US Army Corps
of Engineers
Los Angeles District

Paseo de las Iglesias
Tucson, Arizona

Draft F3
Without-Project Conditions

April 2002

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PASEO DE LAS IGLESIAS, PIMA COUNTY
FEASIBILITY STUDY

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CHAPTER I

STUDY AUTHORITY

General authorization for the Paseo de las Iglesias Study is provided by the Flood Control Act of 1938 (for the Gila River and its tributaries – which includes the Santa Cruz River). The specific authorization for the Reconnaissance and Feasibility phases of the Paseo de las Iglesias Study are provided in House Report 105-581 dated June 16 1998 which accompanied the 1999 Energy and Water Development Appropriations bill and read, in part.

"*Santa Cruz River (Paseo de las Iglesias), Arizona*.-The Committee has provided $200,000 for the Corps of Engineers to complete a reconnaissance study and initiate the feasibility phase of a project to address the environmentally degraded, flood-prone area upstream of the City of Tucson downtown area on the Santa Cruz River, in Pima County, Arizona."

A copy of the House Resolution follows as Figure 1.1

U.S. House of Representatives

COMMITTEE ON PUBLIC WORKS AND TRANSPORTATION

SUITE 2165 RAYBURN HOUSE OFFICE BUILDING
WASHINGTON, DC 20515
(202) 225-4472

COMMITTEE ON PUBLIC WORKS AND TRANSPORTATION
U.S. HOUSE OF REPRESENTATIVES
WASHINGTON, D.C.

RESOLUTION

State of Arizona
Docket 2425

Resolved by the Committee on Public Works and Transportation of the United States House of Representatives, That, the Secretary of the Army is requested to review the reports of the Chief of Engineers on the State of Arizona, published as House Document 331, Eighty-first Congress, First Session; Senate Document 116, Eighty-seventh Congress, Second Session; Senate Document 127, Eighty-Seventh Congress, Second Session; House Document 625, Seventy-Eighth Congress, Second Session, House Document 648, Seventy-Eighth Congress, Second Session; Senate Document 63, Eighty-eighth Congress, Second Session; and other pertinent reports, to determine whether modifications of the recommendations contained therein are advisable at the present time, in the interest of flood damage reduction, environmental protection and restoration, and related purposes.

Adopted: May 17, 1994

ATTEST:

NORMAN Y. MINETA, Chair

Figure 1.1 House Resolution

CHAPTER II
STUDY PURPOSE, STUDY SCOPE, AND STUDY AREA

A. Study Purpose

The Paseo de las Iglesias, Tucson, Arizona Feasibility Study and Environmental Impact Statement is being conducted U.S. Army Corps of Engineers, Los Angeles District (Corps) and the Pima County Flood Control District. The specific purpose of this study is to define environmental, flooding and related problems in the watershed area of Santa Cruz River in the City of Tucson and Pima County, Arizona, and to investigate the feasibility of providing solutions to these problems.

This report will describe the base year conditions in the project area and the future without-project condition. The without-project condition is the same as the "no action" alternative and describes what is expected to happen in the absence of Federal action.

Alternative plans are being developed to provide for restoration, flood control, and related water resources. This report is intended to be a complete decision document that presents the results of both the reconnaissance and feasibility phases of the General Investigation effort. This feasibility report is intended to accomplish the following tasks:

- Present the study results and findings, including those developed in the reconnaissance phase, so that readers can reach their own conclusions regarding the report recommendations;

- Indicate compliance with applicable statutes, executive orders, and policies; and

- Establish a sound and documented basis for decisions makers at all levels to judge the recommended solution(s).

B. Study Scope

The scope of this study consists of: 1) identifying problems and needs associated with loss of riparian habitat, flooding and related water resource concerns; 2) formulating alternative measures for environmental restoration, reduction of future flood damages and maximization of National Environmental Restoration (NER) and National Economic Development (NED) benefits; and 3) identifying the opportunity and the role for Corps' participation in environmental restoration, flood control and related water resources planning.

C. Study and Report Process

The Los Angeles District of the Corps of Engineers completed the first phase of the General Investigations study in November 1999. The results and conclusions of the first phase were presented in the Santa Cruz River Paseo de las Iglesias, Arizona Reconnaissance Report. The reconnaissance report established Federal interest in proceeding to a second, feasibility phase of the General Investigation Study to investigate the opportunities for providing environmental restoration and flood protection in the Paseo de las Iglesias area of Tucson, Arizona.

D. Study Area

The City of Tucson is located in the northeast portion of Pima County in southeast Arizona, approximately 110 miles southeast of Phoenix. Tucson is bordered by the Coronado National Forest and the Saguaro National Monument to the north and east. A smaller portion of the monument lies to the west of Tucson. Tucson is the second largest city in Arizona and is the County seat of Pima County.

The Santa Cruz River has its headwaters in the San Rafael Valley in southeastern Arizona. From there, the river flows south into Mexico. After a 35-mile loop through Mexico, it reenters Arizona about six miles east of Nogales. The river continues northward to Tucson then northwest to its confluence with the Gila River 12 miles southwest of Phoenix. The river runs approximately 43 miles north of the US-Mexico border before entering the study area. The Paseo de las Iglesias study area consists of a 7-mile reach of the Santa Cruz River and its tributary washes beginning where Congress Street crosses the river in downtown Tucson and extending upstream to the south along the river to the boundary of the San Xavier District of the Tohono O'Odham Nation (Figure 2.1). The area name, Paseo de las Iglesias, translates to "Walk of the Churches." The study area derives its name from the fact that it provides the physical and cultural connection between the 18th century San Xavier Mission and the Mission San Augustin archeological site. This area is the cradle of modern day Tucson and has a lineage of continued habitation dating thousands of years before settlement of the area by the Spanish missionaries.

The study area was defined in coordination with the Pima County Flood Control District and the City of Tucson. The area comprises approximately 5,000 acres of urban and suburban Tucson. The main channel of the Santa Cruz River flows in a relatively straight northerly direction from the southern to the northern borders of the study area. The West Branch of the Santa Cruz River currently extends from the southern border of the study area north approximately 3.5 miles to where it flows into the mainstem Santa Cruz River just north of Irvington Road. The portion of this channel just north of Irvington Road has been re-routed. The former channel (before it was re-routed) extends from just north of Irvington to just south of 22nd Street where it joins the main branch of the Santa Cruz River.

Currently the area lacks significant stands of native vegetation except at the southeast corner of the study area where native wetland habitat and cottonwood stands have reestablished at a pond maintained by an existing gravel operation. That habitat will cease to flourish when gravel pit operations cease, an outcome expected in about five years. The study area includes a portion of Tucson designated for redevelopment under the Rio Nuevo Master Plan. That plan includes historic restoration and landscaping initiatives which could integrate with environmental restoration measures to increase project outputs. The area has also been designated for inclusion in Pima County's Sonoran Desert Conservation Plan.

Population

The population of Pima County has grown sharply in recent years, going from 531,443 in 1980 to 843,746 in 2000, an increase of 59% in 20 years. The population is expected to rise to 1,206,244 by the year 2020.

TABLE 2.1

Population Trends in Tucson and Pima County

Jurisdiction	1980	1990	1997	2000	% Increase (1980-2000)	% Annual Increase (1980-2000)*	% Projected Growth (2000-2020)
Tucson	330,537	405,390	452,836	486,699	47.2%	2.4%	21.2%
Total Pima County	**531,443**	**669,139**	**789,650**	**843,746**	**58.8%**	**2.9%**	**43.0%**

Meteorology and Climate

The climate in the Santa Cruz River Basin is desert in character with short, dry winters and long, hot summers. High diurnal temperature variations are characteristic of the region due to the low humidity and general lack of cloud cover. Temperature extremes below 3,000 feet elevation range from about 1̃ degreę Fahrenheit in the winter to about 1̃20 degreeș F in the summer. Temperatures can exceed 8̃0 degreeș F in any month of the year.

Precipitation occurs in two distinct seasons of the year: summer and winter, and primarily occurs in the form of rainfall. Summer runs from June into October. Winter runs from December through February. The primary precipitation falls during the summer months as a result of thunderstorms caused by moist air flowing from the Gulf of Mexico. These storms occur frequently in the afternoons and evenings of summer days, producing

generally localized precipitation. Floods can occur from heavy thunderstorms, but are typically of short duration (lasting up to three hours). The frequently occurring 2-year, 6-hour event in Tucson is about 1.5 inches of rainfall. The extreme 100-year, 6-hour event is about 3.6 inches.

Occasionally, longer-term summer storms occur, associated with tropical storms from the Gulf of Mexico or the Pacific Ocean. These storms may provide heavy precipitation for up to 24 hours, causing longer lasting flood events (24 hours or more). The 2-year, 24-hour event is about 1.8 inches in Tucson. The more extreme 100-year, 24-hour event is about 4.6 inches.

Winter storms provide lesser amounts of precipitation and are associated with frontal storm systems from the Pacific Ocean. Precipitation typically occurs as rainfall in the lower elevations, but can occasionally occur as snow.

Existing Land Use

The reach of the river between San Xavier Mission and downtown Tucson is characterized as an arroyo with most high flows entirely contained within the main channel. Soil cement bank protection is discontinuous and is located on both banks at the Valencia Road bridge; on both banks from Ajo Way to Irvington Road; and from Silverlake Road to Grant Road. The corresponding unprotected areas include the reach between San Xavier Mission and Valencia Road; the reach north of Valencia Road to Irvington Road; and the reach from Ajo Way to Silverlake Road.

The 100-year floodplain of the Santa Cruz River is narrow as it passes through the study area due to the effects of earlier channelization and downcutting by the river. While the Paseo de las Iglesias is within the City of Tucson, significant amounts of the land adjoining the river are publicly owned. As a result, a significant percentage of the study area remains undeveloped.

Within the entire City of Tucson, approximately 30 percent of the land area is vacant or 79 square miles. If fully developed, this vacant area may accommodate up to 250,000 additional residents. Complete build out of developable land is expected by 2030.

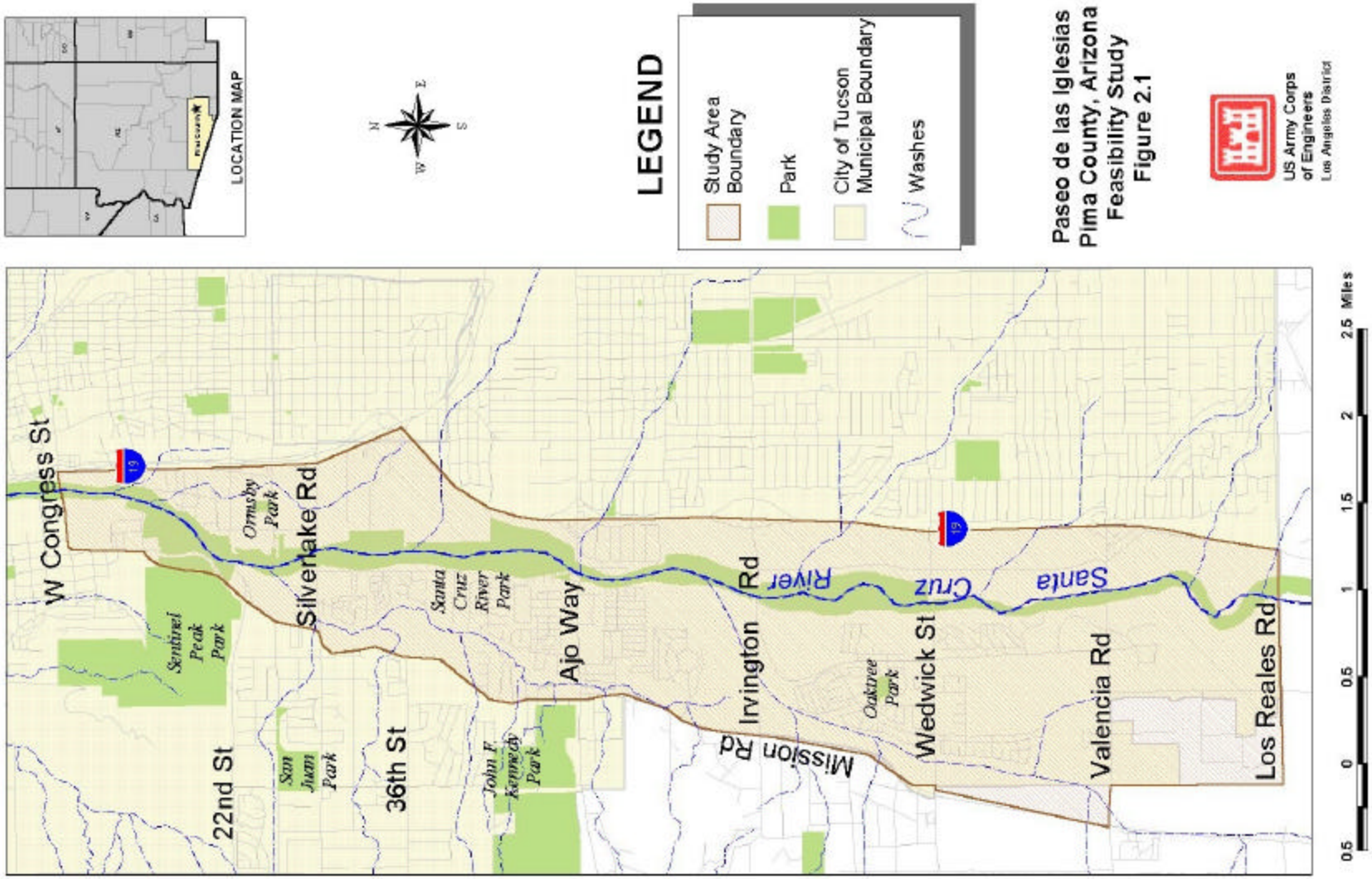


Figure 2.1 Location Map

CHAPTER III
PRIOR STUDIES, REPORTS & EXISTING PROJECTS

A. Prior Studies or Reports

Many studies have been conducted pertaining to water and related land resources within the study area. These studies have examined themes including development trends, environmental resources, water supply, groundwater recharge, wastewater management, flooding and erosion, geology, cultural resources, history, and recreation. The following is not intended to be a comprehensive list of previous reports, but to provide a sample of the types of studies that have been completed in the study area.

Arizona Stream Navigability Study for the Santa Cruz River (Gila River Confluence to the Headwaters) Final Report, Prepared by SFC Engineering Company for the Arizona State Land Department

Sonoran Desert Conservation Plan: Relationships Between Land and People –The Cultural Landscapes Approach in Archaeology and History (May 2000) Pima County

Overview of Traditional Cultural Places in Pima County (May 2000) Pima County

Preserving Cultural and Historic Resources – A Conservation Objective of the Sonoran Desert Conservation Plan, (May 1999) Pima County

Sonoran Desert Conservation Plan: Pygmy Owl Update (November 1999) Pima County

Final Documentation October, 1993 Flood Damage Report, Pima County Department of Transportation and Flood Control District

Pima County Flood Control District Comprehensive Program (December 1990), Pima County Department of Transportation and Flood Control District, Planning and Development Division

Pima County Flood Control District Comprehensive Program Report FY1990-91-FY1995-96 (January 1997), Pima County Department of Transportation and Flood Control District, Planning and Development Division

Santa Cruz River Alignment Recharge Study - Final Report (July 1986), Prepared by Pima Association of Governments for City of Tucson

Existing Conditions Hydrologic Modeling for the Tucson Stormwater Management Study (TSMS), Phase II, Stormwater Master Plan, Task 7, Subtask 7A3. prepared by Simons, LI & Associates, Inc. for the City of Tucson, November 1995.

Landfills and Waste Disposal Sites along the Lower Santa Cruz River - Final Report (February 1995) Prepared by Pima Association of Governments for Pima County Flood Control District

Landfills Along the Santa Cruz River in Tucson and Avra Valley – Final Report, Arizona (May 1995) Prepared by Pima Association of Governments for City of Tucson Office of Environmental Management

Arizona Stream Navigability Study for the Santa Cruz River (Gila River Confluence to the Headwaters) Final Report Prepared by SFC Engineering Company for the Arizona State Land Department

Sonoran Desert Conservation Plan: Mountain Parks (August 1999) Pima County

Pima County River Parks Master Plan (December 1996) Prepared by Planners Ink for Pima County Department of Transportation and Flood Control District

Sonoran Desert Conservation Plan Draft Report (October 1998), Pima County

Sonoran Desert Conservation Plan Update – Focus on Riparian Area (July 1999), Pima County

Paseo de las Iglesias – Restoring Cultural and Natural Resources in the Context of the Sonoran Desert Conservation Plan (April 1999), Pima County

Paseo de las Iglesias, Pima County, Arizona - Reconnaissance Phase Study, 905B Analysis (1999) Pima County, Arizona

Reconnaissance Phase Study, 905B Analysis (September 2000) (*Includes Tres Rio del Norte and Agua Caliente),* U.S. Army Corps of Engineers Los Angeles District

Gila River, Santa Cruz River Watershed, Pima County Arizona – Final Feasibility Report (August 2001), U.S. Army Corps of Engineers Los Angeles District

B. Existing Projects

There are no existing Federal projects within the study area. Local improvements include:

- Soil cement bank stabilization on the Santa Cruz River between 29th Street and Mission Lane and between Irvington Road and Ajo Way.
- Repair and protection of the 22nd Street and Valencia bridges.
- Construction of an energy dissipator on the West Branch of the Santa Cruz River
- Establishment of the Santa Cruz River Park between 29th Street and Mission Lane and between Irvington Road and Ajo Way.

There are other Federal projects and studies in the vicinity of the study area. Those projects/studies are on tributaries to the Santa Cruz in or near the study area. They include the Rillito River, Tucson Diversion and Tanque Verde Wash flood control projects and the El Vado Wash study. Existing or planned features of these projects to add environmental restoration or recreation measures have the potential to multiply the benefits of a project in the Paseo de las Iglesias area through linkage of the features.

C. Master Planning

Sonoran Desert Conservation Plan

The Sonoran Desert Conservation Plan is a comprehensive, local planning initiative to conserve the County's most valued natural and cultural resources, while accommodating the inevitable population growth and economic expansion of the community.

In the most recent phase of this planning effort a Science Technical Advisory Team and staff of the County developed the concept for a differentiated biological reserve where Pima County biological resources are ranked in level of importance. That concept was applied to establish a framework for designing a Conservation Lands System for eastern Pima County. The Conservation Lands System is a first draft attempt to place value on conserving natural biological resources of the County. The intent of the master planning effort is to ultimately extend the system to the establishment of similar priorities for cultural and historic resources, ranching, riparian and mountain parks.

Rio Nuevo Master Plan

The Rio Nuevo Master Plan addresses redevelopment of urban Tucson. Much of the focus of that redevelopment is along the Santa Cruz River to the south of West Congress. The aim of the master plan is the creation of a network of unique experience areas, linked by shaded plazas that connect new cultural, civic, entertainment and business uses interwoven in a historically accurate and aesthetically pleasing manner throughout the Rio Nuevo District.

Following the completion of the Rio Nuevo master plan in early 2001, the City of Tucson began to evaluate the ability of a myriad of public, private and non-profit agencies to participate in new development, management and marketing activities. In an October memorandum to the City Council, city staff evidenced concern with "duplication of effort and lack of accountability" among the agencies involved. To advance downtown development, a strategic approach was recommended to clarify organizational responsibilities and develop stronger public/private collaboration. Subsequently, the City of Tucson Rio Nuevo Multipurpose Facilities District (RNMFD) contracted with an urban planning consultant to conduct a downtown Tucson stakeholder summit. That

summit was held on January 16th and 17th 2002 and resulted in a series of recommendations to City government to advance the Rio Nuevo master plan.

