

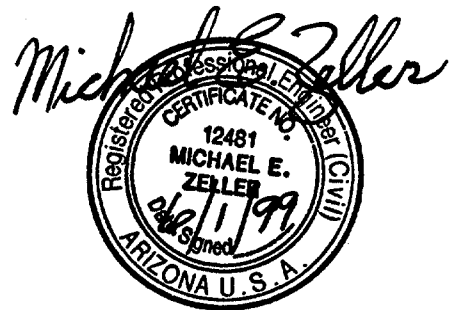
**BRAWLEY WASH
PRIMARY FLOOD CORRIDOR STUDY**

Prepared for:

Pima County Department of Transportation
and Flood Control District

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BRAWLEY WASH PRIMARY FLOOD CORRIDOR STUDY

EXECUTIVE SUMMARY

The Brawley Wash is located approximately 15 miles west of Tucson, Arizona, within Avra Valley. The Brawley Wash is one portion of a larger wash system which flows from its upper tributaries, near Mexico, to its confluence with the Santa Cruz River. The confluence of the Brawley Wash with the Santa Cruz River is located just west of the Town of Marana. The "Brawley Wash Primary Flood Corridor Study" encompasses approximately 30 miles of this wash system; extending from the unincorporated town of Three Points, on the south, to the confluence of the Brawley Wash with Los Robles Wash, on the north. The northern and southern ends of the study area are located relatively close to metropolitan areas and suburbs surrounding the City of Tucson.

Increasing pressures from development around the Brawley Wash have led to the need for an in-depth assessment of floodplain management policies and protocols for the area. Regulatory tools available for management of the Brawley Wash floodplain are contained primarily within the "Pima County Floodplain Management and Erosion Hazard Management Ordinance"¹ and the Federal Emergency Management Agency "Flood Insurance Study"² for the Brawley Wash. While these regulatory tools provide the government (i.e., the Pima County Flood Control District) with the authority to manage the Brawley Wash floodplain, they cannot absolutely insure that a continuous, unobstructed flow path along the wash system will be maintained in the future. An unobstructed flood corridor, however, is essential in minimizing flood and erosion damage to property and reducing the threat to human life during the occurrence of a regulatory flood event.

"State Standard (SSA 2-92) for the Delineation of Riverine Floodplains and Floodways in Arizona,"³ was used as a guide in the determination of floodway widths along the flood corridors of the "Brawley Wash Primary Flood Corridor Study." Flood corridor alignments were constructed based upon utilization of best available information. Past studies, aerial photography, historic available topography, soils information, historic documentation, and technical information were all relied upon to construct the primary flood corridor alignments of the Brawley Wash system during the development of the "The Brawley Wash Primary Flood Corridor Study". The resulting flood corridors provide continuous flow alignments which will (1) assist in minimizing flood and erosion damage to properties; and (2) reduce flood and erosion hazards to human life—thus increasing the health, safety, and welfare of the public.

Three mapping products associated with this study effort were submitted to the Pima County Flood Control District under separate cover. The mapping products were constructed at a scale of 1" = 24,000", and included a Brawley Wash Primary Flood Corridor overlay on: (1) a U.S.G.S. Quadrangle;(2) a Parcel Map; and (3) the Federal Emergency Management Flood Insurance Study.

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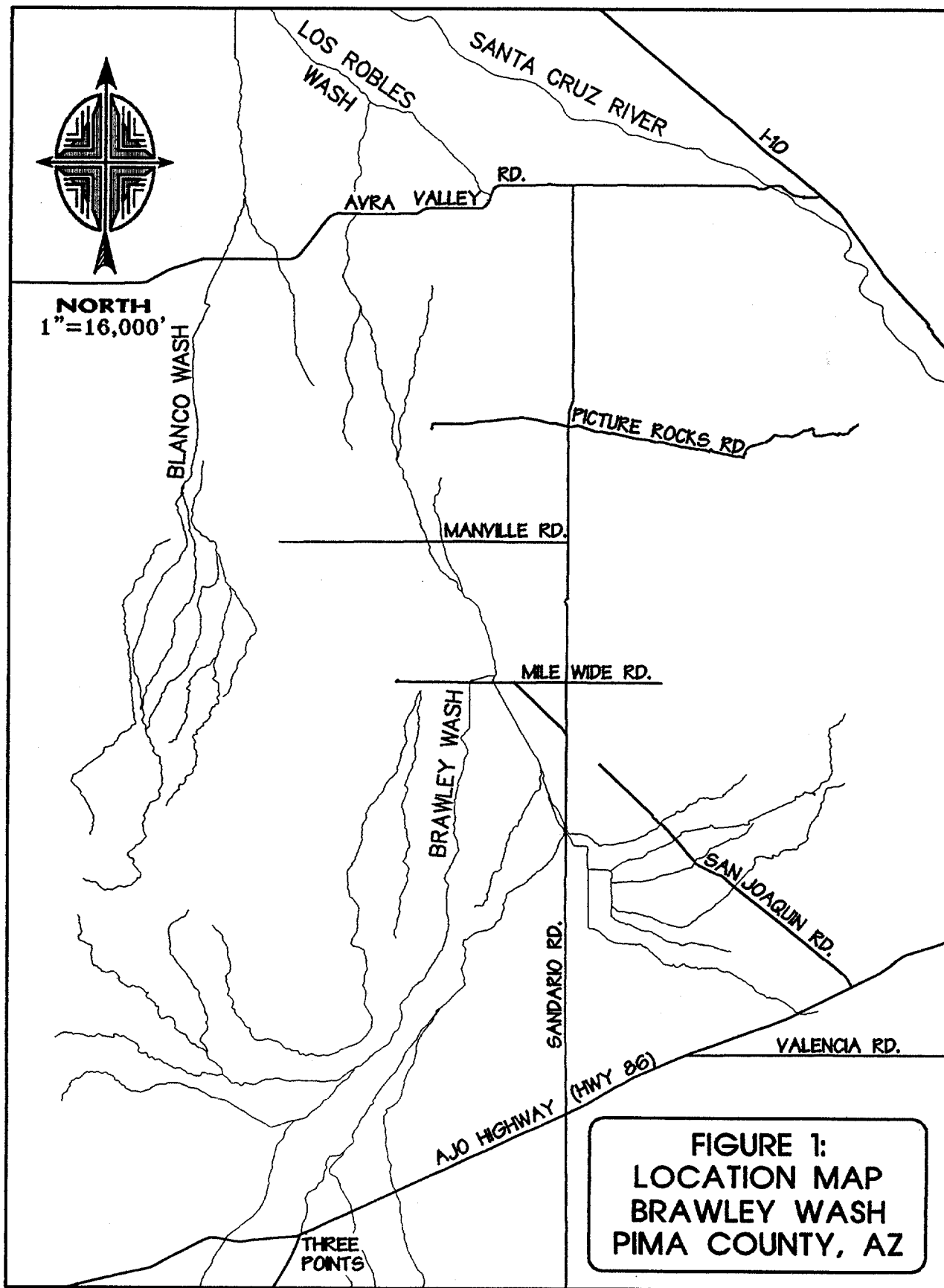
I. INTRODUCTION

The Brawley Wash is located approximately 15 miles west of Tucson, Arizona, within Avra Valley. The Roskrige Mountains define the west boundary of the Brawley Wash watershed, and the Tucson Mountains define the eastern boundary of the watershed. The Brawley Wash is one portion of a larger wash system which flows from its upper tributaries, near Mexico, to the confluence with the Santa Cruz River. The confluence of the Brawley Wash with the Santa Cruz River is located just west of the Town of Marana. According to the Federal Emergency Management Agency (FEMA) "Flood Insurance Study for Pima County," for those areas encompassed by the Flood Insurance Study (FIS) the larger wash system is second in size only to the Santa Cruz River watershed. The "Brawley Wash Primary Flood Corridor Study" encompasses approximately 30 linear miles of this larger wash system, and extends from the unincorporated town of Three Points, on the south, to the confluence of the Brawley Wash with Los Robles Wash, on the north (see Figure 1: Location Map). The northern and southern ends of the study area are located relatively close to metropolitan areas and suburbs surrounding the City of Tucson.

The proximity of Avra Valley to metropolitan areas within Pima County has led to increased residential development within the Brawley Wash floodplain. The increased number of residences, in turn, has led to the need for an assessment of current policies and protocols for managing associated floodplain areas. Regulatory tools available for management of the Brawley Wash flood plain are contained primarily within the "Pima County Floodplain Management and Erosion Hazard Ordinance" (Ordinance) and the FEMA FIS maps for the Brawley Wash.

