

# CENTRAL MARICOPA COUNTY DRAINAGE AREA ARIZONA

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## RECONNAISSANCE STUDY



**US ARMY CORPS  
OF ENGINEERS**  
Los Angeles District  
South Pacific Division

**June 1992**

**A901.301**



DEPARTMENT OF THE ARMY

LOS ANGELES DISTRICT, CORPS OF ENGINEERS  
P.O. BOX 2711  
LOS ANGELES, CALIFORNIA 90053-2325

June 23, 1993

REPLY TO  
ATTENTION OF:

Office of the Chief  
Water Resources Branch

Mr. Neil Erwin, P. E.  
Chief Engineer and General Manager  
Flood Control District of Maricopa County  
2801 W. Durango  
Phoenix, Arizona 85009

Dear Mr. Erwin:

In June, 1992, the U. S. Army Corps of Engineers, Los Angeles District, concluded the Central Maricopa County Drainage Area Reconnaissance Study. Three copies of the report are enclosed.

As the local sponsor for this Reconnaissance Study, the Flood Control District of Maricopa County provided timely information and technical data which contributed to a thorough analysis of the flooding problems and water resource opportunities in central Maricopa County. Thank you for your cooperation and support.

Sincerely,

Robert S. Joe  
Chief, Planning Division

Enclosure

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**CENTRAL MARICOPA COUNTY DRAINAGE AREA  
ARIZONA**

RECONNAISSANCE REPORT

**U.S. ARMY CORPS OF ENGINEERS  
LOS ANGELES DISTRICT - SOUTH PACIFIC DIVISION**

**JUNE 1992**

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## CHAPTER 1

### AUTHORITY, PURPOSE AND SCOPE

#### 1.1 INTRODUCTION

The Central Maricopa County Drainage Area Reconnaissance Study involves the investigation of the water resource problems and opportunities in the Phoenix metropolitan area, Arizona (Figure 1.1). This report is organized to outline the study purpose and scope of the study effort, a description of the study area, a thorough presentation of the problems addressed, a description of the alternatives considered, a presentation of the results of these alternative, and the identification of the alternative(s) which will likely have a Federal interest.

#### 1.2 AUTHORITY

This study has been conducted under the authority of Public Law 761, Seventy-fifth Congress, June 28, 1938, which reads, in part, as follows:

SEC. 6. The Secretary of War is hereby authorized and directed to cause preliminary examinations and surveys for flood control including floods aggravated by or due to tidal effect at the following-named localities, and the Secretary of Agriculture is authorized and directed to cause preliminary examinations and surveys for run-off and water-flow retardation and soil-erosion prevention on the watersheds of such localities:

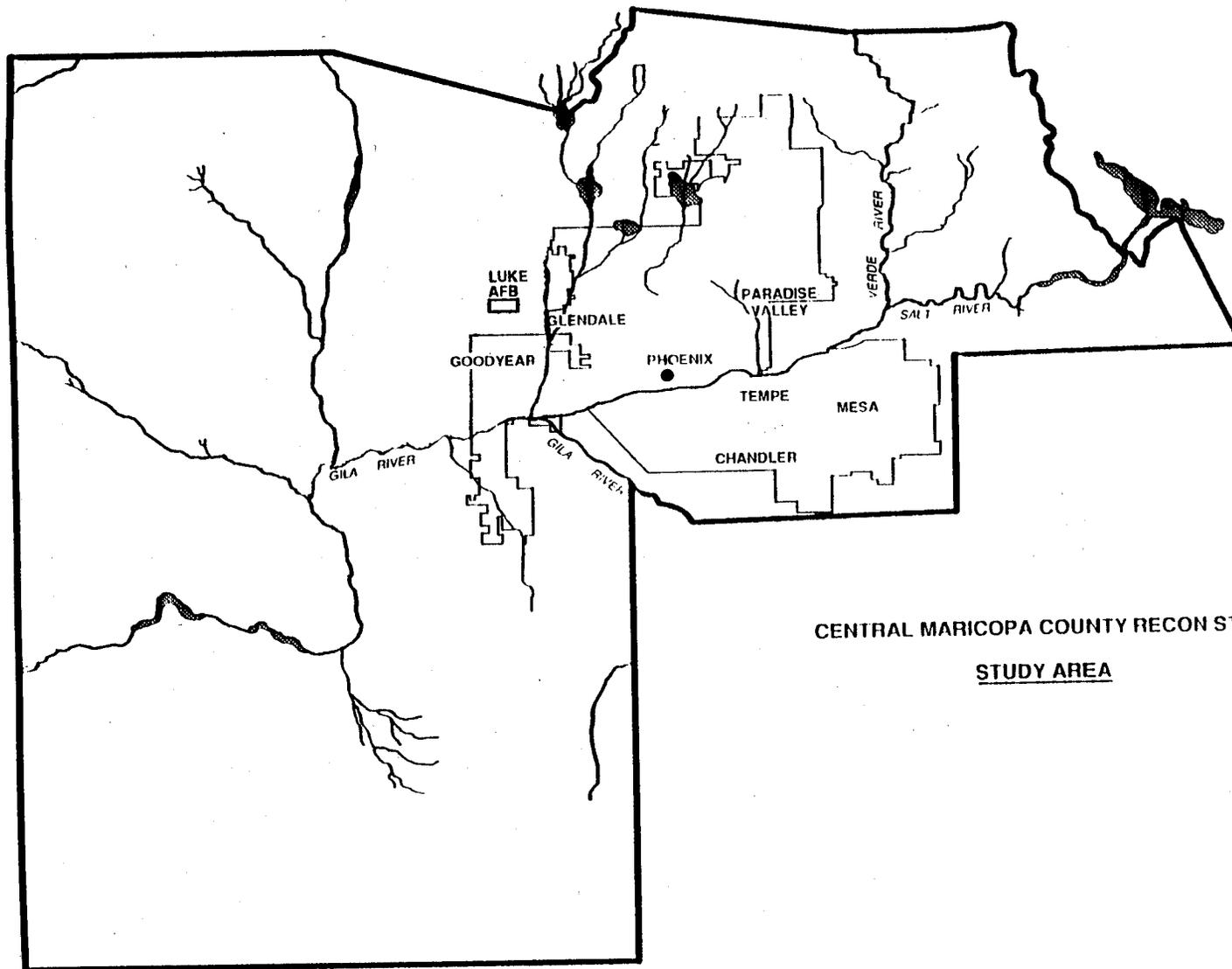
Gila River and tributaries, Arizona and New Mexico.

#### 1.3 PURPOSE AND SCOPE

This reconnaissance study provides an interim response to the study authority, cited above. The study focuses on flood problems and water resource opportunities in Central Maricopa County, Arizona which encompasses the greater Phoenix metropolitan area where the majority of the population within Maricopa County is concentrated.

The purpose of this study is to fully describe and analyze flooding problems and water resource opportunities within this area and to develop a wide range of alternatives that would reduce the severity, or totally eliminate these problems. The main objective of this reconnaissance study is to develop and present sufficient

# MARICOPA COUNTY, ARIZONA



CENTRAL MARICOPA COUNTY RECON STUDY  
STUDY AREA

GENERAL INVESTIGATIONS-SURVEYS  
FLOOD DAMAGE PREVENTION STUDIES

CENTRAL MARICOPA COUNTY  
DRAINAGE AREA  
RECONNAISSANCE STUDY

LOS ANGELES DISTRICT  
SOUTH PACIFIC DIVISION  
1 JANUARY 1992

FIGURE 1.1

information to determine whether or not at least one alternative is capable of accomplishing the following:

- 1) Can the alternative be implemented in accordance with environmental laws and statutes,
- 2) Does it fall within the purview of current policies and budgetary priorities,
- 3) Will the alternative have the support of a non-federal sponsor, and
- 4) Will the alternative have a likely Federal interest?

An analysis and evaluation of an array of alternatives will identify those alternatives which fully comply with the above objectives. Should one or more of such alternatives be identified, the reconnaissance study will conclude with a recommendation that the study effort continue into the feasibility phase of planning.

## CHAPTER 2

### PRIOR STUDIES, REPORTS, AND EXISTING WATER PROJECTS

#### 2.1 STUDY HISTORY

In May of 1989 a letter was written by D. E. Sagramoso of the Flood Control District of Maricopa County, Arizona to Colonel Ono, District Engineer, USACE, Los Angeles, California requesting that a reconnaissance study of the Central Maricopa County Area be conducted.

Funding for the study was provided at the request of Congress, through a Congressional add for Fiscal Year 91. The study was initiated on April 1, 1991 and was completed on June 15, 1992.

#### 2.2 PRIOR STUDIES AND REPORTS

The prior studies and reports that are summarized below were conducted and prepared by the Corps of Engineers and other agencies, and have been incorporated, as appropriate, into the study.

- 1) Floodplain Regulation for Maricopa County, Arizona. Flood Control District of Maricopa County. August 4, 1986, amended September 18, 1989.
- 2) Flood Control in the Desert. Phoenix, Arizona. Flood Control District of Maricopa County, 1989.
- 3) Final Environmental Impact Statement. Central Arizona Water Control Study-Plan 6. U.S. Bureau of Reclamation February 10, 1984.
- 4) Summary of a Preliminary Study of Proposed Alternatives for Flood Control. Royden Engineering Co. February, 1979.
- 5) New River and Phoenix City Streams, Maricopa County, Arizona. U.S. Army Corps of Engineers, Los Angeles District March, 1976.
- 6) Capitol Improvements Program Five Year Flood Control Projects. Maricopa Association of Governments, Transportation and Planning Office, 1975.

- 7) Final Environmental Statement; Indian Bend Wash. Maricopa County Arizona. U.S. Army Corps of Engineers. Los Angeles District, 1973.
- 8) Flood Control. Flood Control District of Maricopa County, Arizona, 1973.
- 9) Compilation of Flood Data for Maricopa County, Arizona. U.S. Geological Survey, 1967.
- 10) Watersheds Work Plan Buckeye Watershed, Maricopa County Arizona Flood Control District of Maricopa County. Assisted by Department of Agriculture, Soil Conservation Service, 1963.
- 11) Comprehensive Flood Control Program Report. Flood Control District of Maricopa County, 1989.

### 2.3 EXISTING WATER PROJECTS

Currently there are numerous existing flood control protection structures in the Central Maricopa County area. These structures are primarily in the form of dams, channel improvements and diversion channels. Two large scale projects involving the Corps of Engineers were the Arizona Canal Diversion Channel (ACDC), and Indian Bend Wash. The ACDC is the most recent project, as it is presently nearing completion. The channel runs across Phoenix from east to west intercepting flood flows that flow from the north. It then flows west to Skunk Creek where it is discharged into the natural channel. Indian Bend Wash carries water through a greenbelt floodway to the south where flows are discharged into the Salt River. These two channels were designed by the Corps of Engineers to relieve the flooding problems within communities of Phoenix and Scottsdale.

## CHAPTER 3

### PUBLIC INVOLVEMENT

#### 3.0 GENERAL

The public involvement activities which have been conducted as part of the Central Maricopa County Drainage Area Reconnaissance Study are summarized in this chapter.

#### 3.1 PUBLIC MEETINGS

On June 27, 1991, a public workshop for the Study was conducted in Glendale, Arizona (Phoenix Metropolitan Area). Public notification of the workshop was made through press releases and direct mailings to Federal, state and local agencies. A representative from the Flood Control District of Maricopa County (the local sponsor) was also present.

The purposes and accomplishments of this meeting are summarized as follows:

- 1) Initiation of a reconnaissance study was announced.
- 2) Those in attendance were informed of the goals and objectives of the study, and the process used to arrive at a first-cut listing of the problem areas to be analyzed in this reconnaissance study.
- 3) Input from participants was utilized to help identify the flooding problems areas to be addressed in this study.
- 4) Questions regarding the elimination of specific areas during the preliminary stages of the reconnaissance study were raised by attendees and responded to by the Corps.

### 3.2 AGENCY COORDINATION

Throughout the reconnaissance study, coordination with Federal, state and local agencies was an ongoing process. Representatives from the agencies listed below served as an integral component of the plan formulation process.

- U.S. Fish and Wildlife
- U.S. Environmental Protection Agency
- U.S. Air Force, Luke Air Force Base
- Arizona State Game and Fish Department
- Arizona State Department of Environmental Quality
- Arizona State Department of Water Resources
- Flood Control District of Maricopa County
- Maricopa County Parks and Recreation
- City of Phoenix
- City of Glendale
- City of Avondale
- City of Goodyear
- Sub Regional Operating Group

### 3.3 PROFESSIONAL ORGANIZATIONS AND CIVIC GROUPS

During the course of the study, meetings with civic groups and organizations helped define the problems, opportunities, and courses of action considered in this reconnaissance study. The following organizations or representatives thereof were involved in this process:

- Arizona Water and Pollution Control Association
- Arizona Riparian Council
- Sierra Club
- Arizona Center for Law

## CHAPTER 4

### STUDY AREA DESCRIPTION

#### 4.1 STUDY AREA

The study area is located in Central Maricopa County, Arizona. The Corps has played an active role in providing flood protection in Arizona. In view of the flood control structures currently in place, this reconnaissance study examines the residual flooding problems of the greater Phoenix metropolitan area as rapid population and land use changes have occurred since the area was last studied in the mid 1970's. Central Maricopa County was selected as the study area in order to address the potential for flooding in those cities and communities where recent urban flooding has occurred or where the potential exists for flooding in rapidly developing areas. A map identifying the geographic limits of the area identified as Central Maricopa County study area is displayed in Figure 4.1.

Study area boundaries included Cave Creek/Carefree and the White Tank Mountains to the north and west, respectively. The southern border is represented by South Mountain and the Sierra Estrella Mountains. Queen Creek defines the study area's eastern border.

#### 4.2 TOPOGRAPHY AND DRAINAGE

The Salt River Valley is predominantly a flat desert alluvial valley ringed by rugged mountain ranges. Hills and buttes with steep gradients (25% or greater) rise as distinctive landmarks within the otherwise flat basin that encompasses the urban study area.

The Salt and Agua Fria Rivers provide drainage for the Northern and Eastern mountain ranges. Within the study area, the tributaries of these two rivers include New River, Skunk Creek, Cave Creek, Indian Bend Wash, Verde River and innumerable washes and arroyos. The Salt and Agua Fria converge with the Gila River in the Southwestern corner of the study area. Both the Salt and the Agua Fria Rivers are ephemeral waterways that are dry year-round with the exception of periodic flooding or releases from the mountain reservoirs east of the valley. Both the Salt and Agua Fria Rivers are tributaries of the Gila River, the largest drainage area serving as a tributary to the lower Colorado River.

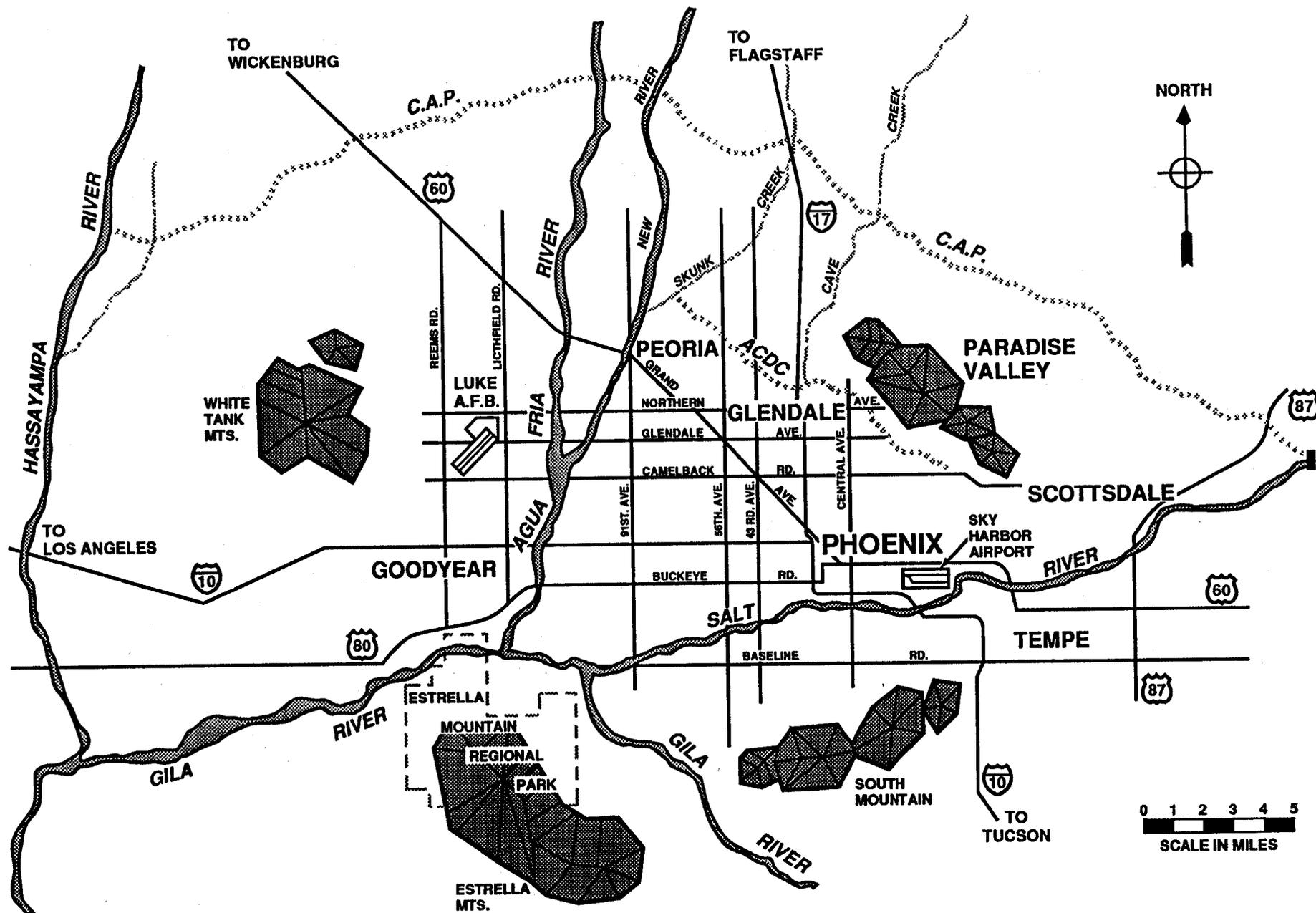


FIGURE 4.1

#### 4.3 CLIMATE

The climate in Central Maricopa County is characteristic of the sonoran desert. The average annual rainfall is 7.5 inches, although the intensity of rainfall varies widely. Storms on record have produced over 5 inches of rainfall in a 24 hour period.

