Catalina Foothills Watercourse Studies:
Technical Data Notebook for Hydrologic and Hydraulic Mapping of the Soldier Wash and its Tributary,
Pima County Arizona.
FEMA FIRM Panel 04019C-1690K

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Soldier Canyon TDN with supporting models and GIS data.

Section 1: Introduction

1.1 Purpose

The purpose of this study is to provide flood and erosion hazard information for Soldier Canyon 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;
- 100-yr floodplain maps for the alluvial fan on Soldier Canyon.

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 Soldier Canyon Wash. The watershed extends to Sections 27, 28, 32, and 33 of Township 12 South, Range 16 East, and Sections 05-07 of Township 13 South, Range 16 East Pima County, Arizona. Flow on the alluvial fan at the base of this watershed is distibutary and extends over Sections 18 and 19 of Township 13 South, Range 16 East. Much of the wash in the developed portion of the watershed is mapped as a Zone A as shown on the current Flood Insurance Rate Map (FIRM) number 04019C-1690K.

The watershed is 3.6 square miles above the Catalina Highway at the apex to the fan. The upper part of the watershed was divided into nine sub-basins. The flow becomes divided on the fan, and the channel extends for about two miles below the apex. The full limits of the watershed are shown in Figure 1.1. While not considered an Active Alluvial Fan by FEMA, the potential for avulsion and flow migration exists on the fan below the apex. Because flow is distributary on the fan, the flow area is not precisely known. This study mapped the flow using the FLO-2D model to account for the distributary flow on the fan. The floodplain mapping limits extend from Tanque Verde Creek to the Catalina Highway (Fig.1.2).

1.4 Methodologies Used for Hydrology and Hydraulics

Topographic, hydrologic and hydraulic analyses were performed to determine drainage conditions in Soldier Canyon Wash. ArcGIS, Version 9.3, HEC-HMS version 3.2 (HEC-HMS), Hec-RAS Version 4.0 (HEC-RAS), HEC-GeoRAS, Version 4.1.1 (HEC-GeoRAS) and FLO2-D (version 2007-06) were used for the analyses.