When applied to a large, braided wash system such as the Brawley Wash, the Ordinance and FIS maps contain certain limitations. The Pima County Flood Control District (District) Ordinance contains floodway and erosion-hazard standards which were primarily designed to provide constraints on development in the proximity of a single-threaded watercourse which conveys all flow from a watershed. The original FEMA FIS mapping for the Brawley Wash (which was predominately mapped by approximate methods) does not provide enough detailed hydraulic information for implementing adequate constraints on development in high velocity, flood corridor areas. These limitations were of enough concern to the District to justify funding for preparation of the "Brawley Wash Primary Flood Corridor Study." An unobstructed flood corridor, which follows the natural terrain and historic flow paths, is an integral element in preventing damage to property and reducing the threat to human life during the occurrence of a regulatory flood event. This study is not intended to be used as a replacement for site-specific regulations which may be imposed upon properties by existing regulations. Rather, the purpose of the study is to identify and establish a continuous flow corridor which can be utilized to maximize land-use effectiveness by protecting development from major flood and erosion damage.

Past studies, historic aerial photography, available topography, soils information, historic documentation, and technical information were all relied upon to construct the primary flood corridor alignments of the Brawley Wash system during the development of the "The Brawley



**FIGURE 1:
LOCATION MAP
BRAWLEY WASH
PIMA COUNTY, AZ**

Wash Primary Flood Corridor Study". Unfortunately, at the time that this study was conducted, detailed topographic information for the Brawley Wash was limited. Consequently, traditional step-backwater calculations (e.g., HEC-2) for a floodway could not be performed due to the lack of detailed topographic information. As an alternative approach, current State Standards provide guidelines for designating a floodway in areas with limited topographic information. Accordingly, flood corridors along the Brawley Wash have been constructed based upon using the best available information in combination with State Standard methodology.

Flow paths lying within the "Brawley Wash Primary Flood Corridor Study" area are herein referred to as "primary flood corridors," in lieu of describing them as "administrative floodways." This nomenclature was used to underscore the use of analysis, available studies, and flood documentation to construct the flood corridor alignments. The resulting flood corridors provide continuous flow alignments which will assist in minimizing flood and erosion damages to properties, while reducing flood and erosion hazards to human life—thus increasing the health, safety, and welfare of the public. A primary task of this study has been to establish reasonable flood corridor alignments based upon past studies, accepted methodologies, and historic channel alignments for the Brawley Wash area.

II. STUDY OBJECTIVES

The "Brawley Wash Primary Flood Corridor Study" was developed as a two-phased project. The first phase identified the resources and applicable methodology for the delineation of primary flood corridors in the second phase of the study. The first phase of the Brawley Wash Primary Flood Corridor Study included:

A. Previous Tasks (Phase I)

- Review of past and present aerial coverage which is available for the study area;
- Review of past studies within the study area;
- Review of various available methodologies for defining floodway corridors; and
- Recommendations for the best available methodology for defining a floodway corridor.

B. Scope of Work (Phase II)

The second phase of the "Brawley Wash Primary Flood Corridor Study" was based upon the recommendations contained within the first phase of the study. The second phase was defined as three tasks, which included:

Task 1

- Review the 1998 aerial photography, which became available during the course of the study;
- Review area soil maps and geomorphic information available for the study area;
- Provide a overview of the Phase II flood corridor alignments with the existing FEMA Map zones; and
- Provide property ownership information for areas affected by the proposed flood corridor alignment.

Task 2

- Define the initial width of the flood corridor using the Level 1 procedure from State Standard Attachment 2-96;
- Adjust the width to ensure that the average depth of flow within a typical flood corridor section is limited to a maximum depth of approximately three feet;
- Define additional width that may be needed to accommodate drainage from the south;
- Establish a reasonable building-setback distance from the boundary of the flood corridor, using the erosion potential of the primary flood channel as a guide.

Task 3

- Prepare a final report including discussion of the previously outlined work;
- Prepare a reproducible map using USGS 7.5 minute quadrangle maps of the Brawley wash area; and
- Prepare a map showing the location of affected property owners.

III. OVERVIEW OF STUDY AREA

A. Location of Watershed

The Brawley Wash is located approximately 15 miles west of the City of Tucson, Arizona, within Avra Valley. The Brawley Wash is one portion of a larger wash system which extends upstream (south) almost to the United States border with Mexico, and extends downstream (north) to the confluence with the Santa Cruz River, located at a point near the town of Marana. Names vary along this ephemeral fluvial system. Upstream of the Brawley Wash, the name of the watercourse changes to Altar Wash. At the headwaters, the Altar Wash watercourse forks into two tributaries. The tributaries are named Puertocito Wash and Arivaca Wash, respectively. Downstream of the Brawley Wash, a small segment of the system is known as Los Robles Wash. From this point on downstream, the watercourse retains the name Los Robles Wash until its confluence with the Santa Cruz River.

The Avra Valley watershed is defined by the Tucson Mountains to the east and the Roskrige Mountains to the west. Avra Valley extends south to an adjoining basin named Altar Valley. Altar Valley defines the northern reaches of the Brawley/Altar Wash watershed, and is defined by the Baboquivri Mountains to the west and several small ranges to the east, including the Sierrita and San Luis Mountains. From its confluence at the Santa Cruz River to its headwaters near Mexico, the entire watershed contains a drainage area of 1,349 square miles².

B. Watercourse Characteristics

The Brawley Wash is an ephemeral watercourse, typical of many of the rural watercourses which are located within the upper Sonoran Desert. The channel is ill defined, and flow is conveyed through a series of low-flow braids and diversions along the valley bottom. Grasslands and mesquite bosques push overbank Manning's "n" values to as high as 0.09². Past flood descriptions indicate that, historically, large flows have remained fairly confined at the bridge located west of the Three Points area, but then spreads broadly across the valley in downstream areas. The floodplain was documented as expanding to several miles wide in these downstream areas during significant flood events which occurred in 1962 and in 1970.

C. Reach Definitions

During preparation of Phase I of the "Brawley Wash Flood Corridor Report," the unique characteristics of each distinct reach of the wash were researched. Historic photographs,^{4,5} as well as relatively recent aerial flights,⁶⁻¹⁰ were compared in order to provide an overview of each length of reach which was evaluated. In all, a total of five distinct reach lengths were identified along the Brawley Wash. A detailed description of each of these five reach lengths is provided in the paragraphs which follow.

Reach 1

The Brawley Wash enters the study area as a well-defined primary channel, with an average width varying between 30 and 50 feet over the first four miles. Along the majority of this reach, the alignment of the main channel has not changed significantly over the past 40 to 50 years. A piecemeal levee system has been somewhat effective in limiting the magnitude of overbank flooding that otherwise would have naturally occurred along this reach of the wash during the occurrence of more frequent flow events. The average width of the 100-year flood plain along this reach is approximately 1.5 miles. The reach terminates near the historic Donaldson Dam.

The Donaldson Dam appears to have been originally constructed to serve as a holding pond for the purpose of watering livestock. In addition, it appears that the main channel for the Brawley Wash was diverted northward to serve as the source of water for the pond. To accomplish this diversion, an open channel similar in size to the Brawley Wash was constructed between the holding pond and the downstream terminus of the natural channel. The approximate length of this diversion channel and its overbank levee was 4,000 feet. The most recent photographs of the area indicate that the dam has been removed. However, the historic drainage pattern was not restored. Instead, the diverted channel section appears to have been extended approximately 3,600 feet. Low flows conveyed along the main channel are now released along a flow path that is directed due north, towards the site of the Donaldson Ranch.

Reach 2

Prior to construction of the Donaldson Dam and its upstream diversion levee, low flows conveyed in the main channel dispersed in a northeasterly direction, utilizing a crisscrossing network of braided, low-flow channels. Approximately four miles downstream of the Donaldson Dam diversion, three distinct flow paths began to emerge. One flow path directs runoff due north toward Mile Wide Road, and one flow path continues in a northeasterly direction toward the Black Wash confluence. The third flow path heads in a north/northeasterly direction, and joins the Brawley Wash above its confluence with the Black Wash. The latter two flow paths meet the Black Wash channel just downstream of Sandario Road.

The braided-channel network following the northeasterly alignment appears to represent the historic Brawley Wash. Mile Wide Road can be considered the downstream end of the historic Brawley Wash/Black Wash confluence area. This area extends upstream approximately 3.5 miles to Sandario Road. The combined flows from the Brawley Wash and Black Wash confluence at Sandario Road appear as a distinct and separate flow path, relative to the outflows from the Donaldson Dam, and cross Mile Wide Road at a point located approximately one-half mile east of Avra Road. Outflows from Donaldson Dam eventually cross Mile Wide Road at a point located approximately 1.5 miles above the combined confluence of the entire Brawley Wash system and the Black Wash.