CHAPTER IV
PROBLEMS AND OPPORTUNITIES

A. Historical Conditions and Problem Development

The Santa Cruz floodplain experienced a complex alluvial history culminating in a major cut and fill cycle between 500 and 300 years ago. Prior to the arrival of European settlers, the Santa Cruz River was a shallow stream occupying a wide flat floodplain covered with mature mesquite forests and cottonwood trees. Discontinuous arroyos existed 6 to 12 miles upstream of Tucson as early as 1849 but elsewhere the steam flowed across the valley surface. Historic accounts of Tucson indicate that the Santa Cruz River flowed year round at San Xavier del Bac, and approximately 10 miles north near downtown Tucson. Near the former confluence of the Santa Cruz and the West Branch there was a natural Cienega/wetland. Photos of the Santa Cruz River near Sentinel Peak from the early and late 20th Century provide an illustration of how historic habitat conditions have changed (Figure 4.1).

Human habitation of the study area dates backs thousands of years. Agriculture has a long history in the study area with evidence of maize cultivation over 2000 years ago. The Tohono O'odham Indians at San Xavier, and farmers at Tucson, used the surface waters of the river for irrigation. The Santa Cruz River served as an important transportation route for Native Americans, missionaries, Spanish explorers, colonizers, miners, cattlemen, and settlers. The river provided a well-established route from the south and the east into present day Arizona as far as Tucson, providing food and water for the traveler. The river also provided food, water, wood and shelter for the people who lived near it. Farmers diverted the surface water of the river and millers powered their grinders with the river's water. Dams on the river created lakes used for fishing, boating, and swimming.

Early accounts of the vegetation in these areas describe dense mesquite growth in the dry reaches above and below the perennial stretch through Tucson. Near Tucson, cottonwoods and willows marked the course of various irrigation ditches. A grassy marsh covered 1.5 square miles on each side of the Spring Branch above San Xavier. An impressive mesquite forest, interspersed with small meadows, was located in the western floodplain of the Santa Cruz River near the San Xavier Mission. Historical accounts describe specimens with trunks over four feet in diameter and heights exceeding 60 feet.

During the late 1800s the character of the river, particularly within Pima County, began to change rapidly. Groundwater pumping for agricultural and municipal uses caused the groundwater table to drop significantly. At the time of statehood (1912), the Santa Cruz River was still perennial in some of the reaches that had shown historic surface flows, but flows were becoming increasingly intermittent in most areas. As perennial surface

Confluence of the West Branch and the Santa Cruz River from Sentinel Peak, 1904

The same area as it appears in a contemporary photograph

Figure 4.1 Comparison of Historic and Present Conditions

Cottonwoods persisted at the base of Martinez Hill near San Xavier in the 1940s

Figure 4.2 Historic Conditions

waters disappeared, so did the marshes and large mesquite and cottonwood forests they supported. Dramatic downcutting of the riverbed occurred. Much of the area's riparian vegetation had been cut for wood or lumber. Homes and farms, using increasing amounts of the scarce water, left little water to maintain the existing riparian growth.

U.S. Geological Survey stream gage summaries (1907, 1912) indicate that all surface water flows were diverted at the Tucson gauging station by irrigation ditches. Agricultural uses in Tucson and San Xavier accounted for most of the area's surface water with supplemental irrigation water coming from groundwater pumps. Diversions, and groundwater pumping, also diminished flows on major tributaries, especially the Rillito River. As diversions and pumping took most, if not all of the flow, springs dried up in the San Xavier area. A high water table still supported a large mesquite bosque south of the San Xavier Mission. As development and farming activities increased, the growing numbers of wells contributed to declines in the groundwater table.

In 1935, the Works Progress Administration (renamed the Works Projects Administration in 1939) straightened the channel from San Xavier downstream to Congress Street. The current was deflected into the channel by revetments made of discarded automobile frames. The remaining riparian vegetation was destroyed during the process of placing

the revetments. In the 1950s and 1960, nearly a million tons of garbage was dumped in the channel or on the adjacent floodplain, resulting in a artificial narrowing of the channel. Overburden from highway construction was also deposited on the east bank of the river to allow construction inside the meander. Significant riparian and floodplain fringes vegetation were lost during the construction of Interstates 10 and 19.

The study area is now characterized by a deep, dry Santa Cruz River channel with steep vertical banks through many areas (Figure 4.3). Today, the biological resources within the study area are severely reduced. Annual groundwater overdrafting has dramatically lowered the area's groundwater table. Surface water is rare, and occurs only following rainfall events or release of water by people. The water table is over 100 feet below the riverbed.

Currently, the study area consists primarily of urban and disturbed land on both sides of a frequently disturbed, deeply entrenched ephemeral riverbed (Figure 4.3 &4.4). It is effectively isolated from natural vegetative communities by urban development and impacted lands. Current disturbances include channel bank erosion, urban development, active and inactive agricultural fields and landfills, off-road vehicle use, soil cement lined banks, wildcat dumping, and transient camps. The major aquatic and riparian communities have vanished, and the mesquite bosques are represented only in diminished, isolated pockets of stunted trees sprouting from cut stumps. Exotic plant species, including saltcedar and Athel tamarisk, have replaced most of the native cottonwood and willow. The only remaining marshland was formed as the direct result of human activity at a gravel pit, and is dependent of water used to wash gravel. No portion of the study area is without some impacts of human activity. Despite degradation, the study area supports a range of distinct vegetation communities.

Flooding History

The four most severe flooding events in recent history occurred in 1977, 1983, 1990 and 1993. Details regarding the events are presented below.

October 1977 Flood Event

The storm of October 6-10, 1977 in southern Arizona resulted from a combination of meteorological factors. The primary source of moisture was Tropical Storm Heather, which came in off the eastern Pacific Ocean, crossed the Baja California peninsula and entered Arizona near Nogales where it collided with a cold front moving northwest to southeast across Arizona. The result was approximately 12 to 14 inches of precipitation near Nogales and a peak discharge on the Santa Cruz River at Tucson of approximately 23,700 cfs. Based on the Corps mixed-population discharge-frequency relationship (Santa Cruz River Watershed Study) the estimated recurrence interval for the Santa Cruz River gage at Tucson is the 25-year event.

Note the nearly vertical banks in this unprotected reach south of Drexel

Debris left in channel north of Irvington

Figure 4.3 Existing Conditions

Bank and River Park trail south of Ajo Way

New Housing on the west bank of the Santa Cruz south of Ajo Way

Condition of tributary wash upstream of its confluence with the Santa Cruz River

Figure 4.4 Existing Conditions

October 1983 Flood Event

From September 29th to October 2, 1983, the combination of a cold front to the north of Arizona and the dissipation of tropical storm Octave over the southwestern United States brought record amounts of precipitation to much of Arizona. Approximately seven inches fell in southern Arizona over this five-day period. This precipitation came on the heels of an unusually wet August and September. The result was record flooding throughout Pima County and particularly along the Santa Cruz Valley, with peak discharge on the Santa Cruz River at Tucson of approximately 53,080 cfs, which is estimated as the 100-year event.

July 1990 Flood Event

On July 24, 1990 an intense thunderstorm developed in the Phoenix area in the early morning hours and moved southeast toward the Tucson area bringing intense rainfall between 3:00 and 11:00 am that day. The storm was considered atypical of the Tucson area monsoons, which are usually fed by moisture from the Gulf of California or Gulf of Mexico and move from southeast to northwest across the Tucson area. Isolated locations received rainfall depths in excess of 2 inches to the southwest of the City of Tucson and within the central portion of the city, with the southwest area being the hardest hit. The flood event led to a state declaration of Pima County as a disaster area, primarily as a result of flood damages to the two areas described above.

January 1993 Flood Event

From late December 1992 through February 1993, a series of winter storms produced record breaking amounts of precipitation and severe weather across Arizona. The rainfall in January, in particular, was 520% above normal statewide levels and, combined with rapid melting of snow-pack in higher elevations, caused intense runoff and flooding. Within Pima County, flooding occurred along the Santa Cruz River with most damage occurring in the Green Valley and Marana areas, with inundation of considerable tracts of pecan groves in Green Valley and farmland in Marana.

Flood Damage Areas

Much of the Santa Cruz River has been channelized and embanked with soil cement in the study area. Soil cement revetment has been constructed up and downstream of the Valencia Road Bridge, between Irvington Road and Ajo Way, and from Silverlake Road up to Grant Road. The Santa Cruz channel conveys the design 100-year floodwaters in these areas. However, the 100-year design flows will inundate areas upstream of St. Mary's Road where the Santa Cruz River has not been embanked. Within the Paseo study area, stretches of the river that lack stabilization are from Los Reales Road to Irvington Road and from Ajo Way to Silverlake Road.

A narrow 100-year floodplain is characteristic of the river from Los Reales Road at the upstream limit of the study area to Silverlake Road. Flooding can also occur on tributaries and flood problems exist on the New West Branch in the Indian Road area. While the Santa Cruz River's 100-year floodplain is narrow, damage from lateral channel migration in unprotected reaches remains a threat during major flow events.

Historic Damages

As a part of the Santa Cruz Watershed Study a review of reports and records of damages resulting from past flooding was performed. The review focused on four floods for which sufficient documentation was available. These were the floods of October 1977, October 1983, July 1990 and January 1993. Each event resulted in either a state or federal disaster declaration (or both) for Pima County. The following paragraphs provide a general description of the events and their associated damages.

October 1977 Flood Event

Flooding along the Santa Cruz River and tributaries caused an estimated $8,607,000 in damages, of which approximately $6.8 million was in agricultural damages associated with pecan and cotton production. Residents suffered most in Sahuarita, located south of the City of Tucson near Green Valley, where four of the ten damaged homes were evacuated. Considerable damage, estimated at $230,000, was done to the Silverbell Golf Course, located along the Santa Cruz River near the Roger Road alignment, which was under construction at the time.

October 1983 Flood Event

Considerable damage was caused to both public and private property. The 1983 flood caused extensive damage to the Green Valley Wastewater Treatment Facility and destroyed the Sunset Road bridge in the Tucson area. Numerous other bridges and at-grade crossings along the Santa Cruz River, Rillito River, Pantano Wash and Canada del Oro Wash were damaged or destroyed. An office complex and several apartment buildings along the Rillito River were substantially damaged or completely destroyed as a result of riverbank erosion and avulsion. Numerous power lines along the Santa Cruz and Rillito Rivers were damaged when the foundations of the support towers, some of which were located within the riverbeds, were undermined by erosion. Unfortunately, little information is available regarding specific dollar values associated with damages along the various reaches of the Santa Cruz River and major tributaries. However, in response to the flood damage, a mitigation plan was developed to repair the damage and provide flood control works to prevent future damage. The plan combined Federal, state and local funding into a $105.8 million program.

July 1990 Flood Event

Information on damage amounts is limited but the Operations Division of the Pima County Department of Transportation and Flood Control District estimated damages at approximately $1.7 million, a figure that was also issued by the State Emergency Services Division.

January 1993 Flood Event

Shifting of the channel caused considerable damage to the roadway approaches and bank protection at the Ina and Cortaro Road bridge crossings of the river. The Trico Road bridge crossing north of Tucson was completely filled with sediment and a new channel course was cut by the river north of the bridge. Most segments of the river within the Tucson metropolitan area have soil-cement lined banks and were of sufficient capacity to pass the flood flow without damage. Considerable erosion damage occurred along the Tanque Verde Creek, a major tributary to the Santa Cruz River and along the Agua Caliente Wash, a tributary to the Tanque Verde Creek. The January 1993 flood was particularly hard on the northeast part of the Tucson metropolitan area. Erosion damage along the Agua Caliente Wash was dramatic and rendered the area east of the wash inaccessible (except by air) for a period of days.

While little information exists regarding specific damages within the study area, the types of damages described above, particularly those relating to erosion and sedimentation, are representative of the flood risks that exist in the unprotected reaches of the Paseo de las Iglesias area. Erosion protection has not been constructed south of Irvington Road, except for the Valencia Street Bridge or between Ajo Way and Silverlake Road. These areas are at risk of experiencing significant lateral channel migration during major flood events. The damage potential arising from such erosion is not limited to the immediate area but can also impact downstream areas when aggradation of the channel invert from deposition of sediment can reduce the rivers ability to convey flood flows.

B. Base Year Conditions

Definition of Base Year Conditions

Base Year conditions are defined as those conditions which are expected to exist with the study area in the earliest year that a project could begin to produce NED/NER benefits. A thorough assessment and evaluation was conducted for current conditions for this study. A complete discussion of those conditions is referenced in the associated appendices to this report. This section focuses specifically on the without-project conditions in a base year of 2012. The future without-project condition, discussed later in this report, is a projection of how the base year without-project conditions are expected to change over the 50 year period of analysis to provide the basis against which alternatives could be developed, compared and evaluated.

Environmental Resources

Cultural Resources

There are over 100 recorded archeological sites in the vicinity of the Paseo de las Iglesias Area of Potential Effect (APE). Of those 11 (9 prehistoric, 2 historical-period) are considered major sites. Thirty-six of the recorded sites fall within or immediately adjacent to the APE, including six of the nine major prehistoric sites and the historical-period Mission San Agustin site. In addition to the recorded sites, approximately 10 percent of the APE has not been previously surveyed for archaeological sites. Since all of this area falls within the floodplain of the Santa Cruz River and the West Branch, all of it has the potential to preserve both surficial and buried sites.

The major sites are listed in Table 4.1 below. Complete descriptions of these and other sites within the APE may be found in the Cultural Resources Appendix.

TABLE 4.1

Major Archeological Sites

ASM Site No.	Site Name	Period	Relation To APE
AZ AA:16:3	West Branch	Prehistoric	Adjacent
AZ AA:16:51	Tumamoc Hill	Prehistoric	Outside
AZ AA:16:26	St. Mary's Hospital	Prehistoric	Outside
AZ AA:16:49	Dakota Wash	Prehistoric	Within/Adjacent
AZ BB:13:3	Martinez Hill Ruin	Prehistoric	Outside
AZ BB:13:6	Clearwater	Prehistoric	Within/Adjacent
AZ BB:13:14	San Xavier Bridge	Prehistoric	Adjacent
AZ BB:13:15	Valencia	Prehistoric	Within Adjacent
AZ BB:13:17	Julian Wash	Prehistoric	Within Adjacent
AZ BB:13:6	Mission San Agustin del Tucson	Historic	Within/Adjacent
AZ AA:16:10	Mission San Xavier del Bac	Historic	Outside

Water Resources

Groundwater: The main groundwater in the Tucson basin occurs in the sedimentary rocks and alluvium that form a single aquifer. The aquifer consists of the Pantano Formation, the Tinaja Beds, and the Fort Lowell Formation (from bottom to top). The Pantano Formation yields small to moderate amounts of water to wells while the Tinaja beds yield small to large amounts of water to wells, frequently in excess of 1000 gal/min. The water table for this main aquifer is within 350 ft. of the ground surface throughout most of the basin. Due to localized and/or perched water tables, the depth to groundwater ranges from less than 20 feet to about 170 feet below the ground surface

along the Santa Cruz and Rillito Rivers. The current well information included in this report indicates that depths to groundwater in the wells generally ranged from about 100 to 200 feet below ground surface in areas close to the Santa Cruz channel.

Large-scale pumping of groundwater in the Tucson basin began about 1900 and increased dramatically in the 1940s. Most of the groundwater pumped in 1940 was used for irrigation. The centers of greatest water-level decline are along the Santa Cruz River near Sahuarita and in the City of Tucson. Declines exceeding 100 ft. have occurred in Tucson and portions of the study area, while to the south along the river, the maximum decline has been about 150 ft.

Infiltration of storm runoff in the stream channels during the rainy seasons is the major source of recharge to the groundwater basin (Davidson 1973). Seepage of runoff along the mountain fronts constitutes the second largest source of recharge. This natural system recharges about 100,000 acre-ft/yr; however, there is currently a demand for 300,000 to 400,000 acre-ft annually. The resulting deficit is causing the water table to decline at an approximate average annual rate of 2.7 ft (PCDOT 1986). For additional information regarding groundwater see the Geotechnical Appendix.

Surface Water: No local permanent water resources exist along the Santa Cruz River in the study area. Surface water is rare and occurs only following rainfall events or release of water by people. There are existing ponds in the southern portion of the study area. However, those ponds were created for the purpose of washing the gravel from local mining operations. The remaining useful life of the mine is estimated at five years and the ponds will cease to exist after mining operations terminate.

Biological Resources

Vegetation: Six vegetative communities were identified in the study area: 1) Sonoran Desertscrub, 2) Sonoran Riparian Deciduous Forest and Woodlands, 3) Sonoran Deciduous Riparian Scrub, 4) Sonoran Interior Strand, 5) Cultivated and Cultured Uplands, and 6) Cultivated and Cultured wetlands. The largest percentage of area (60.8%) is the Urban: Residential, commercial and industrial, a subset of Cultivated and Cultured Uplands with the next largest (17.6%) being Sonoran Vacant or Fallow Lands, another subset from the same vegetative community. Less than 20 percent of the study area is occupied by uncultivated/uncultured habitat.

Wildlife: A modified Habitat Evaluation Procedure (HEP) was conducted as part of the environmental studies to document the without project condition. That procedure assigned a Habitat Suitability Index (HSI) based upon the remaining natural habitats' ability to support native wildlife.

Species considered in establishing the HSI's included any species of interest to any regulatory or management agency of the Federal, State or local government. These included species listed by the U.S. Fish and Wildlife Service as Threatened, Endangered, or Candidate species, and species designated as Wildlife Species of Special Concern in

Arizona (WSCA) by the Arizona Game and Fish Department that are known or likely to occur in the study area. In addition, species currently included as Priority Vulnerable Species in Pima County's Sonoran Desert Conservation Plan are considered. Priority Vulnerable Species are those 55 species that Pima County has determined are at risk or have been extirpated but have potential to be reintroduced within the county.

During field reconnaissance, all of the species were considered for their potential to occur within the study area. No federally listed threatened or endangered species were detected in the study area. The following eight species were determined to occur or have a potential to occur within the Paseo de las Iglesias corridor: Tumamoc globeberry, giant spotted whiptail, western yellow-billed cuckoo, burrowing owl, Abert's towhee, Bell's vireo, western red bat, and western yellow bat. Other wildlife species observed during the field investigations were recorded as well.

The results of that analysis indicate that the majority of the existing natural habitat has an average HSI in the range of 0.4-0.6 on a scale where 1.0 indicates the best quality habitat and less than 0.1 indicates a complete lack of natural vegetation. That range is described in the HEP analysis as:

> *"Remnants of the natural condition of vegetation remain and are obvious to the trained eye. Some mature individuals of long-lived species are present, and there is some evidence of successful continuing reproduction and maturation of the association. The association is generally consistent with natural processes, although it may show effects of anthropogenic disturbance that impacts the vegetation association. Larger species of native animals are absent and unlikely to occur. Some invasive non-native species have become established in small areas, but do not dominate the association. The area may be small and isolated from other areas of similar vegetation."*

The distribution of vegetative communities in the study area is depicted in Figures 4.5 – 4.7. Table 4.2 summarizes the results of the Modified HEP analysis. All details regarding the Modified HEP analysis and the results of that analysis, as well as complete descriptions of the vegetative communities, are incorporated in the Environmental Appendix.

Sensitive Areas:

Entrenchment of the eastern river channel and a water control and irrigation project in 1915 isolated the western chammel, cutting off its water supply. The western channel became known as the West Branch of the Santa Cruz and, ironically, has been able to maintain a distinctive biological community in part because it was subjected to less scouring and entrenchment than the east branch.

