Catalina Foothills Watercourse Studies: Technical Data Notebook for Hydrologic and Hydraulic Mapping of the Woodland Wash and its Tributaries, Pima County Arizona.

FEMA FIRM Panel 04019C-1670K

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Prepared by

Evan Canfield, PE
Chief Hydrologist

Registered Professional Engineer (Civil)
Certificate No. 15610
SUZANNE J. SHIELDS
Date Signed 2/19/2010
Arizona U.S.A.

Suzanne Shields, PE
Director

Pima County Regional Flood Control District
97 E Congress Street
Tucson Arizona, 85701

Pima County Regional
FLOOD CONTROL
DISTRICT

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Section 1: Introduction

1.1 Purpose

The purpose of this study is to provide flood and erosion hazard information for Woodland Wash for use by the Pima County Regional Flood Control District (District) in floodplain use permitting and floodplain management. More specifically, it provides:

- discharge values for sub-basins and important concentration points;
- hydrographs for use with floodplain mapping;
- floodplain mapping for channels with contributing areas greater than 1 square mile, and channels with 100-yr discharges greater than 2000 cfs, which are treated differently under the Pima County Ordinance.

1.2 Project Authority

The State of Arizona has delegated the responsibility to each county flood control district to adopt floodplain regulations designed to promote the public health, safety and general welfare of its citizenry as provided under the Arizona Revised Statutes, Title 48, Chapter 21, Article 1, Sections 48-3601 through 3627. More specifically, A.R.S. 3609 directs county flood control districts to adopt floodplain regulations that:

> A. Regulate all development of land, construction of residential, commercial or industrial structures or uses of any kind which may divert, retard or obstruct flood water and threaten public health or safety or the general welfare; and
> B. Establish minimum flood protection elevations and flood damage prevention requirements for uses, structures and facilities which are vulnerable to flood damage; and
> C. Comply with state and local land use plans and ordinances, if any.
> In conformance with A.R.S. 3609, this ordinance provides for protection of the public health safety and welfare by regulation of flood and erosion hazard areas to control flood hazards and prevent repetitive loss from flood damage.
> D. The flood hazard areas of Pima County are subject to periodic inundation which may result in loss of life and property, create health and safety hazards, disrupt commerce and governmental services, require extraordinary public expenditures for flood protection and relief, and impair the tax base, all of which adversely affect the public health, safety, and general welfare.
> E. These flood losses are caused by the cumulative effect of obstructions in areas of special flood hazards which increase flood heights, flow velocities, and cause flood and erosion damage. Uses that are inadequately flood-proofed, elevated, or otherwise protected from flood damage, also contribute to the flood loss. (Ord. 2005 FC-2 § 2 (part), 2005).

Section 16 of the Pima County Ordinance describes the provisions for floodplain regulation in Pima County.

1.3 Project Location

The study was performed to provide drainage information for Woodland Wash (Figure 1.1). The site includes Sections 13-14, and 22-27 of Township 13 South, Range 15 East, Pima County, Arizona. Most of the wash is in FEMA Zone X, as shown on the current Flood Insurance Rate

Map (FIRM) number 04019C-1670K. The most downstream portion of FEMA A-zone mapping extends about 1/4 of a mile upstream of the confluence with the Woodland Wash (Figure 1.2). The limits of this study are also shown on Figure 1.2.

The watershed is approximately 6 square miles at its outlet. The upper portion of the watershed drains the Catalinas with well-defined and steep channels with an average gradient of 7%. At the transition to the alluvial fan, flow becomes distributary in places and channel slope becomes shallower (<1%). Because of the distributary nature of the flow on the alluvial fan split flows occur that can bring more or less flow into any one channel.

A major split flow occurs at Gibbon Springs Wash, which is modeled as flowing into Woodland Wash, though some of it does flow into the Tres Lomas Watershed (Figure 1.2).

Most of the watershed is covered in desert brush with small amounts of mountain brush, herbaceous cover. Xeroriparian B Major zoning classifications of the watershed are SR, SP and CR-1 (Figure 1.3).

1.4 Methodologies Used for Hydrology and Hydraulics

Topographic, hydrologic and hydraulic analyses were performed to determine drainage conditions in Woodland wash. ArcGIS, Version 9.3, Pima County Hydrology Procedures (PC-Hydro), Version 5.3.1, HEC-HMS version 3.3 (HEC-HMS), Hec-RAS Version 4.0 (HEC-RAS), and HEC-GeoRAS, Version 4.1.1 (HEC-GeoRAS) were used for the analyses.

1.5 Acknowledgements

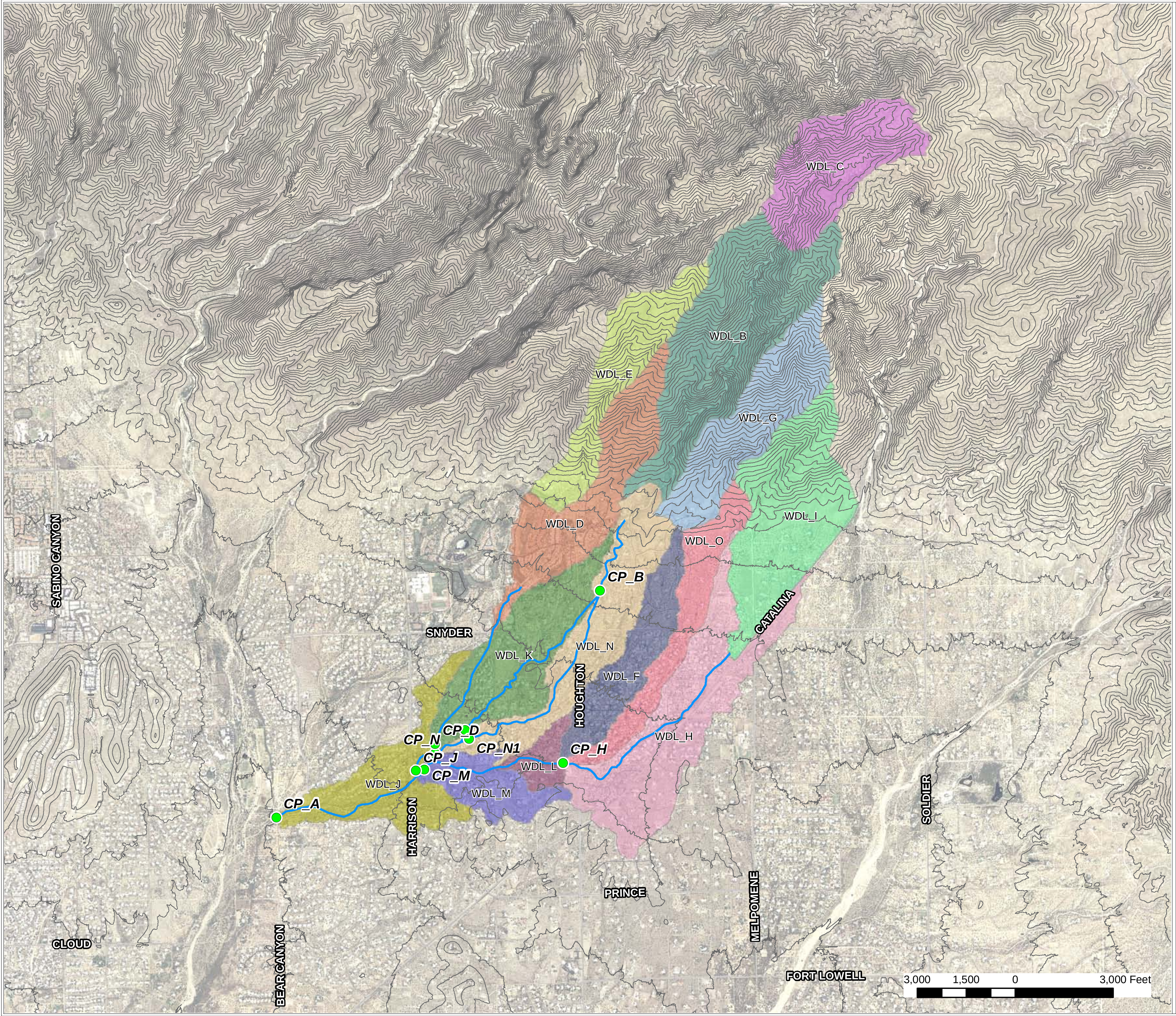
This study relied on assistance of RFCD GIS staff, who were integral to the development of the models and maps.