These storms typically occur during the monsoon season starting around mid July and extending into September. Temperatures during this time range from 75° F at night to 122° F during the peak times of the day.

#### 4.4 GEOLOGY AND SOILS

The area is characterized by steep mountains and broad alluvium-filled valleys. The mountain ranges, which are generally parallel and trend Northwest to Southeast, are composed of metamorphic and volcanic rock. The basins are filled with alluvial and colluvial materials, primarily gravel, sands and clays to depths of over 1,000 feet. The valley floor was formed by extensive alluvium deposits, which have filled the basin and covered the foreslopes of the hills and mountains. Alluvium in the valley may extend to depths of over 1,000 feet and consists of coarse unconsolidated, unsorted sands, gavels and cobbles. The deep dissection of the mountains and the extent of the alluvial fans suggest that the study area has had a long history of erosion and deposition.

#### 4.5 VEGETATION

The vegetation of Central Maricopa County is characteristic of the sonoran desert. This vegetation occupies the lowest, most arid regions and extends to elevations of 3,000 feet where terrain is gentle and to 4,500 feet on steep slopes. Natural plant life is described to be of three communities: Desert wash or Riparian, Desert outwash plain and Desert upland. The natural vegetation still exists on the perimeters of the urban area, on the steep slopes and mountain tops, and along arroyos, washes and major drainageways. Urban development, irrigated agriculture, and domestic grazing have eliminated or altered much of the natural plant communities that have historically occupied the Phoenix area.

#### 4.6 POPULATION

The population of Maricopa County has grown by approximately 82 percent since the 1970's; from 1,297,000 in 1970 to 2,132,975 in 1990. The population is projected to continue to grow to 2,801,000 by the year 2000 representing a 31 percent increase (Maricopa Association of Governments (MAG) Regional

Development Summary 1989). As shown in Table 4.1, population growth is expected to continue well into the future (MAG Regional Development Summary 1989).

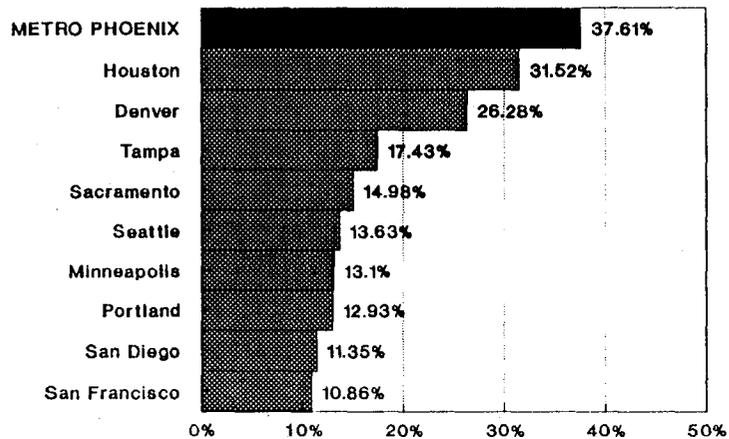
Table 4.1 Maricopa County Population - Actual and Projected

YEAR	POPULATION	% INCREASE
1974	1,297,000	+ 82
1990	2,132,975	+ 31
2000	2,801,000	+ 25
2010	3,490,000	

1. Source: 1989 MAG Regional Development Summary

The Phoenix Metropolitan area has increased in rank among the 35 largest population centers in the United States. As shown in Figure 4.2, the Phoenix metropolitan area has gone from a rank of 33rd in 1970 to 20th in 1988 and is projected to be the 13th largest metropolitan area in the United States by the year 2000. Accompanying this rapid increase in population, has been the rapid urbanization of central Maricopa County.

### Highest Percent Changes in Population of the Thirty Largest CMSAs: 1988-2000



### Highest Absolute Changes in Population of the Thirty Largest CMSAs: 1988-2000

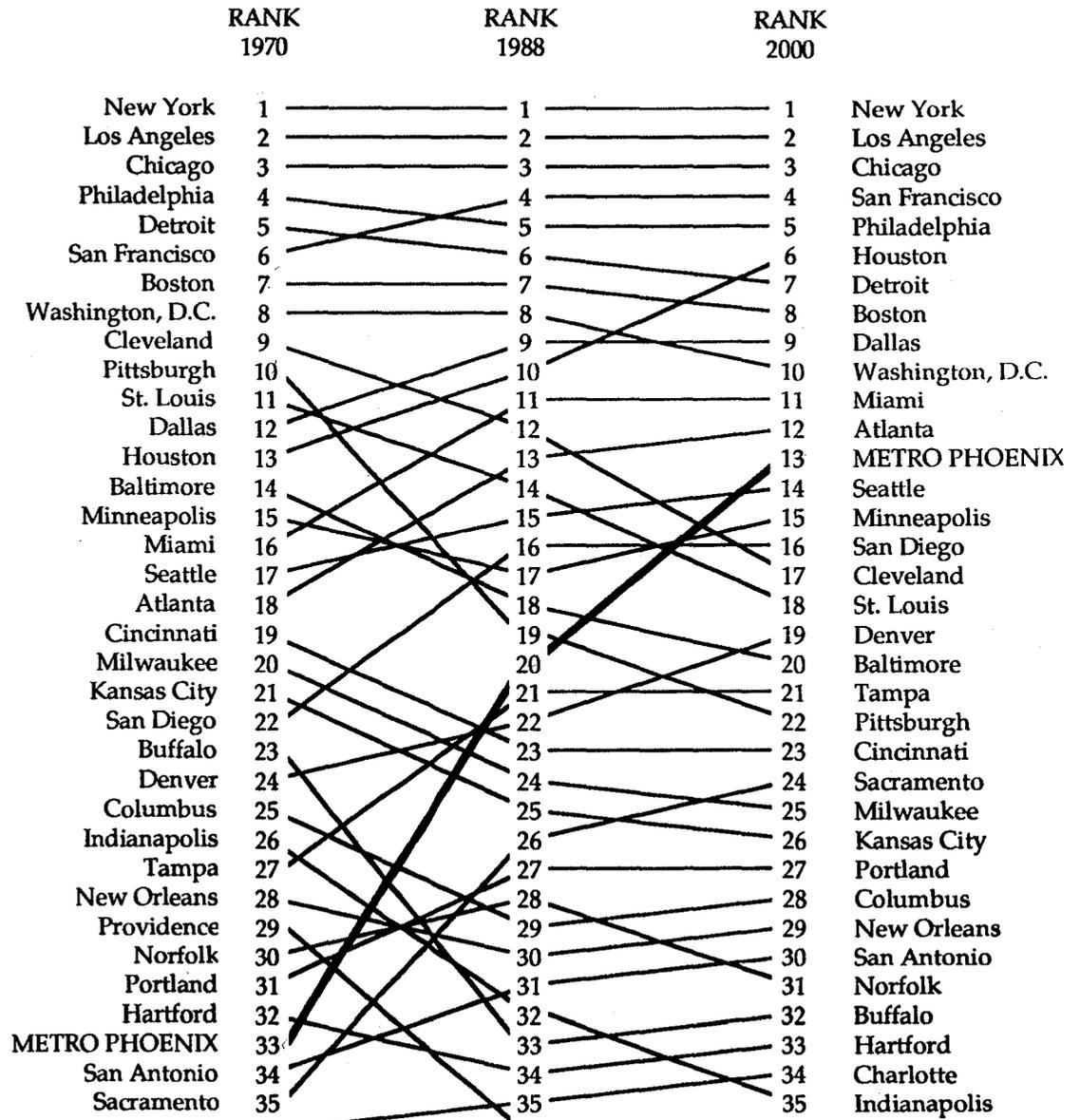
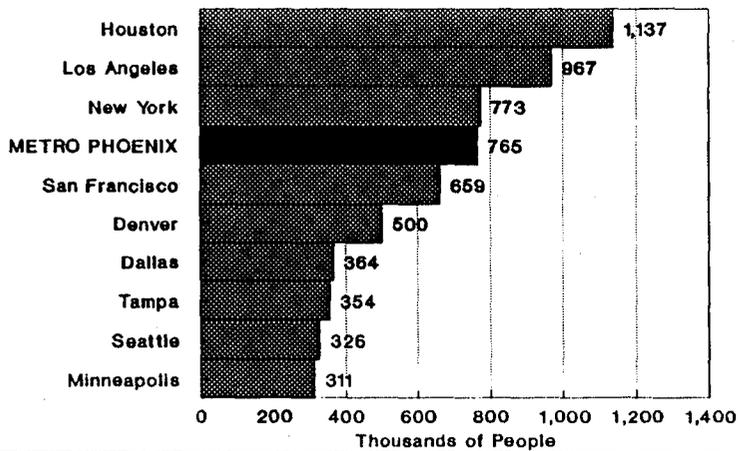


FIGURE 4.2

## CHAPTER 5

### PLAN FORMULATION

#### 5.0 GENERAL

This chapter presents the plan formulation rationale used during this reconnaissance study to develop, evaluate, compare and select the recommended alternative from the array of alternatives which have been identified. The alternatives considered are evaluated with respect to technical criteria such as hydraulics/hydrology/design as well as economics/cost and implementation criteria.

The plan formulation process was accomplished in cooperation with the Flood Control District of Maricopa County (FCDMC). The process consisted of 6 steps to identify problems and opportunities associated with the Federal objective and specific local concerns. This process involved an orderly and systematic approach to making determinations and decisions at each step. The following identifies those steps:

- Step 1: Through scoping, identify problems and opportunities associated with the Federal objective and specific state and local concerns.
- Step 2: Inventory and forecast water and related land resource conditions
- Step 3: Formulation of alternative plans
- Step 4: Analysis and evaluation effects
- Step 5: Comparison of alternative plans
- Step 6: Plan selection

The plan formulation process is a creative and analytical process that is dynamic. Alternative plans were formulated on the basis of available data and information and were revised as new information became available during the course of study.

#### 5.1 PROBLEMS AND OPPORTUNITIES

##### 5.1.1 Scoping Process

During the initial stages of the study, a rigorous scoping effort was conducted to identify the flooding problem areas to be addressed in

this reconnaissance study. The process began with an examination of individual drainages identified in the Flood Control District's Area Drainage Master Study (ADMS) program. This program is designed to assess the flooding problem within a watershed and develop alternatives that are uniquely suited to that watershed or group of watersheds. The product of the ADMS is an Area Drainage Master Plan which provides guidelines for stormwater management as development in each area proceeds.

In cooperation with the FCDMC, the following list of 21 ADMS areas, plus two additional areas not identified specifically as an ADMS area, were initially considered for analysis in this reconnaissance study:

ADMS Areas

Spook Hill  
East Maricopa County  
Glendale-Peoria  
East Fork Cave Creek  
Wittman  
Queen Creek  
Wickenburg  
White Tanks/Agua Fria  
Laveen  
New River  
Adobe Dam  
Cave Creek/Carefree  
Buckeye/Sun Valley  
Arizona Canal Diversion Channel (ACDC)  
Pinnacle Peak  
48th Street Drain  
Mesa-Gilbert-Chandler  
Maryvale  
Rainbow Valley/Waterman  
Gila Bend  
Foothills

Additional Areas

Northeast Valley  
Gila River Channel Clearing (now called Tres Rios)

Using the following three step process, the twenty-three potential study areas were reduced to sixteen:

Step 1 Is the area within Central Maricopa County? The following areas were eliminated, leading to a first-cut listing of 18 areas:

- Wickenburg
- Wittmann
- Buckeye/Sun Valley
- Rainbow Valley/Waterman
- Gila Bend

Step 2 What is the Status of the Area Drainage Master Study (problem area) as reported in the "Comprehensive Flood Control Program Report, 1989"?

The following areas were eliminated:

- 48th St Drain (storm drain analysis)
- Northeast Valley - hydrologic information not currently available

Step 3 The remaining 16 areas were evaluated using site-specific screening criteria to identify those areas that have a potential Federal interest.

A tour by the Branch Chiefs (Corps of Engineers, Los Angeles District) involved a review of the results of the screening process and an on-site visit of the potential study areas. Based upon their recommendations of areas having potential Federal interest, the sixteen areas were further reduced to the following five areas:

1. Glendale/Maryvale
2. White Tanks/Agua Fria
3. Laveen
4. ACDC
5. Tres Rios

Upon recommendation of the Branch Chiefs, a tour of the five remaining areas by Corps of Engineers economists resulted in the elimination of the Glendale/Maryvale area. While it is acknowledged that this area has a ponding problem north and east of Grand Avenue, a potential for a Federal interest could not be identified.

The FCDMC's concern for ACDC relates to residential area ponding upstream of ACDC. The Corps decided that any type of

ponding or backwater problem was not caused by ACDC. It appears that a ponding problem on the north side of ACDC is caused by inadequate subdivision and street drainage. As a result, ACDC was eliminated from further consideration.

The three remaining areas (White Tanks/Agua Fria, Laveen, and Tres Rios) were brought forward in this reconnaissance study and became the focus of public input. During our public involvement efforts a review of the screening process and its results were presented and favorably received. Public comments and suggestions helped identify the water resource problems and opportunities for the remaining three areas, particularly Tres Rios.