As noted, this reach of the Brawley Wash lies between the Donaldson Dam diversion (i.e., the downstream terminus of the first reach) and Mile Wide Road. The total length of this reach is approximately 7 miles. Although three distinct flow paths can be identified with respect to this reach, the second reach exists, for the most part, as a wide, braided network of ill-defined channel sections. Crisscrossing flows result in an average floodplain width that exceeds four miles in the heart of the confluence area. At Mile Wide Road, the flood plain narrows to a width that is approximately equal to two miles.

A detailed floodplain study was recently conducted along a reach that extends approximately two miles upstream and two miles downstream of Mile Wide Road. This study was prepared for the City of Tucson Water Department in order to determine the impact of placing a groundwater recharge basin within the Brawley Wash flood plain.

In addition, the Tohono O'odham Nation recently completed a design study for the Schuk Toak farm development. This development will cross the majority of Brawley Wash flood plain from Sandario Road, westward approximately 3.5 miles. Since the development is located in the heart of the confluence area, it will have a significant impact on drainage. In order to offset this impact, two interior channels will be used to convey the 100-year discharge through the farm development. The main channel follows the alignment of the historic Brawley Wash, as previously described. However, the secondary channel, which parallels the main channel, will intercept the majority of the northeasterly flows and release these flows into the Brawley Wash/Black Wash channel a few thousand feet downstream of its current point of interception along the reach. Some surface runoff will bypass the farms project on both the east and west sides. On the west side of the project, a perimeter channel was designed to work in concert with the natural conveyance area in order to limit the overall impact of floodplain encroachment.

Reach 3

The third reach of the Brawley Wash study area begins at Mile Wide Road, and proceeds downstream to where a divergence into West and East Branches of the wash occurs. This third reach is approximately 5.5 miles long, and terminates in the vicinity of the Orange Grove Road alignment. Although there are a few well-defined flow paths which exist along this reach, the Brawley Wash continues to exist as essentially a braided network of low-flow channels. The FEMA FIS flood plain transitions from a width of nearly 2.0 miles to a width that is approximately 2.7 miles. Most of the flows conveyed in the eastern overbank along this reach will follow the East Branch flow path.

Reach 4

Along Reach 4, a three-mile segment of the Brawley Wash lying between the Orange Grove Road alignment and the Emigh Road alignment, the braided channel network diverges into two distinct paths, the West Branch of the Brawley Wash and the East Branch of the Brawley Wash. Initially, both paths possess similar braided channel characteristics; however, the braids

of the East Branch appear to disappear as the "finger" channels first spread, then reappear, as the levees around the active agriculture fields redirect and concentrate flow.

The West Branch appears to be the dominant flow path throughout the reach. At the downstream end of the reach, overbank braids and separated surface flows rejoin to form a more concentrated network of parallel low-flow channels.

Most of the floodprone area associated with both the West Branch and the East Branch has been subdivided into 20-acre parcels. One of the most recent floodplain studies conducted in the area concentrated on this reach in an effort to regulate development of these parcels. Although a detailed floodplain analysis was conducted, the study did not include a floodway designation, since the study was conducted using FIS guidelines which recommend against the determination of a computed floodway when the average depth of flow along the primary flow path is less than three feet. As previously noted, a computed floodway is normally based on the equal loss of conveyance from both sides of a single-threaded channel. However, the study did recommend that the West Branch be considered as the primary channel for the purpose of establishing an "administrative floodway."

Reach 5

Reach 5 includes both the West Branch and the East Branch, and extends from Emigh Road to El Camino de Tres Arroyos, a length of approximately four miles. Within this reach of the wash, watercourse definition improves along the West Branch, as numerous low-flow channels combine between Emigh Road and Avra Valley Road to form a single channel section that extends downstream to El Camino de Tres Arroyos. This reach of the West Bank was mapped by detailed methods as part of the current FEMA FIS. Consequently, detailed water-surface elevations are provided. However, no floodway definition is provided. The width of the flood plain along this segment of the West Branch ranges between one-half mile, at the downstream limit, to approximately one mile, at the upstream limit of the study reach.

Diversion levees constructed to protect agricultural fields funnel the East Branch flows into a man-made earthen section. The inlet to the earthen channel is located approximately 4,600 feet upstream of Avra Valley Road. The improved section continues north to a point located approximately one-half mile north of Avra Valley Road. At this location, two earthen channel sections exist. One directs flow to the north, towards what appears to be the historic East Branch section; while the other directs flow to the west for one-half mile, and then to the north to join the same historic section. The average width of the flood plain along this segment of the East Branch is approximately two miles.

The combined width of the 100-year flood plain along Reach 5 of the Brawley Wash is in excess of three miles. However, several areas of high ground exist between the two identified branches. It appears that the transfer of flow between the East Branch and the West Branch is what contributes to the combined areas of flooding.

Immediately downstream of El Camino de Tres Arroyos, the two branches join to form the Los Robles Wash. The width of the flood plain immediately downstream of the confluence area of the two branches is approximately one-half mile.

D. Land Uses

Historically, land use within the Brawley Wash watershed were primarily agricultural in nature. This type of use, however, appears to have steadily changed since sometime in the 1950's. As the Tucson Metropolitan area has enlarged, demand for low-cost land has expanded urbanization into areas lying further west, and land splits are now occurring in several locations along the Brawley Wash. The area east of Three Points has experienced a significant increase in population since 1995. Areas between the Manville and Picture Rocks Road alignment, upslope of the east and west branches of the Brawley Wash, have also experienced increases in population.

A secondary use within Avra Valley is land acquisition by public agencies. The Central Arizona Project skirts a majority of the Brawley Wash floodplain, transporting water via a canal for future Tucson metropolitan use. In some areas, this canal effectively forms a levee between the Brawley Wash Floodplain and the eastern slopes of the watershed. In addition to the land acquired for the Central Arizona Project, the City of Tucson Water Department has acquired sections of land within the Brawley Wash floodplain. This land has grandfathered groundwater rights which provide a supplemental source of potable water for the Tucson metropolitan area.

E. Historic Flood Information

Several technical reports identify and document specific flood events which have occurred over the last 40 years within the Brawley Wash area. The most descriptive reports were written by D. Lewis¹¹ (1963) and by R.H. Roeske¹² (1978). Both of these reports were published by the United States Geological Survey (USGS). These USGS reports outline the storm conditions and impacts of flooding for regional areas, and contain some detailed descriptions of the Avra Valley area. In addition, there were two flood maps which were published independently of the written reports that are also specific to the Avra Valley area.

A draft flood map of the 1962 floods was provided by the District for the purposes of this report¹³. A second map, created by R.H. Roeske, titled "Areas Subject to inundation by the 100-year flood in Avra Valley, Pima County, Arizona,"¹⁴ has been in general circulation since its publication in 1977. This map utilized high-water marks and debris-line information from the floods of 1962 and 1970 (as well as step backwater computations along limited reaches) as a means of providing a more detailed analysis for projecting a flood path for the 100-year event.

Peak flows for flood events have differed by a factor of more than 250% at consecutive gage locations located along the Altar, Brawley, and Los Robles Washes (see Table 1). The peak flow variations are related to the source of the flooding, such as (1) a storm inundating upstream tributaries; (2) upstream flow from the Altar Wash area; (3) a storm stalled over the Avra Valley

area; (4) flow from downstream, side-tributary systems; and (5) flow from any combination of these sources of flooding. Significant tributaries along the study reach include the Little Brawley Wash, located to the west; an un-named watershed located to the northeast of Three Points (draining from the Sierrita Mountains); and the Black Wash watershed, which is also on the east side of the Brawley Wash.

A summary table of peak-flow estimates and gage data from recorded floods has been extracted from USGS gage data¹⁵ and flood reports, and is compiled in Table 1, below.

TABLE 1: Peak Discharges for Selected Floods Along the Brawley Wash				
Location/Wash Name	Date and Magnitude of Peak Discharge (in cubic feet per second)			
	September 1962	September 1970	October 1983	August 27, 1993
at Highway 286 <i>Altar Wash</i>	N/A	22,000	N/A	6,390
near Three Points <i>Brawley Wash</i>	13,000	13,700	19,100	10,800
at Mile Wide Road <i>Brawley Wash</i>	38,800	6,140	N/A	N/A
near Marana <i>Los Robles Wash</i>	32,000	4,490	12,500	N/A
at Silverbell Road <i>Los Robles Wash</i>	32,600	N/A	N/A	N/A

Specific descriptions of the floods identified in Table 1, above, are provided in the paragraphs which follow.