1.6 Study Results

The floodplains for delineation of watersheds greater than one square mile were delineated at part of this study. The study found several homes at risk for flooding during the 100-yr flood. The modeled discharge for the Woodland wash at the confluence with Sabino Wash (near the confluence with Tres Lomas) is 5,841 cfs, where the area is 5.95 square miles.

The channels draining greater than one square mile are not confined. The 100-yr discharge for all watersheds greater than 1 square mile is greater than 2000 cfs. The channels are not confined, and in most cases the 100-yr floodplain is about twice as large as the 25-yr floodplain. One channel with a watershed area of 0.83 square miles and a discharge of 1940 cfs is mapped. The remaining watersheds smaller than one square mile will be further refined as part of a future effort to map tributaries smaller than one square mile using the PC Hydro program to determine discharge.

Figure 1.1
Watershed Map
Woodland Wash



WoodCPs

Channels

Contour 50ft

Subbasins

- WDL_B
- WDL_C
- WDL_D
- WDL_E
- WDL_F
- WDL_G
- WDL_H
- WDL_I
- WDL_J
- WDL_K
- WDL_L
- WDL_M
- WDL_N
- WDL_O

Note: Photo is 2007 USDA

Pima County Index Map

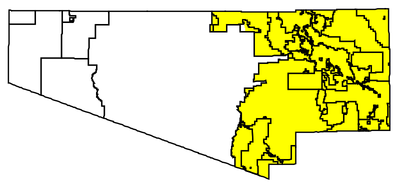


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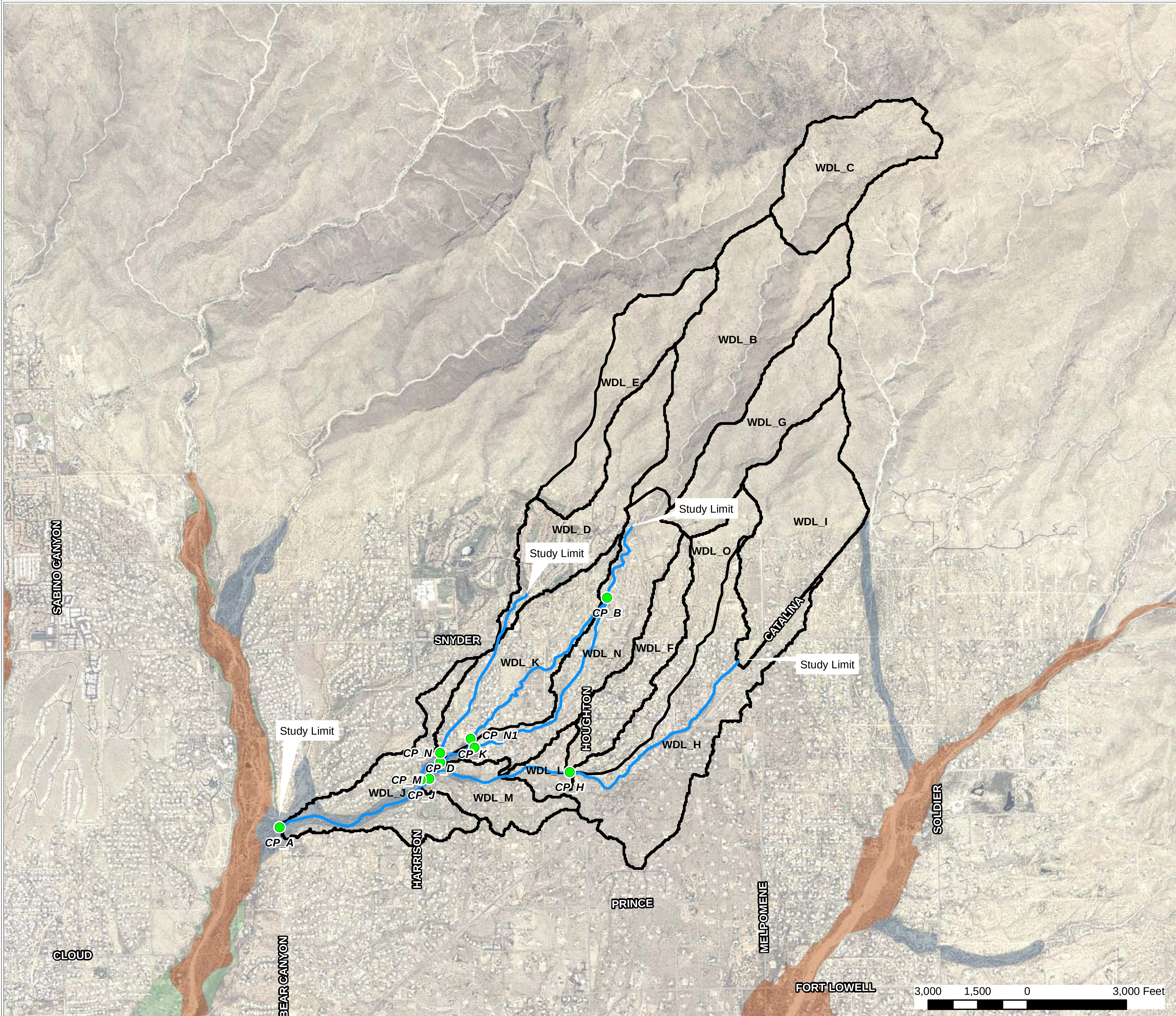
Figure 1.2
Study Limit
Woodland Wash



WoodCPs

Channels

Subbasins

Existing FEMA Floodplain

ZONE A

ZONE AE

ZONE X - SHADED

Note: Photo is 2007 USDA

Pima County Index Map

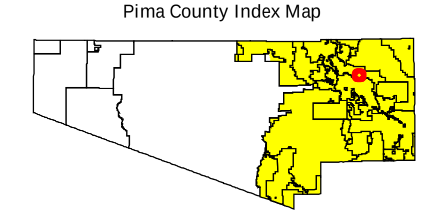


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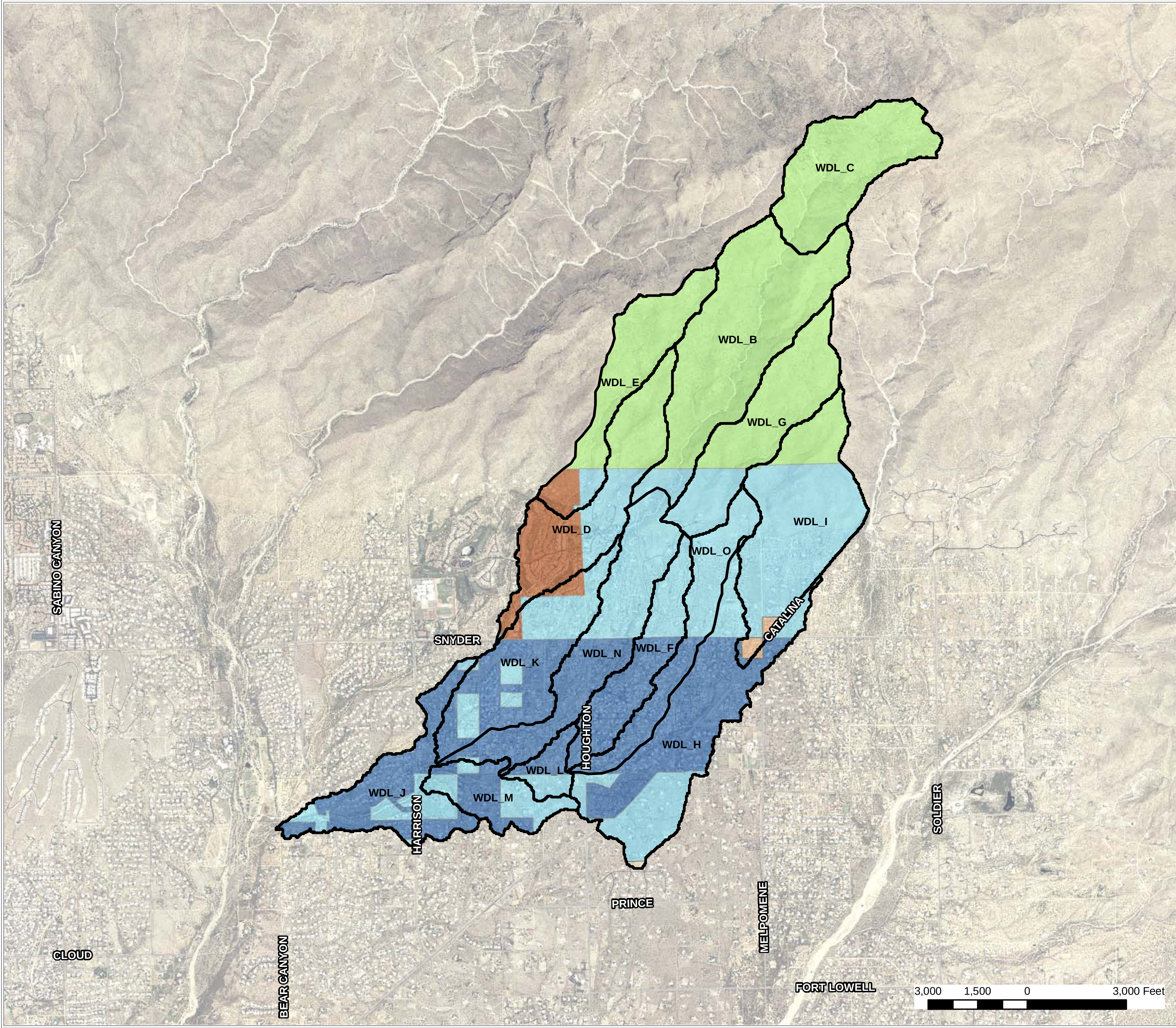
Figure 1.3
Zoning Classification
Woodland Wash