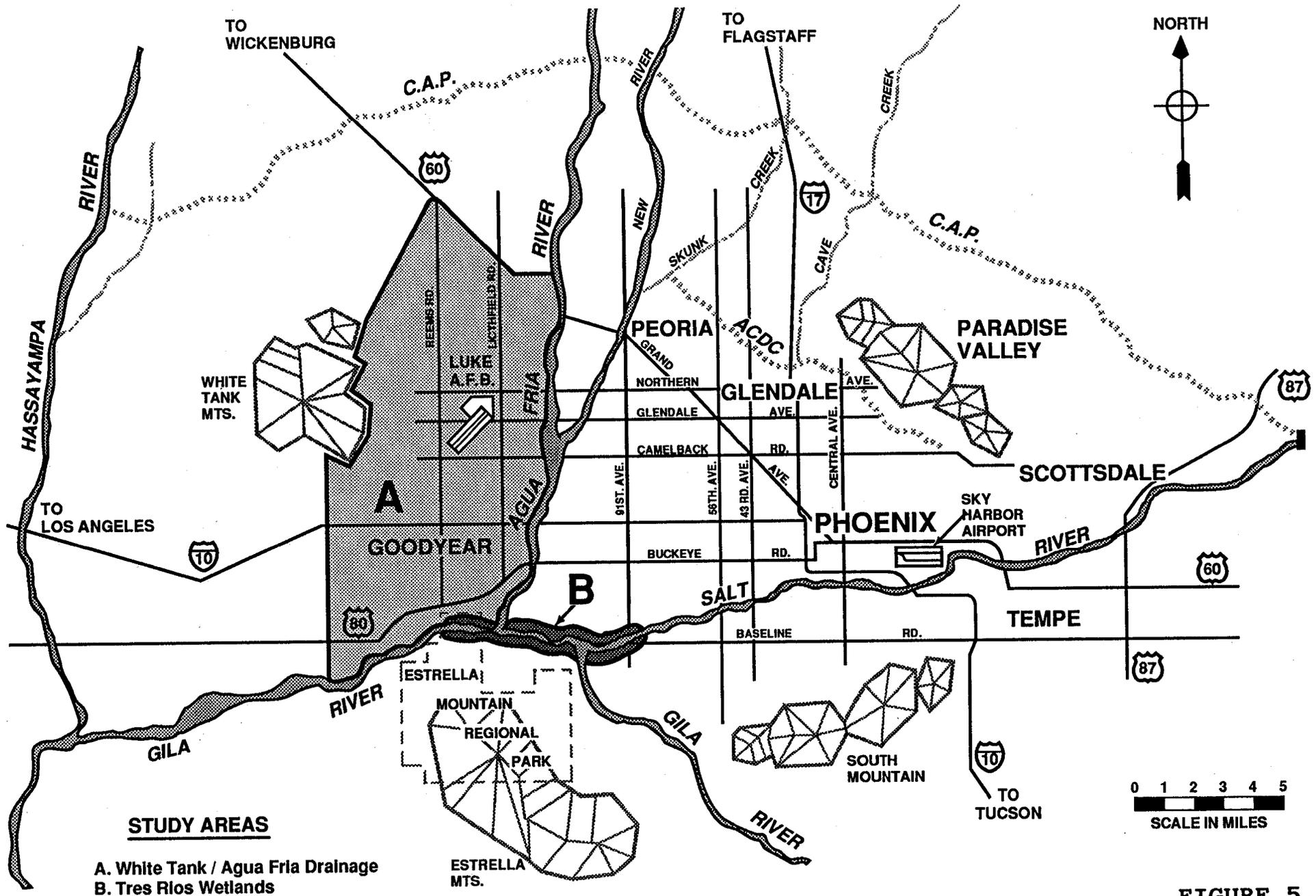
During a briefing on the status of the Central Maricopa Reconnaissance Study with the local sponsor, a discussion of the preliminary findings of the hydraulic analysis, associated 100 year floodplain damages, and implications of low expected annual damages, led to the FCDMC's decision not to participate in a 50-50 cost-shared feasibility study of the Laveen drainage. As a result, the Laveen drainage was eliminated from further analysis in this study.

The remainder of this chapter is divided into two sections; each discussing the flooding problem and water resource opportunities of the White Tanks/Agua Fria drainage and Tres Rios.

## 5.2 WHITE TANKS/AGUA FRIA DRAINAGE AREA

### 5.2.1 Study Area Description

The White Tanks/Agua Fria drainage is located in the northwest area of the Phoenix metropolitan area (see location map, Figure 5.1). The boundaries are McMicken Dam and Grand Ave (U.S. Highway 80) on the north, the Agua Fria River to the east, the Gila River to the south, and the White Tank Mountains to the west. Land use varies widely including several incorporated cities, Luke Air Force Base, rural residential areas with the occurrence of new sub-division developments, and a large agricultural land base.



**STUDY AREAS**  
 A. White Tank / Agua Fria Drainage  
 B. Tres Rios Wetlands

**FIGURE 5.1**

ACOE-MS5B,R1

## 5.2.2 Historical Events

Historical accounts indicate that damaging floods have occurred in the Gila River Basin, dating back to February of 1884 have been recorded as events producing damages. Winter storms may cause flooding in the study area, but most severe floods generally occur during the summer months as a result of local thunderstorms. Severe local storms and floods occurred in 1921, 1935, 1936, 1939, 1943, 1951, 1955, 1956, 1957, 1963, 1964, 1967, 1969, 1970 and 1972. Brief descriptions of the floods of September 4-6, 1970, June 21-22, 1972, and February-March, 1978 (which was most significant to White Tanks/Agua Fria drainage) are described below.

a. Storm and flood of September 4-6, 1970. During the storm of September 4-6, 1970 numerous precipitation stations recorded 5 to 8 inches of rainfall in 24 hours. The Workmen Creek rain gage, about 60 miles northeast of Phoenix, measured 11.4 inches of rainfall which exceeded the previous 24 hour rainfall record for Arizona by more than 5 inches. Record floods occurred in many portions of Arizona, Southwestern Utah, and Southwestern Colorado during September 4-7. Heavy rainfall in the mountainous areas of central Arizona resulted in sudden large flood flows in Tonto, Sycamore, Oak and Beaver Creeks and the East Verde and Hassayampa Rivers. The peak flow at the New River near Rock Springs stream gage was 21,100 cfs, the highest since records began in 1960. The Hassayampa River at Box Dam site near Wickenburg had a peak of 58,000 cfs, which is more than twice the previous known maximum of 27,000 cfs which occurred in both 1927 and 1951.

b. Storm and Flood of June 21-22, 1972. The heavy thunderstorm which hit northeastern Phoenix, Arizona on the morning of June 22, 1972, was part of a series of moderate-to-heavy early summer storms which affected the entire southwest during the period of June 20-23, 1972. Most of the storms rainfall in the Phoenix areas occur during the periods 0600 - 1000, on June 22, 1972, and many of the stations observed their greatest intensities during a 1 1/2 to 2 hour period. Bucket survey amounts of 4.87 inches at 24th Street and Indianola Avenue and 4.8 inches at 28th Street and Indian School road were confirmed by the National Weather Service. The maximum recording gage intensity measured in this storm was 3.85 inches in 1 hour and 20 minutes at 18th Street and Turner Avenue. The storm in Phoenix was highly localized. Heavy runoff from the south slopes of the Phoenix Mountains occurred as a result of the intense rainfall of June 22. In Paradise Valley and on the southwest slopes of the McDowell mountains, large areas were inundated by sheet flow. Flooding occurred along Indian Bend Wash from Paradise Valley through Scottsdale and Tempe to the Salt River. A peak discharge of 20,000 cfs was measured at Indian Bend road in Indian Bend Wash. Flooding occurred upstream of Arizona Canal as floodwater ponds behind the canal

levees. Much of the damage downstream of Arizona Canal resulted from breaks in the canal as overtopping occurred.

c. Storm and Flood of February-March 1978. The major amount of rainfall occurred in the north and east of metropolitan Phoenix. Rain which began in the northwestern portion of the state on February 27, fell intermittently in the following days with the largest amounts during the periods of March 1-2. A secondary storm system passed through the area on March 4-5, but the amounts were much less than the earlier storm period. The storm system of March 1-2 was critical in the region northwest of Phoenix. During this period, heavy rains were falling in the drainage areas contributing to the Trilby Wash Basin which is formed by the McMicken Dam. At 0130 hours on March 2, the Flood Control District of Maricopa County reported approximately one foot of water was passing through the emergency outlet. The report was not specific as to which of the two emergency outlet notches it was referring. Flood waters passing through the northernmost outlet (110 foot notch) overtopped Beardsley Canal, with some of the flow being carried away by the canal and the remaining flow going into the dam outlet works channel. Flows passing through the southern emergency outlet (700 foot notch) overtopped Beardsley Canal and proceeded downslope across agricultural fields in the form of sheetflow. When encountering an obstacle, such as a road embankment or irrigation canal lateral, water ponded until sufficient volume accumulated to overtop or breach the obstacle. Flow from the 700 foot notch could be easily discerned for about 3 miles downslope of the dam, and possibly extended for 6 to 7 miles.

The McMicken Dam embankment has been repaired by the Flood Control District of Maricopa County, and the emergency notches through which flood waters passed in 1978 no longer exist. This flood was useful, however, in understanding the shallow flow characteristics in this agricultural area.

### 5.2.3 Present Conditions

Flooding events in the White Tanks/Agua Fria drainage area have typically been the product of heavy localized thunderstorms. These thunderstorms are short-duration, high-intensity events occurring in the mountainous or alluvial fan regions of the watershed.

Flooding damages have occurred at Luke Air Force Base. The Air Force Base is located in the northwest valley, approximately nine miles west of Glendale, Arizona. The Base is bounded on the north by

Northern Avenue, on the south by Bethany Home Road, on the east by Dysart Road, and on the west by Sarival Avenue. Luke AFB contains a large number of industrial, office buildings, as well as dormitories, cafeterias and other miscellaneous structures. Since Luke is the largest jet fighter training Base in the world, a large number of high tech training facilities are located on the Base; many of which are situated in the floodplain. Also included in the floodplain, are commercial establishments, a hospital, Base housing and parking ramps for F-15 and F-16 aircraft.

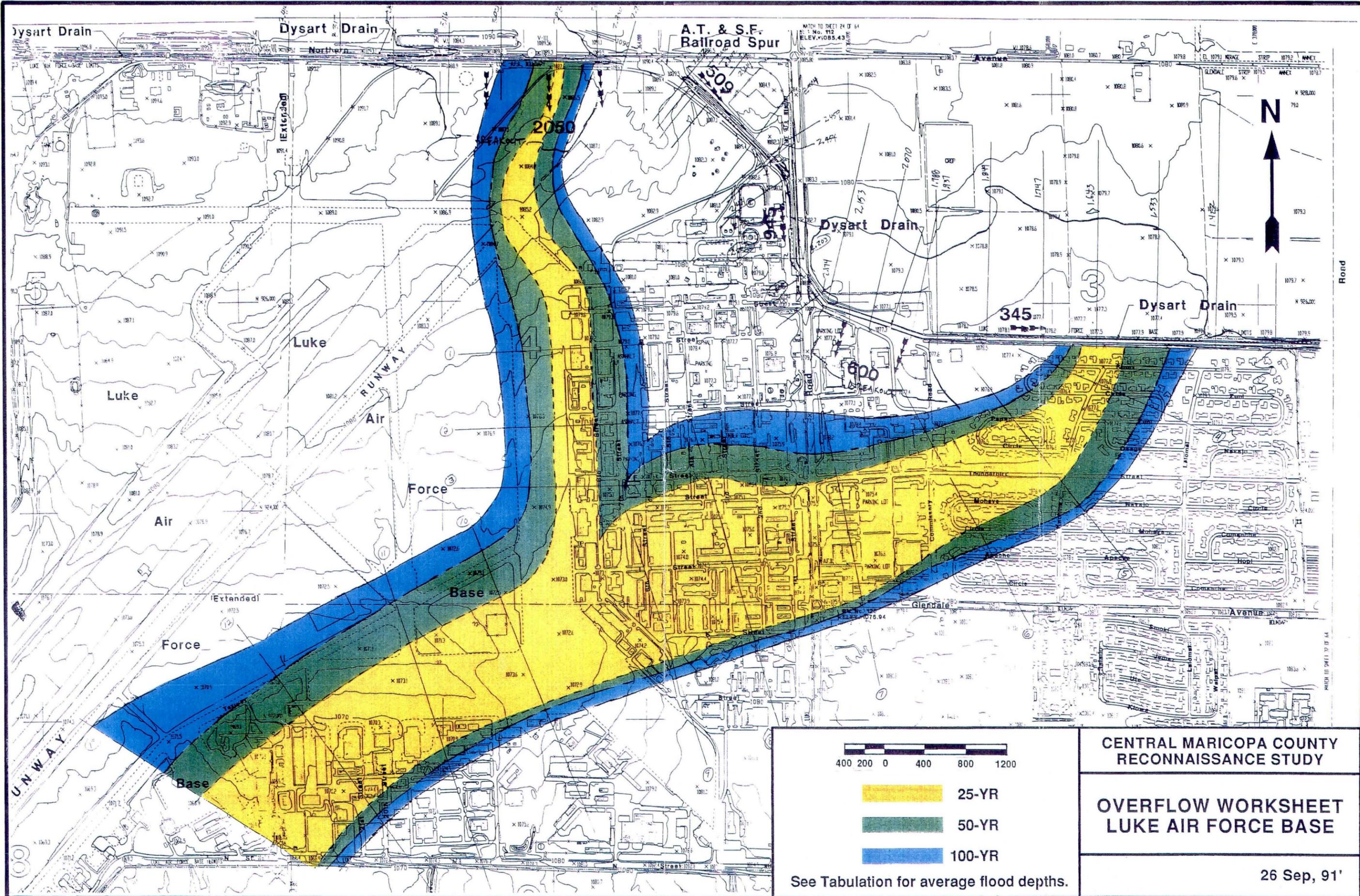
The flooding problem associated with the White Tanks/Agua Fria drainage is that sheet flow collects in the Dysart drain which is located along the northern border of Luke Air Force Base. Due to the limited channel capacities of the drain, breakouts of flow occur. The western breakout occurs in approximately the eighteen-year event with flows of about 400 cubic feet per second (cfs), while the eastern breakout occurs in approximately the nine-year event with flows as low as 300 cfs. Flows from the western breakout flow south, while flows from the eastern breakout flow southwest until the two flows combine in approximately in the center of the Base. Average flood depths range from .5 to 1.8 feet in the 100-year event which approximates flows of 1800 cfs.

A major portion of flood damages in this drainage occur at Luke Air Force Base. With respect to Base damages, Figure 5.2 displays the overflows associated the 25, 50, and 100-year flood events. As these flows merge on the Base and flow south into Bullard Wash approximately 1000 acres of the City of Goodyear is impacted. At present, the land use of Bullard Wash is mostly in agricultural. Erosion of these lands results during major storm events. As the City of Goodyear continues to develop in this area, flood protection will be a necessary component of future development.

#### 5.2.4 Without Project Conditions

As residential and commercial development continues in the study area, the threat of flooding and need for precautionary measures will increase. In absence of measures taken to alleviate the flooding problem along the Dysart Drain, significant damages are expected to occur at Luke Air Force Base during major storms and in particular the 100-year event. During such events operations associated with the Base's mission are seriously impacted.

An extensive development, Pebble Creek Golf Resort and residential development, has been planned immediately downstream of the Air Force



- 25-YR
- 50-YR
- 100-YR

See Tabulation for average flood depths.

**CENTRAL MARICOPA COUNTY  
RECONNAISSANCE STUDY**

**OVERFLOW WORKSHEET  
LUKE AIR FORCE BASE**

26 Sep, 91'

Base, through which Bullard Wash is located. Without flood protection to the air base and in Bullard Wash, development costs and land utilization in the City of Goodyear will be less than optimal.

#### 5.2.5 Problems and Opportunities

During the plan formulation process several flood control measures have been identified. The following is a list of measures that were considered as a means of achieving the flood control opportunities within the study area:

- Channel improvements to increase channel capacities and reduce flood damages caused by breakouts through certain reaches.
- Construction of a new channel upstream of the existing channel to reduce flows in the existing channel.
- A detention basin used to detain a portion of the flows entering the channel from the watershed.

#### 5.2.6 Planning Objectives and Constraints

The primary objective of Federal water and related land resources project planning is to contribute to National Economic Development (NED) in a manner consistent with protection of the Nation's environment, pursuant to national environmental statutes, applicable Executive Orders, and other Federal planning requirements.

##### General Objectives of The White Tanks/Agua Fria Drainage:

- Reduce flood related damages and costs to residential, commercial and industrial property, community infrastructure, and transportation corridors within the study area.
- Protect and, as appropriate, improve existing Threatened and Endangered Species habitat where opportunities exist to support the USFWS in their efforts to provide habitat.
- Preserve existing historical, cultural, and archaeological resources within the area of potential effect.
- Recognize and consider all practical means and measures to preserve the significant values of the flood plain in accordance with Executive Order 11988.

- Improve, where feasible, water quality and water quantity within the study area.
- Involve the public to ensure that proposed alternatives are responsive to the needs and concerns of the public.

#### Project Constraints:

No project constraints have been identified. Fish and wildlife habitat, recreation and other environmental resources are not associated with any issues in this study area.

#### 5.2.7 Alternatives

Three preliminary alternatives have been formulated to address the flooding problem in the White Tanks/Agua Fria Drainage area. Two alternatives involve channel solutions and one alternative utilized a detention basin solution. These alternatives are described as follows:

##### Alternative A. Improve Existing Channel.

This alternative includes improving the existing Dysart drain. The concrete channel trapezoidal in cross section follows the existing Dysart drain alignment and is entirely entrenched to prevent interior drainage problems from occurring. The invert slope generally follows the ground contours. The channel is 3.95 miles in length. Four bridges (AT & SF Railroad, Litchfield Road, Dysart Road and El Mirage Road) have to be lengthened and improved. The design also includes a grouted rock outlet structure at the Agua Fria River and an inlet structure at the upstream end of the project. The design is based on calculations at the outlet and normal depth calculations for the channel.

Additional hydraulic features of this design are as follows: The flow is subcritical for the channel and supercritical near the outlet; Mannings coefficient of roughness is 0.016; the channel side slopes are 2:1 horizontal to vertical; the invert width varies between 15 and 25 feet; the freeboard is 2.5 feet; the design flood is 1250 cfs between the railroad and to a point downstream of Litchfield Road and 1850 cfs for the remaining distance to the Agua Fria River.