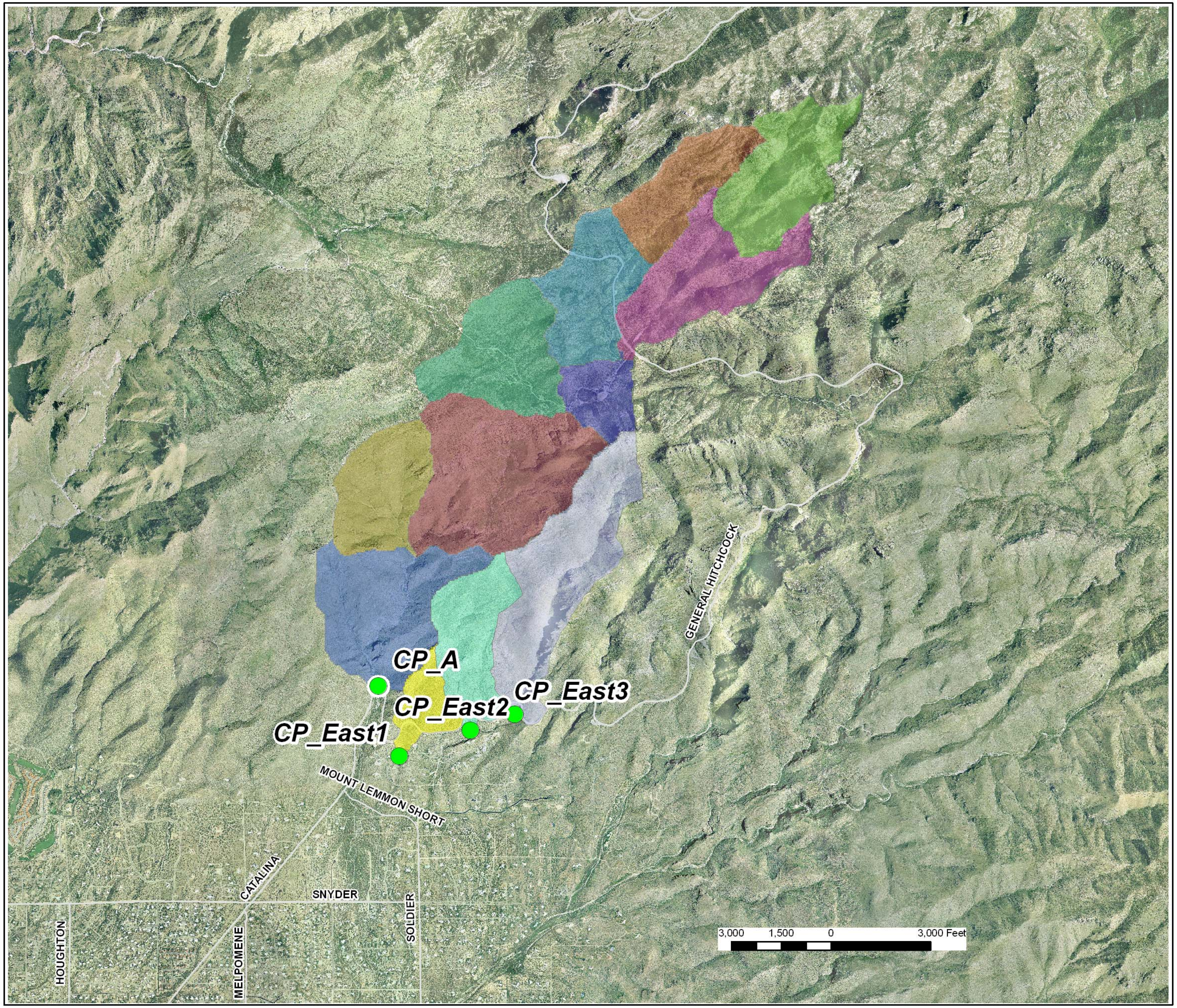
1.5 Acknowledgements

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 modeled discharge for the Soldier Canyon Wash at the Catalina Highway is 5562 cfs (see CP-A, Fig. 1.1). The hydrograph at Catalina Highway was input to the FLO-2D model at the apex of the Soldier Canyon Fan. The FLO-2D model, which included rainfall and infiltration, showed that a major flow split occurs on the fan south of the Mt Lemmon Short Rd, showing a wide two-channel floodplain, south of the Mt Lemmon Short Rd., which is in contrast to the FEMA floodplain map, which shows a narrower A zone following the western braid on the northern half, and the eastern braid on the southern half of the mapped floodplain. Some part of 130 parcels will intersect the floodplain with the new mapping, while the FEMA A-zone intersected 46 parcels.

Figure 1.1
Upper Watershed for Soldier Canyon Wash



Concentration Point

SoldierBasins

- SOL_0
- SOL_1
- SOL_2
- SOL_3
- SOL_4
- SOL_5
- SOL_6
- SOL_7
- SOL_8
- EastSub1
- EastSub2
- EastSub3

