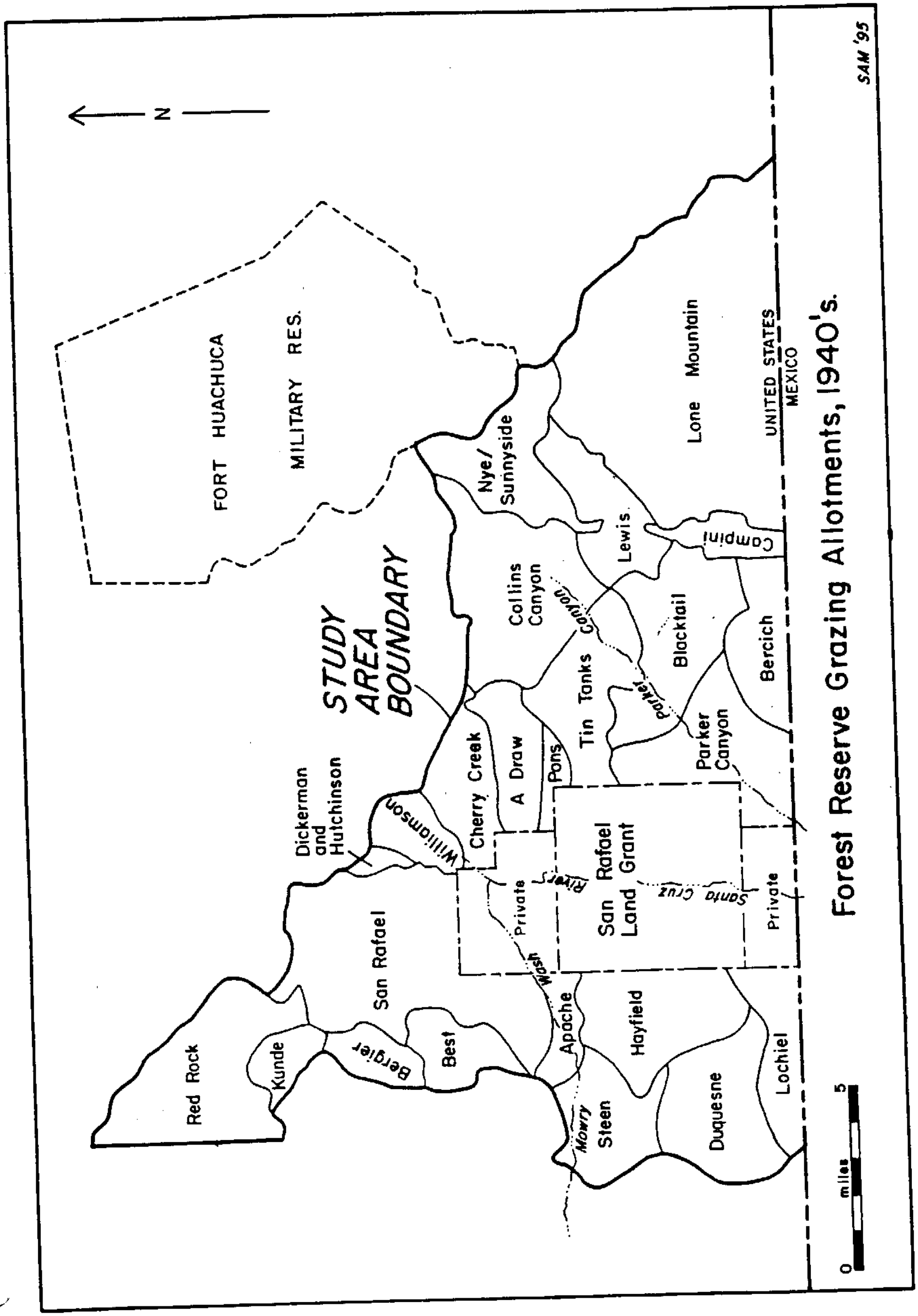

SAM '95
N
FORT HUACHUCA MILITARY RES.
STUDY AREA BOUNDARY
Lone Mountain Range
UNITED STATES
MEXICO
Parker Canyon Range
Parker Canyon
San Rafael Land Grant
San Rafael Range
Private
Santa Cruz River
Private
Red Rock Range
Harshaw Range
Mowry Wash
Duquesne Range
Forest Service Ranges, 1917.
0 miles 5

Figure 12



Forest Reserve Grazing Allotments, 1940's.

Figure 13

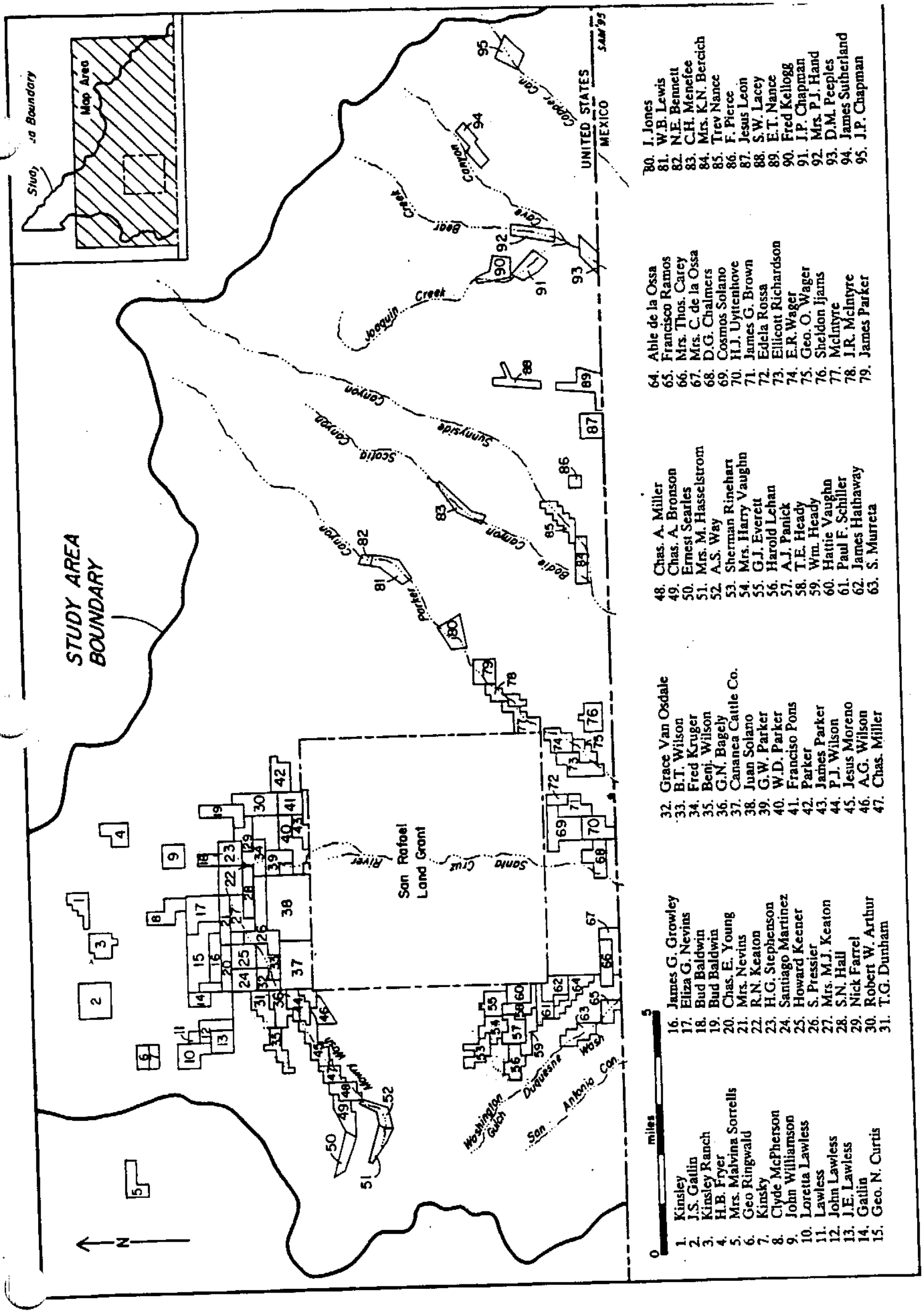


Figure 20—Homesteads in the study area.

Hendrickson + Minckley 1984

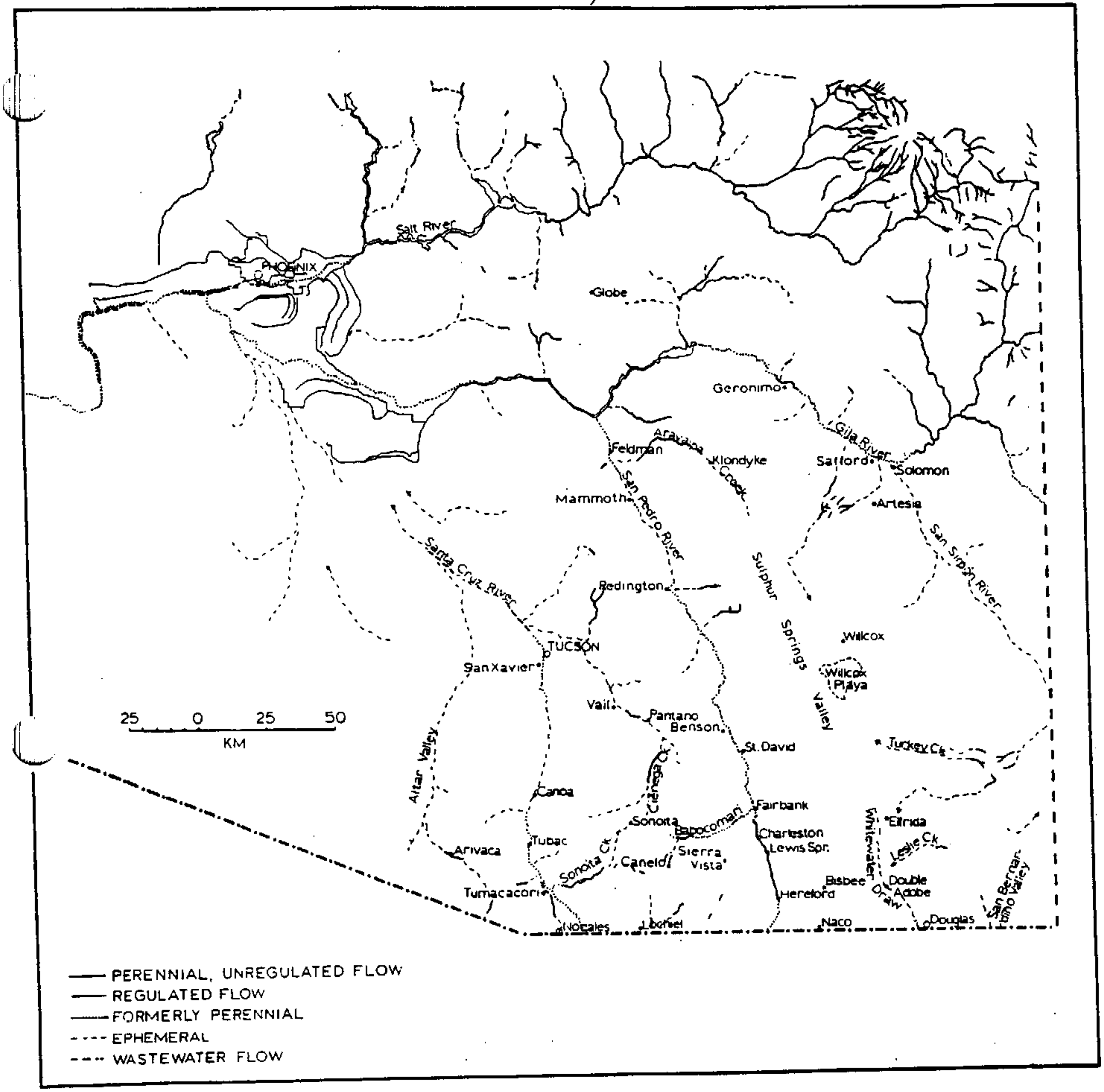


Figure 3. Sketch map of southeastern Arizona, with some place names mentioned in the text. Historical and present status of surface streamflows are indicated as adapted from Brown, Carmony, and Turner (1981).

ranges. Mostly hunters and gatherers, these groups practiced little agriculture.

Older residents were the Pimas Altos of the Santa Cruz and San Pedro valleys. These rancheria peoples lived in semi-permanent settlements wherever perennial surface water was available. They subsisted primarily by floodplain and irrigated farming (Bryan, 1929, 1941), supplemented with wild food gathering. Adjacent rancheria peoples were the Opatas who lived on northern Río Yaqui tributaries in the area of Rancho San Bernardino and the upper Río Sonora drainage in México, and the Pimas Bajos who occupied lower reaches of these same drainages. Papagos inhabited more arid deserts west of the Pimas Altos, and they were bordered on the west by Yumans of the lower Gila and Colorado rivers (Sauer 1934; Crosswhite, 1981). Size of these Indian populations 4 to 8 centuries ago was larger than the total European and Indian population of 1880 (Hastings and Turner, 1965).

Spanish colonization brought new impacts on the environment. However, descriptions of their missionary settlements are rare and provide few data for comparison with recent landscapes. A major impact of Spanish conquest on aboriginal populations predated that culture's arrival in the study region. Smallpox, introduced in 1520

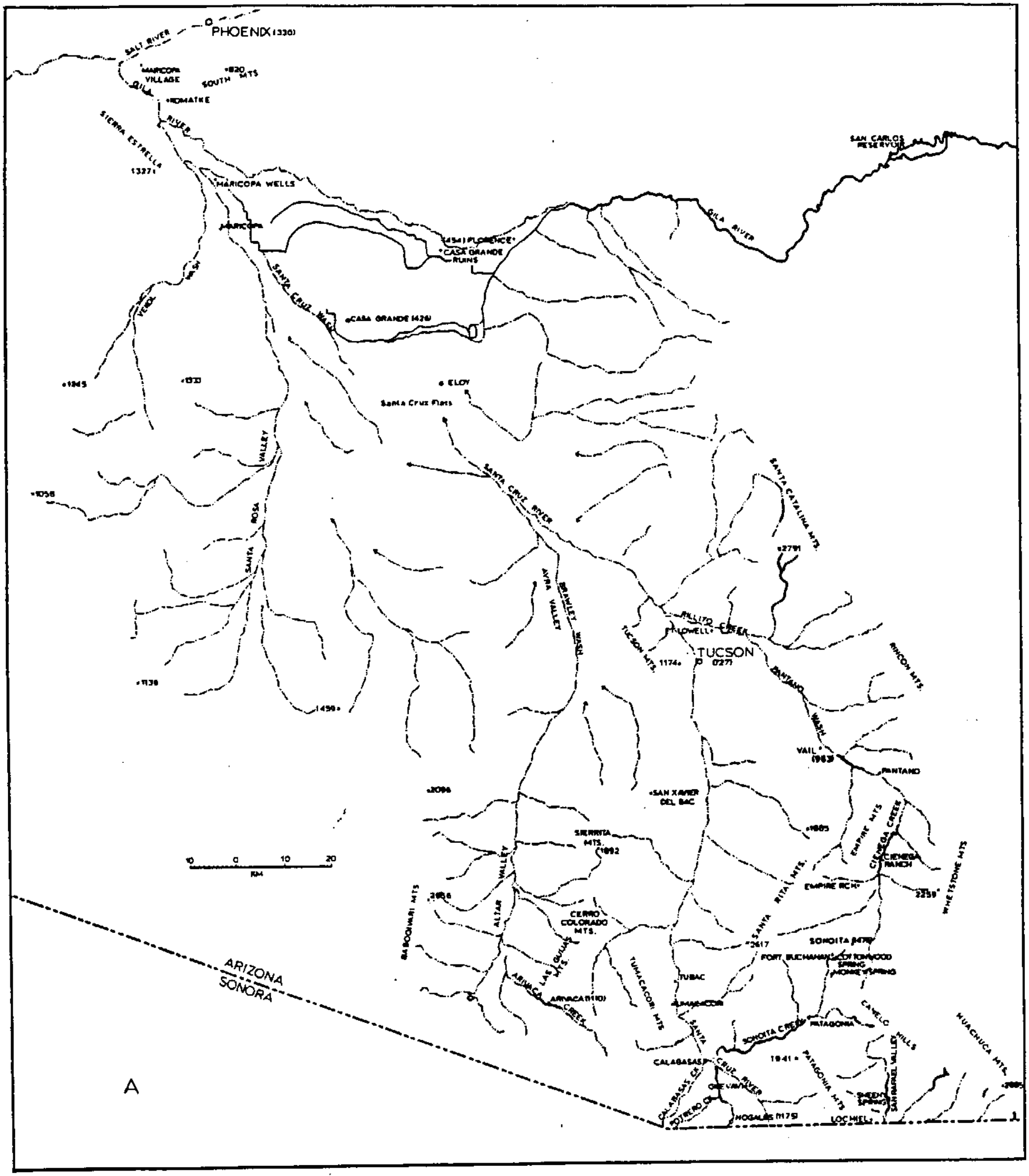


Figure 12. Sketch map of the Santa Cruz Valley, Arizona, with some place names mentioned in the text and present-day aquatic and semiaquatic habitats (excluding stock tanks). Elevations are in meters. Symbols are as in Figure 4.

we visited in 1981. Cook's lake is similarly dominated by Willows, but also has peripheral Cottonwoods. Open water is essentially absent, although present when Smith and Bender (1973a, 1974d) did their survey. In the interim between their work and ours, *Typha* sp. completely closed the open-water area. Cattail and Watercress also cover an adjacent area of tree-dominated swamp, which is drained *via* a broad, diffuse, shallow channel choked by Cattail, to a small artificial lake. Both these systems are best defined as wooded swamps, resembling such associations in the southeastern United States.

Santa Cruz Basin. Headwaters of the Rio Santa Cruz (Figs. 12, 13) drain the north, west, and south slopes of the Canelo Hills, and all sides of both the Patagonia and Santa

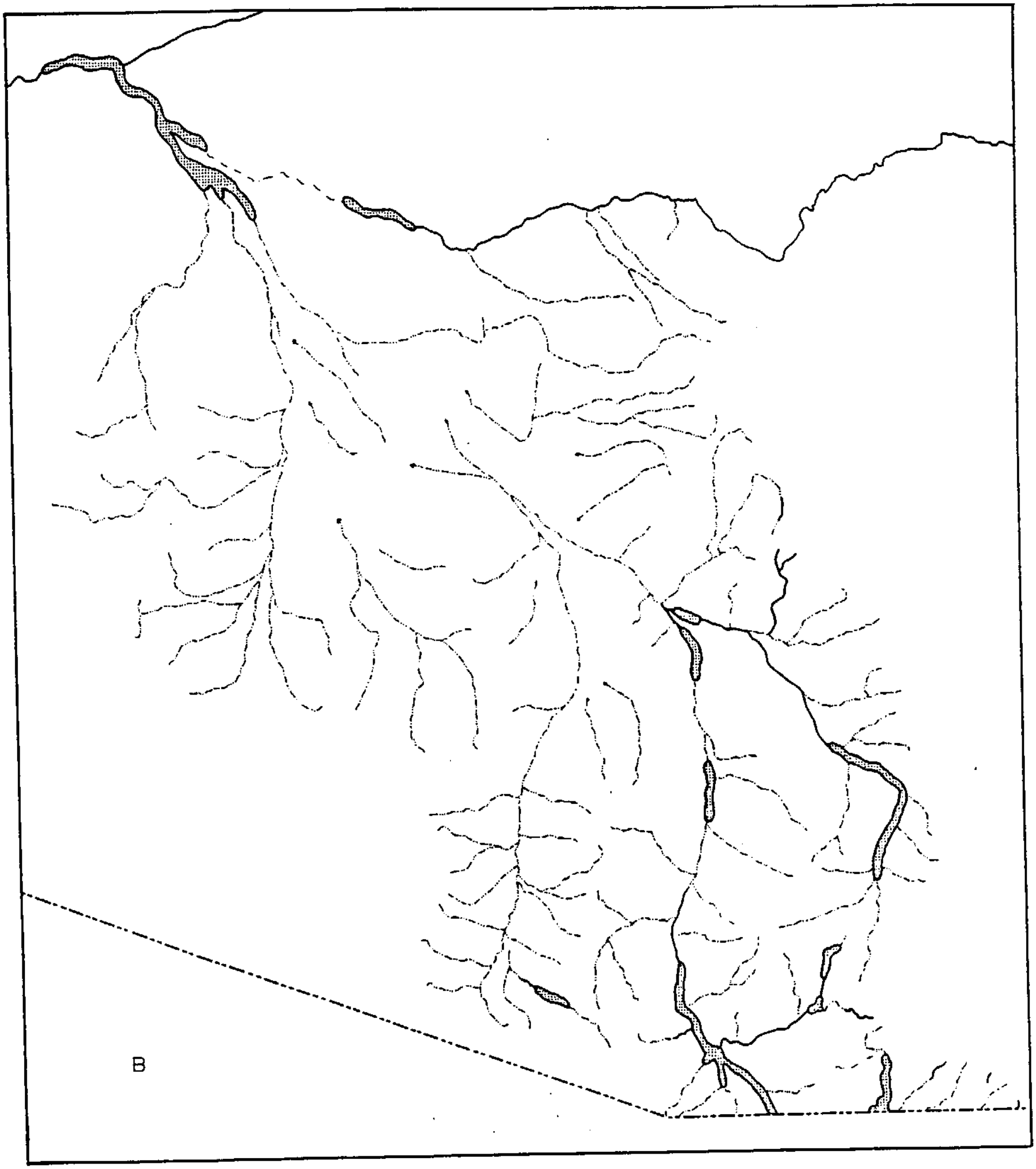


Figure 13. Sketch map of the Santa Cruz Valley, with aquatic and semiaquatic habitats before 1890 as inferred from historic records. Symbols are as in Figure 4.

Rita Mountains. Maximum elevations range from 1,900–2,600 m. The mainstream flows south through the San Rafael Valley, receiving tributaries from the Huachuca Mountains on the east. Entering Sonora it loops south of the Patagonia Mountains to flow into Arizona. It then receives discharge from the western Canelo Hills *via* Sonoita Creek, which passes between the Santa Rita and Patagonia Mountains. The valley broadens as it passes between the Santa Rita and Sierrita mountains and continues north to Tucson. North of Tucson, Rillito Creek enters from the east with drainage from the north slope of Canelo Hills *via* Cienega Creek and Pantano Wash. Further downstream the broad Avra-Altar Valley enters from the southwest, draining the area between the Baboquivari and Sierrita mountains. The Rio Santa Cruz historically disappeared into its bed, except in flood, in the vicinity of

Parker 1995

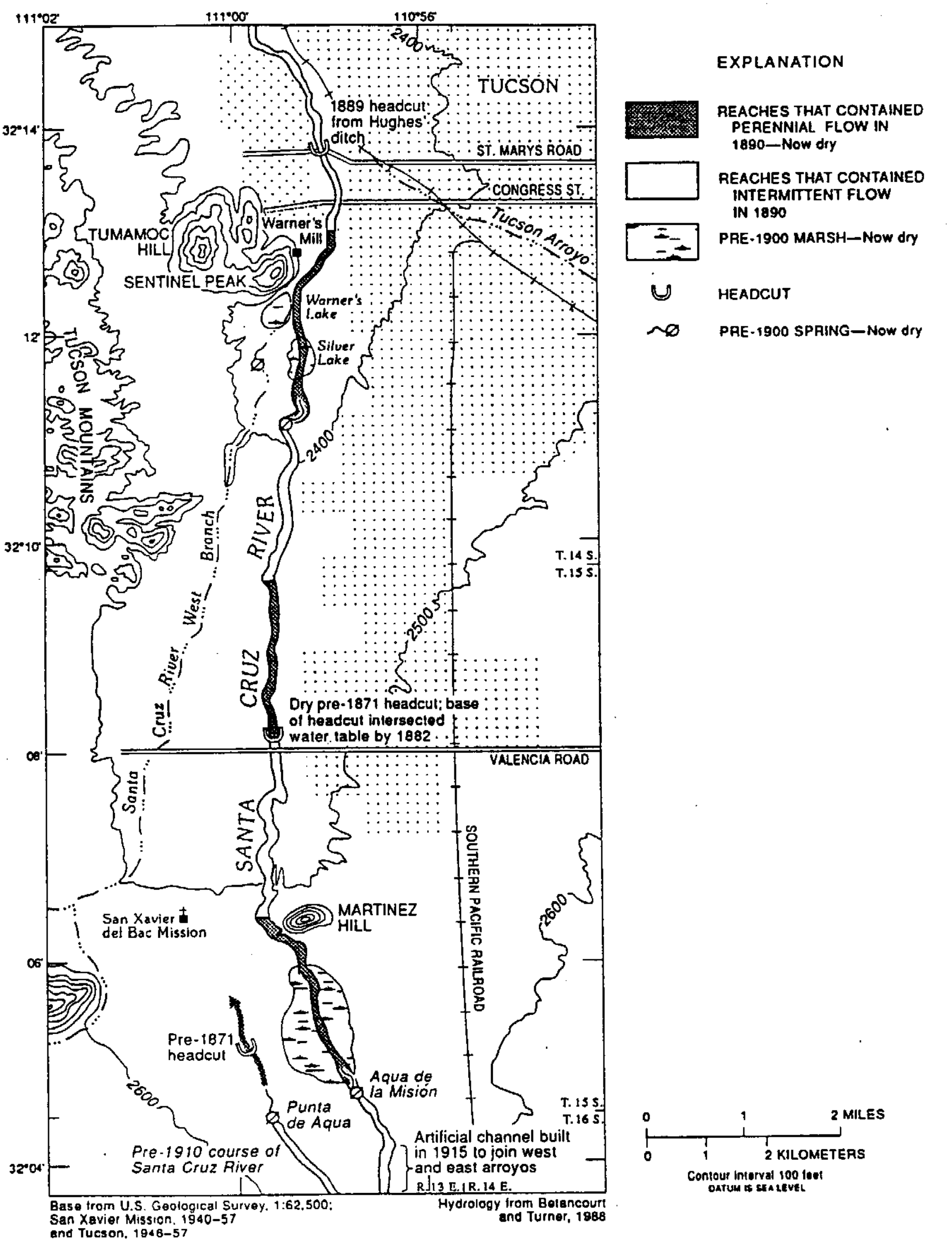


Figure 3. Santa Cruz River in 1988, perennial and intermittent reaches in 1890, and location of headcuts in relation to marshes in the late 19th century.

APPENDIX B -- HISTORIC PHOTOS

The Arizona Historical Society and Special Collections at the University of Arizona Library have a wealth of photos relating to the Santa Cruz River. Unfortunately, many of these photos are inadequately labeled. For example, one may say "person crossing Santa Cruz River" without giving date or place. A series of photos of the Santa Cruz County portion of the river was made by a surveyor, but the exact locations are unknown. Recently the Buehman Collection was made available at the AHS Library, consisting of some one million photos. Only about a fourth have been cataloged, however, and few have dates or locations. Other AHS collections of value include the Roskruge file, Arizona-places-Santa Cruz River, Arizona-Santa Cruz River-floods and Arizona-places-ranches. A fine collection of photos is available at the Tumamoc Hill office of the U.S. Geological Survey, the collection from which the photos in The Changing Mile are drawn. The Turner photos listed below are from that collection.

Most of the photos listed below are available at the AHS as well as in their published form which is the one listed if applicable.

Betancourt 1990

- B-I — Page 32 - "Figure 4. Aerial view of Tucson reach of the Santa Cruz River, Looking southeast on October 9, 1983."
- B-II — Page 49 - "Figure 7. Upstream view in 1912 of Acequia de Punta de Agua, a streambed spring along the Santa Cruz River south of the San Xavier Mission (from Olberg and Schanck, 1913)."
- B-III — Page 53 - "Figure 8. Looking west across Silver Lake in the 1880s. Structure on the right was a hotel."
- B-IV — Page 53 - "Figure 9. Same view as Figure 8, taken on December 16, 1981."
- B-V — Page 83 - "Figure 14. Solomon Warner's house and mill in 1880, looking southeast from lower slope of Sentinel Peak, with the Santa Cruz Valley in the background."
- B-VI — Page 84 - "Figure 15. The Santa Cruz Valley from the base of Sentinel Peak looking east ca. 1880. Warner's Mill is the structure at left margin of photograph. White structure at center right is Leopoldo Carrillo's ice house, which was cooled by water from the mill's tail race."
- B-VII — Page 84 - "Figure 16. Same view as Figure 15 on December 1, 1981."
- B-VIII — Page 85 - "Figure 17. East view of Santa Cruz Valley and Tucson from Sentinel Peak in 1882, showing the San Agustin Mission (center) and Warner's Mill Complex at lower left. The Acequia Madre, which was fed by Silver lake, runs from right to left across center of photograph. The Acequia may have followed the mainstem of the Santa Cruz River, which at that time had no discernible channel."
- B-IX — Page 85 - "Figure 18. Same view as Figure 17 on December 1, 1981."
- B-X — Page 93 - "Figure 19. Southeast view of Warner's Lake in 1883. The shallow channel of the Santa Cruz River is visible downstream of the dam at extreme left of the photograph."
- B-XI — Page 93 - "Figure 20. Approximately the same view as Figure 19 on December 31, 1988."
- B-XII — Page 105 - "Figure 22. Upstream view of the heading of Sam Hughes' intercept ditch at the St. Mary's Road crossing in October 1889."

B-LXIII Page 176 - "Figure 78. Southeast view of the Santa Cruz River, looking upstream from a point just south of the Congress Street Bridge."
B-LXIV Page 176 - "Figure 79. Same view as Figure 78 on February 26, 1982."
B-LXV Page 177 - "Figure 80. Downstream view of the Rillito-Santa Cruz confluence, looking north in 1939."
B-LXVI Page 177 - "Figure 81. Same view as figure 80 on November 9, 1983."
B-LXVII Page 178 - "Figure 82. East view of Congress Street and the then active floodplain of the Santa Cruz River, taken from West Congress Terrace in the 1890s."
B-LXVIII Page 178 - "Figure 83. Approximate view as Figure 82 in the 1930s."
B-LXIX Page 179 - "Figure 84. Same view as Figure 83 on February 26, 1982."

Betancourt 1978
B-LXX Page 67 - "Figure 13. Confluence of the West Branch and the Santa Cruz in 1904."
B-LXXI Page 67 - "Figure 14. The new confluence of the West Branch and the Santa Cruz."
B-LXXII Page 69 - "Figure 15. The Convento structure of the San Augustin Mission (Arizona Historical Society)." [no date]
B-LXXIII Page 70 - "Figure 16. Warner's Mill around 1880 (Arizona Historical Society)."
B-LXXIV Page 85 - "Figure 23. Silver Lake, the Silver Lake Hotel, and the residence of a Mr. Kelley to the left. Photograph (taken in 1880) looks west across the lake toward the Tucson Mountains in the background (Arizona Historical Society)."

Hadley and Sheridan 1995
B-LXXV Page 41 - "Figure 3. San Rafael Valley during the drought of 1892-93. From the 1893 U.S. Border Report Survey."
B-LXXVI Page 140 - "Figure 18. San Rafael Valley, looking east from Monument 110. From the 1893 U.S. Boundary Survey Report."
B-LXXVII Page 141 - "Figure 19. San Rafael Valley, 1917. U.S. Forest Service. Exact location unknown, probably north end of study area, near Meadow Valley."

Halpenny 1962
B-LXXVIII Page 21 - "Figure 2. -- Photographs of river channel and of desert vegetation."
B-LXXIX Page 28 - "Figure 3. -- Photographs of bottom lands taken from the air."
B-LXXX Page 38 - "Figure 4. -- Photographs of dead mesquite."
B-LXXXI Page 40 - "Figure 5. -- Photographs of dead mesquite."

Photo Files from Arizona Historical Society, Tucson
Pictures - Places - Tucson - Businesses - Milling Companies
[photos of Warner's Mill]
Pictures - Places - Tucson - Santa Cruz River
[photos of Santa Cruz River, most during floods of unspecified date]
Picture - Places - Tucson - Warner's Lake
[a few photos of Warner's Lake circa 1880s]

Betancourt 1990

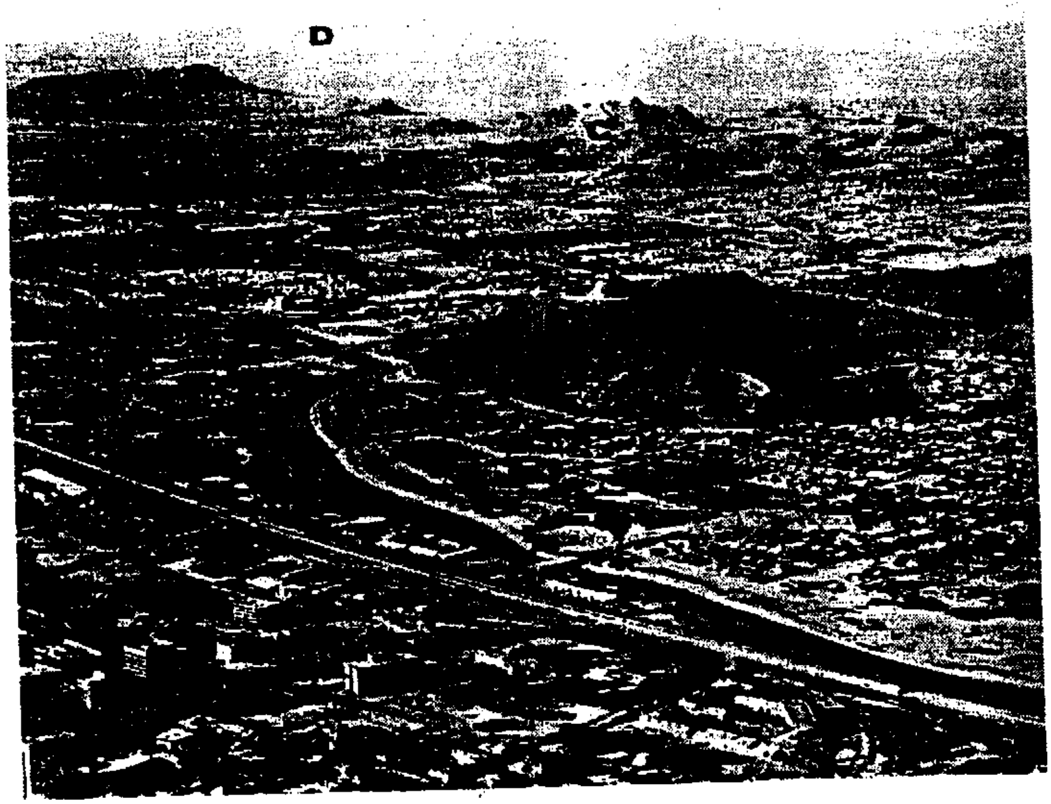


Figure 4. Aerial view of Tucson reach of the Santa Cruz River, looking southeast on October 9, 1983. Downtown Tucson is at lower left. Identified features are: A. Congress Street Bridge, B. Sentinel Peak, C. Tucson Mountains, D. Sierrita Mountains, E. Black Mountain, F. Former site of Silver Lake, G. former site of Warner's Lake, H. West Branch of the Santa Cruz River (Photograph by Peter Kresan).

Figure 7. Upstream view in 1912 of Acequia de Punta de Agua, a streambed spring along the Santa Cruz River south of the San Xavier Mission (from Olberg and Schanck, 1913).

B-III

Figure 8. Looking west across Silver Lake in the 1880s. Structure on the right was a hotel (Arizona Historical Society, Tucson, Negative No. 18335; U.S.G.S. Stake 1060).

B-IV

Figure 9. Same view as Figure 8, taken on December 16, 1981 (Photograph by R.M. Turner, U.S.G.S. Stake 1060).

Figure 14. Solomon Warner's house and mill in 1880, looking southeast from lower slope of Sentinel Peak, with the Santa Cruz Valley in the background (Photograph by Carleton Watkins, Arizona Historical Society, Tucson, Negative No. 14846).

Figure 15. The Santa Cruz Valley from the base of Sentinel Peak looking east ca. 1880. Warner's Mill is the structure at left margin of photograph. White structure at center right is Leopoldo Carrillo's ice house, which was cooled by water from the mill's tail race (Arizona Historical Society, Tucson, Negative No. 6608; U.S.G.S. Stake 1052).

B-VII

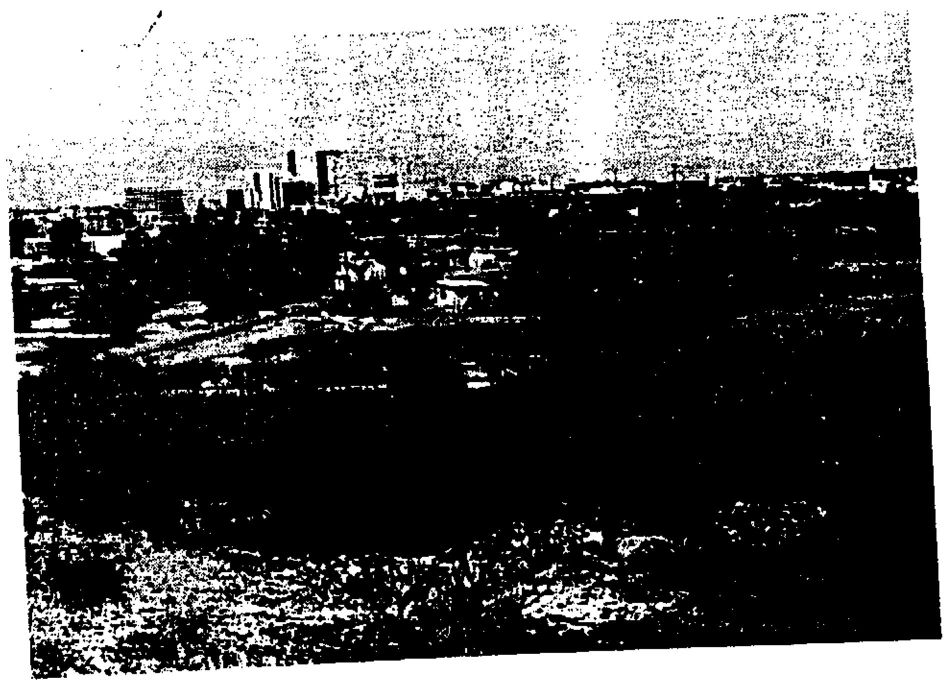


Figure 16. Same view as Figure 15 on December 1, 1981 (Photograph by R.M. Turner, U.S.G.S. Stake 1052).

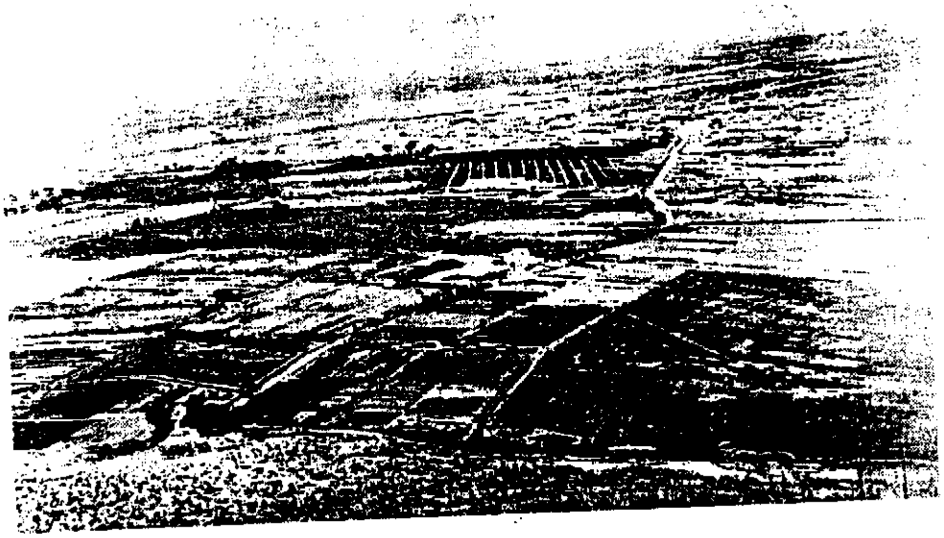


Figure 17. East view of Santa Cruz River Valley and Tucson from Sentinel Peak in 1882, showing the San Agustin Mission (center) and Warner's Mill Complex at lower left. The Acequia Madre, which was fed by Silver lake, runs from right to left across center of photograph. The Acequia may have followed the mainstem of the Santa Cruz River, which at that time had no discernible channel (Arizona Historical Society, Negative No. 18233; U.S.G.S. Stake 1053).

B-IX

Figure 18. Same view as Figure 17 on December 1, 1981. The only recognizable feature in both photographs is Solomon Warner's house in lower left corner. Most of the modern floodplain has been elevated a few meters by landfills (Photograph by R.M. Turner, U.S.G.S. Stake 1053).

Figure 19. Southeast view of Warner's Lake in 1883. The shallow channel of the Santa Cruz River is visible downstream of the dam at extreme left of the photograph (Arizona Historical Society, Tucson, Negative No. 12565; U.S.G.S. Stake 1055).

B-XI

Figure 20. Approximately the same view as Figure 19 on December 31, 1988. The course of the Santa Cruz is obscured by saltcedars at lower left. Elevated road is 22nd Street (Photograph by R.M. Turner, U.S.G.S. Stake 1055).

Figure 22. Upstream view of the heading of Sam Hughes' intercept ditch at the St. Mary's Road crossing in October 1889. The heading here behaved as a headcut actively eroding even with minor flooding. Note that in 1889, this reach was unentrenched and even moderate flows would inundate the valley (Photograph by H. Buehman, Special Collections, University of Arizona Library, Tucson).

B-XIII

Figure 23. Taken on the same day, a slightly different view of the headcut in Figure 22, with Sentinel Peak at upper right (Photograph by H. Buehman, Arizona Historical Society, Tucson, Negative No. 2922).

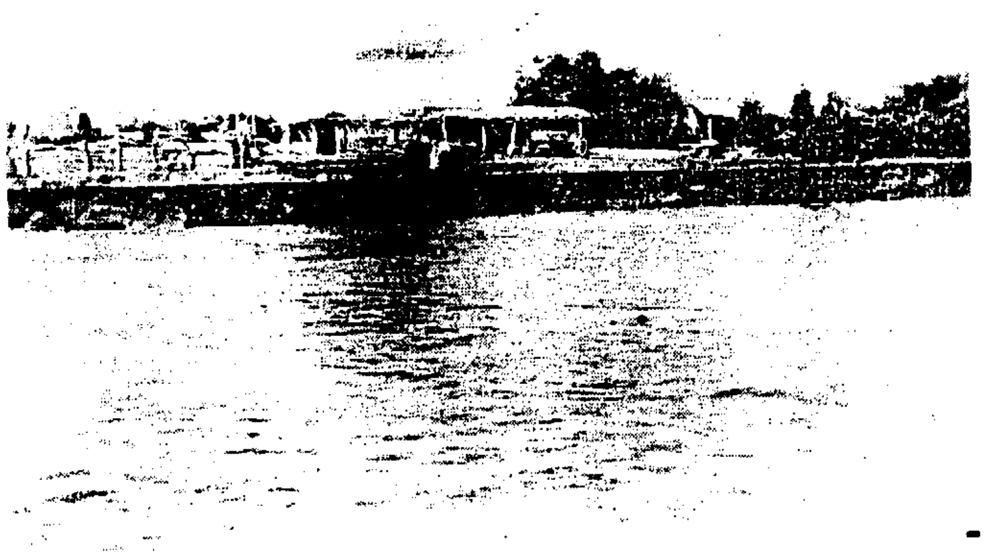


Figure 25. View looking directly west across the St. Mary's Road crossing in August 1890, with newly formed arroyo threatening homestead on opposite bank (Photograph by G. Roskruge, Arizona Historical Society, Negative No. 45854; U.S.G.S. Stake 1065A).

B-XV

Figure 26. Same view as Figure 25 on February 4, 1982. St. Mary's Road Bridge appears on extreme far right. Landfill occupies the upper 1-2 m of the floodplain (Photograph by R.M. Turner, U.S.G.S. Stake 1065A).

Figure 27. Downstream view of the Santa Cruz river during the flood of August 1890, taken from east bank at the St. Mary's Road crossing. Note erosional remnants in the middle of the newly-formed arroyo (Photograph by G. Roskruge, Arizona Historical Society, Tucson, Negative No. 45851).

B-XVII

Figure 28. Upstream view of the Santa Cruz River on the same day and from same location as Figures 26 and 27. On August 8 or 9, the headcut forked into two channels, their confluence shown in this photograph. Note cottonwood with distinctive, asymmetrical crown on right bank. The same tree appears in Figure 31. Also, compare with Figure 22, which was taken only 10 months before (Photograph by G. Roskruge, Arizona Historical Society, Tucson, Negative No. 45852).

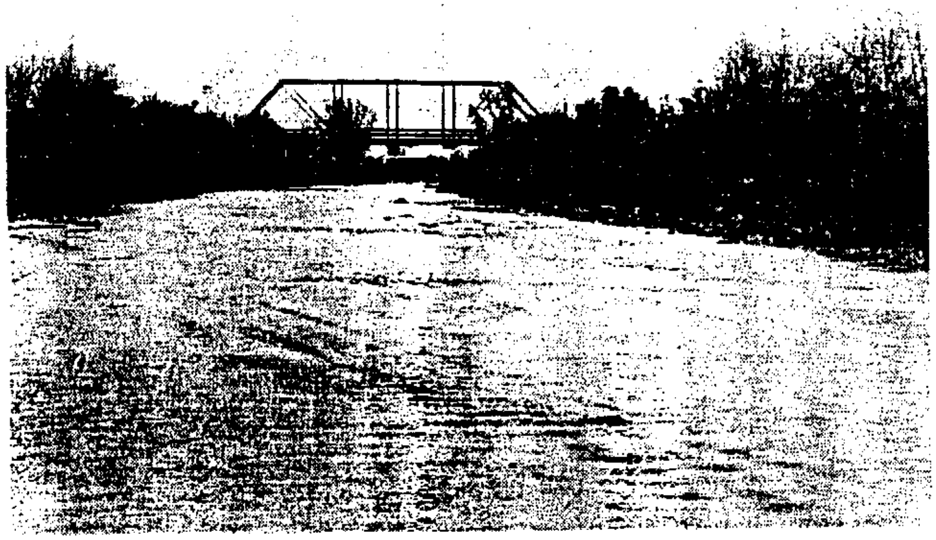


Figure 29. View looking upstream at Congress Street in 1902. The deep arroyo that eroded in 1890 and 1891 made river crossings more difficult. By 1902, a Pratt Truss steel bridge had been erected to span the river at Congress Street. This photograph shows a young stand of willows and cottonwoods that were probably established after the 1890 flood (Arizona Historical Society, Tucson, Negative No. 26698).

B-XIX

Figure 30. Downstream view of the Santa Cruz river in 1902. This photograph shows active erosion where the meandering thalweg strikes the right bank. Congress Street is on far left and is seemingly in a precarious position should the meander continue eroding downstream. The Santa Catalina Mountains are in the background (Arizona Historical Society, Tucson, Negative No. 26699).

Figure 32. The San Agustin Mission or Convento Ruins as sketched by John Spring in 1871, looking west across the Acequia Madre. In 1890-1891, the arroyo from Hughes' ditch extended headward along the Acequia Madre. Compare with Figures 33 and 34.

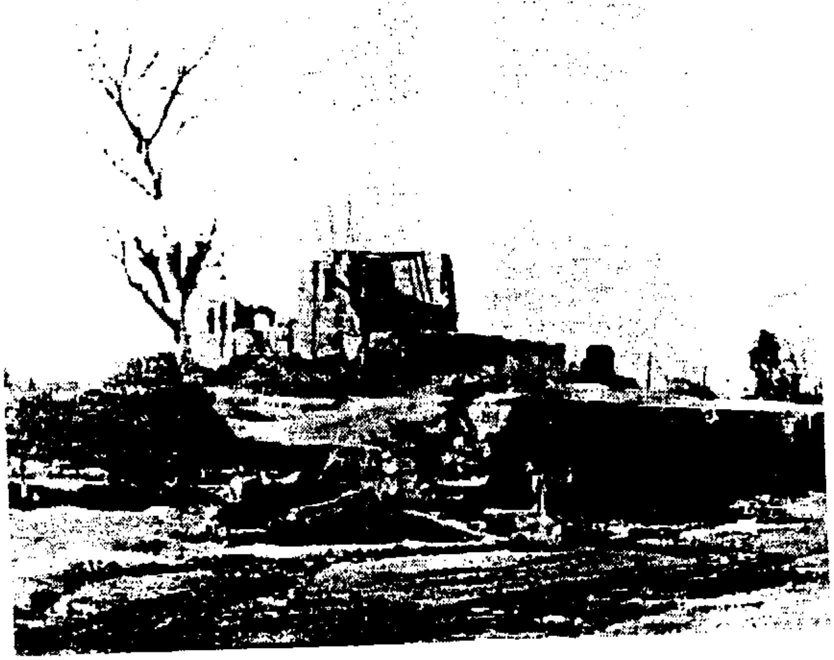


Figure 33. The San Agustin Mission in 1903, looking across to the west bank of the Santa Cruz River. The ditch at left center was the tail race or waste channel from Warner's Mill into the Acequia Madre. The tail race postdates John Spring's 1871 sketch (Figure 32) (Photograph by B.R. Bovee, Arizona Historical Society, Tucson, Negative No. 52644).

Figure 34. The San Agustin Mission, most likely in the the 1910s, from roughly the same vantage point as Figures 32 and 33 (Arizona Historical Society, Tucson, Negative No. 24802).

Figure 35. Downstream view of the confluence of the West Branch and the Santa Cruz River, looking northeast from the lower slope of Sentinel Peak in 1904. The lower half of the photograph incorporates the former area of Warner's Lake (see Fig. 19). A remnant of Warner's Dam is visible at left center, just upstream of the confluence. By 1904, the headcut from Sam Hughes' Ditch had extended along the Santa Cruz mainstem and the West Branch (Photograph by Walter Hadsell, Arizona Historical Society, Tucson, Negative No. 24868; U.S.G.S. Stake 1026).

B-XXIV

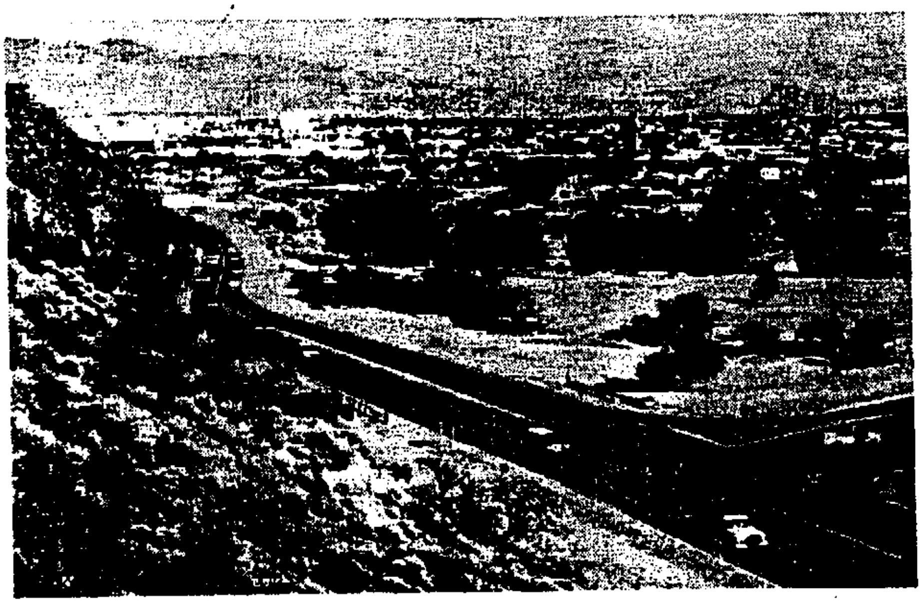


Figure 36. Same view as Figure 35 on December 17, 1981. The West Branch was filled in artificially in the 1960s and is now marked only by a shallow depression lined with a few mesquites. The Santa Cruz proper is bordered by taller saltcedars. The intersection of Mission Road and 22nd Street is in lower right (Photograph by R.M. Turner, U.S.G.S. Stake 1026).