1. *Flood of September 1962*

D. Lewis provided the most detailed description of the flood of 1962 within a report titled "Desert Flood"¹¹. According to this report, a dissipated tropical storm moved inland "approximately 300 miles SSW of the Arizona border". Heavy precipitation fell west of Tucson on September 25-26, 1962. The Arizona-Sonora Desert Museum recorded 5.95 inches of precipitation, and two ranches located just south and west of the museum recorded over 6 inches of precipitation (Note: the actual rainfall at the ranches overtopped the rain gages). The resulting

peak flow from the Altar and Brawley Washes "overtopped Ajo Highway (State Highway 86) near Three Points and caused some damage to the road shoulders and abutment fill." Dikes which surrounded farmlands further downstream "quickly overtopped and crevassed. . . . Most of the crop damage occurred in these agricultural lands". To assist in compiling the synthetic hydrograph, information was obtained from local land owners concerning the time flooding occurred; rate of rise; and time of flood crest. The report estimated that a peak flow of 38,800 cubic feet per second (cfs) occurred on September 26, 1962 near Mile Wide Road.

A subsequent summary written by R.H. Roeske¹² (in conjunction with a map of areas subject to inundation during a 100-year flow) also cited a peak discharge in 1962 of 38,800 cfs at Mile Wide Road, but additionally provided peak discharges at Three Points; Los Robles at Rico; and Los Robles Wash at Silverbell. These peak flow values were 13,000 cfs, 32,000 cfs, and 32,600 cfs, respectively.

A draft map of the flooding of 1962 provided information on the location of major tributary flows. The map showed significant tributaries flowing from the direction of the Sierrita Mountains and crossing Highway 86 east of Three Points. The tributaries intersected the Brawley Wash several miles north of Highway 86, and also joined Black Wash flows near the confluence with the Brawley Wash¹³.

2. *Flood of September 1970*

A 1978 USGS report (R.H. Roeske, et al.)¹² summarizes September 1970 floods in Arizona, Colorado, Utah, and New Mexico, and provides a skeletal summary of the impact on the Brawley Wash system. The "flooding began on September 4, and the last thrust of the storm caused additional flooding on September 6." Most of the flows entered Altar Wash, located south of Three Points, from the west. The gaging station on State Highway 86 near Three points was submerged, and the "bridge was overtopped and traffic was halted for several hours". Downstream of Three Points, "wide areas of desert and farmland were inundated".

Discharges for the basin were described from upstream to downstream. South of Three Points, the gage on the Altar Wash at State Highway 286 was washed out. The maximum discharge on Altar Wash was subsequently calculated to be 22,000 cfs. This peak discharge estimate decreased to 13,700 cfs at the gaging station located near Three Points; and further decreased to 6,140 cfs at Mile Wide Road.

A short summary, written in conjunction with a map of 100-year floodprone areas,¹⁴ repeats the peak-flow values, and additionally provides a discharge for Los Robles Wash at Trico Road (Estimate: 4,490 cfs).

3. *Significant flows in October 1983 , July 1990, and August 1993*

The Brawley Wash area has had significant flows in years subsequent to 1970, but detailed reports were not compiled for these events. This may have been due to the extensive damage and consequential attention paid to nearby urban watersheds, such as the Santa Cruz River, Rillito Creek, or the Black Wash tributary to the Brawley Wash.

In 1983, while the Santa Cruz sustained record flows and damages were highlighted in the national news, a USGS gage record for the Brawley Wash near Three Points showed a flow of 19,100 cfs¹⁵. This discharge is the largest peak flow recorded at the Three Points crossing. The Brawley Wash peak flow then decreased, as the flood moved downstream, to a estimated value of 12,500 cfs on the Los Robles Wash near Silverbell. Several Brawley Wash gages were destroyed in the flood. After this flood event, debris lines were not used to obtain peak-flow estimates, and damaged gages were not replaced.

In July 1990, rainfall averaging 4.2 inches in 1-3 hours fell within the Black Wash watershed (a tributary to the Brawley Wash). A storm assessment prepared by the Department of Transportation and Flood Control District Planning Division¹⁷ stated that flow estimates for a series of points along Brawley Wash are "less than 10,000 cfs". USGS gage data was not available along the downstream Brawley Wash system; however, the report on the Black Wash flood stated that the Brawley Wash "experienced deep flows as both sheet flooding and concentrated flows."

A significant flow was also recorded in August 1993 on the Altar Wash and on the Brawley Wash at Three Points¹⁵. A gage in Altar Valley showed a flow of 6,390 cfs, and at Three Points the flow increased to 10,800 cfs. These flows affected the upstream portion of the study area. Information for the downstream gages was not available.

IV. DATA COLLECTION

Aerial and topographic mapping, hydraulic data, and related technical resources which were available for the study area were collected in order to establish the alignment of the flood corridors for the Brawley Wash area. These resources (see references) included:

- Historic flood descriptions and studies for the Brawley Wash (previously discussed)
- Aerial photography from 1953, 1972, 1986, 1990, 1995, 1996, and 1998
- Two Soil Surveys of the Avra Valley area
- USGS Topographic Mapping
- FEMA Flood Insurance Studies and Flood Insurance Rate Maps
- USGS Flood Study for Avra Valley
- Detailed Studies and topographic mapping for portions of the Brawley Wash

A. Watershed Area

A comprehensive hydrologic analysis was not included as a part of the scope of work for the "Brawley Wash Primary Flood Corridor Study." As a consequence, data for the watershed areas and 100-year peak flows were taken from published documents. The FEMA FIS was considered to be the primary source of hydrologic information, and the Roeske Study of 1977 was used as a secondary source of hydrologic data. Additionally, a tributary watershed was delineated east of Three Points in order to provide supplemental flood-corridor information for the Brawley Wash along a segment located between Three Points and the Black Wash. The information has been provided within Table 2 of this report, along with the data source for each tributary or watercourse reach.

B. Soils Information

Soil data was derived from two studies compiled by the Soil Conservation Service (now called the Natural Resource Conservation Service, or NRCS). One study provided detailed soils mapping for a large portion of the study area, and the other study had a more general mapping of soils distribution in the Avra Valley area. The detailed study, the "Soil Survey of Tucson Avra Valley Area, Arizona," covered the northern 2/3 of the study area. The more general study, the "Eastern Pima County Soil Survey," was consulted for those Brawley Wash Study areas which were excluded from the more detailed mapping.

Soil classes were obtained from the maps and the detailed soil characteristics were requested from the NRCS for these specific soil classes. Three characteristics were of particular interest: (1) the existing erosiveness of the soils; (2) the tendency for erosion of the soils; and (3) the permeability of the soils. These soil characteristics were used as an aid in corroborating channel alignment, the potential for lateral migration, and for assessing possible previous alignments of major braids of the Brawley Wash.

TABLE 2: Sources of Discharge and Flow Data

Location/ Wash Name	Data Source	Watershed Area (mi ²)	100-Year Flow (cfs)
Near Three Points/ Brawley Wash	USGS (Roeske)	776	27,000
East of Three Points/ Un-Named Tributary	SLA Watershed Delineation	26.77	N/A
At Mile Wide Road/ Brawley Wash	USGS (Roeske)	1,077	32,000
North of Manville/ East Branch Brawley Wash (split flow calculated)	USGS (Roeske)	N/A	21,000
	SLA detailed Mapping for PCFCD	N/A	14,000
North of Manville/ West Branch Brawley Wash (split flow calculated)	USGS (Roeske)	N/A	14,000
	SLA detailed Mapping for PCFCD	N/A	21,000
North of Manville/ Lateral flow between East & West Branches (split flow calculated)	SLA detailed Mapping for PCFCD	N/A	12,000
Ajo Highway/ Black Wash	1995 FEMA FIS for Pima County	48.8	8,872
Above Confluence with Blanco Wash/ Los Robles Wash	1995 FEMA FIS for Pima County	1,165	35,000

C. Aerial Photography and Topography

USGS Topography of the area was collected for the Brawley Wash area. This included six 1" = 24,000" quadrangle maps from the "West of Marana" quadrangle on the north, to the "Three Points" quadrangle on the south. Most quadrangle maps contained 10' contour-interval mapping in the Brawley Wash lowland areas.

Detailed topographic mapping was available for approximately 15 sections of land located south of the Emigh Road alignment¹⁸. The topographic information was digital-based, and contour intervals were 2 feet. This mapping provided additional information on the East and

West Branch flow distributions of the Brawley Wash, as well as for the lateral flow which occur between the two washes.

Aerial orthophoto flights were flown for the NRCS in 1953 and in 1972. These flights were flown in conjunction with the soil surveys previously mentioned. The orthophoto photography of 1953 and 1972^{4,5} spanned two significant floods which occurred on the Brawley Wash in 1962 and 1970.

Nonrectified aerial flights were available for the years 1986, 1990, 1995, 1996, and 1998. These flights documented residential development, agricultural use, and significant watercourse changes located near the Donaldson Dam area.