##### Alternative B. New Channel.

A channel located north of Luke Air Force base would be designed to provide 100-year level of protection. This concrete channel of trapezoidal cross section is entirely entrenched to prevent interior

drainage problems from occurring. The invert slope generally follows the ground contours. It is approximately 3.8 miles long, extending easterly from the northwest corner of Luke Air Force Base to the Agua Fria River. The design also includes an inlet structure at the upstream end of the project, a grouted rock outlet structure at the Agua Fria River and four new bridges (AT & SF railroad, Litchfield Road, Dysart Road and El Mirage Road). The design is based on normal depth calculations for most of the channel and calculations for the outlets.

Additional hydraulic features are as follows: The flow is subcritical for most of the channel and supercritical near the outlet; Mannings coefficient of roughness is 0.016; the channel side slopes are 2:1 horizontal to vertical; the invert width varies between 10 feet, and 15 feet; the freeboard is 2.5 feet; the design flood is 1250 cfs from the upstream end (northwest corner of Luke Air Force base) to the AT & SF railroad, and 1850 cfs for the remaining reach to the Agua Fria River.

#### Alternative C. Detention Basins.

A detention basin alternative providing 100-year level of protection was considered. Proposed locations for the basins are just north of Luke Air Force base. These basins are designed to contain the 100-year flood discharge. Basin drains will be designed to collectively total 300 cfs (the existing capacity of Dysart Drain).

#### 5.2.8 Alternatives Analysis and Evaluation

Only Alternatives A and B were fully analyzed and evaluated. Alternative C was considered and later eliminated as it appeared that real estate costs, outlet works, spillway cost, etc., would cause the benefit/cost ratio to be less attractive than the channel alternatives.

The expected annual benefits resulting from Alternatives A and B are equal to the total damages reduced (\$1,924,000). The expected annual costs total \$968,000 for Alternative A and \$972,000 for Alternative B. Thus the net benefits for Alternative A total \$952,000, and the net benefits for Alternative B total \$956,000. The resulting benefit/cost ratios for each alternative equal 1.99 and 1.98, respectively. Both alternatives are economically justified.

#### 5.2.9 Selected Alternative

Two economically justified alternatives have been identified. However, in view of the fact that a significant share of flood damages

occur to the Federal property, in this case Luke Air Force Base, the local sponsor (Flood Control District of Maricopa County), chose not to participate in cost-sharing with the Corps in the Feasibility study. Therefore, in absence of a willing local sponsor, this aspect of the Central Maricopa County Reconnaissance Study will conclude at the reconnaissance phase. It is recommended that the opportunity for flood protection at Luke Air Force Base be presented to the U.S. Air Force under the "work for others" program.

### 5.3 TRES RIOS STUDY AREA

#### 5.3.1 Study Area Description

The study area is located at the confluence of the Salt, Gila and Agua Fria Rivers, immediately west of the City of Phoenix, Arizona (see location map, Figure 5.1, page 17). The upstream boundary of the study area is located at 91<sup>st</sup> Avenue where the City of Phoenix operates a wastewater treatment plant, and extends west for approximately seven miles through the confluence of both the Gila and Agua Fria Rivers, terminating at the Buckeye Irrigation Company diversion canal (Bullard Avenue). For the purposes of this reconnaissance study, the study area is being identified as "Tres Rios" which is Spanish for three rivers.

Elevations at the confluence of the Agua Fria and the Gila Rivers are approximately 990 feet above sea level. The South Mountains and Sierra Estrella Mountains, lie south and southwest of the study area, respectively.

#### 5.3.2 Historical Flood Damages

As reported by the FCDMC, the study area has been subjected to four floods in excess of 100,000 CFS since February, 1978. Two have occurred in 1978; one in 1980; and one in 1983. Subsequent to the floods of 1978 and 1980, the FCDMC conducted an analysis of the flooding problems. While residents suffered costly damages three times between March 1978 and February 1980, traditional 100 year protection was not economically feasible at that time.

#### 5.3.3 Present Conditions

The present or existing conditions at Tres Rios may be best described as an area comprising a multiplicity of resource issues. During the course of our public involvement effort, the Corps identified a

variety of water resource issues that come to bear at Tres Rios involving flood control, water quality, wildlife habitat (including an Endangered Species habitat), and recreation. A discussion of these resource issues is included in the subsections that follow.

a. Flood Control The FCDMC developed two flood control projects that are currently in place. One was a 1.25 mile long bank stabilization and levee project designed to protect the Holly Acres subdivision from flows up to 115,000 cfs plus three feet of freeboard. The levee was designed to provide 100 year protection under the assumption that Cliff Dam, a component of a regional flood control management plan (Central Arizona Water Control Study), would be in place. However, the Cliff Dam project was not implemented and according to FEMA regulations the levee does not offer 100 year protection. The second and more ambitious project involved clearing a 1,000 foot wide corridor free of phreatophytes (primarily salt cedar) from 91st Avenue, through the study area, and continuing downstream to Gillespie Dam for a total distance of approximately 36 miles. This project was designed to allow floodwater to flow unimpeded through a watercourse previously occupied by dense salt cedar stands. Although a wider clearing (e.g., 2000 feet) was desirable from a flood control standpoint, the environmental impacts prohibited this alternative from being fully developed and analyzed. The final 1,000 foot wide alignment avoided stands of cottonwoods and willows and included the natural low flow channel in many locations.

A second area concerning flood control pertains to releases of water stored in upstream dams built on the Salt River by the Bureau of Reclamation and operated by Salt River Project. While storage releases during periods of potential flooding are necessary from a dam safety standpoint, these releases could result in a variety of downstream impacts on the Salt River. During periods of serious flood potential, large volumes of water are released from upstream dams and may cause flood damage in the Phoenix metropolitan area. At the same time, lower volume releases, which may not result in economic losses to public or private property, have an impact on riparian habitat and in particular that of the Yuma Clapper Rail, a Federally listed Threatened and Endangered Species (T&E). Cattail/bulrush marsh communities provide habitat for the Yuma Clapper Rail. As flows reach 10,000 - 15,000 cfs, nesting and cover habitat of the Yuma Clapper Rail is overtopped with high water. The duration and extent to which habitat is unavailable to the species could have a serious impact on its recovery in the study area. Given the scouring effects of higher flows, the cattail/bulrush marsh communities, if unprotected, are virtually destroyed as upstream dam releases approach 30,000 - 50,000 cfs.

b. Water Quality The concern for wildlife habitat in the study area is further compounded by a water quality issue involving the City of Phoenix, the U.S. Environmental Protection Agency (EPA), the Arizona Department of Environmental Quality (ADEQ), the Arizona Game and Fish Department, and environmental interests. A water source supporting riparian habitat in the study area is secondary effluent from the 91st Avenue wastewater treatment plant operated by the City of Phoenix in conjunction with the Sub-Regional Operating Group (SROG) cities. Current plans may involve the elimination of this water source.

Proposed Surface Water Quality Standards (SWQS) and National Pollutant Discharge Elimination System standards administered by ADEQ and EPA, respectively, have prompted the City of Phoenix to conduct an analysis of the costs of upgrading the facility to meet these new discharge requirements. Current estimates include plant upgrades amounting to \$350 million. The SROG cities evaluated the costs of moving forward with a plan for total reuse of the effluent through an aquifer recharge program rather than bearing the high costs of upgrading the existing facility. The estimated cost of a groundwater recharge project is \$150 million. While this project would provide a future water supply, discharges into the Salt River would be eliminated. A discontinuation of wastewater discharge will impact riparian habitat, including that of the Yuma Clapper Rail. The manner in which the water quality issue is resolved will have a direct bearing on wildlife issues at Tres Rios.

Current capacity of the treatment plant is 153 Million Gallons per Day (MGD). Contractual agreements for this effluent require the City to provide a maximum of approximately 123 MGD to the Palo Verde Nuclear Generating Power Plant (actual use rates range between 0 MGD on a frequent basis to a peak of 90 MGD which is very rare). A second contract is with the Buckeye Irrigation Company which uses approximately 31.5 MGD. These flows are deliverable through an existing pipeline. At present, only Palo Verde Nuclear Plant flows utilize the pipeline; the Buckeye Irrigation Company currently takes its water from the natural channel through a diversion structure on the Gila River.

c. Wildlife Habitat The study area provides wetland and riparian habitat for numerous species of fish and wildlife, including waterfowl and Federal and State listed T&E Species. Both wetland and riparian habitats are disappearing at an alarming rate in Arizona and the

Southwest. These habitats are used by a high percentage of Federal and state T&E species. The Yuma Clapper Rail (Rallus longirostris yumanensis) a Federally listed endangered species is found in the study area. A survey conducted in May 1991 found three pair of Yuma Clapper Rail nesting in the study area. According to the USFWS, if the proper habitat was provided and managed for the Yuma Clapper Rail, a significant increase in population would be expected in this area. The razorback sucker (Xyrauchen texanus), also an endangered species, was reintroduced in 1982 and could possibly still inhabit the area.

The study area has undergone change in the last 10 to 15 years. A 1,000 foot wide channel clearing passes through the study area. While vegetation patterns have been modified by the clearing, habitat impacts have been mitigated. The Arizona Department of Game and Fish owns or manages several hundred acres in the area as this area is considered important for fish and wildlife resources, including T&E species.

How the issue of water quality and possible elimination of wastewater discharge into the Salt River is resolved could have a serious impact on riparian habitat including that of the Yuma Clapper Rail. While phreatophytes are expected to continue to occupy the channel due to the high groundwater table (Graf, 1992) in the study area, the cattail/bulrush communities which support habitat for the Yuma Clapper Rail are more dependent upon surface flows. While other, less regular flows occur in the channel, such as upstream dam releases and agricultural tailwater runoff, it appears that effluent from 91st Avenue plant plays a major role in supporting riparian habitat, especially the cattail/bulrush marsh communities which are directly supported by the continuous surface flows.

A second concern pertains to releases of water stored in upstream dams and their impact on riparian habitat and in particular that of the Yuma Clapper Rail. As cattail/bulrush marsh communities are inundated by high waters, feeding and nesting habitat of the Clapper Rail becomes unavailable, causing stress on this endangered species. It appears that this habitat may be completely washed out when upstream dam releases approach 30,000 - 50,000 cfs. Salt River Project administrators report the frequency of releases of this magnitude have occurred 26 times since 1916 with an average duration of 2 to 4 days per release. Protection of this habitat from storage releases from Federally constructed dams, to provide for the flood control component at these facilities, would assist the U.S. Fish and Wildlife Service in their efforts to provide for a recovered population of the Yuma Clapper Rail.

d. Recreation Approximately 20 percent of the Tres Rios study area, on its western border, lies within Estrella Mountain Regional Park. The park is owned and managed by Maricopa County Parks and Recreation Department. The rugged and scenic Sierra Estrella mountains are the most dominant feature of Estrella Mountain Regional Park. The terrain of these mountains is characterized by very steep slopes, numerous rock out-crops, shallow soils and sparse desert vegetation.

The County has developed a master plan for the 19,200 acre park, located approximately 20 miles southwest of downtown Phoenix. The master plan envisions the preservation of scenic desert wilderness areas while incorporating sensitive development of recreational facilities and activities. The Plan accommodates the expected annual demand of 1,000,000 visitors while insuring that the existing sonoran desert environment remains in its pristine condition. In fact, 90 percent of the park will remain essentially untouched. The remaining 10 percent will be sensitively utilized for educational, camping, picnicking, and sporting activities.

While water is a highly attractive feature for recreationists, park trails and facilities have presently been planned away from the Gila River. Once the County completes its Sun Circle Trail System through this reach of the Gila and Salt Rivers, recreation use patterns are expected to expand throughout the study area. The Sun Circle Trail System, a component of the National Recreation Trail System, comprises a 110 mile loop encompassing the Phoenix metropolitan area. The trail offers a unique opportunity for hiking, horseback riding and bicycling throughout the urban area. The 110 mile loop and 580 miles of secondary trails are designed to link valley urban areas with county regional parks. Approximately 70 percent of the trail system is in place.

#### 5.3.4 Without Project Conditions

a. Flood Control While the 1.25 mile levee project provides protection to the Holly Acres subdivision, other less densely populated subdivisions and industrial/commercial lands will continue to be susceptible to flood damages. As urban sprawl and commercial/industrial development continues west from the Phoenix metropolitan area, the threat of flood damages through the study area can be expected to increase in the future. In view of Arizona Department of Transportation plans to complete the outer-loop (South Mountain Freeway) approximately 1.5 miles east of the study area, future development is expected to occur along the freeway and to the west. In addition, the recreation complex

that is being developed at Estrella Mountain Regional Park, will continue to attract off-site commercial and residential development in the area.

b. Water Quality As the City of Phoenix moves forward with its aquifer recharge plan, secondary effluent flows into the Salt River would be discontinued. From a technical standpoint, water quality standards pertaining to the 91st Avenue effluent have been satisfied as the zero-discharge scenario becomes reality.

c. Threatened and Endangered Species In the absence of a continuous water source in the river channel, riparian habitat within the sonoran desert ecosystem is expected to be severely impacted, including that of the Yuma Clapper Rail. The USFWS has taken the position that a loss of these flows would result in the loss of most of the wetland and riparian habitats and the fish and wildlife populations they support.

d. Recreation. Recreation activities within the study area are limited. The Sun Circle Trail would continue as planned through the area, however, the diversity of recreational settings along the trail would be minimal.

#### 5.3.5 Problems and Opportunities

Through public involvement, a variety of water resource problems and opportunities were identified for Tres Rios. Local, State and Federal agencies as well as various interest groups had taken opposing positions on the issue of water quality and related standards for effluent discharge compliance. Associated with the issue of water quality standards is the concern for the cost of upgrading sewage treatment facilities for compliance purposes, water conservation, and wildlife habitat. The City of Phoenix has taken the position to move forward with the aquifer recharge program and thus eliminate its effluent discharge into the Salt River. Impacts to existing riparian habitat and wildlife, including the Yuma Clapper Rail, are expected to be serious.

It is in this setting that the Corps and the FCDMC began an evaluation of the flood control opportunities along the Salt and Gila Rivers. Through our scoping effort, it became apparent that an analysis of flood control opportunities and environmental impacts would become superimposed on a pre-existing water resources controversy. Recognizing the interrelatedness of flood control, water quality and wildlife issues, the Corps facilitated a dialogue among the various agencies and interest groups involved in the debate.

In coordination with FCDMC, the local sponsor, and in meetings with local State and Federal agencies and special interests, an opportunity was identified for a constructed wetlands in the area of the 91st Avenue Wastewater Treatment Plant and extending downstream through the confluence of the Salt, Gila and Agua Fria Rivers to the site of the Buckeye Irrigation District diversion (approximately seven miles). A constructed wetlands at Tres Rios would provide the following water resource opportunities: flood control, habitat diversity, Threatened and Endangered Species habitat (Yuma Clapper Rail), water quality and recreation.

In addition to the opportunity for a multi-purpose wetlands, other flood control opportunities have been identified including: an evaluation of various phreatophyte clearing alternatives, and consideration of an extension of the existing levee protecting Holly Acres for the length of the study area.

#### 5.3.6 Planning Objectives and Constraints

The primary objective of a Federal water and related land resources project planning is to contribute to National Economic Development (NED) in a manner consistent with protection of the Nation's environment, pursuant to national environmental statutes, applicable Executive Orders, and other Federal planning requirements.

##### General Objectives of the study of Tres Rios:

- Reduce flood related damages and costs to residential, commercial and industrial property, community infrastructure, and transportation corridors along the Salt and Gila Rivers.
- Protect and, as appropriate, improve existing Threatened and Endangered Species habitat where opportunities exist to support the USFWS in their efforts to provide habitat.
- Improve, where feasible, the water quality within the study area.
- Preserve existing historical, cultural, and archaeological resources within the area of potential effect.
- Recognize and consider all practical means and measures to preserve the significant values of the flood plain in accordance with Executive Order 11988.

- Involve the public to ensure that proposed alternatives are responsive to the needs and concerns of the public.

#### Project Constraints:

- Project constraints for the Tres Rios study area include the avoidance of negative impacts to T&E species habitat.

#### 5.3.7 Alternatives

In response to public input and coordination with Local, State and Federal agencies, six solutions have been identified as alternatives to the without project condition. Three of the alternatives involve traditional analysis of flood control opportunities and assume that discharges from the 91st Avenue plant have been eliminated. Alternatives five, six and seven examine a multi-purpose wetlands opportunity in conjunction with flood control measures and assume that the technical and legal requirements for effluent discharge into the Salt River have been effectively addressed.