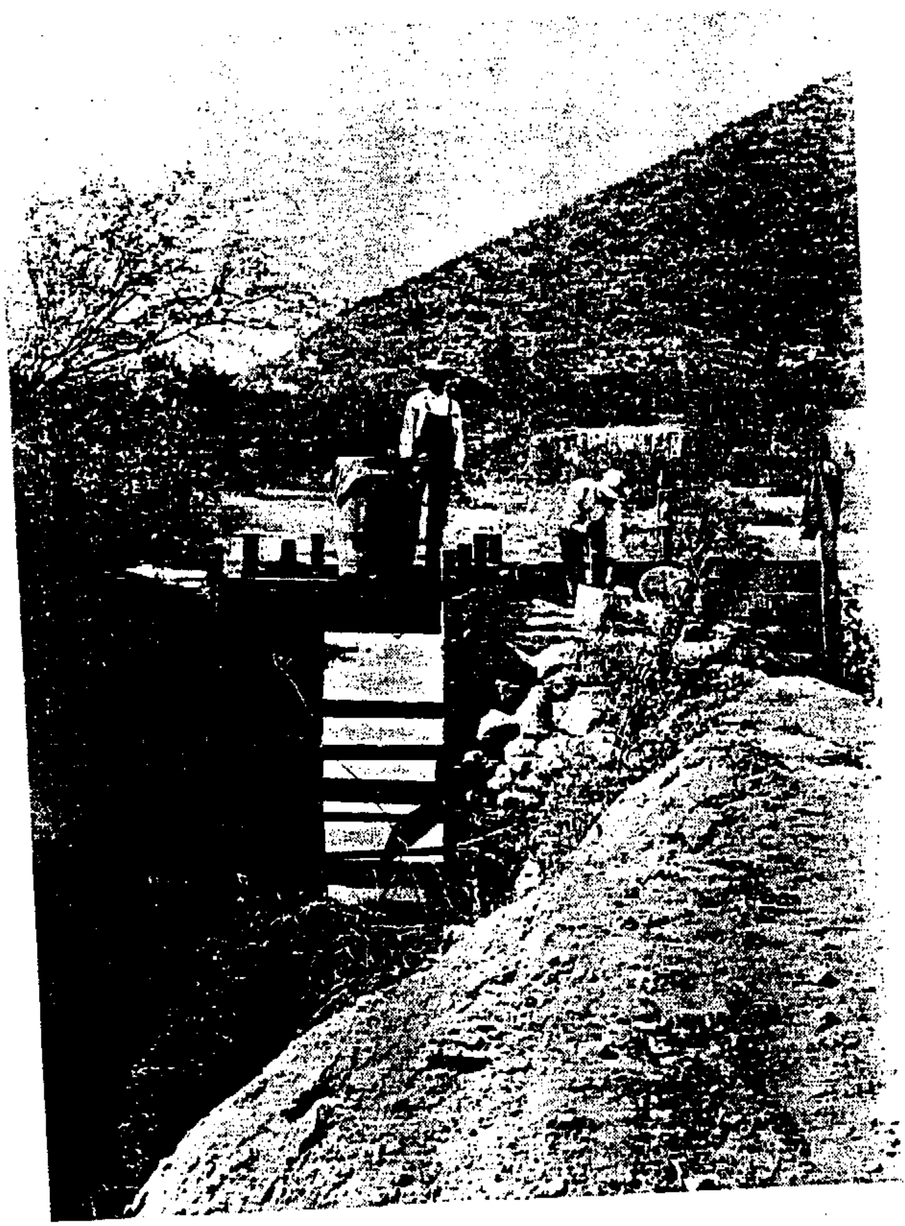


Figure 37. Head of the Manning Ditch in 1907, with the Santa Cruz River and Sentinel Peak in background. The men in the photograph are dumping copper sulfate in the ditch, presumably to retard accumulation of moss. Even though the stream had become entrenched throgh this reach in the 1890s, it remained perennial. In fact, the flow may have increased with deeper intercept of the water table (Special Collections, University of Arizona Library, Tucson, Negative No. 2709; U.S.G.S. Stake 1073).

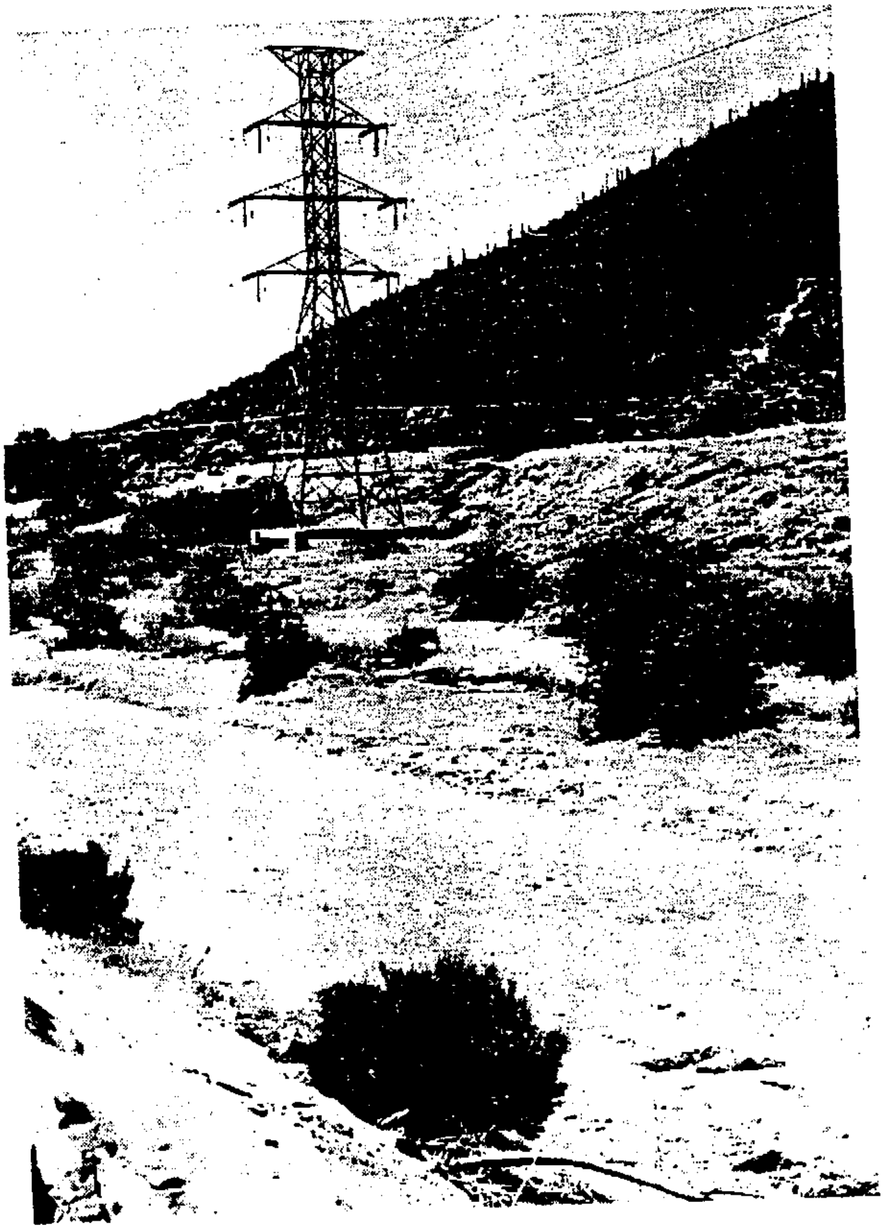


Figure 38. Same view as Figure 37 on February 4, 1982 (Photograph by R.M. Turner, U.S.G.S. Stake 1073).

Tucson Farms Crosscut - 19 wells across Santa Cruz
1913

Figure 41. East view of the Crosscut in 1913, with trenching for concrete conduit in progress and well casing in foreground. The channel of the Santa Cruz River runs from right to left across center of photograph (Photograph by Percy Jones, Special Collections, University of Arizona Library, Tucson, Negative No. 2803).

B-XXVIII

Tucson Farms Co
Crosscut 1912

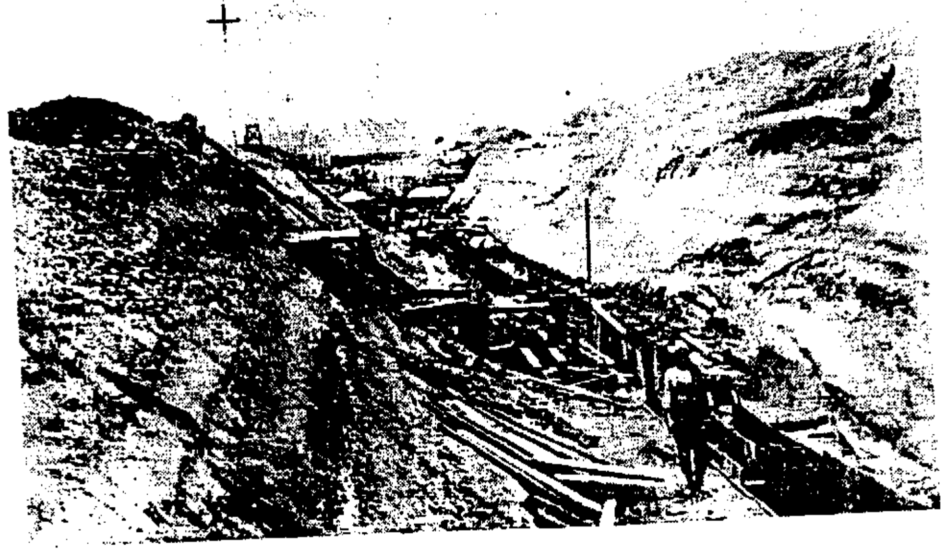


Figure 42. West view of the Crosscut under construction in 1912 (Photograph by Percy Jones, Special Collections, University of Arizona Library, Tucson, Negative No. 2758).

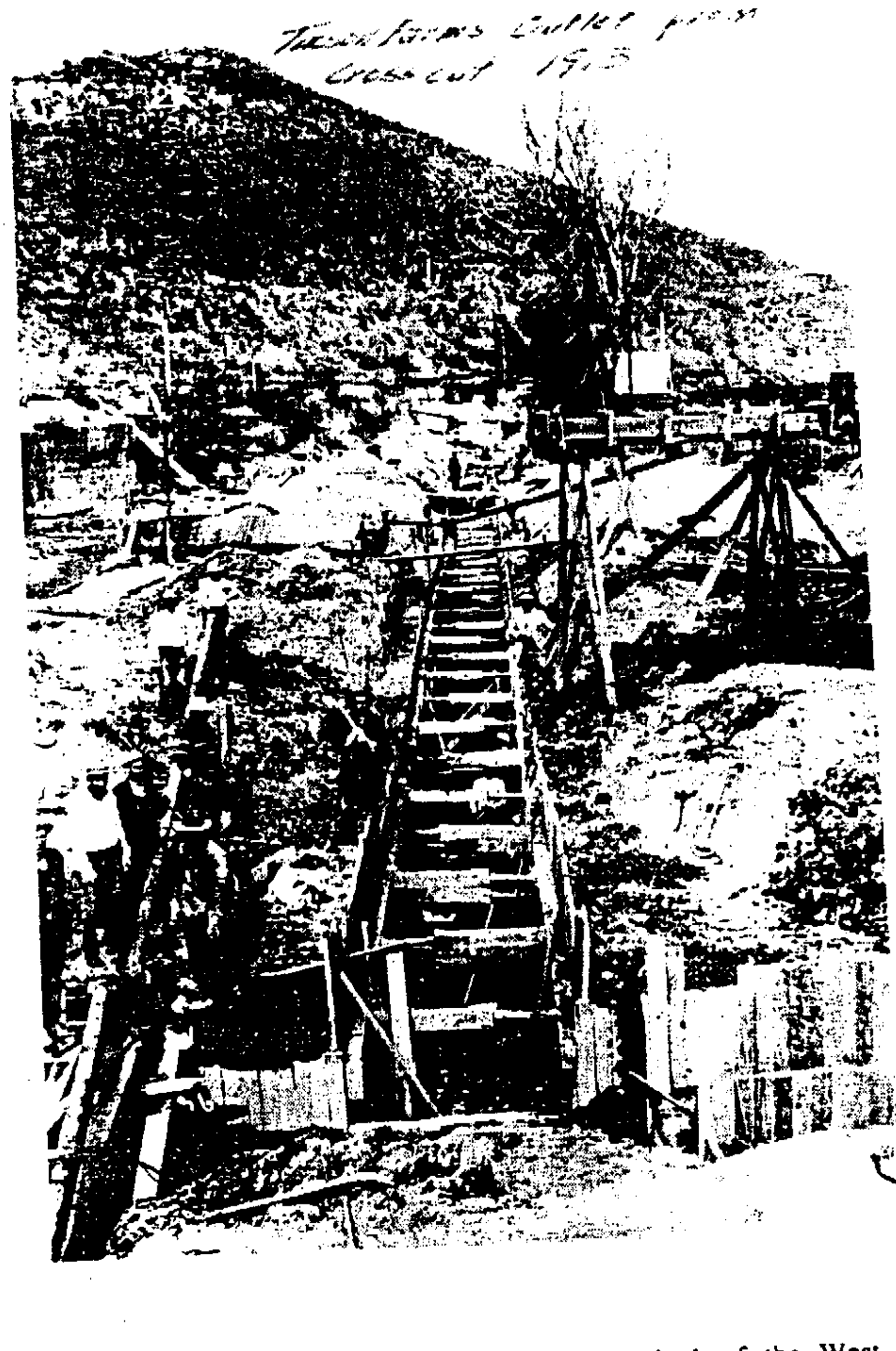


Figure 43. Outlet from the Crosscut in the streambed of the West Branch in 1913 (Photograph by Percy Jones, Special Collections, University of Arizona Library, Tucson, Negative No. 2709; U.S.G.S. Stake 1066).

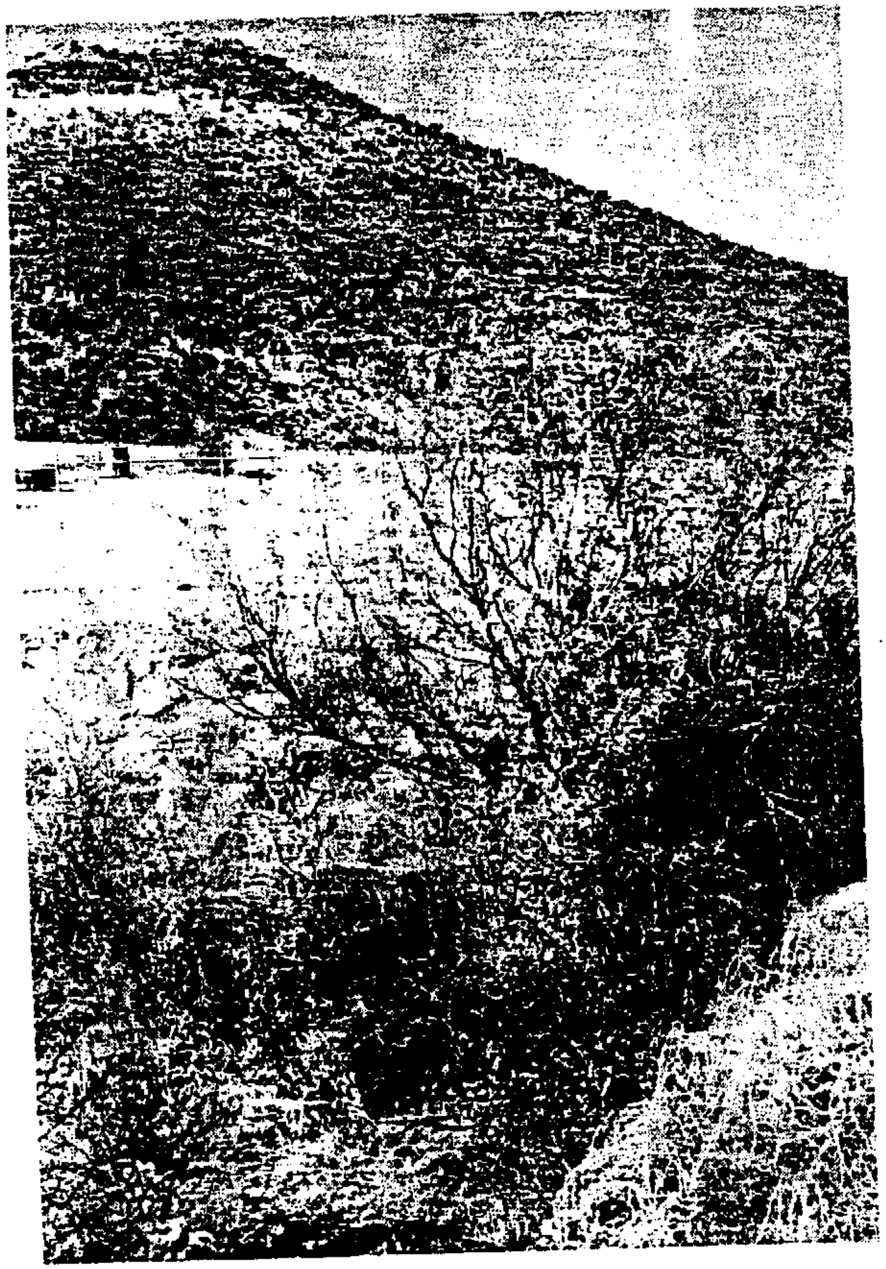


Figure 44. Same view as Figure 43 on February 4, 1982. The West Branch was filled in ca. 1965. The shrubbery in the foreground marks the course of the Crosscut (Photograph by R.M. Turner, U.S.G.S. Stake 1066).

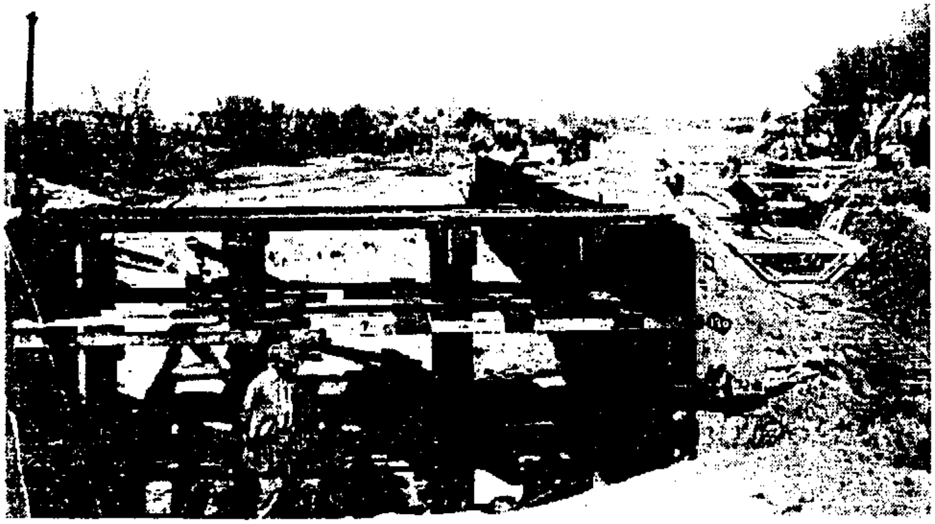


Figure 45. Diversion point for water developed by the Crosscut, about 3 km downstream along the bed of the Santa Cruz River, in 1912. (Photograph by Percy Jones, Special Collections, University of Arizona, Tucson).

B-XXXII

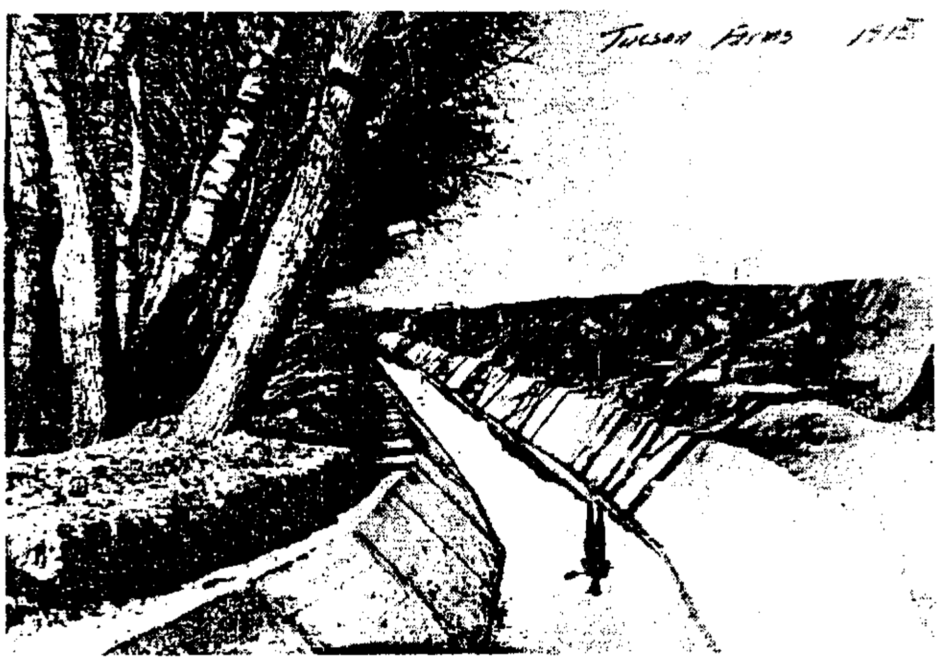


Figure 46. Sector of finished concrete lined canal inside the east bank of the Santa Cruz River in 1913 (Photograph by Percy Jones, Special Collections, University of Arizona Library, Negative No. 2713).

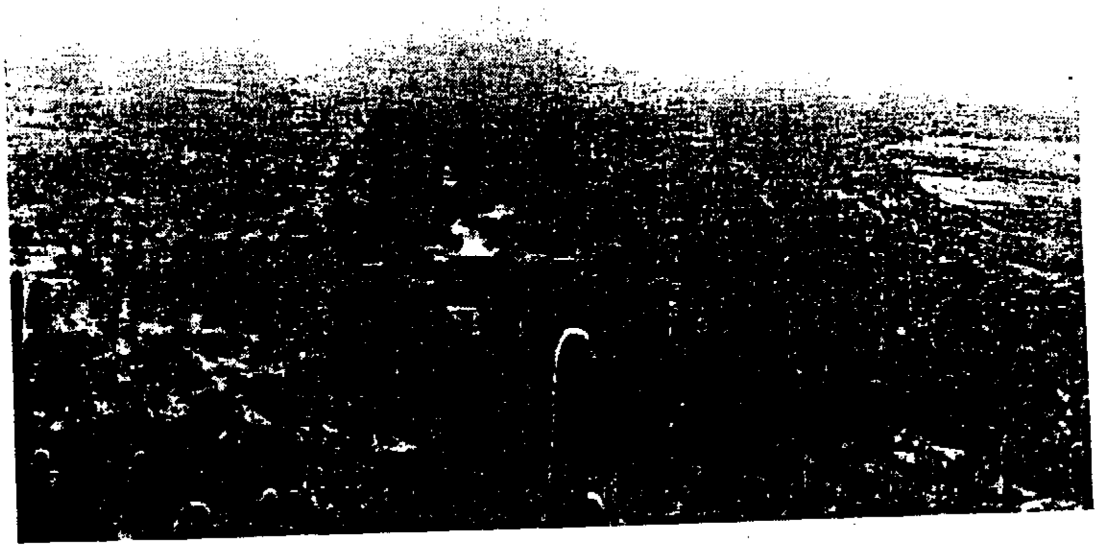


Figure 48. Upstream view from Martinez Hill in 1912, with dense mesquite growth in the valley bottom. By this date, a channel 9 m deep marked the course of the Spring Branch, with a steep headcut terminating just below the dam in the center of the photograph (from Olberg and Schanck 1913, National Archives, U.S.G.S. Stake 1057).

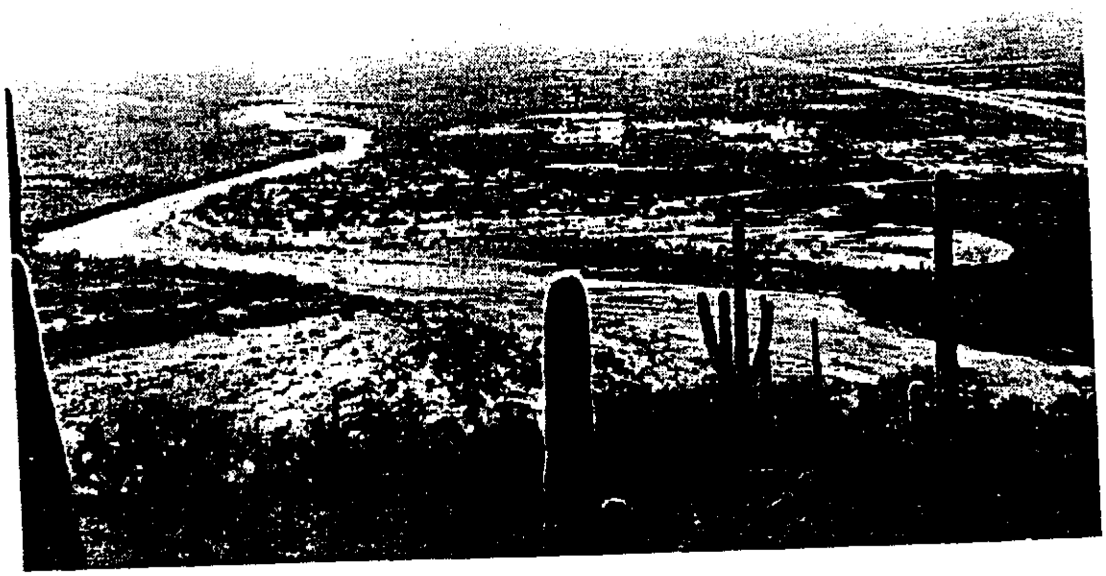


Figure 49. Similar view as Figure 48 on December 15, 1981. The floodplain is now sparsely vegetated due to a substantial drop in the water table, the consequence of heavy pumping since 1940. The Santa Cruz now courses along what was formerly the Spring Branch in a deeply entrenched and broad channel (Photograph by R.M. Turner, U.S.G.S. Stake 1057).

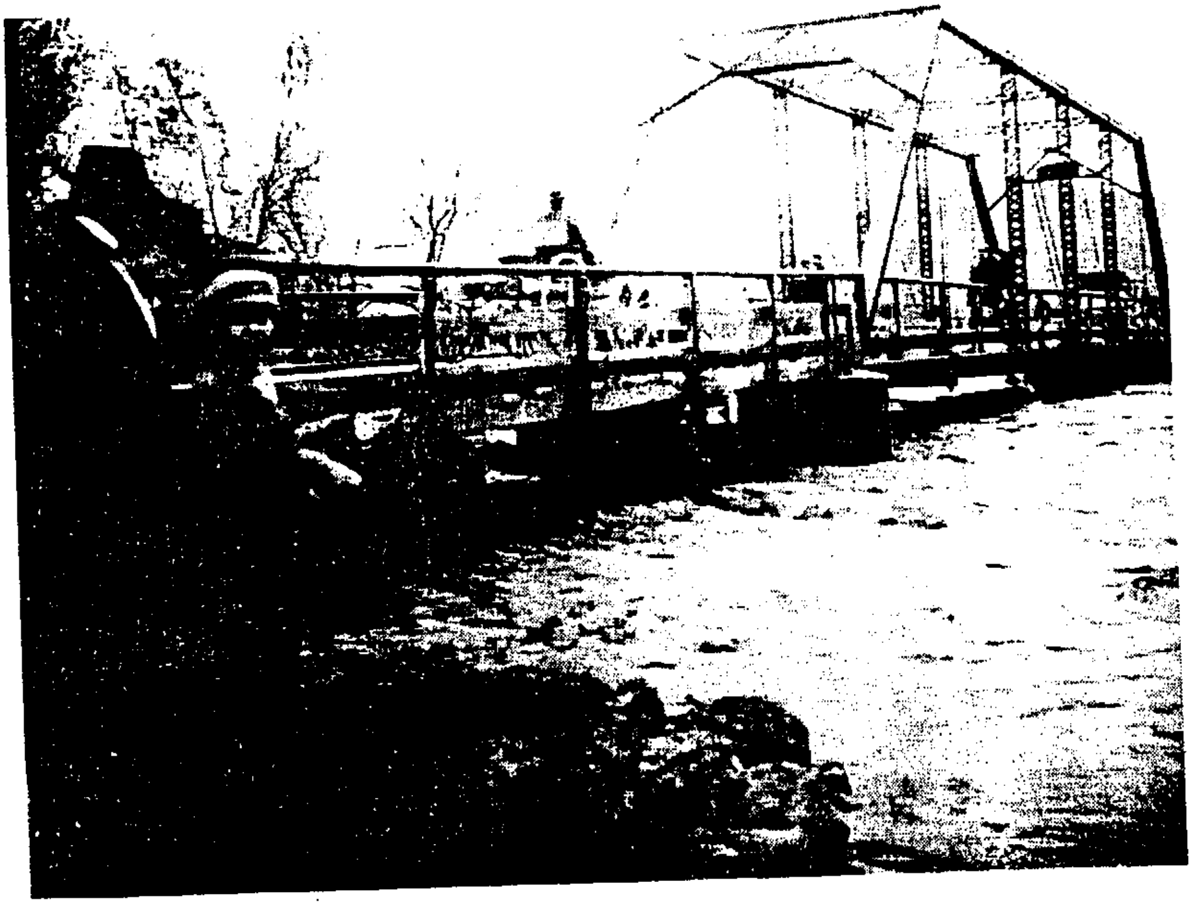


Figure 50. The Santa Cruz River in flood at Congress Street on December 23, 1914. This was the peak flow (420 cms) for the 1915 water year. Heavy flows continued into January, eventually destroying the meander where the people in the foreground are standing (Photograph by H. Buehman, Arizona Historical Society, Tucson, Negative No. 93470).

Figure 51. Upstream view of the Congress Street Bridge on the morning of January 31, 1915, as the east approach to the bridge began to give way. Note sinking piers of the bridge (Arizona Historical Society, Tucson, Negative No. 17439).

B-XXXVII

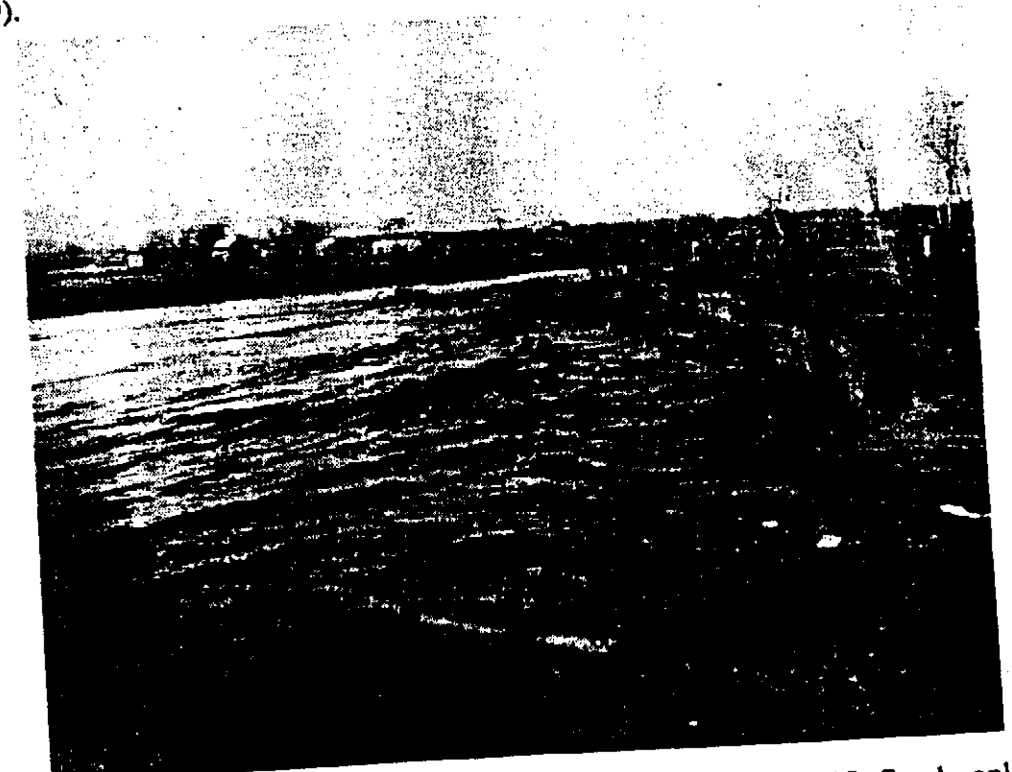


Figure 52. In this northwest (downstream) view of the 1915 flood, onlookers stand perilously close to the eroding east bank of the Santa Cruz River, just downstream of the Congress Street Bridge. Note undercutting of the east bank at right center of photograph (Photograph by H. Buehman, Arizona Historical Society, Tucson, Negative no. 38373).

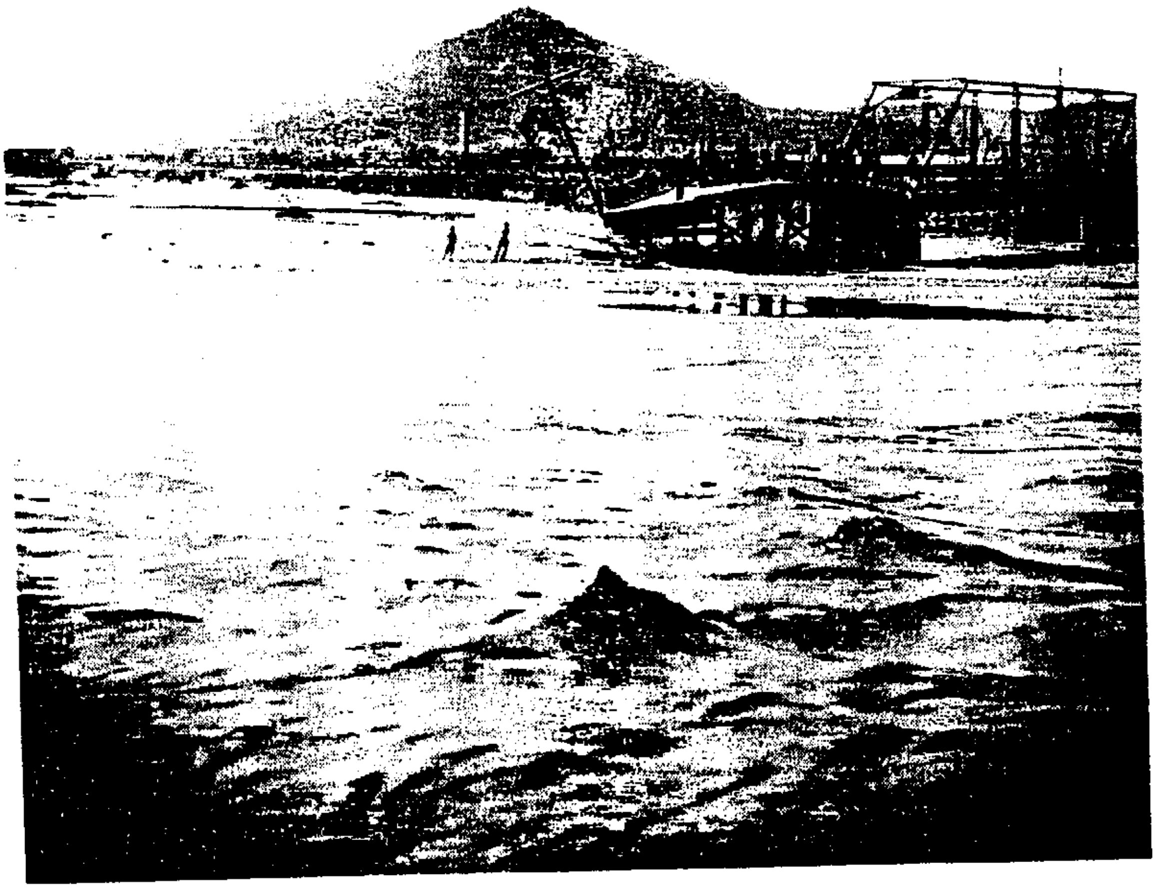


Figure 53. Southwest (upstream) view of Santa Cruz River in flood in February 1915. The thalweg shifted several tens of meters to the west bank, abandoning its former course under the Congress Street Bridge (Photograph by H. Buehman, Arizona Historical Society, Tucson, Negative No. 93468).

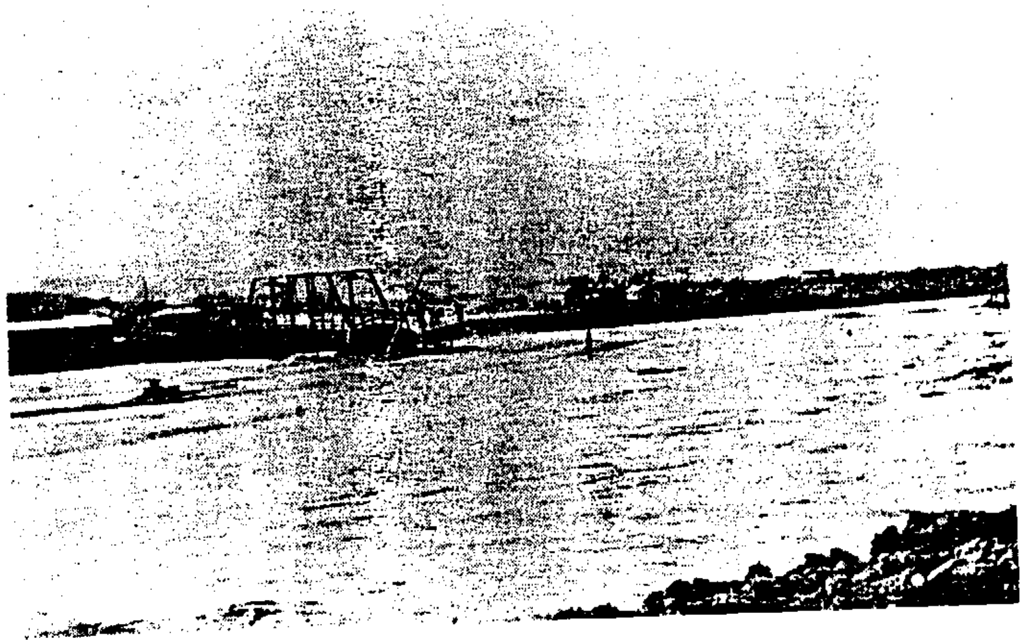


Figure 54. The Congress Street Bridge after erosion of east bank in January 1915, looking northwest. The cottonwood stand evident in 1902 (Fig. 29) was completely removed during the 1915 flood (Special Collections, University of Arizona Library, Tucson).

B-XL

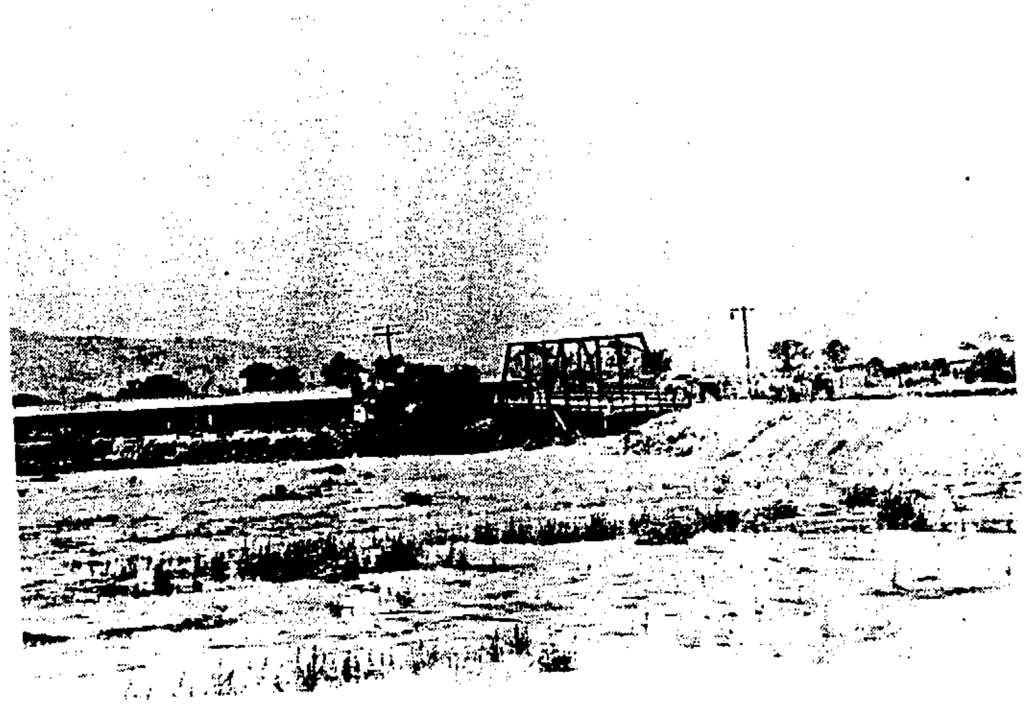


Figure 55. A similar view as Figure 54 in July 1915. A berm was built to join the east approach to the bridge (Special Collections, University of Arizona Library, Tucson).

Figure 56. North (downstream) view of the Santa Cruz River from the Congress Street Bridge in November 1907. Note narrow channel (Photograph by W.T. Hornaday, Arizona Historical Society, Tucson, Negative No. 11669).

B-XLII

Figure 57. Similar view as Figure 56 on July 29, 1916 after the 1915 flood widened the Santa Cruz River channel (Special Collections, University of Arizona Library, Tucson).

Figure 58. In March 12, 1910, Ellsworth Huntington, the noted geographer, took this photograph and described it as follows in his unpublished journal, "looking northwest from end of Tucson Mountains [Rillito Peak] at Santa Cruz Valley, now dry, near where this river finally merges into a large playa....The dry channel of the river...here possibly 5 feet [1.5 m] below the terrace (Yale Universi'v Library, New Haven; U.S.G.S. Stake 1105).

B-XLIV

Figure 59. Same view as Figure 58 taken on November 30, 1983. Note the relatively narrow channel at extreme right and the widening that occured to the left of it during the flood of October 1983 (Photograph by R.M. Turner, U.S.G.S. Stake 1105).

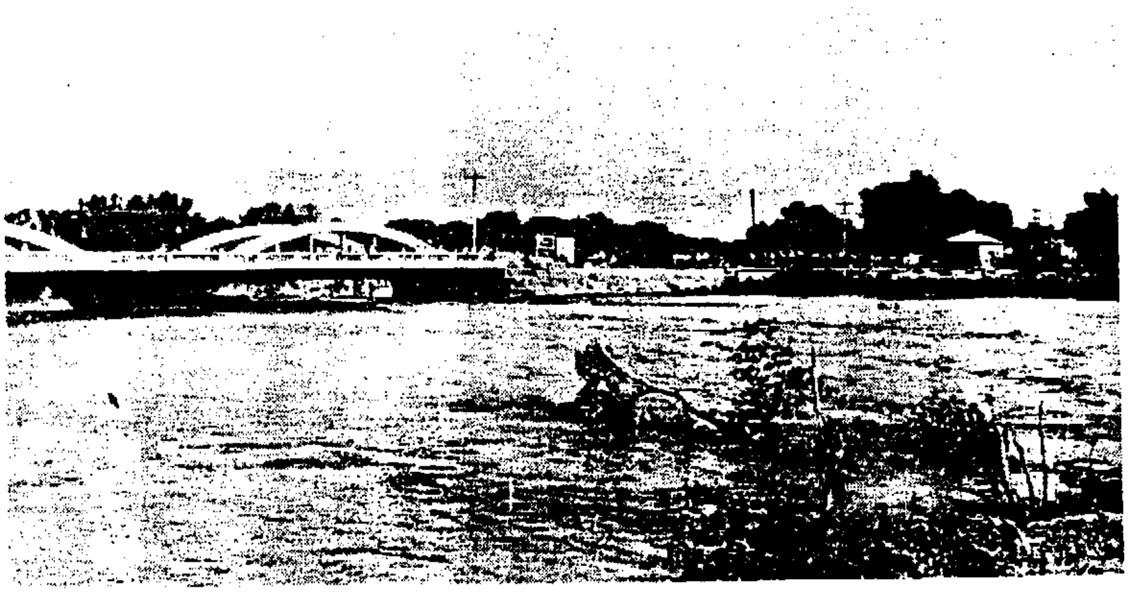


Figure 60. Santa Cruz River in flood, November 1926, showing road embankment on the east approach from Congress Street. As is customary for normally-dry rivers such as the Santa Cruz, the flood attracted a crowd of onlookers (Arizona Historical Society, Tucson, Tucson, Negative No. 28765; U.S.G.S. Stake 1084).

B-XLVI

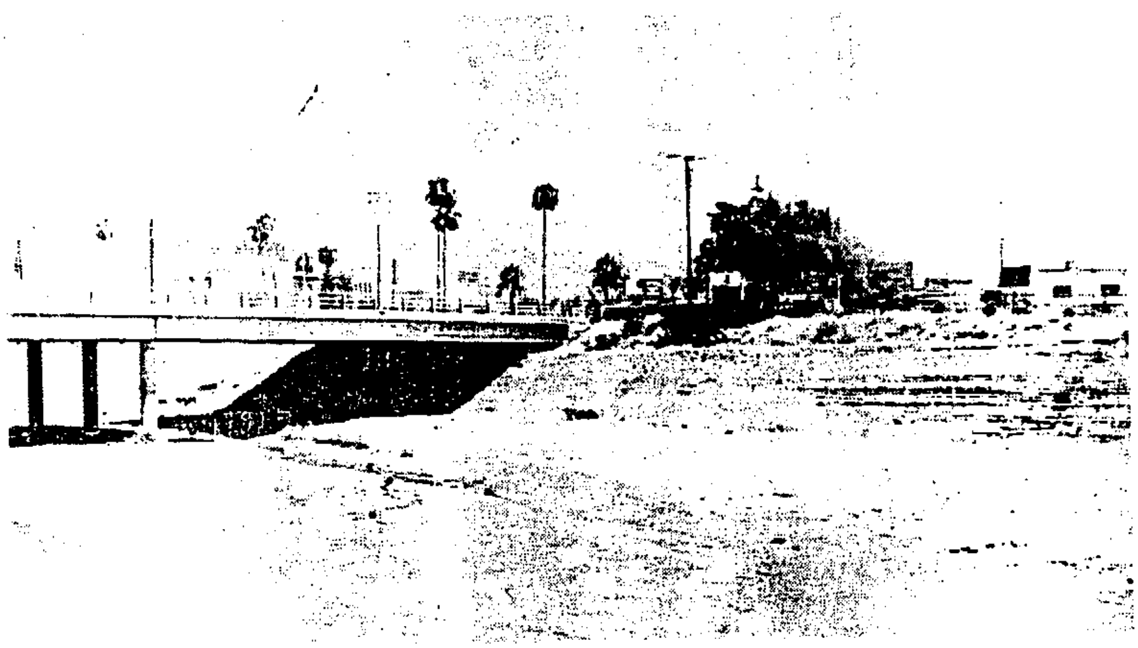


Figure 61. Same view as Figure 60 taken on September 12, 1983. The new bridge was constructed in 1972. The channel has been narrowed artificially, eliminating the embankment on the east approach. This narrowing contributed to renewed downcutting and a considerable lowering of the streambed in the period from 1950 to 1980. Note soil-cemented east bank (Photograph by R.M. Turner, U.S.G.S. Stake 1084).

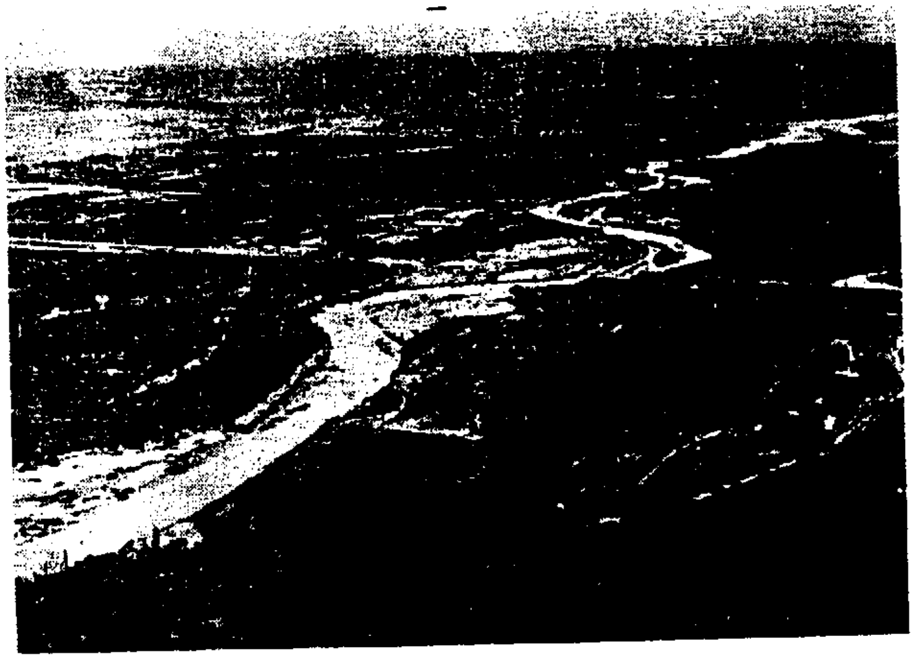


Figure 62. View south from summit of Sentinel Peak in 1919, looking upstream along the Santa Cruz River. Note the Tucson Farms Company Crosscut running from left to right across center of photograph. The entrenched channel of the West Branch is in lower right (Photograph by Godfrey Sykes, Arizona Historical Society, Tucson; U.S.G.S. Stake 1306).

B-XLVIII

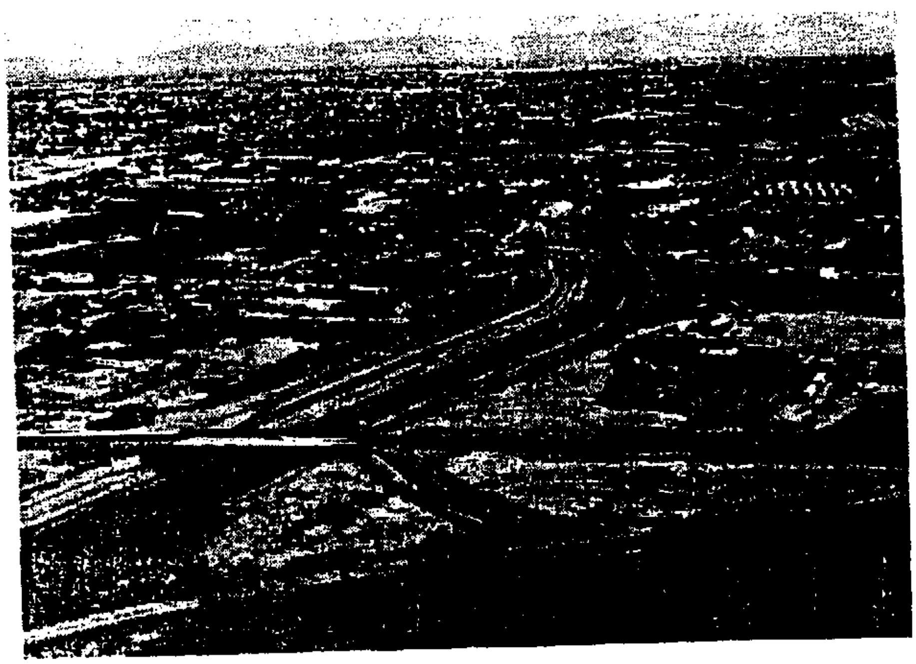


Figure 63. Same view as Figure 62 on January 6, 1988. Note bank stabilization with soil cement and the modified confluence of the West Branch and the Santa Cruz. The bridge in the foreground is 22nd Street, which was routed across the former site of Warner's Lake (Photograph by R.M. Turner, U.S.G.S. Stake 1306).