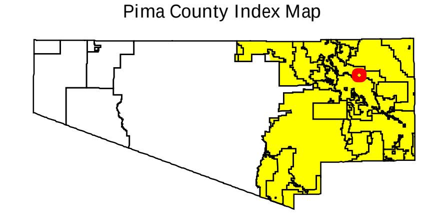
Subbasins

Pima County Zoning

- CB-1
- CR-1
- IR
- SP
- SR
- SR-2

Note: Photo is 2007 USDA

Pima County Index Map



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Section 2.0 Summary of Key Facts

2.1: General Information

2.1.1 Community: Pima County Regional Flood Control
2.1.2 Community Number: NFIP Community Number 04019C
2.1.3 County: Pima
2.1.4 State: Arizona
2.1.5 Date Study Accepted: February, 2010
2.1.6 Study Contractor: Pima County Regional Flood Control District – Evan Canfield
2.1.7 State Technical Reviewer: Not Applicable
2.1.8 Local Technical Reviewer: Suzanne Shields
2.1.9 River or Stream Name: Woodland Wash
2.1.10 Reach Description: Woodland Wash, Gibbon Canyon Wash (a tributary), and five un-named tributaries
2.1.11 Study Type: Hydrology and Hydraulics study of a Riverene System

2.2: Mapping Information

2.2.1 FIRM Panels: 04019C-1670K
2.2.2 Mapping for Hydrologic Study: Lidar based on 2006 flight for the Catalinas used to derive 15' grid and 10' and 20' contour interval maps using ARC-GIS 9.3
2.2.3 Mapping for Hydraulic Study: Lidar based on 2006 flight for the Catalinas used to derive a TIN for use with GeoRAS

2.3: Hydrology

2.3.1 Model or Method Used: HEC-HMS (v. 3.3) model parameterized using methods of RFCD Draft Tech Policy 018 (October 10, 2008)
2.3.2 Storm Duration: 3-hr
2.3.3 Hydrograph Type: SCS Unit Hydrograph
2.3.4 Frequencies Determined: 100 yr
2.3.5 List of Gages used in Frequency Analysis or Calibration: None
2.3.6 Rainfall Amounts and Reference: SCS Type II, NOAA 14 Upper 90% Confidence Interval
2.3.7 Unique Conditions and Problems: None
2.3.8 Coordination of Q's: Comparison with previous studies on file with RFCD and discharge estimates

2.4: Hydraulics

2.4.1 Model or Method Used: HEC-RAS 4.0, GeoRAS to parameterize
2.4.2 Regime: Modeled as subcritical
2.4.3 Frequencies for which Profiles were Computed: 100 yr
2.4.4 Method of Floodway Calculation: No Floodway
2.4.5 Unique Conditions and Problems: Boundary set at critical.

2.5: Additional Study Information:

Floodplains not delineated into recent subdivisions, which should have accurate floodplain maps. The primary objective of this study was modeling subdivisions platted before 1980.

Section 3: Survey and Mapping Information

3.1 Field Survey Information

No field survey was used.

3.2 Mapping

Study used lidar data collected by Sanborn Mapping in 2007 for mapping debris flows and characterizing flooding of the July 31, 2006 event. Coordinates were in Pima County projection:

Projection = State Plane, Arizona Central Zone
Datum = NAD83 HARN
Units = International Feet
North American Vertical Datum of 1988 (NAVD, 1988)

The 2007 Light Detection and Ranging (LiDAR) data collected to support the analysis of the 2006 flooding in the Catalinas provided the topography for this analysis. The LiDAR was used to derive three different kinds of topographic information. A Digital Elevation Model (DEM) derived on 15’ centers provided the basis for delineating the watershed and sub-basins (Figure 3.1). Contour maps derived from the DEM 10’ and 20’ con tour allowed modelers to visualize topographic differences in making decisions on how to model different areas. A triangular Irregular Network (TIN) derived from data was used to characterize the topography along channels used for the floodplain mapping process.

Section 4: Hydrology

4.1 Method description.

For the floodplain mapping, a 100-yr discharge is required. This analysis followed the guidance of the District's Tech Policy 018 (draft of 10/08). Most of the 100-year return interval peak discharge rates for watersheds were computed by using HEC-HMS (v 3.3). Discharge values were calculated for each sub-basin as well as for seven different junctions on the watershed.

4.2 Parameter estimation.

Methods are summarized in Table 4.1.

Table 4.1 - Methods used for a Hec-HMS analysis

	Selected Method
Rainfall Depth	NOAA 14, upper 90% Confidence Interval
Rainfall Distribution	3-hr SCS Type II Storm
Rainfall Loss	SCS Curve number
Time of Concentration	SCS Segmental Method
Transform	SCS Unit Hydrograph
Routing	Modified-Puls and Kinematic Wave