The discussion below includes a brief description of each alternative. A presentation of the outputs and effects of the alternatives is included in the section that follows (i.e., 5.3.8 Analysis of Alternatives).

#### Alternative 1. No Action -

The No Action Alternative defines the "without project conditions" or the probable future condition of the study area without a project in place. The without project condition provides a baseline datum against which alternative outputs, effects and economic efficiency can be evaluated in relative terms.

The No Action alternative includes no flood control measures outside of maintaining the 1,000 foot clearing and the existing levee at Holly Acres. Thus, the existing level of expected annual damages would remain unchanged. While flood protection is expected to remain at the current level, a loss of existing riparian habitat, including T&E species, will occur as the No Action Alternative does not include provisions to secure continuous surface water flows of effluent discharges from 91st Avenue Wastewater Treatment Plant into the Salt River. In addition, riparian habitat would not be protected from releases from upstream dams which contribute towards washing out Yuma Clapper Rail habitat. No measures to improve habitat diversity in the study area is expected.

Without a continuous water source in the channel, the Sun Circle Trail, a National Recreation Trail planned to go through the study area, will offer a narrower range of recreation experiences in the Salt River channel.

#### Alternative 2. Complete Channel Clearing -

The purpose of this alternative is to maximize hydraulic efficiency by clearing all phreatophytes from the entire channel. The alternative will serve as a benchmark for evaluating tradeoffs between hydraulic efficiency and environmental impacts.

#### Alternative 3. 2000 Foot Clearing -

The purpose of this alternative is to examine the efficiencies of improved flood flow conveyance by expanding the width of the existing 1000 foot alignment by clearing an additional 500 feet on each side. The total cleared width between the banks is 2,000 feet.

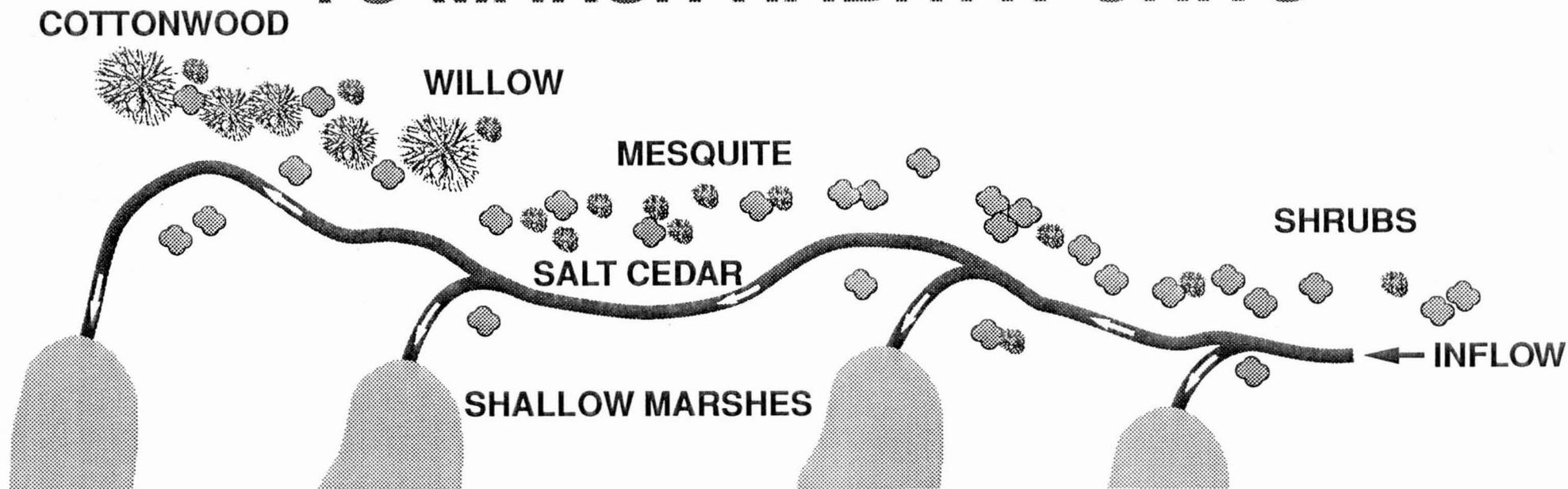
#### Alternative 4. Levee Along North Bank -

This alternative proposes to extend an existing levee protecting the Holly Acres subdivision through the entire length of the study area. The existing levee, approximately 1.25 miles long would be extended on both its upstream and downstream sides for a total of approximately 5.75 miles of additional levee protection along the north bank.

#### Alternative 5. Constructed Wetlands -

The purpose of this alternative is to provide an improvement in flood flow conveyance through the channel and at the same time achieve water quality, wildlife habitat and recreation opportunities via a multi-purpose wetlands. This alternative would maintain the 1000 foot clearing and replace an additional 500 feet of dense salt cedar along the existing alignment with a 300 acre mosaic of shallow and deep water marshes, cattail/bulrush and cottonwood/willow plant communities (see Figures 5.3 through 5.8 for preliminary concept designs and channel cross-section). Only a portion of 91st Avenue Wastewater Treatment Plant effluent (approximately 40,000 acre feet per year) would be treated in this alternative. The City of Phoenix would continue to pursue its plan for groundwater recharge with the balance of its effluent. Habitat diversity would be significantly enhanced over and above the No Action Alternative. Recreation opportunities for Estrella Mountain Regional Park and the Sun Circle Trail would be greatly expanded and would also include an environmental education component.