Figure 64. View from Sentinel Peak on May 30, 1927, looking east across Santa Cruz River. The east bank is visible across bottom of photograph. Note secondary mesquite growth across formerly cultivated fields. Photograph is part of a panorama, which includes Figures 64-69 (Photograph by Norman Wallace, Arizona Historical Society, Tucson, Negative No. 518; U.S.G.S. Stake 1307d).

B-L

Figure 65. Same view as Figure 64 taken on October 6, 1987. Soil-cemented banks of the Santa Cruz River are visible across bottom of photograph and 22nd Street in center (Photograph taken by R.M. Turner, U.S.G.S. Stake 1307d).

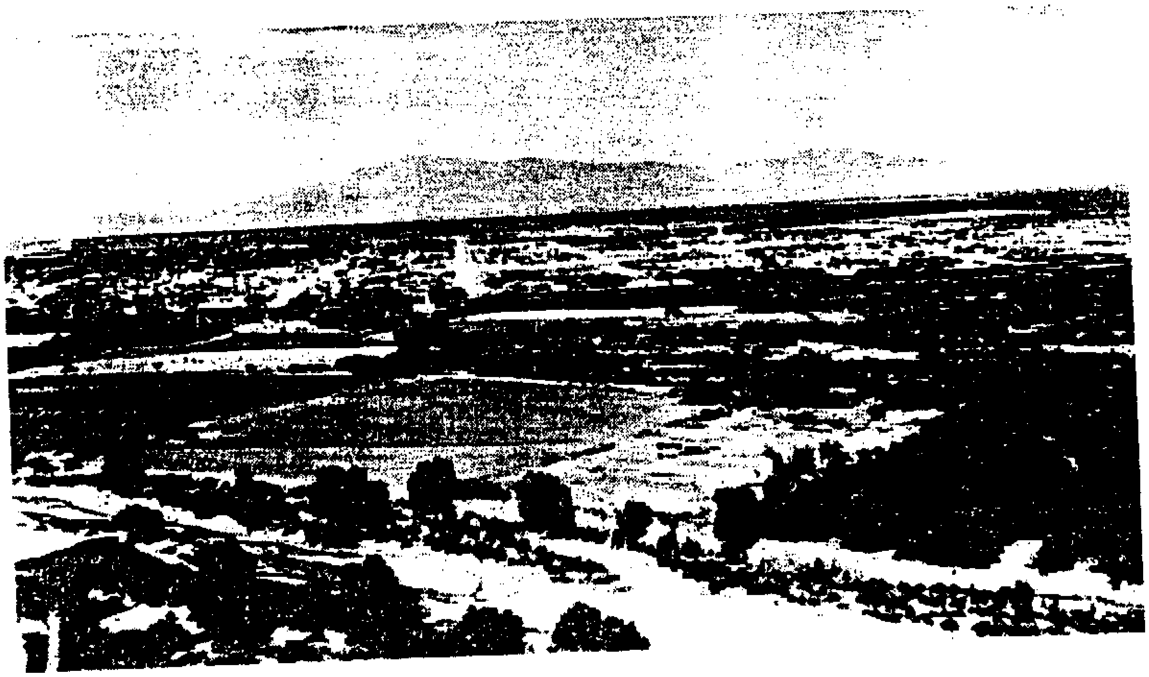


Figure 66. View east-northeast from Sentinel Peak on May 30, 1927, with Santa Cruz River in foreground (Photograph by Norman Wallace, Arizona Historical Society, Tucson, Negative No. 522; U.S.G.S. Stake 1307c).

B-LII

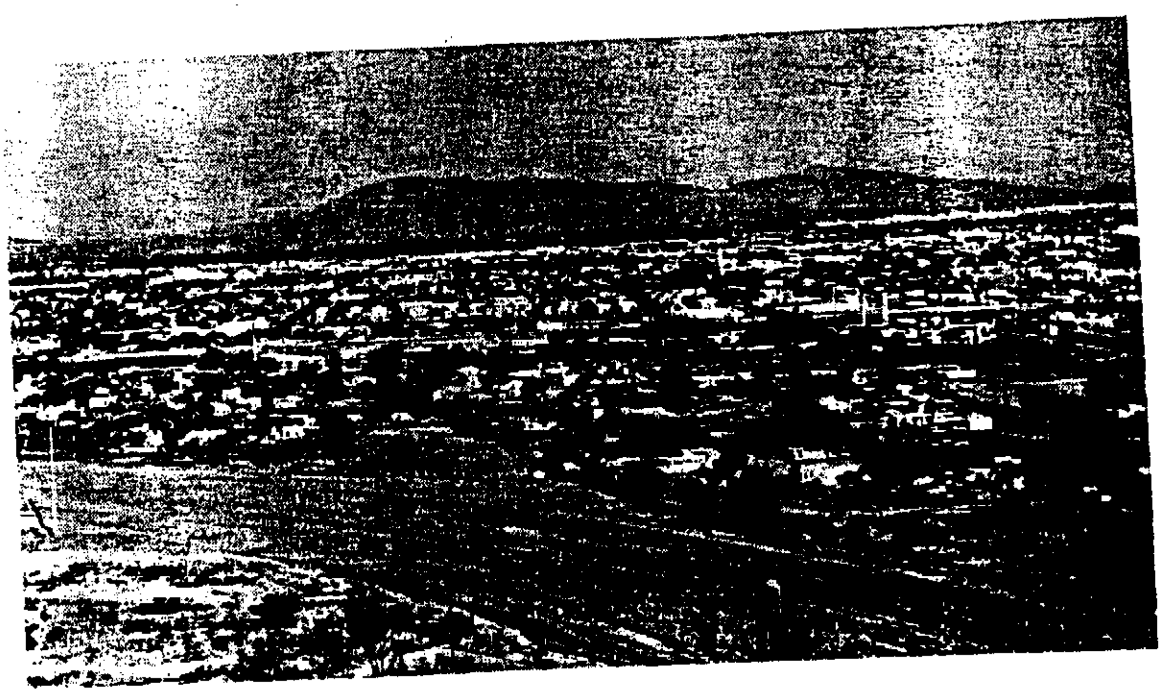


Figure 67. Same view as Figure 66 on October 6, 1987 (Photograph by R.M. Turner, U.S.G.S. Stake 1307c).

Figure 68. View northeast from Sentinel Peak on May 30, 1927 with Santa Cruz River running from right to left (Photogrpah by Norman Wallace, Arizona Historical Society, Tucson, Negative 502; U.S.G.S. Stake 1307b).

Figure 69. Same view as Figure 68 on October 6, 1987 (Photograph by R.M. Turner, U.S.G.S. Stake 1307b).

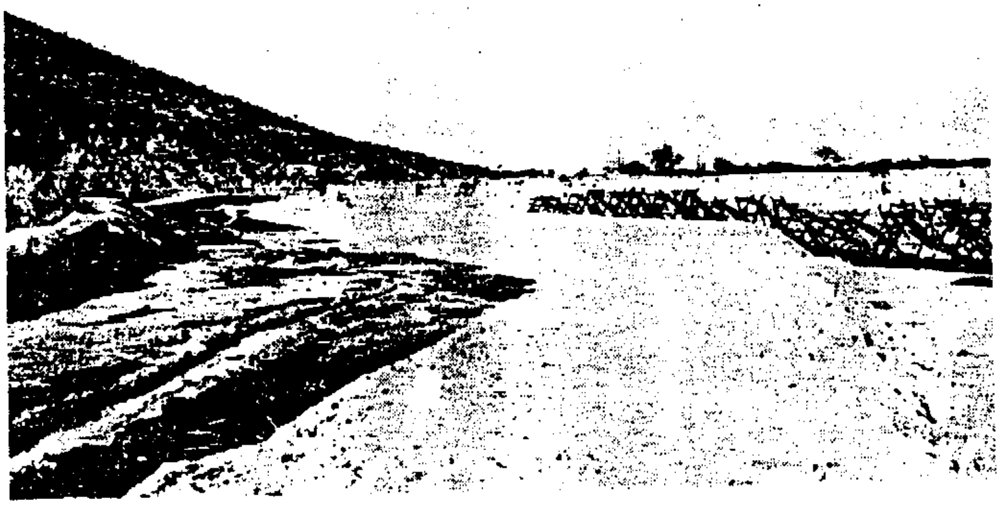


Figure 70. In 1935, the Works Projects Administration (WPA) constructed several flood control features along the Santa Cruz River River. In the reach just south of Sentinel Peak (left), the river's flow was deflected into pilot channels by means of revetments, in this case fashioned from old automobile frames (right). By the following year, summer flows had filled the area behind the revetment with about 1 m of sediment. The intent was to eliminate sharp meanders and to reclaim the areas they incorporated for cultivation (Photograph by R.C. Baker, State of Arizona Archives, Phoenix, U.S.G.S. Stake 1074).

B-LVI

Figure 71. Same view as Figure 71 on May 11, 1982. The WPA measures were largely effective in eliminating the sharp meanders (Photograph by R.M. Turner, U.S.G.S. Stake 1074).

Figure 72. South view from Martinez Hill in June 1942. A gallery of cottonwoods flanks the river channel and dense mesquite occupied the bottomlands, then a haven for nesting and roosting whitewing doves. As late as 1942, one could dig by hand and find water in the streambed (Arizona Game and Fish Commission, Phoenix; U.S.G.S. Stake 937).

B-LVIII

Figure 73. Same view as Figure 72 on May 29, 1981. Note the broad river channel and badly denuded bottomlands. The latter resulted from a considerable drop in the water table since 1940 (Photograph by R.M. Turner, U.S.G.S. Stake 937).

Figure 74. Upstream view of the Santa Cruz River bridge at Continental on June 4, 1940 (U.S.G.S. Stake 940).

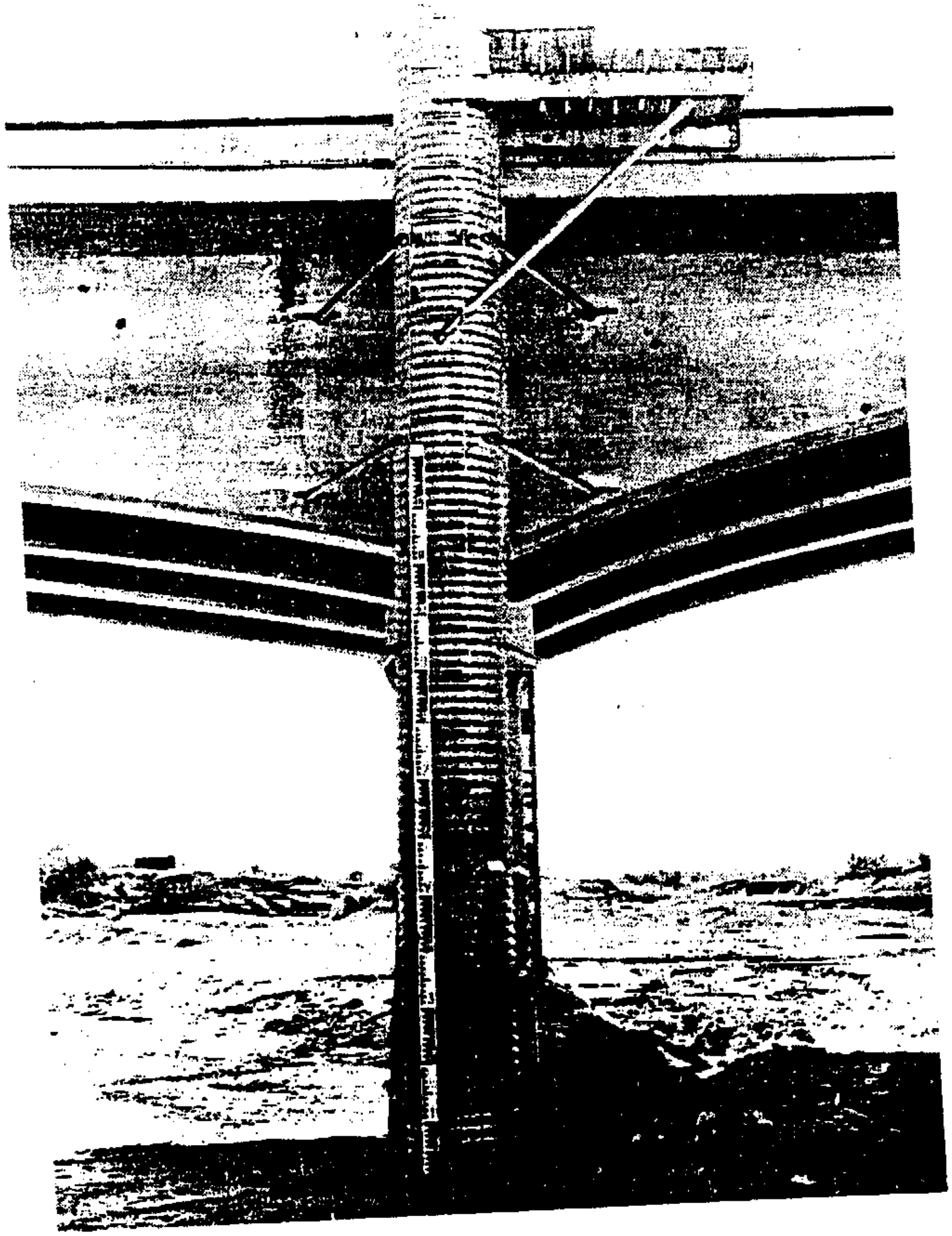


Figure 75. Same view as Figure 74 on November 16, 1978, showing deepening of the channel by ca. 1 m, as indicated by the exposed pier (Photograph by R.M. Turner, U.S.G.S. Stake 940).

Figure 76. East view of the Santa Cruz River Valley and Tucson from Sentinel Peak in 1932. The river runs from right to left across center of photograph, with the Congress Street Bridge at far left. Note the broad entrenched channel lined with cottonwoods. Solomon Warner's house and the ruins of his mill are in lower left corner (Arizona Historical Society, Tucson, Negative No. 26758; U.S.G.S. Stake 1044).

B-LXII

Figure 77. Same view as Figure 76 on July 8, 1981. Since 1950, landfill operations and construction of an interstate highway have constricted the channel. Much of the floodplain surface has been elevated by landfill, in some places by 2-3 m. The only non-elevated part of the floodplain is the former Mission garden in the lower center of both photographs (Photograph by R.M. Turner, U.S.G.S. Stake 1044).

Figure 78. Southeast view of the Santa Cruz River, looking upstream from a point just south of the Congress Street Bridge. This photograph shows the sweeping meander along the east bank, as it eroded on January 31, 1915 (Special Collections, University of Arizona Library, Tucson, Negative No. 6518; U.S.G.S. Stake 1067).

Figure 79. Same view as Figure 78 on February 26, 1982. Landfill operations, which began in 1950, have narrowed the channel and thus promoted further downcutting (Photograph by R.M. Turner, U.S.G.S. Stake 1067).

Figure 80. Downstream view of the Rillito-Santa Cruz River confluence, looking north in 1939 (Special Collections, University of Arizona Library, U.S.G.S. Stake 1102).

B-LXVI

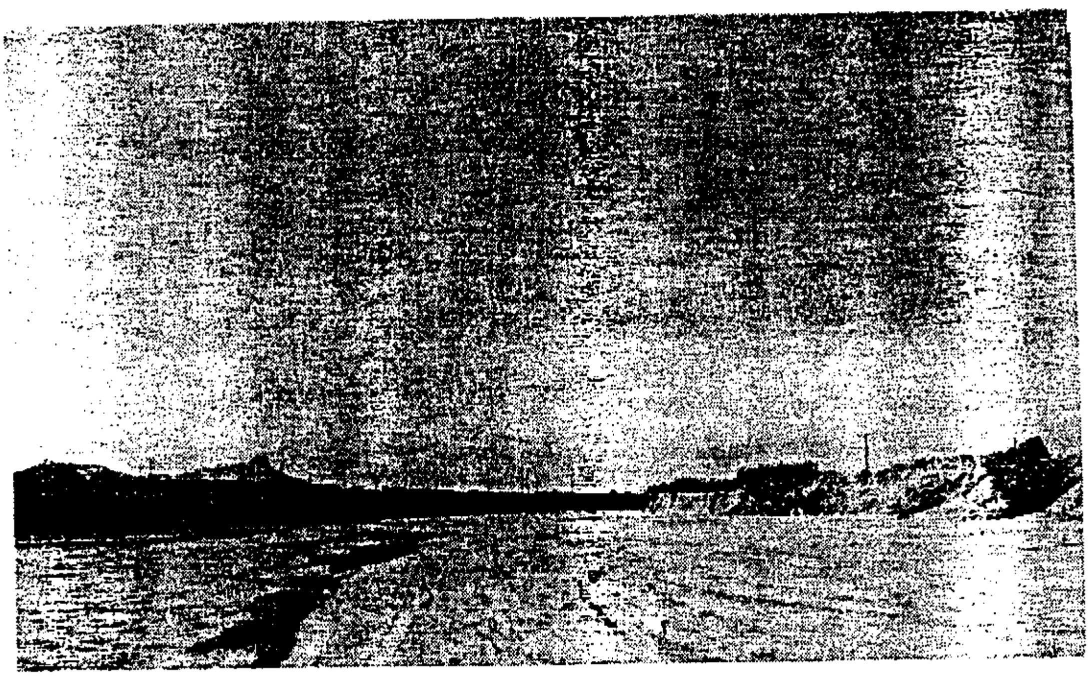


Figure 81. Same view as figure 80 on November 9, 1983. Note entrenched banks and the general lack of vegetation, compared to 1939 (Photograph by R.M. Turner, U.S.G.S. Stake 1102).

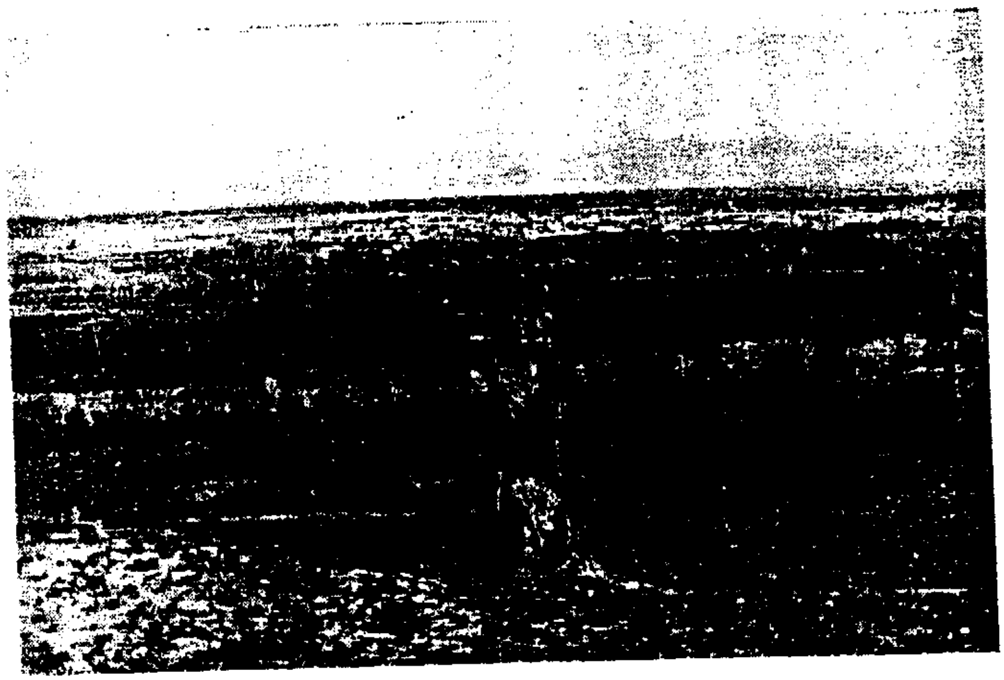


Figure 82. East view of Congress Street and the then active floodplain of the Santa Cruz River, taken from West Congress Terrace in the 1890s (Photograph by George Roskruge, Arizona Historical Society, Tucson, Negative No. 46397; U.S.G.S. Stake 1061).

B-LXVIII

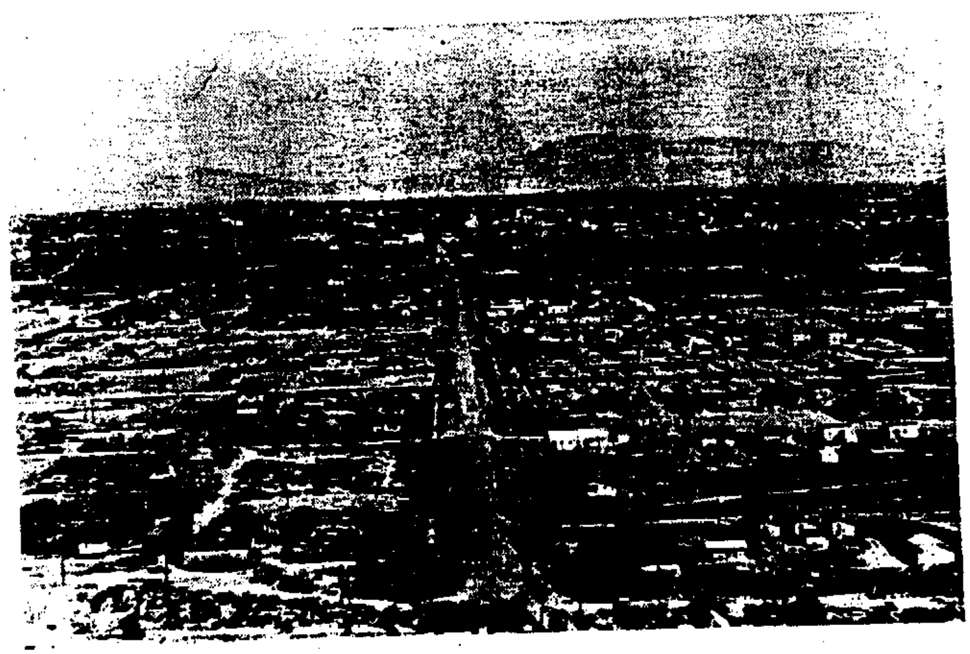


Figure 83. Approximate view as Figure 82 in the 1930s. Entrenchment of the Santa Cruz arroyo enhanced drainage and thus encouraged urbanization of the inactive floodplain (Photograph by Ed Ronstadt, Special Collections, University of Arizona Library, Tucson, U.S.G.S. Stake 1061).

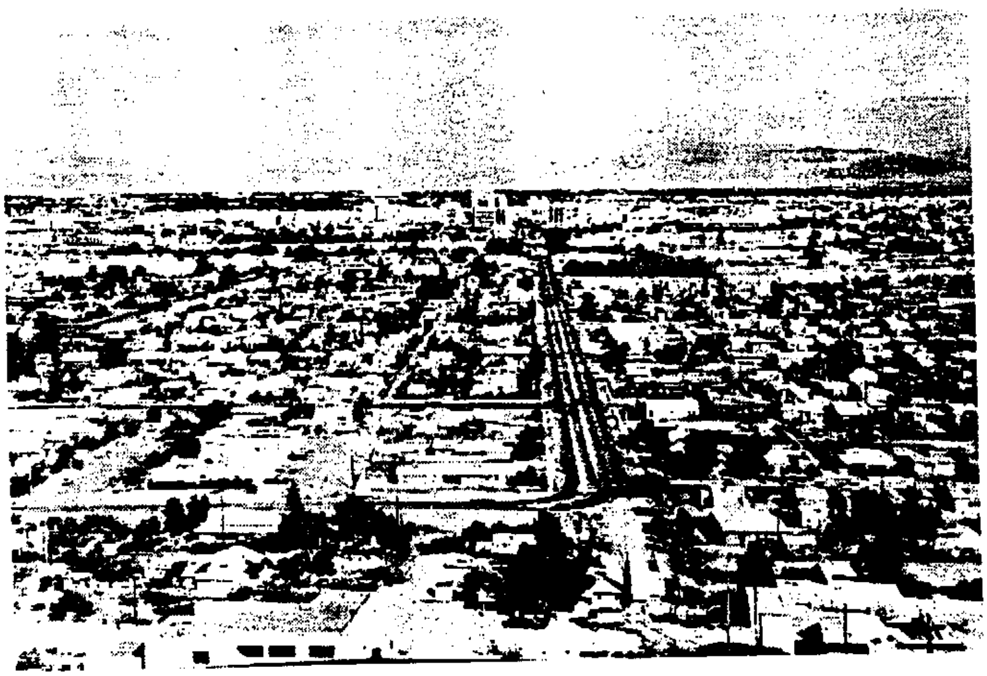


Figure 84. Same view as Figure 83 on February 26, 1982. The once-active floodplain is now completely urbanized within the downtown Tucson reach (Photograph by R.M. Turner, U.S.G.S. Stake 1061).

Setancourt 1918

Figure 13. Confluence of the West Branch and the Santa Cruz in 1904. Photograph was taken looking northeast from the southeastern slope of "A" Mountain (Arizona Historical Society).

Figure 14.

The new confluence of the West Branch and the Santa Cruz. This recent photograph was taken from the northeastern slope of "A" Mountain looking south. Martinez Hill is shown in the background. Note the denuded condition of the river environs.

William Wasley and Sidney Brinckerhoff managed to map the foundations of the mission buildings and the compound wall surrounding the mission before the site was destroyed. The foundations were large basalt boulders set in adobe mortar, the basalt probably obtained from the slopes of Tumamoc Hill. Some evidence for the use of lime plaster on the convento walls was found. A few of the plaster fragments had been painted in red and white. The compound wall had been built on a basalt-boulder foundation which measured about 75 cm wide. It was noted that the western portion of the site, containing the granary and some outlying buildings (Wasley 1956), was more-or-less intact.

In 1975, ASM excavated a series of backhoe trenches, to determine if anything remained of the mission complex within the right-of-way of a proposed sewage interceptor route. The fill from these trenches was filled with modern garbage. Archaeological clearance was granted (Doelle and Hard 1978).

Recommendations. As the above discussion indicates, major portion of BB:13:6 have been either destro or excavated. The portion that does remain includes the foundations to the granary and other outlying buildings of the mission complex. In the 1960s, Sidney Brinckerhoff and Kieran McCarty (1978, personal communication) exposed the walls of the granary to determine what , if anything, remained. The site was visited during the present survey and it was noted that a portion of the granary foundation had indeed been excavated.

An adequate study of previously recovered materials is lacking. The mission's history is also far from complete. There is a need to find primary documents which may yield more accurate information on the mission's early beginnings. The manuscript by Smiley and others (1953) on excavations in 1949-1950 is badly in need of careful review and editing. All of this should be accomplished before any excavation of the western and intact portion of the site is undertaken.

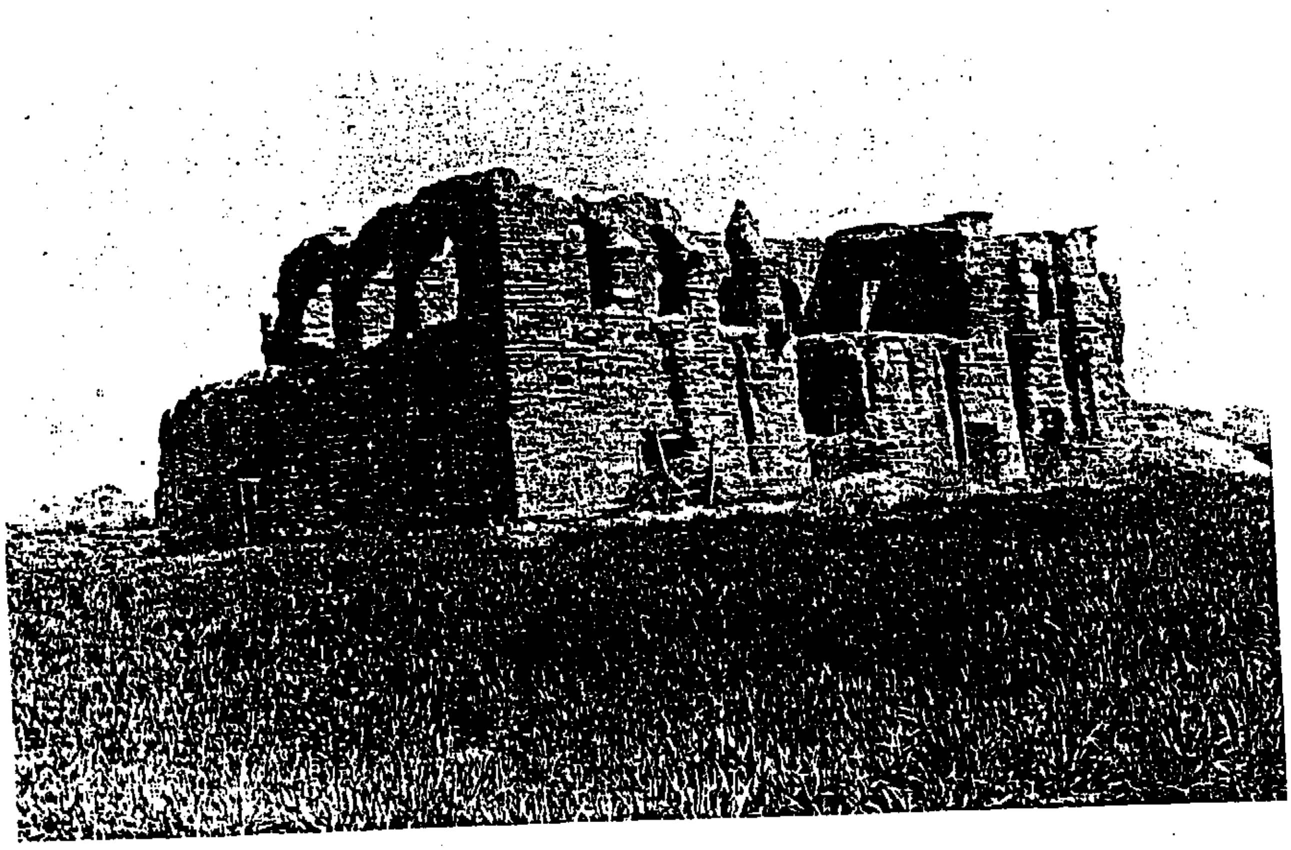


Figure 15.
The Convento structure of the San Augustin Mission (Arizona Historical Society)

Some measure for protection of the western portion of the site (that area immediately adjacent to Brickyard Lane) should be taken. A fence could be constructed around the site. The disadvantage would be that any marker would attract the curious and may result in vandalism. On the other hand, leaving the site in its present condition may lead to inadvertent destruction. For instance, someone needing large boulders for backyard landscaping may inadvertently remove the basalt boulders which delineate the foundations to the granary and the compound wall.

BB:13:22

Description. This site was completely destroyed by landfill operations in 1957-1958. It was initially recorded as a large sherd and lithic scatter. The site was predominately Tanque Verde phase, although there was some mixing with Rillito phase materials. The site is located at the foot of "A" Mountain along the west bank of the river.

Recommendations. The site has been totally destroyed. No further work can be done.

BB:13:57, Warner's Mill Complex

Description. The site of Warner's Mill complex is located at the foot of "A" Mountain just west of the intersection of Mission Lane and Grande Avenue. The house is in excellent condition considering its age. The mill structure is dilapidated and in ruins. Once a large two-storied structure (Figure 16), all that remains today are the basalt masonry walls of the first story. The second story was torn down by a subsequent owner after the building had been abandoned and become a hazard to neighborhood children. Several pot holes have been dug in the rubble fill inside the structure.

An adequate biography of Solomon Warner is provided by Cosulich (1953: 101-13) and Lockwood (1953: 50-56). Here, it is sufficient to say that by

Figure 16. Warner's Mill around 1880 (Arizona Historical Society).

The historic component is limited to the edge of the riverbank and consists of basalt-boulder structural foundations and historic trash. Square nails appear throughout this portion of the site. Also found were Papago Red-on-brown sherds, which are the earliest known Papago pottery within the Tucson area, oyster shell fragments, and purple glass.

A long-time resident in the area, Albert Ormsby (1978, personal communication), claims that the structural foundations and historic trash belong to the old Silver Lake Hotel (Figure 23). Since the hotel was constructed along the western shore of the lake, evidence for the former lake should be visible immediately to the east of the site. This evidence was found in the form of low, wide benches below the present riverbank on opposite sides of the river. Below the western bank, the bench has been covered by fill obscuring its extent. Prior to landfilling, the bench was shaded with large cottonwoods and was a favorite picnic area as late as the early 1960s. The ... pletely landfilled making the east shore of the lake no longer visibl Aerial photographs taken prior to the 1950s should show the extent of this bench and thus show the area formerly occupied by Silver Lake. George J. Roskruge's official map of Pima County (1893) shows Silver Lake to be located in the southern half of Section 23, T14S, R13E, and places the hotel on the western shore of the lake. No other historic maps showing Silver Lake were found.

In 1880, a man by the name of Smith was proprietor of George J. Roskruge's boating, swimming and bathing facilities at Silver Lake (Arizona Daily Star 6/10/1880). Around 1881, James Lee leased 20 acres to J. F. Rickey and J. O. Baily for the purpose of setting up a resort along the shores of Silver Lake. The 1881 City of Tucson Directory describes the resort and lake in the following manner:

> *...lake is caused by a dam of masonry in the Santa Cruz River and extends*

Figure 23.
Silver Lake, the Silver Lake Hotel, and the residence of a Mr. Kelley to the left. Photograph (taken in 1880) looks west across the lake toward the Tucson Mountains in the background (Arizona Historical Society)

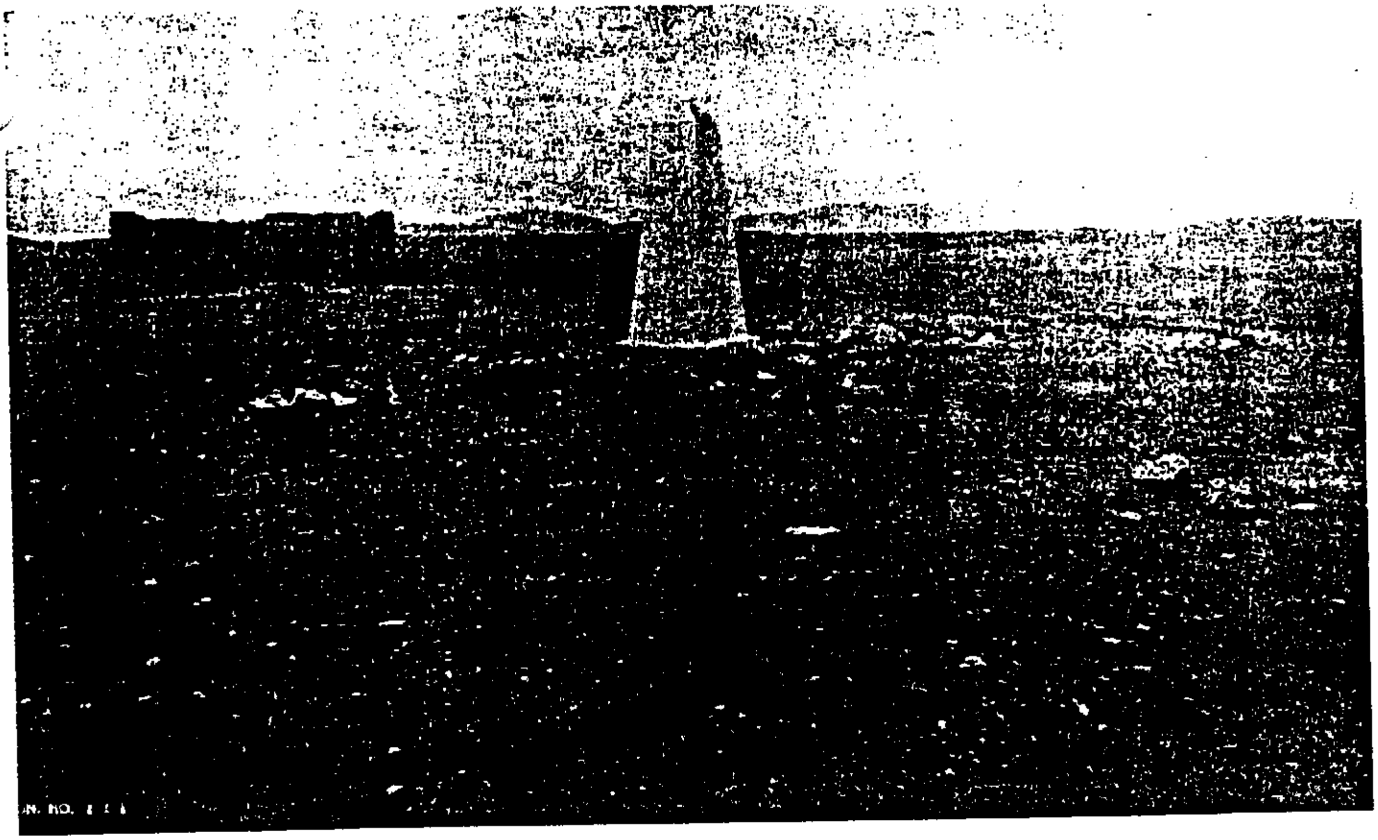


Figure 3. — San Rafael Valley during the drought of 1892–93. From the 1893 U.S. Border Report Survey.

to twelve inches in length, weighing from one to two pounds (Gustafson 1966:113). Fish of the same size are described by other army officers near Camp Wallen, who observed that deer and coyotes abounded on the plain between Wallen and Crittenden. Flocks of geese and ducks could be found at almost any time along the Santa Cruz River, where they particularly gathered in cornfields that were scattered along the river (Gustafson 1966:208).

The reflections of John Spring, written several decades after he was stationed at Camp Wallen, shed considerable light on the depletion of wildlife. His memoirs include several examples of hunting excesses. During the 1860s and 1870s, miners, wood haulers, and army personnel were easily able to supply their camps with wild meat. "The men in the wood camp were really not in any need of fresh meat, as they had killed several wild turkeys that very morning, and had game of some kind at all times" (Gustafson 1966: 113). Spring also gave examples of hunting practices which he thought injurious to population levels. For hunting the "numerous herds of antelope" near the post, Spring described a method the Apache scouts had taught the troopers. It proved so successful that "before long the excitement of hunting them wore off, as it resembled more a deliberate butchery than the sport of the chase. . . ." Using the Apache technique, several army herders would circle around an antelope herd and drive them toward a ravine where the hunters were hiding next to a long pole driven into the ground with a handkerchief fastened to it. The antelope were attracted by the fluttering cloth and would move into shooting range and were quickly shot. This procedure could be repeated several times a day, without creating apprehension among the antelope. According to Spring, overhunting in combination with "the numerous cattle herded all over Arizona since the forced pacification of the Apaches" had made both deer and antelope scarce and those that remained had become very shy (Gustafson 1966:111–13).

During the two decades following Spring's description of the San Rafael Valley, the United States Army increased its presence in southern Arizona and stock on 'em they're destroyin' the range" (Parker ms:187). Parker was expressing his resentment over the study area's first closing of the open range, which in reality may have resulted in preservation of rangeland rather than the perceived destruction. As can be seen from the Water Resources Appendix 7.2, a substantial number of wells and stock tanks were installed at a surprisingly early period. Although the San Rafael Valley suffered from the "tragedy of the commons," overstocking within the study area was probably less severe than in other parts of southern Arizona.

Despite the early penetration of highly capitalized ranching, however, the study area did undergo periods of severe stress. The most important factor in alteration of the grassland ecology has been drought. Three major droughts—the first in the 1880s and 1890s, the second following World War I between 1918 and 1921, and the third at the onset of the Great Depression in 1933–34—did considerable damage to San Rafael rangelands. The first drought was more severe, lasted longer, and came at a time when ranchers in southern Arizona had little understanding of arid lands cattle ranching and no plans or ability to enact an emergency offtake strategy. (See Fig. 18 of the San Rafael Valley during the drought of 1893.) In 1885–86, 1892, and again in 1902, large numbers of cattle starved to death on the range. During this drought, many ranchers in the study area lost the majority of their cattle. Mrs. de la Ossa lost all but one head (Ashburn 1994). James Parker lost such a high percentage of his herd that he had to "start over again." Parker family memoirs recall that by June 1885, many cattle in the valley were dying. When rain finally came, watercourses flooded and the floodwaters carried away many of the weakened, starving cattle.

After two "good years" in 1888 and 1889, the drought returned. This time, some of the area ranchers were better prepared. Parker's granddaughter, Mary Fenter, was married to Tom Turner, foreman of the Vail and Gates cattle company. Before the drought

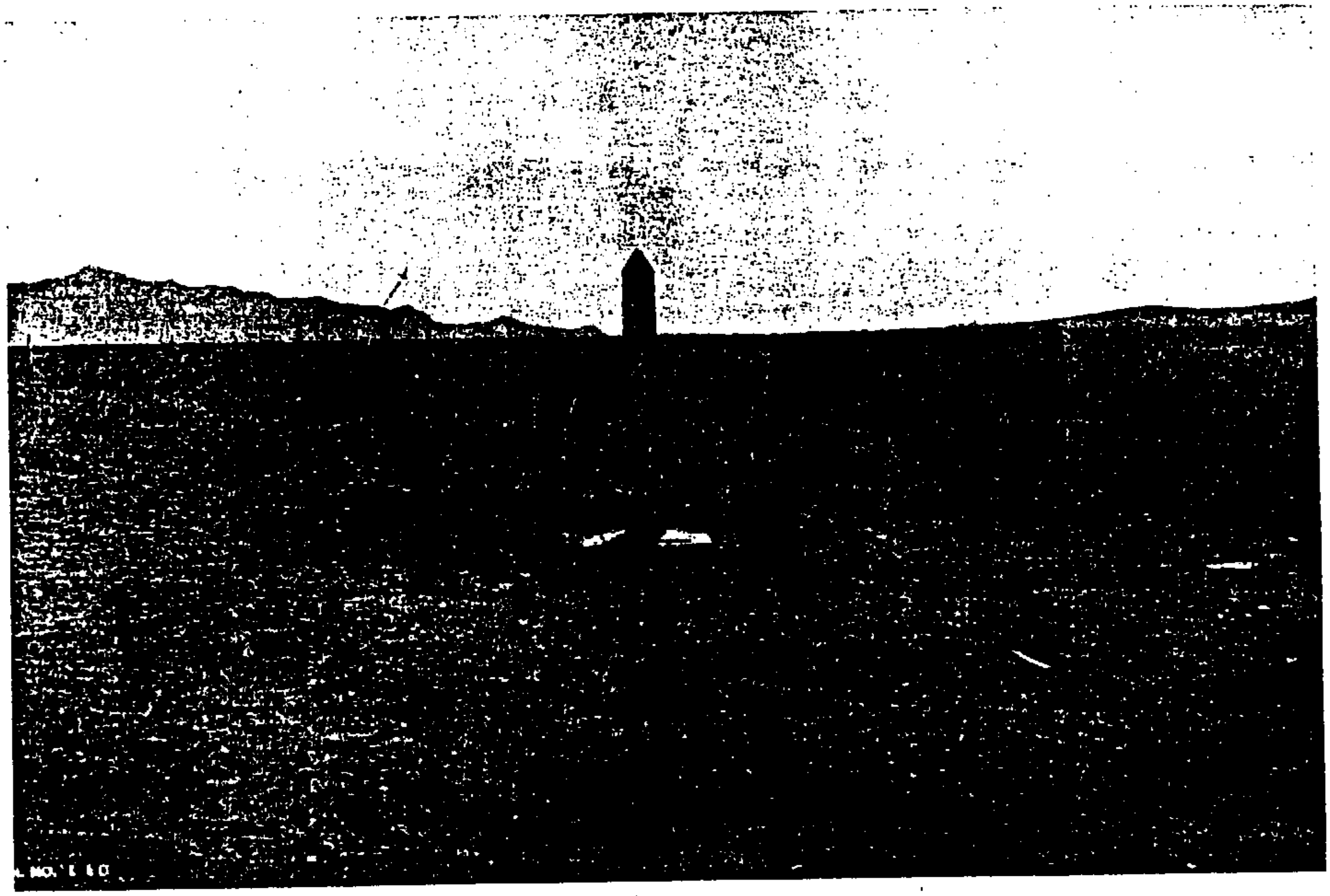


Figure 18—San Rafael Valley, looking east from Monument 110. From the 1893 U.S. Boundary Survey Report. (Note: small portion of fence at left of photo, possibly along the International boundary, and evidence of overgrazing during the drought.)

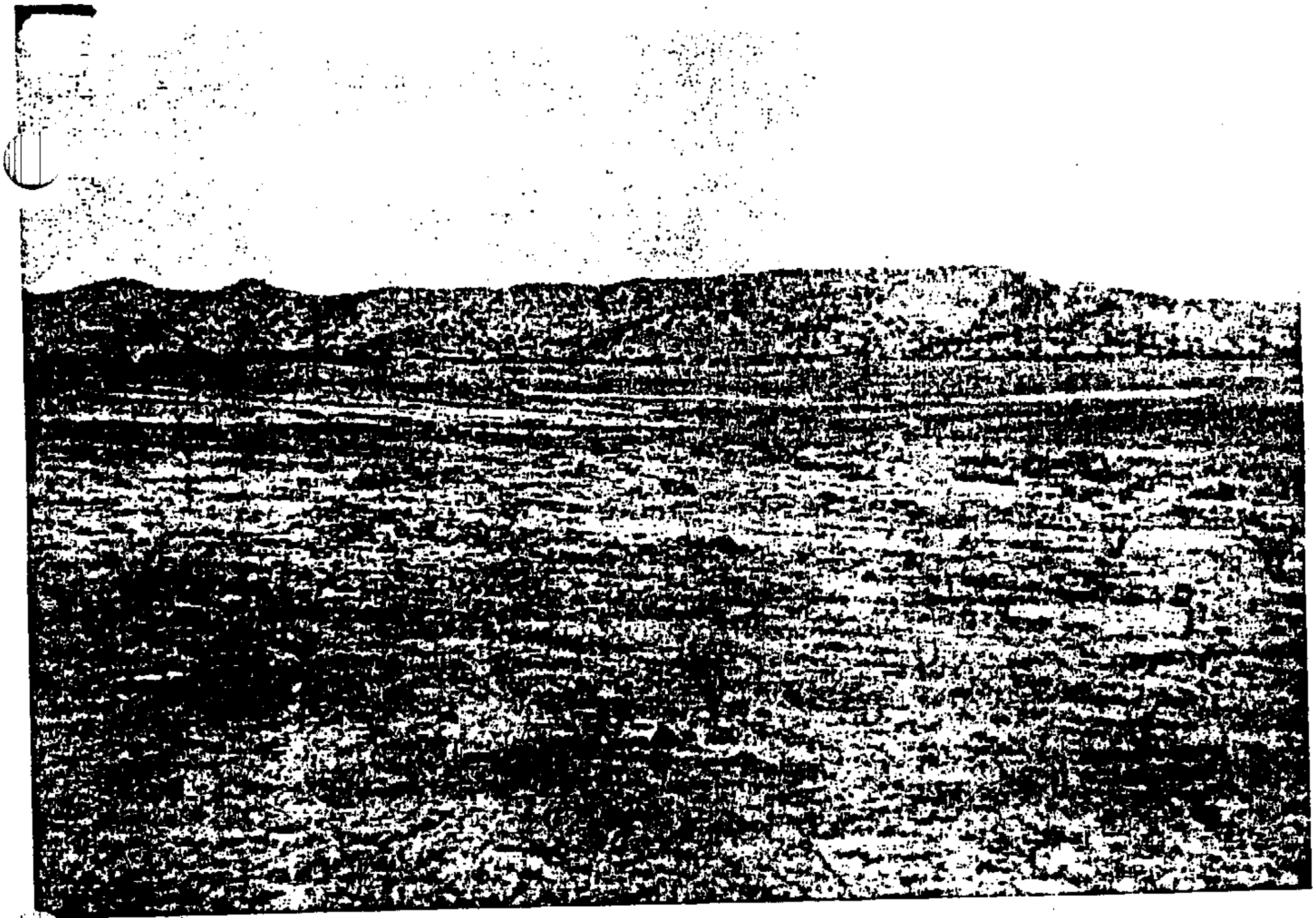


Figure 19—San Rafael Valley. 1917. U.S. Forest Service. Exact location unknown, probably north end of study area, near Meadow Valley.

reached its peak in 1892, Turner left for California, trail herding approximately 1,700 steers. He encouraged other cattlemen to do the same, thereby avoiding exorbitant railroad shipping charges (Parker ms: 183–87).

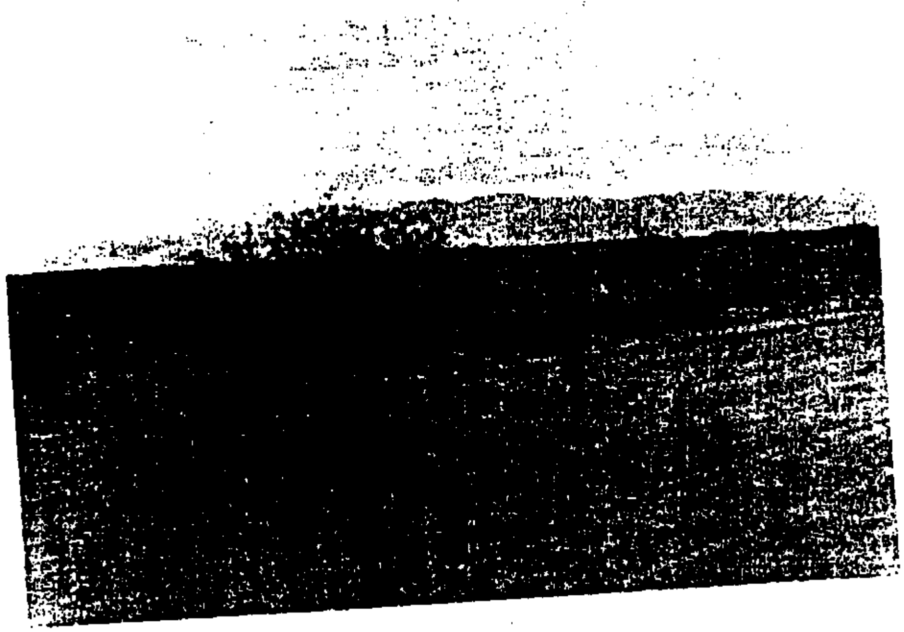
Despite some limited off-take, however, damage to the valley in 1892 was severe. With no fences, cattle crowded around the few remaining sources of water, particularly the Santa Cruz River, where many of them died. Two of James Parker's granddaughters recalled that the "heavy clumps of sacaton and tules, which had regrown since the first drought, were eaten into the ground." Water holes had become bogs, which trapped the weakened cattle. "Bleached bones of horses and cattle were strewn over the valleys and hills and along the road sides, a grim reminder for years of that great tragedy." When the rains finally returned, flooding performed the much needed service of washing cattle corpses and bones of watercourses (Parker ms: 181–188).

During the drought, ranchers employed many tactics to save their cattle. James Parker drove all the cattle that could walk into the foothills of the Huachucas and then sent his sons George and Duke to set up a camp in the hills so that they could cut any tender growth from the oak and ash trees to feed the cattle on a daily basis. The Parkers recalled that the cattle "followed them like dogs from tree to tree." They also recalled "tailing up" the cattle that were too weak to walk. James Parker even made a swing to support them on their feet (Parker ms: 181–88). After the drought of the 1880s–1890s, many former springs and cienegas disappeared. Although ranchers had done considerable work to drain some of the cienegas, the drought contributed to the drying process.

The second and third droughts caused more range deterioration. The post World War I drought coincided with a depression. Many ranchers did not have the financial resources to buy feed for their cattle, leaving the animals entirely dependent on range forage. After this drought, George and Duke Parker lost their ranch. Ranchers believed that the misinformed generation of homesteaders, who arrived in 1915 and

Halpenny 1962

a. Channel of Santa Cruz River incised about 25 feet into flood plain, at location (D-16-13) 12 ccd.