The data processing methods are summarized in Figure 4.1

4.2.1 Drainage area boundaries.

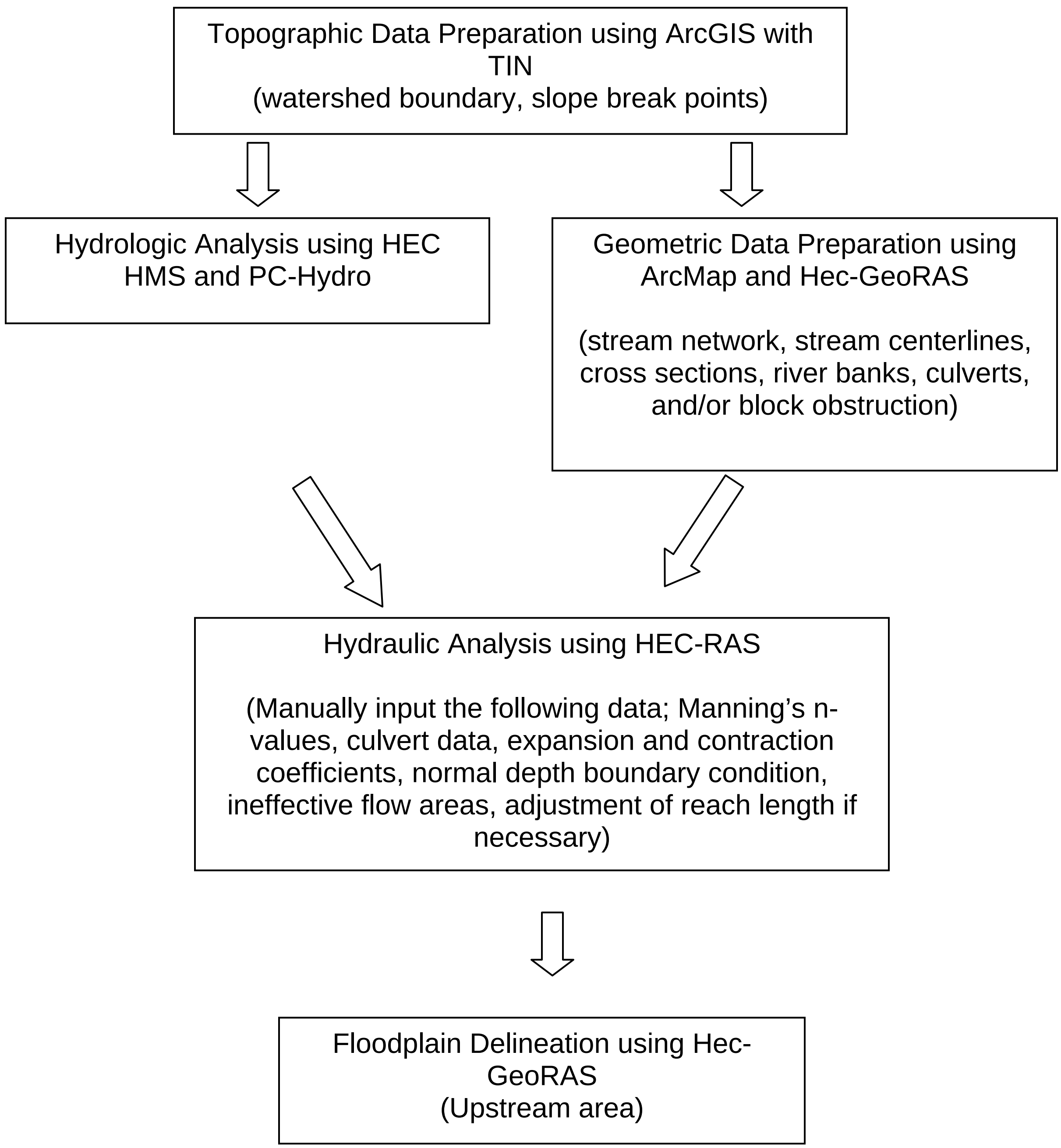
The limits of this study are shown in Figure 4.2. The limits of the watershed were determined using topographic data based on the DEM and contour data.

4.2.2 Watershed work maps

The boundary of the watershed and internal sub-basins were determined using the Hydrology tools in ARC GIS. Sub-basins were delineated based on internal concentration points. Sub-basins were further refined visually using the contour maps and orthophotos. The sub-basins reflected predominant topographic, soils, cover and development conditions, so that the sub-basins would represent hydrologic response from the sub-basin. The locations of the stream centerline, cross-sections, river banks, culverts, and other physical attributes of the wash were determined by using a topographic data (TIN and contour maps) and 2002 aerial photo.

Sub-basins were labeled with the prefix WDL, for Woodland Wash followed by a letter (e.g WDL_C). For the purposes of the hydrologic assessment, stream centerlines extended up into the sub-basins, so that channel geometry and slope characteristics could be ascertained for determining Time of Concentration, and discharge storage characteristics of the modified puls routing.

Figure 4.1 – Flow Chart of Mapping Process



4.2.3 Gage Data.

None Available

4.2.4 Statistical parameters

None Available

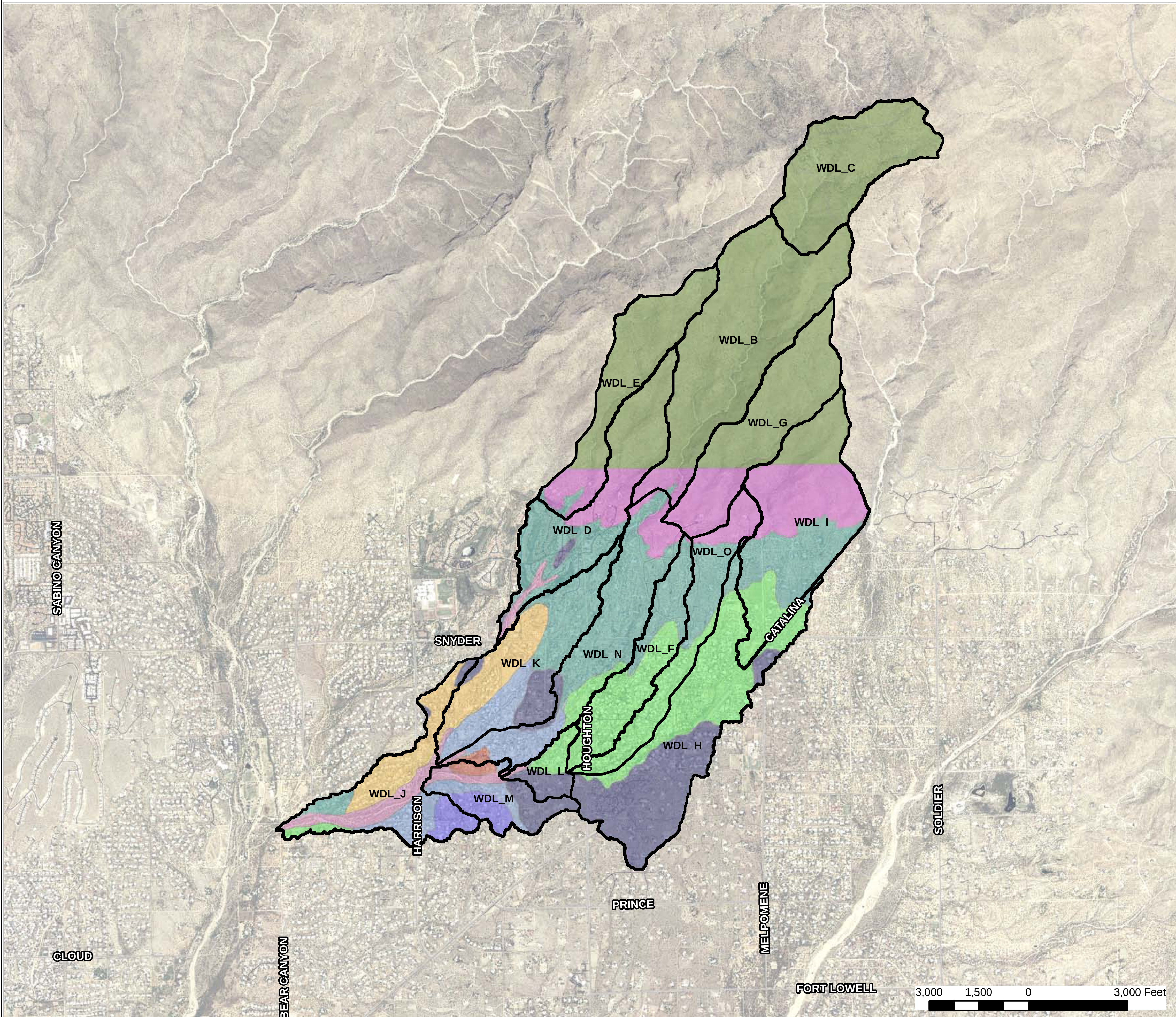
4.2.5 Precipitation.

Rainfall depth was selected from the NOAA 14 Upper 90% rainfall data used in PC Hydro for a point at the corner of Houghton and Snyder Rds (Lat 32.295; Long 110.778). The 3-hr rainfall data provided the basis for distributing a Type II rainfall using the methods described in Haan et al (1994). Because the different channels had different drainage areas, discharges were calculated for 2, 4 and 6 square mile aerial reduction.

4.2.6 Physical parameters.

A soils classification map for the study area is presented in Figure 4.2. In the mountains, Hydrologic Soil Group D is the dominant soil type, while Hydrologic Soil Group B is the dominant soil type on the alluvial fan. The SCS Curve Number was determined using maps obtained from NRCS (http://soildatamart.nrcs.usda.gov/) as a basis for preparing a Hydrologic Soil Group Map for Pima County. The CN charts in the PC Hydro Manual (Arroyo Engineering, 2007) were the basis for CN selection. A vegetation cover density of 30% was used to select the SCS Curve Number for the hydrologic calculation of the mountainous watersheds. On the urbanizing alluvial fan, turf and golf courses are common, so cover density depended on the relative fractions of desert brush, turf and impervious cover. Impervious cover percentage from 0-20%, were selected based on lot size, the fraction of the sub-basin that is developed and the tables in the PC Hydro manual. The CN selections and impervious cover selections are summarized in Table 4.2.