TABLE 4.2

Modified HEP Analysis Results

BLP Code	Vegetation Classification to Series Level	Hectares (Acres) in Study Area	% of Study Area	Habitat Suitability Index (Average)	Habitat Units Hectares (acres)
154.1	Sonoran Desertscrub Biome	134.6 (332.5)	6.6	0.65	87.5 (216.1)
154.12	Paloverde-Mixed Cacti Series	95.8 (236.6)	4.7	0.73	69.9 (172.7)
154.17	Saltbush Series	38.8 (95.9)	1.9	0.57	22.1 (54.7)
224.5	Sonoran Riparian Deciduous Forest and Woodlands Biome	68.7 (169.7)	3.4	0.60	41.22 (101.8)
224.52	Mesquite Series (includes 234.71 Mixed Scrub Series of Sonoran Deciduous Riparian Scrub Biome)	68.7 (169.7)	3.4	0.60	41.22 (101.8)
234.7	Sonoran Deciduous Riparian Scrub Biome	35.3 (87.3)	1.7	0.40	14.1 (67.9)
234.72	Saltcedar Disclimax Series	35.3 (87.3)	1.7	0.40	14.1 (67.9)
254.7	Sonoran Interior Strand Biome	105.5 (260.7)	5.2	0.50	52.8 (130.4)
254.71	Mixed Shrub Series	105.5 (260.7)	5.2	0.50	52.8 (130.4)
300	Cultivated and Cultured Uplands	1624.4 (4013.9)	80.2	0.20	324.9 (802.8)
314.1	Urban: Residential, commercial, and industrial	1231.8 (3043.9)	60.8	0.20	246.36 (608.6)
314.15	Recreational (=maintained park)	36.6 (90.5)	1.8	0.30	10.98 (27.15)
364.1	Sonoran Vacant or Fallow lands	355.8 (879.2)	17.6	0.10	35.6 (87.9)
400	Cultivated and Cultured (or Anthropogenic water dependent) wetlands	56.7 (140)	2.8	0.4	22.68 (56)
414.12	Urban Drainage	40.8 (100.7)	2.0	0.20	8.16 (20.14)
424.53	Cottonwood-Willow Series	3.6 (8.8)	0.2	0.50	1.8 (4.4)
444.71	Cattail Series	12.3 (30.5)	.6	0.50	6.2 (15.3)
Total Study Area		2025.1 (5004.1)	100	0.50	1012.5 (2502.1)

NEPA Compliance/Issues & Concerns

There are no known occurrences of threatened or endangered species in the proposed project area. One USFWS Candidate Species for listing, the Yellow-billed Cuckoo (Coccyzus americanus) may possibly occur in the study area and one USFWS Species of Concern, the Giant Spotted Whiptail (Cnemidophorus burti stictogrammus) is known to occur in the area.

Fish and Wildlife Coordination Act, as amended: Coordination efforts with the USFWS and the State of Arizona Game and Fish (AGFD) are in process and will continue through the feasibility study. Formal coordination is integral to the feasibility study.

Endangered Species Act of 1973, as amended: As required by Section 7 of this Act, the Corps requested a list of threatened, endangered, proposed, and candidate species know to occur within the proposed project areas. All pertinent species information is addressed and incorporated in the Environmental Appendix. A fully coordinated Environmental Impact Statement (EIS) will be prepared during this feasibility study.

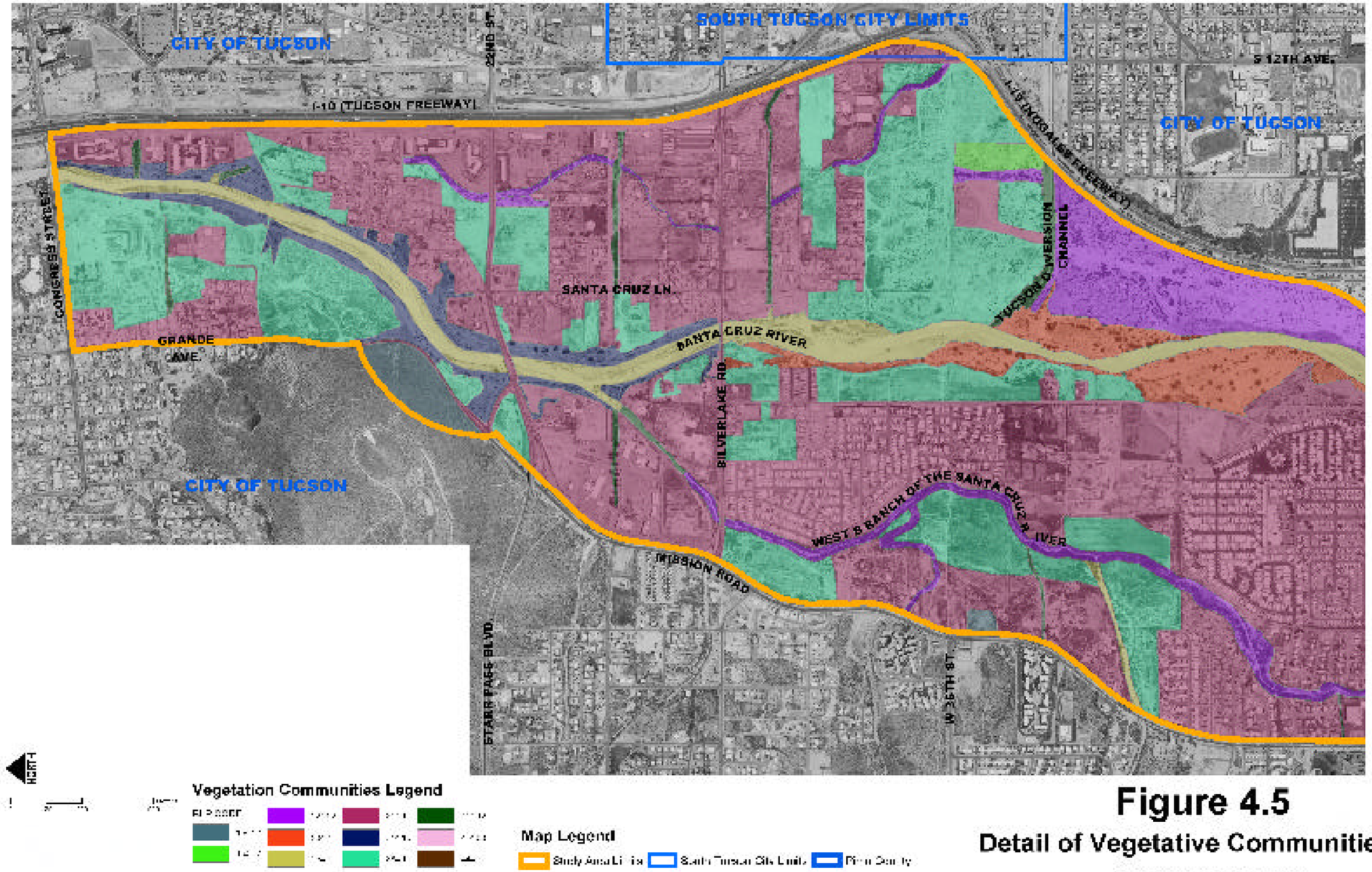


Figure 4.5

Detail of Vegetative Communities

Northern Reach

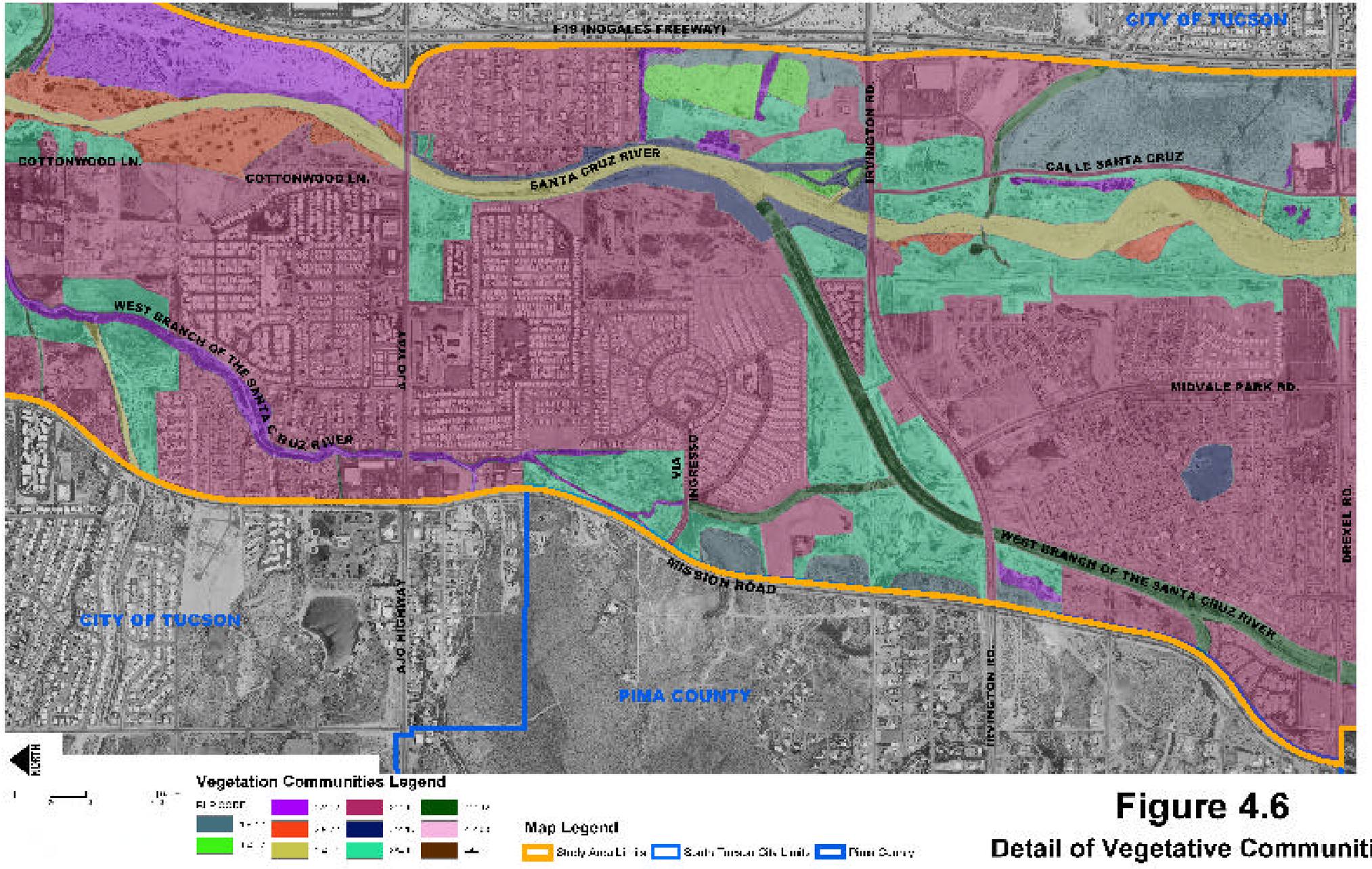


Figure 4.6

Detail of Vegetative Communities Center Reach

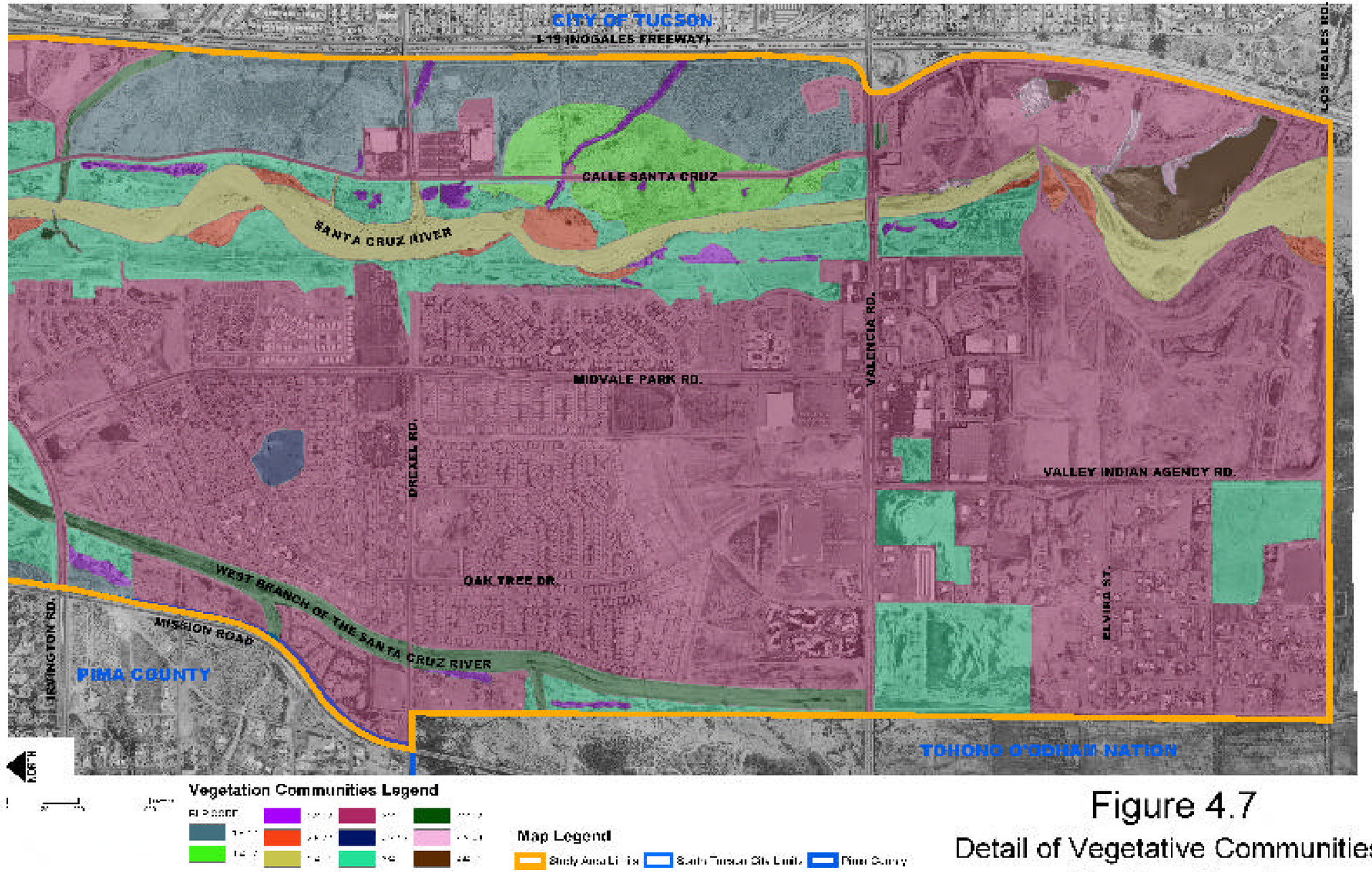


Figure 4.7
Detail of Vegetative Communities
Southern Reach

Recreation

A survey of local parks shows substantial existing recreation in the area. Two of those parks, the Santa Cruz and the Rillito River Parks represent models for planned future park expansions of the Santa Cruz River along Paseo de las Iglesias and future development of a river park along the New West Branch of the Santa Cruz River. The Santa Cruz River Park is constructed within and adjacent to the 100-year floodplain. Along with the potential future development of River Parks within the Study Area, the City of Tucson master plan for the Rio Nuevo District includes creation of recreation areas and parks along the Santa Cruz River in the northern portion of the study area.

In addition to the planned park expansions noted above, future river parks are planned for Tanque Verde Creek and Pantano Wash. Together the Santa Cruz, Rillito, Tanque Verde Creek, and Pantano Wash river parks will function as one large unified trail system. In the 1997 Bond Election funding was approved for the Santa Cruz River Community Park (a sports field complex) along the east bank of the Santa Cruz River, north of Ajo Way.

The future needs for these parks, trails and recreational areas can be supported through a discussion of recreational demand and the unit day value method. Details of the recreational analysis are incorporated in the Economic Appendix.

Geology and Soils

Topography

The study area is located near the central portion of the Tucson basin, a broad 1,000 sq. mi. valley in the Santa Cruz River drainage basin. The topography of this basin is typical of the Basin and Range Physiographic Province. Northwestward trending, steep, rugged fault block mountains border the broad, gently northwestward sloping alluvium-filled valley. The basin is about 50 miles long and is approximately 20 miles wide in the southern and central parts, narrowing to 4 miles wide at the northwest outlet. The basin is bounded on the north and east by the Tortolita, Santa Catalina, Tanque Verde, Rincon, Empire and Santa Rita Mountains, and on the west by the Tucson, Black and Sierrita Mountains. The mountains on the west side of the basin range from 3000 to 6000 ft. elevation, and those on the north and east side have elevations generally ranging from 6000 to 8000 ft., with peaks rising to elevations of 9400 ft. The metropolitan City of Tucson resides at the approximate center of this basin at an elevation of about 2400 ft.

Geology

The complex geological history of Arizona has resulted in the formation of three geologic physiographical provinces. The three provinces consist of the Colorado Plateau (in the northern area of the state), the Basin and Range Province (encompassing southern and western Arizona), and the Central Highlands or Transitional Zone (encompassing the central part of the state). The Santa Cruz River Watershed lies within the Sonoran Desert

of the Basin and Range Physiographic Province. The north to northwest trending alluvial basin is characterized by a semi-arid to arid broad valley.

The present relief of the Santa Cruz River Basin is a direct result of a period of regional uplifting due to block faulting that took place during the late Tertiary (63 to 2 million years ago) or early Quaternary (2 million years ago to present). The Basin and Range province in southwestern Arizona has been considered tectonically inactive since that period. Concurrent with the uplifting of the regional mountains, large amounts of alluvium from the surrounding mountains have been deposited within the basin (at the center of the Santa Cruz River basin, bedrock is currently buried by more than 11,000 feet of alluvial sediments).

Soils

The alluvial sediments deposited within the basin have been divided into four geologic units that are, in descending order of depth: surficial or recent alluvial deposits, the Fort Lowell Formation, the Tinaja Beds, and the Pantano Formation. The extent of these layers in the study area is shown in Table 9 in this section of the report. The surficial deposits occupy the streambed channels and are generally less than 100 feet thick. The coarse surficial deposits allow the infiltration of surface water to recharge the underlying units.

Large-scale pumping of groundwater in the Tucson basin began about 1900 and increased dramatically in the 1940s. Most of the groundwater pumped in 1940 was used for irrigation. Later, groundwater pumpage was approximately equally divided among irrigation, municipal, and industrial uses. The centers of greatest water-level decline are along the Santa Cruz River near Sahuarita and in the City of Tucson. Declines exceeding 100 ft have occurred in Tucson and portions of the study area, while to the south along the river, the maximum decline has been about 150 ft. This difference has resulted in the formation of two distinct cones of depression in the groundwater table.

The alluvial deposits in the study area consist mainly of recent stream channeland floodplain deposits. These alluvial basin sediments are generally gravel and gravelly sand. Locally, the sediments in the study area are sand to sandy silt of fluvial origin. Lithified sediments do not crop out along the Santa Cruz River and generally they should not be present within excavation depths of the channel for structure installation, though such formations do approach the riverbed elevation in the vicinity of 22nd Street.

The material generally encountered within the banks was typically a fine sandy silt. This material is not layered and has little plasticity but is cemented. There are very few cobble-sized rocks within this sandy silt material. The stability of the existing native embankments is marginal due to the existence of two conditions. One, the natural cementation of the soils allows the banks to stand at a near vertical inclination at many locations along the reaches of the study area. The vertical banks, when impacted by the any significant stream flow, are susceptible to being undercut at the bottom and collapsing into the streambed. The undercutting occurs mainly by water breaking down

the weak cementation present in the silty material. The second form of stream bank erosion is piping. As previously noted, the particle size of the slope embankment material is such that it is very susceptible to piping. Either surface or subsurface water flowing over or beneath the banks form large cavities or cave-like structures as the materials are removed by piping thru the embankment and out its face.