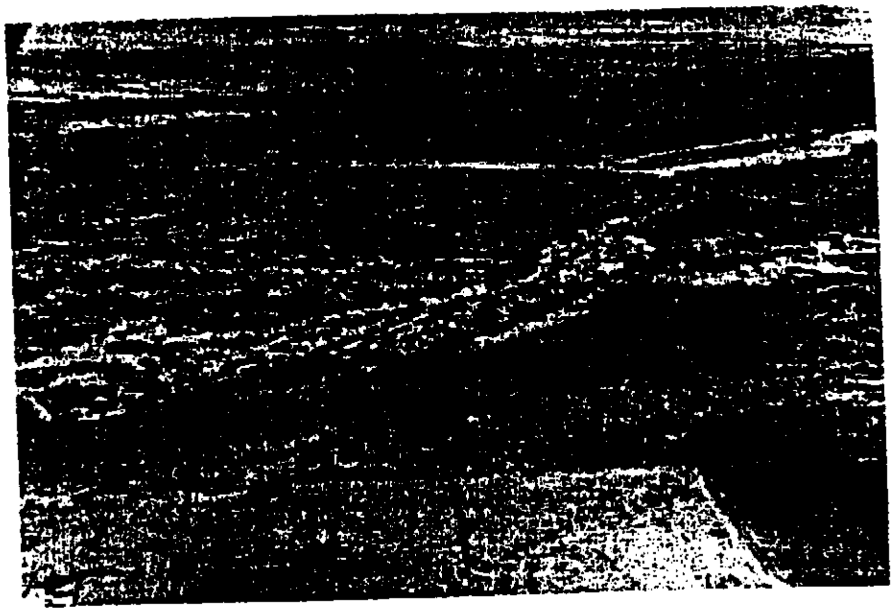
b. Mesquite about 12 feet high growing along wash in area where depth to water is about 75 feet, at location (D-15-13) 23 adb.

Figure 2. -- Photographs of river channel and of desert vegetation.

a. Aerial view of bottom lands. Most of the mesquite trees are dead owing to decline of the water table. The live growth in the middle foreground follows the course of a channel which collects runoff from desert washes on the east side of the river. The live growth surrounding the fields in the background is supported by waste irrigation water and by runoff from washes entering the river bottom from the west.

b. Close-up of general view shown above. The cottonwoods at the right side are presently dying because of declining ground-water levels.

Figure 3. -- Photographs of bottom lands taken from the air.



a. Air view northwest along side wash which enters river at (D-16-13) 1 bdb. Note dead mesquite; note course of abandoned canal parallel with river on west side.

b. Dead mesquite in abandoned canal on west side of river at locality (D-15-13) 35 dba; the plants have died in spite of the fact that the canal bottom is about 15 feet below the prevailing land surface. There is one salt cedar shown in the lower right corner; it was still alive in September 1962.

Figure 4. -- Photographs of dead mesquite.

a. Aerial view northeast showing dead mesquite in bottom lands and present channel of river. The narrow borders of live growth live on the occasional river flows.

b. Stumps of dead mesquite in bottom land at location (D-16-13) 2; their size indicates these former phreatophytes grew under favorable conditions for many years.

Figure 5.-- Photographs of dead mesquite.

ARIZONA STATE LAND DEPARTMENT

Section 4

ARIZONA STREAM NAVIGABILITY STUDY
for the
SANTA CRUZ RIVER
Gila River Confluence to the Headwaters

Final Report

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November 1996

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January 12, 2004

Historical Geomorphology and Hydrology of the Santa Cruz River

A report Submitted to the Arizona State Land Department
-Final Draft-

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EXECUTIVE SUMMARY

This report provides baseline information on the physical characteristics of the Santa Cruz River to be used by the Arizona Stream Navigability Commission in its determination of the potential navigability of the Santa Cruz River as of the time of Statehood. The primary goals of this report are: (1) to give a descriptive overview of the geography, geology, climatology, vegetation and hydrology that define the character of the Santa Cruz River; and, (2) to describe how the character of the Santa Cruz River has changed since the time of Statehood with special focus on the streamflow conditions and geomorphic changes such as channel change and movement. This report is based on a review of the available literature and analyses of historical survey maps, aerial photographs, and U.S. Geological Survey stream gage records.

The Santa Cruz River has its source at the southern base of the Canelo Hills in the Mexican Highlands portion of the Basin and Range province. The river flows south through the San Rafael Valley before crossing the international border into Mexico. It follows a looping path of about 30 miles before it re-enters the United States six miles east of Nogales, and continues northward past Tucson to its confluence with the Gila River a few miles above the mouth of the Salt River. The "upper" Santa Cruz River (the river south of Marana) and the "lower" Santa Cruz (the river north of Marana) are often discussed separately in this report because of their different geomorphic and hydrologic characteristics. Along the upper Santa Cruz River, the channel is located in an inner valley that was created within broad, dissected pediments and alluvial basin deposits, and flanked by mountains. The well-defined, often entrenched channel in the upper reaches contrasts strongly to the ill-defined system of braided channels that exist north of Rillito Peak at the northern end of the Tucson Mountains near Marana. In this lower part of the basin, the Santa Cruz River flows into the great adobe flats known as the "Santa Cruz Flats," a broad plane of indistinct, non-continuous channels in Pinal County. Floodwaters spread over a wide area with flow concentrated in numerous small washes. A well-defined channel exists only at Greene's Canal and near the Santa Cruz River's confluence with the Gila.

Both the upper and lower reaches of the Santa Cruz River have been subjected to a complex combination of climatic and geomorphic processes and human activities that have resulted in both subtle and dramatic changes in its geomorphic and hydrologic character. While arroyo development is the most obvious type of channel change to occur since the 1890s in the upper Santa Cruz River, most of the initial channel incision occurred before the time of Statehood. Since 1912, various reaches of the upper Santa Cruz River have been dominated by such processes and activities as meander migration and cutoff, channel widening, arroyo widening,

channelization, and the effects of vegetation growth resulting from the discharge of sewage effluent. The channel locations in different reaches have shifted on the order of a few feet to a few thousand feet, depending on the processes that resulted in the movement, and often change could be detected from one year to the next.

The lower Santa Cruz River, which overall is characterized by aggradation of its streambeds, experienced changes of a completely different magnitude from the upper Santa Cruz. Changes in the location of the channel in the lower basin can be measured in miles, and, due to the nature of the causes of the changes, the timing spans decades. Before the construction of Greene's Canal in 1910, the Santa Cruz River downstream from Marana was a broad, flat alluvial plain with intermittent channels. Now the transition from defined channel to alluvial plain occurs near Chuichu, Arizona. Prior to and during the floods of 1914-1915, flood flows followed routes down the North Branch of the Santa Cruz Wash and McClellan Wash through the Casa Grande area. The influence of Greene's Canal and its subsequent development as an arroyo have caused flood flows since 1915 to take more westerly paths *via* Greene's Canal.

The hydrology of the Santa Cruz River, like its geomorphology, has been affected by natural geomorphic and climatic processes and by human activities. Historically (~1890), the Santa Cruz River had year-round (or perennial) flow from its source to Tubac. Climate change since the turn of the century, combined with the extensive groundwater pumping for irrigation and the flow diversion for municipal use that began near the international border during the 1930 to 1950 drought period, has resulted in no flow in the channel in Sonora, Mexico, and discontinuous flow in the channel near Nogales, Arizona. The 1913 gage record at Nogales (the earliest in that region) indicates that by the time of Statehood, the Santa Cruz River at Nogales was no longer perennial, but instead had continuous flow during the winter and occasional flow during the spring, summer and fall. The winter discharge averaged about 15 cubic feet per second (cfs), except for an increase caused by a rainfall event that ranged from 35 to 174 cfs. A survey of the daily data for the rest of the Nogales record indicates that during wet years there were only a few days of no-flow conditions, while during dry years there were entire months that passed with no flow recorded in the channel. At present, naturally occurring perennial reaches occur only in the uppermost part of the river in the San Rafael Valley. A separate perennial reach occurs north of Nogales due to the discharge of sewage effluent from the Nogales International Wastewater Treatment Plant that began in 1972.

The Santa Cruz River historically had several springs and marshes (*cienegas*) within its channel from Tubac to Tucson, and a marsh at its confluence with the Gila River at Laveen. Even in the historical record, only the very largest floods were sustained from the headwaters to the confluence with the Gila River. A review of the daily discharge record at Tucson indicates that there was some semblance of baseflow with an average of about 12 cfs during the fall and winter of 1912-1913. Such continuous flow for months at a time was not seen again in the years that followed, though there were periods of several weeks that experienced continuous or nearly continuous flow during very wet winter seasons. The Laveen gage recorded nearly year-round flow from its beginning date, 1940, until June of 1956, when it began to measure zero flow for weeks at a time. During the 1940 to 1956 period, the daily flow averaged about 3 cfs during low-flow conditions and had peaks as high as 5060 cfs during the wet periods. By 1960, the Santa Cruz at Laveen also was experiencing no-flow conditions for months at a time. In contrast to the reaches near Tucson and in the lower Santa Cruz River basin, the reach of the Santa Cruz River near Marana and Cortaro now has perennial flow due to the discharge of sewage effluent from the Ina Road and Roger Road sewage treatment plants.

Not only has the location of perennial flow in the Santa Cruz River changed since the time of Statehood, but the seasonality and magnitude of flows also have shifted as a result of climate change in this region. Though the majority of flow events occur during the summer season, the magnitude and number of flows that occur in the fall and winter was higher before 1930 and after 1960 than during the 1930-1960 period. Also, annual peak discharges increased significantly after 1960. For example, six of the seven largest floods on the Santa Cruz River at Tucson occurred after 1960.

In the lower Santa Cruz River basin, human activities as well as climate change have had notable effects on the magnitude of peak flows. Since 1962, the construction of flood-control channels in the washes of the lower Santa Cruz basin have resulted in the reduction of floodplain storage and infiltration losses, therefore reducing the attenuation (the downstream decrease of the flood peak) of peak discharges. For example, the attenuation of peak flow was greater during the 1962 floods than during the 1983 floods because water was able to spread out over the broad flow zones in the lower reaches of the Santa Rosa and Santa Cruz washes. In contrast, much of the floodwater during the 1983 floods was efficiently transmitted downstream by the flood-control channels, resulting in higher flood peaks in downstream reaches.

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I. INTRODUCTION

This report provides baseline information on the physical characteristics of the Santa Cruz River to be used by the Arizona Stream Navigability Commission in its determination of the potential navigability of the Santa Cruz River as of the time of Statehood. The primary goal is to give a descriptive overview of the geography, geology, climatology, vegetation and hydrology that define the character of the Santa Cruz River. A secondary goal is to describe how the character of the Santa Cruz River has changed since the time of Statehood, with special focus on the streamflow conditions and geomorphic changes such as channel change and movement. This report is based on a review of the available literature, and analyses of historical survey maps, aerial photographs and U.S. Geological Survey streamgage records. Unfortunately, there is little data presented in the literature or in the gage records, aerial photographs and maps of the Santa Cruz River for the year 1912. Therefore, the character of the river at the time of Statehood must be interpolated from descriptions made before and after that year.

The Santa Cruz River has been subjected to a complex combination of processes that have resulted in changes in its character. These changes have taken many forms, including changes in the types and density of vegetation in the river basin, the average flow or magnitude of peak flows, the presence of surface water, and even the location of the river channel itself. Human activities clearly have played a role in changing the geomorphology and hydrology of the Santa Cruz River, but it is difficult to separate the effects of human impact from the effects of climate change and "natural" riverine processes. Where possible we have noted the causes of specific changes, whether they are anthropogenic or naturally induced.

Each of the following chapters, except for the chapter on geography and geology, begins with a general overview of the topic, followed by a description of the changes that have occurred since the time of Statehood. The "upper" Santa Cruz River (the river south of Marana) and the "lower" Santa Cruz (the river north of Marana) are often discussed separately in the following chapters because of their different geomorphic and hydrologic characteristics. The concluding chapter provides a comparison of the hydrological and geomorphological characteristics at the time of Statehood to those of the present day. Throughout this document, key words are highlighted by bold, italicized print. These words have been defined in the "Glossary" section that follows the last chapter. Ten ground photographs that illustrate the key differences between the different reaches of the upper and lower Santa Cruz River are given in Appendix A. Appendix B is a detailed description of the mapping of ordinary low and high watermarks. Appendix C explains the creation and use of stage-discharge rating curves. Appendices D, E and F provide lists of the contacts and resources we developed in our search for historical maps, aerial photographs and previous channel change studies. Appendix G is an extended bibliography containing relevant references that were not included in the text of the report.

II. GEOGRAPHY & GEOLOGY

The Santa Cruz River has its source at the southern base of the Canelo Hills in the Mexican Highlands portion of the Basin and Range province (Figure 1). Its waters gather into a shallow, perennial channel that flows south through the San Rafael Valley before crossing the international boundary into Mexico. The river describes a loop of about 30 miles with a 348-square-mile contributing drainage area before re-entering the United States 6 miles east of Nogales. Its channel continues northward past Tucson to the Gila River a few miles above the mouth of the Salt River, a distance of about 225 miles.

Along the upper Santa Cruz River, south of Marana (refer to Figure 2), the channel lies within an inner valley created within broad, dissected pediments and alluvial basin deposits, and flanked by mountains (Cooke and Reeves, 1976; Bryan, 1925b). The well defined, commonly entrenched channel in the upper reaches contrasts strongly to the discontinuous system of channels that exist north of the northern end of the Tucson Mountains near Marana. In this lower part of the basin, the Santa Cruz River flows into the great ***adobe flats***[1] known as the "Santa Cruz Flats," a broad plain of indistinct, noncontinuous channels in Pinal County. On most United States Geological Survey (USGS) maps, the term "Santa Cruz Flats" is restricted to the area south and west of Eloy, extending west to the Sawtooth Mountains, south to the alignment of Greene's Canal, and north to the Casa Grande Mountains. In this region, floodwaters spread over a wide area with flow concentrated in numerous small washes. Distinct channels exist only along the former alignment of Greene's Canal and near the Santa Cruz River's confluence with the Gila River.

[1] Bold, italicized words are defined in the Glossary following the final chapter.

Figure 1. Physiographic Features in the Santa Cruz River Basin.

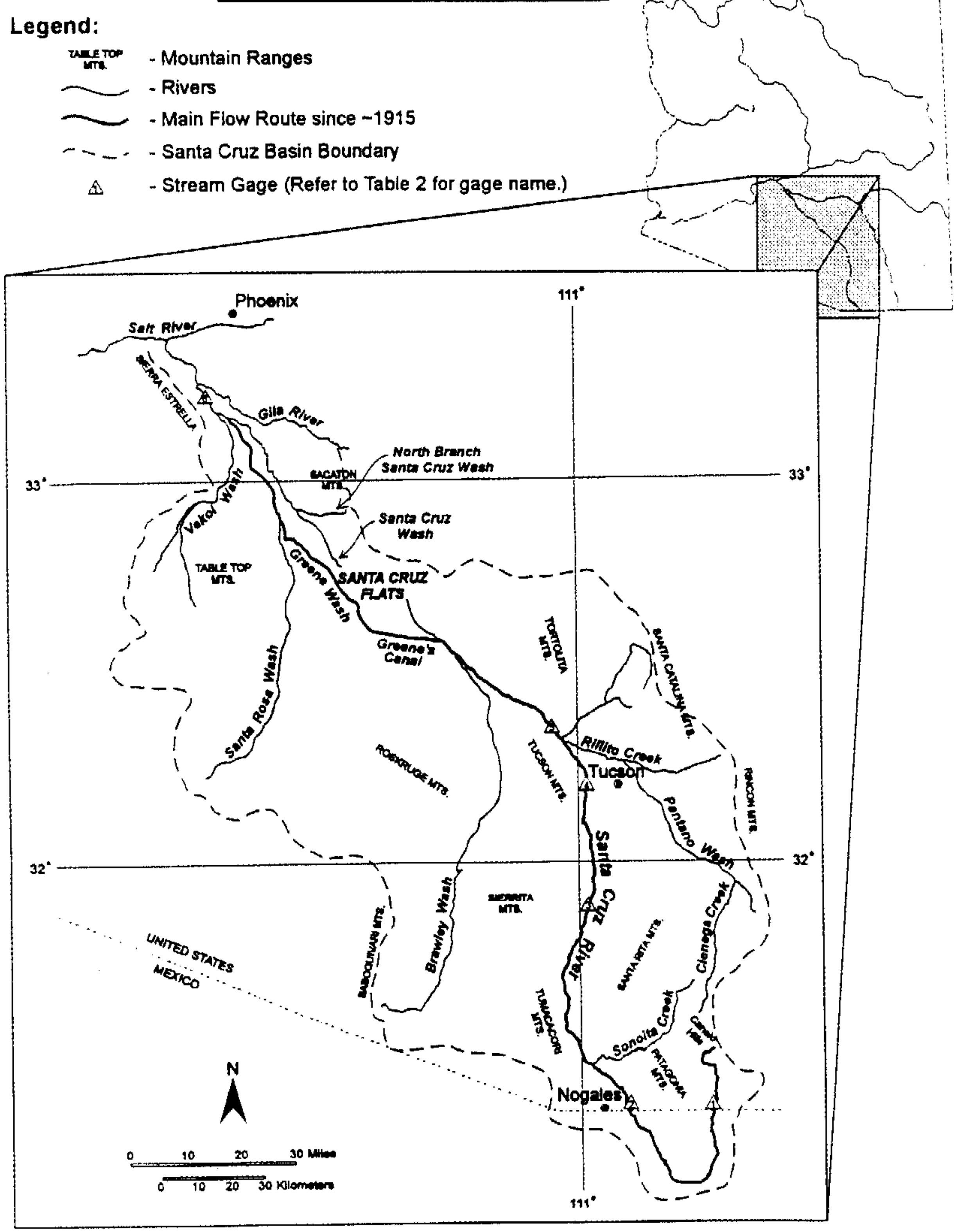
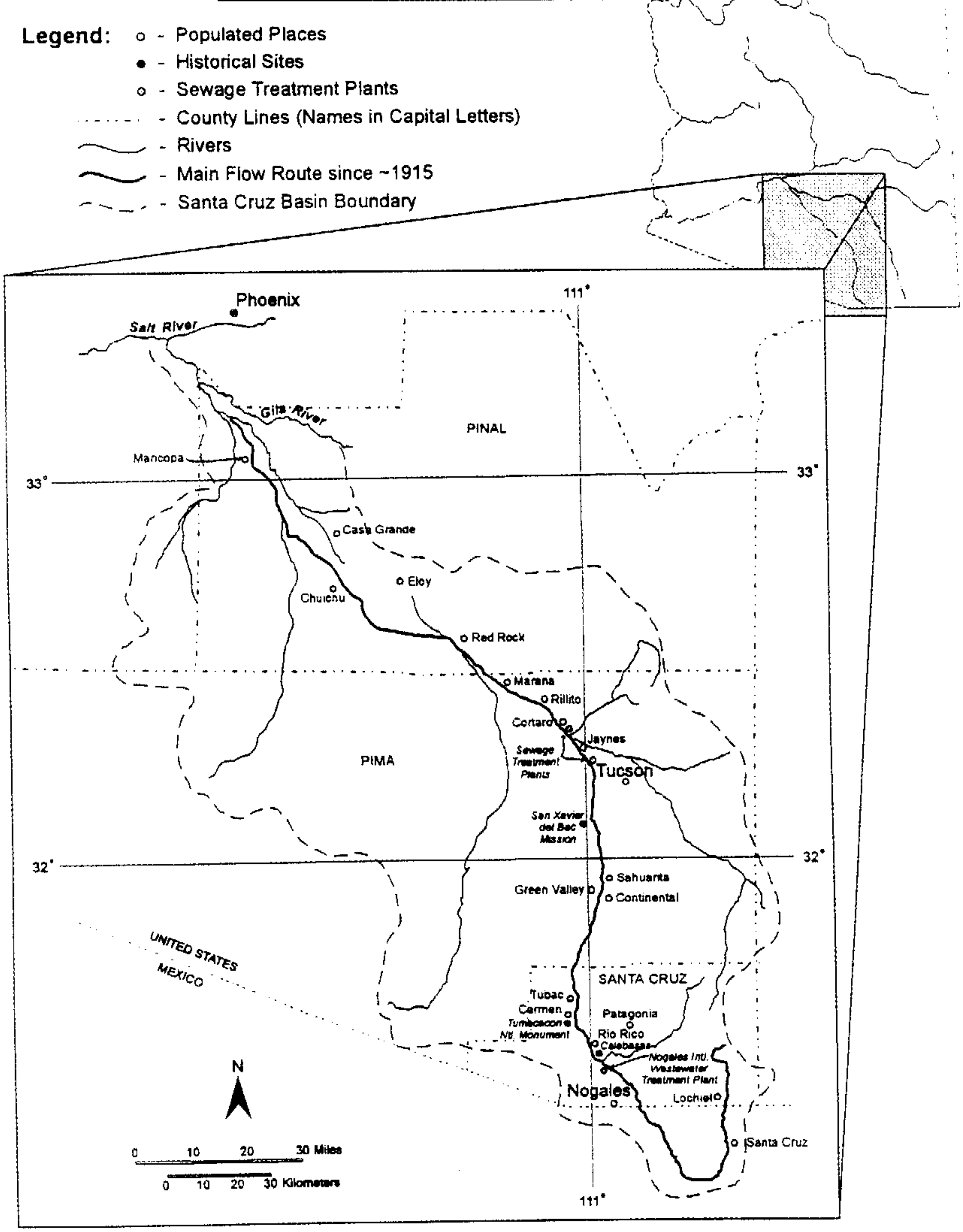


Figure 2. Santa Cruz River Basin: Places mentioned in the text.



III. CLIMATE

Climate plays both direct and indirect roles in defining the character of the Santa Cruz River. Temperature and precipitation control the amount of evaporation that occurs, which in turns affects the amount of water that flows into and remains in the river channel, the amount of ***infiltration,*** the type and vigor of vegetation along the river banks, and the character of vegetation throughout the basin. The amount and nature of the precipitation plays an even stronger role in defining the character of the river because both the surface and groundwater supplies of the drainage basin have as their primary source the precipitation that occurs in the basin (Schwalen, 1942).

This chapter provides a brief overview of the seasonal changes in temperature. Seasonal, annual, and decadal changes in the source and nature of precipitation events will be described in more detail because of the role average and unusual precipitation conditions play in defining the hydrology and geomorphology of the Santa Cruz River system.

A. Temperature

Average January temperatures range from about 40° F in the higher elevations to about 50° F in the lower lying regions, with mean minimum temperatures averaging near or below freezing. Average July temperatures range from 65° in the higher elevations to 85° and 90° in the lower regions, with mean maximums ranging from 80° to 105°, depending on the elevation. The spring and fall months are characterized by large daily temperature changes that average 30° or even 40° (Santa Cruz-San Pedro River Basin Resource Inventory, 1977; Sellers and Hill, 1974).

B. Precipitation

Annual precipitation in the Santa Cruz River basin tends to increase with altitude and is extremely variable from year to year (Condes de la Torre, 1970). Two distinct seasons of precipitation are evident in the mean monthly precipitation of the Santa Cruz River Basin, with slightly greater precipitation in the summer than in the winter (Sellers and Hill, 1974). This pattern is illustrated by two rain gage records in the basin (Figure 3). Hirschboeck (1985) and Webb and Betancourt (1992) provided thorough reviews of the sources of the precipitation and identified the circulation anomalies that are associated with variations in monthly and peak streamflow for the Santa Cruz River. The following sections describing seasonal precipitation patterns and variability are based primarily on their work.

Summer. The summer rainy season occurs from the latter part of June through September. During the summer rainy season, the thermally induced high-altitude anticyclonic circulation centered over the southern and southwestern United States entrains moist air from the Gulf of Mexico, the Pacific Ocean and the Gulf of California (Reed, 1933; 1939). The summer rains are often referred to as "monsoon" rains because of the similarity of the southwestern atmospheric circulation pattern to the monsoonal circulation in other parts of the world (Tang and Reiter, 1984). The storm centers of summer thundershowers are the result of convective air currents set up in the lower atmosphere by extremely high temperatures next to the earth's surface, and the effects of local topographic features. Summer precipitation is characterized by widespread and locally scattered thunderstorms. The summer storms tend to result in locally intense rainfall on any given day, yet for short periods during the summer, rainfall may occur in the entire drainage basin (Schwalen, 1942). In the upper Santa Cruz River basin, the precipitation during the summer rainy season is the most dependable and generally is greater than the total for the remaining eight months of the year (Schwalen, 1942; Condes de la Torre, 1970). From north to south in the drainage basin, the ratio of summer rainfall to total annual rainfall increases (Schwalen, 1942).

Winter. The winter rainy season occurs during the period December through March. This second rainy season results primarily from trailing cold fronts associated with large-scale low pressure systems steered into the region by very deep troughs over the western United States in the belt of upper air westerly wind flow. Winter rains in the Santa Cruz River basin are associated with the eastward passage of the cyclonic storm centers

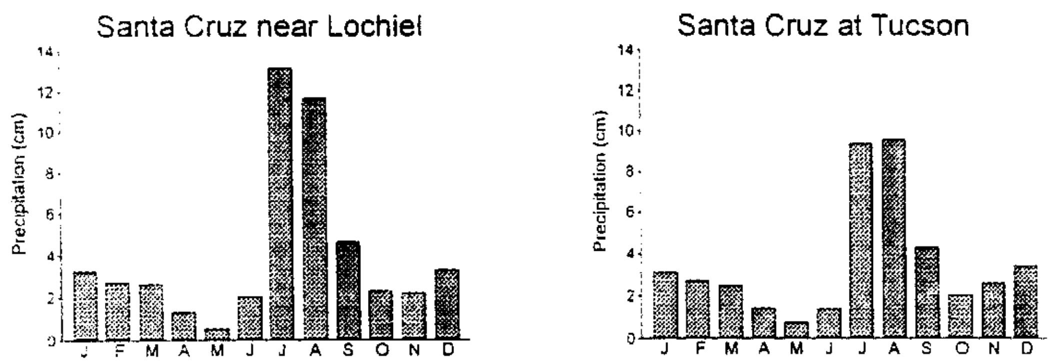


Figure 3. **Monthly precipitation at two gages in the Santa Cruz River Basin.**
[Source: Hirschboeck, 1985]

originating on the Pacific Ocean. Although individual storms may persist for several days, have wide spatial extent (i.e. one storm system may cover the entire state of Arizona), move slowly, and have fairly steady intensity, winter rains themselves show a wider variation in their seasonal totals and are more irregular in monthly distribution than the summer rains (Schwalen, 1942; McDonald, 1956). Though the majority of flow events on the Santa Cruz River occur in the summer rainy season, the second largest flood measured at Tucson was caused by a series of winter frontal passages. The fronts were steered along a southerly displaced storm track into the region (House and Hirschboeck, 1995).

Fall and Spring. The spring and fall months in Arizona are usually characterized by clear skies and little precipitation (SC-SP River Basin Resource Inventory, 1977; Sellers and Hill, 1974). While winter frontal storms and summer convectional storms are the most common sources of precipitation in this region, tropical storms and cutoff lows also contribute significant amounts of precipitation (Douglas and Fritts, 1973; Douglas, 1974; Hirschboeck, 1985). Tropical storms tend to influence the precipitation of the region during the months of August through October (Douglas and Fritts, 1973; Hirschboeck, 1985; Smith, 1986). For example, remnants of Tropical Storm Claudia in 1962 caused flooding on the Santa Cruz River at and north of Tucson, Santa Rosa Wash, and Brawley Wash (Lewis, 1963).

Cutoff cyclones tend to develop in the upper atmosphere off the west coast of North America during the fall (September - November) and late spring (May - June) periods, times that are typically dry in the Santa Cruz River basin. Hirschboeck (1985) observed that tropical storms at the surface were often associated with troughs or cutoff lows in the upper atmosphere. Tropical Storm Octave in late September and early October 1983 is an example of such an interaction between a tropical cyclone and a cutoff low pressure system that caused the flood of record on the Santa Cruz River (Roeske *et al*, 1989; Webb and Betancourt, 1992).

C. Historical Climate Change in the Santa Cruz River Basin

During the past two decades, more and greater flood flows have occurred in the fall and winter seasons and fewer in the summer (Webb and Betancourt, 1992; Hirschboeck, 1985). This increase in magnitude and number of flows in the fall and winter results from a shift in the seasonal distribution of precipitation. Webb and Betancourt (1992) explain the shifts in the seasonal distribution of precipitation in terms of fluctuations in large-scale oceanic and atmospheric processes:

"Twentieth-century climatic variability stems from decadal trends in atmospheric circulation over the Northern Hemisphere and in the frequency of El Niño-Southern Oscillation (ENSO) phenomena in the equatorial Pacific Ocean. Before 1930 and after 1960, westerly winds on average followed a more meridional path, and ENSO conditions occurred more frequently and with greater variability in the equatorial Pacific. By contrast, the westerlies followed a more zonal flow, and ENSO conditions occurred less frequently with less variability between 1930 and 1960. Meridional circulation and the climatology associated with ENSO conditions enhance Tucson precipitation in the winter, spring, and fall and possibly reduce summer rainfall." (Webb and Betancourt, 1992, p.35-36) ..... "Winter frontal storms are more numerous and intense during certain ENSO years... the probabilities for generation and recurvature of tropical cyclones change during ENSO conditions, but the advection of moisture needed to fuel monsoonal storms is reduced. Hypothetically, ENSO conditions could reduce the number of monsoonal storms but increase the number of frontal systems and tropical cyclones that affect Arizona." (Webb and Betancourt, 1992, p. 12)

Arizona's Statehood occurred during a period characterized by relatively intense winter storm activity. Such intense storm activity, when combined with human activities and other riverine processes, resulted in significant geomorphic changes of the Santa Cruz River channel. These changes and other related hydrologic changes associated with the shift from fall-winter dominated precipitation, to summer dominated and then back to fall-winter dominated, are described in greater detail in the chapters on hydrology and geomorphology.

IV. VEGETATION

The type and density of vegetation in the Santa Cruz River basin also directly and indirectly affects the character of the Santa Cruz River. For example, the presence of vegetation affects channel form by stabilizing the channel banks against erosion, and affects flow by withdrawing quantities of water that would otherwise contribute to either surface flow or ***subflow*** in the channel. Vegetation indirectly affects the character of the river by how it impedes runoff during precipitation events. Relationships between vegetation, hydrology and geomorphology are discussed in greater detail in the following chapters on hydrology and geomorphology. The purpose of this chapter is to give a brief survey of vegetation types present in the upper and lower Santa Cruz River basin and to provide a description of how that vegetation has changed since the time of Statehood. The Latin names of all plants mentioned in the following text are listed in Table 1.

A. Vegetation Types

The vegetation cover of the upper Santa Cruz River basin is dominated by semidesert grasslands at elevations between 3000 and 5500 feet, plains grasslands between 4500 and 6000 feet, evergreen woodland between 4000 and 7000 feet, and ponderosa pine and mixed-conifer forests above 7000 feet. Prominent grasses in the semidesert grasslands community are the gammas, threeawns, tobosa, curly mesquite, cotton grass, and bush muhly. The plains grasslands community, in which grasses form a mostly continuous cover, is dominated by such perennial grasses as the gramas, bluestems, plains lovegrass, threeawn, galleta, and plains bristlegrass. Historically, there have been increases in the woody shrubs such as snakeweed and acacia, and in trees such as mesquite and one-seed juniper in the grasslands area. The evergreen woodland community is composed mostly of oaks, the most prevalent being Emory oak, Arizona white oak, and Mexican blue oak. Interspersed among the oaks are alligator juniper, one-seed juniper, and Mexican pinyon. The ponderosa pine and mixed-conifer forests account for only a very small area of the total vegetation cover, occupying the upper parts of the Santa Rita, Santa Catalina, Huachuca, and Rincon mountains. This vegetation community is dominated by ponderosa pine, Douglas fir, and white fir, with some aspen, and Gambel oak.

Riparian forests line some reaches of the Santa Cruz River and its tributaries. Such forests are composed predominantly of cottonwood and willow with dense thickets of mesquite, and other important riparian trees such as Arizona sycamore, velvet ash, walnut, and saltcedar or tamarisk, an introduced tree that has invaded nearly all of southeastern Arizona's major riparian habitats below 5,000 feet.

Table 1. Vegetation Communities in the Santa Cruz River Basin. [Source: Bahre, 1991]

A. Upper Santa Cruz River Basin:

Semidesert Grasslands Community:
- acacia/catclaw (Acacia greggii)
- burroweed (Haplopappus tenuisectus)
- bush muhly (Muhlenbergia porteri)
- cotton grass (Trichachne californica)
- curly mesquite (Hilaria belangeri)
- gammas (Bouteloua spp.)
- mesquite (Prosopis spp.)
- one-seed juniper (Juniperus monosperma)
- snakeweed (Gutierrezia sarothrae)
- threeawns (Aristida spp.)
- tobosa (Hilaria mutica)

Ponderosa Pine and Mixed-Conifer Forests:
- Douglas fir (Pseudotsuga menziesii)
- Gambel oak (Quercus gambelii)
- ponderosa pine (Pinus ponderosa)
- quaking aspen (Populus tremuloides)
- white fir (Abies concolor)

Plains Grasslands Community:
- bluestems (Andropogon spp.)
- galleta (Hilaria jamesii)
- gramas, perennial grasses (Bouteloua spp.)
- plains bristlegrass (Setaria macrostachya).
- plains lovegrass (Eragrostis intermedia)
- threeawn (Aristida spp.)

Evergreen Woodland Community:
- Arizona white oak (Quercus arizonica)
- Emory oak (Quercus emoryi)
- Mexican blue oak (Quercus oblongifolia)
- alligator juniper (Juniperus deppeana)
- one-seed juniper (Juniperus monosperma)
- Mexican pinyon (Pinus cembroides).

Riparian Forests:
- Arizona sycamore (Platanus wrightii)
- cottonwood (Populus fremontii)
- mesquite (mostly P.velutina and P. glandulosa)
- saltcedar or tamarisk (Tamarix chinensis)
- velvet ash (Fraxinus pennsylvanica)
- walnut (Juglans major)
- willow (Salix spp.)

B. Lower Santa Cruz River Basin:

Lower Colorado River Valley Desertscrub Community:
- big galetta (Hilaria rigida)
- bursage (Ambrosia spp.)
- creosote bush (Larrea tridentata)
- saltbush (Atriplex canescens)

Arizona Upland Desertscrub Community:
- acacia/catclaw (Acacia greggii)
- brittlebush (Encelia farinosa)
- bursage (Ambrosia spp.)
- creosote bush (Larrea tridentata)
- foothill paloverde (Cercidium microphyllum)
- ironwood (Olneya tesota)
- ocotillo (Fouquieria splendens)
- saguaro (Carnegiea gigantea)
- teddy bear cholla (Opuntia bigelovii)
- [some annual and perennial grasses]

The present day vegetation cover of the lower Santa Cruz River basin is dominated by two Sonoran desertscrub communities, the lower Colorado River Valley (LCRV) and the Arizona

Upland (AU) communities (Shreve, 1942 and 1951; Bahr, 1991). The LCRV community is composed of creosote bush, bursage, and saltbush, interspersed with species of bunch grasses such as big galetta. The AU community is comprised mostly of foothill paloverde, saguaro, teddy bear cholla, ocotillo, brittlebush, ironwood, catclaw, bursage, and creosote bush, and some annual and perennial grasses.

B. Changes in Vegetation

Human activities have modified the vegetation of the Santa Cruz River basin. Bahre (1991) described historic human impact on vegetation in southeastern Arizona. He found no evidence that the Sonoran desertscrub communities had invaded extensive areas of former grassland or that grassland distribution had changed during the historic period. However, he and other researchers found that there has been a decline in native grasses (attributed to grazing and a slight trend towards aridity) and an increase in woody ***xerophytes*** such as mesquite. The increase in woody trees and shrubs is generally attributed to a combination of overgrazing and wildfire exclusion. Agricultural clearing, wild hay cutting, clearing for urban and rural development, range management policies, and the introduction of exotics are other factors that have caused changes in the grasslands. Also, there have been changes in the cover, density and number of bursage, brittlebush, foothills paloverde, and other native desertscrub dominants that may be related to plant life cycles and/or short-term cycles linked to climatic and other environmental fluctuations.

In the evergreen woodlands, the density of oaks, brush and shrubby trees has increased and decreased in different areas since 1870. Fire suppression policies in this century and grazing have diminished the occurrence of wildfires, allowing brush and shrubby trees to increase and causing a decline in oak regeneration (i.e., due to browsing of oak seedlings and damage to acorns by livestock). Bahre (1991) notes other changes in the evergreen woodlands are due to clearing of native cover for expanding settlement, invasion of exotics, and an increase in oak in areas that have been protected from fire, grazing and fuelwood cutting.

Since the 1850's and 1860's, the native riparian vegetation has largely disappeared or been replaced by exotics (Bahre, 1991). The development of more efficient water pumps in the 1940's led to a boom in irrigated agriculture in southeastern Arizona. Groundwater irrigation between the 1940's and 1970's led to groundwater overdrafts that had a major impact on riparian ***phreatophytes***, killing extensive areas of mesquite and galeria forests. Rea (1983, as summarized in Bahre, 1991) noted several other causes of riparian deterioration in southern Arizona, i.e., overgrazing of arid and adjacent semiarid uplands, excessive woodcutting in watersheds and mesquite *bosques* (forests), overtrapping of beaver and loss of beaver dams, gullying of stream banks and hillsides by trampling of cattle, and cutting unprotected wagon roads.

Overall, riparian habitats in southeastern Arizona have been significantly altered or decreased by extensive groundwater pumping. However, sewage effluent discharge from two sewage treatment plants located adjacent to the Santa Cruz River have led to the establishment of riparian habitat where formerly there was no perennial flow, or the re-establishment of riparian vegetation in reaches of the river where historically there was perennial flow. Such altered reaches of the Santa Cruz are discussed in greater detail in the following chapters.

V. HYDROLOGY

The location and character of surface water in the Santa Cruz River Basin is intrinsically linked to the regional climate, to the level of groundwater, and to the geomorphology of the channel itself. This chapter describes several aspects of the hydrology of the Santa Cruz River basin. It begins with a brief background on the historical and present-day surface water locations. The main section of this chapter is devoted to the description of the average flow conditions (including no-flow conditions) and peak flows as recorded by the six USGS stream gages located throughout the basin. Descriptions of the effects of human activities on river flow and groundwater are interwoven with the discussion of the hydrologic changes throughout this chapter. More detailed information about the changes of the location and character of the surface flow as they relate to geomorphological changes is discussed in the next chapter.

A. Description of Surface Flow and Groundwater

The upper Santa Cruz River is an ***intermittent*** stream, meaning, most of the river flows for only part of the year or only during wet weather, while some short reaches of its course flow throughout the year (Bryan, 1925b); the lower Santa Cruz River has ***ephemeral*** flow that results directly from precipitation. Even in the historical record, only the very largest floods were sustained from the headwaters to the confluence with the Gila River near Laveen. Historically, the Santa Cruz River was perennial above Tubac. Perennial ***subflow*** maintained several marshes (***cienegas***) near Sentinel Peak in Tucson, where a subsurface dike and an impervious layer formed by the convergence of Pleistocene terraces and the bedrock at the foot of the Tucson Mountains forced the groundwater to surface. ***Cienegas*** existed about 10 miles south of Tucson above the San Xavier Mission (the *Agua de la Misión* and the *Punta de Agua,* see Figure 4) and along both the West Branch and the Santa Cruz River proper about 3 miles south of the Congress

Street Crossing in Tucson (Betancourt and Turner, 1988; Halpenny, 1988). Bryan (1922a) observed another *cienega* at the confluence of the Santa Cruz and the Gila Rivers.

In 1949, during the unusually dry period that lasted from 1930 to 1950, the diversion of the Santa Cruz River's flow 19 miles upstream from the Nogales gage began for municipal supply for the city of Nogales, Sonora (USGS Gage Remarks). Because of the increased extraction as Nogales' population has grown and the expansion of irrigated agriculture along the inner valley of the river in Santa Cruz County during the period after the second World War to about 1955, the ***water table*** in the inner valley has been lowered and the ***subflow*** of the river depleted (Halpenny, 1988). The once perennial flow in Sonora, Mexico, is now captured by wells and infiltration galleries for agricultural and municipal use. Today, naturally occurring perennial reaches occur only in the uppermost part of the river in the San Rafael Valley (Betancourt and Turner, 1988).

Two reaches of the upper Santa Cruz River have perennial flow and riparian forests resulting from the discharge of secondary-treated municipal effluent. Discharge of sewage effluent from the treatment plants at Ina Road and Roger Road began in 1970 and has resulted in perennial flow in the channel past the Cortaro streamgage. The second reach, south of Nogales, has had perennial baseflow since the Nogales Wastewater Treatment Plant began discharging effluent into the Santa Cruz at the mouth of Potrero Creek in 1972

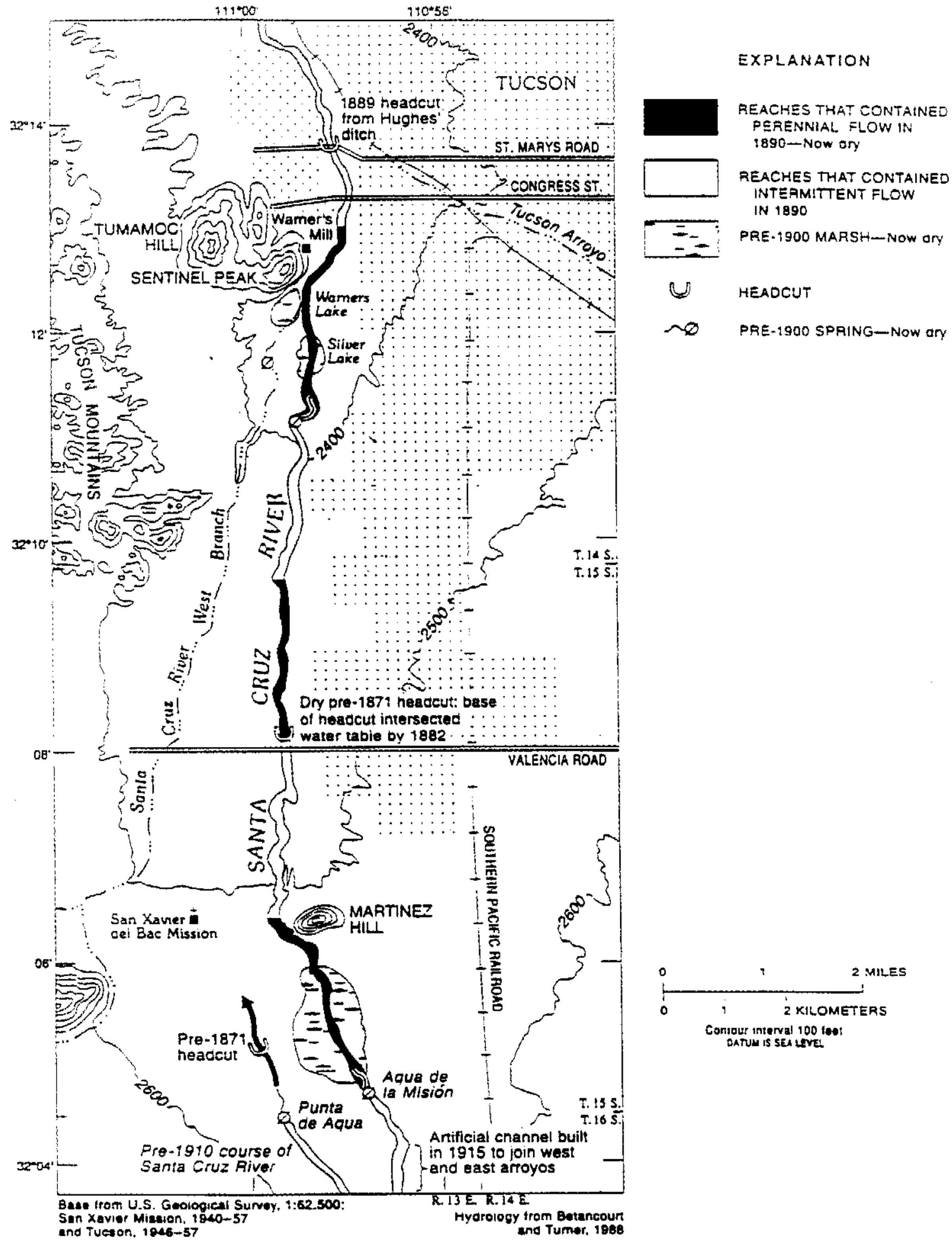


Figure 4. Santa Cruz River in 1988, perennial and intermittent reaches in 1890, and location of headcuts in relation to marshes in the late 19th century. [Source: Parker, 1995. First cited in Betancourt, 1990.]

(Brown *et al*, 1978). The flow is now perennial from the mouth of Potrero Creek to Tubac, as it was during the historical period of 1775-1872, though surface flow becomes underflow near Otero and reemerges upstream from the Rancho Santa Cruz guest ranch, just north of Josephine Canyon. (Applegate, 1981). In winter, the stream frequently flows to just south of Continental Road due to less water consumption by vegetation upstream (Betancourt and Turner, 1990; Halpenny, 1988).

B. Streamflow Characteristics

The goal of this section is to provide a description of the flow characteristics at the time of Statehood and to determine how the flow characteristics have changed over time. We combine information gathered from previous studies with an analysis of annual peak, daily average and monthly average discharge series. The discharge series records are from gages located near Lochiel, Nogales, Continental, Tucson, Cortaro and Laveen, and are of varying lengths and quality. Table 2 lists the period of record and contributing drainage area for each gage. We begin this section with a description of infiltration processes and the no-flow characteristics of the Santa Cruz River channel, and then focus on the characteristics of the daily, monthly and peak discharge series.

Infiltration and No-Flow Conditions. The streambed of the Santa Cruz River is generally quite permeable, and water is lost to the subsurface as flood flows move downstream (Condes de la Torre, 1970). Figure 5 illustrates the reduction by channel losses of the September 12-14, 1965 flow event. Burkham (1970) analyzed two reaches of the upper Santa Cruz River in his study of streamflow depletion by ***infiltration*** in several streams in the Tucson Basin. He found that about 40.2% of the average annual inflow was depleted by infiltration along the 28.5 mile reach between the gaging station at Continental and the gaging station at Tucson. About 29.9% of the inflow was depleted along the 12.3 mile reach between the gaging station at Tucson and the station at Cortaro.

Condes de la Torre (1970) discerned several relevant hydrologic characteristics in his analysis of the time distribution of streamflow. He found by studying ***flow-duration curves*** for the period 1936 to 1963 that streamflow occurred in direct response to precipitation and that snowmelt and groundwater discharge did not contribute sufficient

Table 2. Santa Cruz River U.S. Geological Survey Streamflow Gages.

GAGE	PERIOD OF RECORD (Monthly Flow)	DRAINAGE AREA MI^2
1. LOCHIEL:	Jan. 1949 to May 1990	82.2
2. NOGALES:	Jan. 1913 to June 1922, May 1930 to July 1990	533
3. CONTINENTAL:	May 1940 to Dec. 1946, Oct. 1951 to Sep.1985 Oct. 1989 to July 1989	1,682
4. TUCSON:	Oct. 1905 to Dec. 1907, Jan. 1913 to Sept. 1982	2,222
5. CORTARO:	Oct. 1939 to June 1947, July 1950 to Sept. 1984	3,503
6. LAVEEN:	Jan. 1940 to Sept. 1946, Dec. 1947 to Aug. 1990	8,581

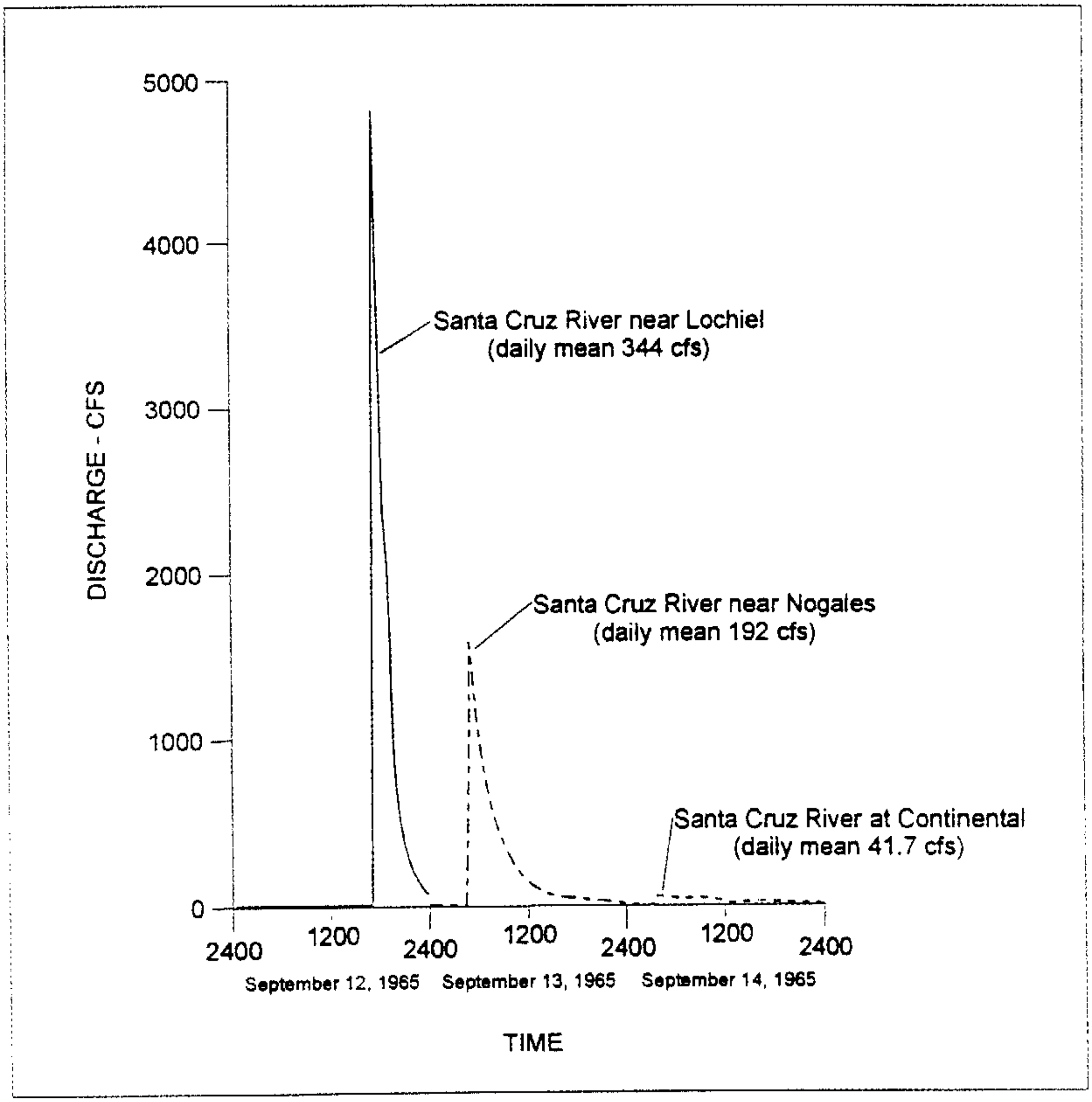


Figure 5. Reduction of the flood peak by channel losses in the Santa Cruz River.
[Source: Condes de la Torre, 1970.]