Figure 4.2
Soil Classification Map
Woodland Wash



Subbasins

Soils

- Soil Group: A (100%), ARIZO-RIVERWASH COMPLEX, 0 TO 3 PERCENT SLOPES
- Soil Group: B (100%), HAYHOOK SANDY LOAM, 1 TO 5 PERCENT SLOPES
- Soil Group: B (100%), HAYHOOK-SAHUARITA COMPLEX, 1 TO 5 PERCENT SLOPES
- Soil Group: B (100%), PINALENO VERY COBBLY SANDY LOAM, 1 TO 8 PERCENT SLOPES
- Soil Group: B (100%), PINALENO-STAGECOACH COMPLEX, 5 TO 16 PERCENT SLOPES
- Soil Group: B (100%), YAQUI FINE SANDY LOAM, 1 TO 3 PERCENT SLOPES
- Soil Group: C (47%) D (53%), PANTANO-GRANOLITE COMPLEX, 5 TO 25 PERCENT SLOPES
- Soil Group: C (50%), D (50%)
- Soil Group: C (53%) D (47%), PALOS VERDES-JAYNES COMPLEX, 2 TO 8 PERCENT SLOPES
- Soil Group: D (100%), CELLAR-LAMPSHIRE-ROCK OUTCROP COMPLEX, 15 TO 60 PERCENT SLOPES

Note: Photo is 2007 USDA

Pima County Index Map

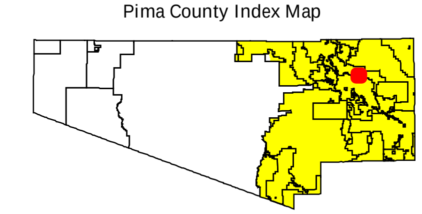


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Table 4.2 - Sub-basin Soils & CN Selection

Sub-basin	Area (Ac)	Hydrologic Soils Groups				Cover Type					CN
		A	B	C	D	Desert Brush	Mountain Brush	Herbaceous	Juniper Grass	% Impervious	
WDL_B	498.5	0.0%	0.3%	0.0%	99.7%	80.7%	10.8%	6.7%	1.7%	2%	**90.1**
WDL_C	280.7	0.0%	0.0%	0.0%	100.0%	20.7%	56.2%	11.5%	11.6%	0%	**87.0**
WDL_D	295.1	4.8%	40.0%	1.1%	54.1%	100.0%	0.0%	0.0%	0.0%	10%	**87.4**
WDL_E	234.6	0.0%	3.2%	0.0%	96.8%	94.9%	2.5%	2.6%	0.0%	2%	**90.5**
WDL_F	181.9	0.0%	99.6%	0.0%	0.4%	100.0%	0.0%	0.0%	0.0%	14%	**83.0**
WDL_G	282.2	0.0%	0.0%	0.0%	100.0%	100.0%	0.0%	0.0%	0.0%	0%	**91.0**
WDL_H	426.0	0.0%	48.2%	24.1%	27.7%	100.0%	0.0%	0.0%	0.0%	10%	**86.4**
WDL_I	390.6	0.1%	45.1%	0.0%	54.8%	100.0%	0.0%	0.0%	0.0%	5%	**87.4**
WDL_J	237.2	21.2%	58.8%	10.4%	9.5%	100.0%	0.0%	0.0%	0.0%	7%	**84.3**
WDL_K	298.0	2.0%	58.5%	20.2%	19.3%	100.0%	0.0%	0.0%	0.0%	10%	**85.6**
WDL_L	54.8	4.8%	44.5%	23.8%	26.9%	100.0%	0.0%	0.0%	0.0%	10%	**86.3**
WDL_M	126.2	13.7%	34.4%	25.8%	26.2%	100.0%	0.0%	0.0%	0.0%	7%	**86.4**
WDL_N	310.0	0.3%	76.5%	5.3%	17.8%	100.0%	0.0%	0.0%	0.0%	10%	**84.7**
WDL_O	188.0	0.0%	79.9%	0.1%	20.0%	100.0%	0.0%	0.0%	0.0%	15%	**84.6**

The SCS TR-55 segmental Time of Concentration (TC) methods were used. The hydraulically most distant point on the sub-basin was identified. The length of sheetflow was estimated at 100’, the distance from the end of the sheetflow to a well-defined channel was selected as the shallow concentrated portion of the flow path, and the channel portion was the path from the well-defined channel to the sub-basin outlet was the ‘channel flow’ portion of the flow path.

Travel times were the sum of the sheetflow, shallow concentrated flow and channel flow. Sheetflow and shallow concentrated flow were calculated using the methods described in the TR-55 manual (USDA-1986). However, the overland flow travel time was calculated using the kinematic wave with the travel time for channels used estimates from a HEC-RAS model. The methods are described in Appendix D. Table 4.3 summarizes the results.

Table 4.3 – Summary of TR-55 Time of Concentration Calculations

Sub-Basin	Area (sq mi)	CN	Impervious Area (%)	Vegetation Cover (%)	Lag Time (min)
WDL_B	0.779	90.1	2	30	9.2
WDL_C	0.439	87.0	0	30	8.5
WDL_D	0.461	87.4	10	30	13.2
WDL_E	0.367	90.5	2	30	13.0
WDL_F	0.284	83.0	14	30	18.0
WDL_G	0.441	91.0	0	30	11.8
WDL_H	0.666	86.4	10	30	22.8
WDL_I	0.610	87.4	5	30	14.0
WDL_J	0.371	84.3	7	30	20.5
WDL_K	0.466	85.6	10	30	19.1
WDL_L	0.086	86.3	10	30	14.0
WDL_M	0.197	86.4	7	30	7.9
WDL_N	0.484	84.7	10	30	15.7
WDL_O	0.294	84.6	15	30	23.0

The lag time was calculated as 0.6 Tc, and used to calculate sub-basin discharge using the 3-hr Type II storm. A single value of 3.47 inches was used for all sub-basins based on a NOAA 14 estimate near the centroid of the watershed. The SCS unit hydrograph was used to produce hydrographs at the outlet of the sub-basin in HEC-HMS. Sub-basin discharges are summarized on Table 4.4.

Table 4.4 – 100 –yr Discharges at Sub-basin Outlet

Element	Area (mi)	Area (Ac)	Time to Peak (hrs)	Runoff Vol (in)	Runoff Vol (ac-ft)	Qp (cfs)
WDL_B	0.78	498	01:33	2.35	97.5	***2,362***
WDL_C	0.44	281	01:32	2.06	48.2	***1,223***
WDL_D	0.46	295	01:37	2.22	54.5	***1,114***
WDL_E	0.37	235	01:36	2.38	46.6	***970***
WDL_F	0.28	182	01:42	1.97	29.8	***502***
WDL_G	0.44	282	01:35	2.41	56.7	***1,237***
WDL_H	0.67	426	01:46	2.14	76.1	***1,114***
WDL_I	0.61	391	01:37	2.15	70.1	***1,401***
WDL_J	0.37	237	01:44	1.95	38.5	***605***
WDL_K	0.47	298	01:43	2.08	51.8	***851***
WDL_L	0.09	55	01:37	2.14	9.8	***194***
WDL_M	0.20	126	01:32	2.1	22.1	***566***
WDL_N	0.48	310	01:39	2.02	52.2	***966***
WDL_O	0.29	188	01:46	2.09	32.7	***471***

Hydrographs were routed using modified puls. Modified puls routing employed the methods described in the HMS manual.

4.3 Problems encountered during the study.

None

4.3.1 Special problems and solutions

4.3.2 Modeling warning and error messages

Several minor errors were encountered. A complete list of errors is included in Appendix D.

4.4 Calibration.

No Calibration

4.5 Final results.

4.5.1 Hydrologic analysis results.

HEC-HMS calculated discharges above the reaches. In general, the discharge from the downstream point was used for the hydraulic analysis. In this way, estimates were conservative.

Aerial reduction was used for 2, 4 and 6 square mile watersheds. Discharges were calculated for 25, 100 and 500 year recurrence interval. Rainfall depths used in the analysis are summarized on table 4.6.