Any plan to construct features associated with ecosystem restoration or stabilize the slopes would have to be implemented during the dry season when the Santa Cruz River is not flowing. Wet seasonal times and, consequently, stream flow can be expected to occur during the monsoons of late July and August, the early fall time of late September and October, and during the December and January winter rains. During these times the channel can fill up with flow extending from bank to bank. As the predominate material comprising the channel bed is a fine gravelly sand, significant bed infiltration during flows and quick drainage of the bed material occurs once the stream flow subsides. Deep borings for the bridges have shown the presence of clay layers on which perched water could and, in some cases, does reside. Also, there are cemented soils and/or rock at relatively shallow depths in the vicinity of 22nd and 29th (Silverlake) Streets. The depth of such formations is typically more than 20 ft. below the streambed elevation and, thus, would not impact construction.

Existing Landfills

Several closed City of Tucson landfill sites are located along the Santa Cruz River within the study area. These landfills were closed prior to federal, state or local regulations for closure specifications and monitoring of landfill gases. They include:

a. Rio Nuevo South (located south of Congress Street along the west bank of the Santa Cruz River; approximately 40 acres; operated 1953-1960)

b. Nearmont (located south of Congress Street, northeast of Rio Nuevo landfill; approximately 10 acres; operated 1960-67)

c. "A" Mountain (located between Mission Lane and 22nd Street; approximately 36 acres; operated 1953-1962)

d. Mission (located north of 22nd Street/Starr Pass Boulevard, west of the Santa Cruz River; approximately 30 acres; operated 1963-1970)

e. 29th Street (located north of Silverlake Road along the west bank of the Santa Cruz River; approximately 50 acres; operated 1963-1967)

f. Ryland (located between 36th and 44th Streets along the east bank of the Santa Cruz River; approximately 50 acres; operated 1960-1965)

In addition to these closed landfills, there is evidence of unauthorized or wildcat dumping, both along the banks and in the channel of the river adjacent to these landfill sites.

Preliminary Site Assessment

Seventy-two aerial photographs, made from 1930, 1959, and 1963 through 2001, were reviewed. The aerial photograph review did not reveal evidence of Reportable Environmental Conditions RECs. The most recent (1954, photo-revised 1992, text revised 1995) USGS topographic map of the site did not reveal evidence of any REC's.

As part of the Phase I ESA, applicable federal and state environmental regulatory databases were reviewed. Twenty-three sites were identified in the database search that may cause contamination due to migration of contaminants if the sites are not monitored and maintained properly. During a site reconnaissance debris was observed throughout the entire length of the subject area. Based on the wide distribution of the disposal sites and the contents of the debris piles (papers, boxes, food and beverage containers, scrap wood and metal, household trash, furniture, appliances), it does not appear that the river bottom has been the site of prolonged commercial or industrial waste disposal activities.

The Site Reconnaissance did not reveal evidence of any REC's. The study area could be affected by migration of contaminants from facilities observed nearby and/or identified in the environmental regulatory databases. In most instances, only catastrophic releases would result in impacts to the subject site from off-site facilities. On-site landfills have the potential to affect groundwater, surface water and soil quality, depending on landfill contents and potential mobility of contaminants. Further investigation should be made into the wealth of documents and research that are available.

Due to voids, decomposition of materials, and lack of compaction during filling, the landfills can pose engineering and structural risks with respect to structures built on or near the landfills. Chemical exposure hazards could be created during excavation of landfill materials for possible building or utility construction. Construction or excavation on or near landfills should be prohibited until potential hazards are fully characterized and mitigated. Additional details may be found in Appendix H, Phase I Site Assessment.

Hydrology

Climate

The climate in the Santa Cruz River Basin is typically desert in character with short, mild winters and long, hot summers. High diurnal temperature variations are characteristic of the region. Temperature extremes range from about 12° Fahrenheit in the winter to 122° Fahrenheit in the summer. The prevailing winds are from the east and are usually light, although severe windstorms occur at rare intervals. Mean annual precipitation ranges from 11 inches in the valleys to over 37 inches at elevations greater than 8000 feet NGVD. Studies conducted in the Tucson vicinity show an extremely low percentage

(about 1%) of the rainfall appears as runoff, generally evaporating or returning to groundwater. Precipitation occurs in two distinct seasons of the year; summer (late June, July, August, September, and into October; and winter - December, January, February, and March.

Monsoon Season

Summer rains in the form of thunderstorms originating in moist air that flows into Arizona from the Gulf of Mexico generally occur in middle to late afternoon and are usually of local extent. Approximately 80% of the thunderstorms over the basin occur in the summer months. Floods associated with summer thunderstorms can be extremely flashy (up to 3 hours) and are of short duration.

Cyclonic Season

Some general summer storms do occur during the period July through September. They are associated with an influx of tropical maritime air originating over the Gulf of Mexico or the south Pacific Ocean and entering the area from a southeast or a southwest direction. Usually the influx of tropical air is caused by the circulation about a high-pressure area centered in the southeastern United States, but occasionally is caused by remnants of a tropical hurricane. There is often relatively heavy precipitation for periods of up to 24 hours and showers may continue intermittently for as long as 3 days. Flooding commonly covers a wide area with durations of about 24 hours.

Frontal Season

Winter precipitation is normally associated with the passage of cyclonic storm centers originating in the Pacific Ocean, which commonly are a result of interaction between polar Pacific and tropical Pacific air masses. Some snow falls at the higher elevations, but the effect on flood flows is negligible. Individual storms usually are of several days' duration and wide areal extent, with slow and steady intensity. Winter floods from these storms are of longer duration with lower flood crests.

Floods can occur from heavy thunderstorms, but are typically of short duration (lasting up to three hours). The frequently occurring 2-year, 6-hour event in Tucson is about 1.5 inches of rainfall. The extreme 100-year, 6-hour event is about 3.6 inches in Tucson. Occasionally, longer-term summer storms occur, associated with tropical storms from the Gulf of Mexico or the Pacific Ocean. These storms may provide heavy precipitation for up to 24 hours, causing longer lasting flood events (24 hours or more). The 2-year, 24-hour event is about 1.8 inches in Tucson. The more extreme 100-year, 24-hour event is about 4.6 inches in Tucson. The mountainous areas may receive up to 5.5 inches during a 100-year event. Winter storms provide lesser amounts of precipitation and are associated with frontal storm systems from the Pacific Ocean.

Runoff

While all surface flows in the study are ephemeral in nature, storm flows can be of significant magnitude. The Santa Cruz River flood of 1983 was estimated at approximately 53,000 cfs at Tucson. This discharge is 1.8 times the previously estimated 100-year (regulatory) discharge of 30,000 cfs at Tucson. As a result of that flood, the validity of the 30,000 cfs estimate had been called into question by local regulatory agencies. Several new estimates had been prepared, ranging from 30,000 cfs to 100,000 cfs. Historically, the flood frequency estimates by the U.S. Army Corps of Engineers (USACE), the U.S. Geological Survey (USGS), the Federal Emergency Management Agency (FEMA) and some local jurisdictions were at odds with one another. This has the effect of resulting in a loss of opportunity for the various entities to work together on floodplain management and flood control projects toward common goals.

Investigations aimed at resolving these differences were conducted as part of the Corps' Gila River, Santa Cruz River Watershed Study (August 2001). The analysis conducted for that study separated annual peak flow data into three sub-populations: summer thunderstorms (generally occurring from June through August), dissipating tropical cyclones (generally occurring in September and October) and winter storms (generally occurring from November through March). That analysis resulted in discharge frequency estimates which more closely approximated local estimates. The estimated frequency discharges relationships for Tucson resulting from that analysis are presented in Table 4.3 below.

TABLE 4.3

Santa Cruz River: Mixed Population Frequency Analysis – Combined Results

(cubic feet per second)

Location	Drainage Area sq. mi.	500-yr	200-yr	100-yr	50-yr	20-yr	10-yr	5-yr	2-yr
Tucson	2,222	120,000	75,000	55,000	35,000	17,000	14,000	9,500	4,900

The City of Tucson Report "Existing Conditions Hydrologic Modeling for the Tucson Stormwater Management Study (TSMS), Phase II, Stormwater Master Plan, Task 7, Subtask 7A3" provided the hydrologic analysis for existing (baseline) storm water quantity conditions for tributaries along the Santa Cruz River within the City limits. The results of that analysis are presented in Table 4.4.

Water Budget

Data concerning flows at tributary confluences is important since the flows at the end of flood events represent a portion of the potential quantities of storm water that might be harvested to support restoration efforts. In the Santa Cruz River near Tucson an average daily flow of 1 cfs was exceeded during 17% to 43% of the record during the summer

season (July-August-September). Average daily flows of 10 cfs, have been exceeded from 12% to 30% of the record. In the winter months (December through March) average daily flows of 1 cfs were exceeded in 7% to 14% of record. Average daily flows of 10 cfs were exceeded in 5% to 8% of the record. During the remaining months (October-November, April-June) there are zero flows in upwards of 92% of the record.

Within the overall geologic groundwater basin, Infiltration of storm runoff in the stream channels during the rainy seasons is the major source of recharge. Seepage of runoff along the mountain fronts constitutes the second largest source of recharge. This natural system recharges about 100,000 acre-ft/yr; however, there is currently a basin-wide demand for 300,000 to 400,000 acre-ft annually. The resulting deficit is causing the water table to decline at an approximate average annual rate of 2.7 feet.

This water table decline is generally consistent with conditions in the study area. Minor ephemeral flows from several tributaries, in addition to ephemeral flows within the Santa Cruz River, provide a source of water that currently is sufficient to support only minor (less than 5% of the river corridor) patches of riparian habitat. There can be considerable variation in the timing of these flows from the various tributaries and the main river. The 100 feet or more to existing groundwater, in combination with insufficient flows to support habitat, result in an existing conditions water budget that is incapable of supporting larger amounts of habitat. More efficient capturing and retention of the existing flood flows within the study area may result in an incremental increase in the amount of habitat that is supportable.

TABLE 4.4

Santa Cruz River Tributary Washes Frequency Analysis

Data at the Confluence of Washes with the Santa Cruz River
(cubic feet per second)

Tributary Names South to North	WS Acres	100-yr	50-yr	25-yr	10-yr	5-yr	2-yr
Hughes Wash	5336	2376	1875	1258	738	334	93
Santa Clara Wash	250	389	314	221	143	86	47
El Vado Wash	1468	1558	1327	1003	716	474	287
Valencia Wash	1047	1510	1292	1026	721	441	230
Airport Wash	14546	5164	3981	2691	1549	7740	346
Wyoming Wash	449	877	719	519	335	184	82
Irvington Wash	161	427	343	237	145	75	40
Rodeo Wash	5371	3453	2839	2448	1340	744	321
Julian Wash	27859	5962	4767	3202	1901	945	389
Mission View Wash	1039	1802	1538	1201	885	599	355
18th Street Wash	2345	3085	2503	1921	1363	886	523
Cushing Street Wash	323	1165	993	770	562	375	221
Ajo Wash	1224	3465	2817	2007	1286	689	242
Enchanted Hills Wash	1989	3968	3270	2386	1540	801	256
San Juan wash	731	1757	1470	1104	757	423	152
Cholla Wash	833	2273	1882	1379	920	529	224
Old West Branch at Confluence with SCR	9543	6621	5417	3818	2447	1352	397
New West Branch at Confluence with SCR		9908	7925	5250	3665	2020	595

Base Year (2012) Floodplain

The results of the hydraulic analysis of the Santa Cruz River, Old West Branch, New West Branch and Los Reales Improvement District are presented below.

Santa Cruz River

The 2-, 5-, 10-, 20-, 50-, 100-, 200-, and 500-year flood events were simulated for the Santa Cruz River. This study reach of the Santa Cruz River has between a 50- and 100-year capacity. The 100-, 200-, and 500-year flood events would overtop the channel banks. The bridges within the study reach would not be overtopped during the 100-year flood event. However, most of the bridges would likely be overtopped during the 200- and 500-year flood events.

The 50-, 100-, 200-, and 500-year floodplains are plotted in Figure 4.4. The floodplains associated more frequent discharges were not plotted since they would be within the channel banks. Very few structures would be inundated by the 100-yr flood event. However, the 200- and 500-year flood events would inundate considerably more structures. Breakouts would be caused by a combination of backwater from bridges and low channel banks. The breakouts would be confined within the valley and would not flow independently of the channel. In general, the breakouts would be confined by high ground surrounding an area of low ground.

Old West Branch

Only the 100-year flood event was simulated for the Old West Branch since Economics Section will use approximate methods to determine the average annual flooding damages. The capacity of the channel is approximately 1000 cfs before the banks are overtopped. The 100-year flood event would overtop the channel banks.

The 100-yr floodplain is plotted in Figure 4.5. Breakouts would occur from stations 5 to 6, 7 to 9, 11, and 12 to 13.5. Silverlake Road Bridge at station 4.1 would likely be overtopped. The backwater caused by the bridge would cause the breakout between station 5 and 6. Low channel banks would cause the rest of the breakouts. In general, the breakouts would be confined by high ground surrounding an area of low ground. Very few, if any, structures would be inundated.

New West Branch

The 100-yr floodplain would stay in the channel.

Los Reales Improvement District

Results for the New West Branch are as follows. The 100-yr and 500-yr floodplains are plotted in Plate 4.6. The inundation boundaries were from the FIS Report (LMT Engineering, 2001).

Figure 4.8 Santa Cruz River Floodplain

Figure 4.9 Old West Branch 100 year floodplain

Figure 4.10 Los Reales Improvement District Floodplain

Economics

The economic analysis focused on four areas:

1. *The Paseo de las Iglesias Segment of the Santa Cruz River*-- Certain areas of Paseo de las Iglesias have been channeled and embanked to combat the destruction resulting from flooding. A soil cement channel has been constructed up and downstream of the Valencia Road Bridge, from Irvington Road to Ajo Way and Silverlake Road up to Grant Road. The stretches of the Paseo de las Iglesia that lack channel stabilization are located from Los Reales Road to Irvington Road and Ajo Way to Silverlake Road.

   Currently, the Santa Cruz channel contains the 100-year flood in most of the study area. However, some localized areas are still susceptible to the 500-year flood and flooding from tributary flow. One area is located on the east bank from Congress to San Juan Road. A second area is located on the west bank of the river near the Old West Branch of the Santa Cruz River and the Paseo de las Iglesias confluence. A third area is located on both banks of the river just south of Ajo Way. A fourth area susceptible to 500-year flooding is located South of Drexel Road.

2. *The New West Branch of the Santa Cruz River*--The New West Branch located to the west of the Santa Cruz from Valencia Road to Irvington Road has been channeled and embanked combating the destruction from flooding. At Irvington Road, the New West Branch channel merges with the Santa Cruz River. The entire stretch contains the 100-year flood except for some small areas. These small areas are a result of other tributaries flowing into the New West Branch.

3. *The Los Reales Area of the New West Branch of the Santa Cruz River*--A small area just south or the New West Branch between Valencia Road to the north and Los Reales Road to the south floods.

4. *The Old West Branch of the Santa Cruz River*--The Old West Branch, also located to the west of the Santa Cruz, is located from Irvington Road to 22nd Street. This river does not have any channel embankment, but 100-year flood flows for the most part stay within the channel and produce an insignificant amount of damages to warrant further analysis. Since discharge frequency values other than the 100-year were unobtainable, the U.S. Army Corps of Engineers and the local sponsor have agreed to limit the analysis to 100-year flow data. Analysis up to the 500-year will not be performed for the Old West Branch.

Economics, Hydrology, and Hydraulics study team members participated in the segmenting of the Santa Cruz and West Branch floodplain into distinct reaches of homogeneous characteristics. Critical factors for differentiation included: the discharge-frequency characteristic, the overflow spatial characteristic, and economic activity.

Tables 4.5 & 4.6 provide a summary of reach delineations (each starts at the downstream end of each stream and moves upstream), including stream name, and beginning and ending cross-sections for each reach.

TABLE 4.5

Reach Delineation Breakdown for the Santa Cruz River

Reach Name	Cross Streets	Stream	Beginning Cross-Section	Ending Cross-Section
1 SC	Congress St. Starpass Blvd.	Santa Cruz River	32.61	33.38
2 SC	Starpass Blvd. Ajo Way	Santa Cruz River	33.38	35.77
5 SC	Drexel Rd. Valencia Rd.	Santa Cruz River	37.87	38.96

TABLE 4.6

Reach Delineation Breakdown for the New West Branch and Los Reales Areas

Reach Name	Cross Streets	Stream	Beginning Cross-Section	Ending Cross-Section
4 NWB	Irvington Rd. Drexel Rd	New West Branch		
5 NWB	Drexel Rd Valencia Rd	New West Branch		
6 LR	Valencia Rd. Los Reales Rd.	Los Reales		

Without-project structure and content damages were computed utilizing the HEC-FDA Flood Damage Reduction Model. The model computes equivalent annual damages based upon the input parameters of structure data, category of structure (single family residence, multi-family residence, public, commercial, industrial, mobile home), stream location, ground elevation, first floor elevation, structure value and content value. These parameters are compared with hydrologic and hydraulic data including frequency-discharge and stage-discharge relationships. Data was input including the appropriate risk and uncertainty variables, for the base year (2012) and the future condition (2062).

The results of the base year computations are presented in Table 4.7 and Table 4.8 below, which display the expected annual damages for the base year condition using current (2001) price levels. Economics for the year 2062 may be found in Section C, "Future, Without-Project Conditions."

TABLE 4.7

Without Project Conditions Santa Cruz River Expected Annual Damages

Reach	Residential			Nonresidential		Total
	SFR	MFR	MH	Commercial	Public	
1 SC	$6,650	$24,800	$630	$1,790	$0	$33,870
2 SC	$12,890	$20,340	$41,150	$14,030	$1,260	$89,670
3 SC	$6,050	$53,140	$31,640	$9,450	$4,420	$104,710
5 SC	$17,900	$450	$0	$0	$0	$18,350
Total	$43,490	$98,740	$73,420	$25,270	$5,680	$246,600

TABLE 4.8

Without Project Conditions New West Branch River and Los Reales Area

Expected Annual Damages

Reach	Residential			Nonresidential		Total
	SFR	MFR	MH	Commercial	Public	
4 NWB						
5 NWB						
6 LR						
Total						

Baseline information regarding the analysis of the value of existing habitat is presented above in the Environmental section.

Socioeconomics

Three primary areas of employment in Pima County are in education, government, and military. Sources of employment in the educational sector include the University of Arizona, Pima County Community College, and the Tucson Unified School District. Government offices offer employment in the state, county and city level. Two military establishments provide further employment opportunities. They are Davis-Monthan Air Force Base and Raytheon Missile Systems Company. All three areas of employment generally require a higher percentage of professional and technical skills as well as some collage education. This helps to explain why 24.70% of people employed in Pima County fall within the professional and technical occupations.

This demand for higher paying jobs, combined with steady population growth, may explain why Pima County has enjoyed a low employment rate as much as 1.4 and 1.8 percentage points lower than Arizona and the United States. In 1998, local unemployment was 2.7% compared with 4.1% for Arizona and 4.5% for the United States.

Construction of housing units has been increasing over the last decade. 348,508 housing units were constructed in Pima County in 1999 to accommodate population expansion in the area. This figure is up from 298,207 in 1990. In fact, the 1999 American Community Survey Profile for Pima County, Arizona, indicated that about 21 percent of the housing stock has been constructed in the past ten years. Most of the newer homes, in master planned communities, are reasonably priced compared to other metropolitan areas. The average cost of a new single family home is about $109,102, a primary factor making the overall cost of living in Pima County among the lowest of major U.S. metropolitan areas.

C. Future Without-Project Conditions

Definition of Future Without-Project Conditions

The future without-project conditions for the 50-year planning horizon were identified in order to define and describe the most likely future conditions that are expected without a Federal project. This condition represents the longer-term planning horizon that is reasonably expected to exist in the absence of a Federal project implementation. It consists of the base year 2012 conditions projected to a future year 2062 utilizing reasonable assumptions of how the base year conditions may change in the absence of any Federal project. The base and future year without-project condition is used to compare and evaluate any proposed actions which are developed.