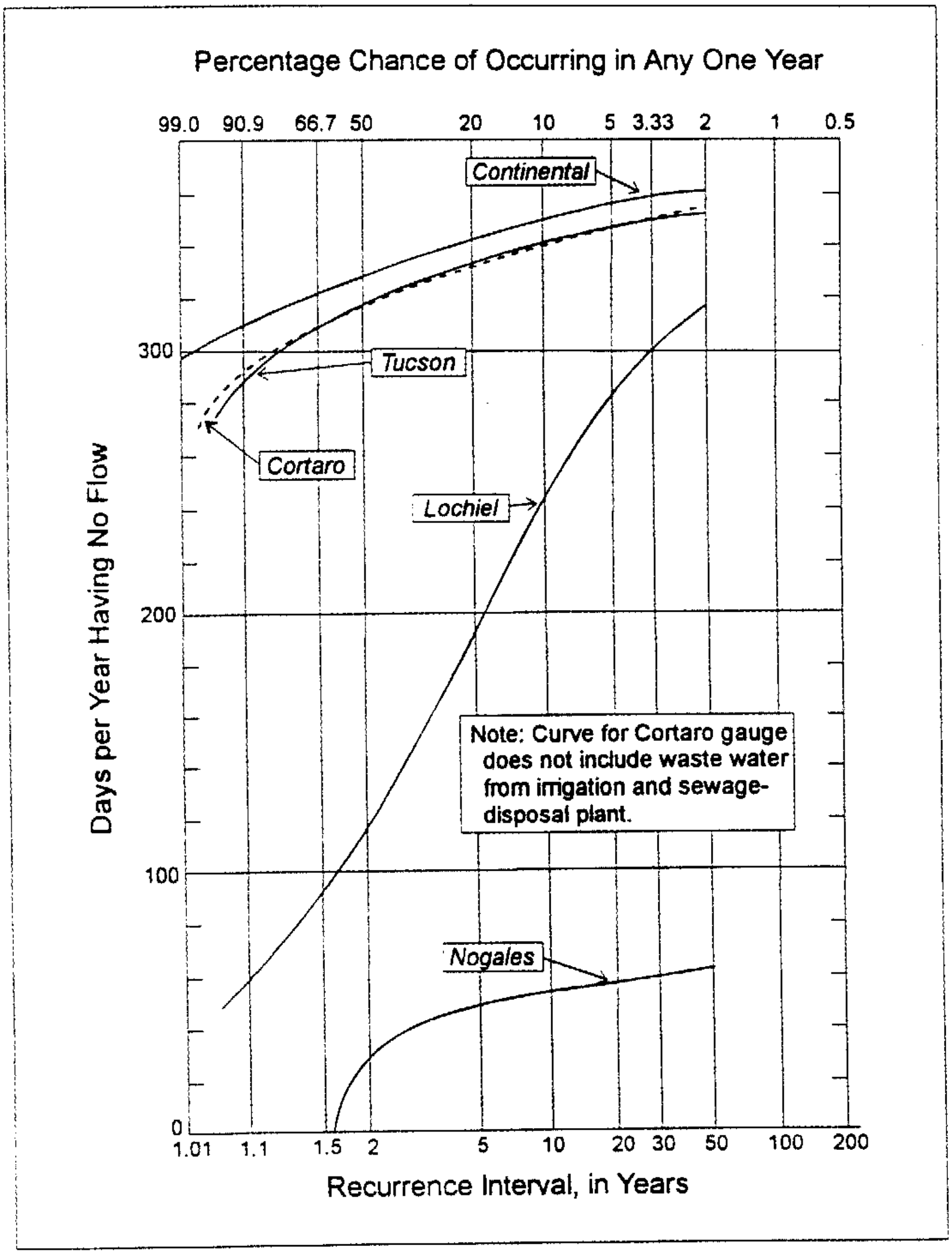


Figure 6. Frequency of days having no flow at selected gaging stations on the Santa Cruz River. [Source: Condes de la Torre, 1970.]

amounts of water to sustain flow at any of the gaged reaches in his study. In his analysis of low flows in the Santa Cruz River basin, he calculated the frequency of days having no flow and their return intervals for the period of record for selected gages (Figure 6). For example, in any future year there is a 50 percent chance of 30 or more days of no flow at Nogales and 328 or more days of no flow at Continental.

Daily Average Flow Characteristics. Summer floods are extremely flashy and rarely last longer than a few days in both the upper and lower Santa Cruz River Basin (Figure 7). Schwalen (1942), in his study of the basin south of Rillito, found that flows in the upper part of the basin tend to be more or less continuous during the winter rainy season. Even in the reach near Tucson, flows may continue for four or five days, and during exceptionally wet winters, such as 1914-1915 and 1992-1993, flow may continue over several months. Figure 8 uses the earliest recorded gage data to provide an example of winter daily flow at Tucson and Nogales near the time of Statehood. Figure 9 illustrates the shift from the continuous winter flow to the sporadic flow of the summer season. The gage record indicates that by the time of Statehood, the Santa Cruz River at Nogales was no longer perennial, but instead had continuous flow during the winter and occasional flow during the spring, summer and fall. The winter discharge averaged about 15 cubic feet per second (cfs) except for an increase caused by a rainfall event that ranged from 35 to 174 cfs. The flow throughout the rest of the year ranged from 0 to 80 cfs. The streamflow record at Tucson indicates a similar seasonal flow pattern: an average daily flow of about 12 cfs during the winter, and during the April to September period there were only five days with recorded flow in that reach.

The daily stream flow of the Santa Cruz River has changed markedly over time in response to climate changes and human activities. Webb and Betancourt (1992) discerned that daily discharges in summer months that were exceeded less than 2 percent of the time were much higher for 1930-59 than for 1915-29 or for 1960-1986, and that daily discharges in fall months that were exceeded less than 2 percent of the time were much less for 1930-59 than before or after. These temporal changes in daily flow characteristics reflect the changes in climate over the past century that were discussed previously.

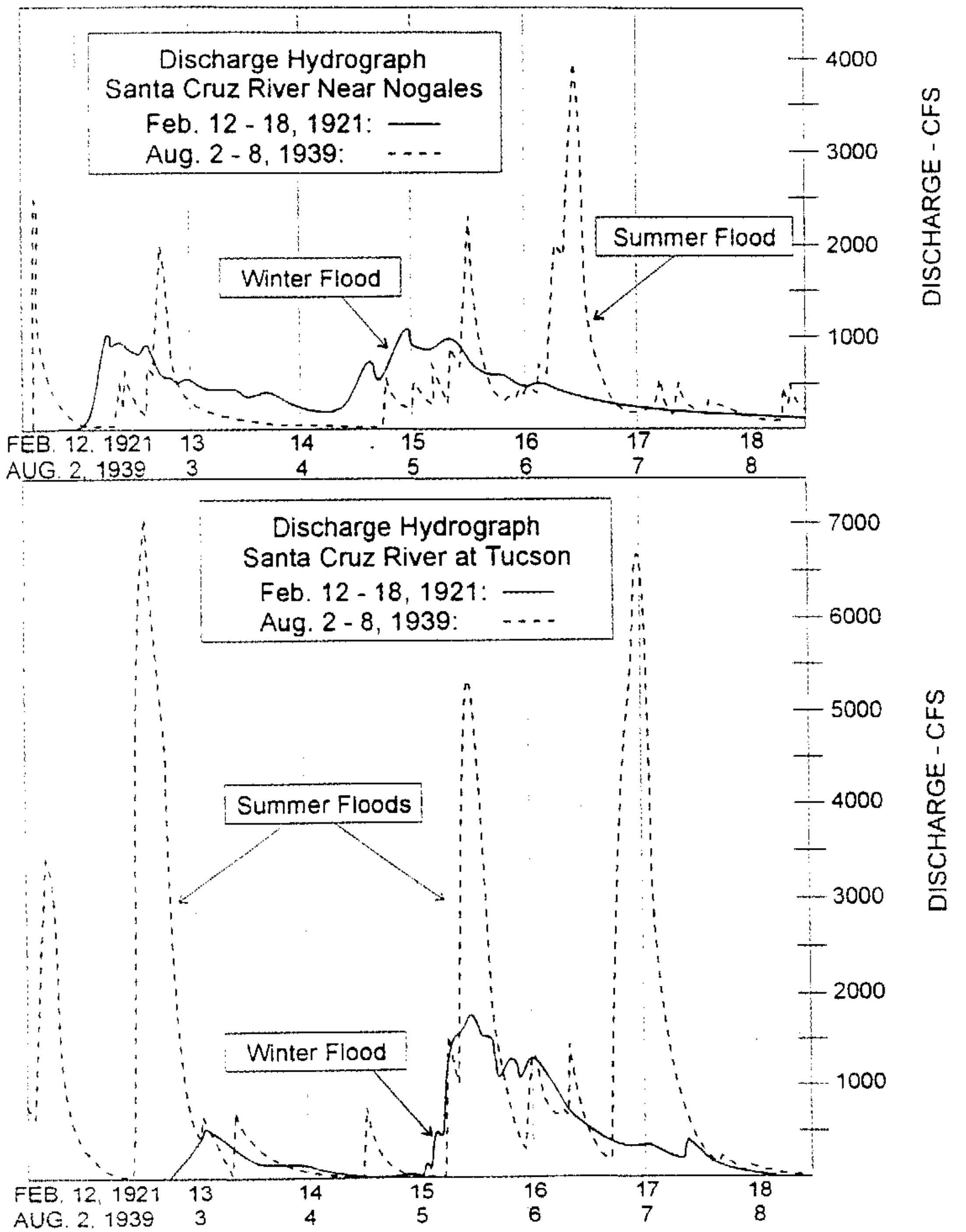
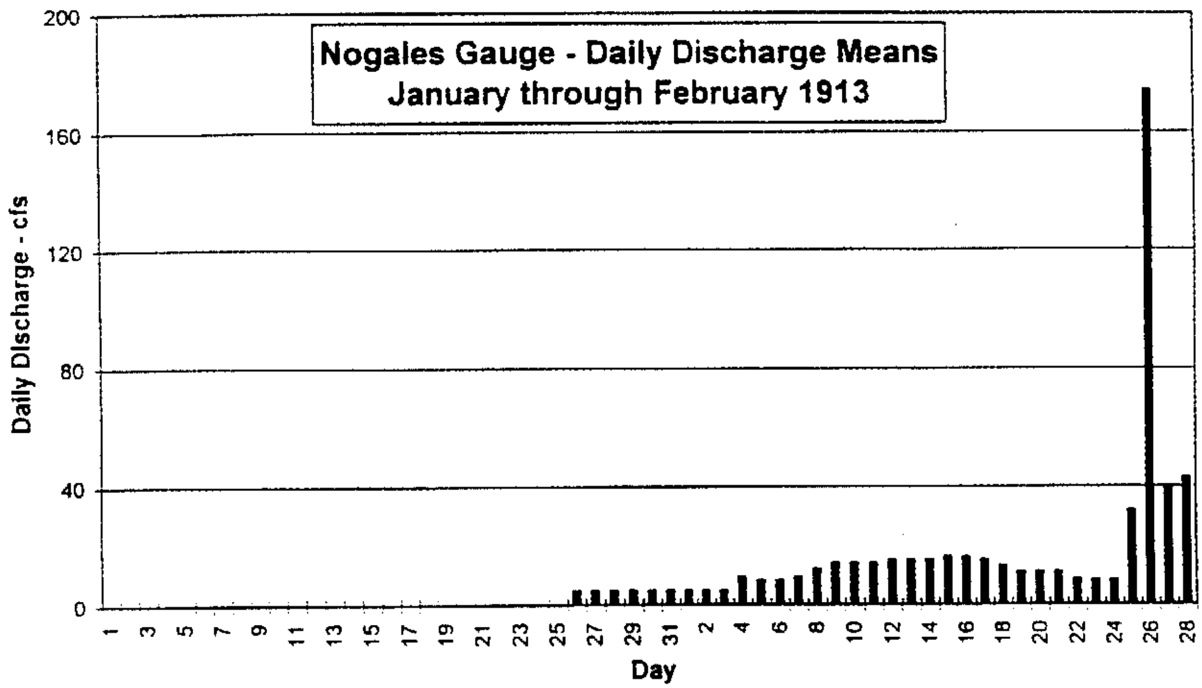
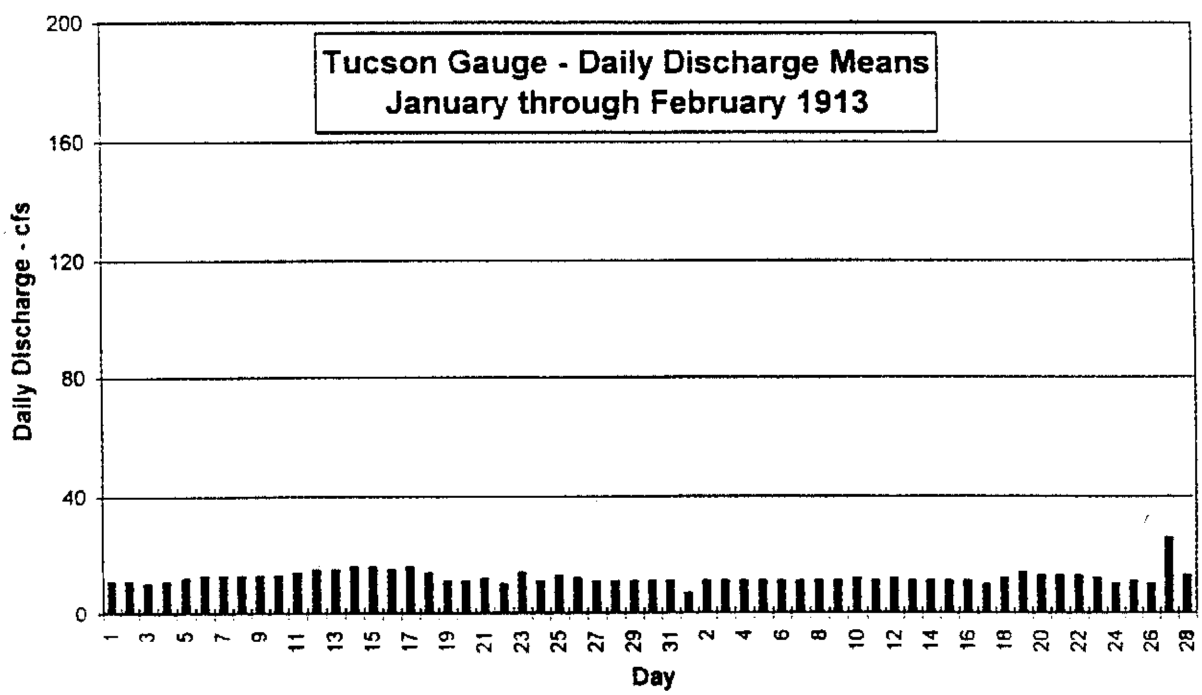


Figure 7. Comparative discharge hydrographs for the Santa Cruz River near Nogales and at Tucson for a summer and winter period of large flow. [Source: Schwalen. 1942.]

Figure 8. Daily discharge data for a winter period at the beginning of the centuy.

Note: the Nogales record began January 26, 1913.





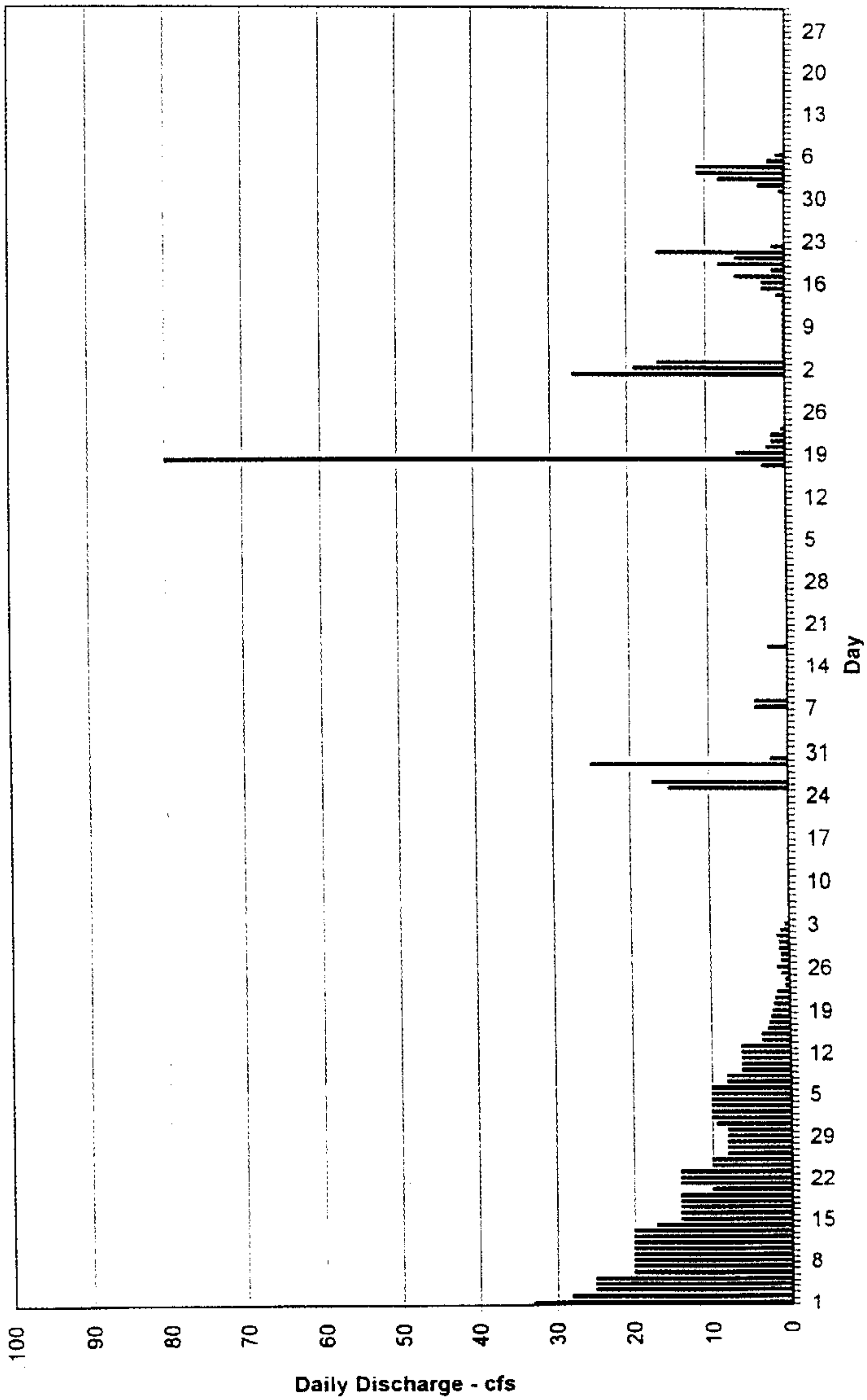


Figure 9a. Daily discharge means at the Nogales gage, March through September, 1913.
Note: days of each month are numbered from left to right, beginning with March 1 and ending with September 30.

Figure 9b. Daily discharge means at the Tucson gage, March through September, 1913.
Note: days of each month are numbered from left to right, beginning with March 1 and ending with September 30.

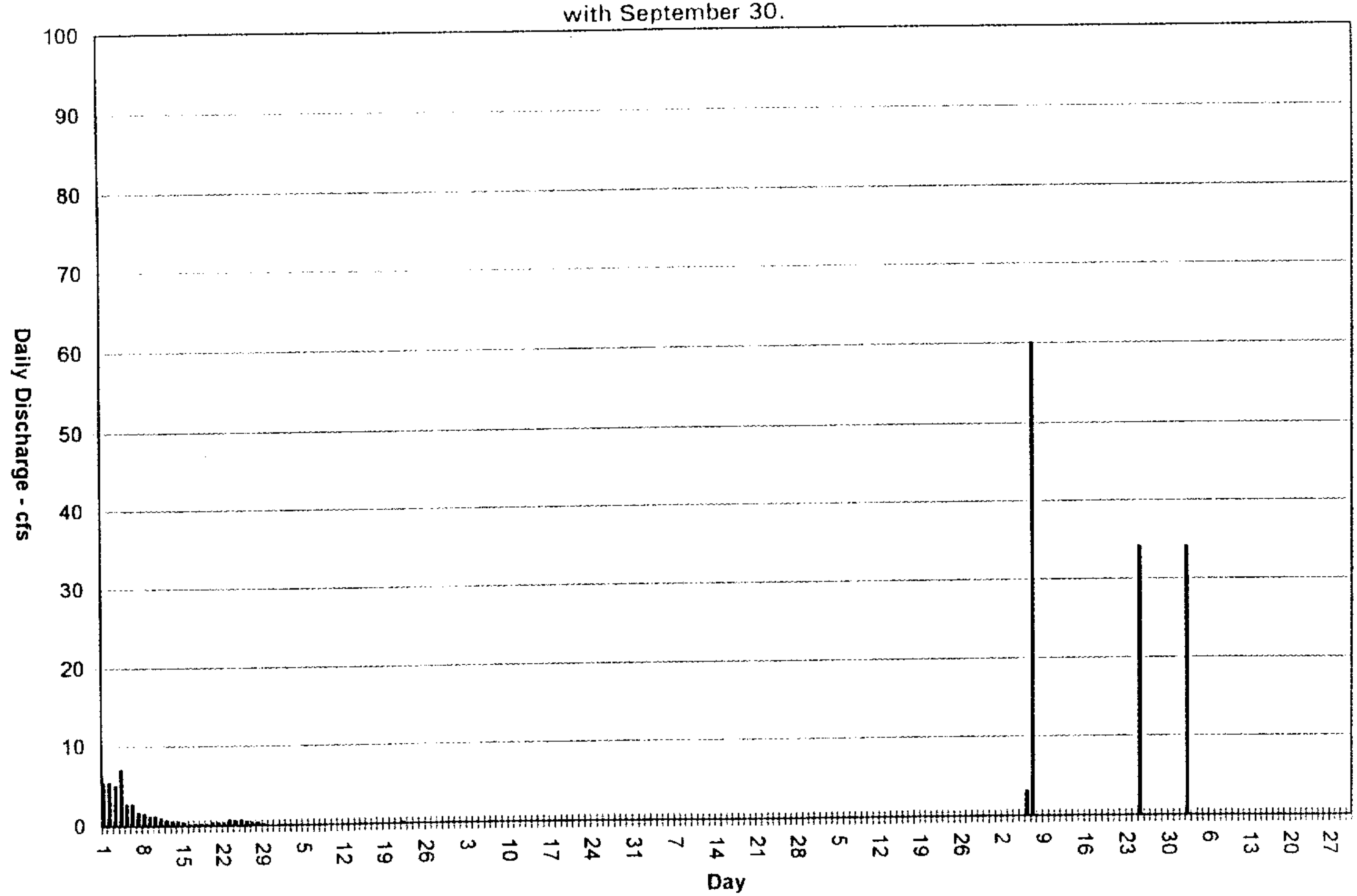
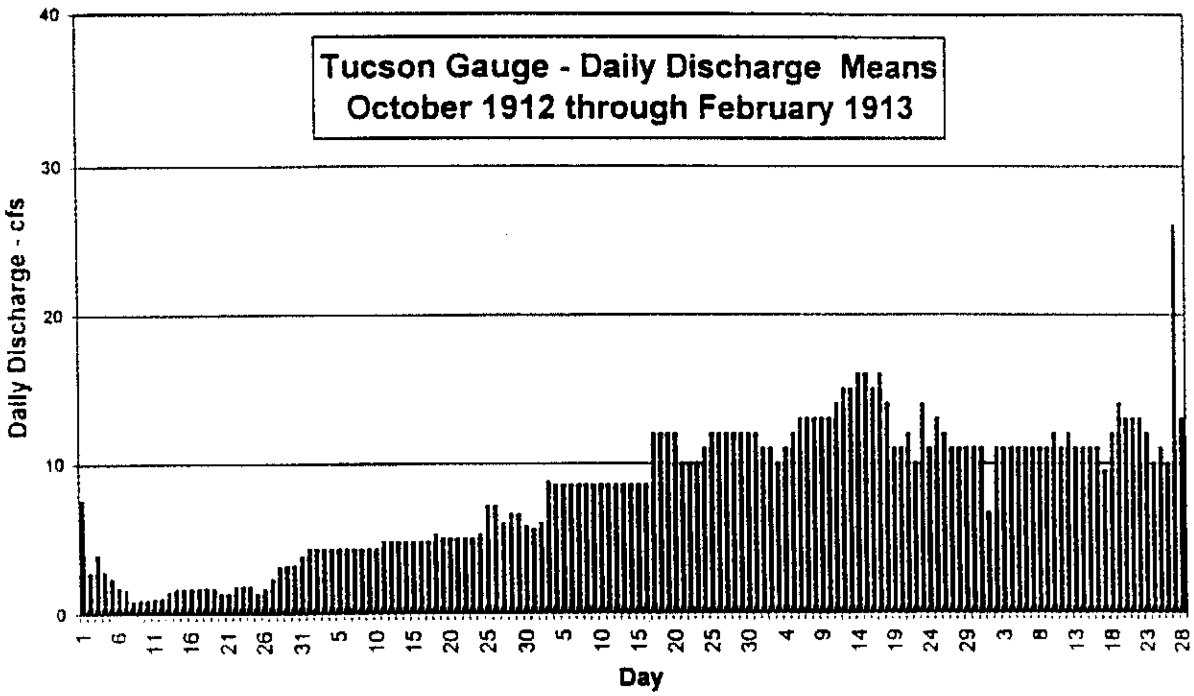
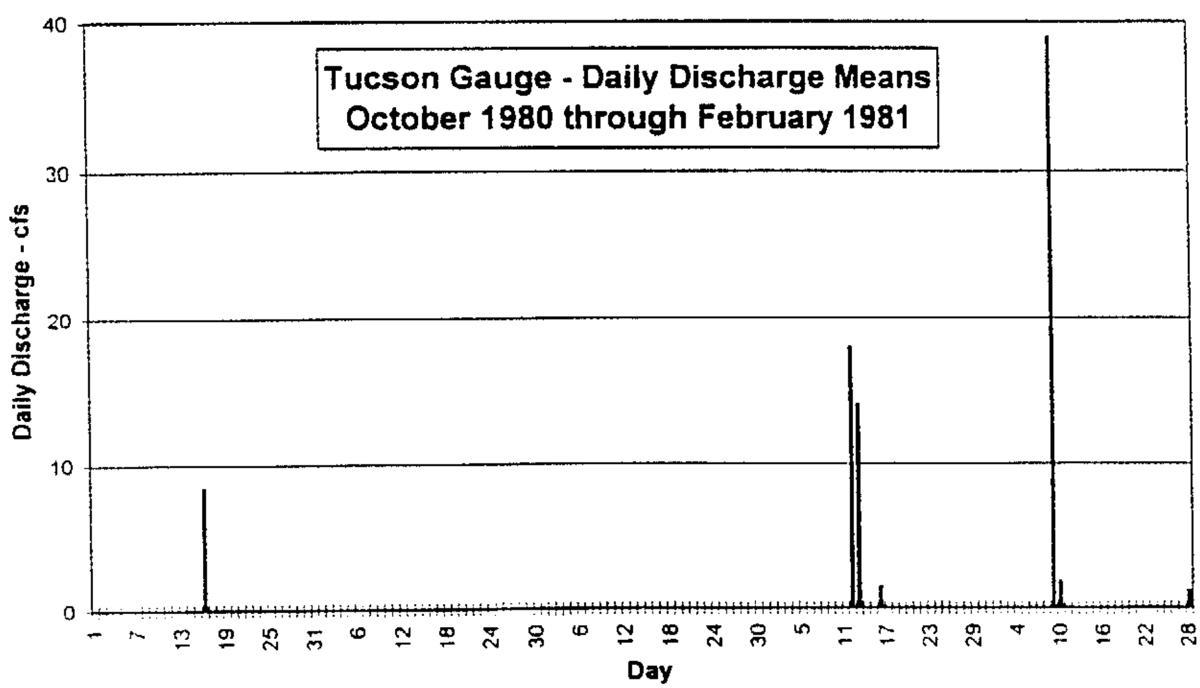


Figure 10. Comparison of daily discharge data for the fall-winter period of 1912-13 and 1980-81.





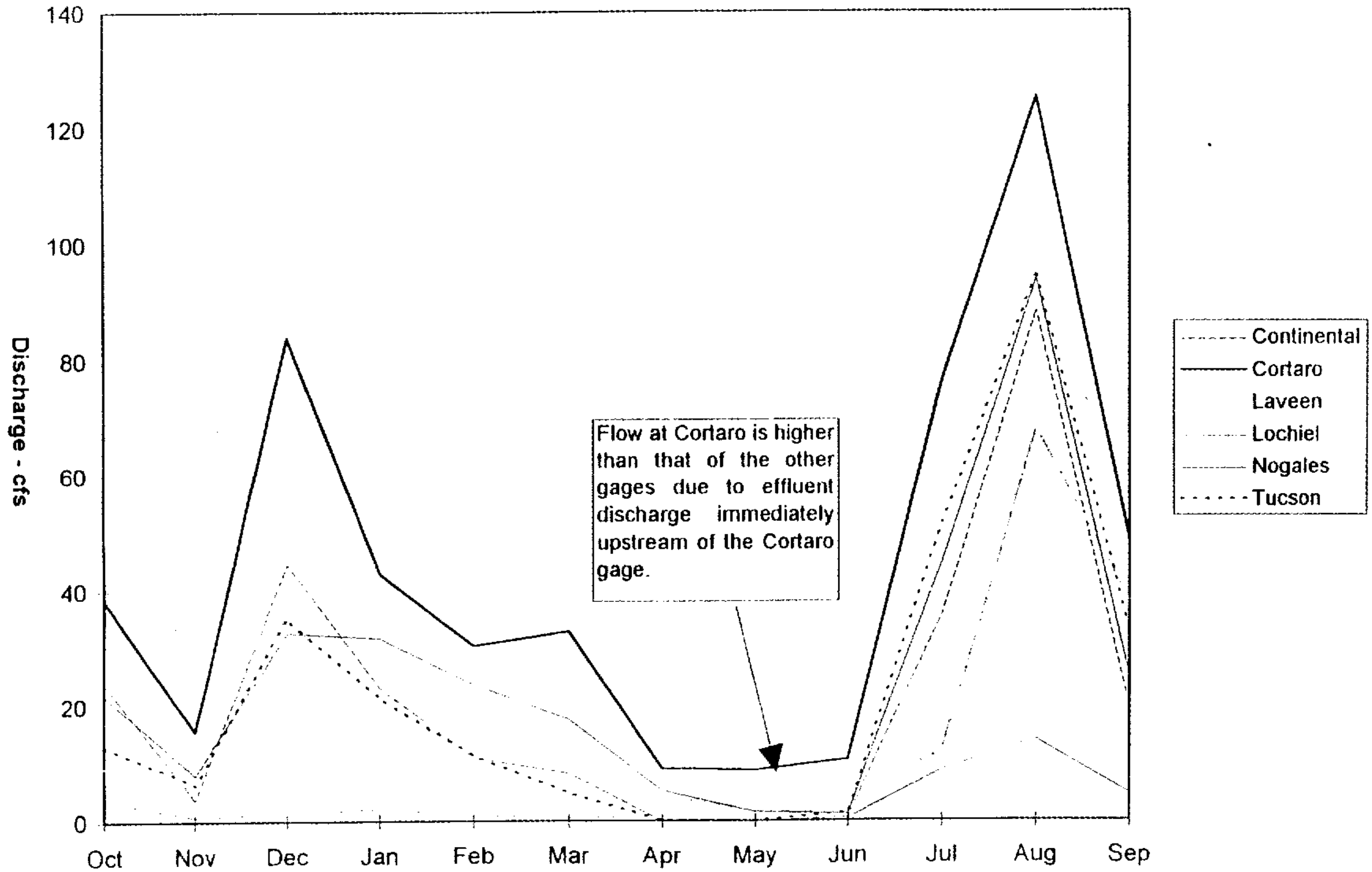
Though much of the change in the hydrologic record can be explained by changes in the climate, some have more direct links to human activities and channel changes. Figure 10 compares the daily flow at Tucson for the period nearest in time to the date of Arizona's Statehood (1912-1913) to the more recent period (1980-1981) measured by the gage before it was deactivated. Although both the 1912-1913 and 1980-1981 records were measured during periods that were dominated by fall and winter flows, the 1980-1981 record does not have the continuous flow that characterizes the 1912-1913 record, and it has much higher daily flow averages. These hydrologic changes resulted from a combination of factors: climate change, the lowering of the water table induced by groundwater pumping, and channel changes such as arroyo development and channelization that are discussed in the next chapter.

The Laveen gage, which was established in 1940 near the confluence of the Santa Cruz and Gila Rivers, apparently also had continuous baseflow until about 1956. During the 1940 to 1956 period, the daily flow averaged about 3 cfs during low flow conditions and had peaks as high as 5060 cfs during wet periods. In 1960, the Santa Cruz at Laveen began to experience no-flow conditions for months at a time. In the following years, the Laveen reach continued to experience months at a time with no flow. Again, this change probably was a result of the combination of climate change, channel incision at that reach, and the dramatic increase in groundwater pumping that occurred in that region during the middle part of the century.

Monthly Average Flow Characteristics. The monthly flow averages illustrated in Figure 11 reflect the seasonality of the precipitation. The peaks occur during the summer and winter seasons. The high frequency of no-flow conditions result in very low monthly averages for April, May and June. The Cortaro gage records the highest monthly averages during drought months because of the input of discharge from the sewage treatment plants upstream.

Figure 12 compares the average monthly discharge and monthly streamflow variability of the Santa Cruz River at Tucson. It shows that the year-to-year variability is less for the summer months than for the fall, winter and spring seasons. Decadal

Figure 11. Monthly flow averages at the six gages on the Santa Cruz River.



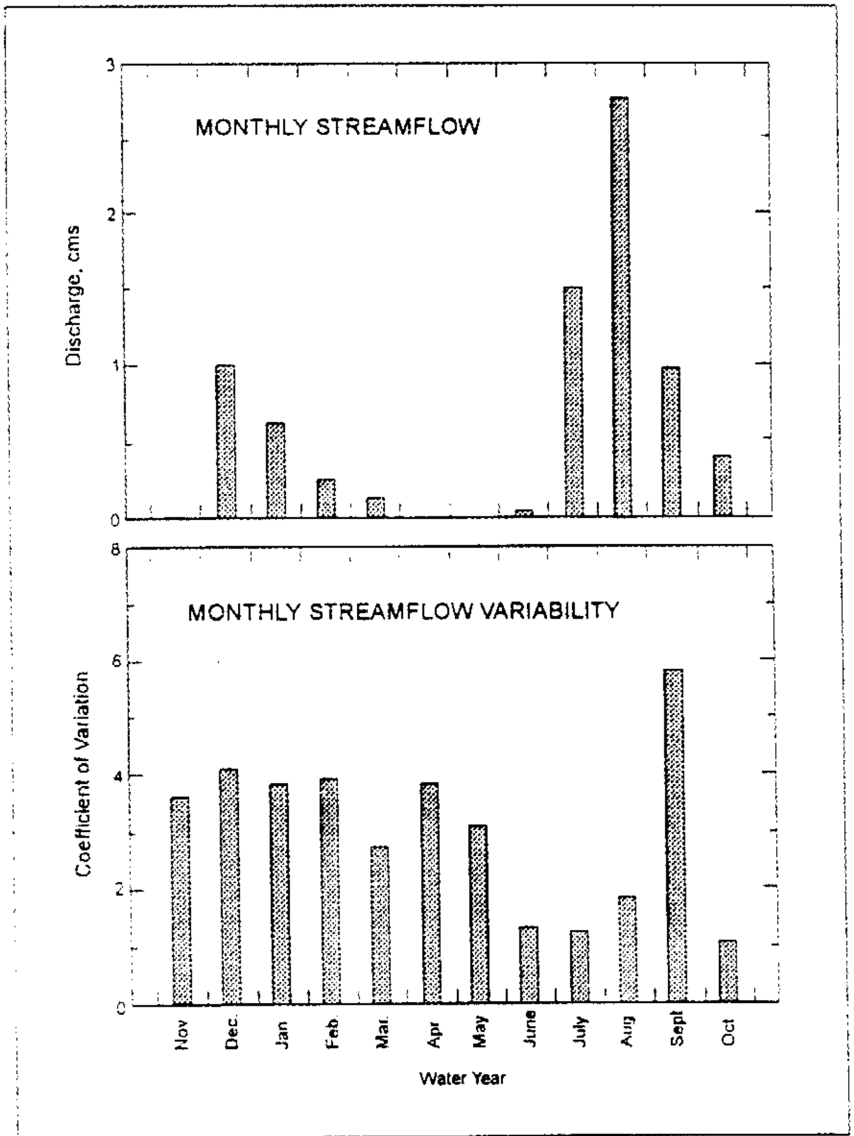


Figure 12. Average monthly streamflow and monthly streamflow variability, Santa Cruz River at Tucson, [Source: Webb and Betancourt, 1992.]

variability in the monthly averages reflects changes in the peak flow characteristics discussed below and are strongly related to climate change.

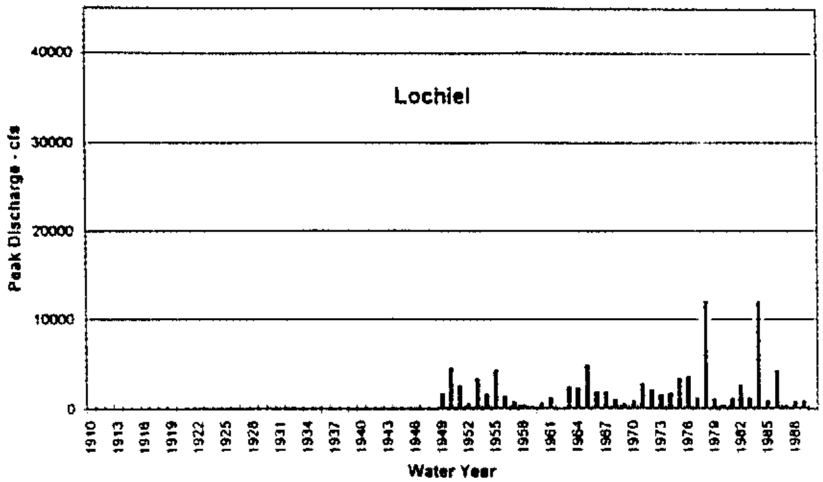
Peak Flow Characteristics. Peak flows in the Santa Cruz River typically result from summer monsoon storms, fall tropical storms and/or cutoff lows and winter frontal storms. Hirschboeck (1985) assigned a hydroclimatic classification to each flow event occurring at selected gauging stations during the period 1950 through 1980. (See Figure 1 for locations of the streamgages.) For the gage at Tucson, 104 of the 140 flow events analyzed occurred during the monsoon season, 18 were attributed to tropical storm and/or cutoff lows, and 11 were attributed to frontal passages. Of the 119 flows analyzed at the gage near Nogales, 95 were attributed to monsoonal weather patterns, 8 to tropical storms/cutoff lows, and 10 to fronts. At Lochiel, 47 of the 56 flows studied were classified as monsoonal, 4 as tropical storms/cutoff lows, and 3 as frontal in origin.

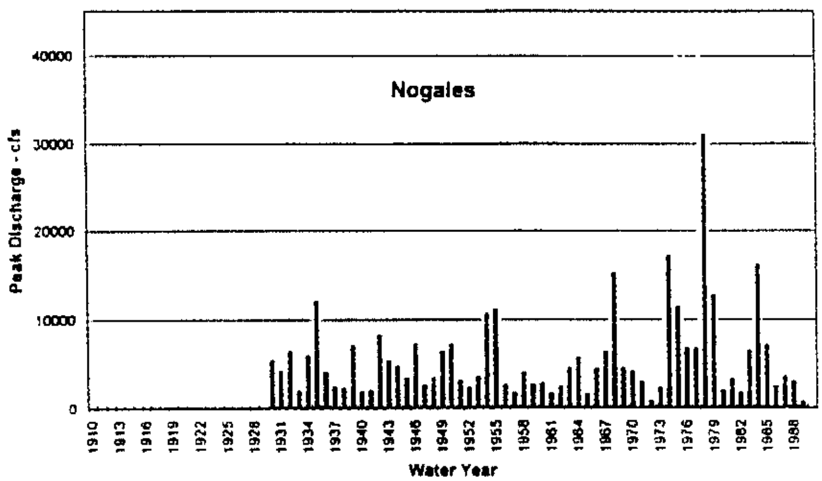
All six gages measured their highest discharges in the latter portions of their records (Figure 13). Webb and Betancourt (1992) argued that the changes in magnitude and seasonality of annual peak flows resulted from climate change rather than channelization and land-use changes:

> "Although land use and changes in channel conveyance undoubtedly have increased flood discharges to some unknown extent, climatic effects are the only common link between the six gauging stations on the Santa Cruz River... At Lochiel, flows in the Santa Cruz River could not have been affected significantly by land use, yet peak discharges have increased since 1960... The August 1984 flood at Lochiel, the peak of record, was larger than the October 1983 flood, which indicates the apparent changes are not caused by a few isolated large floods. Changes in the hydroclimatology of the basin are reflected by a shift in the seasonality of annual peaks, which is also the most striking symptom of the underlying climatic control of flood frequency." (Webb and Betancourt, 1992, p. 23)

Although flood-frequency estimates for the Santa Cruz River are strongly influenced by the extraordinary October 1983 flood, six of the seven largest floods at Tucson occurred after 1960. Winter and fall floods account for 53 percent of annual peaks before 1930, only 3 percent from 1930 to 1959, and 39 percent after 1960. Seven of the eight largest peaks in the flood series were produced by fall or winter storms, and five of these

Figure 13a. Annual peak discharges at Lochiel, Nogales, and Continental.





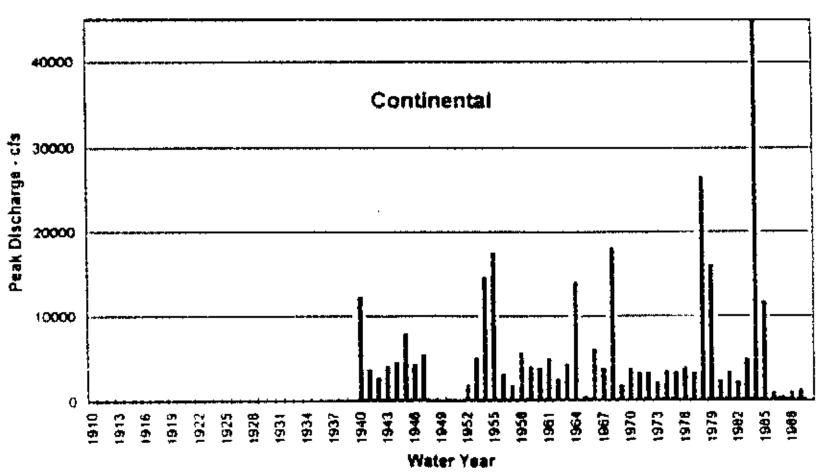
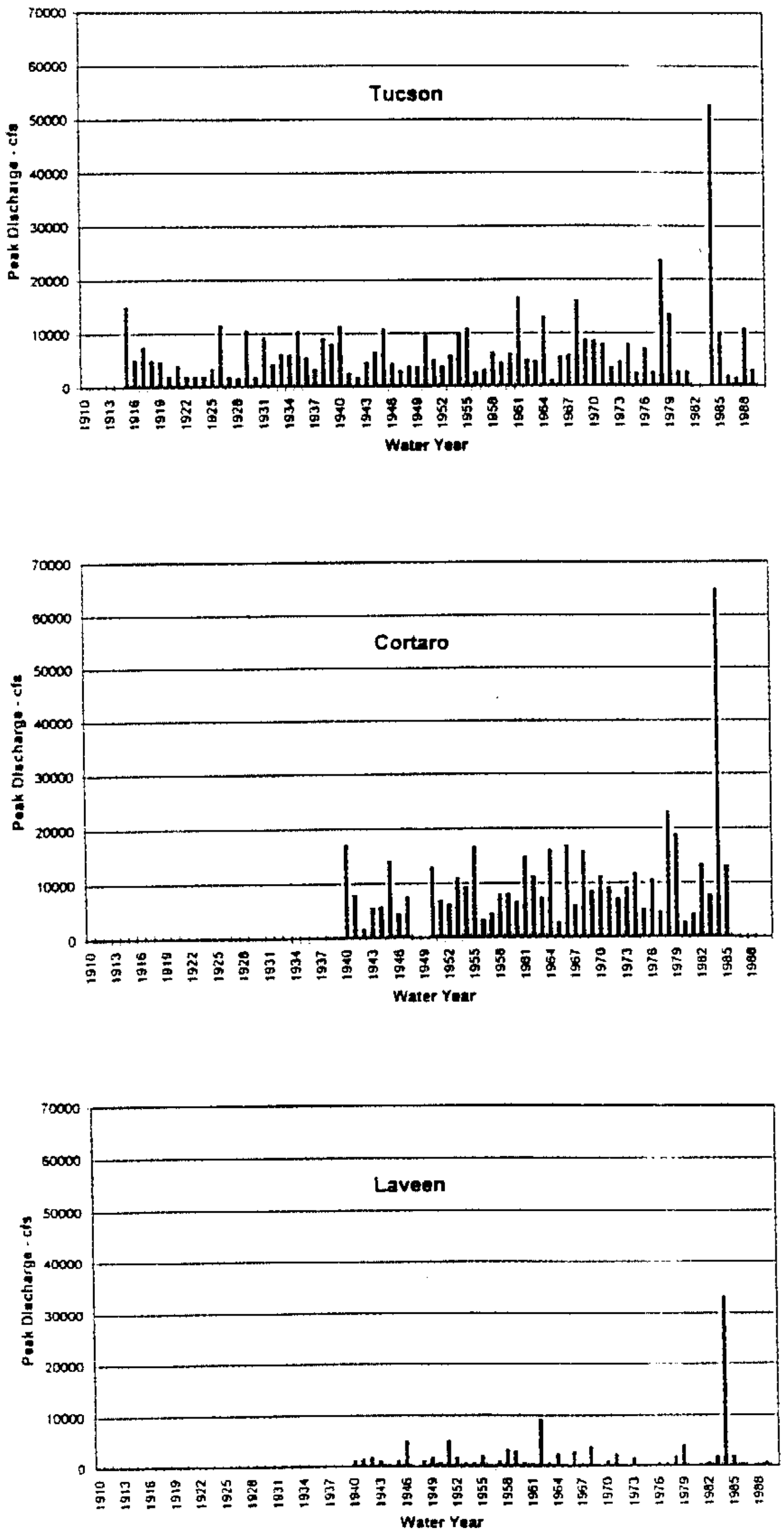


Figure 13b. Annual peak discharges at Tucson, Cortaro, and Laveen.



occurred between 1960 and 1986. Although most of the annual floods at Nogales occurred in summer, four of the six largest floods occurred in fall or winter. Webb and Betancourt (1992) concluded that these changes indicate that the seasonality of flooding is not stationary or random on the Santa Cruz River.

Rhoades (1991) determined that land-use changes in the lower Santa Cruz River basin have affected the peak flood discharges. Since 1962, the construction of flood-control channels in the washes of the lower Santa Cruz basin have resulted in the reduction of floodplain storage and infiltration losses, therefore reducing the *attenuation* -- the downstream decrease of the flood peak -- of peak discharges. Rhoades (1991) compared the input/output volume ratios for the floods of September 1962 and October 1983, both events caused by widespread, heavy precipitation associated with tropical storms. He concluded that attenuation of peak flow was greater during the 1962 flood because water was able to spread out over the broad flow zones in the lower reaches of the Santa Rosa and Santa Cruz washes. In contrast, much of the floodwater during the 1983 flood was efficiently transmitted downstream by the flood-control channels.

VI. GEOMORPHOLOGY

One of the main goals of this study is to determine the nature of channel changes along the Santa Cruz River, especially any changes in location of the channel boundaries since the time of Statehood. To do this, we focused on three objectives: 1) to gather the oldest and most recent aerial photographs and historical and current survey maps of the Santa Cruz River; 2) to compile channel configurations through time (as determined from the aerial photographs and survey maps) onto a single base map; and 3) to integrate historical accounts, previous channel change studies and channel location data.

The temporal and spatial scales of channel change along the upper and lower Santa Cruz River are dramatically different. Channel change in the upper reaches of the river have been on the order of thousands of feet, and they can be detected through the comparison of aerial photographs for one year to photographs of consecutive years. In contrast, changes in the location of the channel in the lower basin can be measured in miles, and due to the nature of the causes of the changes, the timing spans decades of years. For this reason, we developed different strategies for the mapping of channel locations in the upper and lower reaches. For the upper Santa Cruz River north of the Mexico-United States border, we compiled the channel locations discerned from the oldest survey maps (~1904-1916), the oldest aerial photographs (1936), and the most recent aerial photographs (1995) onto 1:24,000-scale base maps. For the lower Santa Cruz River, we compiled the flow paths of several of the largest flow events that occurred on the Santa Cruz River in this century onto one 1:100,000-scale base map.

The first section of this chapter provides a background of the different types of geomorphic processes that result in changes of a river's channel. Examples from along the upper Santa Cruz River are used to illustrate the different types of channel change. Because of the important role that arroyo formation and change play in defining the character of the upper Santa Cruz River, the second section is devoted to a review of the theories of arroyo development and to descriptions of arroyo formation and change along the Santa Cruz River. The third section documents the disparate courses taken by the flood flows of 1914-15 and 1983, with a focus on the effects of the Greene's Canal construction on the flood paths. Descriptions of channel location changes and arroyo development from the literature are integrated with information gathered from our study of aerial photographs and historical survey maps.

A. Types of Channel Change

Channel patterns are a result of the interplay between local geology, precipitation and runoff, sediment influx and movement, vegetation and land-use, and the larger context of the drainage basin (Hays, 1984). Parker (1995) thoroughly reviewed mechanisms of channel and arroyo change on the Santa Cruz River in Pima County. He described three types of lateral change: meander migration, avulsion and meander cutoff, and channel widening. He described two types of vertical change: aggradation and degradation of the channel bed. He determined that the dominant mechanism in each reach depended on channel morphology, channel sediment, bank resistance, and flood magnitude, and he noted that where the channel is entrenched into an arroyo, a combination of fluvial processes and bank retreat mechanisms leads to arroyo change. Table 3 describes the various channel change mechanisms outlined in his review. Hays (1984) noted that soil types bordering the channel reaches affect the stability of channel location, and that banks

Table 3. Channel Change Mechanisms [Source: Parker, 1995]

MECHANISM	DESCRIPTION
Meander migration:	Lateral shifts of centerline position associated with the inception of meanders and their subsequent downstream translation, lateral extension, or rotation of meander axis.
Avulsion:	An abrupt shift in channel position that occurs when overbank flow incises new channels as other channels aggrade and are abandoned.
Meander cutoff:	An abrupt shift in channel position that occurs at meanders and may or may not involve concurrent aggradation of the abandoned channel segment. Meander cutoff and avulsion tend to occur where channels are shallowly incised, the floodplain is active, and aggradation rates generally are high.
Channel widening:	Results primarily from high flows that erode weakly cohesive banks. It is different from arroyo widening because arroyo boundaries may delineate not only a channel but also a floodplain at the bottom of the arroyo. It is product of corrasion by fluvial erosion during rising flow, or mass wasting by of banks following the flow peak.
Vertical change:	Results from changes in stream power, sediment concentration, or resistance that occur as a result of variation in flood magnitude, sediment availability, channel morphology, or local channel gradient. "Degradation and aggradation occur over years to decades and may reflect climatic changes, adjustments to channel widening or narrowing, sediment storage and episodic transport, and natural or artificial changes in channel-hydraulic properties... Degradation and aggradation can alternate in time and space." [Parker, 1995, p.24]

composed of coarser soils tend to be more prone to erosion than those composed of more cohesive soils containing more silts and clays.

Several human modifications have resulted in channel change on the Santa Cruz River (Hays, 1984; Betancourt and Turner, 1990; Rhoades, 1991; Parker, 1995). Nine different categories of modifications and their effects in the upper and lower Santa Cruz River basin are summarized here. The first six modifications listed have had the greatest effect on channel morphology in the Santa Cruz River basin:

1) **Bank protection and bridge construction** stabilize the position of an alluvial channel by preventing the channel from adjusting its dimensions laterally in response to increased discharge. This results in the artificial concentration of streamflow, increases in stream power, and increased peakedness of flood hydrographs. Bank protection also can remove a major sediment source by preventing bank erosion, thus lowering sediment concentrations of a given discharge and enhancing the erosiveness of streamflows. Bridge construction has locally stabilized channel positions in both the San Xavier and Cortaro reaches.