Table 4.6 – Rainfall Depths Used in Simulation (inches)

	100-yr	500-yr	25-yr
No Reduction	3.36	4.37	2.61
Reduction 2 Sq-mile	3.09	4.02	2.40
Reduction 4 Sq-mile	2.97	3.85	2.30
Reduction 6 Sq-mile	2.86	3.72	2.20

Calculations were performed on one-minute time step over six hours. Rainfall occurred on a 5 minute time step with rainfall occurring in the first three hours. Woodtrib2 splits off from Woodland at the transition between reach 1 and 2. Woodtrib 2 then joins back up with Woodland 2 and becomes Woodland reach 3. In order to determine how much flows into each portion of the split, the splitflow optimization feature of HEC RAS determined how much could flow down each split. In order to ensure that the value in each split was conservative, flow at the upper end was increased by 50%. This methodology previously used in splitflow analysis at Diamond Bell and the southwest. In this case, the analysis showed that Woodland reach 2 could carry most of the flow.

For the hydraulic analysis the following discharges were used:

Table 4.7 – Peak Discharge Values for 100-yr Event

Concentration Point	Location	Area (sq mile)	Rainfall Depth (in)	Runoff Volume (in)	Q100 HMS (cfs)	Time to Peak
CP_A	**Woodland at Sabino**	5.95	2.86	1.72	5778	2:15
CP_B	**Woodland above Split**	0.78	3.36	3.3	2362	1:33
CP_D	**Tributary 1 Upstream of Woodland**	1.29	3.36	2.22	2650	1:50
CP_H	**CatHwy West of Houghton**	1.57	3.09	1.9	2196	1:59
CP_J	**Woodland Upstream of CatHwy**	3.00	2.96	1.83	4146	1:54
CP_K	**Woodland West Split**	a			800	
CP_M	**CatHwy East of Harrison**	2.58	2.96	1.8	3090	2:10
CP_N	**Woodland below Split**	1.70	3.09	1.94	2310	1:56
CP_N1	**Woodland East Split**	a			2362	

Table 4.8 – Peak Discharge Values for 25-yr Event

Concentration Point	Location	Area (sq mile)	Rainfall Depth (in)	Runoff Volume (in)	Q25 HMS (cfs)	Time to Peak
CP_A	**Woodland at Sabino**	5.95	2.22	1.18	3543	2:23
CP_B	**Woodland above Split**	0.78	2.61	1.66	1686	1:33
CP_D	**Tributary 1 Upstream of Woodland**	1.29	2.61	1.55	1780	1:55
CP_H	**CatHwy West of Houghton**	1.57	2.40	1.3	1491	1:56
CP_J	**Woodland Upstream of CatHwy**	3.00	2.30	1.26	2740	1:56
CP_K	**Woodland West Split**	a			330	
CP_M	**CatHwy East of Harrison**	2.58	2.30	1.24	1957	2:14
CP_N	**Woodland below Split**	1.70	2.40	1.33	1503	1:59
CP_N1	**Woodland East Split**	a			1686	

Table 4.9 – Peak Discharge Values for 500-yr Event

Concentration Point	Location	Area (sq mile)	Rainfall Depth (in)	Runoff Volume (in)	Q500 HMS (cfs)	Time to Peak
CP_A	**Woodland at Sabino**	5.95	3.71	2.49	9134	2:09
CP_B	**Woodland above Split**	0.78	4.37	3.3	3280	1:32
CP_D	**Tributary 1 Upstream of Woodland**	1.29	4.37	3.15	3810	1:48
CP_H	**CatHwy West of Houghton**	1.57	4.23	2.74	3482	1:51
CP_J	**Woodland Upstream of CatHwy**	3.00	3.85	2.64	6318	1:52
CP_K	**Woodland West Split**	a	4.37		1500	
CP_M	**CatHwy East of Harrison**	2.58	3.85	2.6	4744	2:06
CP_N	**Woodland below Split**	1.70	4.23	2.79	3562	1:54
CP_N1	**Woodland East Split**	a	4.37		3810	

4.5.2 Verification of results.

Results are reasonable when compared with USGS Regression Equation 13 (Thomas et al, 1997) and other studies. The equation 13 results were generally lower than the HMS results, which would be expected, because these steep watersheds could be expected to produce higher than average discharge on average.

Concentration Point	Location	Area (sq mile)	Q100 HMS (cfs)	Q100 RRE 13 (cfs)
CP_A	**Woodland at Sabino**	5.95	5778	3682
CP_B	**Woodland above Split**	0.78	2362	1063
CP_D	**Tributary 1 Upstream of Woodland**	1.29	2650	1489
CP_H	**CatHwy West of Houghton**	1.57	2196	1689
CP_J	**Woodland Upstream of CatHwy**	3.00	4146	2504
CP_K	**Woodland West Split**	a	2185	
CP_M	**CatHwy East of Harrison**	2.58	3090	2292
CP_N	**Woodland below Split**	1.70	2310	1775
CP_N1	**Woodland East Split**	a	800	

Section 5: Hydraulics

5.1 Method description.

Steady flow analysis was performed to determine 100-year water surface elevations in the study area by using HEC-RAS with the discharge obtained from HEC-HMS. The hydraulic analysis was performed in reaches in subdivisions older than 1980 in order to establish local floodplain maps. The model ran in subcritical mode with downstream boundary conditions set to critical flow conditions.

5.2 Work study maps

As described above, geometric data for HEC-RAS including stream centerline, cross-sections, and river banks, were obtained from HEC-GeoRAS. The locations of cross sections and channels used for the 100-yr floodplain and 500-yr floodplain maps are show in Exhibit 1. The annotated Flood Insurance Rate Map is shown in Exhibit 2.

5.3 Parameter estimation.

The watershed was modeled using methods consistent with District Tech Policy 019.

5.3.1 Roughness coefficients.

Manning's roughness coefficients for the main channel and the over-bank areas were determined by using a 2002 aerial photo and field evaluation. Channel roughness varied between 0.03 and 0.05. The roughness used in this study ranges from 0.04 to 0.06 for overbank areas. Bank stations were originally established in HEC-GeoRAS, and refined by selecting bank stations consistent with ¼ or ½ of the 100-yr discharge. The discharge that filled the channel in well-defined cross-sections was used to select bank stations. The bank-stations were, therefore, selected to match a channel flow.

Differentiation of channel and overbank 'n' values should be done only when channel flow is at least twice as deep as overbank flow (Phillips and Tadayon, 2006). On the alluvial fans, there are many reaches that are wide with several flow paths. Rather than assign a channel and overbank Manning's n, an average n for the whole cross-section of 0.045 was assigned. Contraction and expansion coefficients are 0.1 and 0.3 which were obtained from HEC-RAS Hydraulic Reference Manual. Boundary conditions were based on critical flow conditions.

5.3.2 Expansion and contraction coefficients.

Default HEC RAS expansion (0.3) and contraction (0.1) coefficients were used.

5.4 Cross section description.

Cross-sections were placed so as to capture changes in channel geometry, bends and changes in flow regime.

5.5 Modeling considerations.

5.5.1 Hydraulic Jump and drop analysis.

No Hydraulic Jumps were encountered.

5.5.2 Bridges and culverts.

One bridge is located on Woodland wash at Wolford Rd. Bridges and large culverts are present in the upper part of the watershed that was not mapped as part of this study.

5.5.3 Levees and dikes.

None.

5.5.4 Islands and flow splits.

One location of split flow was noted on Woodland Wash near Snyder Rd. In order to determine how much flowed in each part of the split flow, the discharge was increased 50% and the optimal flow in each split calculated. The additional discharge was used to ensure that conservative values were selected. In general the flows indicated that the main part of the Woodland Wash could carry the full flow, while half of this value could flow in the tributary (WoodTrib2).

5.5.5 Ineffective flow areas.

Ineffective flow areas were noted on all reaches. In general these ineffective flow areas were disconnected overbank areas that would not convey flow to the next downstream cross-section.

5.5.6 Supercritical flow.

No supercritical reaches.

5.6 Floodway modeling

No encroachment calculations were performed.

5.7 Problems encountered during the study.

5.7.1 Special problems and solutions.

None.

5.7.2 Modeling warning and error messages.

No errors occurred. The following warning messages occurred:

- Divided flow
- Energy loss greater than 1.0
- Energy equation could not be balanced and defaulted to critical.
- Cross-section extended vertically.
- Multiple critical depths calculated.
- Conveyance ratio is less than 0.7 or greater than 1.4.