Basic Assumptions

It is assumed that no new ecosystem restoration or flood control projects will be in place prior to construction of a Federal project. In the event that a new feature is constructed by local interests prior to such authorization, the feature may be considered as an integral and compatible part of the Federal plan if prior approval is obtained. The earliest projected year that a Corps of Engineers project could begin to be operational is 2012. This is the first year (base year) that benefits could begin to accrue.

Environmental

South of Valencia Road, along both sides of the River, there are approximately 400 acres of land currently being used for sand and gravel extraction. Industrial development continues adjacent to this area. The area contains one of the few marshlands in Southern Arizona, created as a byproduct of the extraction process. Both public and private interests have prepared numerous development concepts for this area, primarily because of its marketable location along the Interstate 19 (I-19) corridor. If river restoration does not occur, it is anticipated that private development will significantly alter the existing ecosystem in this area.

This is also the case for currently undeveloped portions of the study area that lie between the River and I-19 and Valencia and Irvington Roads. Currently, the Desert Vista Campus of the Pima Community College (PCC) is located in this area, just south of Drexel Road, and east of the Santa Cruz River. The Campus is projecting an increase in student enrollment in response to the area's growing population. Other emerging development in this area includes business park uses (Honeywell facility immediately north of the PCC campus), and "Big Box" home improvement and discount stores just south of Irvington. Although the City of Tucson and Pima County own land immediately adjacent to the east bank of the River in this area, land that is privately held in this area will come under increased pressure for commercial development and park industrial development, due to its proximity to I-19.

Given this location and the history of past development in the metropolitan area, the future without-project conditions suggest the following scenario. As privately held land develops for commercial and park industrial uses (highest and best use based on market demand), adjacent publicly owned areas, currently available for restoration of upland habitat, preservation of cultural resources, and associated recreational amenities, will come under increased development pressure. Real estate values will rise in response to market demand. In order to maximize development acreage in areas adjacent to the River, a conventional, engineered solution for bank protection and erosion control (i.e., soil cement) would likely be implemented, and there would be minimum development setbacks from the River. (according to local land use codes, setbacks can be reduced following bank protection).

Although this development scenario would include trail and recreation amenities (River Park) as mitigation for bank protection, the River's east corridor would have lost any remaining natural resource value.

Looking further downstream, the River segment that lies between Irvington Road and Congress Street has experienced minimal development in the past five years, as compared to areas in the southern portion of the study area. However, this may change since the City of Tucson is embarking on a major urban revitalization project (Rio Nuevo) for a large parcel immediately west of the River, between Congress and 22nd Streets. In addition, the larger Rio Nuevo district concept will promote residential, commercial, and public development in areas that are currently vacant and in close proximity to downtown and the River's eastern bank.

As a result of development pressures and the availability of residentially-zoned land, population will continue to increase along this 7-mile reach of the Santa Cruz River, regardless of project status. Without-project, the riverbanks will most likely be soil cemented, thus greatly decreasing native vegetation growth and the floodplain area. In addition, the use of soil cement would increase the amount of developable land in the study area and result in increased residential and non-residential development adjacent to the River. This development would greatly reduce, if not preclude, the opportunity for ecological restoration and that would accrue from an integrated program of flood control and riparian restoration.

Increased development will not only reduce or eliminate restoration opportunities. Over the past century, a reduction in vegetation adjacent to the River has resulted in an exponential loss of wildlife habitat. Without-project, this trend is expected to continue at an accelerated rate, due to the pressures of urbanization and competing demands on water and other resources within the region. Although the characteristics of this environmental decline will vary within the study area, the overall effect will be the reduction of existing habitat value.

Recreation Demand

Many factors contribute to make the proposed riparian habitat areas along the Paseo de las Iglesias and New West Branch study areas attractive in terms of their potential to meet unmet demand for passive recreation through combination with adjacent facilities. Those factors include:

1. *Recreation Experience*--Proposed general recreation activities for the study area include trails for hiking, biking, and jogging. Among the activities identified, most have significant unmet demand.

2. *Availability of Opportunity*--The proposed facilities along the Paseo de las Iglesias and New West Branch will provide opportunity for many urban individuals to recreate close to their homes, work, and downtown

3. *Carrying Capacity*--As previously discussed, Pima County has experienced rapid population growth. Pima County's MSA population is 843,746 at year 2000 and is expected to reach 1,518,000 by year 2025—a difference of 674,254 over 25 years. With this increase in population comes an increased demand for recreational facilities.

4. *Accessibility*--According to 43% of the Arizona Trails 2000 survey respondents, loss of access to trails is the top three most important issues facing trails today.

5. *Environmental*--As demonstrated earlier, there are several recreation areas located in the study area. Of these parks, there are no significant thriving riparian areas.

Recreation demand in the study area is expected to grow steadily in the future due to regional population growth and increased tourism.

Geotechnical

The following determinations have been made regarding the future without project geotechnical conditions:

- Subsurface conditions would not impact the construction of engineered bank stabilization measures.
- Seismicity is not a constraint on the implementation of a project in the Paseo de las Iglesias study area.
- All of the landfills within the study area are expected to be completely remediated by the base year of 2012 and completely developed by 2062.

Hydrology

For the next 20 years, it is anticipated that average annual population growth within the city limits of Tucson will increase slightly to 2.3%. In contrast, annual growth in Pima County will decrease by 1%. Although the following 30 years will continue to see a decline in the growth rate for both the City and County (a projected annual increase of 1.6% and 1.2%, respectively), the region's growth will be steady and positive. The anticipated population of Tucson in 2020 is 711,812. This will result in more than 97,800 new dwelling units or approximately 4,800 dwelling units, on average, per year for the next twenty years. Between the years 2020 and 2050 it is anticipated that population in this area will level off due to final build out of vacant land currently zoned for residential.

Consideration of increases/decreases in watershed runoff was made in order to predict study area discharge for the year 2062 without-project condition. The magnitude of anticipated future growth in Tucson was investigated based on the City's development plans. The increase in runoff due to an increase in urbanization is reflected in the discharge-frequency values for the Santa Cruz River in the future, without-project condition displayed in Table 4.9. In comparison with Table 4.1 for the 2008 condition, as would be expected, the smaller flood events (10-, 25-year) experience a greater percentage increase in discharge due to increased development. Future condition without-project discharges for the 100-year event increase by approximately __%

TABLE 4.9

Santa Cruz River: Mixed Population Frequency Analysis – 2062 Combined Results

(cubic feet per second)

Location	Drainage Area sq. mi.	500-yr	200-yr	100-yr	50-yr	20-yr	10-yr	5-yr	2-yr
Tucson	2,222								

Hydraulics

Discharges will increase in the study vicinity due to anticipated build out of developable lands. However, the increases in volumes of discharges in the future without-project condition are insufficient to significantly effect the base year floodplain.

Economics

Economic damages include damages to structures, content damages, emergency and clean-up costs, transportation damages, and future floodproofing expenditures. Structure and content damages are based upon flood depths. Transportation damages are based upon time and reroute distances. Physical damages to utilities (power lines, sewer systems and water supply systems) are included.

Damages to Structures and Contents

Without-project structure and content damages as well as risk and uncertainty analyses were computed for the year 2062 using current price levels. Results are shown below in Table 4.10.

TABLE 4.10

Future Without-Project Conditions Expected Annual Damages

Reach	Residential			Nonresidential		Total
	SFR	MFR	MH	Commercial	Public	
Santa Cruz						
New West Br						
Total						

Expected annual damages for the years between 2012 and 2062, inclusive, were converted to equivalent values using standard discounting procedures. The results of these calculations using current price levels are shown below in Table 4.11.

TABLE 4.11

Future Without-Project Conditions Expected Annual Damages (50 years, __%)

Reach	Residential			Nonresidential		Total
	SFR	MFR	MH	Commercial	Public	
Santa Cruz						
New West Br						
Total						

Emergency and Clean Up Costs

Due to the limited amount of information available concerning emergency response costs along the Santa Cruz and West Branch Rivers, emergency response cost estimates will be based on estimate derived in the January 1993 Flood Damage Summary Report written by the Pima County Department of Transportation and Flood Control District. In the report, Pima County has provided limited information on the emergency response cost to residents as they evacuate, relocate and, reoccupy their residence during a flood event. Based on the experience of residents who were flooded in the 1993 flood, the temporary relocation cost was approximately $1,400 per resident. This number was applied to the number of residences in the 500-year floodplain and was used along with a non-damaging frequency of a 100-year event to perform equivalent annual damages. The equivalent annual damages (EAD) to residents due to flooding along the Paseo de las Iglesias portion of the Santa Cruz River is $8,288 and the New West Branch of the Santa Cruz River is $_____.

Transportation Costs

Typically, expected annual traffic damages are estimated based upon delineations of floodplain areas with inundation levels exceeding one foot and durations of flooding. However, Hydrology and Hydraulics used the steady state or peak flow method in computing overflows. This method does not allow a means to estimate durations of flooding by flooding event; therefore, traditional methods of computing traffic damages will not be used. Instead, traffic damages are estimated as a single event assuming traffic flow will be disrupted for a day no matter what the duration.

According to this analysis, the Santa Cruz River could cause temporary closures of Silverlake Road, 22nd Street, and Congress Street. Using a traffic delay cost of $1.40 and $7.06 per hour depending on the length of the delay, potential damages resulting from delays are $884, $2,153, and $13,463 for the three roads. At an operation cost of 14.4 cents per mile, the potential annual damage is $32,306. Total vehicle delay and operation damages equal $48,806 while average annual vehicle delay and operation damages equal $2,968. For the West Branch River, only Silverlake Road may be affected by temporary closures due to road flooding. Vehicle delay damages are $884 and vehicle operation

damages are $5,011 along this road for a total of $5,895. Average annual vehicle delay and operation damages equal $380.

Summary of Damages in the Future Without-Project Condition

Table 4.12 summarizes the expected annual damages discussed above using the current (October 2001) price levels, and is futher detailed in the Economic Appendix.

TABLE 4.12

Without-Project Conditions, Expected Annual Damage Summary

Category	Expected Annual Damages
Structure & Content	
Emergency/Clean-Up	
Transportation	
Total	

D. Problems and Opportunities Summary

Problems

Problems within the study area, although interrelated, are principally related to either ecosystem degradation, water supply or flood damage.

While the potential for flood damage resulting from out of bank flood flows exists in some parts of the study area, the principal risk of flood damage arises from a sediment regime that is capable of producing dramatic effects in the course of a single large flood event. Rapid aggradation or degradation of the channel invert poses the risk of completely filling the channel, as happened at the Trico Road crossing in 1993 or the loss of a bridge, as occurred to the Cortaro Road Bridge in 1983. Furthermore, historical rates of lateral channel migration on some unprotected reaches of the Santa Cruz River exceed 10 feet per year.

As noted earlier, extensive fresh water marshes, riparian forests and adjacent floodplain fringe forests existed in the study area well into the late 19th century. The diversion of surface flows and increased pumping of groundwater combined with early flood control efforts and pressure from development led to loss of nearly all native aquatic habitats in this area. The loss of those habitats is associated with declines in the populations of many native species.

Without-Project Summary (No Action Plan)

Under the Without-Project Condition there will not be sufficient water to support expansion of existing areas of riparian and associated floodplain fringe habitats. In fact, as development continues throughout the Santa Cruz watershed, loss of riparian and floodplain fringe habitat is likely to accelerate and many native species may be increasingly confined to isolated pockets of suitable environments. Furthermore, the lack of native riparian and associated floodplain fringe habitat will mean the absence of many species of native wildlife from the area. In addition, risks resulting from unstable river geomorphology will remain in unprotected reaches of the study area. Flooding will remain a risk in specific locations such as the Indian Road area..

Opportunities

Environmental Restoration

Opportunities for large-scale ecosystem restoration exist within the study area. Restoration of wetlands, riparian forests and riparian terrace habitats could be accomplished either in or adjacent to the Santa Cruz River and its major tributary washes. Specific opportunities may include:

- Creating wetlands
- Planting riparian species
- Enhancing/widening stream courses
- Supplying additional water to stream courses
- Establishment of Mesquite bosques adjacent to stream courses

Water Resource Management

Water resource management opportunities include:

- Storm water harvesting
- Groundwater recharge
- Provide a point of disposal for localized runoff
- Alternative uses of treated effluent
- Utilization of CAP and TARC water sources through future negotiated agreements

Recreation

The opportunity exists to provide recreational resources in conjunction with any Federal project implemented for flood control purposes. In addition, limited passive recreational

opportunities may be provided adjacent to restored habitat areas. Maintaining open space (recreation facilities) adjacent to restoration sites could help promote successful restoration in that it precludes the stress to habitat and wildlife associated with more intensive land use in adjacent areas. In general, facilities would likely consist of trails and interpretative signage.

Flood Control

Flood control opportunities consist of structural and non-structural measures that could be implemented in association with environmental restoration features. Among those measures is the potential to purchase flood prone structures and remove them from the flood plain to reduce future flood damages.

Finally, the opportunity exists to formulate a project that addresses multiple purposes by, for example, providing storage for local runoff in a manner which facilitates groundwater recharge and helps to support habitat restoration.

Specific opportunities have been identified in prior planning efforts. These opportunities fall within four broad categories:

- Old West Branch of the Santa Cruz River.

The West Branch offers unique biological values within a largely degraded urban environment. A recent study entitled "Biological Values of the West Branch of the Santa Cruz River," notes that the West Branch is the one area in Tucson where hydro-riparian restoration is most feasible. In spite of diverse flora and fauna, the West Branch remains in peril because of pressures of urbanization and further habitat fragmentation.

- Unprotected Reaches of the Main Stem of the Santa Cruz River.

Areas currently without structural bank protection and soil cement offer an environmental setting to test alternatives for flood and erosion control. These "softer" bio-engineered approaches provide more opportunities for multiple benefits such as recreation and cultural and ecological interpretation. Identified reaches may be suitable for riparian ecosystem restoration with the introduction of intermittent or seasonal water. Habitat could include maintenance and further restoration of created wetlands, with expansion of cottonwood-willow habitat.

- Tributary Washes.

Restoring the natural hydraulics of selected tributaries, and creating associated riparian habitat areas at confluences will offer multiple benefits consistent with the County's Sonoran Desert Conservation Plan.

- Riparian Corridor.

Areas within the floodplain fringe offer opportunities for restoration of Sonoran grassland and desertscrub, and wildlife corridor benefits.

Specific opportunities within the study area include:

Congress Street to Silverlake Road (29th Street)

- Remove existing bank protection from Mission Lane south to 29th Street (Silverlake); terrace to widen floodplain; integrate with urban design and redevelopment for Rio Nuevo, especially pedestrian bridges over the River at Mission Lane and Clearwater and viewing areas and plazas and special design features of Rio Nuevo.
- Lower the profile of the bank protection from 100-year+ water-surface elevation that exists from Mission Lane to 29th Street.
- Integrate new modified cross-section with River Park improvements and upland revegetation.
- Pending landfill remediation, revegetate as upland grassland or with mixed desertscrub and grasses (burrow bush, saltbush).
- With future high pedestrian traffic, major cultural and commercial destinations, and proximity to several residential neighborhoods, habitat revegetation in "A" Mountain area could be tied to environmental and cultural resources interpretation (Rio Nuevo Master Plan shows a Nature Park and cultural center on the site of the remediated "A" Mountain landfill).
- Restore and revegetate east bank tributary/drainage (18th Street Wash) just north of Mission Lane. The adjacent River Park areas could be revegetated (likely irrigation dependent) with upland species.
- Restore and revegetate the wash/drainage located just west of the I-10 frontage road, both north and south of 22nd Street (existing patch of mesquite, many infested with mistletoe; trash and signs of wildcat dumping).

29th Street to Ajo Way

- Connection of River Park improvements along Santa Cruz to Julian Wash bicycle/multi-purpose trail.
- Grassland and desertscrub revegetation on terrace along west bank of Santa Cruz (currently mostly vacant area between the River and Cottonwood Lane); street tree planting and community gardens; equestrian trail along Cottonwood Lane, the latter primarily for historic, rural character, and recreation goals rather than habitat/ecological concept).
- Main channel: revegetation along grassy terrace within the west half of the channel If riparian vegetation were encouraged in this location, it would reduce the potential for erosion during floods. Without such a measure, the western bank will be more susceptible to erosion when flows rise over the terrace.

- West Branch: portions of the West Branch and adjacent lands under County ownership; potential for acquisition or conservation easements for other adjacent vacant/fallow lands (Gastelum property); highest potential for restoration, enhancement, environmental interpretation.
    1. Could be the cornerstone of an extensive ecological restoration area in Tucson with opportunity to conserve and restore, xero-, meso-, and hydro-riparian ecosystems.
    2. Since the City of Tucson owns the West Branch channel from 44th Street to Ajo Way, this area shows a high potential for restoration as riparian or aquatic habitat.
    3. The Enchanted Wash delta-like formation is almost unique to the Tucson region and would support rich habitat restoration.
    4. Many of the property owners along Cottonwood Road south of 29th Street are very active in and supportive of environmental restoration in this area.
    5. The bottom and flow channel has a fairly dense substratum that would support stream flow and aquatic species.
    6. In-channel provides favorable conditions to restore cottonwood/willow bosques.
    7. Regenerating habitat could bring back wildlife species that are now rare or non-existent but were once prevalent in Tucson's rich meso-riparian areas.
    8. Because the West Branch is not subject to catastrophic flooding, restored habitat would be protected.
- Stormwater harvesting at confluence of tributaries with main channel; will reduce headward erosion of the tributaries and provide supplement water for riparian growth.
- Check dams, weirs or catchment structures would provide areas for in-channel revegetation.

Ajo Way to Irvington Road

- Because of bank protection and other flood control measures, and newly constructed housing development adjacent to the River Park along the west bank, this reach offers few opportunities for ecosystem restoration. In-channel revegetation is a possibility with a low-flow channel.
- TARP water could be recharged in this channel reach or otherwise made available for in-channel revegetation.

Irvington Road to Valencia Road

- Retain existing floodplain width and channel sinuosity to preserve flood storage areas.
- Reestablish tributary hydraulics to reduce erosion, distribute flows and promote water harvesting (promote revegetation on bars above the low-flow channel, not directly in the channel).

The area east of the channel near El Vado (aka Mission Manor) Wash could be used for a demonstration of Hohokam floodwater farming techniques adjacent to the archeological site north of Valencia Road. The farm project would utilize tributary flows for the water source, potentially augmented by CAP or reclaimed water, for indigenous crops such as corn, beans and squash. Mission Manor and El Vado washes possess significant wildlife habitat and should not be modified.

Palisades/fence-jetties could be used to preserve these features while still providing erosion protection.

The high, erodible channel banks contain many voids that are the result of soil piping. The voids are valuable to certain bird and bat species. Wildlife surveys should be performed to examine the significance of these features as part of the alternatives analysis for bank modifications.