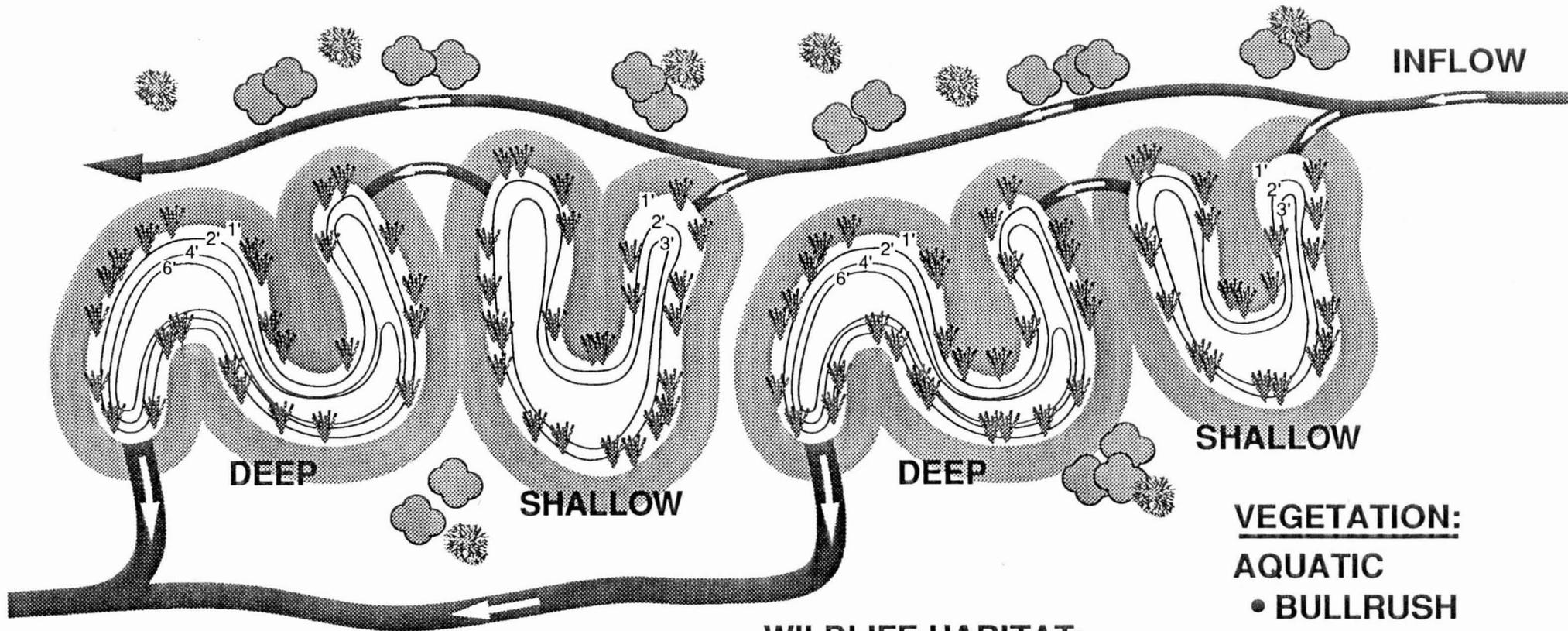
# WATER DELIVERY CHANNEL TO MARSH HABITAT UNITS



## WILDLIFE HABITAT:

- YUMA CLAPPER RAIL
- MIGRATORY BIRDS
- RAPTORS
- QUAIL
- SMALL MAMMALS

# MARSH HABITAT UNITS



OUTFLOW CHANNEL

## FEATURES:

- SHALLOW/DEEP UNITS
- 2 - 10 AC EA.
- 2' - 6' DEPTH

## WILDLIFE HABITAT:

- YUMA CLAPPER RAIL
- WATERFOWL
- OTHER MIGRATORY BIRDS
- SHOREBIRDS
- RAPTORS

## VEGETATION:

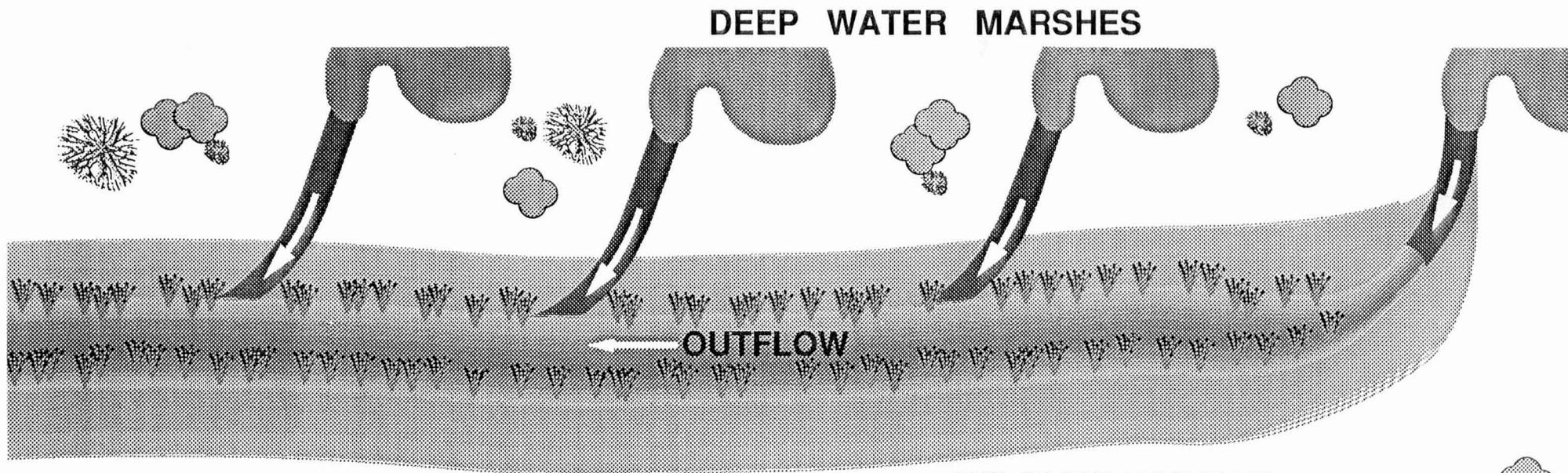
### AQUATIC

- BULLRUSH
- POND WEED

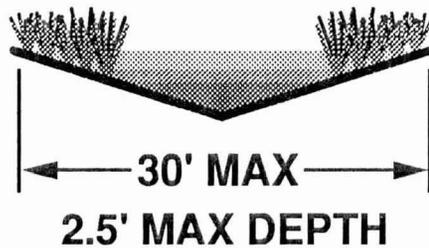
### TERRESTRIAL

- SALT BUSH
- MESQUITE
- HACKBERRY
- GRASSES

# WATER DELIVERY CHANNEL TO DEEP PONDS



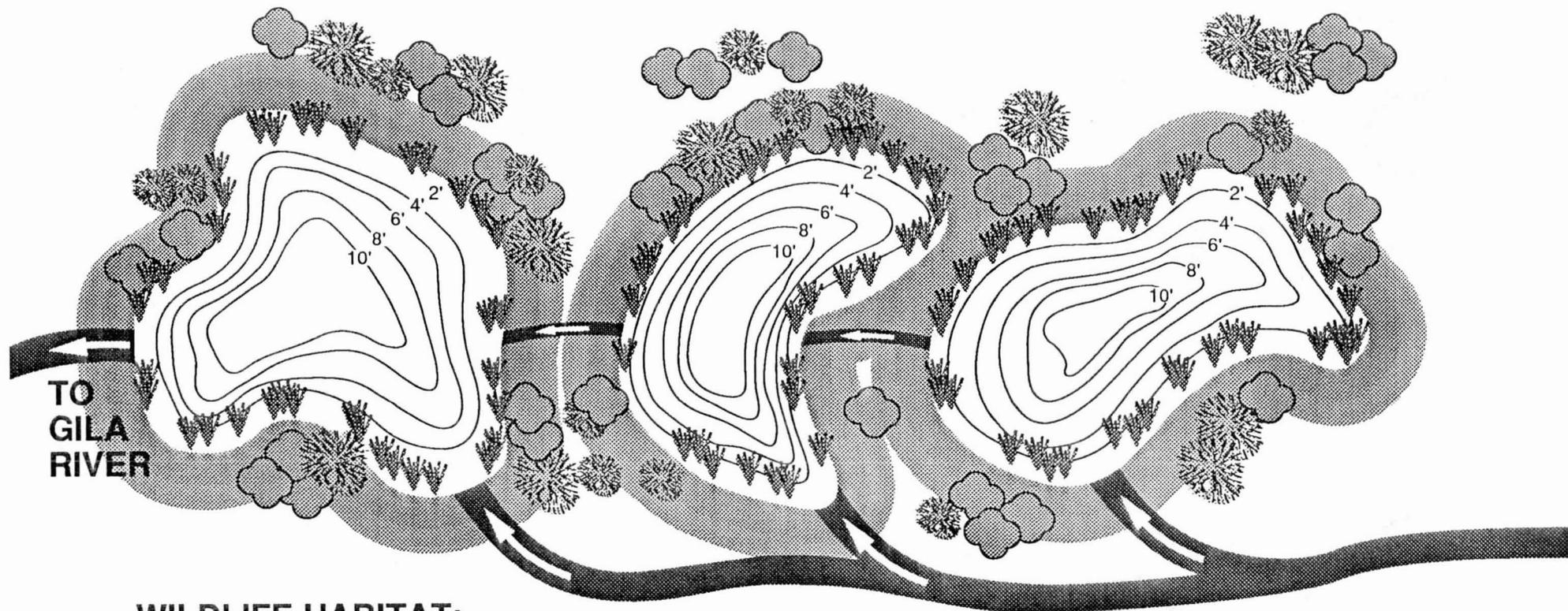
## CROSS SECTION



## WILDLIFE HABITAT:

- YUMA CLAPPER RAIL
- MIGRATORY BIRDS
- RAPTORS
- QUAIL
- SMALL MAMMALS

# DEEP PONDS



## WILDLIFE HABITAT:

- SPORTFISH
  - CHANNEL CATFISH
  - LARGEMOUTH BASS
  - TROUT
- SONGBIRDS

## MARSH OUTFLOW CHANNEL

## VEGETATION:

DIVERSE

## FEATURES:

- 10 AC MINIMUM
- 8' - 10' DEPTH

# WETLANDS/CHANNEL CLEARING ALTERNATIVE

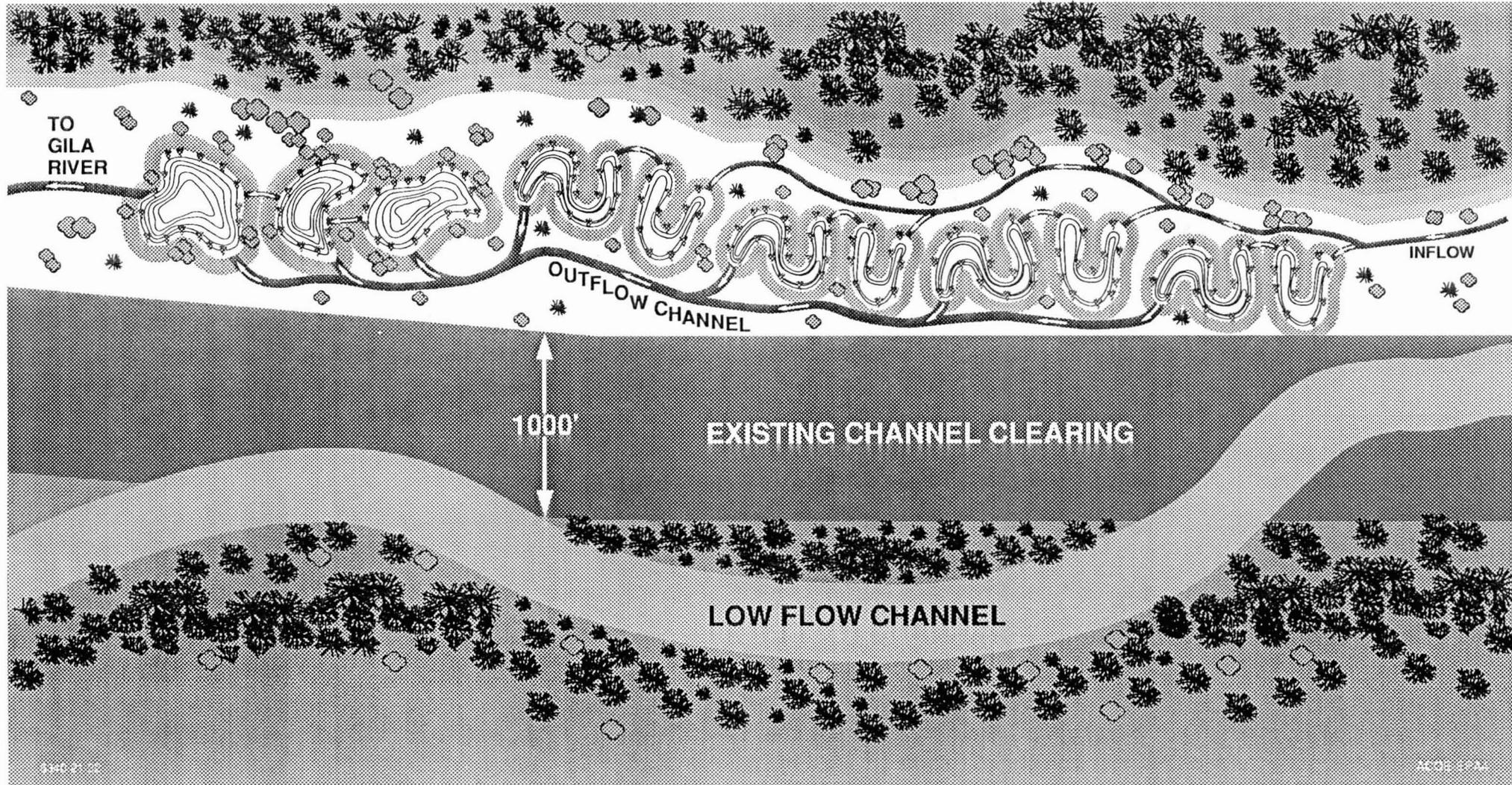
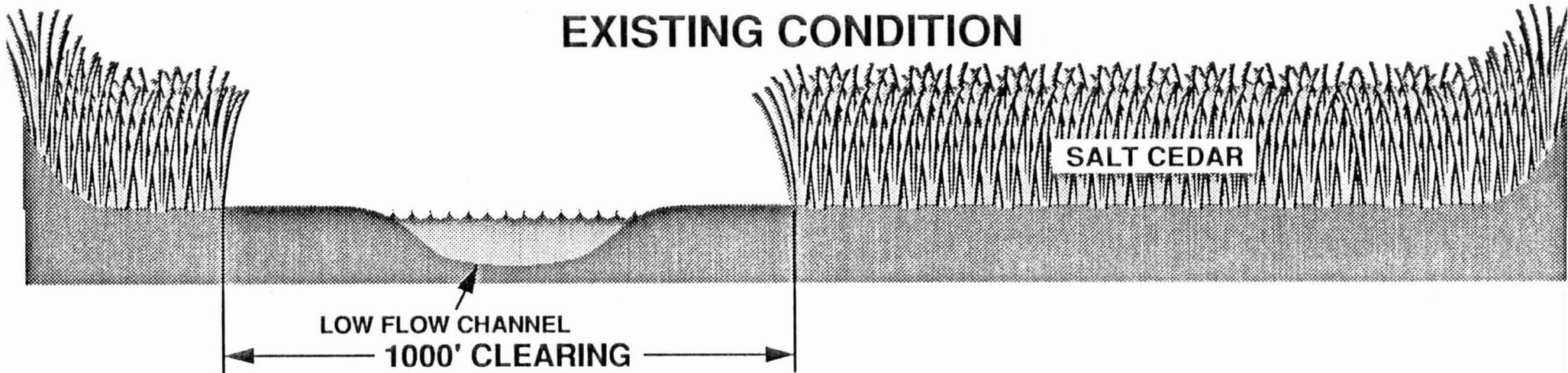


FIGURE 5.7

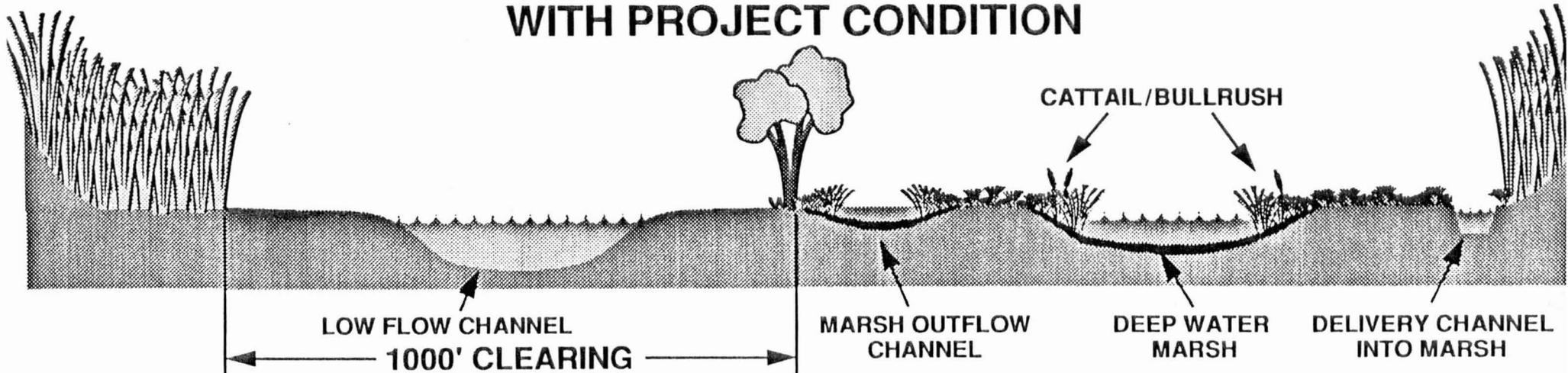
# CHANNEL CROSS SECTION

## WETLANDS/CHANNEL CLEARING ALTERNATIVE

EXISTING CONDITION



WITH PROJECT CONDITION



#### Alternative 6. Wetlands/Levee -

The purpose of this alternative is to achieve the combined benefits of Alternatives 4 and 5. The flood control measures and benefits associated with a levee along the north bank of the channel are incorporated into this alternative. Complete flood protection would be provided to the residential, industrial and agricultural areas in the study area. The environmental benefits of Alternative 5 are not only incorporated into this alternative but are exceeded as the 1,000' clearing through the study area would not be necessary and could therefore be revegetated. A mosaic of plant communities that are complementary to the habitat values provided by the wetlands could be created enhancing habitat diversity.

As in the case with Alternative 5, the wetlands would be treating approximately 40,000 acre feet per year as the City of Phoenix proceeds with its plans for groundwater recharge. Figures 5.9 and 5.10 display conceptual designs of how a levee/wetlands might be arranged in the channel.

#### Alternative 7. Total Treatment Wetlands -

Alternative 7 incorporates a large scale wetlands, capable of polishing the entire effluent from the 91st Avenue Plant while providing flood control and wildlife habitat, and recreation benefits. Approximately 1000 acres wetlands would be used to treat the future capacity of the 91st Avenue Plant's scheduled for 1996 (180 MGD). As part of the wetlands design, a water delivery channel along the channel side of the wetlands will carry secondary effluent from the 91st Avenue Plant to the wetlands units. As it extends the length of the wetlands, it has been determined that the water delivery channel will not only provide flood protection to the wetlands habitat itself, but will also provide an additional benefit of a 25 year level of flood protection to the communities along the north bank of the Salt River. Figures 5.11 and 5.12 display a plan view and cross-section of the wetlands and the water delivery channel as arranged in the river channel.

As cattail/bulrush plant communities comprise a significant portion of the wetlands treatment process, the project would assist the USFWS' their efforts to provide for a recovered population of the Yuma Clapper Rail. Yuma Clapper Rail habitat would be protected from upstream dam releases as the water delivery channel protects the wetlands from flows of up to 100,000 cfs. Habitat diversity would be substantially increased over the without project condition as wetlands habitat would comprise an area of approximately 1000 acres.

# WETLANDS/LEVEE ALTERNATIVE

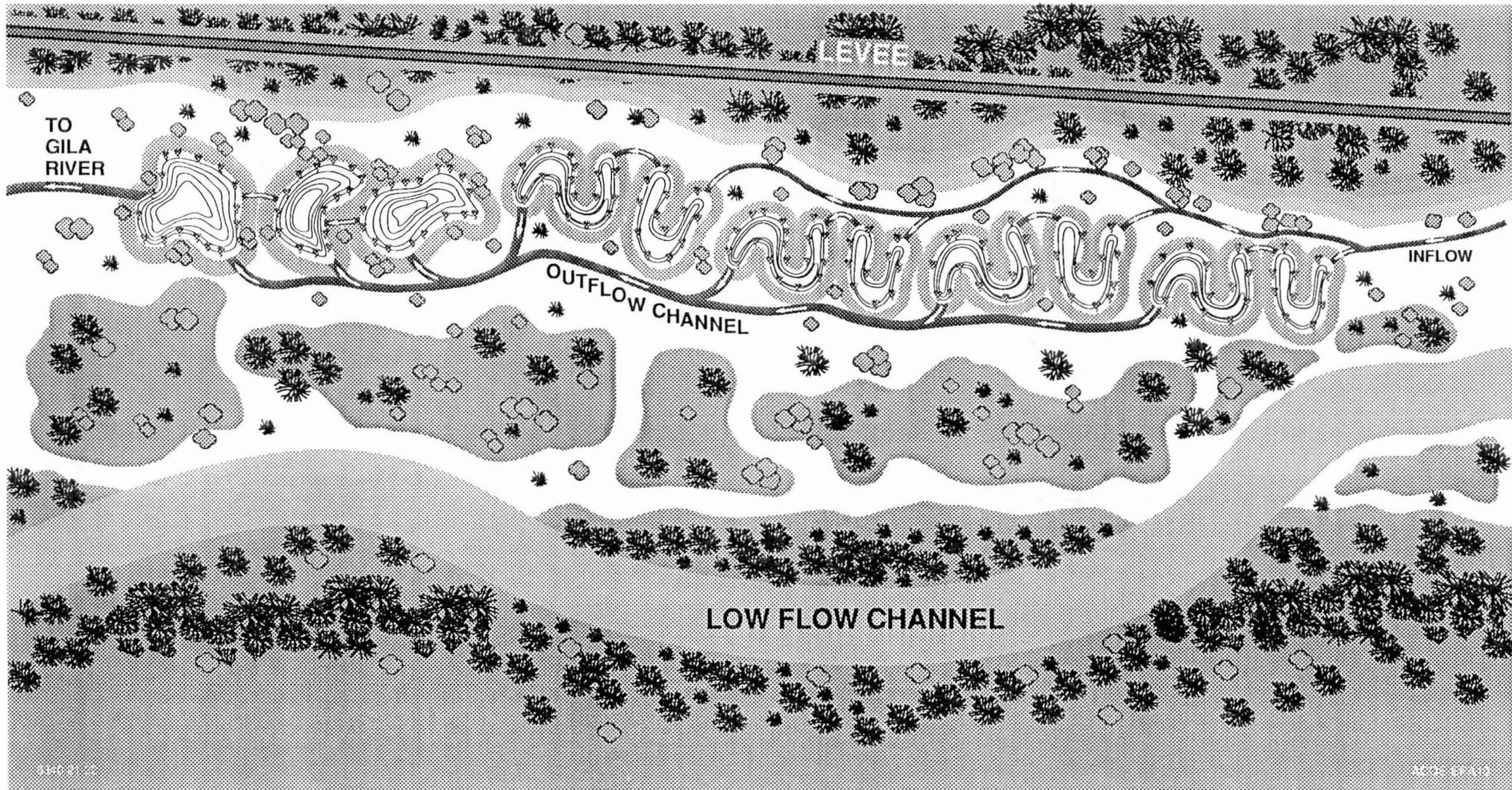
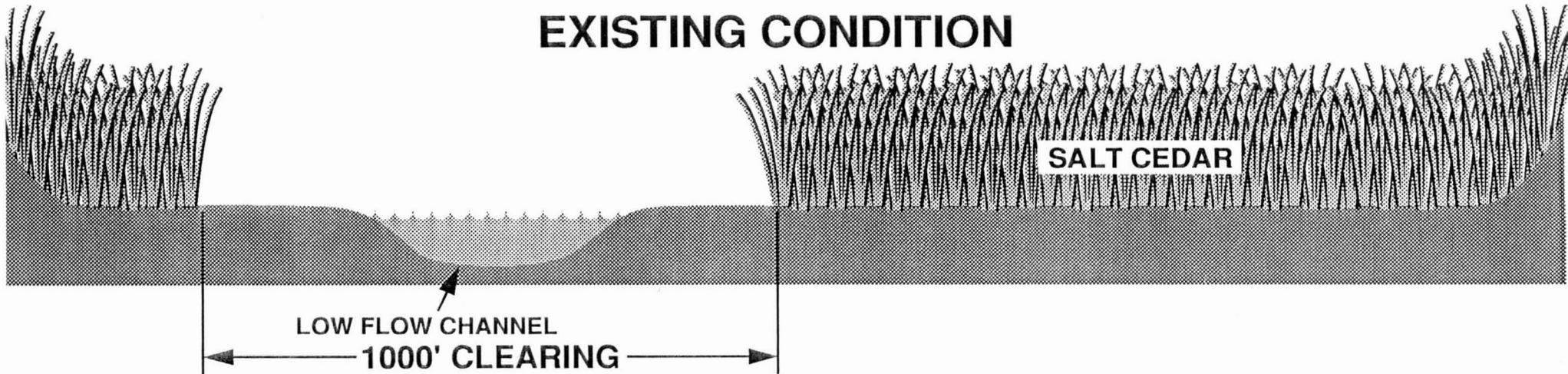