Inspection indicated that the modeling is accurate given the steep channel conditions. Most of these errors force a critical solution which is reasonable for these steep watercourses. A summary of errors is available in Appendix E.

5.8 Calibration.

None.

5.9 Final results.

5.9.1 Hydraulic analysis results.

The floodplain map for the 100-yr and 500-yr discharge is shown in Exhibit 1.

5.9.2 Verification of results.

Existing floodplain maps are not available except at the downstream end of the study area where there is an existing FEMA A zone. The new map tends to follow this existing map on the western boundary, but not extend as wide in the eastern edge. The results suggest that the mapping is reasonable, and that discrepancies with the existing FEMA A zone are attributable to the availability of more accurate topographic data, new rainfall data, more accurate soils and land use maps, and changed land use since the existing FEMA maps.

Section 6: Erosion and Sediment Transport

6.1 Method description.
None – not applicable
6.2 Parameter estimation.
None – not applicable
6.4 Modeling considerations.
None – not applicable
6.5 Problems encountered during the study.
6.5.1 Special problems and solutions.
None – not applicable
6.5.2 Modeling warning and error messages.
None – not applicable
6.6 Calibration.
None – not applicable.

6.7 Final results.

6.7.1 Erosion and sediment transport analysis results.

None – not applicable

6.7.2 Verification of results.

None – not applicable

Appendix A: References

A.1 Data collection summary.

Include a list of previous studies, other applicable studies, published and unpublished historical flood information, and research contacts.

A.2 Referenced documents.

Arizona Department of Water Resources, Flood Mitigation Section
"Requirements for Flood Study Technical Documentation" SS1-97, November 1997

Arroyo Engineering. 2007. *PC-Hydro User Guide*. Pima County Regional Flood Control District

Eychaner, J.H., 1984. *Estimation of magnitude and frequency of floods in Pima County, Arizona, with comparisons of alternative methods*: U.S. Geological Survey Water-Resources Investigations Report 84-4142, 69 p.

Haan, C.T., Barfield, B.J., Hayes, J.C. 1994. *Design Hydrology and Sedimentology for Small Catchments*, Academic Press.

National Weather Service. 1984. *Depth-Area Ratios in the Semi-Arid Southwest United States*, NOAA Technical Memorandum NWS Hydro-40

NOAA, 2006. NOAA Atlas 14, Precipitation Frequency Atlas for the United States: Volume 1 - Version 4.0 The Semiarid Southwest. National Weather Service, Hydrometeorological Design Studies Center. Available on the internet at: http://hdsc.nws.noaa.gov/ hdsc/pfds/sa/az_pfds.html

Phillips, J., and S. Tadayon. 2006. *Selection of Manning's roughness coefficient for natural and constructed vegetated and non-vegetated channels, and vegetation maintenance plan guidelines for vegetated channels in central Arizona*: U.S. Geological Survey Scientific Investigations Report 2006–5108, 41 p.

Thomas, B.E., H.W. Hjalmarson, and S.D. Waltemeyer. 1997. *Methods for Estimating Magnitude and Frequency of Floods in the Southwestern United States*. USGS Water Supply Paper 2433. 195 p.

U.S. Army Corps of Engineers (COE). 1998. *HEC-1 Flood Hydrograph Package, Users Manual*, CPD-1A, Hydraulic Engineering Center, Davis, CA.

U.S. Army Corps of Engineers (COE). 2001. *HEC-RAS, River Analysis System, Hydraulic Reference Manual,* CPD-69, Hydraulic Engineering Center, Davis, CA.

U.S. Army Corps of Engineers (COE). 2006. *HEC-HMS, Hydrologic Modeling System User's Manual*, (v. 3.1.0) CPD-74A, Hydraulic Engineering Center, Davis, CA.

U.S. Department of Agriculture Natural Resources Conservation Service (NRCS), 1986. *Urban Hydrology for Small Watersheds*, Technical Release 55. Washington, DC.

Appendix B: General Documentation & Correspondence

B.1 Special Problem Reports.

B.2 Contact (telephone) reports.

Provide copies of correspondence documenting notification of the client and the methods of addressing any special problems described in Sections 4.4.1, 5.5 and 6.5.

B.3 Meeting minutes or reports.

B.4 General Correspondence.

B.5 Contract Documents.

Provide a copy of the contract Scope of Work, not financial documents.

Appendix C: Survey Field Notes

C.1 Survey field notes for aerial mapping control.

C.2 Survey field notes for hydrologic modeling.

C.3 Survey field notes for hydraulic modeling.

Appendix D: Hydrologic Analysis Supporting Documentation

D.1 Precipitation data.

From the NOAA 14, Upper 90% atlas Version 4.0 (2006) embedded in PC Hydro v5.3.

D.2 Physical parameter calculations.

D.3 Hydrograph routing data.

Include routing data, confidence checks on results and cross section plots.

D.4 Reservoir routing data.

Include hydraulic calculations and rating curve plots for control structures, and volume calculations.

D.5 Flow splits and diversions data.

Include hydraulic calculations and rating curve plots used to define each flow split and diversion table.

D.6 Hydrologic calculations.

Appendix E: Hydraulic Analysis Supporting Documentation

E.1 Roughness coefficient estimation.

Include copies of photographs and calculations.

E.2 Cross section plots.

E.3 Expansion and contraction coefficients.

Include any special data or calibration efforts made for estimation of expansion and contraction coefficients.

E.4 Analysis of structures.

Include any separate hydraulic modeling of structures used to estimate control data for floodplain delineation calculations.

E.5 Hydraulic calculations.

Include computer model output for floodplain and floodway hydraulic calculations.

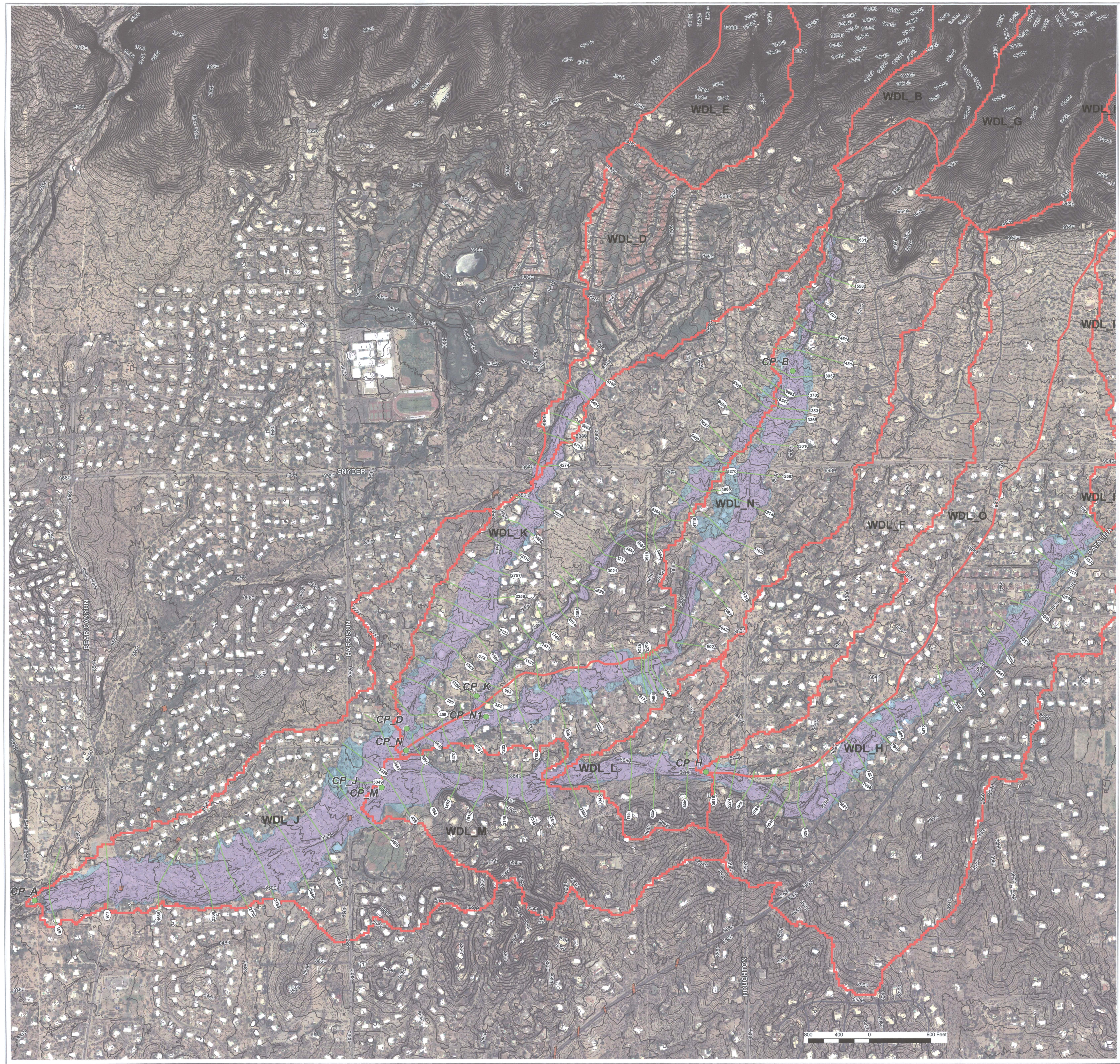
Appendix F: Erosion and Sediment Transport Analysis