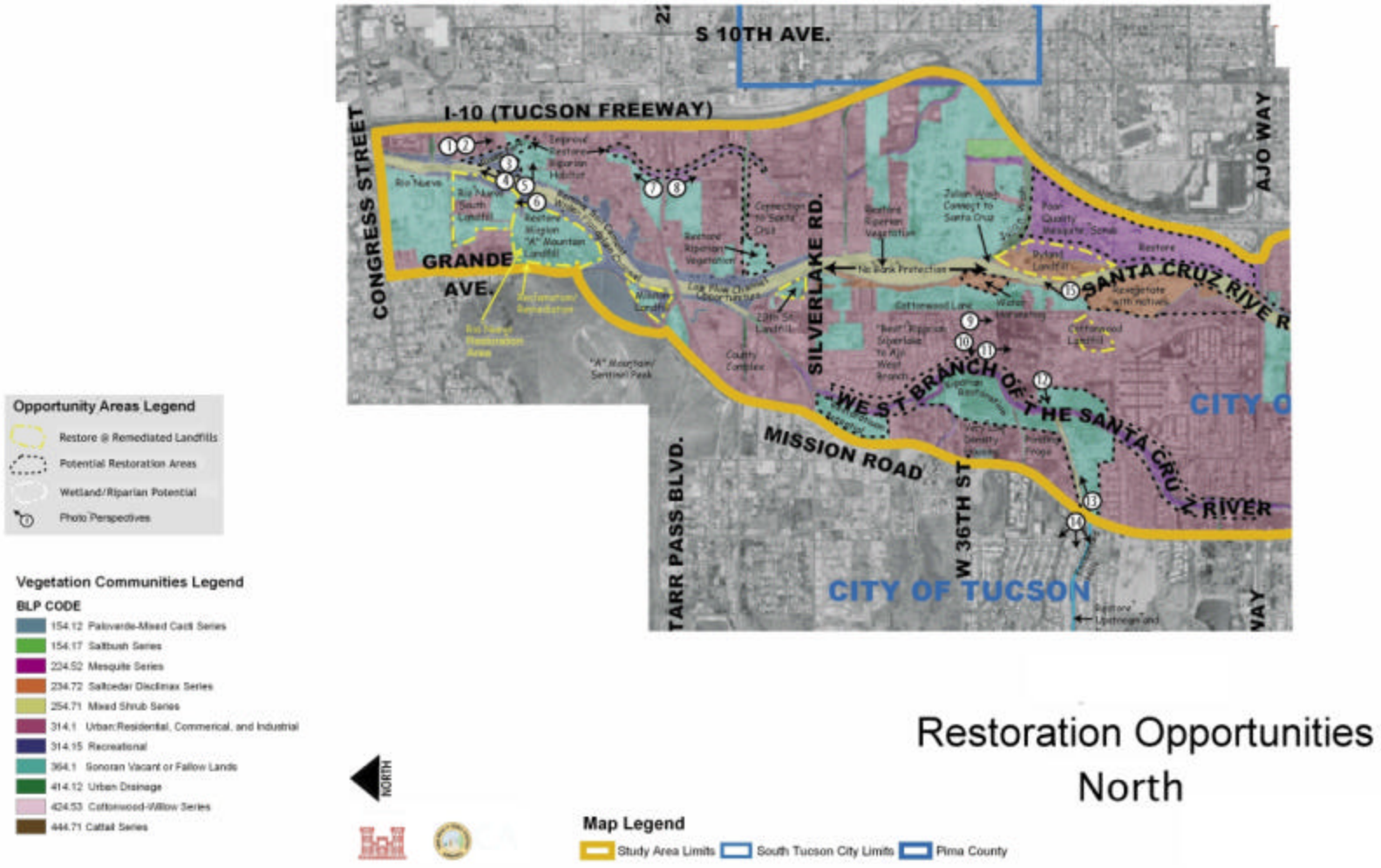
City and County owned property, especially between Calle Santa Cruz and the River, offers opportunity for riparian floodplain corridor fringe revegetation. Areas east of Calle Santa Cruz are under development pressure for large-scale commercial and park industrial.

Valencia Road to Los Reales Road

- Public acquisition and rehabilitation of this area would provide multiple community benefits, such as recharge and storage of CAP water, habitat restoration, and recreation (including ATV/dirt bike tracks in upland areas). The Mayor and City Council of Tucson voted on March 17, 1998 to proceed with planning an extension of the raw CAP distribution system to Valencia Road at the Santa Cruz River to facilitate groundwater recharge at the San Xavier gravel pits. The City will evaluate two pipeline routes. The pipelines could be oversized to deliver additional volumes of CAP water for recharge and ecosystem restoration on nearby washes.
- Wildlife observation and other passive recreation would be suitable for this area. Emphasis should be on restoration and expansion of cottonwood-willow and wetlands vegetation. Any ponding or open water should be integrated into a dynamic system for vector control.
- Depending on water quality, water levels and vegetation management, the lake could also be suitable for swimming and non-motorized boating.
- Flows from Hughes Wash should continue to be diverted around the lake due to potential water quality concerns.
- County recommendations for riparian restoration and water resource opportunities include urban fisheries and non-motorized boating. The County report notes that many native fish, as well as the Huachuca water umbel, need a flowing river to survive, not merely ponds.
- Excavated areas west of the existing open water and wetlands would have little ecological value without developed water resources. These areas would be suitable for high impact (ATV/dirt bike) recreation, and locating these uses in reclaimed excavation areas would take the pressure off areas with higher ecological value or potential.

- Erosion protection would be needed to protect the land and associated facilities as well as the El Paso Natural Gas pipeline and Interstate Highway 19. The Bureau of Reclamation has stabilized the channel banks south of Los Reales Road to protect the San Xavier District of the Tohono O'odham Nation.

Specific locations where opportunities exist to implement restoration measures are depicted in Figures 4.11 and 4.12



Restoration Opportunities North

Figure 4.11 Restoration Opportunities North

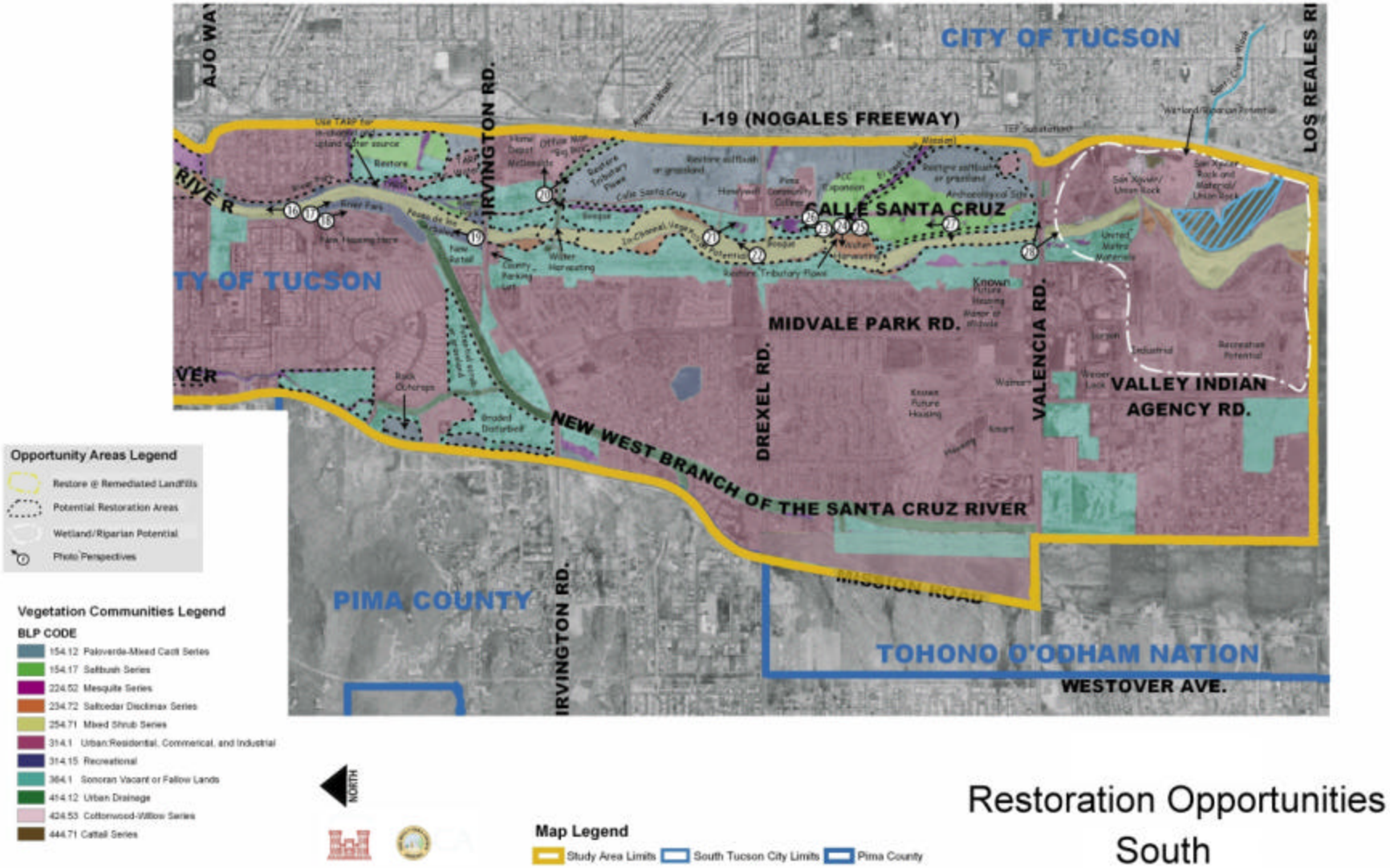


Figure 4.12 Restoration Opportunities South

CHAPTER V

PLAN FORMULATION

A. Study Methodology

This chapter presents the plan formulation rationale used during this feasibility study. The Corps of Engineers six step planning process specified in ER 1105-2-100 was used to develop, evaluate, and compare the array of candidate plans that have been considered. Steps in the plan formulation process include:

1. The specific problems and opportunities to be addressed in the study were identified, and the causes of the problems were discussed and documented. Planning goals were set, objectives were established, and constraints were identified.
2. Existing and future without-project conditions were identified, analyzed and forecast. The existing condition resources, problems, and opportunities critical to plan formulation, impact assessment, and evaluation were characterized and documented.
3. The study team formulated alternative plans that address the planning objectives. An initial set of alternatives was developed and will be evaluated at a preliminary level of detail.
4. Alternative project plans will be evaluated for effectiveness, efficiency, completeness, and acceptability. The impacts of alternative plans will be evaluated using the system of accounts framework (NED, EQ, RED, OSE) specified in the Principles and Guidelines and ER 1105-2-100.
5. Alternative plans will be compared. A benefit-cost analysis will be conducted to prioritize and rank flood damage reduction alternatives. Cost effectiveness and incremental cost analysis will be used to prioritize and rank ecosystem restoration alternatives. The public involvement program will be used to obtain public input to the alternative identification and evaluation process.
6. A plan will be selected for recommendation, and a justification for plan selection will be prepared.

B. Planning Objectives

Federal Planning Objectives

Planning objectives and constraints provide a framework for the development of alternative plans. As planning objectives for this investigation, it is in the Federal interest to:

- contribute to National Ecosystem Restoration (NER) through restoration of

degraded ecosystem structure, function, and dynamic processes to a less degraded, more natural condition.

- contribute to National Economic Development (NED) through the reduction of flood hazards

NER contributions result from creating new habitat or increasing the value of existing habitat and are measured in terms of non-monetary outputs. NED contributions include increases in the net value of national output of goods and services and can be measured in terms of monetary outputs such as reductions in flood damages and emergency response costs.

Specific Planning Objectives

Specific planning objectives were developed to guide formulation of a restoration plan. Those objectives are:

- Restore wetland and riparian vegetative communities within the river corridor to a more natural state
- Increase the acreage of functional wetland habitat within the resource
- Minimize disturbance-type impacts to restored wetlands
- Minimize potential for sediment and organic matter accumulation in restored wetlands (low maintenance design)
- Increase habitat diversity by providing a mix of habitats within the river corridor including the riparian fringe
- Reduce flood damages in specified areas

Public Meetings were held in Tucson from March 30, 2001 to April 1 2001. Over 100 people attended one or more of the sessions. Written comments were submitted by seventy-six attendees. Many goals were expressed by the attendees and considered in development of the above study objectives. Public input included:

- Restore water, vegetation, diverse structure of native vegetation (grasses, shrubs, trees).
- Evaluate water sources such as storm water harvesting, treated effluent and CAP.
- Evaluate restoration of the West branch of the river near Mission Gardens and convents.
- Ensure habitat is sustainable with available water.
- Give consideration to plans that complement and area consistent with the County's Sonoran Desert Conservation Plan
- Re-evaluate the use of soil cement in currently unprotected reaches. Using permeable bank protection would aid restoration efforts.
- Look for opportunities to remove the cement soil banks, return the Santa Cruz to a meandering river again.
- Preserve the less developed west side in its historical context.

- Set aside land to create a wider floodplain.
- Promote ground water recharge.

Public input specific to the Old West Branch included:

- Develop plans which serve multiple objectives.
- Incorporate more permaculture techniques in water harvesting, planning, design, and implementation. Permaculture is an approach that strives for the harmonious integration of human dwellings, microclimate, annual and perennial plants, animals, soils, and water into stable, productive communities.
- Incorporate civic amenities such as a self-guided historic walk with benches and written information, shade and benches; trails, picnic areas and ramadas with BBQs.

C. Planning Constraints

Availability of Water

A principal constraint on any restoration project is the limited availability of water to support establishment and maintenance of healthy riparian habitats.

Maintenance of Floodway Capacity

Restoration of riparian habitat cannot be done in such a way that it would substantially reduce the capacity of the Santa Cruz or its tributary washes to convey damaging flood flows.

Proximity of Recreation to Restoration

Projects must be formulated in such a way as to avoid impacts from existing and planned recreational facilities in adjoining areas.

Endangered Species

The study area is located in an urban area that is not known to contain endangered or threatened species. Any potential project would be required under the Endangered Species Act to not jeopardize the continued existence of threatened or endangered species or to destroy or adversely modify their habitat. Furthermore, ecosystem restoration projects may potentially attract endangered or threatened species. Projects should be sited so that their habitation by those species does not adversely impact the ability to preserve the flood control functions and maintenance of the channels.

Local Acceptability

Any plan must be acceptable to local residents and consistent with local planning efforts.

Displacement of People

The Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970 requires any local sponsor acquiring land for a project involving the Federal government to comply with the provisions of this act.

Rapid Growth

The steady growth in the area creates increasing competition for water and land resources needed for ecosystem restoration.

Real Estate

Real Estate costs can significantly affect project costs. Since right-of way costs may not be uniform with respect to location within the study area or width of acquisition, real estate costs represent a constraint on the location and dimensions of potential alternatives.

County and City Lands

The City of Tucson and Pima County own lands that could be affected by any project in the study area. See Figures 5.1 and 5.2 for a map of land ownerships in the study area.

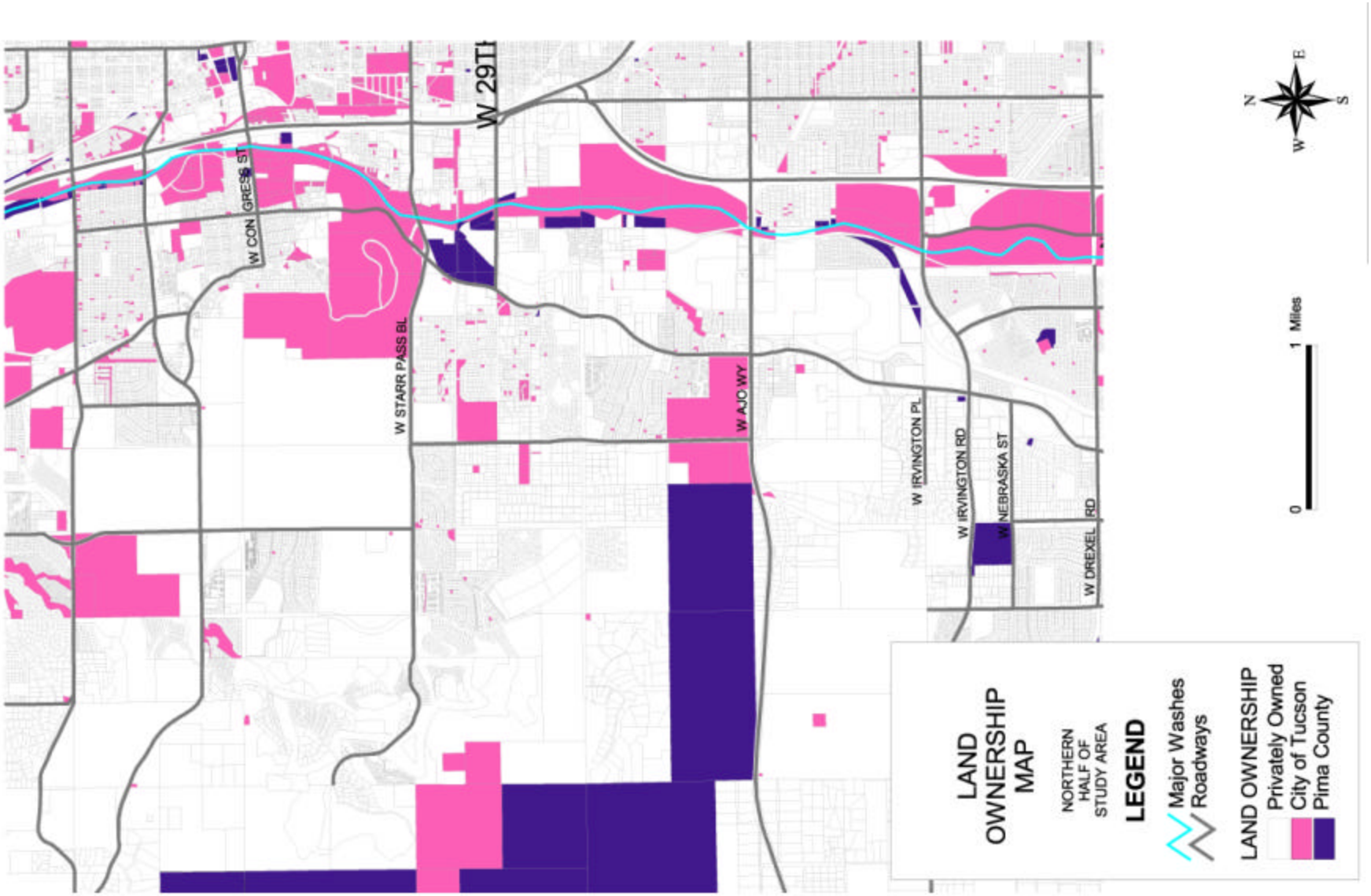


Figure 5.1 Property Ownerships North

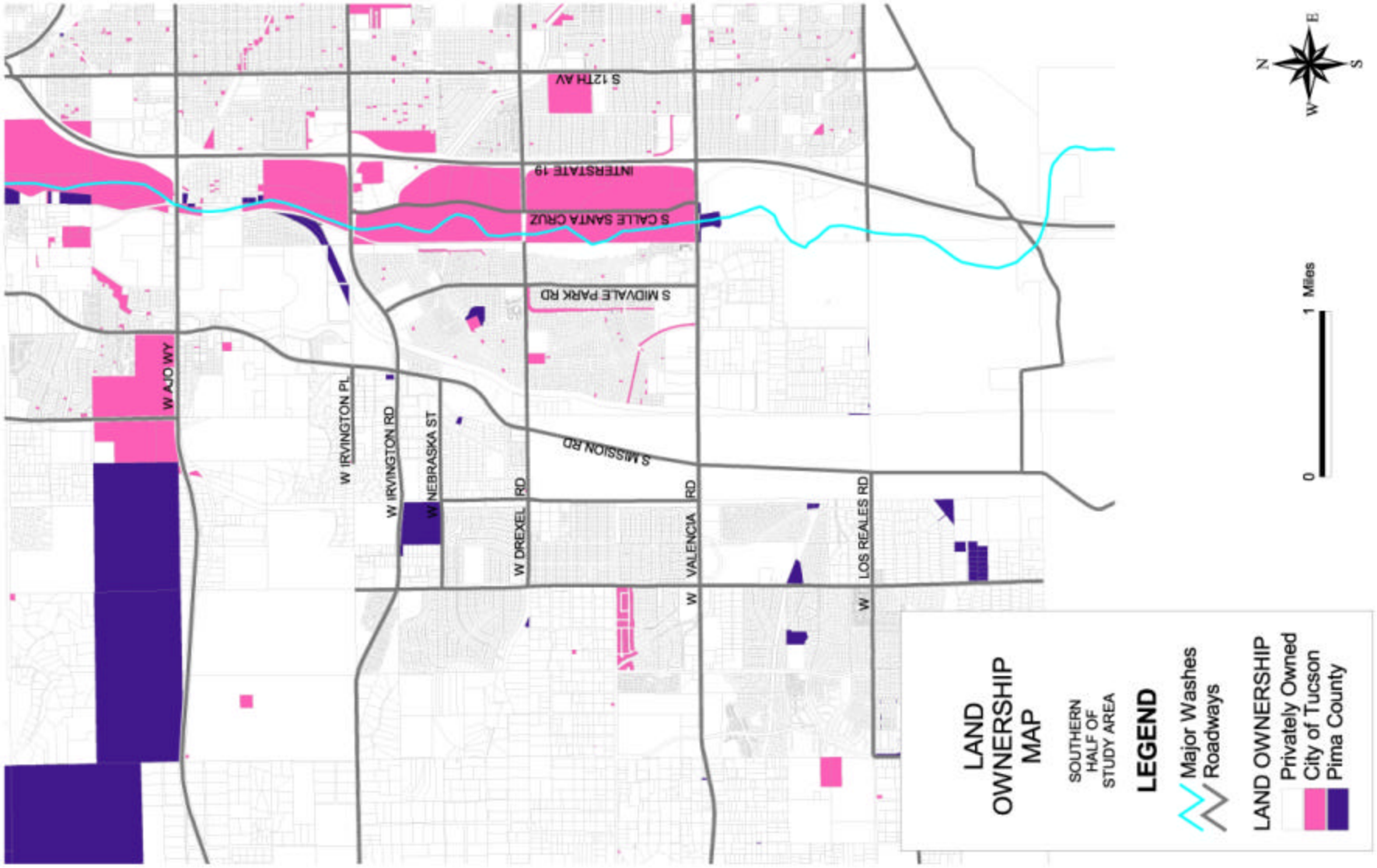


Figure 5.2 Property Ownerships South

D. Alternative Development Rationale

The alternatives are developed for the purposes related specifically to the requirements for a Corps of Engineers Feasibility Report. As such, the alternatives described in this feasibility report are not proposals for actual construction, nor are they of sufficient design detail to be constructed. Following the completion of the feasibility report, EIS, and project authorization by Congress, if such action occurs, detailed design analysis and preparation of plans and specifications would take place. Alternatives were formulated to address a comprehensive Federal project for ecosystem restoration to:

a. Comply with NEPA and other environmental laws and regulations;

b. Restore a variety riparian and associated floodplain fringe habitats to a more natural state;

c. Provide an acceptable means of capturing storm water and conveying it into restored habitat areas;

d. Maintain or enhance existing conveyance of peak discharges and ensure that the system of storm water collection would not increase flood flows or worsen flooding conditions downstream in the existing developed areas;

e. Address specific flooding characteristics within the floodplain and major contributing washes;

f. Produce NER benefits while positively contributing to the National Economic Development Account (NED), Regional (RED) Account, and the Other Social Effects (OSE) Account;

g. Provide decision makers with information that could be utilized to help determine the balance between construction costs, real estate costs, and social issues and concerns;

h. Provide a framework for responding to future urban development in the floodplain, consistent with Executive Order 11988;

i. Match existing and proposed improvements where possible to take advantage of local improvements and to be consistent with the future master planning efforts of the local community.

E. Alternative Development and Evaluation Process

The Paseo de las Iglesias feasibility study process involves successive iterations of alternative solutions to the defined ecosystem degradation problem. Those solutions are based upon the study objectives and designed to address the opportunities while

remaining within the limitations imposed by the identified constraints. The general feasibility criteria that are required to be met are as follows:

Technical Feasibility: Solutions must be technically capable of performing the intended function, have the ability to address the problem, and conform to Corps of Engineers technical standards, regulations, and policies;

Environmental Feasibility: Solutions must comply with all applicable environmental laws, including the National Environmental Policy Act;

Economic Feasibility: Solutions must be economically justifiable in that the economic benefits or, in the case of ecosystem restoration NER (non-monetary) benefits, must exceed the economic costs, in accordance with applicable regulations, policies, and procedures; and

Public Feasibility: Solutions must be publicly acceptable as evidenced by a cost sharing non-Federal sponsor and further documented through an open public involvement process that incorporates the public's input into the formulation of the solutions.

Initially, specific measures were developed to satisfy the four feasibility criteria. Measures are specific stand alone features to address the defined problems. There are numerous specific measures that can be utilized to restore habitats depending upon site location, technical considerations, environmental conditions, and a host of other factors. In determining the set of measures to be evaluated for this study, specific consideration was given to public input and suggestions, Corps experience with similar restoration opportunities, technical considerations based upon the specifics of the area, and flood control considerations for improving or maintaining the existing level of protection.

F. Ecosystem Restoration Measures

A wide variety of measures were identified for use in developing alternatives. In some cases, multiple variations of measures were enumerated. The initial list of measure included:

1. Delivered Water Sources:
   - Tucson Airport Remediation Project (TARP) water and TARP effluent. The TARP facility, located midway between Irvington Road and Ajo Way is producing remediated groundwater that could be a source for irrigation.
   - Other Remediated Water
   - Recharge
   - Central Arizona Project (CAP) water. The CAP delivers Colorado River water from Arizona's allocation to various location in the state including Tucson. CAP allocations available for importation into the Tucson Active Management Area total 192.2 MGD (215,333 acre-feet/year).

- Acquisition and transfer of Type 2 water rights. Three types of rights are derived from past individual water use; these are referred to as "grandfathered rights." Those rights are irrigation grandfathered rights, type 1 non-irrigation grandfathered rights, and type 2 non-irrigation grandfathered rights. The right is based on historical pumping of groundwater for a non-irrigation use and equals the maximum amount pumped in any one year between 1975 and 1980. Examples of non-irrigation uses include industry, livestock watering and golf courses. Type 2 rights are the most flexible because they can be sold separately from the land or well. In addition, the owner of a Type 2 right may, with ADWR approval, withdraw groundwater from a new location within the same AMA. It is possible to lease a portion of a Type 2 right, but if the right is sold, it cannot be split; instead, the entire right must be sold.
- Treated Effluent (Reclaimed water)
- Runoff from the San Xavier District of the Tohono O'Odham Nation. Increased use of CAP water for irrigation of Indian lands may lead to runoff which could be used to help support restored habitat.
- Other Groundwater.

2. Natural Water Sources:

- Two measures for harvesting storm water were identified. Passive capture would involve grading/contouring of restoration areas to promote capture of local runoff. Active capture would involve pumping storm flows from channels to small basins for recharge or subsequent irrigation use.

3. Low Flow Channel:

- Reconfiguration of the existing low channel or modifications to stabilize it could be accomplished to promote maintenance and/or expansion of existing in-channel habitat areas.

4. Open Water:

- Year-round or seasonal pools or channel reaches with flowing water could be established to support restoration of aquatic habitat and benefit migratory waterfowl.

5. Laid Back Banks/Channel Widening (changing bank angle):

- Reducing steepness of existing banks could create a wider and more natural channel. This measure could be applied in a variety of ways if sufficient right-of-way was available to accommodate the measure.

6. Terracing:

- Creation of terraces above the channel invert but below the existing top of bank offers opportunities for habitat restoration which maintains a connection to the channel with less risk of damage from flood events.

7. Islands/ Sand Bars/ Oasis

- Modify channel inverts to create islands of riparian habitat at elevations that would not be affected by frequent floods.
- Modify channel inverts to promote formation of sand bars and associated habitat.

8. Modify Confluence/Distribute Incoming Flows

- Confluences of tributary washes with the Santa Cruz River could be modified to mimic naturally occurring deltas which have the effect of distributing flows over a wider area and thereby support more habitat.

9. In-Channel Vegetation:

- Establish riparian habitat areas in the channel, possibly in association with channel widening.

10. Bank Vegetation

- Vegetate banks to restore to a more natural state and reduce erosion.

11. Floodplain Vegetation

- Vegetative communities such as Sonoran Riparian Deciduous Forest and Woodlands and Sonoran Deciduous Riparian Scrub typically are established in the floodplain fringe that experiences less frequent inundation. Reestablishment of these habitats within the river corridor would provide additional habitat diversity and linkages.

12. Berms/ Debirs/ Obstruction Removal:

- Berms, debris, and other obstructions to natural flow conditions exist at various points in the study area. Removal of these would promote a better distribution of naturally occurring flows and support habitat restoration.

13. Soil Cement Removal

- Soil cement could be removed in some reaches to allow restoration of banks to a more natural state.

14. Palisades/Fence Jetties

- Modification of channel inverts/banks would promote habitat establishment and reduce bank erosion through placement of low structures angled out from banks to slow flows and catch sediment.

15. Drop Structures/Weirs

- Placement of semi-permanent structures with associated weirs to aid in channel stabilization and create seasonal pools.

16. Erosion Protection for Restored Areas

- Placement of natural or engineered bank stabilization would limit erosion damages to restored areas.

17. Elements Conducive Wildlife/Fish

- Restore a mix of habitat sited in such a way as to be more beneficial to native wildlife/fish.

18. Recreation Components

- Passive recreation associated with restored areas including trails, viewing areas, and kiosks. Establishment of Equestrian and off-road vehicle areas in neighboring sites to reduce the likelihood of impacts to restored areas from those activities.

19. Agricultural Education Components

- Establish associated interpretative centers to provide instruction on historic agricultural practices.

20. Cultural Education/ Interpretation/ Ecological Interpretation

- Establish associated interpretative centers to provide instruction on cultural resources and native ecology.

21. Land Acquisition

- Purchase or obtain conservation easements for land that possesses valuable habitat or has a high potential for successful habitat restoration.

G. Flood Control Measures

The feasibility study identified a wide variety of flood control measures which could be used to meet the planning objectives. The broad categories of flood damage reduction

measures investigated are discussed below. Evaluation of structural and non-structural solutions or measures is required by law for any study having a flood control purpose.

Non-Structural Measures

Relocation of Existing Structures

Existing structures could be purchased to allow floodplain residents to move away from the floodplain. Purchased structures could be removed. The areas would be allowed to flood naturally, and could provide flood control benefits in addition to primary restoration benefits.

Floodproofing of Existing Structures

Existing structures in the floodplain could be floodproofed by installing sealants to walls and doors, installing individual or groups of flood walls or dikes, or raising the structure above the inundation elevation. New development is currently required to be constructed one foot above the FEMA 100-year water surface elevation.

Flood Warning System

A flood warning system could provide advance notice of high stage situations and enable people to move themselves, their vehicles, and some high value property out of the flood zone.

Structural Measures

Detention/Retention

Detention or retention of flood flows can reduce flood peaks to levels that are within the capacity of existing channels or improved channels. Detention can be the on-line or off-line type. On-line detention is within the channel or its alignment and typically consists of an embankment with an outlet structure that significantly reduces the downstream flow compared to pre-project conditions. Off-line detention occurs adjacent to the channel or its alignment and requires diversion structure facilities.

Lined Flood Control Channels

Lined flood control channels are a versatile and effective method of conveying detention/retention basin releases or flood flows. The measure includes channel improvements to increase channel capacities and convey flood flows to a safe and adequate point of disposal. Lined channels include collector channels for the capture of tributary flow, the diversion of flood waters between washes, or manmade channels to take advantage of the various capacities in the most efficient manner. Concrete covered

channels would be used for areas where rights-of-way requirements would be prohibitive or when an underground channel is the only practical method to convey the flows. Lining of open channels typically consists of rock revetment, rock revetment with grass cover, natural stone, concrete, or soil cement. Channels lined with vegetation to provide restoration benefits may also provide flood control benefits, provide erosion protection, and other benefits comparable to other more traditional lining techniques.

Unlined Flood Control Channels

Unlined flood control channels have the advantage of providing flood protection by utilizing the existing or modified topography and terrain. Earth bottom channels or channels which utilize the natural topography or widened cross sections may be less costly to construct than concrete or rip-rap lined channel and may be more aesthetically pleasing.

H. Preliminary Evaluation of Measures

Each measure was evaluated in terms of the feasibility criteria. All criteria must be adequately met since any one criterion can serve to eliminate a measure from further consideration. Those measures satisfying all the criteria were carried forward for additional development and evaluation while those that were shown not to meet the criteria were eliminated from further consideration.

Measures that were carried forward were then combined in various configurations to form a preliminary set of alternatives, which was then subjected to a more rigorous evaluation against the criteria. Some measures became alternatives, while other measures were combined to form alternatives.

Restoration Measures

Based upon feasibility criteria, all of the identified restoration were carried forward for Plan Formulation in development of the alternatives. None could be eliminated at the preliminary screening level.

Flood Control Measures

Flood Control is a minor, incidental component of the feasibility study. Identified flood control measures were evaluated in the context of the restoration objectives and for the potential to provide additional flood control benefits. Several flood control measures were eliminated from additional consideration, others are carried forward either to provide stand alone flood control benefits, or incidental flood control benefits over and above the restoration measures. In many cases, flood control measures and restoration

measures can be complimentary. The initial evaluation of flood control measures is discussed below.

Flood proofing

Implementation of non-structural measures such as flood proofing existing structures and the relocation of existing residences and businesses to reduce the overall damage potential has been evaluated. Flood proofing offers the opportunity to provide flood protection on an individual, structure-by-structure basis. Each structure or reasonable group of structures would either be surrounded by a floodwall or elevated in-place. Elevation of structures could be accomplished by rising on piers, foundation walls, or fill material. Floodwalls or levees surrounding structures would consist of either a concrete or masonry wall, or soil material built-up and compacted around the structure. Walls surrounding structures would still require closures that would allow doors, windows, and driveways to be used while preventing water from entering the building. These closures typically would be manually operated based on flood forecasting and prediction that would alert the operator

Within the study area damages are caused by shallow overland sheetflow. The damages to residential structures in the Indian Road area are minor in relation to the cost of individual floodproofing. Most of the structures in the Old West Branch area are mobile homes that are elevated under existing conditions and incur little damage. Aside from the cost, floodproofed homes and businesses can still suffer flood damages due to the potentially incomplete nature of the solution. The enclosures of the windows, doors, and driveways require human action in order to fully implement the solution. And, this would have to occur in a relatively short amount of time.

Do to the excessive costs, minor damages, and lack of practicality of floodproofing it is not carried forward for formulation of alternatives.

Relocation

Land purchase for restoration is already being carried forward for alternatives, and any incidental flood control benefits will be evaluated.

Flood Warning System

Pima County owns and operates a significant ALERT flood warning network that currently provides advance warning of floods. Accordingly, this nonstructural measure was not considered further for plan formulation

Structural Measures

Detention: Preliminary evaluation of this measure indicated that the minor damages would provide insufficient benefits to support a large flood control detention structure. Detention for flood control purposes will not be carried forward.

Lined Channels

1) Rectangular Concrete Channels: An evaluation was performed for the potential for utilizing concrete channels, due primarily to the ability to limit the real estate right-of-way requirements. Based upon great public opposition, rectangular concrete channels are not carried forward for plan formulation of the alternatives.

2) Trapezoidal Rip-Rap/Soil Cement/Vegetation Lined Channels: A preliminary evaluation was performed for the potential for utilizing trapezoidal lined channels, due to the reduced construction costs and improved aesthetics of such channels. The Santa Cruz River contains the 100 year flood, and several reaches within the study area are currently protected from erosion with soil cement. Along the New West Branch, the current trapezoidal channel contains the 100 year flood as well. A trapezoidal channel was previously evaluated for flood control for the Old West Branch, but based upon public opposition to flood control and the environmental impacts to existing riparian habitat; the measure is not carried forward for either the New or Old West Branch.

3) Soil cement or vegetative stabilized banks may offer protection from erosion for restored areas within the Santa Cruz River channel, additionally, in the formulation of alternatives that widen the existing channel and provide floodplain terraces; bank stabilization measures may be needed in order not to induce flood and erosion damages from a restoration project. The measure is carried forward as a restoration measure and incidental flood control benefits will be evaluated for specific appropriate areas.

Covered Channels An initial evaluation indicated that there is no specific location where covered channels could be utilized and this measure is not carried forward for the formulation of alternatives.

Unlined Flood Control Channels: Unlined flood control channels consist of wider, shallower slope channels which can be constructed primarily with grading, shaping, and landscaping techniques. The areas can be over-planted with various types of riparian vegetation and grasses for aesthetics. Construction costs can be minimized if real estate costs are low. Generally the natural topography of the existing channel can be re-formed to accommodate increased flood flows. This measure is carried forward for plan formulation.

The difference between a vegetative "lined" channel and vegetative "unlined" channel is a matter of degree. In general, a vegetative lined channel would have denser vegetation and structure to provide a stabilization function against excessive erosion and would be placed in higher velocity areas, whereas a vegetative unlined channel would have less density and structure with some erosion allowed but from lower velocity flows.

Levees: Levees can provide significant levels of protection in a cost effective manner, however, there are disadvantages such as increases of flood stages, real estate and access considerations, higher environmental impacts, and the potential for failure or overtopping. Levees as a flood control measure for the Indian Road area are carried forward for additional consideration in the formulation of alternatives.

Floodwalls: In evaluating levee measures for the Indian Road area, consideration was given to protective floodwalls in place of levees. This measure has the advantage that the floodwalls can be designed with aesthetically pleasing characteristics, and have a small footprint which minimizes environmental impacts and real estate costs. Since the New West Branch channel is incised already, floodwalls may be provided at a lower cost than levees and provide significant levels of protection over and above the current channels with or without widening and deepening. This measure is carried forward for the Indian Road area.

I. Preliminary Alternatives

The development of preliminary alternatives for ecosystem restoration in the Paseo de las Iglesias study area is discussed in this and subsequent sections. Extensive work to identify and conceptually describe restoration opportunities had been accomplished by Pima County prior to this feasibility study. This work provided a starting point for the development of measures and alternatives in this feasibility study. Detailed information regarding Pima County planning efforts may be found in "Paseo de las Iglesias: Restoring Cultural and Natural Resources in the Context of the Sonoran Desert Conservation Plan, April 1993."

Three preliminary alternatives have been developed from the measures that survived screening. These alternatives demonstrate that there is a range of feasible alternatives for ecosystem restoration in the study area. The alternatives vary with respect to water requirements, habitat focus and total scale. Graphic depictions of each alternative follow this discussion (Figures 5.3-5.5)

Alternative 1: Water Resources and Riparian Habitat

This alternative has the largest scale and the greatest water. The alternative would involve introduction of CAP and TARP into the project area. CAP water would be introduced through periodic releases of water into washes in the western portion of the study area that are tributaries of both the old and new West Branches of the Santa Cruz River. In addition to supporting restoration of habitat along those watercourses, the water would help to expand the existing habitat area along the Old West Branch into adjoining land acquired to accommodate that expansion. The land at the southern end of the project area, currently occupied by a sand and gravel mining operation, would be acquired. Either CAP or TARP water would be introduced to maintain and expand the existing wetland areas. Those areas would be structurally modified to permit periodic releases

from the pools into the Santa Cruz River. TARP water would be released into the Santa Cruz at its confluence with the New West Branch. Finally, periodic releases of water into the Santa Cruz River would occur just upstream of 22nd Street.

Modifications to the Santa Cruz River itself would include construction of five semi-permanent drop structures with associated weirs to create ponding of low flows. Those structures would be located between the wetlands and the Valencia Road Bridge, immediately upstream of Irvington Road Bridge at the confluences of the New and Old West Branches and at the confluence of the 18th Street Wash. The Santa Cruz River channel would be widened between Valencia Road and Irvington Road to allow reintroduction of in-channel vegetation and a more sinuous channel form. Channel widening or terracing would also occur between Los Reales Road and Valencia Road. Tributary confluences would be modified to facilitate habitat restoration throughout the project area.