V. DATA LIMITATIONS

Detailed aerial or topographic information was not available for the entire Brawley Wash watershed. Detailed (2-foot contour) topography had been flown for approximately 15 sections of the study area located north of Manville Road and south of the confluence with Los Robles Wash. USGS topography was used elsewhere. Recent (1990, 1995, 1996, 1998) aerial photography was nonrectified. These aerials provided accurate visual comparisons, but did not allow for precise overlays or detailed measurements to be translated from past studies to recent aerial coverage.

Detailed soils mapping was available for approximately the lower two-thirds the Brawley Wash study area (i.e., from approximately the Black Wash confluence to the Los Robles Wash confluence). General geomorphic and soils information were available for the entire Brawley Wash watershed.

Gages which were damaged during the 1983 floods were not repaired to allow for collection of hydrologic information during more recent runoff events. This has left gaps in the data collected along the Brawley Wash system.

The FEMA mapping performed along the Brawley Wash used approximate methods. An overlay of the Brawley Wash Primary Flood Corridor with FEMA data shows correlations between the AO depths and USGS topography; however, the FEMA FIS did not provide a continuous floodway corridor.

VI. DATA ANALYSIS

A. Study Methodology

State Standard 2-96³ provides guidelines for defining floodways for areas which have not been identified by FEMA. The document states that administrative floodways shall be defined in accordance with State Standard Attachment 2-96, unless the county, by virtue of its floodplain ordinance, has established a more stringent standard that must be followed. Standard Attachment 2-96 provides three methodologies that can be used to define the width of an administrative flood corridor. The first phase of the "Brawley Wash Primary Flood Corridor Study" determined that the most appropriate methodology for the determination of an administrative flood corridor would be to use a "Level I Flood Corridor Width," detailed within Appendix F of State Standard 2-96. This methodology works best when there are limitations on data and detailed topography.

A Level I procedure assumes that data may be limited to use of a USGS quadrangle map for analysis purposes. The methodology provides the equation to describe the relationship between the watershed area and a standard flood corridor width. This equation is:

$$FW = 377A^{0.289}$$

Where FW is the floodway width; and A is the watershed area, in square miles.

B. Corridor Width Determinations

Primary Flood Corridor widths were calculated based upon the watershed areas which are listed in published in FEMA and USGS studies, with the exception of the area of one watershed located east of Three Points, which was specifically delineated for this study. This delineated watershed contributes to a major tributary joining the Brawley Wash at a point located northeast of Donaldson Dam and south of the Black Wash confluence.

The West and East Branches of the Brawley Wash are channels which split from upstream corridors. The channel widths reflect the reduced flow values. Distribution values were obtained from a PCFCD funded study utilizing the detailed topography in the East/West Brawley reaches, and also by using previously published flow distributions, as contained within the 1977 USGS Flood Study¹⁴ previously referenced herein. Areas were assigned to the East and West Branches of the Brawley Wash using proportional values from these split-flow quantities.

The reasonableness of all Primary Flood Corridor widths were checked with normal-depth calculations using Mannings Formula for uniform flow. Average corridor depths did not exceed three feet under encroached conditions. These flow depths were checked to insure that the historically wide flood pattern of the Brawley Wash was maintained so that the overall impact of the flow corridor would be minimized.

C. Corridor Alignment Determination

Corridor alignments were based on the information previously listed within this report under Section IV, "Data Collection". Historic information, aerial photography, topography, and previous studies were generally consistent in the depiction or delineation of primary braids of the Brawley Wash. New information was also added—such as the construction of channels at the Shuk Toak Farm, and the channelization of the Donaldson Dam.

Several sources of information were compared while determining the alignment of the primary corridors. Overlays were constructed of 1953 and 1972 aerial photography^{19, 20}. These photographic series spanned two significant flood events. FEMA Mapping was then compared to the 1953/1972 photography and USGS topography. Available detailed topography was overlaid in the preliminary corridor alignments to assess consistency. Soils information was then compared to past primary braids, FEMA mapping, and USGS topography.

D. Soils Analysis

Soil characteristics were used to corroborate channel alignments, particularly in areas where flow paths were less defined. Soil data was derived from two studies compiled by the NRCS. The detailed study, the "Soil Survey of Tucson Avra Valley Area, Arizona," covered approximately the northern two-thirds of the study area. The more general study, the "Eastern Pima County Soil Survey," provided coverage for the entire Brawley wash reach, but was used primarily for those areas which were not covered by the detailed study. Three characteristics were of particular interest: (1) the existing eroded soils; (2) the tendency for erosion of the soils; and (3) the permeability of the soils.

Soils which were *already* degraded at the time of the NRCS 1972 field survey were classified as "severely eroded". These soils were generally found within in the main flow paths of the Brawley Wash. The second attribute of interest, the *tendency* for erosion or the "erodibility" of soils, is calculated as a function of slope and soil-horizon characteristics. Soil erodibility provides insight into the tendencies for wash braids to migrate laterally. The third characteristic, the permeability of the soil, may be linked with possible past alignments of watercourse reaches, if the soils correlate with other expected patterns and confines.

The erodibility and permeability data for each soil type was requested from the NRCS. The NRCS retains a data base with the attributes for each soil class. The erodibility (or permeability) data had been recorded in inches, according to the depth of each horizon within the soil profile. There were often three or more horizons for each soil profile. The detailed information on each horizon within each soil class was averaged over the entire profile, or for 60 inches, whichever was more limiting. These standardized soil profiles allowed for overall comparisons of erodibility or permeability between the soil types.

VII. REACH-BY-REACH DISCUSSION

Phase I of the "Brawley Wash Primary Flood Corridor Study" determined that there should be several corresponding sources which verify the main flow paths along the Brawley Wash. The basis for the flood corridor alignments involved corroboration using several independent sources, which are outlined on a reach-by-reach basis below:

Reach 1

Historic and aerial documentation verify that the Brawley Wash has been relatively defined through the Three Points to Donaldson Dam reach. Overtopping of the Three Points bridge was mentioned in reports on the 1962 and 1970 floods. Aerial photography shows that this bridge was reconstructed sometime between 1970 and 1986. A levee system remains intact on portions of the east side of the channel, primarily through developed or agricultural areas. Lateral scarring indicates that, during large events, these systems may breach. At a distance of 4 to 6 miles north of Three Points and Highway 86, lateral flow weirs to the northeast in several primary braids.

The more general NRCS "Eastern Pima County Soils Survey" supplied the soils information for Reach 1. Soils maps show a "Arizo-Riverwash" complex along the defined reach of the Brawley watercourse. The averaged permeability for the riverwash complex was high, indicating the presence of repeated scouring and deposition. Other soils in the area were mildly erodible, but did not have as significant a degree of permeability as those located along the defined channel area.

The FEMA FIS maps delineate a semi-riverine flow to a point located south of the Donaldson Dam. According to the Pima County "Flood Insurance Study," along "larger channels and where depths exceeded 4 feet, approximate zone designations were used."

Based on the above evidence, a single Primary Flood Corridor Alignment was assigned to Reach 1 of the Brawley Wash. Soils studies, FIS maps, and historic documentation corroborate this choice. The width of the alignment was assigned based upon the USGS calculated watershed area. Flood Corridor Widths are summarized in Table 4 of this report.

Reach 2

Three primary flood corridors have been identified with respect to this Reach 2 of the Brawley Wash—one aligned to the northeast, a central corridor, and a western corridor. This reach is characterized by a wide, braided network of ill-defined channel sections. The three Primary Flood Corridors reflect the current dispersed flow conditions within the area.

The western corridor was mapped primarily due to significant changes in the apparent quantity and direction of the flow exiting the Donaldson Dam. The construction and subsequent

breaching of Donaldson Dam has been documented via aerial photography. In 1986, aerial photography shows the dam was breached to channelize flows in an northerly direction. The effects of this channelization were still active in 1998 photography. Significant sediment deposition and scarring occurred between 1995 and 1998. The striations indicated an easterly flow out of the channelization. The flow appeared to be captured by the historic northerly alignment of the wash, which crosses Mile Wide Road at a point located approximately 1.5 miles west of the Black Wash/Brawley Wash combined flow. The significant evidence of flow out of the Donaldson Dam area of channelization led to the selection of the western primary flood corridor within Reach 2.

Tributary flow enters the Brawley Wash from two sources along this reach—an un-named tributary from the south and the Black Wash from the east. The un-named tributary enters the northeasterly aligned Brawley Wash flood corridor prior to the Black Wash confluence. The watershed, which extends into the Sierrita Mountains, was a significant source of inundation during the 1962 flood. The Black Wash is also a major tributary, and it is estimated that it contributes approximately 8,900 cfs during the peak of a 100-year flow.