(None – no sediment transport analysis in this report)

Digital Data

Attach CD Here

Exhibit 1
100-year & 500-year Floodplain with cross sections Woodland Wash

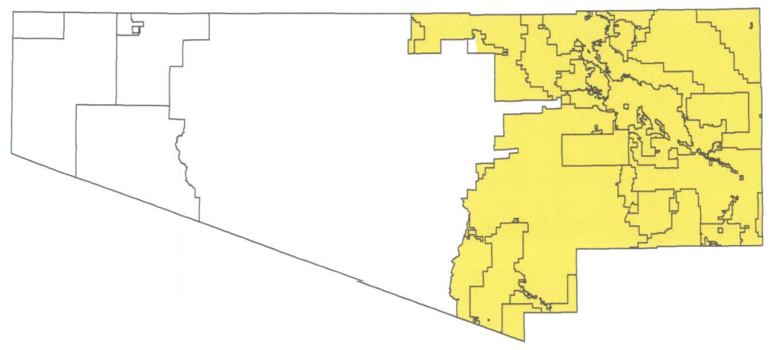


- WoodCPs
- XSCutLines3D
- Contour 20ft
- Contour 5ft
- Subbasins
- 100-yr
- 500-yr

USDAPimaHARN2007.ecw

Note: On this scale 100 and 500yr floodplains appear coincident on much of the map, because the floodplains tend to be confined.

Pima County Index Map



Index Map Scale 1:1,500,000

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Scale 1:400

Pima County Regional Flood Control District

Pima County Regional FLOOD CONTROL DISTRICT

Pima County Regional Flood Control
97 East Congress Street - 3rd Floor
Tucson. Arizona 85701-1207
(520)243-1800 - FAX (520)243-1821
http://www.rfcd.pima.gov

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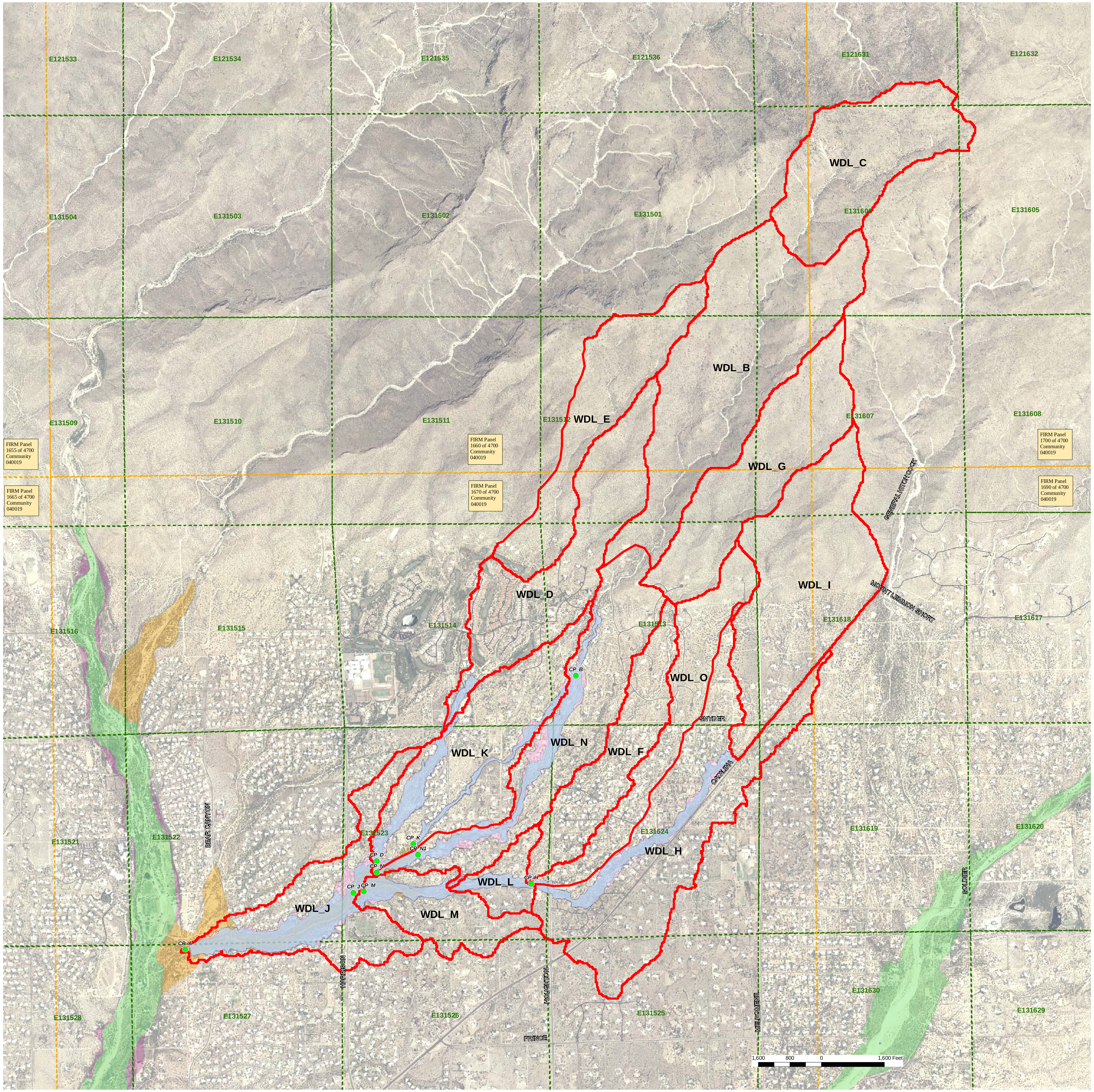


Exhibit 2
Annotated Flood Insurance Rate Map Woodland Wash

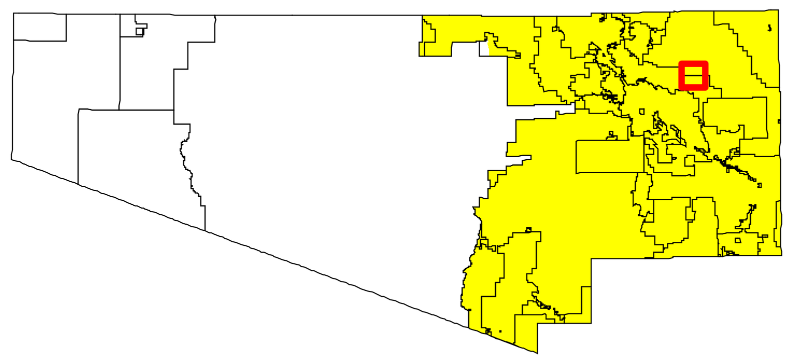
- Woodland CPs
- Woodland Sub-basin
- 100-yr floodplain
- 500-yr floodplain
- vector.GISDATA.fp_panel
- vector.GISDATA.trs
- vector.GISDATA.fp_lomxb

Existing FEMA Floodplain

- ZONE A
- ZONE AE
- ZONE X - SHADED

USDAPimaHARN2007.ecw

Pima County Index Map



Index Map Scale 1:1,500,000

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Pima County Regional Flood Control
97 East Congress Street - 3rd Floor
Tucson. Arizona 85701-1207
(520)243-1800 - FAX (520)243-1821
http://www.rfcd.pima.gov

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