Reestablishment of floodplain habitat in the form of Cottonwood/Willow galleries would occur adjacent to the river on both banks between Los Reales Road and Irvington Road and on both banks from Ajo Way north through the Cottonwood Lane area. Additional reestablishment of floodplain habitat in the form of Cottonwood/Willow galleries would occur immediately upstream of the Congress Street Bridge integrated into the Rio Nuevo District. Finally, a Mesquite Bosques would be established on the west bank of the Santa Cruz River adjoining the Cottonwood/Willow galleries between Los Reales Road and Valencia Road, on the west bank between the river and Sentinel Peak and on the east bank of the New West Branch between Valencia Road and Irvington Road.

This alternative includes acquisition of the land or conservation easements to support restoration efforts between Los Reales Road and Valencia Road, in the Cottonwood Lane area, and on either side of the Old West Branch just upstream of its confluence with the Santa Cruz River.

Alternative 2: Sonoran Grassland and Floodplain Restoration

This alternative has an intermediate scale and the least water requirement. This alternative would rely entirely on storm water harvesting to provide water to support habitat restoration. Water to support restored habitat would come from eight storm water harvesting sites located at confluences of tributary washes with the Santa Cruz River, the Old West Branch and the New West Branch. Confluences would be modified to capture and distribute storm water. Beginning at the northern end of the project area, modifications would occur to the following confluences on the Santa Cruz River: 18th Street Wash, the Old West Branch, Tucson Diversion Channel, Airport Wash and Santa Clara Wash. Modifications would also occur at the 3rd and 6th tributaries to the Old West Branch upstream of its confluence with the Santa Cruz and at the first upstream tributary of the New West Branch.

Reestablishment of floodplain habitat in the form of Cottonwood/Willow galleries would occur adjacent to the Santa Cruz River on the east bank between Los Reales Road and Valencia Road with establishment of transitional grasslands on the west bank. Establishment of banks and terraces vegetated with a mix of riparian species would occur on both banks of the river between Valencia Road and Irvington Road and on both banks from Ajo Way north through the Cottonwood Lane area. Grasslands/desertscrub would also be established adjacent to restored riparian areas on the west bank of the river between Los Reales Road and Valencia Road, on the east bank of the river between Valencia Road and Irvington Road, immediately north of Irvington Road, from Ajo Way north through the Cottonwood Lane area, on the west bank immediately south of the Rio Nuevo District and on the east bank of the New West Branch between Valencia and Irvington.

This alternative includes acquisition of the land or conservation easements to support restoration efforts between Los Reales Road and Valencia Road, in the Cottonwood Lane area, and on either side of the Old West Branch just upstream of its confluence with the Santa Cruz River. A recreational area would be located on the most disturbed portions of lands acquired between Los Reales Road and Valencia Road and trail would be established parallel to the restored areas along the Santa Cruz River running the length of the project.

Alternative 3: Wildlife Corridors and Infrastructure Modifications

This alternative proposes restoration activities similar to those developed in Alternative 2. It differs in that it would involve introduction of CAP, TARP and/or treated effluent into the project area. In general, habitat restoration is occurring in the same areas as in Alternative 2, but the mix of vegetative communities is different and the scale is somewhat reduced. Removal of soil cement as well as a variety of flow obstructions is included.

This alternative proposes to reestablish habitat connections between the Santa Cruz River and public lands in the Tucson Mountains by removing road barriers, restoring tributary washes, and enlarging culverts for wildlife movement. Of the nine areas identified for removal of obstructions or soil cement, six are on the Old West Branch, one is at the confluence of the New West Branch with the Santa Cruz River and the other two are in the Rio Nuevo District.

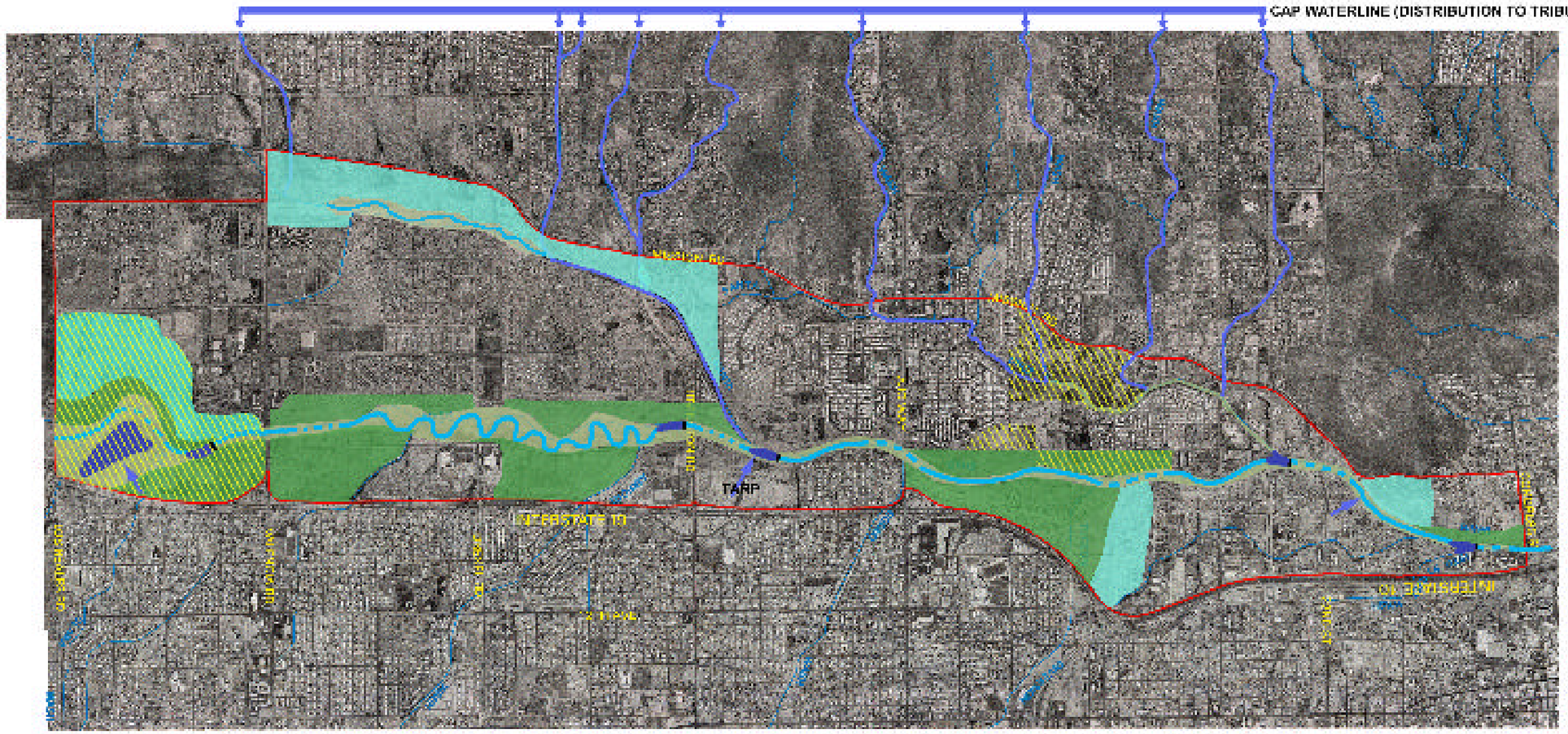
In-channel vegetation is proposed for the Santa Cruz River for the length of the study area. Establishment of banks and terraces vegetated with a mix of riparian species would occur on both banks of the river between Valencia Road and Irvington Road and on both banks from Ajo Way north to 22nd Street. Additional reestablishment of floodplain habitat in the form of Cottonwood/Willow galleries would occur immediately upstream of the Congress Street Bridge integrated into the Rio Nuevo District. Grasslands would also be established adjacent to restored riparian areas on the east bank of the river between Valencia Road and Irvington Road, immediately north of Irvington Road, from

Ajo Way north through the Cottonwood Lane area and between the restored Cottonwood/Willow galleries on the west bank and Sentinel Peak.

This alternative includes acquisition of the land or conservation easements to support restoration efforts between Los Reales Road and Valencia Road, in the Cottonwood Lane area, and on either side of the Old West Branch just upstream of its confluence with the Santa Cruz River. This represents the smallest project footprint in terms of both total size and real estate requirements.

In the next phase of detailed studies the quantity of water that will be reliably available during the period of analysis will be determined and alternatives will be sized accordingly. Each alternative will be refined and analyzed as a series of incremental added measures. Measures from each alternative will be evaluated based on the costs and National Ecosystem Restoration (NER) outputs. They will be considered as increments of a single alternative and as parts of a combined alternative. Based on the results of these analyses an NER plan will be identified that can be recommended for implementation.

Recreation and flood control measures will be developed and overlaid as appropriate and consistent with the restoration alternatives.



SELECTED COMPONENTS ILLUSTRATED (LISTED IN ORDER OF RELATIVE IMPORTANCE)

#1 DEVELOP WATER SOURCES (CAP, TARP, STORMWATER, RECLAIMED) THROUGHOUT CHANNEL
#2 NATURAL WATER SOURCES (GRADING/CONTOURING) THROUGHOUT CHANNEL AREA
#4, #18, #20 OPEN WATER (SAND & GRAVEL PIT) - RECREATION, EDUCATION, CULTURAL)

#9 IN-CHANNEL VEGETATION (MIXED RIPARIAN)

#10, #6 BANK VEGETATION (COTTONWOOD/WILLOW) & TERRACING/CHANNEL WIDENING

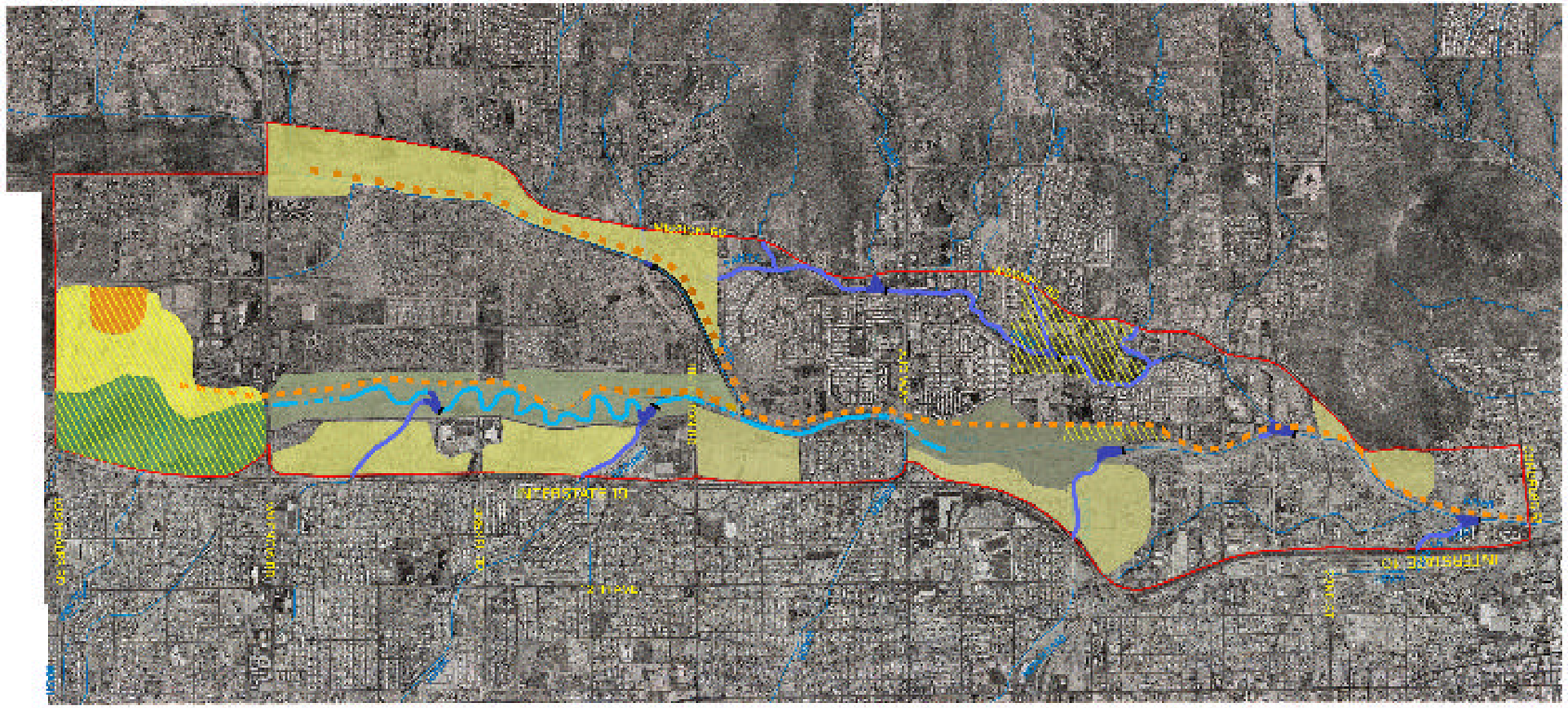
#3, #7 LOW-FLOW CHANNEL & ISLANDS/SANDBARS THROUGHOUT SANTA CRUZ CHANNEL
#15 DROP STRUCTURES/WEIRS/CATCHMENTS

#11 MESQUITE BOSQUE/RIPARIAN FRINGE

#8 MODIFY CONFLUENCE/SINUOUS CHANNEL
#17 WILDLIFE/FISH - THIS ALT. SUPPORTS RESTORATION OF BIRD MIGRATION HABITAT AND PROVIDES OPPORTUNITIES FOR INTRODUCING FISH INTO THE PERENNIAL WATER AREAS.
#21 PURCHASE LAND (SAND & GRAVEL PIT; COTTONWOOD LANE & WEST BANK PARCELS) -RESTORE TO COTTONWOOD/WILLOW

Note:
Alternatives reflect opportunities identified as part of preliminary planning rather than plans or forms proposals for construction.

Figure 5.3
Paseo de las Iglesias
ALTERNATIVE #1: Water Resources & Riparian Habitat



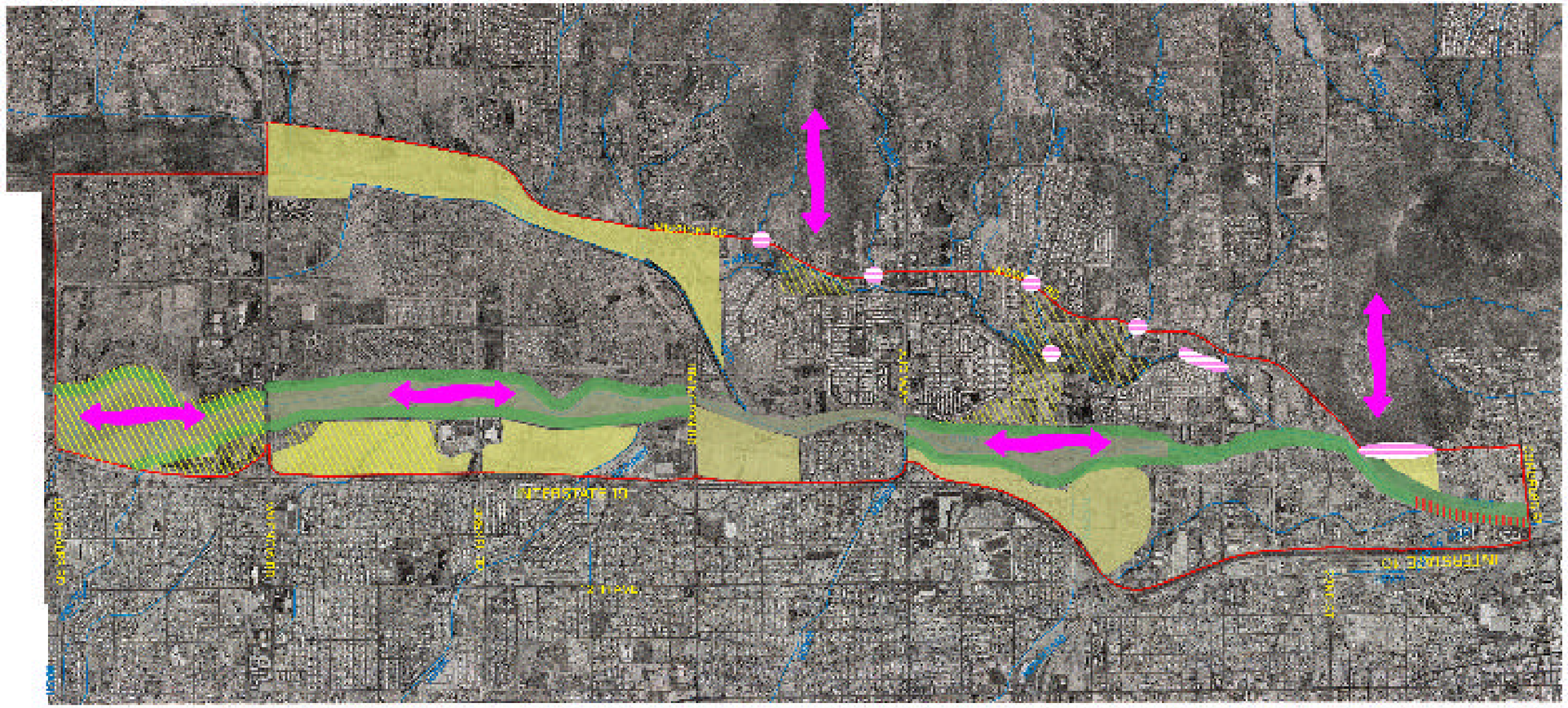
SELECTED COMPONENTS ILLUSTRATED (LISTED IN ORDER OF RELATIVE IMPORTANCE)

- #11 GRASSLAND/SCRUB SHRUB
- #6, #10 BANK/TERRACE VEGETATION (MIXED RIPARIAN)
- #9 IN-CHANNEL VEGETATION (COTTONWOOD/WILLOW & WETLAND)
- #3 LOW-FLOW CHANNEL & ISLANDS/SANDBARS THROUGHOUT SANTA CRUZ CHANNEL
  #8 TRIBUTARY RESTORATION W/ WATER HARVESTING
- #21 PURCHASE LAND/EASMENTS
- #18 REGREATION
  RIVER PARK TRAILS (BIKE, PEDESTRIAN & EQUESTRIAN)

Note:
Alternatives reflect opportunities identified as part of preliminary planning rather than plans or formal proposals for construction.

Figure 5.4
Paseo de las Iglesias

ALTERNATIVE #2: Sonoran Grassland & Floodplain Restoration



SELECTED COMPONENTS ILLUSTRATED (LISTED IN ORDER OF RELATIVE IMPORTANCE)

- #6, #10 BANK VEGETATION & TERRACE AREAS W/O BANK PROTECTION
- #9 IN-CHANNEL VEGETATION (MIXED RIPARIAN)
- #1, #2 DEVELOP SUSTAINABLE WATER SOURCES
  #7 ISLANDS/SAND BARS IN RESTORED FLOODPLAIN
- #11 GRASSLAND/SCRUB SHRUB/MESQUITE MIX (RIPARIAN FRINGE)
- #13 SOIL CEMENT/OBSTRUCTION REMOVAL
- #12 DEBRIS/OBSTRUCTION REMOVAL (CULVERTS & ROADS IMPROVED)
- #21 PURCHASE LAND/EASMENTS FOR RESTORATION
- #17 MAINTAIN/ESTABLISH WILDLIFE CORRIDORS

Note:
Alternatives select opportunities identified as part of preliminary planning rather than plans or formal proposals for construction.

Figure 5.5
Paseo de las Iglesias

ALTERNATIVE #3: Wildlife Corridors & Infrastructure Modifications