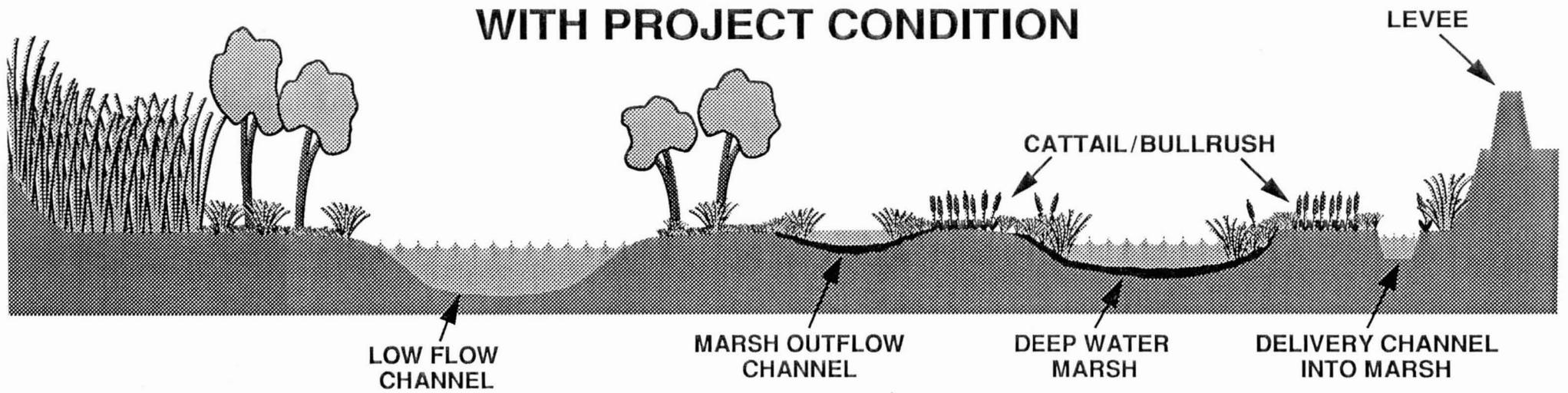
FIGURE 5.9

# CHANNEL CROSS SECTION WETLANDS/LEVEE ALTERNATIVE

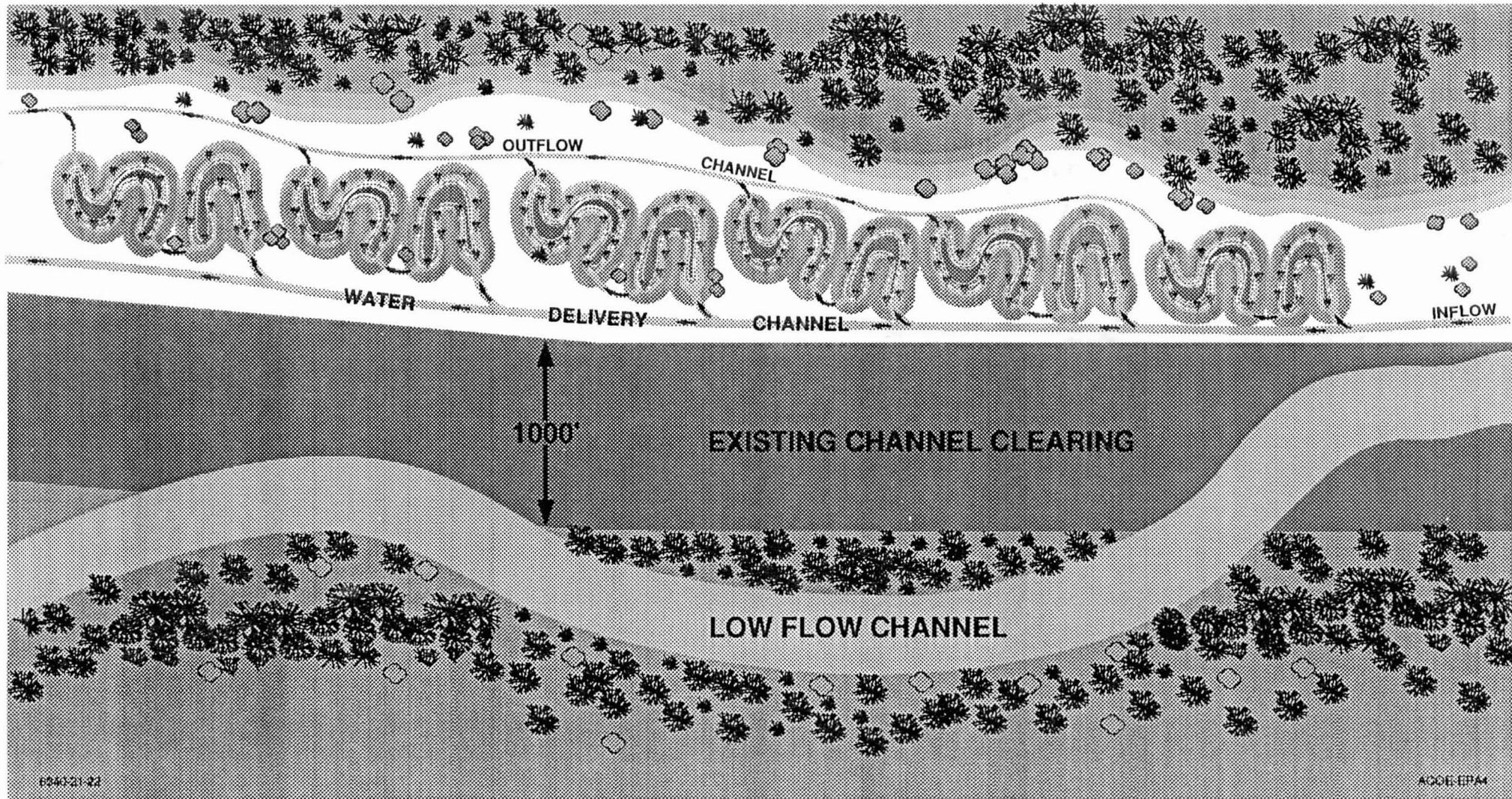
## EXISTING CONDITION



## WITH PROJECT CONDITION



# TOTAL TREATMENT WETLANDS



E040-21-22

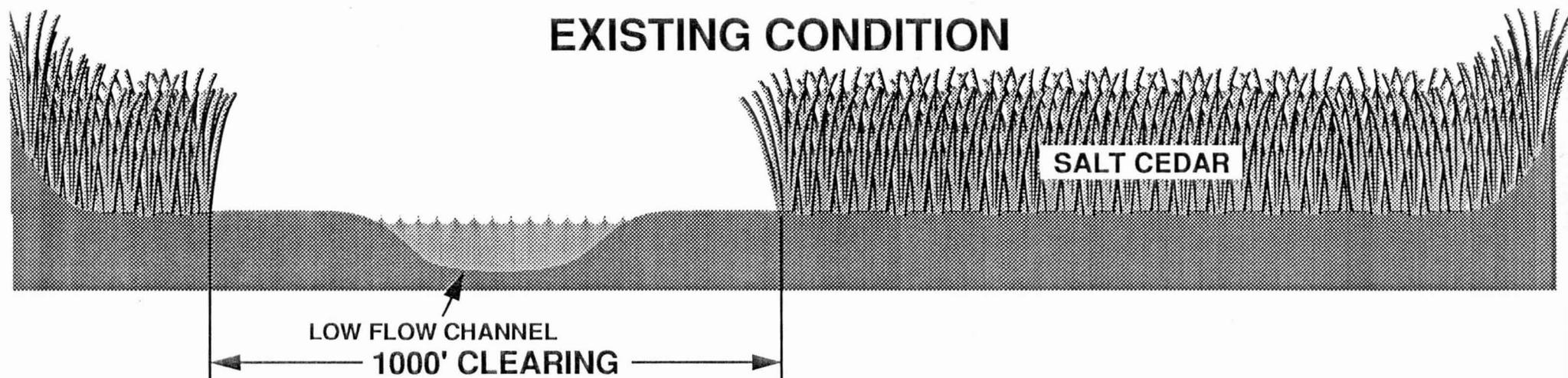
AC06-EP4

FIGURE 5.11

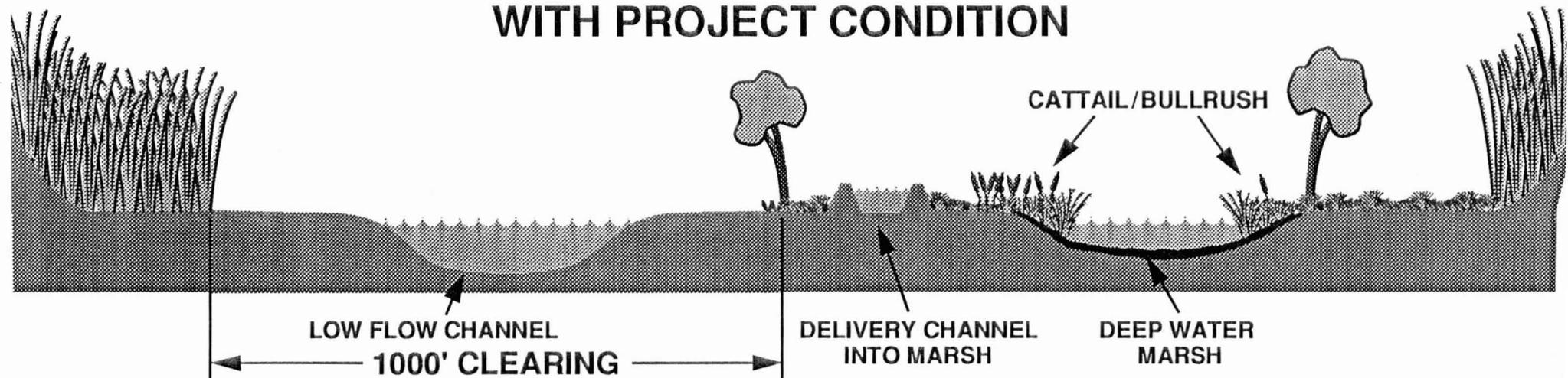
# CHANNEL CROSS SECTION

## TOTAL TREATMENT WETLANDS

### EXISTING CONDITION



### WITH PROJECT CONDITION



Opportunities for a variety of recreation experiences including environmental education are plentiful as Estrella Mountain Regional Park facilities and activities as well as the Sun Circle National Recreation Trail are fully integrated into the Tres Rios wetlands landscape.

In view of the fact that the entire effluent from the 91st Avenue Plant is capable of being treated, Alternative 7 offers the SROG Cities an economically efficient alternative to costly plant upgrades of the existing facility and the groundwater recharge proposal.

### 5.3.8 Analysis of Alternatives

An analysis of alternatives provides a comparative basis for evaluating the alternatives considered at Tres Rios. Based upon a relative assessment of economic benefits, costs, outputs, and effects, a selected alternative will be recommended for further investigation at the feasibility level of study. Table 5.1 displays the outputs and effects of the alternatives presented. Figure 5.13 displays the 100-year floodplain associated with the flood protection measures of each alternative.

#### Alternative 1. No Action -

This alternative attempts to portray the probable future condition of the study area without a project in place. All current public agency plans and programs are assumed to have been implemented; including maintenance of the 1000 foot clearing through the study area and implementation of the plan for groundwater recharge (zero-discharge) from the 91st Avenue Wastewater Treatment Plant.

As the SROG cities move forward with the plan for groundwater recharge, the probable future condition of Tres Rios would be best described as a riparian ecosystem that has undergone a major decline in habitat and wildlife. While elimination of continuous surface water flows would substantially alter a river's ecology anywhere in the U.S., the impacts are even more acute in the arid southwest. Although other sources of water are available in the area such as agricultural tailwater, occasional releases from upstream dams, and high groundwater tables, they do not support those riparian communities and associated wildlife that are dependent upon year-round continuous surface flows such as cattail/bulrush marsh communities. As a result T&E habitat, (i.e., Yuma Clapper Rail) would be seriously impacted if not eliminated in the area.

**TABLE 5.1 ALTERNATIVE ANALYSIS MATRIX**

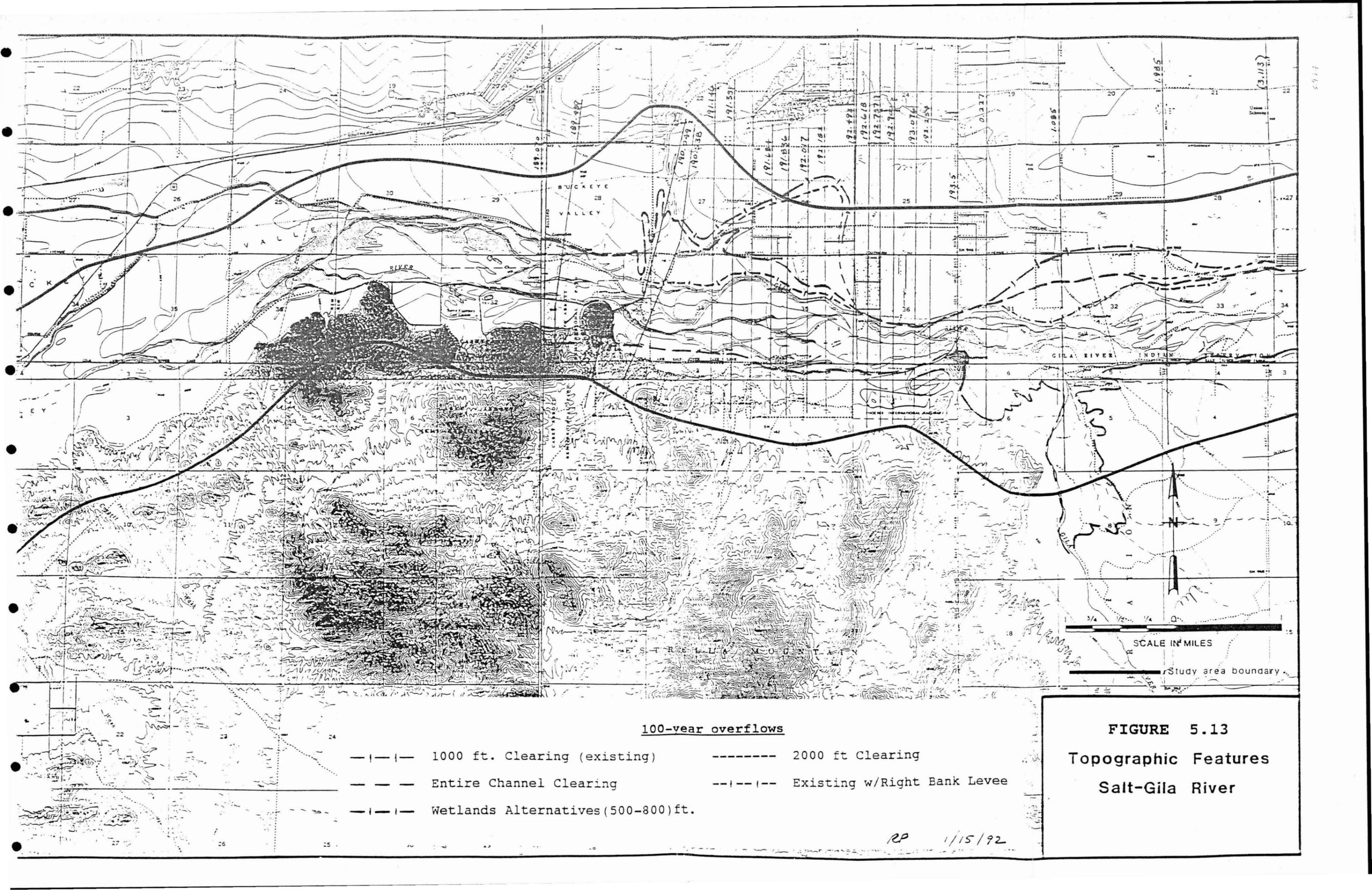
**TRES RIOS STUDY AREA  
ALTERNATIVE ANALYSIS**

	PRESENT <sup>1</sup> COND	ALT 1 WITHOUT PROJECT	ALT 2 COMP CHNNL CLEARING	ALT 3 2000' CLEARING	ALT 4 LEVEEEE NORTH	ALT 5 WETLANDS/ CHANNEL CLEARING	ALT 6 WETLANDS/ LEVEE	ALT 7 TOTAL TREATMENT WETLANDS
<b>HYDRAULICS</b>								
OVERFLOWS	1.5 - 2 MI	NO CHANGE	++	+	+++	+	+++	++
<b>ECONOMICS</b>								
NET BENEFITS <sup>2</sup>	-	-	- 191	- 41	- 356	- 334	- 356	16,097
B/C	-	-	0.2	0.4	0.2	0.0	0.2	6.8
<b>WILDLIFE HABITAT</b>								
T&E YUMA C-R	+	---	---	---	---	+++	+++	+++
T&E RAZORBACK	+	---	---	---	---	+++	+++	+++
WATERFOWL	+	---	---	---	---	+++	+++	+++
HAB DIVERSITY	+	---	---	---	---	++	+++	+++
<b>WATER RESOURCES</b>								
WATER QUAL	-	+++ <sup>3</sup>	N/A	N/A	N/A	+++	+++	+++
SUPPLY	-	++	N/A	N/A	N/A	+/-	+/-	+/-
RECREATION	-	--	---	--	--	++	++	++

1. PRESENT CONDITION: (A) A 1000' CHANNEL CLEARING EXISTS THROUGH DENSE SALT CEDAR  
(B) EFFLUENT FROM 91<sup>ST</sup> AVE PLANT (RANGING FROM 50,000 - 90,000 ACFT/YR) CURRENTLY FLOWS INTO RIVER

2. NET BENEFITS EXPRESSED IN \$1000s

3. HIGH WATER QUALITY RATING AS NO WATER IS ACTUALLY BEING DISCHARGED. WITH ZERO DISCHARGE, THIS REPRESENTS FULL COMPLIANCE ON PAPER.



100-year overflows

- |           |                                     |           |                             |
|-----------|-------------------------------------|-----------|-----------------------------|
| — — —     | 1000 ft. Clearing (existing)        | -----     | 2000 ft Clearing            |
| — — —     | Entire Channel Clearing             | - - - - - | Existing w/Right Bank Levee |
| - - - - - | Wetlands Alternatives (500-800) ft. |           |                             |

**FIGURE 5.13**  
**Topographic Features**  
**Salt-Gila River**

RP 1/15/92

A second factor impacting T&E and riparian habitat involves releases from upstream dams in order to provide capacity for the flood control component at these facilities. While volumes released will vary by year, according to weather conditions and water storage capacities, riparian and T&E species habitat will become impacted with flows as low as 10,000 cfs (McKinstry, USFWS, 1992) and are expected to be completely washed out as releases approach 30-50,000 cfs.