The soils distribution in this reach reflects the less defined nature of the watercourse. The eastern corridor is dominated by Trix-Estrella (Ts3) complex of soils along the most defined channels. Ts3 is classified as "severely eroded." Soils on either side of this eroded complex are mildly erosive, and will not migrate easily given undeveloped watershed conditions.

Soils along the center corridor are mildly to moderately erosive, and are dominated by the Anway complexes. The western corridor (from the Donaldson Dam area) is the least prone to lateral erosion of existing channels under natural conditions. The soils along the western corridor are dominated by Sonoita soils.

The central and eastern Primary Flood Corridors of this Reach 2 are dominated by AO, depth 3, zones as mapped by FEMA and depicted on the FIS rate maps. This is a reasonable overlay for the eastern corridors. One basic departure from previous alignments is the mapping of the western Primary Flood Corridor. The FIS rate maps appear to be significantly influenced by the USGS Mapping performed by R.H. Roeske. The Roeske report, however, was published prior to the breach and channel changes which have occurred north of the Donaldson Dam.

The Tohono O'odham Nation recently completed a design study for the Schuk Toak farm development. This development will cross the majority of the Brawley Wash flood plain from Sandario Road westward for a distance of approximately 3.5 miles. Since the development is located in the heart of the confluence area, it has a significant impact on drainage. To offset this impact, two interior flood-control channels will be used to convey the 100-year discharge through the development. The Brawley Wash Primary Flood Corridors accommodate the Schuk Toak farm development channelization projects, as well as the Donaldson Dam diversion. These channelization projects are reasonably aligned with the eastern Primary Flood Corridors of the Brawley Wash.

In addition to the Tohono O'odham Nation development, the Pasqua Yaqui Tribe purchased the 5,300-acre Tortuga Ranch from John Donaldson on March 12, 1999. A tentative map of property acquired by the tribe has been included with this report.

To summarize, based upon development and natural Brawley Wash flow paths, three Primary Flood Corridors were assigned to Reach 2. Historic aerial photography, soils maps, and recent impacts of flood control projects corroborate the alignment. The width of the Primary Flood Corridors were assigned based on the USGS calculated watershed area from the 1977 Roeske study. A secondary channel width was assigned to a contributory watershed area, as delineated on USGS Quadrangle Maps. The Flood Corridor Widths are summarized in Table IV of this report.

Reach 3

Reach 3 extends from Mile Wide Road to the divergence of the East and West Branches of the Brawley Wash. Through this reach, the Brawley presents itself as a wide corridor of incised interbraided washes. Reach 3 has historically been left in a natural state, without levees or catchments for agricultural purposes.

The central and eastern flood corridors in Reach 3 join at Mile Wide Road, and the Primary Flood Corridor is dominated by the Ts3 complex of soils along the most defined channels. Ts3 is classified as "severely eroded." Soils on either side of this eroded complex are mildly to moderately erosive, and will not migrate easily given undeveloped conditions.

The western corridor joins midway between Mile Wide Road and Manville Road. The western corridor (from the Donaldson Dam area) is, at this time, the least prone to lateral erosion of existing channels. The soils along the western corridor are dominated by a combination of Sonoita and Anway soils.

The historic FEMA FIS maps correlate reasonably well with the primary flood corridor identified within this reach. Zone AO3 delineations are wide though the eastern Primary Flood Corridor, and they follow the same alignment. The west Primary Flood Corridor is substantially broader than the FIS Zone AO, depth 3, in that area; but follows the same alignment. It should be reiterated that the FIS seems to follow the 1977 USGS Roeske Study, which was most likely published prior to the breaching of Donaldson Dam and upstream channelization.

Based upon natural alignments along the wash, Primary Flood Corridors were assigned to Reach 3. The width of the Primary Flood Corridors were assigned based on the USGS calculated watershed area from the 1977 Roeske study. Flood Corridor Widths are summarized in Table 4 of this report.

Reach 4

Reach 4 extends from the divergence of the East and West Branches of the Brawley Wash to approximately the Emigh Road Alignment. A comparison of the 1953 and 1970 aerial photographs for this reach showed relative stability of two of the three alignments chosen for Reach 4. The East Branch of the Brawley Wash, however, showed signs of increased braiding and lateral diversions along the traditional flow path.

The West Branch of the Brawley Wash is dominated by the Ts3 complex of soils, and also contains Vekol soils. Ts3 is classified as "severely eroded," and generally contains the most defined braids of the Brawley Wash watercourse. The East Branch of the Brawley Wash has mildly to moderately erosive soils of the Anway and Vekol Complexes.

The lateral channel between the East and West Brawley washes is mildly erosive and dominated by Vekol soils. Of the three corridors in Reach 4, the lateral channel contains the least erosive soils, and contains the least defined wash braids.

The Primary Flood Corridor alignments in this reach are very similar to the FEMA FIS maps. Zone AO, depth 3, follows the flood-corridor alignments closely; however, it is slightly narrower than the Primary Flood Corridor.

Based on development and natural Brawley Wash flow paths, three Primary Flood Corridors were assigned to Reach 4. The width of the Primary Flood Corridors were assigned based on the watershed area listed within the FEMA FIS, as well as upon split-flow information more recently generated. Flood Corridor Widths are summarized in Table 4 of this report.

Reach 5

Reach 5 of the West Branch of the Brawley Wash extends from the Emigh Road alignment to the alignment of the detailed FIS Study compiled by FEMA. The East Branch of the Brawley Wash extends to the Los Robles Wash confluence. Agricultural use of these lands has been fairly consistent since the 1950's.

The West Branch of the Brawley Wash is dominated by the severely eroded Ts3 complex of soils. Soils surrounding the Ts3 complex are not erosive when compared to other soils of this study. The East Branch contains mildly erosive soils dominated by the Vekol and Anway complexes. The watercourse along the East Branch was channelized prior to the date of the earliest aerial photography available, and therefore the configurations which once characterized the natural wash system cannot be easily determined.

The FIS Map delineations for AO, depth 3, along Reach 5 of the Brawley Wash continue to be narrower than the Primary Flood Corridor alignment. "Depth 3" delineations appear to reflect the constriction by levees and channelization, despite FIS statements about the Avra Valley

systems that “Historically, manmade channels have been overtopped and embankments have failed during major flooding, and they will probably not protect against the 100-year flood.”²⁰ Portions of the AO, depth 3, delineations in these areas should be considered as “at risk” for substantial widening in the future.

Based upon development and natural Brawley Wash flow paths, two Primary Flood Corridors were assigned to Reach 5. The width of the Primary Flood Corridors were established based upon watershed areas listed within the FEMA FIS. Flood Corridor Widths are summarized in Table 4 of this report.

VIII. RESULTS

The widths of the primary flood corridors were calculated in accordance with the guidelines outlined within the State of Arizona Department of Water Resources "Delineation of Riverine Floodplains and Floodways in Arizona." The formula provided in the referenced document represents the best available methodology for this study effort, given the type and detail of the available information. The alignment of the floodway was based on several corroborating sources which verified the main flow paths along the Brawley Wash. The basis for the flood corridor alignments developed during this study involved concurrence and corroboration of:

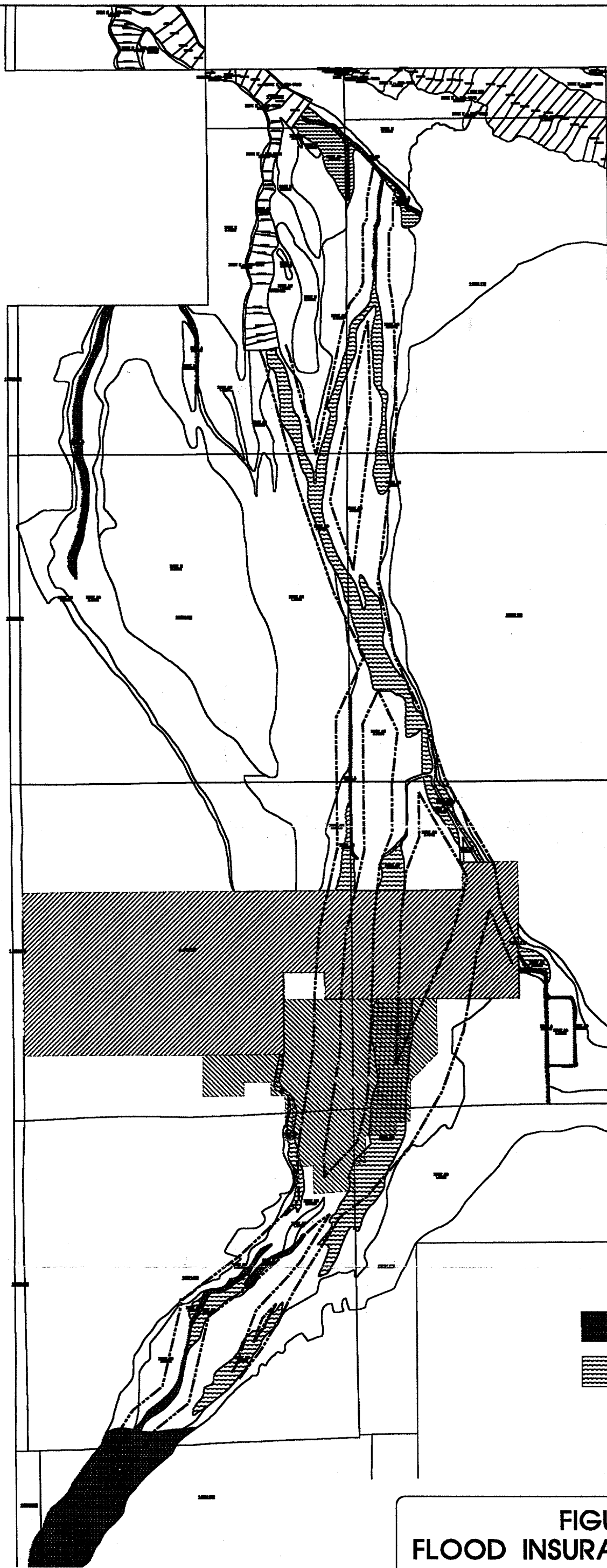
- Soils information for the Brawley Wash
- Alignments of previous flood studies
- Historic channel alignments depicted in aerial photography
- USGS Quadrangle Maps, topography, and channel alignments
- Available detailed topography
- The impact of current flood-control projects

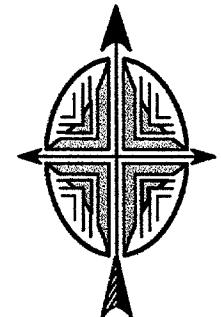
A. Soils

The results of the soils comparisons showed that a majority of soils in the Brawley Wash lowlands are mildly erosive. Trix, Grabe, Glendale, and Anway series soils generally showed a mild potential for erosion. The Laveen and Gila series soils generally showed the most erosive potential. Much of the moderate and mildly erosive soils were within the proximity of the main channels. As previously mentioned, in the 1972 detailed soils study some soils were found to be "severely eroded". These soils (the Trix-Estrella Complex, "severely eroded" and "Glendale Silty Clay Loam, "severely eroded") fell within the main flow paths of the Brawley Wash, as did the "Arizo-Riverwash" complex of the Eastern Pima County study.



B. Flood Summaries and Flood Studies

The historic data from the 1963 and 1970 floods on the Brawley Wash support the single flood corridor along Reach 1. The dual and multiple flood corridors in subsequent reaches are supported by the descriptions of widespread flooding and destruction of agricultural levees. The FEMA FIS follows the approximate alignments of the Primary Flood Corridors through the study area, with the exception of the western corridor of Reach 2 (See Figure 2). The western corridor of Reach 2 was added due to the channel changes north of the Donaldson Dam. These changes included the construction of a channel in the northeasterly direction, as well as evidence of increased erosion and flow feeding into the western corridor of Reach 2.




NORTH
 1"=10,000'

LEGEND

-  ZONE A
-  ZONE AO-3

**FIGURE 2:
FLOOD INSURANCE RATE MAP
AND BRAWLEY WASH
PRIMARY FLOOD CORRIDOR**

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C. Aerial Photography and Topography

Orthographic photography was available for the years 1953 and 1972. These flights spanned two of the most significant flood events on the Brawley Wash, which occurred in 1962 and in 1970. An overlay of the two aerial series showed that the significant spine washes remained intact during the intervening time period between these two events. These two aerial flights supported the selection all flood-corridor alignments, except for the western corridor of Reach 2. The 1972 photography showed an increase in watercourse splits and some scarring north of Manville Road, along the East Branch of the Brawley Wash, giving more weight to the delineation of an eastern flood corridor along Reach 4 of the study area.

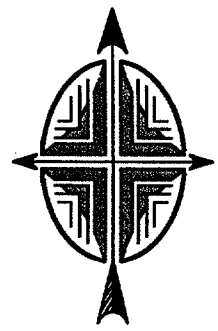
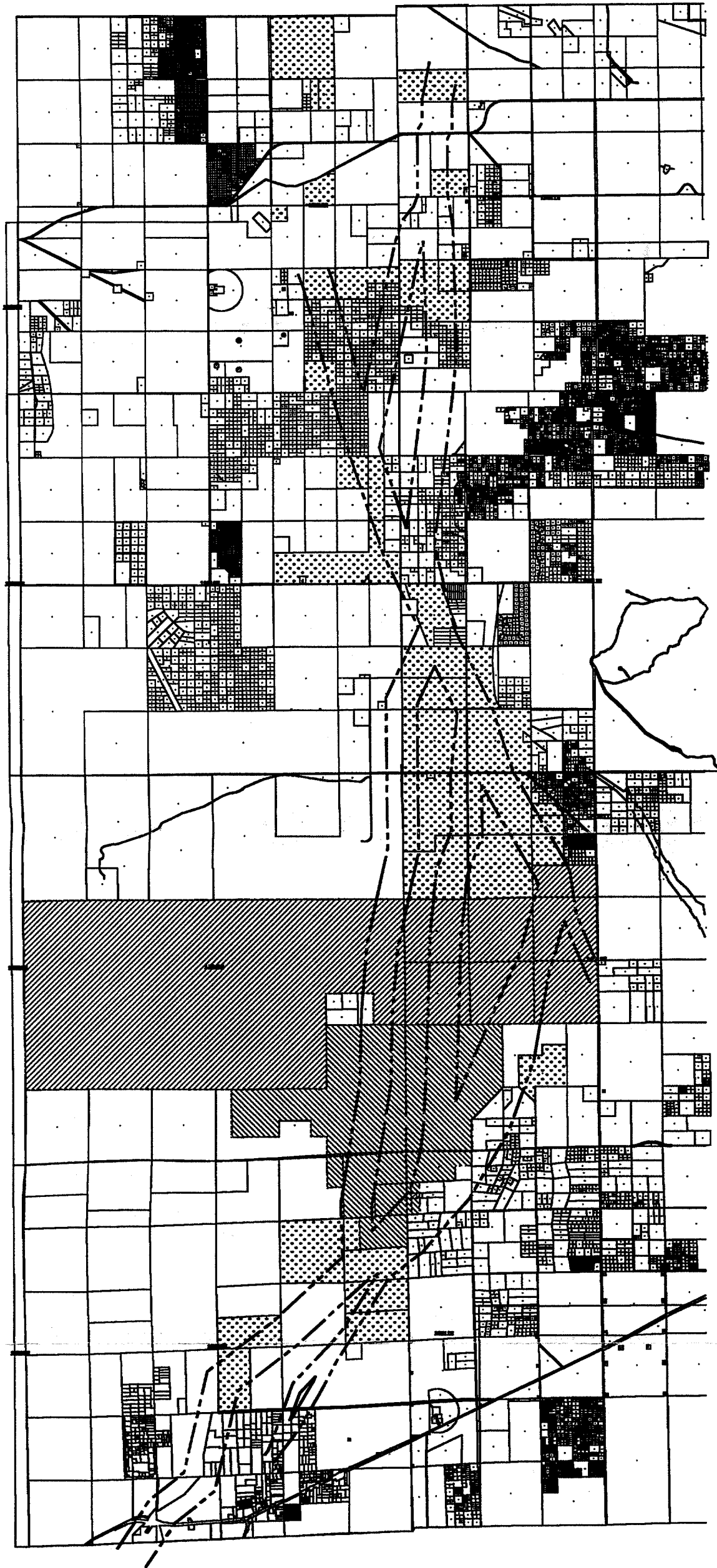
Aerial photography flown in 1986 showed extensive excavation in the Donaldson Dam area. The dam had been breached, and channels had been excavated which continued for well over a mile to the north. In aerial photos taken in 1998, the channelization north of Donaldson Dam showed significant signs of flow and erosion in the eastern direction. This constitutes a significant diversion from past flow alignments, and may significantly alter future flood flow paths along the Brawley Wash. This change has been reflected by incorporating the addition of a western flood corridor along Reach 2 of the study area.

Aerial photography taken in the 1990's showed a significant increase in land splits and mobile-home development in the Three Points area, as well as near the West and East Branches of the Santa Cruz River north of Manville Road. Land ownership within the Brawley Wash Flood Corridors is shown on Figure 3 of this report; and summarized in Table 3 of this report, which follows.