2) **Channelization** typically shortens stream length, increases stream power and decreases attenuation of flood peaks. Both channelization and bank protection initially cause degradation within and upstream from the altered reach, aggradation downstream from the altered reach, and increased erosion at unprotected sites. Continued degradation may result in a period of channel widening by producing steep banks in unprotected reaches that fail readily, while continued aggradation may result in the plugging of downstream channels and a shifting of channel position by avulsion. Channelization has been implemented in several reaches of the Santa Cruz River, most notably in the San Xavier and Tucson reaches of the upper Santa Cruz River, and throughout the lower Santa Cruz River for the purpose of flood control.

3) **Artificial diversion of drainage** diverts flow to a different route or to a reservoir for the purpose of: (a) flood control; (b) irrigation, as was the goal of the Greene's Canal project in the lower Santa Cruz River; or (c) protection from erosion, as in the San Xavier reach in the upper basin.

4) **Obstruction of regional drainage lines** alters flood patterns. The construction of roads, highways, and railroads that trend perpendicular to the courses of washes and streams cause such transportation routes to act as barriers to flow, resulting in widespread inundation immediately upstream. Notable examples of this occur in the lower Santa Cruz River basin where Chuichu Road crosses Greene Wash near Chuichu, where Highway 84 and Interstate 8 cross the Santa Cruz Wash, Greene Wash and Santa Rosa Wash west of Casa Grande, and where the

Southern Pacific Railroad crosses the Santa Rosa and Santa Cruz washes east of Maricopa (Rhoades, 1991).

5) **Artificial narrowing** (i.e. by emplacement of artificial fill along channel margins) may reduce capacity and armor the banks against erosion, producing the same effects as bank protection and channelization. The incision of the channel bottom at Tucson of 9 to 15 feet after 1946 (Aldridge and Eychaner, 1984) may have resulted from the artificial narrowing of the channel by the dumping of garbage and highway construction debris into the channel and adjacent floodplain (Betancourt and Turner, 1988).

6) **Discharge of sewage effluent into downstream reaches** leads to an increase in vegetation that results in more rapid sediment accretion and stabilization of the channel. The Tumacacori and Cortaro reaches dramatically illustrate the effects of the establishment of riparian vegetation that resulted from the perennial flow maintained by sewage effluent.

7) **Dam and reservoir construction** reduces or eliminates the threat of flooding from runoff. The Tat Momolikat Dam in the upper Santa Rosa Wash, completed in 1974, was constructed to control flows originating from the Santa Rosa basin. As footnoted later in this chapter, the dam has not succeeded in eliminating flooding along the lower Santa Rosa Wash.

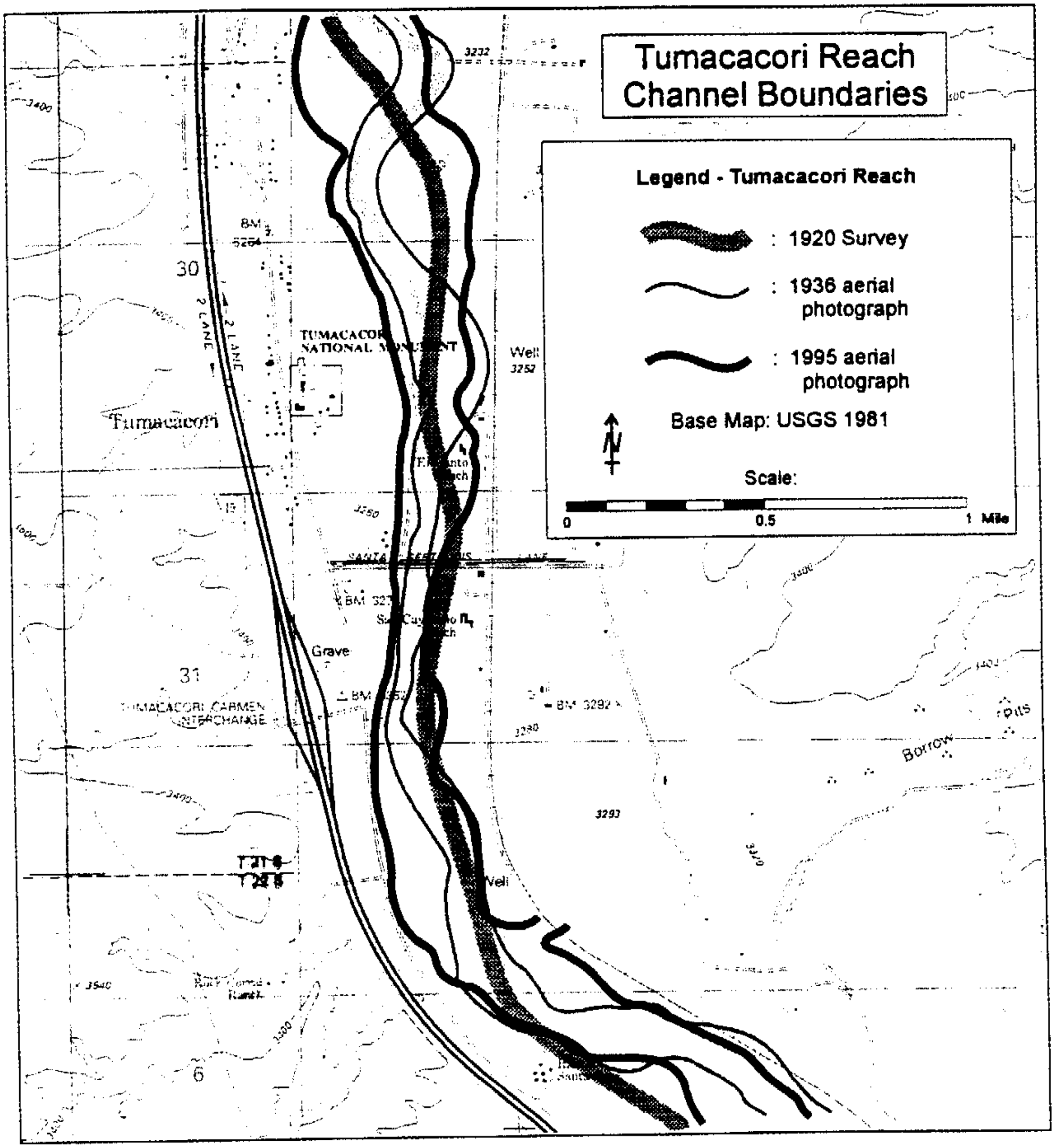
8) **Sand-and-gravel operations** within the floodplain.

9) **Channel-maintenance operations.**

The following sections provide more detailed descriptions of reaches where geomorphic processes and human activities have resulted in dramatic channel change along the Santa Cruz River.

Tumacacori Reach. The reach of the Santa Cruz River near the Tumacacori National Monument (Figure 14) illustrates the effects of channel widening processes. Widening is especially apparent downstream of Tumacacori. Masek and Corkhill (Masek, 1996,

Figure 14



Tumacacori Reach
Channel Boundaries
Legend - Tumacacori Reach
: 1920 Survey
: 1936 aerial photograph
: 1995 aerial photograph
Base Map: USGS 1981
Scale:
0
0.5
1 Mile
N
Tumacacori
TUMACACORI NATIONAL MONUMENT
Well
Grave
30
31
6
Borrow
Pits
3232
3252
3293

personal comm.), using 1954 aerial photographs, observed that the Santa Cruz River in this region was channelized and lacked natural meanders for most of its course downstream of Sonoita Creek. By 1973, Masek and Corkhill observed that the dikes, levees and energy-dissipating structures seen in the 1954 aerial photographs had not been maintained and channel widening had occurred. The flood of October 9-10, 1977, which had a calculated peak discharge of 35,000 cfs at Santa Gertrudis Lane, resulted in several changes in the channel configuration (Applegate, 1981). The flood caused the main channel to become broader and flatter, the low flow channel to change its course in many places, and extensive bank erosion to occur. Applegate (1981) noted that the property owner on the east side built a stone wall to protect his fields, and mechanically widened and cleared the channel for about 1,000 feet of its length. By 1995, the Santa Cruz River had cut new channels, noticeably widened its meanders, eroded farmland, and allowed for the establishment of new cottonwood and willow stands (Masek, 1996, personal comm.).

The Tumacacori reach also illustrates hydraulic and channel changes caused by the re-establishment of riparian vegetation that resulted from the sewage effluent discharge from the International Sewage Treatment plant north of Nogales. Applegate (1981) studied the reach of the Santa Cruz between its confluence with Josephine Canyon and where it crosses Santa Gertrudis Lane, 45 miles south of Tucson and 15 miles north of Nogales. He analyzed large-scale aerial photography that covered the site for ten different time periods from 1965 to 1980 in order to identify channel changes. He found that the average increase in water surface elevation over the reach would have been 2.3 feet for the 10-year flood and 2.0 feet for the 100-year flood from 1967 to September 1977, due to the increased vegetation. After most of the trees were scoured out during the floods of 1977, Applegate estimated that subsequent water surface elevations would have been much lower. Such increases in water surface elevations due to the effects of the increase in vegetation greatly increase the area inundated by flow once the main channel is filled. Figure 15 illustrates the increase in area inundated by the 1967 and 1977 flow events. As can be seen by the 1995 low flow channel illustrated in Figure 16, input of discharge from the sewage treatment plant not only has resulted in re-establishment of riparian vegetation, but also has restored year-round flow to this historically perennial reach.

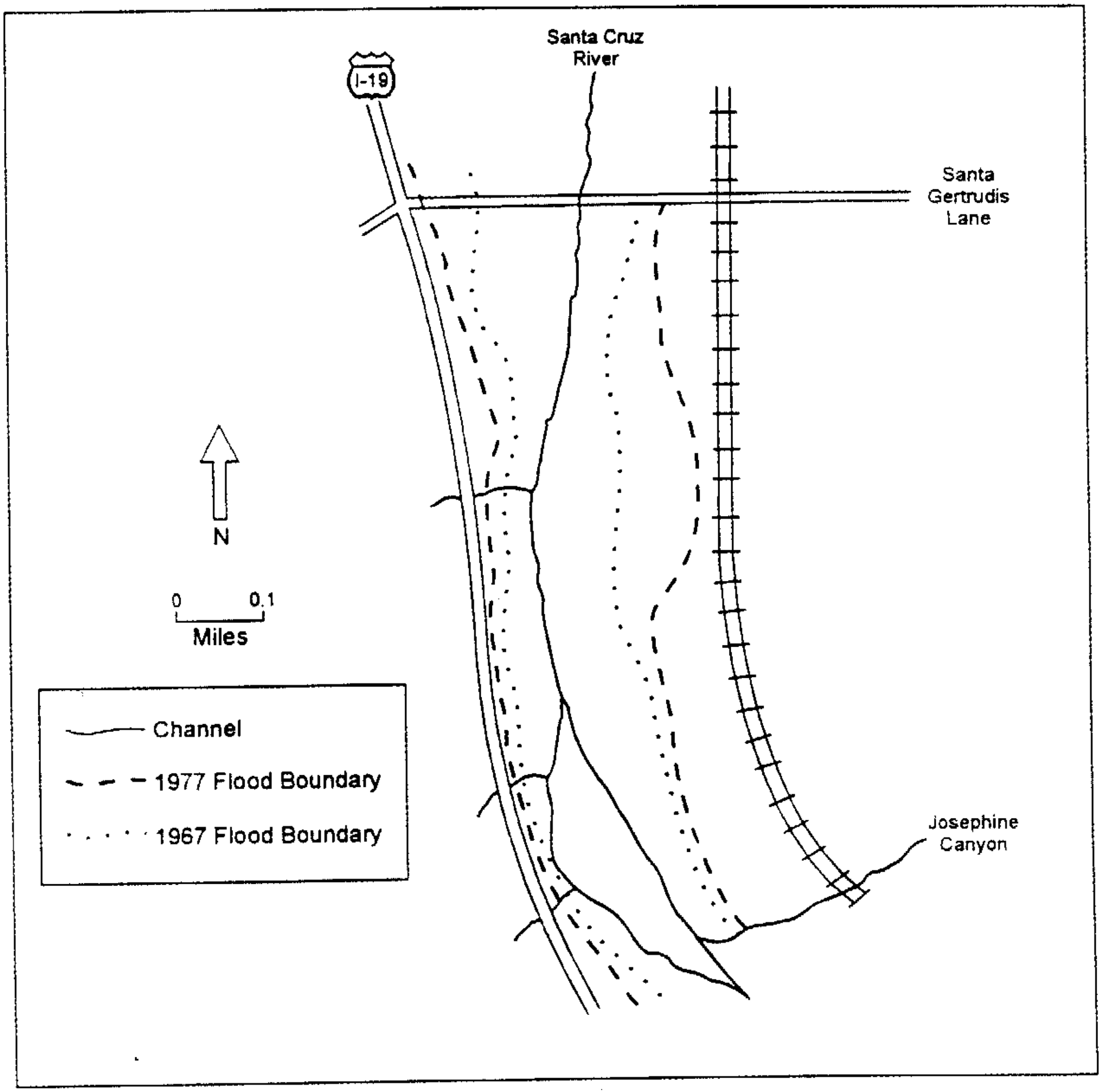
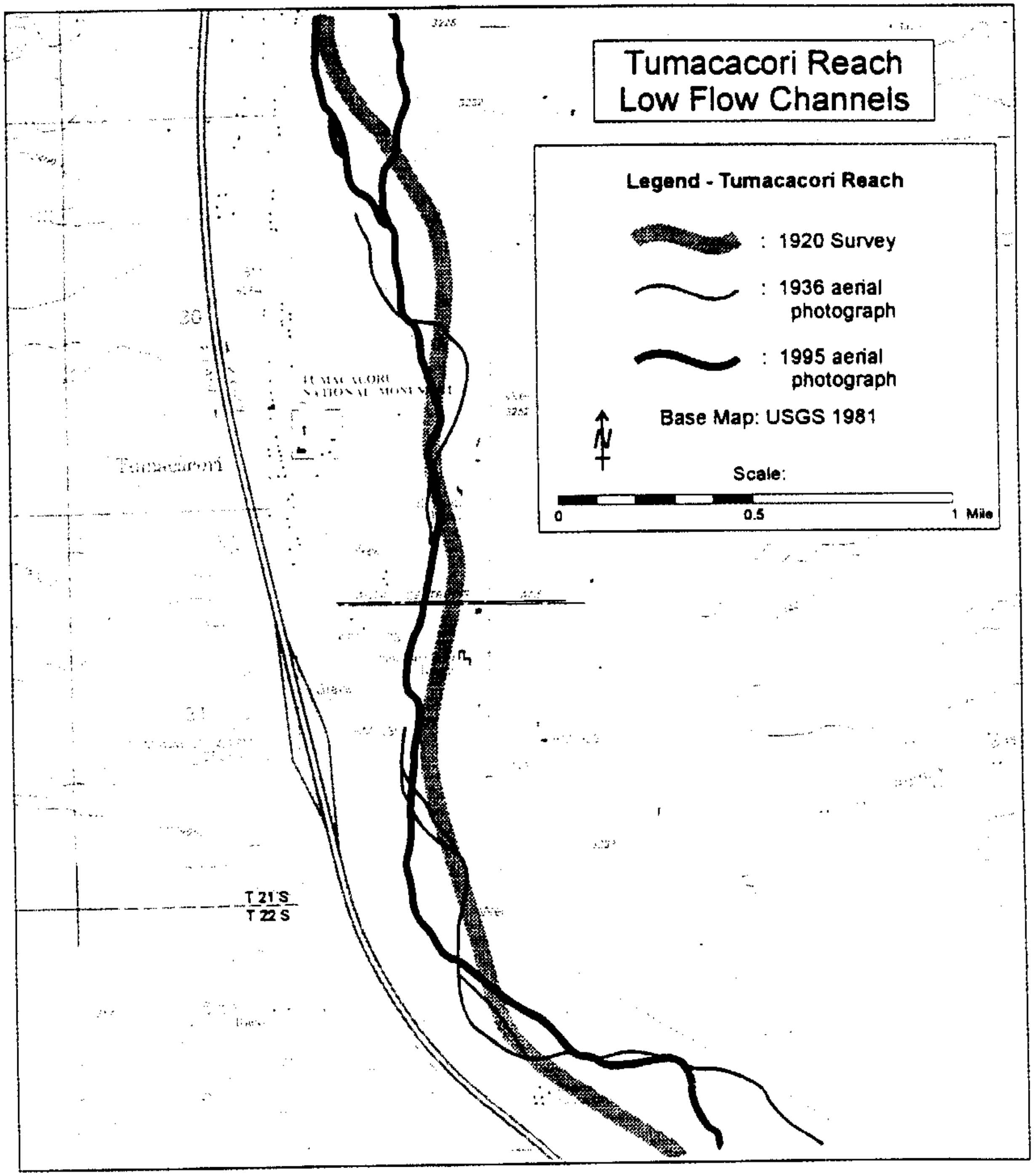


Figure 15. Calculated 100-year flood boundaries for 1967 and September, 1977, for a portion of the Tumacacori Reach of the Santa Cruz River. [Source: Applegate, 1981]

Figure 16


Tumacacori Reach
Low Flow Channels
Legend - Tumacacori Reach
: 1920 Survey
: 1936 aerial photograph
: 1995 aerial photograph
Base Map: USGS 1981
N
Scale:
0
0.5
1 Mile
30
Tumacacori
T 21 S
T 22 S

Marana and Cortaro Reaches. Substantial aggradation, overbank flooding, and stream avulsions have occurred at the northern end of the Tucson Basin and beyond in recent years. Parker (1995) found that the Cortaro and Marana reaches of the Santa Cruz River had the most complex record of channel change since 1936 of all the reaches he studied in Pima County. Between 1936 and 1986, the Marana reach changed from a wide, braided channel to a compound channel that was less than half the width of the channel in 1936. Before 1966 the Marana and Cortaro reaches were sparsely vegetated ephemeral channels that experienced large, frequent shifts in position. At the turn of the century, the channels of these reaches were relatively narrow (Hays, 1984); they were drastically widened by the winter floods of 1914-1915. (See Table 4 for a comparison of channel widths at different sections in 1895 and 1936.) From 1936 to 1982, a period dominated by summer rainfall, there was an overall decrease in channel width from 418 feet to 236 feet. Hays (1984) noted that though the downstream end of the study reach remained braided, much of the length of the study reach had developed into a narrow single channel pattern.

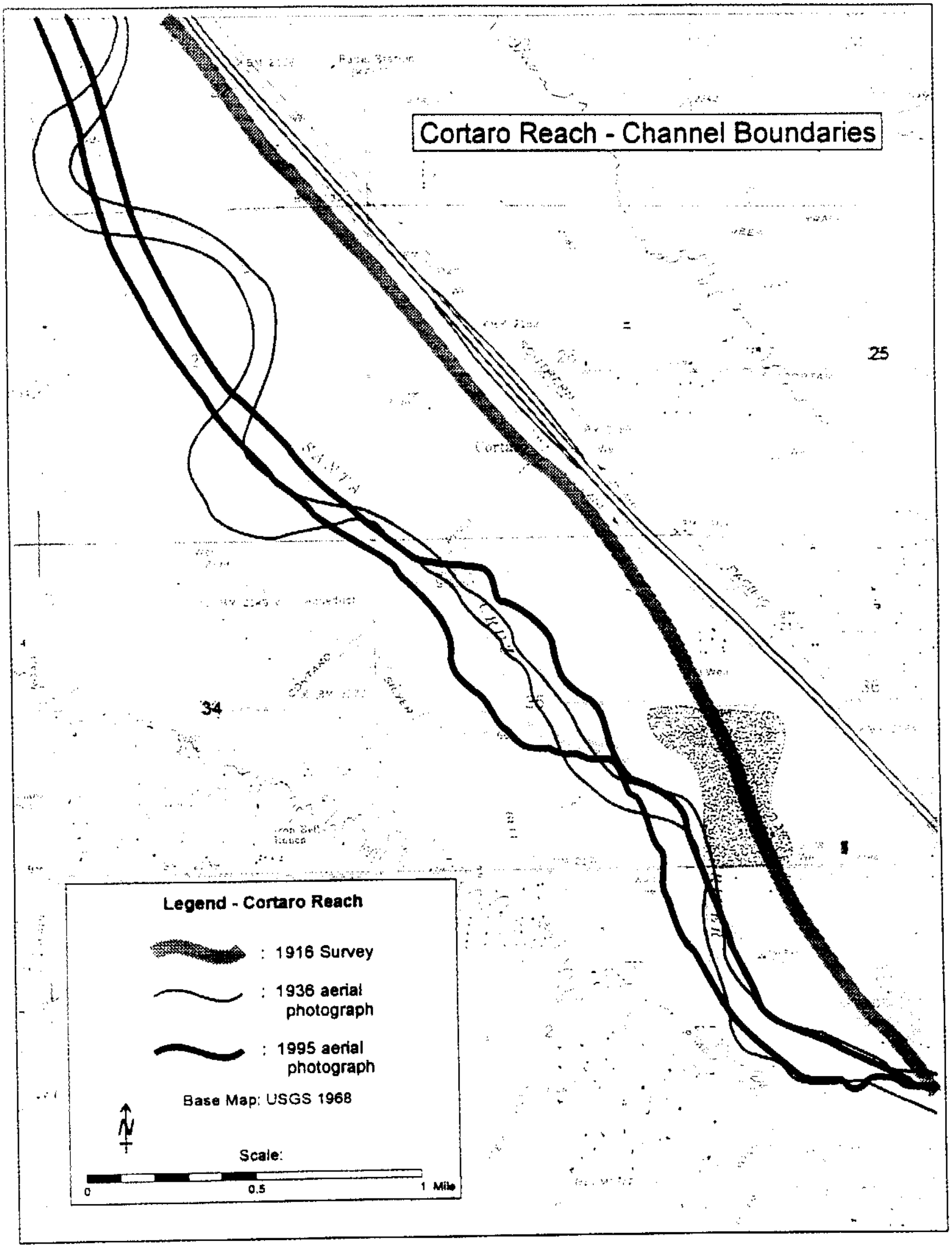
In 1970, when flow from sewage effluent discharge from Pima County's Ina Road and Roger Road treatment plants began, channel morphology became controlled by the low, steady base flows, and the channel became generally more sinuous than previously. The channel was also stabilized by vegetation growth, undergoing little change during the large 1977 flood. As a result of the peak flood of record in October, 1983, channel width widened to a mean width of 477 feet, with a range of 100 to 1300 feet. Figure 17 illustrates the boundaries of the 1916, 1936, 1968 (base map) and 1995 channels in the Cortaro reach. The change in channel boundary locations north of Cortaro Road show the meander migration that occurred between 1916 and 1968. The comparatively straight 1995 channel location indicates the meander cutoffs that resulted from the 1983 floods. The series of unconfined meanders in the Cortaro reach have been undisturbed by channelization throughout the historical period (Parker, 1995). Unconfined meanders do occur on the Marana reach, but they tend to be isolated bends in an otherwise straight channel. These meanders were obliterated between 1976 and 1986 by the flood of 1983.

Channel shifting and widening occurred in the reach near Marana due to overbank flow during fall and winter high flow events (Hays, 1984). During a high discharge, the

Table 4. Comparison of 1895 and 1936 channel widths at selected cross sections downstream of the Cortaro reach illustrated in Figure 17. 1895 channel widths were derived from General Land Office Surveys; 1936 data were obtained from aerial photographs. [Source: Hays, 1984.]

Location	1895 Width (feet)	1936 Width (feet)	Percent Change
Between sec. 7 & 8 T.12 S, R.12 E	99	400	+300
Between sec. 6 & 7 T.12 S, R.12 E	79	170	+120
Between sec. 2 & 3 T.12 S, R.12 E	50	350	+610
Between sec. 3 & 34 T.11 S, R.11 E	152	550	+260
Between sec. 32 & 33 T.11 S, R.11 E	462	670	+150
Between sec. 29 & 30 T.12 S, R.12 E	937	950	+1

Figure 17



Cortaro Reach - Channel Boundaries
25
34
Legend - Cortaro Reach
: 1916 Survey
: 1936 aerial photograph
: 1995 aerial photograph
Base Map: USGS 1968
N
Scale:
0
0.5
1 Mile

flood water followed a direct route down the valley, cutting off meander bends. As the flood flow subsided, the low flow channel established itself along the cutoff routes. In contrast, meander migration occurs through bank erosion during the more typical, less extreme flow events that have occurred after several days of continuous discharge. Channel narrowing has been associated with periods dominated by summer flows that tend to be shorter in duration and smaller in volume, and have a higher sediment concentration than winter flow events (Hays, 1984; Pearthree, 1982). Hays (1984) noted that the most stable reaches of the study area were dominated by an alluvium that was more cohesive due to a higher content of silt and clay, than the coarser alluviums that characterized the least stable reaches.

B. Arroyo Development: Theories and Examples from the Upper Santa Cruz River

Over the last century, several theories explaining the causes for arroyo initiation in the American Southwest have been developed and refined. The following sections review these theories, describe arroyo development along the Santa Cruz River, and provide illustrations showing how the Santa Cruz River arroyos have changed since the time of Statehood. In the convention established by Bryan (1922a) and refined by Antevs (1952), we use the term "wash" where the banks of a river or stream are low and there are multiple channels, and the term "arroyo" when there is a single channel incised in unconsolidated material consisting of clay, silt, sand and some gravel, with banks more than two feet high.

Theories. Antevs (1952) summarized the principal suggested causes of modern trenching given in the literature at that time as:

> "1. Overgrazing, trampling, and human activities, which reduced or destroyed the vegetative cover and made trails, ruts, and ditches, which, in turn, led to greatly accelerated and concentrated runoff, resulting in violently erosive flash floods after torrential rains.
>
> "2. Increase in moisture, which induced denser vegetation, and longer, steadier, and clearer streams with considerable erosive power in the valleys.
>
> "3. Sudden violent showers followed by unobstructed runoff, together with grazing and forest-cutting.
>
> "4. Increasing dryness of climate, which reduced the vegetation and promoted the runoff, which, in turn, enlarged the magnitude and the erosive and transporting power of floods. (Antevs, 1952, p. 376)"

Through his analysis of ancient and modern channeling and filling in the southwestern United States, Antevs (1952) determined that natural arroyo-cutting takes place during drought periods. However, Antevs noted that the above-normal rainfall from 1905 to 1923 or 1932 did not distinctly improve or restore the plant cover and lead to filling of the trenched channels. He also noted that protection from livestock grazing and trampling did enable the vegetation on the grounds of the Desert Laboratory at Tucson to make a remarkable recovery, even during the 1928-1936 period of average rainfall conditions. Antevs therefore considers the ultimate cause of modern arroyo-cutting in the Southwest to be overgrazing since about 1875.

Cooke and Reeves (1976) made two observations of possible climatic change since 1865 that may have affected the development of arroyos in southern Arizona. They noted that the frequency of light rains was lower and the frequency of heavy rains higher at the end of the 19th century than during the 20th century. The lower frequency of light rains could have resulted in a depletion of grasses and other shallow-rooted plants, causing a reduction in surface cover. Increased runoff at that time may have resulted from the heavy rains. The second observation of climatic change made by Cooke and Reeves (1976) was that droughts are often terminated by relatively wet years. Vegetation probably was depleted during the droughts and did not have time to recover during the following wet periods. As a result, runoff and erosion were increased during the heavy rains at that time. Cooke and Reeves also noted that while the pattern of droughts followed by wet years was important in the development of arroyos, there was no evidence to prove that this pattern was peculiar to this time period.

Betancourt and Turner (1990) divided explanations for arroyo-cutting into five general categories: livestock grazing, direct and indirect manipulation of streamflow by man, climatic change, extraordinary floods, and intrinsic geomorphic factors. They noted that both erosional and depositional phases have been linked to cyclical drought. The underlying climatic interpretation of the cutting and filling cycles is the assumption that vegetative cover is the immediate factor affecting erosion, which is controlled by precipitation. Several researchers (i.e. Thornthwaite *et al*, 1942; Leopold, 1951; Martin, 1963; Cooke and Reeves, 1976; Bull, 1964; Hansen *et al*, 1977) have addressed the possible effects of changes in frequency of rainfall intensities on plant productivity and alluvial processes. Betancourt and Turner (1990), after summarizing the different hypotheses, found the different rainfall intensity hypotheses to be inconclusive for two reasons: (1) there are uncertainties in how light versus heavy rains affect vegetation across the broad range of ecological settings that experienced arroyo cutting; and (2) secular trends in rainfall intensity may not be unique to the last hundred years; such trends may characterize other times when arroyos failed to develop but we do not have adequate climatic data to define the trends precisely. They did find agreement in the literature that initial downcutting was associated with extraordinary floods. They noted that, over the past century, most channel erosion in the Southwest was accomplished by large floods during the relatively wet periods of 1884-1891, 1904-1920, and 1965-1987. Recent hydrologic analyses of dated slackwater deposits in bedrock canyons suggest that floods of the past century represent the largest events for periods of up to 2000 years (Baker, 1985). On the Escalante River in Utah, such hydrologic analyses indicated that paleofloods recorded by slackwater deposits in bedrock canyons coincide with the formation of paleoarroyos in alluvial reaches (Webb, 1985).

Betancourt and Turner's 1990 survey and synthesis of historical anecdotes establish a link between initial arroyos and human modifications of the floodplain. They also note that, while many authors considered the widespread erosion that occurred during A.D. 1100-1400 to be unrelated to human activity, prehistoric farmers during this period (i.e., Anasazi on the Colorado Plateau and Hohokom in the Sonoran Desert), may have outnumbered the rural population in the Southwest in the late 19th century, and that these prehistoric farmers harnessed streamflow to grow crops in a similar manner to the Europeans.

Arroyo Development on the Santa Cruz River. The Santa Cruz River system had arroyos no more than a few miles long separated by 12- to 20 -mile-long reaches of unincised alluvium before 1880 (Betancourt and Turner, 1988). For example, the reach below the present site of Valencia Road was described in 1871 as having a channel with vertical banks 60 feet apart and up to 10 feet high (Foreman, 1871, as quoted in Betancourt and Turner, 1988). Since then, a 50-mile-long arroyo through the Tucson Basin has formed, separating relatively unincised reaches upstream and downstream on the Santa Cruz River. Bryan (1925a) and Thornber (1910) place the timing of initial development of large, continuous arroyos on the Santa Cruz River at 1885 to 1890. Thus, arroyo development along the Santa Cruz River began before the time of Statehood.

Schwalen (1942) noted that the deepest arroyo entrenchment is between Continental and Tucson, and a short stretch about a mile and one half above the town of Santa Cruz, Mexico. Betancourt and Turner (1990) noted that the short discontinuous arroyo in Mexico is the only entrenched segment of the river upstream of the Tucson Basin. The Santa Cruz River is entrenched most dramatically within the San Xavier Indian Reservation, with vertical banks up to 30 feet high and 300 feet apart where the river meanders around the base of Martinez Hill.

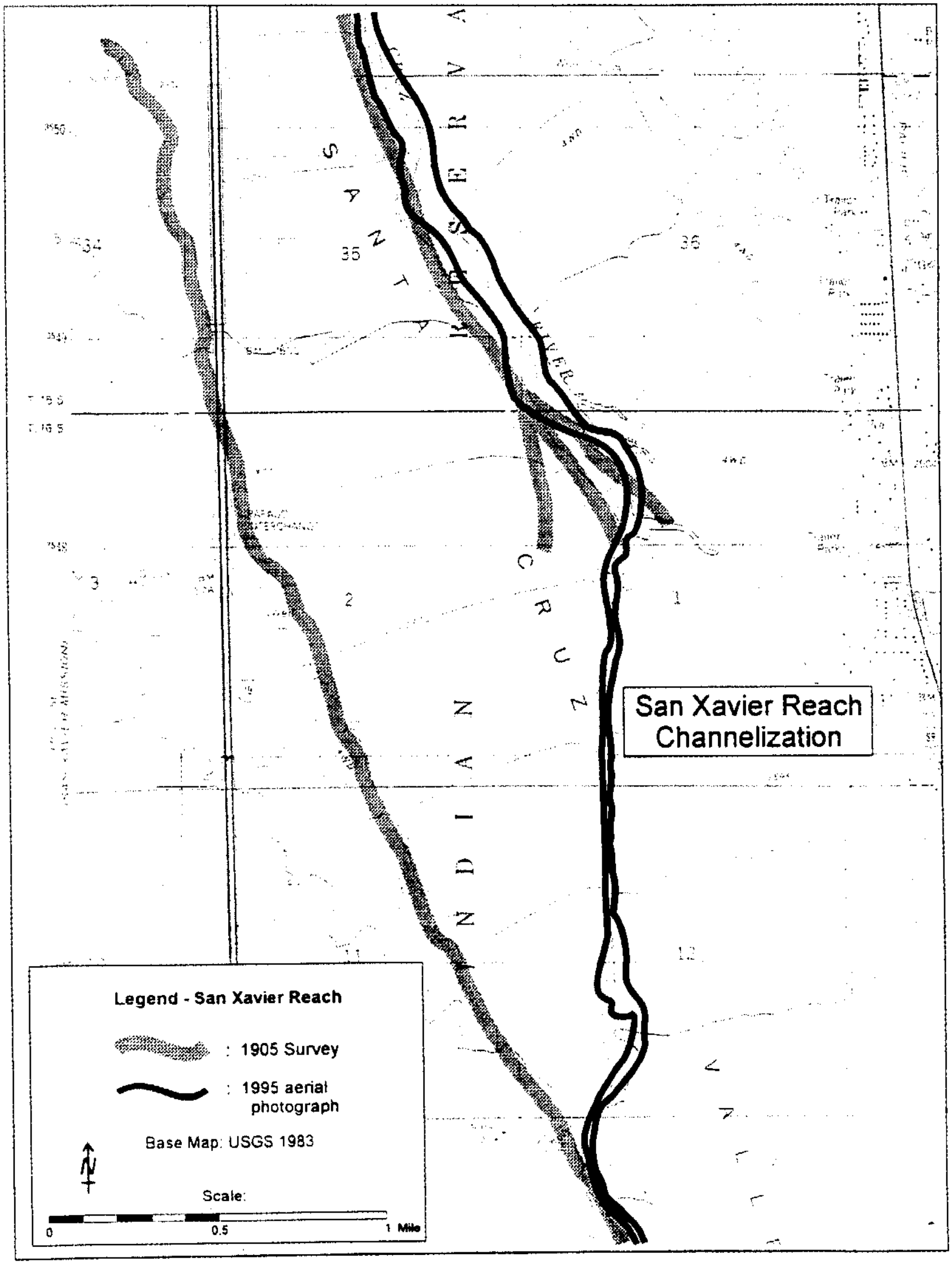
Cooke and Reeves (1976) note that entrenchment in the lower Santa Cruz River Valley is confined to the arroyo along Greene's Canal and to the 5 to 6 mile-long trench that extends south from the Gila River, which probably resulted from headward erosion following downcutting of the main river (Bryan, 1925b).

San Xavier Reach. The chronology of channel change along the San Xavier reach of the Santa Cruz River provides examples of arroyo development and of other channel changes such as channelization that are direct results of human activities. Historically, there were two main sources of spring water in the San Xavier reach, the *Agua de la Misión* and *Acequia de la Punta de Agua*, both south of San Xavier del Bac Mission (see Figure 4). Springs at the *Agua de la Misión* were destroyed by an earthquake in 1887 and flow was forced to the surface higher up in the valley. Development of this water led to the formation of the *East-Side Barranca*, a channel 100-200 feet wide, 15-20 feet deep, and over two miles long. By 1912, a channel 60-100 feet wide, 6-20 feet deep and about two miles long developed after the construction of an infiltration gallery. This channel came to be known as the *West-Side Barranca* (Cooke and Reeves, 1976). Both the *West-* and *East-side Barrancas* were initiated by 1882 (Cooke and Reeve's, 1976) and dried up periodically, which led them to be deepened and extended artificially (Berger, 1901).

The most serious erosion on the San Xavier Indian Reservation resulted when overbank flow crossed from the west to the east side of the valley, and cascaded into the *East-Side Barranca* near the base of Martinez Hill. In 1915, the Santa Cruz River did not have an entrenched channel near the south boundary of the San Xavier Indian Reservation. However, during the 1914-1915 floods, a headcut eroded to a point south of Martinez Hill, destroying the marsh at the source of the Spring Branch. In 1915, engineers acting on behalf of the Papago Indians implemented C.R. Olberg and F.R. Schank's 1913 plan (Olberg and Schanck, 1913) to build an artificial channel that connected the Santa Cruz River channel with the head of the entrenched Spring Branch. The headcut migrated rapidly along the artificial channel and continued upstream so that by the 1930s, a continuous arroyo defined the river's course for a distance of 35 to 45 miles in the Tucson Basin (Betancourt and Turner, 1988). The channel of the Santa Cruz River still follows the route of the 1915 dike into the former course of the Spring Branch (Figure 18) and is now 18 to 24 feet deep (Betancourt and Turner, 1990).

The downstream section of the San Xavier reach, especially the portion above Martinez Hill to Valencia Road, has undergone the most extensive and continuous arroyo widening on the Santa Cruz River. The channel was incised as much as 30 feet in silt and sand of Holocene age, and about 1,200 feet of widening occurred at some places between 1936 and 1986. Mean arroyo width of the entire San Xavier reach increased from 200 feet in 1936 to 500 ft in 1986 (Parker, 1995). Meyer (1989) determined that channels in which bedload transport is significant and bed material are predominantly gravels, such as the Santa Cruz arroyos (i.e. near Nogales, Amado, and I-19), initially widen their arroyos by meandering. Figure 19 illustrates the meandering of the low flow channel within the arroyo walls in the San Xavier reach between 1972 and 1983, while Figure 20 graphs the widening that occurred. Flows undercut weakly indurated, oversteepened arroyo walls, or return flow of bank storage to the channel causes seepage erosion at the base of the walls (Parker, 1995). Figure 21 provides a dramatic time-elapsed view of arroyo widening along the reach upstream of San Xavier Road. Once arroyos widen to the point they no longer constrain flood-channel width, they become braided. The rate of arroyo wall erosion then decreases because the low flow and flood channels can shift freely within the arroyos and only rarely impinge upon the arroyo walls. The arroyos eventually become relatively stable;

Figure 18


SAN XAVIER
SANTA CRUZ RIVER
SANTA CRUZ
INDIAN
San Xavier Reach
Channelization
Legend - San Xavier Reach
: 1905 Survey
: 1995 aerial photograph
Base Map: USGS 1983
Scale:
0
0.5
1 Mile
34
35
36
3
2
1
12

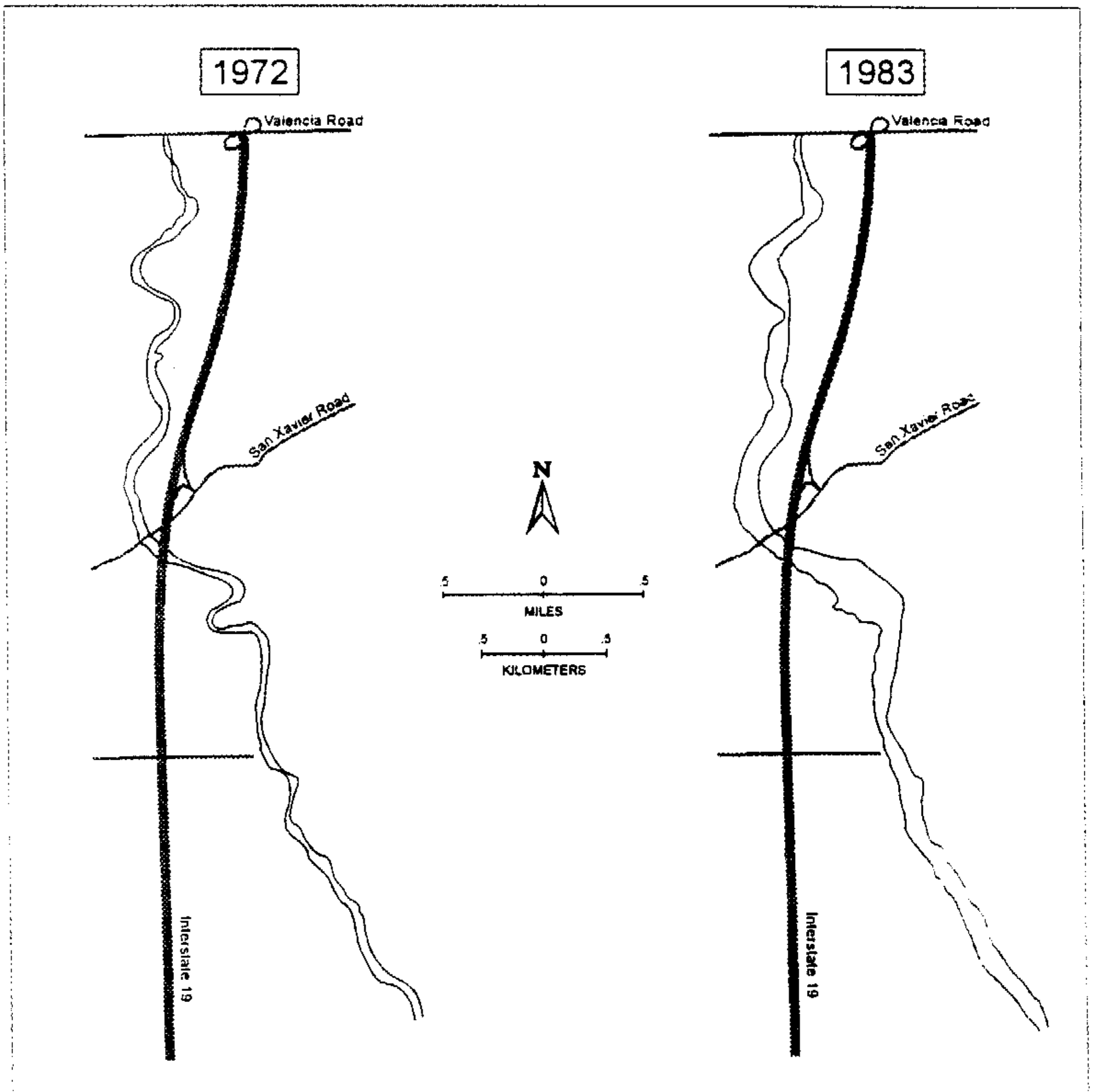


Figure 19. Low flow channel boundaries within the Santa Cruz arroyo in the San Xavier reach. Channel boundaries are represented by solid black lines; roads are indicated by dark grey lines. Boundary data was obtained from aerial photographs. [Source: Guber, 1988.]

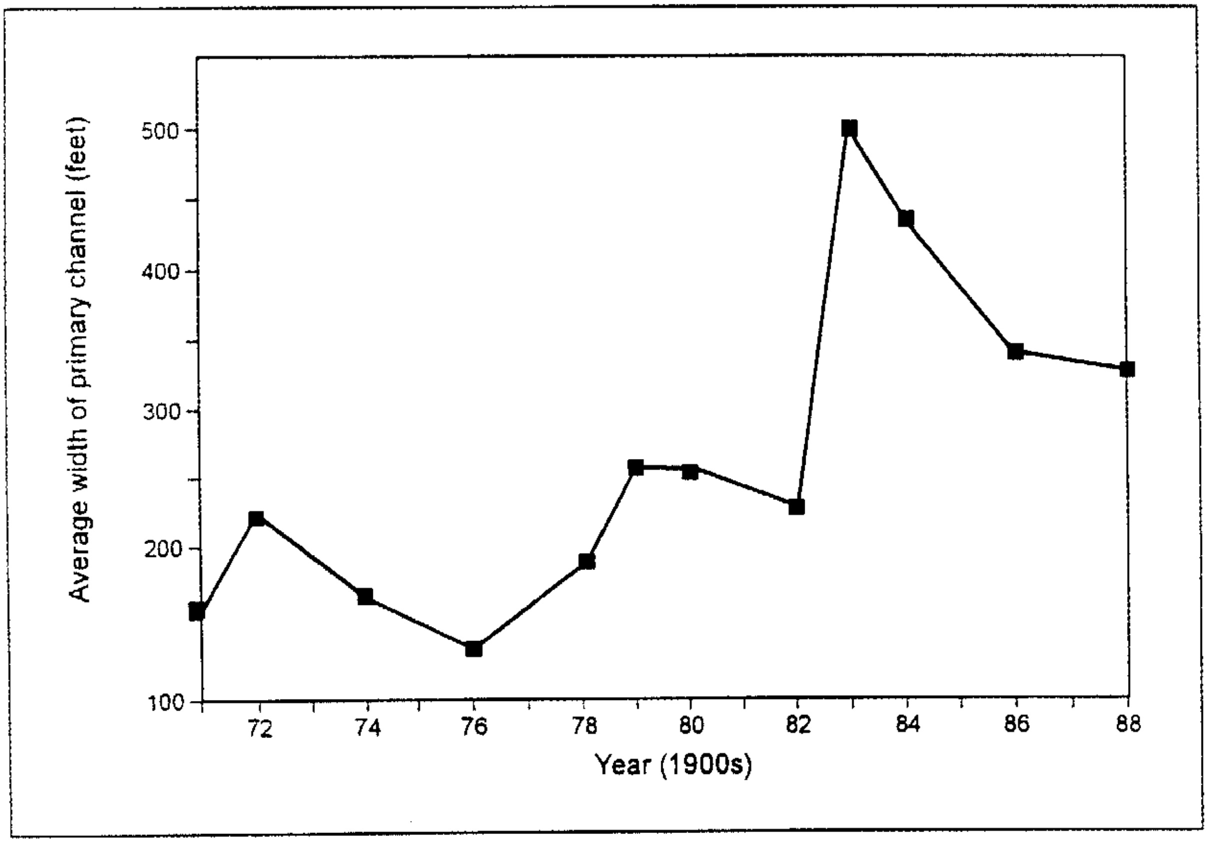


Figure 20. Average width of the primary flow channel within the San Xavier arroyo. Each box in the graph represents a measurement made from an aerial photograph. [Source: Guber, 1988.]

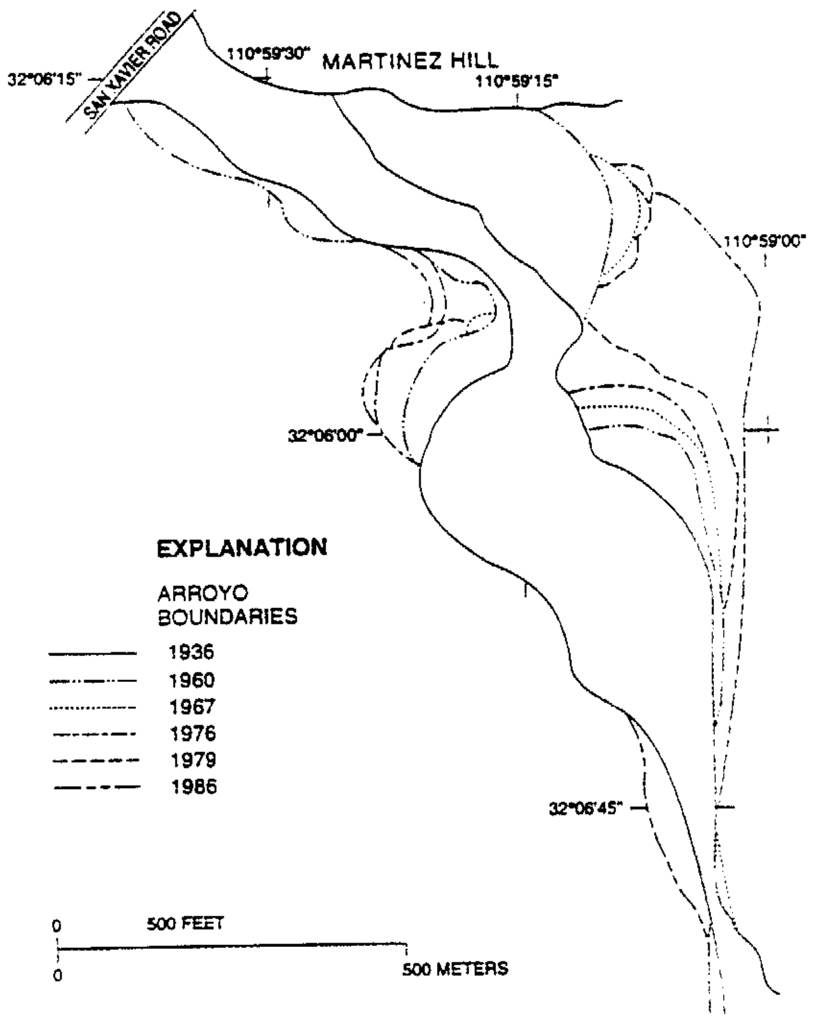


Figure 21. Arroyo widening caused by migration of entrenched meanders in the San Xavier reach at Martinez Hill, 1936-86. Data from U.S. Soil Conservation Service, 1936; Cooper Aerial Survey, 1960, 1967, 1979, 1986; Kucera and Associates, 1976. [Source: Parker, 1995.]

former floodplains become terraces and arroyo floors become floodplains (Meyer, 1989). Unlike channel widening, the process of arroyo widening is not readily reversed on large systems such as the Santa Cruz River (Parker, 1995).

C. Channel Changes in the Lower Santa Cruz River Basin

Change in channel form and pattern on the lower Santa Cruz River is less understood and documented than the upstream reaches. The fluvial system of the lower Santa Cruz River is distinctly different from its upstream counterpart and such changes are more challenging to document and describe. Only during large floods does significant streamflow from the upper Santa Cruz River extend through the lower Santa Cruz River to the Gila River. This hydrological discontinuity is mirrored by a geomorphological discontinuity wherein the basic form of the river transforms from a relatively deep, well-defined channel to a broad, flat, extensive alluvial plain with only intermittent channels. Prior to human disturbance, this transition occurred in the Marana area. Due primarily to the effects of Greene's Canal (discussed in the following section), the Santa Cruz River now has a fairly well-defined channel to Chuichu area. (Refer to Figure 1 and Figure 2 for locations.)

Broad sheetflow that is characteristic of large floods on the lower Santa Cruz River is associated with deposition of abundant sediment that remains in storage for long periods of time between large floods. The widespread sedimentation during large streamflow events and the low gradient of this part of the system are conducive to large scale changes in channel position. However, the low frequency of the recurrence of large floods influences the timing of these changes such that they occur only over long time spans. The evidence for significant changes (primarily in channel position) is present in the regional geomorphology and the spatial distribution of geologically young (i.e. 1000 to 5000 years) alluvial deposits in the area. However, because of data limitations and the long time scale of the processes involved, we cannot provide an assessment of long-term channel change. In terms of channel change in the 20th century, description of the effects of Greene's Canal and documentation of the disparate courses taken by two large floods provide interesting and useful perspectives on the behavior of the Santa Cruz River in this unique environment.

Greene's Canal. The modern Santa Cruz River has a relatively distinct channel from its headwaters to just upstream of Greene's Canal. Greene's Canal is a man-made feature that has dramatically influenced the evolution of the lower Santa Cruz River. In 1908 the Santa Cruz Reservoir Company developed a plan to concentrate water from the Santa Cruz River into Greene's Canal, transfer the water to a reservoir, and distribute it for the irrigation of farm land near Toltec (Cooke and Reeves, 1976). A diversion dam and canal were constructed in 1909-10 under the leadership of Colonel William C. Greene. The irrigation scheme was temporarily halted when Colonel Greene died in 1911 and then reactivated in 1913 (Sonnichsen, 1974). However, during the floods of 1914-1915, the diversion dam was destroyed and the canal was eroded to a depth of about 12 feet (Cooke and Reeves, 1976).

Greene's Canal and headcuts migrating upstream from the canal have continued to capture and concentrate extensive sheetflow in the upstream area during subsequent floods of this century. This unintended flow diversion had the effect of restricting the vast majority of flood runoff to the western Santa Cruz Flats. Prior to the diversion, floodwaters apparently flowed in a more northerly direction, inundating areas that are now covered by Eloy, Toltec, and Casa Grande. Following the diversion by Greene's Canal, these areas have not been affected by significant flooding from the Santa Cruz River. In 1983, a tongue of floodwater extended to the outskirts of Eloy, apparently following part of the old path. Thus, Greene's Canal has become the dominant conduit for flows from the upper Santa Cruz River. The large floods in 1914-1915, 1977, 1983, and 1993 have transformed what was once a relatively small canal into a deep, wide arroyo that bears a strong resemblance to portions of the Santa Cruz River channel upstream.