With respect to flood control, overflows and associated damages would remain the same. Expected annual damages (EAD) amount to \$66,700. Channel obstructions caused by phreatophytes would continue to complicate the flooding problem even without effluent discharges from the 91st Avenue plant. Phreatophytes would continue to occupy the area as high groundwater tables (estimated to be as high as 5 feet below the surface in some locations) are easily accessed by phreatophyte root systems. In addition, the Gila River, which enters the upper 1/3 of Tres Rios will continue to provide a limited water source as well as recharge the aquifer (Graf, 1992) in the study area. The extent of phreatophyte growth upstream on the Gila River, prior to its confluence with the Salt River, where there are no wastewater discharges, is evidence that the Gila River will serve as an effective water source to support phreatophytes within Tres Rios. Therefore, the need to maintain the 1,000 foot clearing in the future is expected to continue.

Diversity of flora and fauna would be severely limited as only phreatophytes, capable of surviving changes in continuous flows, would occupy the channel. Recreation opportunities through the study area would be limited when contrasted to the current situation. In this setting the Sun Circle Trail System would fall short in providing the quality of recreation experiences originally conceived of as part of the National Recreation Trail System.

With respect to water quality, the SROG Cities would satisfy proposed 1996 NPDES and SWQS, at least on paper, as discharges from the 91st Avenue Plant would discontinue. Water supply benefits, are high as the groundwater recharge program for future water supply is implemented.

#### Alternative 2. Complete Channel Clearing -

This alternative was used to serve as a benchmark identifying the maximum extent to which hydraulic efficiency can be achieved through vegetative manipulation. By completely clearing all vegetation from the channel, it is estimated that 95% of expected annual damages are prevented, amounting to \$63,400. However, the benefit/cost ratio of Alternative 2 is only 0.2. As flood damages are effectively eliminated, unfortunately so would any of the remaining riparian habitat. Habitat diversity would be effectively

eliminated under this scenario. Water quality and water supply benefits are incidental to this alternative as Alternative 2 takes no action to affect water quality or supply. Compliance with water quality standards is fully accomplished, at least on paper, as the SROG Cities completely eliminate effluent discharges into the Salt River. Water supply benefits, also incidental to this alternative, are high as the groundwater recharge program is implemented. Impacts from releases from dams upstream of the study area would not negatively impact riparian habitat as the area would already be devoid of habitat as a result of completely clearing the channel for flood control purposes.

#### Alternative 3. A 2000 Foot Channel Clearing -

This alternative examines the improved efficiencies in flood flow conveyance by expanding the width of the existing 1,000 foot alignment by clearing an additional 500 feet on each side. The total cleared width of the channel would be 2,000 feet. By clearing an additional 1000 feet of phreatophytes, expected annual damages prevented amounts to approximately \$30,600 with a benefit/cost ration of 0.4. With respect to environmental impacts, the remaining riparian habitat and associated wildlife capable of surviving non-continuous discharges of effluent from the 91st Avenue plant would be further impacted by doubling the amount of area cleared in the channel. Habitat diversity, while already seriously impacted by zero-discharge, would be further impacted under this scenario. A 2000 foot clearing through the study area may render much of the remaining vegetation unusable as effective wildlife habitat. As in Alternative 2, water quality and water supply benefits are incidental to this alternative. Compliance with water quality standards is fully accomplished and water supply benefits are high as the SROG pursues its groundwater recharge plan. Impacts from releases of upstream dams would not have much of an added negative effect on those habitats susceptible to releases due to the fact that these habitats would have already been eliminated as a result of zero-discharge.

#### Alternative 4. Levee Along the North Bank -

By extending the existing Holly Acres levee through the entire length of the study area, this alternative provides 100 year level of protection along the north bank and totally eliminates expected annual damages (\$66,000), however, the benefit/cost ratio is only 0.2. With a levee in place, flood flows through the channel would shift away from the north bank. In terms of environmental impacts, the remaining riparian habitat and associated wildlife capable of surviving non-continuous discharges of effluent from the 91st Avenue plant would not be seriously further impacted as a result of implementing this alternative. Habitat diversity, while already seriously

impacted by zero-discharge, would not be further affected under this scenario. As in Alternatives 2 and 3, water quality and water supply benefits are incidental to this alternative. Compliance with water quality standards is fully accomplished and water supply benefits are high as the SROG cities pursue zero-discharge. Impacts from releases of upstream dams would not have much of an added negative effect on those habitats susceptible to releases due to the fact that these habitats would have already been eliminated.

#### Alternative 5. Constructed Wetlands/Channel Clearing -

This alternative attempts to provide a comprehensive solution to the array of water resource problems which come to bear at Tres Rios. While the 1,000 foot clearing would be maintained, an additional 500 feet of dense salt cedar along the existing alignment would be replaced with approximately a 300 acre mosaic of shallow and deep water marshes, cattail/bulrush and cottonwood/willow plant communities. Improvements in flood flow conveyance result in an insignificant reduction in expected annual damages. The benefit/cost ratio is 0.0. Alternative 5 is formulated on the basis of treating only a portion of 91st Avenue Wastewater Treatment Plant effluent (approximately 40,000 acre feet). While water quality would be improved, relative to the flows that would be discharged into the Salt River, the City of Phoenix would, however, continue to pursue its plan for groundwater recharge with the balance of its effluent, at a cost of \$150 million.

In contrast with the without project condition, Alternative 5 provides a mechanism to keep a portion of the continuous flows from the 91st Avenue Plant, in the river via a constructed wetlands. A constructed wetlands would provide habitat for a variety of wildlife species, and in particular the Yuma Clapper Rail. By providing habitat for the Yuma Clapper Rail, population numbers are expected to increase in the area. Habitat for shorebirds, raptors, waterfowl and other migratory birds would also be featured. Species diversity would be significantly improved over that which would be expected in the without project condition where only phreatophytes, capable of tapping shallow groundwater tables for survival, would continue to occupy the channel. Vegetation that would be featured in and along the wetlands would include cattail, bulrush, salt bush, mesquite, hackberry, grasses, cottonwood and willow.

In view of the composite of Federal, state and local agency landownership in the channel, the wetlands would be configured so as to maximize the use of public lands in the river channel and thus significantly reduce real estate acquisition costs.

#### Alternative 6. Wetlands/Levee -

Alternative 6 combines the benefits of Alternatives 4 and 5. The flood control benefits associated with a levee along the north bank of the channel are incorporated into this alternative. Complete flood protection would be provided to the residential, industrial and agricultural areas in the study area; eliminating \$66,000 in expected annual damages. The benefit/cost ratio would be the same as that of Alternative 4 at 0.2. The environmental benefits of Alternative 5 are not only incorporated into this alternative, but are actually exceeded as this alternative eliminates the need for the 1,000' clearing through the study area with a levee in place. Therefore, the 1,000 foot clearing could be revegetated. A mosaic of plant communities that are complementary to the habitat values provided by the wetlands would be featured in the former clearing. The juxtaposition of a revegetated channel with featured plant communities to a constructed wetlands could provide a significant net environmental benefit. In addition, operation and maintenance costs associated the channel clearing would be eliminated through the study area.

As in the case with Alternative 5, the wetlands would be treating approximately 40,000 acre feet per year as the City of Phoenix proceeds with its plans for groundwater recharge.

#### Alternative 7. Total Treatment Wetlands -

Alternative 7 represents a multi-purpose constructed wetlands designed to polish the entire effluent from the 91st Avenue Plant, provide flood protection, establish habitat for Federally listed T&E Species, and expand recreation opportunities. Approximately 1,000 acres wetlands would be used to treat the future capacity of the 91st Avenue Plant's scheduled for 1996 (180 MGD). As part of the wetlands design in Alternative 7, the water delivery channel will be located along the southern perimeter of the wetlands and serve a dual purpose. First, it will carry secondary effluent from the 91st Avenue Plant to the wetlands. Second, the height of the water delivery channel may vary over and above that which is necessary for wetlands operations to provide flood protection to the wetlands itself. A height of 10.8 feet provides 25-year flood protection to the wetlands while a 14.2 foot channel provides 100-year protection. Costs associated with the 25-year and 100-year designs are estimated at \$7.9 million and \$11.0 million, respectively. In Alternative 7, an average height of 10.8 feet was selected. As it extends the length of the wetlands, the delivery channel will protect the wetlands and endangered species habitat from flows of up to 100,000 cfs. Volumes of 30-50,000 cfs are believed to completely destroy Yuma Clapper Rail habitat through the study area. In addition to protecting the wetlands, the water delivery channel provides an additional benefit of 25 year level of flood protection to the

communities along the north bank of the Salt River. Expected annual damages prevented by the water delivery channel amount to \$20,400. These flood protection benefits are "net benefits" as no costs were incurred specifically for the purpose of flood protection of existing structures.

The wetlands would be located along the northern alignment of the 1,000 foot clearing and would average approximately 850 feet in width. Flooding events larger than the 25 year event would overtop the delivery channel and flood the wetlands. Consideration would be given to designing the wetlands to minimize economic and habitat losses during a major flooding event. From a flood control perspective, the wetlands will improve the conveyance of events larger than the 25 year flood as dense stands of phreatophytes (primarily salt cedar) are replaced by wetlands habitat for the length of the study area. Given the 100 year event, Alternative 7 is expected to provide a level of flood protection that is similar to that of Alternative 3 (2,000' clearing) with \$33,100 in annual damages prevented.

As the SROG Cities consider the aquifer recharge strategy in response to proposed 1996 NPDES requirements for discharging effluent into the Salt River, the annual costs of recharge versus a total treatment wetlands have been contrasted. As displayed in Table 5.2, average annual costs of groundwater recharge (which does not include an estimate of groundwater recovery costs) and the total treatment wetlands are estimated at \$18,453,700 and \$2,355,800, respectively. Alternative 7 provides for an estimated \$16,097,900 million in average annual savings over and above the groundwater recharge strategy. Annual savings (costs prevented) are benefits provided by Alternative 7. With \$16,097,900 in annual savings, a benefit/cost ratio of 6.8 is achieved.

Table 5.2. AVERAGE ANNUAL SAVINGS OF ALTERNATIVE 7

ALTERNATIVE	DESCRIPTION	AVG ANNUAL COSTS
Alt 1 (No Action)	Zero-Discharge	\$18,453,700
Alt 7 (Wetlands)	Total Treatment	- <u>2,355,800</u>
ANNUAL SAVINGS	BENEFITS	\$16,097,900

With respect to water supply, the SROG Cities would maintain the groundwater recharge option in the future. Instead of transporting water from the 91st Avenue Plant, however, it would be taken from the outfall of the wetlands.

As contrasted against the without project condition, Alternative 7 provides a mechanism to keep current levels of discharge into the Salt River channel. A constructed wetlands of approximately 850 acres would provide a substantial amount of habitat for a variety of wildlife species, including the Yuma Clapper Rail. By providing Yuma Clapper Rail habitat to this extent, expected population increases would be greatest in this alternative. Habitat for shorebirds, raptors, waterfowl and other migratory birds would also be significantly improved over the without project condition. Overall, species diversity throughout the study area would be enhanced versus a without project condition where only phreatophytes would continue to occupy the channel. Vegetation that would be featured within and along the wetlands includes cattail, bulrush, salt bush, mesquite, hackberry, grasses, cottonwood and willow.

In view of the composite of Federal, state and local agency landownership in the channel, the wetlands would be configured so as to maximize the use of public lands in the river channel and thus significantly reduce real estate acquisition costs.

#### 5.3.9 Selected Alternative -

One economically justified alternative has been identified in the study of Tres Rios. With the only positive benefit/cost ratio, Alternative 7 provides a

benefit/cost ratio of 6.8. Alternative 7 is the obvious choice as the selected alternative in that it provides the greatest contribution towards National Economic Development objectives and environmental policies.

## CHAPTER 6

### CONCLUSIONS

#### 6.0 GENERAL

An investigation of twenty-three flooding problem areas throughout central Maricopa County has led to the identification of two areas having a potential Federal interest. These two areas, the White Tanks/Agua Fria drainage and Tres Rios, have been analyzed and evaluated in this reconnaissance study. In this chapter, the conclusions and recommendations associated with the study of each area are presented.

#### 6.1 WHITE TANKS/AGUA FRIA DRAINAGE AREA

The flooding problem associated with the White Tanks/Agua Fria drainage is that sheet flow collects in the Dysart drain which is located along the northern border of Luke Air Force Base. Due to the limited channel capacity of the drain, breakouts occur with flows as low as 300 - 400 cfs. These breakouts result in significant flooding damages across Luke Air Force Base. With a large number of high-tech training facilities on base, many are situated in the floodplain. Also located in the floodplain are commercial establishments, hospital facilities, base housing and parking ramps for F-15 and F-16 aircraft. Flood flows collect at the south-central area of the base continue downstream into Bullard Wash causing damage to agricultural lands as well as increase the costs of future development.

Two economically justified alternatives have been identified for the White Tanks/Agua Fria drainage. However, in view of the fact that a significant share of flood damages occur to Luke Air Force Base, the local sponsor (Flood Control District of Maricopa County), chose not to participate in cost-sharing with the Corps in a Feasibility study of this area. Therefore, in absence of a willing local sponsor to participate in a Feasibility study, this aspect of the Central Maricopa County Reconnaissance Study will conclude at the reconnaissance phase. It is recommended that the findings of this study be presented to the Base Commander, Luke Air Force Base, as requested in a letter from the Base civil engineer. At that time, the opportunity for flood protection at Luke Air Force Base will be presented to the U.S. Air Force under the "work for others" program.

#### 6.2 TRES RIOS STUDY AREA

A wide array of water resource issues have been raised at Tres Rios. Of the seven alternatives considered, only Alternative 7 is economically justified, and is so by a significant margin. Alternative 7 proposes a comprehensive solution consisting

of a multi-purpose constructed wetlands of approximately 850 acres along the northern alignment of an existing 1000 foot channel clearing. A design feature of the wetlands is to utilize a dual purpose water delivery channel. The water delivery channel serves the primary purpose of transporting effluent from the wastewater treatment plant to marsh habitat units. By elevating and reinforcing the channel, a second feature is realized as the channel can also serve as a flood control measure; protecting the wetlands from flows of up to 100,000 cfs. An added benefit of the water delivery channel is that it provides a 25 year level of protection to existing structures, property, and agricultural lands along the north bank of the river.

Alternatives 5 and 6 also involve use of constructed wetlands. However, only a portion of the effluent (40,000 acre feet) would be treated in these alternatives. The balance of effluent would be allocated for groundwater recharge. As such, the costs of a groundwater recharge program would still be incurred in Alternatives 5 and 6. In contrast, Alternative 7 proposes to treat the entire effluent from the 91st Avenue Wastewater Treatment Plant. Through the use of a constructed wetlands the SROG Cities would satisfy proposed 1996 NPDES requirements. Thus, the need and cost for a groundwater recharge program, at this point in time, would be avoided by implementing Alternative 7. This cost foregone provides an annual savings of \$16,097,900 and serves as the basis for an economically justified solution with a benefit/cost ratio of 6.8.

In contrast to the without project condition, a substantial number of benefits are achieved in Alternative 7:

1. Estimated Annual Benefits of \$16,097,900; B/C Ratio of 6.8
2. Flood control benefits of \$20,000 are economically justified
3. Proposed 1996 water quality standards (NPDES) expected to be satisfied
4. Contribution towards Federal goals of protecting T&E Species habitat
5. Contribution towards the National interim goal of no net loss of wetlands, and long term goal of increasing the quantity and quality of wetlands (WRDA 90)
6. Continuous surface flows will remain in the river channel and support riparian habitats
7. Species diversity among flora and fauna enhanced

8. Recreation and education opportunities are significant, including enhancing recreation experiences along the Sun Circ Trail, a component of the National Recreation Trail System

In order for a reconnaissance study to proceed into the feasibility phase, several study criteria must be satisfied (Chapter 2.2 of this report). The challenge facing this study effort, in terms of moving forward into the feasibility phase, concerns a matter of existing Corps of Engineers policy. While numerous water resource benefits are achievable at Tres Rios and an economically justified solution has been identified, water quality benefits comprise the basis for economic justification. Currently, it is not within the purview of Corps policy to participate in feasibility level studies or in the construction of projects that are economically justified on the basis of water quality benefits. It is therefore recommended that this study not proceed into the feasibility phase.

CHAPTER 7  
RECOMMENDATIONS

7.1 RECOMMENDATION

I recommend that the Central Maricopa County Drainage Area Reconnaissance Study, Az. be terminated at the Reconnaissance phase.



CHARLES S. THOMAS  
Colonel, Corps of Engineers  
District Engineer