TABLE 3: Land Ownership		
Owner	Percentage	Acres
Public (Federal, State, County, City)	29%	5,151
Native American (Tohono O'odham, Pasqua Yaqui)	28%	4,997
Private	43%	7,642

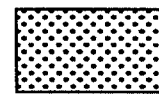
D. Flood Widths

A list of Flood Corridor widths was calculated according to the procedure described in the analysis section of this report. Maps of the Primary Flood Corridor (1" = 24,000") have been submitted to the District under separate cover, and include (1) a parcel overlay; (2) a U.S.G.S. Quadrangle overlay and (3) a FEMA FIS overlay. These widths are also presented in Figure 4 of this report; and are summarized within Table 4 of this report, which follows.



NORTH
1"=10,000'

LEGEND



PUBLIC LANDS



NATIVE AMERICAN LANDS



PRIVATE LANDS

NOTE: PARCEL OWNERSHIP WAS DETERMINED FOR PRIMARY FLOOD CORRIDOR AREAS ONLY.

**FIGURE 3:
PARCEL OWNERSHIP WITHIN
BRAWLEY WASH PRIMARY
FLOOD CORRIDOR**

TABLE 4: Flood Corridor Width				
Location	Wash Name	Watershed Area (mi²)	100-Year Flow (cfs)	Flood Corridor Width (ft)
Near Three Points	<i>Brawley Wash</i>	776	27,000	2,579
East of Three Points	<i>Un-Named Tributary</i>	26.77	N/A	975
At Mile Wide Road	<i>Brawley Wash</i>	1,077	32,000	2,836
Near Manville	<i>East Branch Brawley Wash</i>	NA	21,000	2,503
Near Manville	<i>West Branch Brawley Wash</i>	NA	21,000	2,503
North of Manville	<i>Un-Named Lateral Flow Between East & West Branches</i>	NA	12,000	2,129
Ajo Highway	<i>Black Wash</i>	48.8	8,872	1,160

R10E
R1E

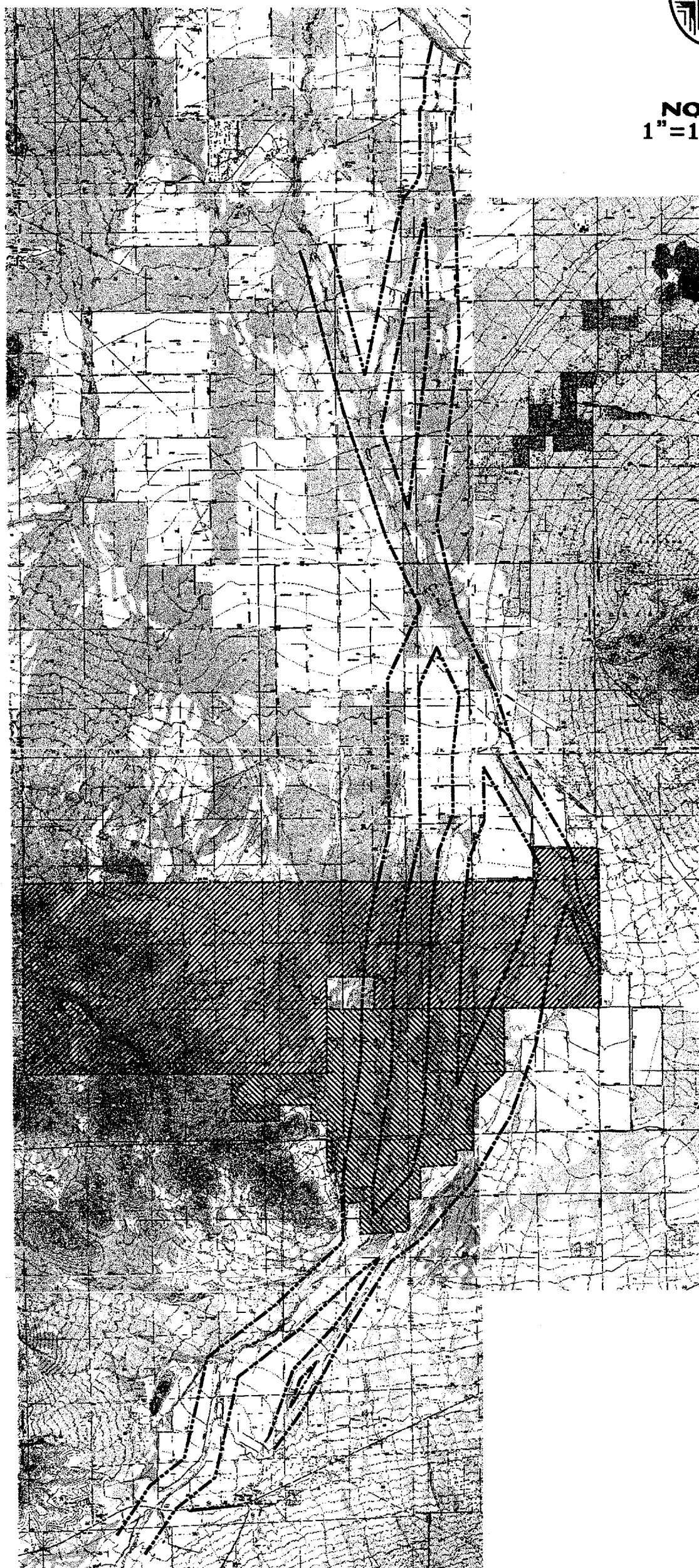


NORTH
1"=10,000'

T12S
T13S

T13S
T14S

T14S
T15S



R10E
R1E

FIGURE 4:
U.S.G.S. QUADRANGE MAPS
AND BRAWLEY WASH
PRIMARY FLOOD CORRIDOR

REFERENCES

1. Pima County Flood Control District, "Floodplain and Erosion Hazard Management Ordinance No. 1998-FC1" for Pima County, Arizona.
2. Federal Emergency Management Agency, "Flood Insurance Study," Pima County, Arizona, Unincorporated Areas. Revised February 8, 1999.
3. Department of Water Resources Flood Warning and Dam Safety Section, "Delineation of Riverine Floodplains and Floodways in Arizona," State Standard Attachment SSA 2-92. July 1996 (Revised).
4. Soil Conservation Service, "Soil Survey of Tucson-Avra Valley Area, Arizona," April 1972. (Orthophoto Aerials, 1953).
5. Soil Conservation Service, "Eastern Pima County Soil Maps," 1972. (Orthophoto Aerials, 1972).
6. Cooper Aerial Nonrectified Aerial Photographs, Scale: 1"=400', 1990 and 1998.
7. Photowise Nonrectified Aerial Photographs, Scale: 1"=400', 1995.
8. Landiscor Nonrectified Aerial Photographs, Scale: 1"= 1,200', 1996.
9. McLain Aerial Mapping and Surveying, Inc., Nonrectified Aerial Photographs, Scale: 1" ≈ 1,600', 1986.
10. United States Geological Survey Quadrangle Maps (7.5-Minute and 15-Minute). Various Quadrangles and Dates.
11. United States Geological Survey (Douglas D. Lewis), "Desert Flood—a Report on Southern Arizona Floods of September, 1962", April 1963.
12. United States Geological Survey, R. H. Roeske, "Floods of September 1970 in Arizona, Utah, Colorado and New Mexico," 1978.
13. United States Geological Survey, 1962 Flood Map supplied by Pima County Department of Transportation and Flood Control District.
14. United States Geological Survey, R. H. Roeske, "Areas Subject to Inundation by the 100-Year Flood in Avra Valley, Pima County, Arizona," 1977.

15. United States Geological Survey Website: waterdata.usgs.gov/nwis-w/AZ (Gage Data Obtained on 3/16/99).
16. United States Geological Survey, "Floods of October 1983 in Southeastern Arizona," Water-Resources Investigations Report 85-4225-C, 1985.
17. Pima County Department of Transportation and Flood Control District, "Storm Assessment for the Event of July 24, 1990," August 7, 1990 (Revised).
18. Simons, Li and Associates, Inc., "Brawley Wash Floodplain Study," September 1996.
19. Federal Emergency Management Agency, "Flood Insurance Rate Maps," August 2, 1995.
20. Federal Emergency Management Agency, "Flood Insurance Rate Maps," Digital version, February 8, 1999.
21. Pima County Department of Transportation and Flood Control District, "Black Wash Drainage Analysis and Policy Assessment Report," September 12, 1990 (Revised).
22. United States Geological Survey, J. O. Rostvedt, et al., "Summary of Floods in the United States During 1962," Geological Survey Water-Supply Paper 1820.
23. United States Geological Survey, "Arizona Floods and Droughts—National Water Summary 1988-89 Floods and Droughts: Arizona," United States Geological Survey Water-Supply Paper 2375.