Flood Flow Patterns in the Lower Santa Cruz River Valley. Greene's Canal flows west-northwest to the site of the abandoned reservoir for which the canal was originally constructed. The reservoir outlet, now Greene Wash, flows towards the north-northwest. Northwest of Casa Grande, Greene Wash is joined by the Santa Rosa Wash and the North Branch of the Santa Cruz River (refer to Figure 1). The North Branch of the Santa Cruz Wash is an east-west flowing tributary between the town of Casa Grande and the piedmont of the Sacaton Mountains to the north. This drainage currently receives runoff from the southern side of the Sacaton Mountains. Flow in the Santa Rosa Wash and the Santa Cruz Wash intermingle during large runoff events because agricultural modification of the landscape has removed the effective drainage divide between the two systems[2] (Rhoades, 1991).

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[2] An interesting and somewhat unfortunate consequence of the floodwaters crossing the drainage divide between the Santa Cruz Wash and the Santa Rosa Wash, combined with the effects of Greene's Canal, is that it nullifies much of the flood-control effect of the Tat Momolikat Dam on the Santa Rosa Wash (Rhoades, 1991). The dam was constructed in 1974 to protect communities in the floodplain of the lower Santa Rosa Wash. These areas are now subject to inundation by floods on the Santa Cruz River, which are historically more frequent than floods on Santa Rosa Wash.

Detailed mapping of flow paths on the lower Santa Cruz River is possible because two of the largest flood events on the Santa Cruz river this century followed distinctly different paths and have been mapped in reasonable detail at various scales. Previous flood mapping in this area has been combined and compiled on a 1:100,000-scale base map of the lower Santa Cruz River area (Plate 1, in pocket). Lines have been drawn to indicate: 1) the spatial extent of the winter flood of the 1914-15 as discerned from Smith's 1938 and 1940 publications and the General Land Office (GLO) surveys; and, 2) the distribution of floodwaters of the 1983 flood event, as published by Roeske *et al* (1989).

Smith's mapping was transferred directly to the 1:100,000-scale base map by enlarging the original map. Smith's 1940 publication indicates only areas "overflowed by floods (not complete)." The 1938 map claims to show the 1914-1915 flood swath, thus it is possible that Smith's maps indicate areas overflowed by earlier (or subsequent) events, i.e. the 1905 flood event. The data sources for the maps by Smith are unknown. No verbal description of methods compilation, data sources, or likely evolution of the flow path depicted for the 1914-1915 map is available. Smith's mapping can only be taken as a somewhat rough depiction of inundation; however, Smith's delineation of one branch of the flow swath extending through Eloy and towards the northwest is consistent with the position of the Santa Cruz River and Santa Cruz Flats as mapped by the GLO surveyors. Lines that represent interpretations of channel positions made by various survey parties also were transferred from the original GLO plats to the 1:100,000 base map.

Roeske *et al* (1989) mapped the distribution of floodwaters from the flood of 1983 using high altitude aerial photography, field reconnaissance, and flood reports. Their rendering is probably considerably more precise than Smith's mapping. The path of the 1983 flood was first transferred from Roeske *et al*'s high altitude aerial photograph to a 1:130,000 scale aerial photograph, and then overlain on the 1:100,000-scale base map. In a few places, flow paths of the 1977 flood on the lower Santa Cruz River mapped by Aldridge *et al* (1984) were added to refine the mapping of likely flow paths of the 1983 event where imagery was not available. This addition was done under the assumption that the general flow paths were the same, although the extent of the 1983 flood was likely greater.

The effect of Greene's Canal can be seen by the comparison of the strikingly different flood paths illustrated in Plate 1. According to both the GLO surveys and Smith's map, the North Branch of the Santa Cruz River near Casa Grande was an important element of the Santa Cruz system. According to Smith (1938, 1940), the floodwaters in 1914-1915 also crossed the low divide near the southeastern corner of the Sacaton Mountain Piedmont between the North Branch and McClellan Wash, the principal drainage of the Picacho Basin. This resulted in the Santa Cruz River flowing along both the east and west sides of the Sacaton Mountains and entering the Gila River at two points separated by more than 20 miles. The very low gradient in the region explains the apparent variability of flow paths through this area. Also evident in Smith's map are broad areas of inundation associated with flow down Greene's Canal and along the western margin of the lower Santa Cruz River Valley. This flow path became the main flow route during the 1983 and 1993 floods.

The low-relief characteristic of the area and the widespread distribution of geologically recent alluvial deposits indicates that much of the area in the lower Santa Cruz River basin has conveyed flow at some point during the last few thousands of years. Only in a few areas are there relatively high standing surfaces (aside from the isolated mountains) that obviously have been free from any inundation. Since the construction of Greene's Canal and the development of the arroyo it initiated, the main flow of the Santa Cruz no longer follows its former paths down the North Branch and McClellan Wash. Instead, it follows the western route via Greene's Canal.

VII. SUMMARY

The hydrology and geomorphology of the Santa Cruz River have experienced both subtle and dramatic changes in their character since the time of Statehood. These changes have resulted from a combination of climate change, human activities and geomorphologic processes. In this concluding chapter, the characters of the Santa Cruz River at the time of Statehood and the Santa Cruz River of the last decade are described and contrasted.

A. Hydrology

Historically (~1890s), the Santa Cruz River was perennial from its source to Tubac. Climate change since the turn of the century, combined with the extensive groundwater pumping for irrigation and the flow diversion for municipal use that began near the International Border during the 1930 to 1950 drought period, has resulted in no flow in the channel in Sonora, Mexico, and in discontinuous flow in the channel near Nogales, Arizona. The 1913 gage record at Nogales (the earliest in that region), indicates that by the time of Statehood, the Santa Cruz River at Nogales was no longer perennial, but instead had continuous flow during the winter and occasional flow during the spring, summer and fall. The winter discharge averaged about 15 cubic feet per second (cfs) except for an increase caused by a rainfall event that ranged from 35 to 174 cfs. A survey of the daily data for the rest of the Nogales record indicated that, during unusually wet years, there were only a few days of no-flow conditions. During dry years there were entire months that passed with no flow recorded in the channel. At present, naturally occurring perennial reaches occur only in the uppermost part of the river in the San Rafael Valley. Perennial flow in the reach near Nogales results from the discharge of sewage effluent from the Nogales International Wastewater Treatment Plant that began in 1972.

The Santa Cruz River historically had several springs and marshes (*cienegas*) within its channel from Tubac to Tucson, and a marsh existed at its confluence with the Gila River near Laveen. Even in the historical record, only the very largest floods were sustained from the headwaters to the confluence with the Gila River. A review of the daily discharge record indicated that there was some semblance of baseflow with an average of about 12 cfs during the fall and winter of 1912-1913 at the Tucson gage. Such continuous flow for months at a time was not seen again in the years that followed, though there were periods of several weeks that experienced continuous or nearly continuous flow during very wet winter seasons. The Laveen gage recorded nearly year-round flow from its beginning date (1940) until June, 1956, when it began to measure zero flow for weeks at a time. During the 1940 to 1956 period, the daily flow averaged about 3 cfs during low flow conditions and had peaks as high as 5060 cfs during wet periods. By 1960, the Santa Cruz at Laveen was experiencing no-flow conditions for months at a time.

Not only have the locations of surface flows changed since the time of Statehood, but also the seasonality and magnitude of flows in the Santa Cruz River have changed in response to shifts in the hydroclimatology of the region. Though the majority of flow events occur during the summer season, the magnitude and number of annual peak discharges that occurred in the fall and winter were higher before 1930 and after 1960 than during the 1931-1959 period. For example, six of the seven largest floods at Tucson occurred after 1960, indicating that the magnitude of flood peaks has increased in the past few decades.

Human activities as well as climate change have had notable effects on the peak flows of the Santa Cruz River, especially in the lower Santa Cruz River basin. Since 1962 the construction of flood-control channels in the washes of the lower Santa Cruz River basin have resulted in the reduction of floodplain storage and infiltration losses, therefore reducing the *attenuation* (the downstream decrease of the flood peak) of peak discharges. For example, the attenuation of peak flows was greater during the 1962 floods than during the 1983 floods because water was able to spread out over the broad flow zones in the lower reaches of the Santa Rosa and Santa Cruz washes. In contrast, much of the floodwater during the 1983 floods was efficiently transmitted downstream by the flood-control channels.

B. Geomorphology

The geomorphology of the upper Santa Cruz River is quite different from that of the lower Santa Cruz River. The river has a well-defined, often entrenched channel in its upper reaches that contrasts strongly to the ill-defined system of braided channels that exist north of the northern end of the Tucson Mountains near Marana. Both the upper and lower reaches of the Santa Cruz River have experienced dramatic changes resulting from a combination of both natural geomorphic processes and human activities. Three types of lateral change have occurred: meander migration, avulsion and meander cutoff, and channel widening. Two types of vertical change have occurred: aggradation and degradation of the channel bed. While arroyo development is the most obvious type of channel change to occur since the 1890s in the upper Santa Cruz River, most of the initial channel incision occurred before the time of Statehood. Since 1912, various reaches of the upper Santa Cruz River have been dominated by such processes and activities as meander migration and cutoff, channel widening, arroyo widening, channelization, and the vegetational effects of sewage effluent discharge. The channel locations in different reaches have changed spatially on the order of a few feet to a few thousand feet, depending on the processes that resulted in the change, and often change could be detected from one year to the next.

The lower Santa Cruz River experienced changes of a completely different magnitude from the upper Santa Cruz River. Changes in the location of the channel in the lower basin can be measured in miles, and the timing of changes spans decades. Before the construction of Greene's Canal in 1910, the river transformed from a relatively deep, well-defined channel to a broad, flat, extensive alluvial plain at a point in the Marana area. Now that transition point occurs near Chuichu, Arizona. The construction and subsequent flood damage of Greene's Canal has resulted in dramatic geomorphic changes. Prior to and during the floods of 1914-1915, flood flow had the opportunity to follow routes down the North Branch of the Santa Cruz Wash and McClellan Wash. After the development of the arroyo in Greene's Canal, subsequent flood flows have had westerly paths *via* Greene's Canal.

GLOSSARY

adobe flats: defined in Bryan (1922a) as broad flats that are formed by deposition from sheet floods and are floored with sandy clay, also called "adobe."

aquifer: a permeable geologic formation, group of formations, or part of a formation which stores and transmits water.

arroyo: a river or stream with a single, definite channel incised in unconsolidated material consisting of clay, silt sand and some gravel, with banks more than two feet high.

basin: an extensive depressed area into which the adjacent land drain. The Tucson Basin is the northward-trending, structural depression of about 2600 km^2 into which the adjacent land drains.

cienega: term applied to riparian marshlands by Spanish explorers.

ephemeral stream: a stream or portion of stream which flows only in direct response to precipitation. It receives little or no water from springs and no long continued supply from snow or other sources. Its channel is at all times above the water table.

flow-duration curves: cumulative frequency curves that show the percentage of time specified discharges are equaled or exceeded in a given period.

groundwater: that water which infiltrates the earth's surface, percolates downward, and is stored in the saturated zone of a geologic stratum.

infiltration: the process whereby water passes through an interface, such as from air into soil.

infiltration rate: the rate at which soil can absorb water.

intermittent stream: a stream with reaches that flow only during wet weather or during part of the year.

percolation: the process whereby water passes through fine openings in porous stones.

perennial stream: a stream or portions of a stream that flow throughout the year.

phreatophytes: deep-rooted plants that obtain water from the ***water table*** or the layer of soil just above it.

recharge: inflow to a ***groundwater*** reservoir. ***Aquifers*** may be recharged from ***infiltration*** of water from adjacent mountains, direct penetration of precipitation on valley floors, infiltration of waters used for irrigation, water rising from depths as fault or fracture springs, and ***underflow*** from outside the basin. Water is discharged from aquifers by underflow into a downstream basin, evaporation, transpiration, spring discharge, and pumping.

riparian: refers to that which is related to or located or living along a watercourse whether natural, man-made, ephemeral, intermittent, or perennial.

subflow: see ***underflow***.

underflow: a term used interchangeably with ***subflow*** throughout this report to describe the groundwater underlying the surface of a stream's channel. Sykes (1939) noted that these words imply continuous forward movement of water beneath the stream-bed, which probably seldom occurs in a stream channel like that of the Santa Cruz River. Sykes instead describes the "underflow" as being a series of semi-isolated sub-surface reservoirs, which retain most of the seepage water received from local precipitation, or channel flow, and only intercommunicate when the sub-surface layers of the stream bed become supersaturated.

wash: a river or stream with low banks and numerous channels.

water table: the plane which forms the upper surface of the zone of ***groundwater*** saturation. Should the water table rise so that it intersects the ground surface, a spring results.

xerophytes: plants that are structurally adapted for life and growth with a limited water supply.

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Appendix A

Ground Photographs

The ground photographs provided in this appendix illustrate key differences between the different reaches of the upper and lower Santa Cruz River. Figure A-1 indicates the locations of the photographed reaches. All photographs were taken in 1996. For a review of historical photographs of the Santa Cruz River, refer to Tucson's Santa Cruz River and the Arroyo Legacy.[A-1, A-2]

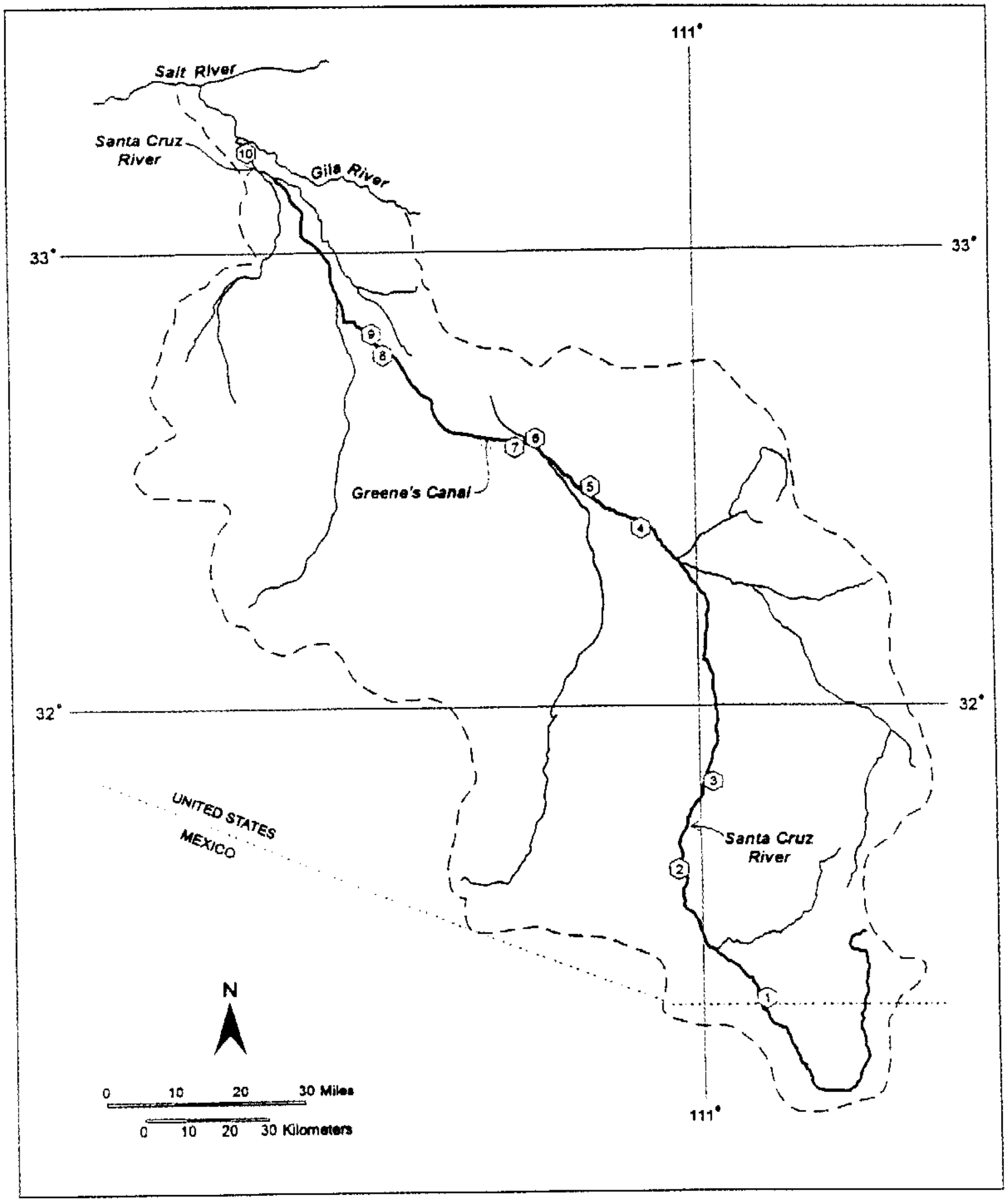
[A-1] Betancourt, J.L. (1990). Tucson's Santa Cruz River and the Arroyo Legacy. The University of Arizona, Ph.D. dissertation, 239 p.

[A-2] Betancourt, J.L., and Turner, R.M. (1990). Tucson's Santa Cruz River and the Arroyo Legacy. To be submitted to the University of Arizona Press, Tucson, as a book manuscript, 239 p.

Figure A-1. Locations of ground photographs provided in this appendix.

Legend:

- Rivers
- Main Flow Route since ~1915
- Santa Cruz Basin Boundary
- Ground Photograph Location



1. Downstream view of the Santa Cruz River, 0.75 mi north of the international border. (9/18/96)

2. View of the Santa Cruz River from Chavez Siding Rd. crossing, ~ 2 miles north of Tubac. (9/18/96)

3. Upstream view of the Santa Cruz River from the Continental Rd. crossing. (2/19/96)

4. Downstream view of the Santa Cruz River where it curves around the base of Rillito Peak. (2/19/96)

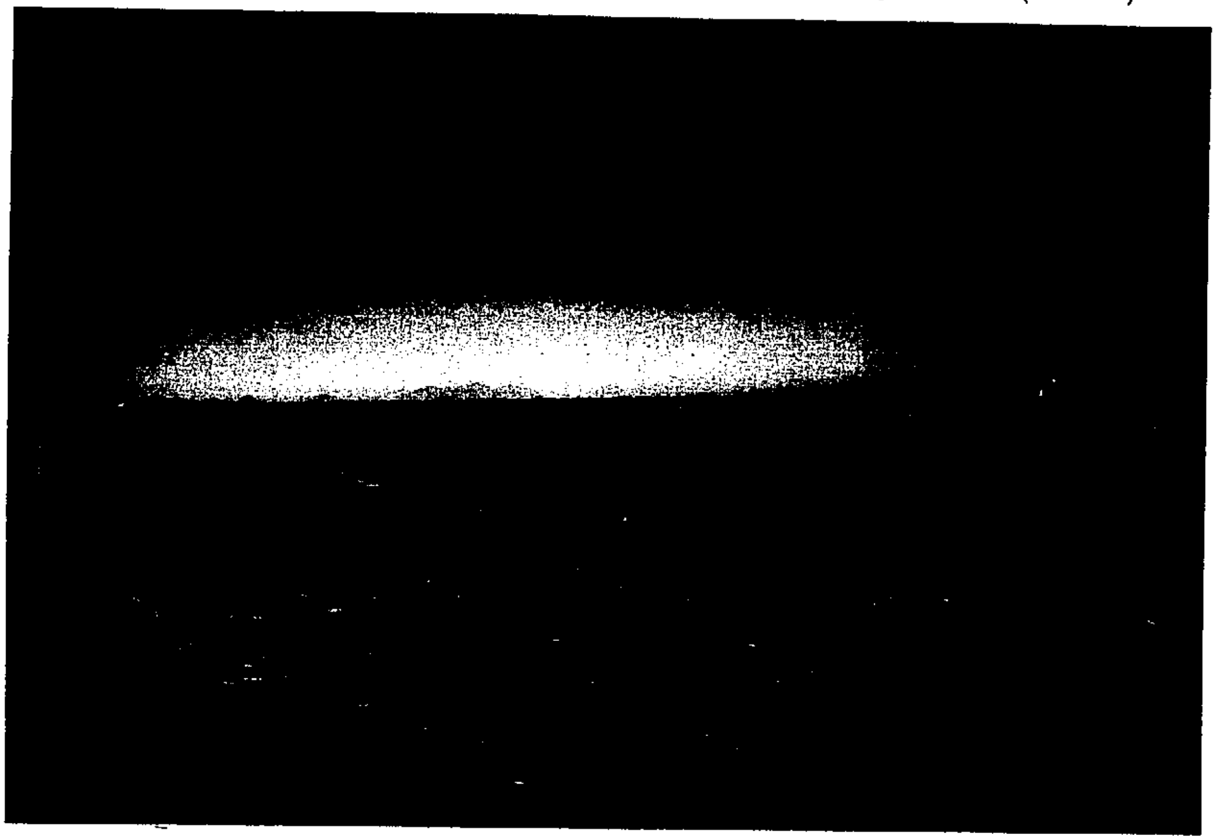
5. Upstream view from Trico-Marana Rd. crossing of the Santa Cruz River with erosion control structures. (9/18/96)

6. Downstream view of the Santa Cruz where it splits from Greene's Canal. Note, the base of the Santa Cruz channel is perched above the base of Greene's Canal. (10/7/96)

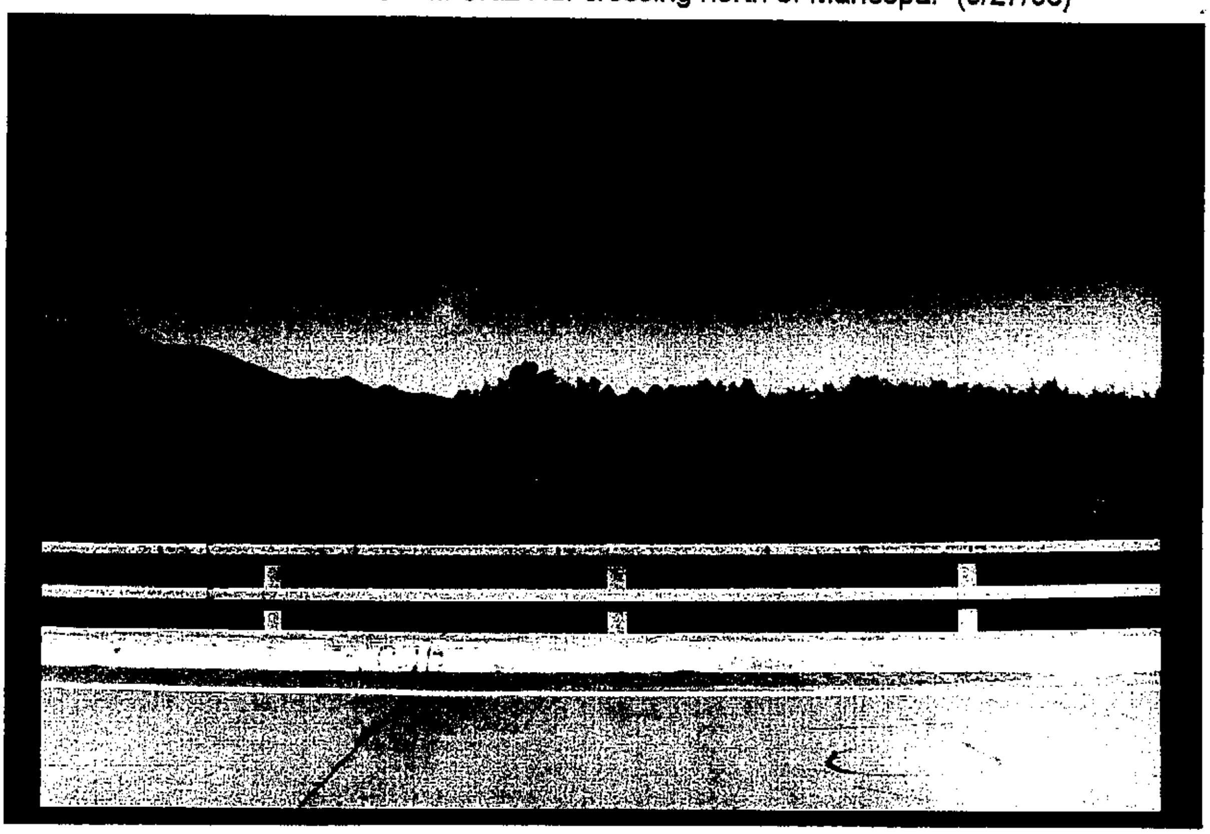
7. Southward view from the north bank of Greene's Canal, ~300 feet downstream of the Santa Cruz split. Note the termination of the man-made levee within the channel and the steepness of the southern channel bank. (10/7/96)

8. Downstream view of Greene's Wash as seen from the levee of the Santa Rosa Canal. The wash has defined banks only where it has been channeled through the canal. (10/7/96)

9. View of Greene's Wash downstream from Montegomery Rd. crossing. The wash has been channeled to form a canal and has been constrained by a levee. (10/7/96)



10. Downstream view of the vegetation-filled channel of the Santa Cruz River, as seen from the Santa Cruz Rd. crossing north of Maricopa. (9/27/96)



Appendix B

Stage-Discharge Rating Curves for the Santa Cruz River at Tucson and near Nogales

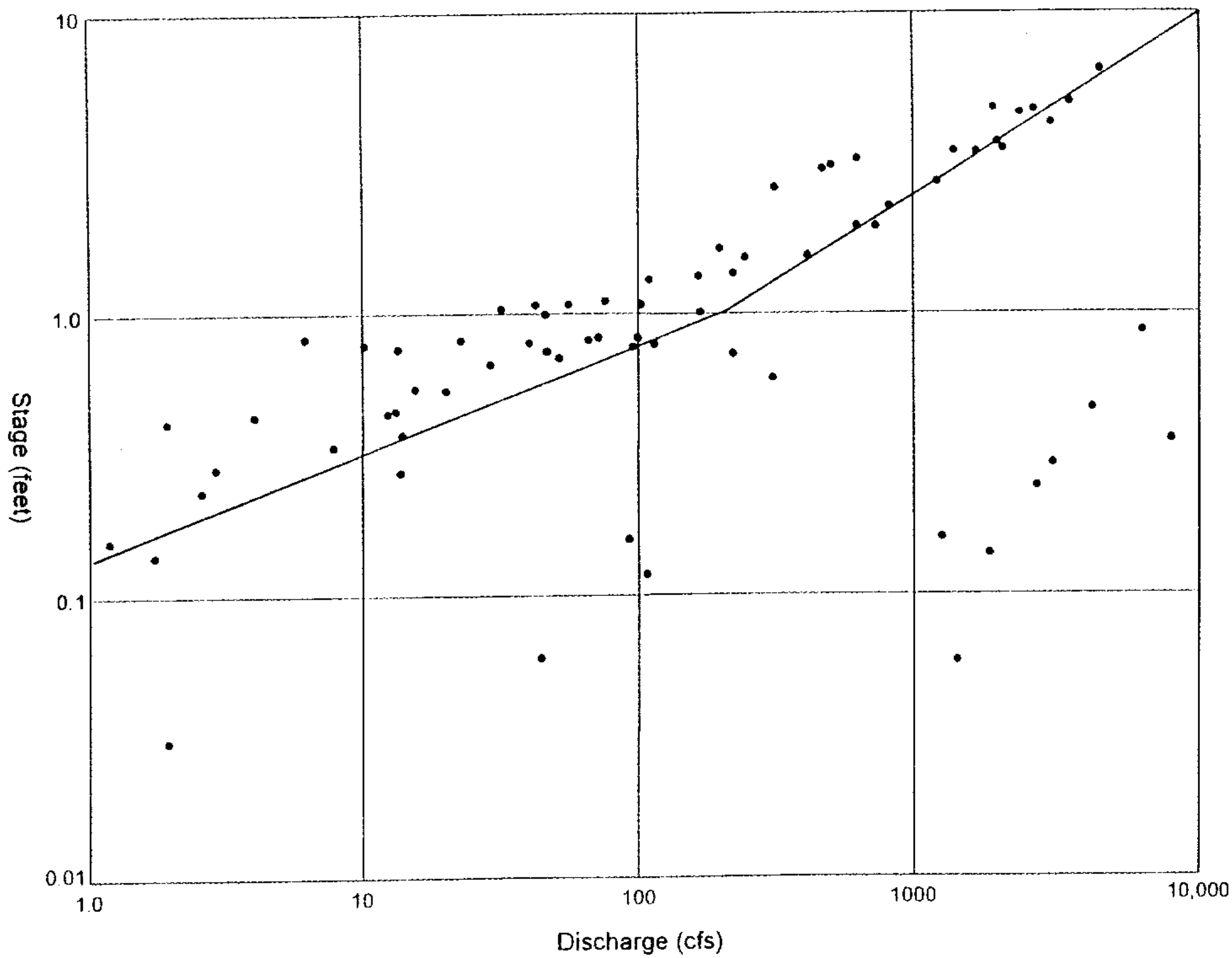
A stage-discharge rating curve is a graphical plot that shows the relationship between the monitored water level at a gaging station (the *stage*) and the corresponding flow rate (the *discharge*). The establishment of a reliable stage-discharge relationship is essential at all river gauging stations when continuous-flow data is needed from the continuous stage record.[C-1] While stage-rating curves are most often used to convert stage data to discharge values, the curves can also be used to do the reverse. Stage-discharge rating curves are provided in this appendix so that the Arizona Stream Navigability Commission may determine the water heights that correspond to the discharge values given in earlier chapters. Below is a brief background of the meaning and use of stage-discharge rating curves for the gages at Tucson and near Nogales, the gages for which the oldest and most complete data was obtainable.

The stage-discharge relationship is dependent on the nature of the channel section and the length of channel between the site of the gage and the cross-section where the discharge was measured. Channel conditions in natural rivers tend to change over time; hence, stage-discharge relationships also tend to change over time, especially after flood flows. Typically new discharge measurements are made throughout a range of stages on a regular basis by the hydrologists responsible for maintaining USGS streamflow records. The hydrologist plots the discharge measurements against the corresponding stage measurements on log-log graph paper and draws a best fit line through the points. Because the data is plotted on log-log paper, the data points tend to group in a more linear fashion that makes relationships more apparent to the hydrologist. If the data was plotted on regular arithmetic graph paper, the data points would group into a curve; hence the name "rating curve" is given to the hand-drawn line through the data points. Each time new measurements are collected, a new stage-discharge rating curve is created. That rating curve is then used until the next time new discharge measurements are made.

Figure B-1 is an example of such a stage-discharge plot using a log-log scale created for the Santa Cruz River at Tucson from data gathered during the period 1955-

[C-1] Shaw, E.M., 1988. Hydrology in Practice, Second Edition. Chapman and Hall: London, 539 p.

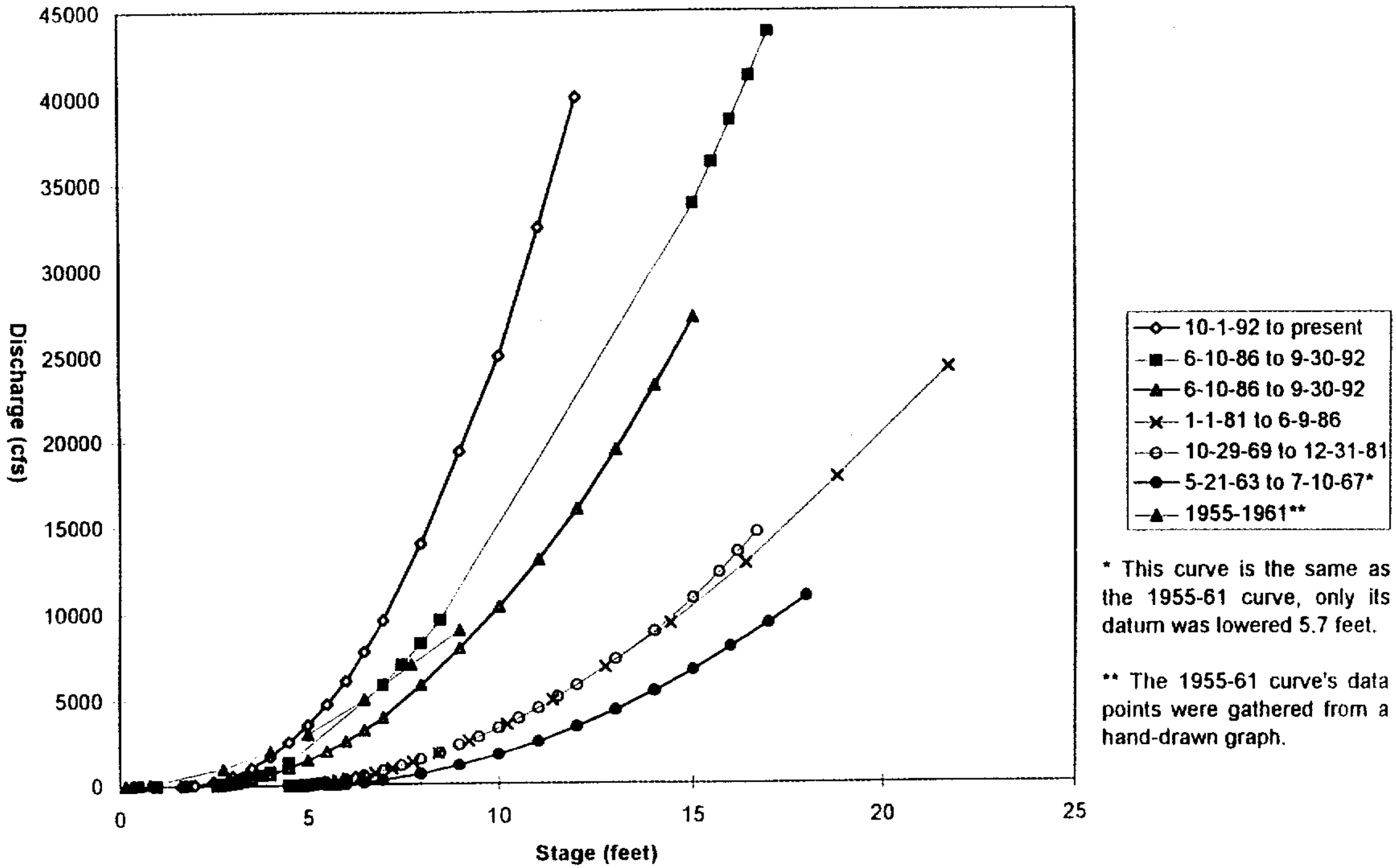
Figure B-1. Stage-rating data for the Santa Cruz River at Tucson, Arizona.
Data points are plotted on a log-log scale.
Discharge measurements were gathered 1955-1961.



1961. There is a great amount of scatter in the data points' location; that is, the points do not cluster close together. Such scatter often occurs in data collected from rivers with channels composed of sandy, unconsolidated materials. Rivers with bedrock channels tend to have flows that remain in a fixed location with a fixed channel geometry; therefore, their stage-discharge points plot closer together. In contrast, channels in unconsolidated materials tend to shift their locations and dimensions through such processes as channel scour and deposition and meander formation and cut-off. (Refer to the section on channel change mechanisms in Chapter VI for a more detailed review.) Channel changes may occur even as a hydrologist is taking the discharge measurements (D. Ufkes, USGS-Water Resources Division, Tucson, personal communication, 1996). The change in the slope of the line drawn through the data points in Figure B-1 at the stage height of about one foot indicates that there was a change in the channel control governing the stage-discharge relationship in this reach (i.e. there may have been a change in the slope of the river banks). In rivers where flood flows overfill the channels and spill onto flood plains, there may be another break in the slope of the line at higher discharges because the stage-discharge relationship of the within-bank flow may be very different from the stage-discharge relationship of the floodplain flow.

Once a USGS hydrologist establishes a satisfactory rating curve, a rating table is constructed from values of stage and discharge read off the line drawn through the data points. We retrieved the rating tables used for different time periods from the USGS-Water Resources Division office in Tucson for the gages at Tucson and near Nogales. We plotted the data as curves on an arithmetic scale rather than as straight lines on a log-log scale to make the graphs easier to read. Figures B-2 and B-3 illustrate how the stage-discharge relationships at these sites have changed over time. While most of the differences between the curves are a result of changes in the channel characteristics, some result from the use of different methodologies in obtaining discharge measurements. For example, the two curves in Figure B-2 plotted for the period June 10, 1986, to September 30, 1992, result from different data collection methodologies. Figures B-4 and B-5 are enlargements of the same curves in Figures B-2 and B-3 that better show the stage-discharge relationships for lower stage heights.

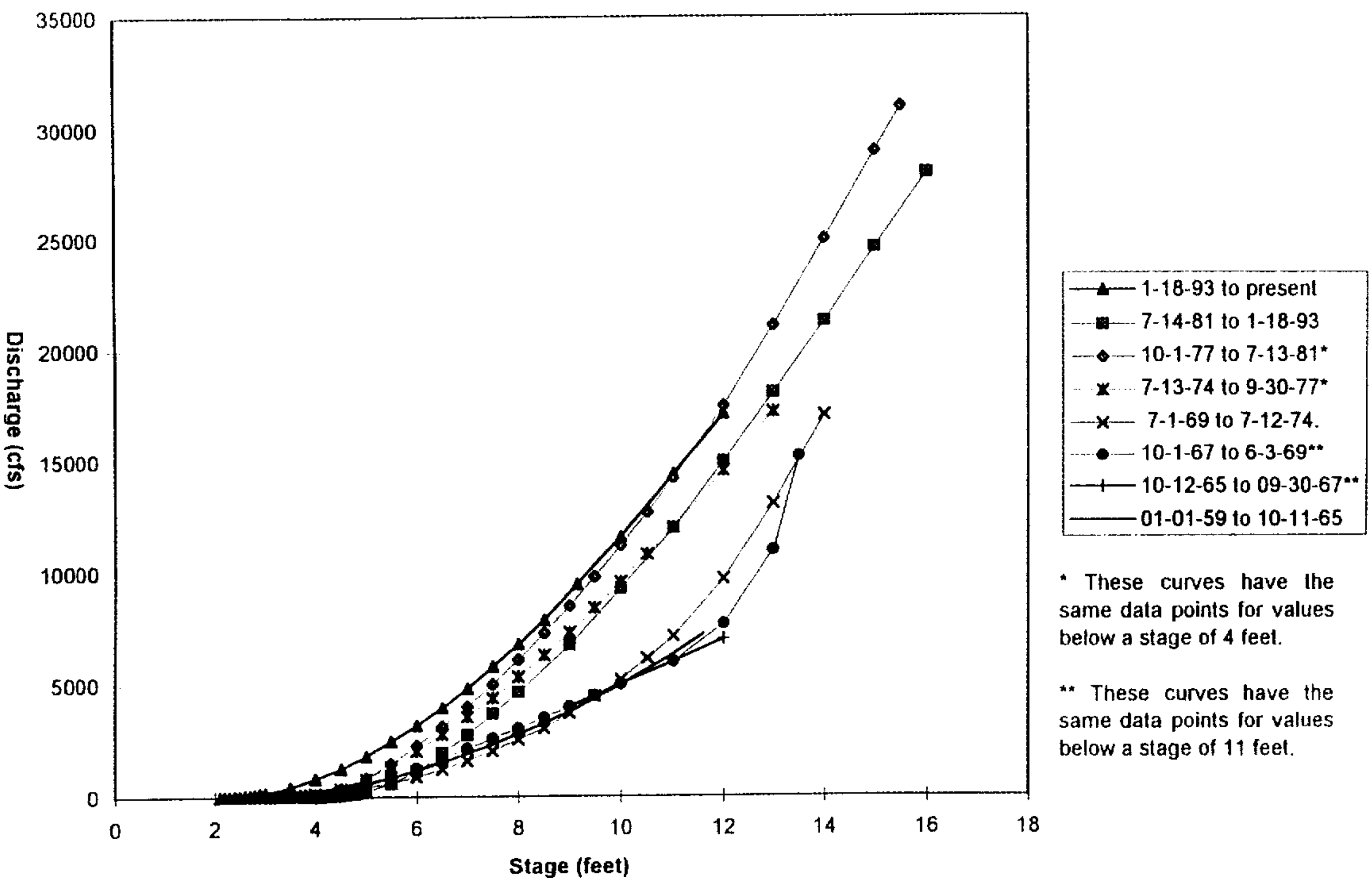
Figure B-2. Stage-rating curve for the Santa Cruz River at Tucson.
Each Line represents the stage-discharge relationship for a different period.



* This curve is the same as the 1955-61 curve, only its datum was lowered 5.7 feet.

** The 1955-61 curve's data points were gathered from a hand-drawn graph.

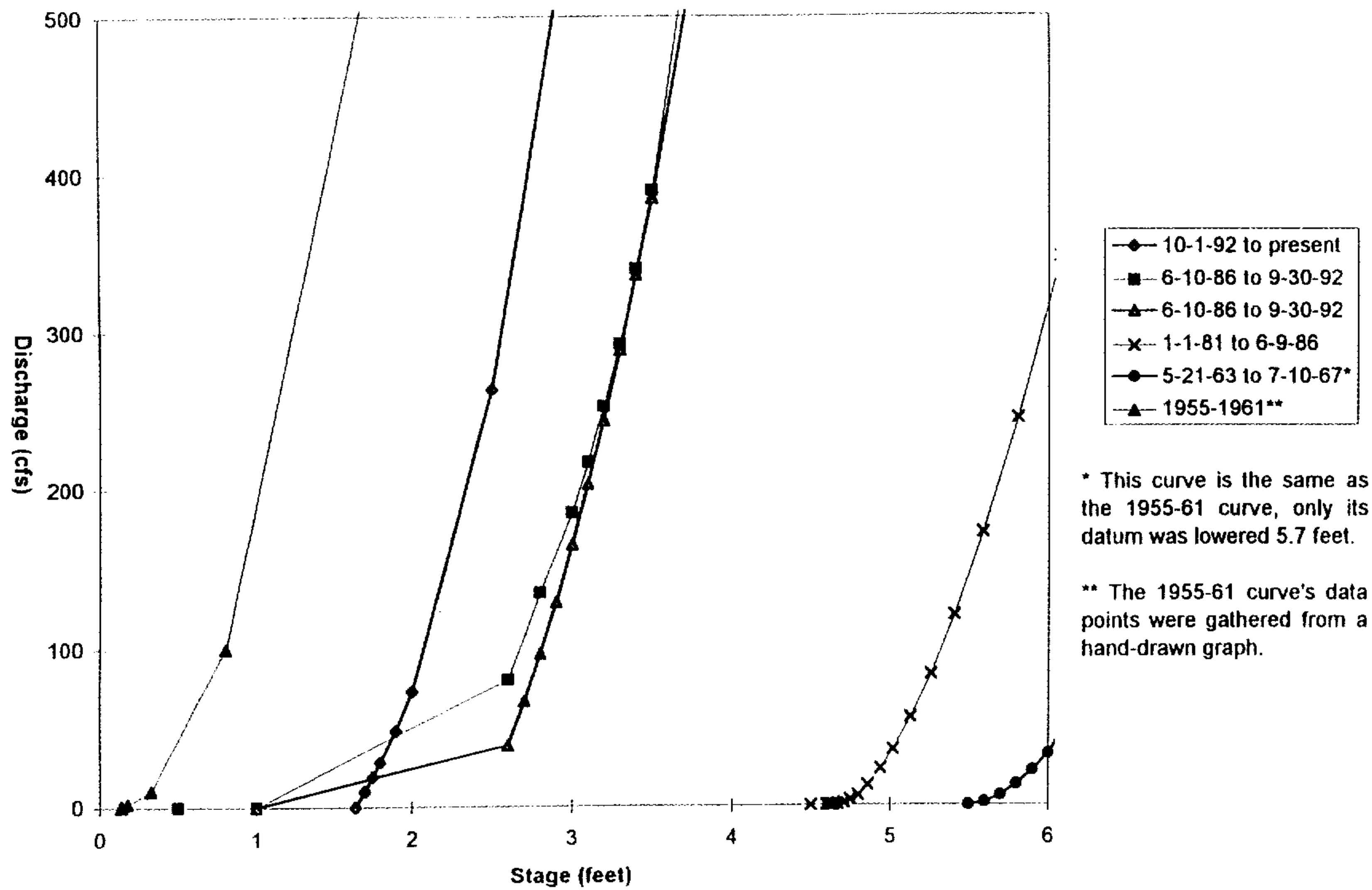
Figure B-3. Stage-rating curves for the Santa Cruz River at Tucson.
Each Line represents the stage-discharge relationship for a different period.



* These curves have the same data points for values below a stage of 4 feet.

** These curves have the same data points for values below a stage of 11 feet.

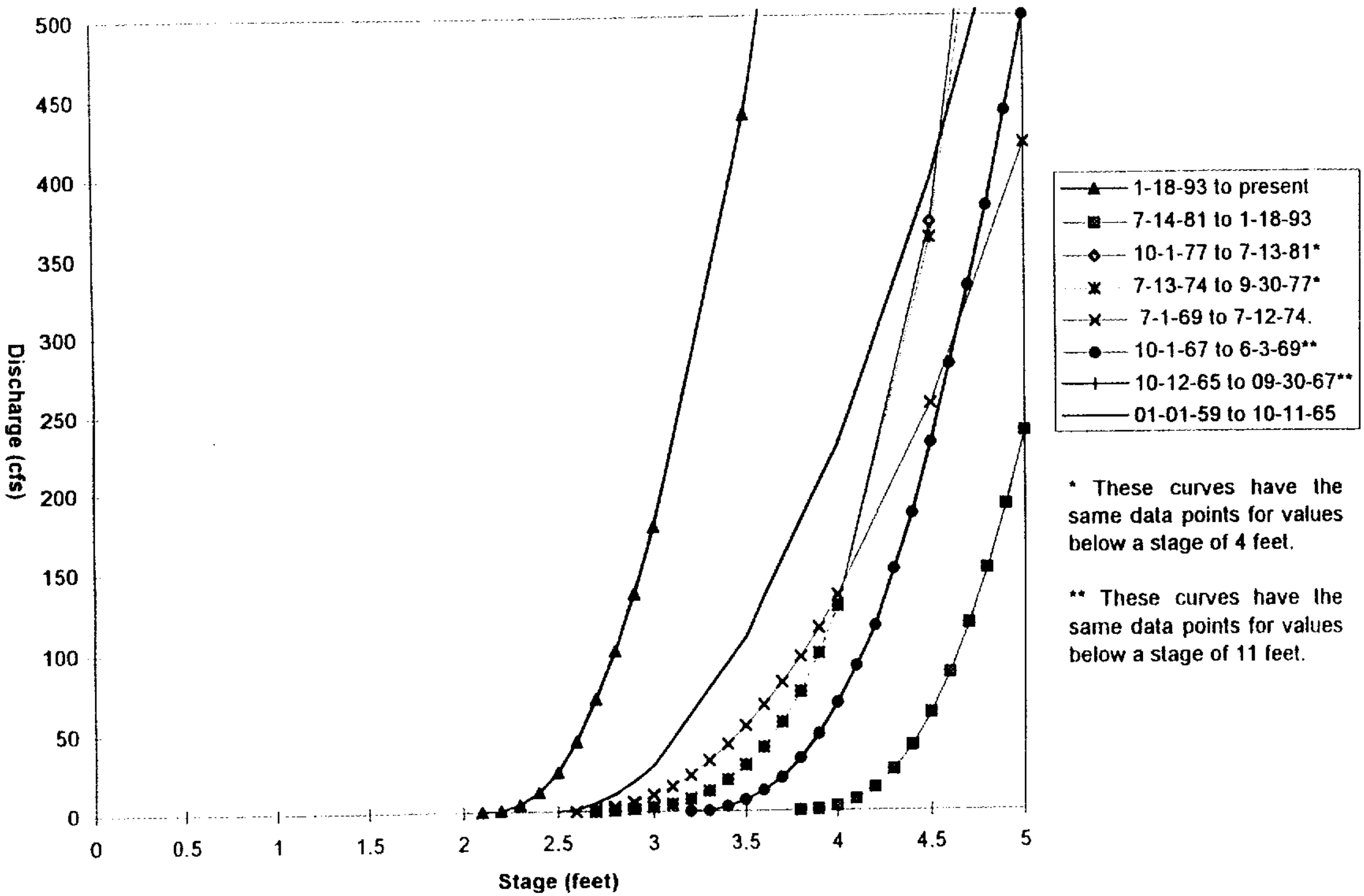
Figure B-4. Stage-rating curve for the Santa Cruz River at Tucson.
Enlarged view of the stage-discharge relationship at low flows for selected periods.



* This curve is the same as the 1955-61 curve, only its datum was lowered 5.7 feet.

** The 1955-61 curve's data points were gathered from a hand-drawn graph.

Figure B-5. Stage-rating curve for the Santa Cruz River at Tucson.
Enlarged view of the stage-discharge relationship at low flows for selected periods.



The following is an example of how to extract information from these rating curves. Figure 10 of Section 4 shows that the Santa Cruz River at Tucson experienced a daily discharge mean of 18 cfs on January 12, 1981. Figure B-4 contains an enlarged illustration of the rating-curve used for the period January 1, 1981, to June 9, 1986. According to this rating curve, a discharge of 18 cfs would have a corresponding stage of 4.9 feet. Because a discharge of zero corresponds to a stage of 4.5 feet, the actual water depth for a discharge of 18 cfs would be 0.4 feet (4.9 minus 4.5 feet) in the channel. [Note: it is common for a discharge of zero *not* to correspond to a stage of zero.[B-1]]

The earliest rating tables we retrieved from the USGS date to the mid-1950's. Because of the multitude of channel changes that have occurred in the upper reaches of the Santa Cruz River in the early part of this century (refer to Chapter VI), the reader is advised not to use the 1950's curves to determine the stages corresponding to earlier discharges presented in this report except to get very rough estimates of stage. Also, these rating curves do not represent the stage-discharge relationships that exist at the Lochiel, Continental, Cortaro and Laveen gage sites. The table below provides a comparison of the estimated stage-discharge values for the gages at Tucson and near Nogales. Though the stage-rating curves in Figures B-4 and B-5 appear to be very different because of the lowering and raising of the stage datum, the stage values derived from these curves that correspond to low discharges remain about the same over time. The stage values that correspond to higher discharges are markedly different.

Table B-1

Discharge (cfs)	**Stage** (feet)			
	Nogales		*Tucson*	
	early 1900's	late 1900's	early 1900's	late 1900's
10	0.3	0.3	0.2	0.1
100	1.0	0.7	0.7	0.4
1000	3.3	2.1	2.6	1.9

Appendix C

Agencies Contacted

Agency	Contact	Telephone #
Aridlands Information Center	Michael Hazelteen	520-621-7897
	Martin Karpiscak	520-621-8589
Aridland and Watershed Management	Dave Goodrich	520-670-6381
AZ Dept. of Water Resources, Pinal AMA	Lisa	520-836-4857
	Duncan	520-836-4857
AZ Dept. of Water Resources, Tucson AMA	Lee	520-770-3800
AZ Dept. of Water Resources, Santa Cruz AMA	Placido Dos Santos	520-761-1814
	Keith Nelson	520-761-1814
Arizona Historical Society Museum	Deborah Shelton	520-628-5774
Arizona State Land Department	-	520-628-5480
Arizona State Museum	Kathie Hubenschmidt	520-621-2445
Bureau of Land Management	Karen	520-722-4289
Cella Barr Associates	Nemecio "Tiny" Trevino	520-750-7474
City of Nogales Public Works (and Floodplain Management)	Alejandro Barcenas	520-287-7245
Cooper Aerial Survey Co.	Beverly	520-884-7580
Desert Botanical Gardens - Phoenix	Joseph McAuliffe	602-947-6029
	Pat Comus	602-996-9391
Earth Science Information Center	Diane Murray	520-670-5584
	Justin	520-670-5584
Farm Service Agency (Pinal County)	Pat Fox	520-836-2028
Forest Service - Coronado	Wally Craig	520-670-4552
LANDIS Corporation	Shelly Knight	520-617-0076
Pima County Flood Control District	David Jones	520-740-6350
	Terry Hendrix	520-740-6350

Pima County Planning/Maps & Records	Barry Rothrock	
	Paul Matty	Rm 205, County Bldg.
Pinal C. Flood Control District	Juanita	520-868-6411
Pinal County Planning and Development	Louis Felix	520-868-6549
Rio Rico Properties	Jay Moyes	602-640-9335
Santa Cruz County Flood Control District	Frank Crupp	520-761-7800, x3071
	Angie	520-761-7800
Soil Conservation Service (Tucson Field Office)	Bud Bowers	520-670-6492
Soil Conservation Service (Pinal C.)	Mark Felix	520-836-2048
UA - Dept. of Geography and Regional Planning	Sharon	520-621-1652
UA - Dept. of Hydrology and Water Resources	Dr. Robert MacNish	520-621-3041
USGS (UA office, Tucson)	Brenda Houser	520-670-5509
USGS (Tumamoc Hill, Tucson)	Robert Webb	520-670-6821
	Julio Betancourt	520-670-6821
USGS - Water Resources Division	Jonathon Parker	520-670-6671
	Doug Ufkes	520-670-6671
WLB Engineering Group	Jim Dean	520-881-7480
Water Resource Research Center	Barbara Tellman	520-792-9591
	Rick Yarde	520-792-9591

Appendix D
Availability of Aerial Photographs

Pima County:

Year	Agency	Contact	Comments
1995	AZ Dept. Water Resources, Tucson Active Management Area	Lee	Only for TAMA region; north to just past Red Rock. We can borrow them for 24 hours at a time. 1'=1200ft, by LANDIS Aerial Surveys (recent)
	Pima County Mapping & Records	Barry Rothrock	St. Mary's Rd. to Ft. Lowell of the SCR; very large scale; shot by Cooper Aerial.
1994	Pima County Flood Control District	David Jones	Stereoscopic photos; complete.
1993	Cooper Aerial*	Beverly	Flood coverage; does not go south of the water treatment plant in Santa Cruz County; does include Pinal County.
1990-91	AZ Dept. Water Resources, TAMA	Lee	1'=1200ft., LANDIS. We can borrow them for twenty-four hours at a time.
1988	AZ Dept. Water Resources, TAMA	Lee	1:12,000; Cooper Aerial Survey. We can borrow them for 24 hours at a time.
1986	AZ Dept. Water Resources, TAMA	Lee	1"=1200'; LANDIS Aerial. We can borrow them for 24 hours at a time.
1986	Pima County Planning and Dev.	Paul Matty	1"=1200'; B/W; **
1985	Pima County Planning and Dev.	Paul Matty	1"=400'; B/W; **
1983	Cooper Aerial	Beverly	Flood coverage; includes Pinal and Santa Cruz Counties
1983/1984	USGS, UA office	Brenda	Color Infrared; 1:60,000. Has good index. Coverage: just north of the Tucson Mts (~Marana); most/almost all of S.C. County. Can borrow this photoset with no problem; it is quite portable.
1983	USGS, UA office	Brenda	B/W; 1:80,000. Coverage: very small area, north to mid-Tucson and south to just before the Mexican border.
1983 (Oct.)	P.C. Planning and Dev.	Paul Matty	1"=10000'; B/W; **
1983 (Sep/Oct)	AZGS	Tom McGarvin	Color; photos taken before and after the flood are mixed together; coverage = north of Tucson south to sewage treatment plant.
1982	P.C. Planning and Dev.	Paul Matty	1"=400'; B/W; **
1980	AZ Dept. Water Resources, TAMA	Lee	For TAMA region and south to Nogales; north to just past Red Rock. We can borrow them for 24 hours at a time.
1980	P.C. Planning and Dev.	Paul Matty	1"=400'; B/W; **
1979/80	AZGS	Tom McGarvin	Cooper Aerial; 1:12,000; "Poor" coverage
1978	P.C. Planning and Dev.	Paul Matty	1"=400'; B/W; **

1977	Cooper Aerial	Beverly	Flood coverage; does not include Pinal County; does include Santa Cruz County.
1976	P.C. Planning and Dev.	Paul Matty	1"=400'; B/W; **
1974	AZ Dept. Water Resources, TAMA	Lee	No index, but the maps look nice.
1974	P.C. Planning and Dev.	Paul Matty	1"=400'; B/W; **
1974	P.C. Planning and Dev.	Paul Matty	1"=2mi; B/W; Infrared film positives - NASA flight 74-022**
1972/73	AZGS	Tom McGarvin	"Good" coverage; 1:4000; N.A.S.A. photography
1972	P.C. Planning and Dev.	Paul Matty	1"=2000'; B/W; Orthophotoquads;**
1972			
1967	P.C. Mapping & Records	Barry Rothrock	DHQ "2HH" & "3HH" Series; coverage seems good but no index (a lot of work....).
1967	P.C. Planning and Dev.	Paul Matty	1"=800'; B/W; **
1965	P.C. Mapping & Records	Barry Rothrock	1965 Flood photos! very large scale; much of Pima County; some photos have yellow post-its marked "'66;" no index.
1965	P.C. Mapping & Records	Barry Rothrock	Blanton/Cole Series; only "mid" part of SCR; missing area south of Tucson that was covered in 1964 photoset; stops north of PC/SC line.
1964	P.C. Mapping & Records	Barry Rothrock	Blanton/Cole Series; only Tucson area; 1':800'; can work at their office ($3.00 per sheet to copy).
1964	P.C. Planning and Dev.	Paul Matty	1"=800'; B/W; **
1963	P.C. Planning and Dev.	Paul Matty	1"=600'; B/W; **
1960	P.C. Planning and Dev.	Paul Matty	1"=800'; B/W; **
1958	P.C. Mapping & Records	Barry Rothrock	DHQ "V" Series; very incomplete coverage 1:20,000; can work at their office ($3.00 per sheet to copy).
1958	P.C. Planning and Dev.	Paul Matty	1"=400'; B/W; **
1956	P.C. Planning and Dev.	Paul Matty	1"=1000'; B/W; **
1955	P.C. Planning and Dev.	Paul Matty	1"=400', 660' or 800''; B/W; **
1954	P.C. Mapping & Records	Barry Rothrock	DHQ "N" Series; good coverage; can work at their office ($3.00 per sheet to copy).
1953/56	AZGS	Tom McGarvin	None for southern-most Santa Cruz County
1953	P.C. Planning and Dev.	Paul Matty	1"=800'; B/W; **
1950	P.C. Planning and Dev.	Paul Matty	4"=650'; B/W; **
1950	P.C. Planning and Dev.	Paul Matty	1"=200'; B/W; **

1949	P.C. Mapping & Records	Barry Rothrock	DHQ "F" Series; missing north Tucson reach of SCR (the %F sub-series); looks like only the SCR area of Tucson & "mid" was purchased.
1946	P.C. Mapping & Records	Barry Rothrock	XXA Series; good coverage 1:20,000; can work at their office ($3.00 per sheet to copy).
1941	P.C. Planning and Dev.	Paul Matty	3"=1mi; B/W; *
1936	P.C. Planning and Dev.	Paul Matty	4"=1'; B/W; "L" Pima - Papago Reservation; **
1936 (37/38)	Soil Conservation Service (Tucson Field Office)	Bud Bowers	Give a call to the field office to make an appointment to come see the photos.

* Beverly could come up with older photos of Pima County but not Pinal and Santa Cruz Counties. Oldest of Pima = 1953. Oldest of broad coverage of Santa Cruz region is 1960.

**P.C. Planning photosets compiled by Paul Matty. Many of these photosets were incomplete and/or had no index.

Pinal County:

Year	Agency	Contact	Comments
1994	Pinal County Planning & Dev.	Pete McGrath & Jaunita Silvernagel	1 map = 9 sections. Mondays all day, Tuesday mornings and Fridays are best; call ahead to make an appointment to use the "hearing room" in which to work.
1993	Pinal County Planning & Dev.	Pete McGrath & Jaunita Silvernagel	Flood photos. See notes above.
(1992)	Farm Service Agency (Pinal C.)	Pat Fox	In process of cataloging.
1987	Pinal C. Flood Control	Juanita	
1983	SCS-Pinal County	Mark Felix	During flood; shot by Cooper Aerial. Call to make an appointment.
1983	Pinal C. Planning & Dev.	Pete McGrath & Jaunita Silvernagel	Flood photos. See notes above.
1982	SCS-Pinal County	Mark Felix	These are mixed with some '79 photos. Call to make an appointment.
1979/80	AZGS	Tom McGarvin	Cooper Aerial; 1:12,000; Need to double check for coverage of Pinal County
1979	ADWR - Pinal AMA	Lisa	Their office has a light table where we can work.
1978	Farm Service Agency (Pinal C.)	Pat Fox	8":1 mile; 2 1/2' photos.
1972/73	AZGS	Tom McGarvin	1:4000; N.A.S.A. photography; need to double check for Pinal County coverage
~1969	Farm Service Agency (Pinal C.)	Pat Fox	Call to make arrangements to visit.
1964	Pinal C. Planning & Dev.	Pete McGrath & Jaunita Silvernagel	9 south, 8 east, sections 31 &32; 10S, 8E, Ss 5-8, 17-20, 29 & 30; 6S, 5E, Ss 8-9, 16-17, 20-21, 28-29, 32-33; 7S, 5E, Ss 4-5.

1954-58	Pinal C. Planning & Dev.	Pete McGrath & Jaunita Silvernagel	complete around the SCR; better than the 1964 photoset.
1953/56	AZGS	Tom McGarvin	None for southern-most Santa Cruz County; need to double check for Pinal County
~ 1954 & '56	SCS-Pinal County	Mark Felix	incomplete with poor indices
1936	Desert Botanical Gardens	Pat Comus	Complete photoset.

Santa Cruz County:

Year	Agency	Contact	Comments
1995	AZ Dept. of Water Resources, SCAMA	Placido Dos Santos	Excellent photoset! Complete coverage of the Santa Cruz Active Management Area, color photos, ~1:24,000.
1983/1984	USGS, UA office	Brenda	Color Infrared; 1:60,000. Has good index. Coverage: just north of the Tucson Mts (~Marana); most/almost all of S.C. County. Can borrow this photoset with no problem; it is quite portable.
1983	Cooper Aerial	Beverly	Flood coverage; includes Pinal and Santa Cruz Counties.
1979/80	AZGS	Tom McGarvin	Cooper Aerial; 1:12,000; "Poor" coverage
1977	Cooper Aerial	Beverly	Flood coverage; does not include Pinal County; does include Santa Cruz County.
~1978	ESIC	Diane	Color photos of ~ 2 miles area on both sides of the international border.
1972/73	AZGS	Tom McGarvin	"Good" coverage; 1:4000; N.A.S.A. photography
1953/56	AZGS	Tom McGarvin	None for most of Santa Cruz County
1936 (37/38)	Soil Conservation Service (Tucson Field Office)	Bud Bowers	Give a call to the field offfice to make an appointment to come see the photos

Appendix E
Upper Santa Cruz River Basin – Collection of Topographic Maps

Note: all the maps prior to 1962 are 15 minute quadrangles or smaller scaled. After 1962, the maps are all 7.5 minute quadrangles unless otherwise indicated.

7.5' U.S.G.S. Quadrangle Names		$	1902	1903	1904	1905	1906	1907	1908	1909	1910	1911	1912	1913	1914	1915	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929	1930	1931
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Jaynes																	▓															
Tucson North						▓											▓ R															
Cat Mountain																	▓						░			▓						
Tucson						▓											▓ R															
San Xavier																	▓						░			▓						
Tucson SW						▓											▓ R															
Sahuarita			▓ *		▓	▓															▓ R						▓					
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Green Valley			▓ *		▓	▓															▓ R						▓					
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Tubac																				░	▓											
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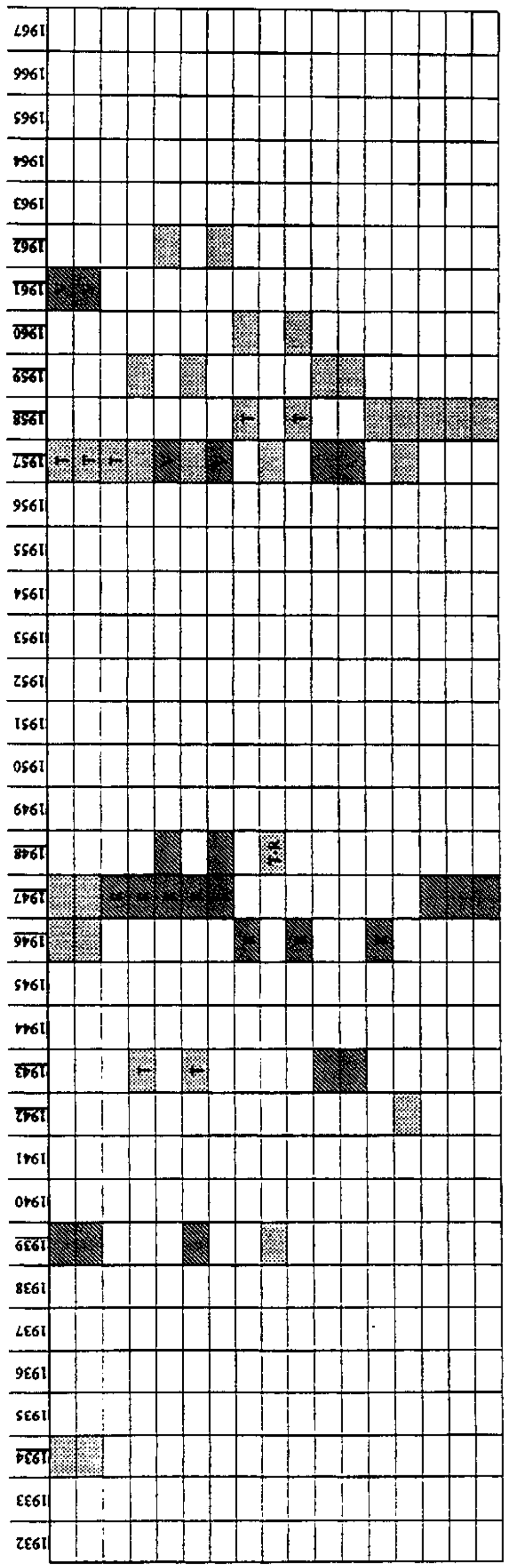
Rio Rico		▓ $				▓											▓ S-04						░									
Cumero Canyon		▓ $															▓ S-04						░									
Kino Springs		▓ $															▓ S-04						░									

KEY:

- ▓ - Map located at AZGS.
- ░ - Map located in the UA Map Collection
- T - Map located at Tumamoc Hill (Julio Betancourt)
- O - Orthophotoquad series located in the UA Map Collection
- P - Photo-revised version
- R - Reprint
- V - Revised version
- S-## - Survey year, 19##
- $ - pre-Statehood
- 15 - Map is a 15' quad. rather than 7 1/2'.
- * - San Ignacio de la Canoa Private Land Claim Map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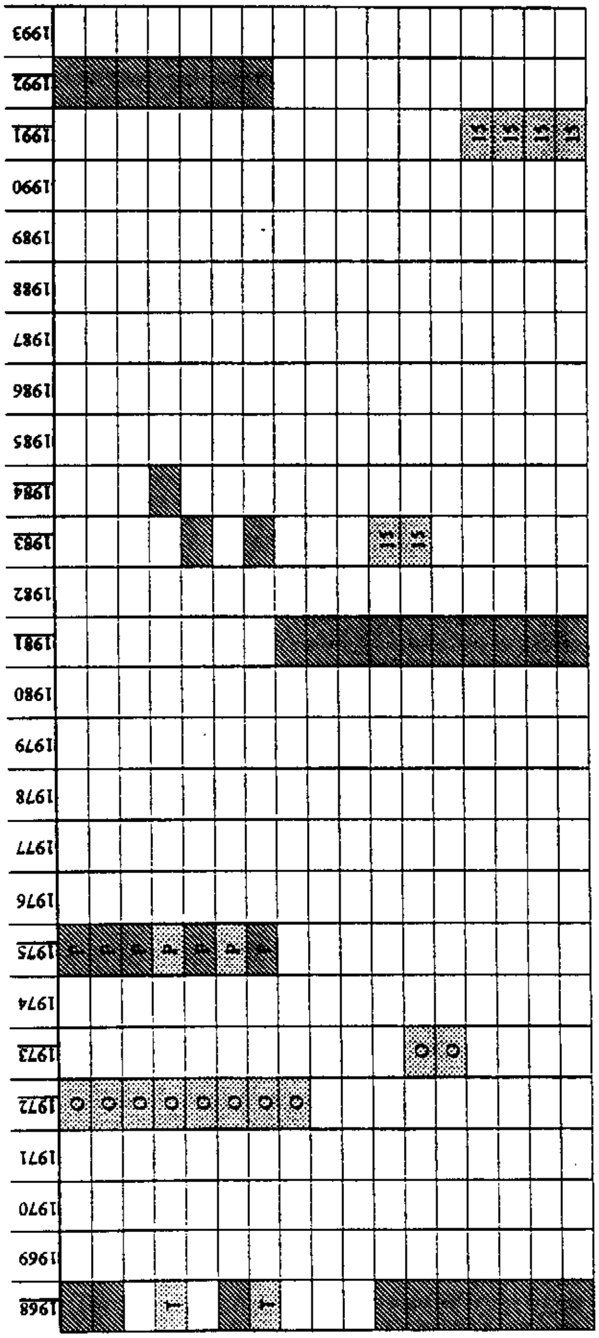
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Appendix F

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ARIZONA STATE LAND DEPARTMENT

Section 5

ARIZONA STREAM NAVIGABILITY STUDY
for the
SANTA CRUZ RIVER
Gila River Confluence to the Headwaters

Final Report

Prepared by:

SFC Engineering Company

In Association with
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January 12, 2004

Navigable Rivers Land Use GIS

I. Methodology

A Geographic Information System (GIS) was developed depicting the 100-year floodplain and land ownership/use within the floodplain (see Appendix A for data organization). The GIS was designed not to aid in the determination of navigability, but to help study the impacts should the river be found navigable. Information regarding the ownership and use of land in the vicinity of the river may be depicted as maps or as statistics.

The general land ownership categories depicted by the GIS are as follows:

Ownership Categories
Private
State of Arizona
Bureau of Land Management (BLM)
U.S. Forest Service
National Wildlife Refuge
National Park Service
Indian Reservation
Other / No Data

The general land use categories depicted by the GIS are as follows:

Land Use Categories
Vacant Land
Residential - Single Family
Residential - Multiple Family
Hotel - Motel - Resorts
Condominiums
Commercial Property
Industrial Property
Farm/Ranch Property
Public Utilities
Natural Resources
Special Use Property
General Service Use

Additional data are also contained in the GIS, such as: county, township, range, section, book, map, parcel, source, legal parcel area, state land use code, and owner descriptions.

A. Base Data

The base layers for the GIS, including rivers, counties, and public land survey system, were obtained from the Arizona Land Resources Information System (ALRIS) maintained by the

Arizona State Land Department (ASLD). Additional river data were obtained from 1:100,000 scale Digital Line Graph (DLG) files maintained by the United States Geological Survey (USGS).

B. Floodplain

The 100-year floodplain was digitized from Federal Emergency Management Agency (FEMA) maps of varying scales. Georeferencing (i.e. registration of map data to real world coordinates) was accomplished via section corners and, in a few circumstances, street intersections. Arbitrary lines were digitized at junctions with tributary floodplains. Adjacent maps were edgematched; significant mismatches were not adjusted but were closed using straight line segments.

C. Land Ownership/Use

Where GIS parcel datasets already existed, they were reprocessed and merged directly into the final product. This was only the case with the Pima County portion of the Santa Cruz River:

1) Parcels were requested from the Pima County GIS Project by section,

2) Section tiles were combined into a single coverage and reprocessed,

3) The Santa Cruz River parcel dataset was updated with the Pima County data and sliver polygons removed, and

4) Parcels outside the floodplain were assigned zero attributes and dissolved.

Otherwise, parcels were digitized from paper County Assessor maps. Georeferencing was accomplished using the following:

1) Section corners or subdivisions (e.g. quarter-quarter-section corners),

2) Legal descriptions using a section corner or subdivision as a reference point,

3) Distances, based on map scale, from a section corner or subdivision,

4) Corresponding features in a smaller scale map (e.g. a map of a housing development might be registered via its corresponding outline depicted in a section map), and/or

5) Adjacent features.

Digitizing was accomplished as follows:

1) Clearly delineated parcel boundaries were digitized as depicted. Lines in large scale maps generally took precedence over corresponding lines in small scale maps.

2) Areas of parcel overlap were assigned to one parcel or the other as deemed best. Unclear boundaries between two parcels were digitized according to best judgement.

3) Parcels of vague or undepicted location were not digitized unless an outline could be obtained from an alternate source (e.g. ALRIS data or USGS 1:100,000 DLG files).

4) Linear (non-polygonal) parcels, depicting railroad right-of-way (ROW), were not digitized. An exception was made if adjacent parcels clearly depended on a ROW edge, in which case a 200' wide corridor was applied.

When necessary, adjacent maps were edgematched. Small scale features were adjusted to large scale features. Attributes were assigned in a fashion consistent with ASLD's standards utilized for the Gila River coverage:

1) Parcel numbers were assigned where clearly designated, unless the parcel clearly was non-private (State, BLM, etc.), in which case a "non-private" parcel code (AZ, BLM, etc.) was assigned.

2) Parcels which were not numbered, but were clearly labeled (Arizona, U.S.A., etc.) were assigned non-private codes as appropriate. Where a conflict existed between assessor maps and ALRIS data over USA versus State ownership, the ownership reflected in the ALRIS data was assigned.

3) Unlabeled or questionable parcels, uncoded road and rail ROW parcels, parcels outside the floodplain, and undigitized regions were assigned a zero parcel number.

4) Sections outside the study area were assigned "background" (BACK) parcel codes.

Relate files, containing land ownership and use data, were generated from State Revenue data. A list of parcel values was generated from the digitized parcels and submitted to the State Revenue office. Data received from the State Revenue office were converted to a table and reprocessed. If, after a quality check, the ID of a digitized parcel was not listed in the State Revenue data (e.g., if a parcel split or merge had not yet been depicted on the County Assessor map), it was assigned "Other / No Data" ownership.

D. Plots

Once all datasets were assembled, checked, and finalized, they were transported to the State Land Department building in Phoenix. Annotation coverages were created for the final plots, and existing scripts and tables adapted to production of the final plots. One complete series was created for each river reach.

II. Results and Discussion

The study area was divided into fourteen map sheets for plotting purposes. The 100-year floodplain was digitized for the entire study area, except within the Gila River, Ak-Chin, and San Xavier Indian Reservations. All parcels in the Pinal County and Santa Cruz County portions of the study area were digitized from paper maps. All study area parcels in Pima County were obtained from the Pima County GIS Project.

Two problem areas have been identified in Santa Cruz County: the Baca Grant region and the headwaters of the Santa Cruz River.

A significant gap in the data exists within the former Baca Grant in Santa Cruz County. Parcel data are available in digital form for that region, but access has not been granted by the Santa Cruz County Planning and Zoning Department. Marlene Shields of ASLD is currently investigating the situation, but the final GIS submitted to ASLD for the 1997 Report did not contain data for that area.

A discrepancy has been noted regarding the alignment of the headwaters of the Santa Cruz River. Data obtained from ALRIS depict the headwaters passing through Sheep Ranch Canyon in Township 22S, Range 17E, whereas other maps show the river passing through Meadow Valley in the same Township and Range. Parcels have been digitized along both reaches.

GIS data prepared for the 1997 SFC report was not updated or modified for the 2004 revision of the Santa Cruz River Report.

Appendix A: GIS Data Organization

A. Base and Reference Layers from ALRIS

Name	Contents
AZTRS	Public Land Survey System of Arizona
COUNTIES	County Boundaries
HYDRO	Hydrology
LAND	Surface Management
RAILS	Railroads
TRANS123	Major Roads

B. Data Organization

A separate workspace is created for each river reach. The principal ARC/INFO coverages contained in each workspace are FLOOD, depicting the 100 year floodplain, PARCELS, containing digitized parcels, RIVER, depicting the river itself, and SHEETS, depicting the mapsheets.

1. FLOOD

The FLOOD coverage has polygon topology wherever possible. The PAT contains the following item:

ITEM NAME	WIDTH	TYPE	N.DEC
IN_OUT	3	C	0

IN_OUT Values:
in = Part of floodplain
out = Not part of floodplain

2. PARCELS

The PARCELS coverage has polygon topology. The PAT contains the following items:

ITEM NAME	WIDTH	TYPE	N.DEC
TOWNSHIP	4	C	0
RANGE	4	C	0
SECTION	2	C	0
COUNTY	2	N	0
BOOK	3	C	0
MAP	3	C	0
PARCEL	4	C	0

ITEM NAME	WIDTH	TYPE	N.DEC
CODEDATE	8	D	0
OWN_CODE	12	C	0
SOURCE	20	C	0
CATEGORY	10	C	0

Items TOWNSHIP, RANGE, SECTION, and COUNTY conform to the data dictionary of the ALRIS LAND layer.

Parcels which have a book, map, and parcel number, are coded as follows:

ITEM	Example
COUNTY	9
BOOK	103
MAP	043
PARCEL	1A
OWN_CODE	091030431A

Other parcels are coded as follows:

STANDARD CODES FOR NON-PRIVATE PARCELS

ITEM	Example
BOOK	101
MAP	040
PARCEL	0
OWN_CODE	0

PARCEL Values:
0 = No data or "other" (e.g. Right-of-Way)
AKCH = Ak-Chin (Maricopa) I.R.
ASNF = Apache-Sitgreaves NF
AZ = State of AZ
BLM = BLM
BWR = Bill Williams N.W.R.
CONF = Coronado National Forest
GILA = Gila River I.R.
NAV = Navajo I.R.
PFNP = Petrified Forest NP
SANC = San Carlos I.R.
SANX = San Xavier I.R.
SALT = Salt River I.R.
SRWR = Salt River N.W.R.

PARCEL Values:
TOHO = Tohono O' Odham (Papago) I.R.
TONF = Tonto National Forest
TONM = Tonto National Monument
WMA = White Mountain Apache I.R.

"Background" parcels, i.e., sections outside the study area, are coded as follows:

ITEM	**Example**
BOOK	999
MAP	999
PARCEL	BACK
OWN_CODE	BACK

The CODEDATE item contains the date of completion of the coverage. The principal source used to determine the geometry of a particular parcel is documented via the SOURCE item.

SOURCE Values:
ASLD Base = Base data from AZ State Land Dept. (AZTRS)
County/Paper = County Assessor paper maps
County/Digital = County Assessor digital maps
County/GIS = County GIS
USGS 100K DLG = USGS 1:100,000 DLG files
ALRIS LAND = ALRIS LAND coverage
Various = Various Sources

The CATEGORY item is a temporary item used in the generation of status maps.

Each PARCEL coverage has a relate file, OWNDATA, with the following structure:

ITEM NAME	**WIDTH**	**TYPE**	**N.DEC**
OWN_CODE	12	C	0
OWNER	2	N	0
LC	2	C	0
DEL_FLAG	1	C	0
STATUS_DAT	8	D	0
LAND_USE	4	C	0
AREA	8	C	0
UNITS	1	C	0
OWNER1	40	C	0
OWNER2	40	C	0
OWNER3	40	C	0

OWN_CODE is the relate item to the PARCELS coverage. OWNER is the ownership lookup code and LC the use lookup code, used for querying and plotting. DEL_FLAG is a State Revenue record code, probably indicating a record slated for future deletion. STATUS_DAT is the date of the record. LAND_USE is the four-digit State land use code. AREA is the legal area of the entire parcel. UNITS is the units of the legal area (acres or square feet). OWNER1 through OWNER3 are the first three fields of the taxpayer name and address section.

3. RIVER

The RIVER coverage has line topology. There are no additional attribute items.

4. SHEETS

The SHEETS coverage has line topology. The AAT contains the following item:

ITEM NAME	WIDTH	TYPE	N.DEC
SHEET	2	N	0

Values correspond to the mapsheet number.

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Section 6

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SUMMARY

The following is a summary of the key findings of the following sections of this report addressing the archaeology, history, hydrology, hydraulics, geomorphology, and land use of the Santa Cruz River from the confluence with the Gila River to the headwaters. Refer to Figure 1 for a map of the Santa Cruz River basin showing the location of the place names mentioned in the text. The most pertinent findings relative to the legislatively mandated evidence of navigation or evidence of susceptibility to navigation are compiled to provide information to support a determination by others of navigability or non-navigability of the Santa Cruz River. This report does not make a recommendation or conclusion regarding title navigability of the Santa Cruz River.

Evidence of Navigation

Archaeological Evidence

Archaeological data augment the historical record of potential river uses at statehood by providing an extended record of river conditions, use of river water, climatic variability, and cultural history along the river. The investigation of the archaeological record focused on prehistoric uses of the river as evidenced by settlement patterns, the presence of canals for irrigated agriculture, and transportation and/or trade routes on or along the river.

Settlement Patterns- The archaeological literature documents prehistoric settlements distributed both temporally and spatially throughout the Santa Cruz River valley. Late Archaic sites (2000- ca. 100 B.C.) were located in floodplains, areas adjacent to floodplains, or alluvial fans. During the Archaic-Hohokam transitional stage (ca. 50 B.C.- A.D. 425), settlement patterns, consisting of agricultural hamlets in floodplain settings and camps in bajada areas, reflected a subsistence strategy based on floodwater farming of maize, hunting, and foraging in the bajada and upland zones. During the Hohokam Pioneer period/late Early Formative period (A.D. 425- 750), the Hohokam emerged as a regional culture with the Tucson Basin becoming a local node in the Hohokam regional system.

Shifts in settlement patterns through time are evident. By the end of the Hohokam Colonial period (A.D. 750- 950), an expanding populationsettled most villages along secondary rather than primary drainages of the Santa Cruz River in the Tucson Basin. Settlement locations further shifted away from floodplains during the late Hohokam Sedentary period (A.D. 950- 1150) partly due to entrenchment - progressive degradation of the streambed- and cienega - marsh - formation. As a result, non-riverine agricultural features began to appear on terraces and bajadas. There was continued use of non riverine agricultural systems as well as floodwaterfarming during the Hohokam Classic period (A.D. 1150- 1400).

Irrigated Agriculture- Prehistoric populations took advantage of potential agricultural areas as conditions allowed, partly because the floodplain environment of the river was highly variable. Arroyo fan deltas and discontinuous gully fan environments had floodwater agricultural potential and Hohokam settlers appeared to locate in those areas for the purpose of optimizing farming conditions.

Certain archaeological investigators suggest that the floodplain environment and surface hydrology of the river was not conducive to canal irrigation, but limited canal or ditch irrigation would have been feasible near cienega environments. Others believe that canals may have been present on a small scale, possibly in association with the primary villages. In fact, recent archaeological findings indicate farming villages near Tucson were using surface water to irrigate crops as long as 2000 to 3000 years ago. These same people supplemented theirdiet with fish caught from the river. More recently, 300 to 400 years ago, Indians were still irrigating crops with surface water near Tucson, San Xavier, and Tubac. This practice continued during the period of the development of the Spanish missions ofsouthern Arizona and well into the period of Anglo settlement.

Transportation and Trade- The archaeological record indicates that the Tucson Basin became a local node in the Hohokam regional trade system. Interregionalexchange is evident by the presence of Mogollon ceramics from the mountainous regions to the east and by shell artifacts from the Sea of Cortez. Further, the Santa Cruz River was the line of communication for the dissemination of new types of pottery, notably, Rincon polychrome vessels among others. Vessels of this type were found at the north and south extremities of the river. The river valley functioned as a communication, transportation, and trade corridor in prehistoric times. No evidence was found to suggest that the early inhabitants of the valley used boats on the river.

Historical Summary

Historical data provide information on actual river uses at the time of statehood, and also provide information on whether river conditions would have supported navigation. The historical investigation focused on use of the river and adjacent areas in historic times, with special emphasis on the establishment, growth, and development of towns, irrigation systems, commercial activities, and developments.

During the historical period, the Santa Cruz River was an important transportation route for Native Americans, missionaries and Spanish explorers, colonizers and wanderers, miners and cattlemen, and new residents. It provided a well-established route from the south and the east into present-day Arizona as far as Tucson, providing water, forage, and food for the traveler. The river also provided water, wood, food, and shelter for the people who lived near it. Farmers diverted the surface water of the river. Millers, both of flour and ore, powered their grinders with Santa Cruz water. Entrepreneurs dammed the river, and the lakes that were created were used by the public for fishing, boating, picnicking, and swimming. Much of the settlement in southern Arizona, to date, is within the valley of the Santa Cruz River.

Probable Condition of the River in 1912- At the time of statehood, the river was probably still perennial - flowing year round - in some of the reaches that had historic surface flow, but intermittent- flowing only during portions of the year- in more areas than previously. An important difference was that the vegetative structure of the valley was much different, and the entrenchment- the progressive degradation of the streambed- of the river meant that surface waters visible in 1912 were much lower than 25 years earlier. In many areas riparian vegetation had been cut for wood or lumber, and farms or homes used much of the water riparian trees had formerly used.

The U.S. Geological Survey Streamgage Summaries report that essentially the entire flow of surface waters from the river were diverted both at the Nogles and Tucson gaging stations by irrigation ditches (USGS 1907, 1912). Agricultural water use in the Tubac, Tucson, and San Xavier areas used most of the available surface water and also intercepted groundwater and subsurface flow. Diversions and pumping also diminished flows on tributaries, especially the Rillito River. In 1910, the University of Arizona Agricultural Experiment Station estimated that flow from the Rillito River reached the Gila River 1 in 15 years (Smith, 1910).

The upper reach of the Santa Cruz River, located in Santa Cruz County, has its headwaters in the San Rafael Valley of southeastern Arizona. Historically, the river consisted of shallow flows similar to present conditions. The river through Mexico still flowed dependably. From the border downstream to the Sonoita Creek confluencethe Santa Cruz River was dry much of the time because of diversions. With the addition of Sonoita Creek waters downstream of the confluence, there was again surface flow visible in the river. Much of that water was diverted for agriculture along the river downstream of Calabasas to the north.

The middle Santa Cruz River reach is defined as that portion of the river located in Pima County. In this reach, the springs were drying up in the San Xavier area and diversions and pumping took most, if not all,the flow. A high water table still supported a lush mesquite bosque south of the mission. The City of Tucson and many others had dug wells in numerous locations, some as far south as San Xavier, which intercepted flow and lowered the groundwater table. In 1915, the first year such measurements were systematically taken, the Santa Cruz River and the Rillito River flowed less than half the year. Through Tucson the deeply entrenched channel carried some flows, but all of the low flow was diverted before the Congress Street bridge. Springs and groundwater still supported some agriculture downstream of Tucson, but there was little perennial flow.

The lower Santa Cruz River, in Pinal County downstream of Marana, continued to have little flowing water exceptin years of high rainfall.

Navigation Accounts- Although the river valley was an important transportation route, it was not normally used for navigation except for the following accounts found in the literature:

- A land speculator portrayed the river at Calabasas (downstream of Nogales) as capable of floating steamboats in the 1880s. This, however, was pure fiction but gave rise to the belief that surfaces, occasionally even today, that the river was navigated by large ships.

- During the 1880s, Silver Lake (a manmade lake just south of downtown Tucson on the Santa Cruz River) was a popular recreation area, featuring boating, fishing and swimming. A paddle boat on the lake was a major attraction. Boating both by rowing and sail was popular in the lake and upstream. Silver Lake was damaged by a combination of floods in the late 1880's, and finally destroyed in 1890. The dam itself was reported standing until the floods of 1900. Based on the limited information available, other conditions (possibly the increase in other water diversions) made the existence of a reservoir behind the dam impossible.

- In December 1914, during a flood period, a group of adventurers attempted to float the Upper Santa Cruz River, but weregrounded. The boat was later located buried in mud. Also in the 1914 flood, numerous people were stranded on rooftops and windmills near Sahuarita. The Arizona National Guard went to rescue them with an inflatable boat, but the current was too strong and the effort was unsuccessful. Later the people were rescued with horses.

- Occasionally, in recent times, a canoer or rafter has floated the river during flood time. Tubers floated the Santa Cruz River in the 1970s during flood time. The Tucson Weekly featured a canoer traveling the effluent-dominated stretch in July 1990, a trip which he repeated during flood time for the Tucson Weekly photographer. The Tucson Citizen reported canoes on the Rillito River during the 1990 flood. The same canoers havealso traveled on the Santa Cruz and Agua Caliente at various times in the 1990s. These canoers stated that when they also traveled the river during the winter of 1989-90, it was "a reasonable canoeing river", but when they made the trip in the summer, it was "more like the Grand Canyon" in terms of difficulty. They are knowledgable with regard to local boating groups, but are unaware of any attempts to boat the upper Santa Cruz River, although they state that it is certainly feasible. Canoers state that the Santa Cruz is just barely navigable by canoe with 4" of water, but that the channel topography is a limiting factor as sand bars are frequent.

- There are no stories of boating at any time on the lower Santa Cruz, although during one high flood event Tucsonan Sam Hughes expressed, in his opinion, that the river was "big enough to float a steamboat all the way to the sea."

- There are no records of ferry service anywhere on the river. Fords and crossable washes are marked on numerous maps. When the bridges went out during floods, people were stranded and had to wait until the river could be crossed by horse. No evidence of boats being used to cross the river at flood time were found.

- No evidence was found of the river being used to transport good such as logs.

- John Spring recorded in his diary that there was an old Mexican settler who had carved a canoe to cross the upper Santa Cruz River when flooding made it too high to cross on the road. According to Spring, this is the origin of the name for that area of the Santa Cruz Valley, "La Canoa."

Changes in the River- The three distinct sections of the river had very different histories. The upper and middle reaches, located in Santa Cruz and Pima Counties respectively, were used extensively by native peoples, Spaniards, and later Americans. The lower reach, located in Pinal County, had much less dependable water and was used much less. Because of underlying geology and the fact that population eventually centered in the Tucson area, the middle Santa Cruz experienced much more extreme changes than either the upper or lower sections in terms of location of perennial flow.

Some portions of the river remain perennial to this day. Other reaches north of Nogales and Tucson have more water now than they did at the time of statehood due to wastewater effluent flow. Many of the perennial sections of the river, however, have been lost. The perennial waters near San Xavier persisted until 1949, and supported native fish until at least 1937. The section of the river near Tucson probably had some perennial flow in 1912, but at this time the river was deeply entrenched. Therefore, the water table was already lower than it was before entrenchment began after the floods of 1890. The United States Geological Survey kept data on streamflow at certain measuring points on the Santa Cruz River. By 1910, it was reported that the entire base flow of the river at both the Mexican border, and near the Congress St. Bridge in Tucson, was diverted for agriculture.

The upper Santa Cruz River in Santa Cruz County, including the headwaters in the San Rafael Valley, has been relatively stable. Perennial flow existed in many places

here, as well as some cienegas. The geology changes norh of Tubac, and the river frequently went
subsurface there throughout history, as it presently does. However, the historical perennial reaches at San Xavier and Tucson are gone.

The lower Santa Cruz River in Pinal County never supported perennial flow.In fact, it was only during rare flood events that water from the upper Santa Cruz River reached the confluence with the Gila River. Early explorers said that the river through Pinal County had a nearly indistinguishable channel, and maps showed a discontinuous channel there. This section of the river remains relatively unchanged in terms of the absence of perennial flow. The lower Santa Cruz River flows only in response to precipitation events.

The biggest changes in the valley have been along the middle Santa Cruz River, especially from Tucson to Tubac, because of population growth, mining, and agriculture. This combination of events has led to loss of perennial water, an increase in groundwater withdrawal, and an extensive change in the vegetativestructure there.

Evidence of Susceptibility to Navigation

The hydrology and geomorphology of the Santa Cruz River have experienced both subtle and dramatic changes in their character since the time of Statehood. These changes have resulted from a combination of climate change, human activities, and geomorphologic processes.

Hydrology

Historically (circa the 1890s), the Santa Cruz River was perennial from its source to Tubac. Climate change since the turn of the century, combined with the extensive groundwater pumping for irrigation and the flow diversion for municipal use that began near the international border during the 1930 to 1950 drought period, has resulted in no flow in the channel in Sonora, Mexico, and discontinuous flow in the channel near Nogales, Arizona. The 1913 gage record at Nogales, the earliest in that region, indicated that by the time of statehood, the Santa Cruz River near Nogales was no longer perennial, but instead had continuous flow during the winter and occasional flow during the spring, summer and fall. The 1913 winter discharge averaged about 15 cubic feet per second (cfs), except for an increase caused by a rainfall event that ranged from 35 to 174 cfs. A survey of the daily data for the rest of the Nogales record indicated that, during wet years, there were only a few days of noflow conditions. During dry years, there were entire months that passed with no flow recorded in the channel. At present, naturally occurring perennial reaches occur only in the uppermost part of the river in the San Rafael Valley. The perennial reach north of Nogales results from the discharge of sewage effluent from the Nogales International Wastewater Treatment Plant that begn in 1972.

The Santa Cruz River historically had several springs and cienegas within its channel from Tubac to Tucson, and a marsh at its confluence with the Gila River near Laveen. Even in the historical record, only the very largest floods were sustaried from the headwaters to the confluence with the Gila River. A review of the daily discharge record indicated that there was some semblance of baseflow, with an average of about 12 cfs during the fall and winter of 1912-1913, at the Tucson gage. Such continuous flow for months at a time was not seen again in the years that followed, though there were periods of several weeks that experienced continuous or nearly continuous flow during very wet winter seasons. The Laveen gage recorded nearly yearound flow from its beginning date in 1940 until June of 1956, when it began to measure zero flow for weeks at a time. During the 1940 to 1956 period, the daily flow averaged about 3 cfs during low flow conditions, and had peaks as high as 5060 cfs during wet peiods. By 1960, the Santa Cruz at Laveen was also experiencing no flow conditions for months at a time.

Not only have the locations of surface flows changed since the time of statehood, but also the seasonality and magnitude of flows in the Santa Cruz River have changed in response to shifts in the hydroclimatology of the region. Though the majority of flow events occur during the summer season, the magnitude and number of annual peak discharges that occurred in the fall and winter were higher before 1930 and after 1960 than during the 1931-1959 period. For example, six of the seven largest floods at Tucson occurred after 1960, indicating that the magnitude of flood peaks has increased in the past few decades.

In evaluating the susceptability of the Santa Cruz River to navigation in historic times, it is important to be cognizant of the significant changes that have occurred in the river. The current condition of the river is not representative of the conditions that existed at statehood. Human activites, as well as climate change, have had notable effects on the peak flows of the Santa Cruz River, especially in the lower basin. Since 1962, the construction of flood control channels in the washes of the lower Santa Cruz River basin has resulted in the reduction of floodplain storage and infiltration losses, therefore reducing the attenuation- the downstream decrease of the flood peak- of peak discharges. For example, the attenuation of peak flows was greater during the 1962 floods than during the 1983 floods because water was able to spread out over the broad flow zones in the lower reaches of the Santa Rosa and Santa Cruz washes. In contrast, much of the floodwater during the 1983 floods was efficiently transmitted downstream by the flood-control channels.

Geomorphology

The geomorphology of the Santa Cruz River upstream of Marana is quite different from that of the lower Santa Cruz River downstream of Marana. The river has a well defined, often entrenched, channel in its upper reaches that contrasts strongly to the ill defined system of braided channels that exist north of Rillito Peak at the northern end of the Tucson Mountains. Both the upper and lower reaches of the Santa Cruz River have experienced dramatic changes resuting from a combination of both natural geomorphic processes and human activities. Three types of lateral change- 1) meander migration, 2) avulsion and meander cutoff, and 3) channel widening- and two types of vertical change- aggradation and degradation of the channel bed- have occurred. While arroyo development is the most obvious type of channel change to occur since the 1890s in the upper Santa Cruz River, most of the initial channel incision occurred before the time of statehood. Since 1912, vaious reaches of the upper Santa Cruz River have been dominated by such processes and activities as: meander migration and cutoff, channel widening, arroyo widening, channelization, and the vegetational effects of sewage effluent discharge. The channel locations in different reaches have changed spatially on the order of a few feet to a few thousand feet, depending on the processes that resulted in the change, and often change could be detected from one year to the next.

The lower Santa Cruz River, downsteam of Marana, experienced changes of a completely different magnitude from the upper Santa Cruz River. Changes in the location of the channel in the lower basin can be measured in miles, and, due to the nature of the causes of the changes, the timing spans decades. Before the construction of Greene's Canal in 1910, the river transformed from a relatively deep, well-defined channel to a broad, flat, extensive alluvial plain at a point in the Marana area. Now that transition point occurs near Chuichu, Aizona. The construction and subsequent flood damage of Greene's Canal has resulted in other dramatic geomorphic changes. Prior to and during the floods of 1914-1915, flood flow had the opportunity to follow routes down the North Branch of the Santa CruzWash and McClellan Wash. After the development of the arroyo in Greene's Canal, the bulk of subsequent flood flows have had westerly paths.

ARIZONA STATE LAND DEPARTMENT

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for the
SANTA CRUZ RIVER
Gila River Confluence to the Headwaters

Final Report

Prepared by:

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November 1996

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January 12, 2004

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Physiographic Province - A region of similar geology. In Arizona, three physiographic provinces are recognized: the Basin and Range, the Central Highland (Transition Zone), and the Colorado Plateau.

Pleistocene - The most recent geologic period, usually the past 1,000,000 years before present.

Point of Zero Flow - The stage on a rating curve or gage record where no discharge occurs.

Quit claim - A transfer of one's interest in a property, especially without a warranty of title to give up claim to property by means of a quit claim deed.

Quit claim deed - A deed that conveys to the grantee only such interests in property as the grantor may have, the grantee assuming responsibility for any claims brought against the property.

Rating Curve - A graph which relates stream discharge to some other measurable stream characteristic such as stage, width, depth, or velocity.

Reach - A segment of a stream, usually with uniform characteristics.

Riparian - Refers to that which is related to, or located near, or living along a watercourse whether natural, man-made, ephemeral, intermittent, or perennial.

Salt Cedar - A non-native, undomesticated tamarisk tree.

Scour - Removal of streambed material by flowing water.

Seep - A small, diffuse spring generally of low discharge rate.

Sinuosity - A measure of how sinuous a stream is: the ratio of the length along the thalweg to the length along the stream valley. Always greater than one.

Sinuous - The "curviness" of the channel planform; the degree of meandering.

Spring - The point where underground sources of water discharge at the surface.

Stage - A term used in stream gaging to describe the elevation of the water surface of a stream relative to some datum (fixed elevation). Stream stage is analogous to stream depth.

Stream Gage - A site operated for the purpose of measuring the rate or volume of water discharge in a stream. Accumulated data from a stream gage are called stream gage records.

Subflow - See Underflow.

Tamarisk (salt cedar) - Non-native riparian plants. Presently the dominant vegetation on the floodplain of many streams due to opportunistic growth in channel systems in the southwestern United States.

Terrace (Bench) - A relatively flat geologic or geomorphic surface which parallels a stream and is elevated above the floodplain, and was formed when the river flowed at a higher elevation.

Thalweg - The centerpoint, or low flow channel, of a stream.

Topwidth - The distance across the water surface, perpendicular to the channel, of a flowing stream.

Transition Zone - See Central Mountain Province.

Transmission Losses - Reductions in stream flow due to infiltration of water into the streambed and subsurface.

Underflow - A term used interchangeably with subflow to describe the ground water underlying the surface of a stream's channel.

Unentrenched - See Entrenchment.

Wash - A river or stream with low banks andnumerous channels.

Water Table - The upper surface of the underground zone of saturation; the plane which represents the elevation of ground water.
Watershed - The land area draining into a stream, or other body of water.

Xerophytes - Plants that are structurally adapted for life and growth with a limited water supply.

LIST OF ACRONYMS

Arizona Geological Survey	AZGS
Arizona Land Resource Information System	ALRIS
Arizona Navigable Stream Adjudication Commission	ANSAC
Arizona Revised Statutes	A.R.S.
Arizona State Land Department	ASLD
Arizona Upland	AU
Bureau of Land Management	BLM
Cubic feet per second	cfs
Federal Emergency Management Agency	FEMA
Flood Insurance Rate Map	FIRM
General Land Office	GLO
Geographic Information System	GIS
House Bill	HB
Lower Colorado River Valley	LCRV
Right of Way	ROW
Santa Cruz River	SCR
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Permeable - A rock or soil unit which is permeable will albw water to pass through it.

Phreatophytes - Deep-rooted plants that obtain water from the water table or the layer of soil just above it.

Physiographic Province - A region of similar geology. In Arizona, three physiographic provinces are recognized: the Basin and Range, the Central Highland (Transition Zone), and the Colorado Plateau.

Pleistocene - The most recent geologic period, usually the past 1,000,000 years before present.

Point of Zero Flow - The stage on a rating curve or gage record where no discharge occurs.

Quit claim - A transfer of one's interest in a property, especially without a warranty of title to give up claim to property by means of a quit claim deed.

Quit claim deed - A deed that conveys to the grantee only such interests in property as the grantor may have, the grantee assuming responsibility for any claims brought against the property.

Rating Curve - A graph which relates stream discharge to some other measurable stream characteristic such as stage, width, depth, or velocity.

Reach - A segment of a stream, usually with uniform characteristics.

Riparian - Refers to that which is related to, or located near, or living along a watercourse whether natural, man-made, ephemeral, intermittent, or perennial.

Salt Cedar - A non-native, undomesticated tamarisk tree.

Scour - Removal of streambed material by flowing water.

Seep - A small, diffuse spring generally of low discharge rate.

Sinuosity - A measure of how sinuous a stream is: the ratio of the length along the thalweg to the length along the stream valley. Always greater than one.

Sinuous - The "curviness" of the channel planform; the degree of meandering.

Spring - The point where underground sources of water discharge at the surface.

Stage - A term used in stream gaging to describe the elevation of the water surface of a stream relative to some datum (fixed elevation). Stream stage is analogous to stream depth.

Stream Gage - A site operated for the purpose of measuring the rate or volume of water discharge in a stream. Accumulated data from a stream gage are called stream gage records.

Subflow - See Underflow.

Tamarisk (salt cedar) - Non-native riparian plants. Presently the dominant vegetation on the floodplain of many streams due to opportunistic growth in channel systems in the southwestern United States.

Terrace (Bench) - A relatively flat geologic or geomorphic surface which parallels a stream and is elevated above the floodplain, and was formed when the river flowed at a higher elevation.

Thalweg - The centerpoint, or low flow channel, of a stream.

Topwidth - The distance across the water surface, perpendicular to the channel, of a flowing stream.

Transition Zone - See Central Mountain Province.

Transmission Losses - Reductions in stream flow due to infiltration of water into the streambed and subsurface.

Underflow - A term used interchangeably with subflow to describe the ground water underlying the surface of a stream's channel.

Unentrenched - See Entrenchment.

Wash - A river or stream with low banks andnumerous channels.

Water Table - The upper surface of the underground zone of saturation; the plane which represents the elevation of ground water.
Watershed - The land area draining into a stream, or other body of water.

Xerophytes - Plants that are structurally adapted for life and growth with a limited water supply.

LIST OF ACRONYMS

Arizona Geological Survey	AZGS
Arizona Land Resource Information System	ALRIS
Arizona Navigable Stream Adjudication Commission	ANSAC
Arizona Revised Statutes	A.R.S.
Arizona State Land Department	ASLD
Arizona Upland	AU
Bureau of Land Management	BLM
Cubic feet per second	cfs
Federal Emergency Management Agency	FEMA
Flood Insurance Rate Map	FIRM
General Land Office	GLO
Geographic Information System	GIS
House Bill	HB
Lower Colorado River Valley	LCRV
Right of Way	ROW
Santa Cruz River	SCR
US Geological Survey	USGS