Aerial Photo:
2002 Pima Association of Government

Pima County Index Map

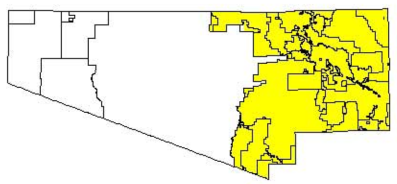


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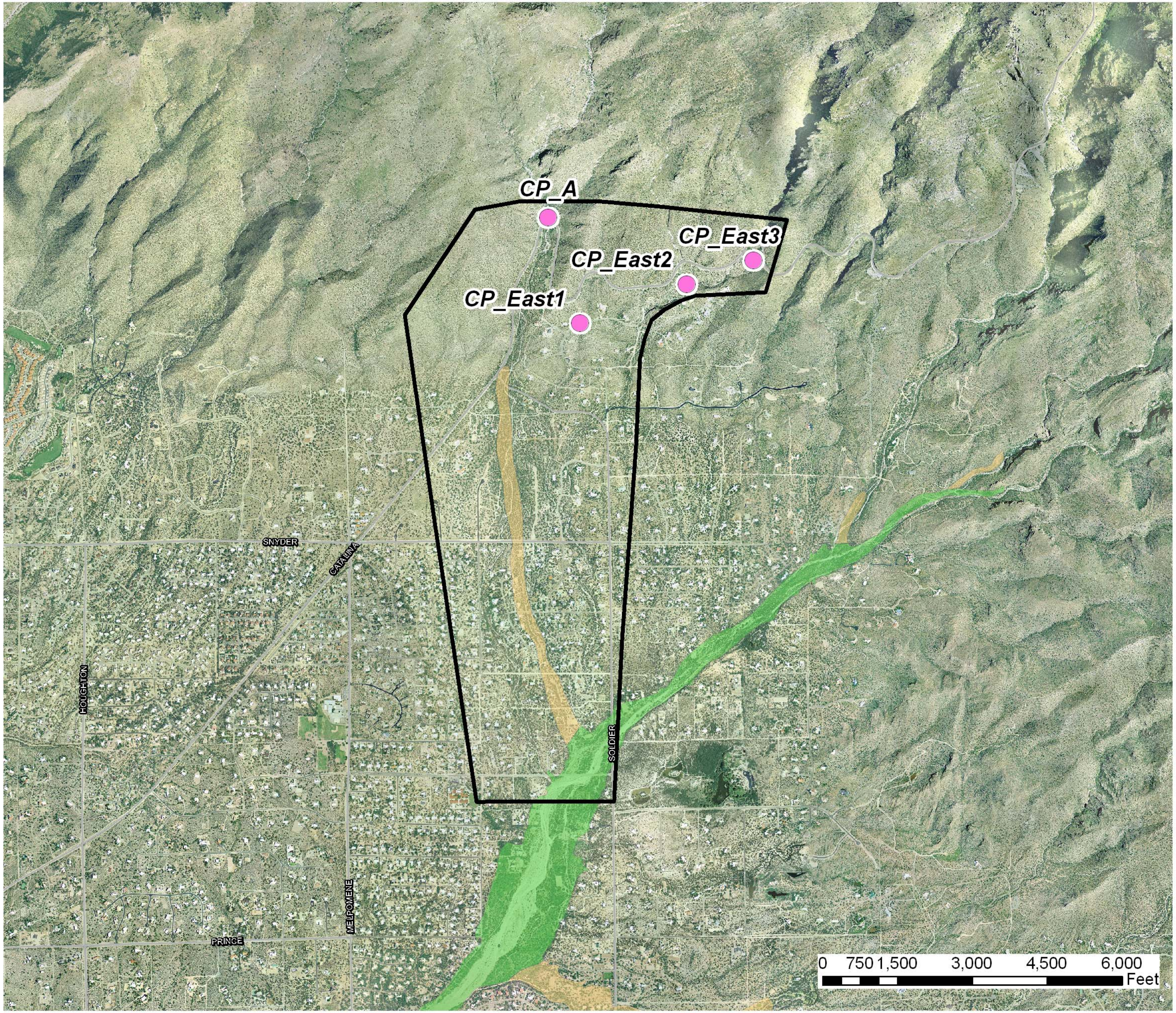
Figure 1.2
Study Limit Map
Soldier Canyon Wash
with FEMA Floodplains



Concentration Points
Study Limit
Existing FEMA Floodplain
ZONE A
ZONE AE
ZONE X - SHADED

Aerial Photo:
2002 Pima Association of Government

Pima County Index Map

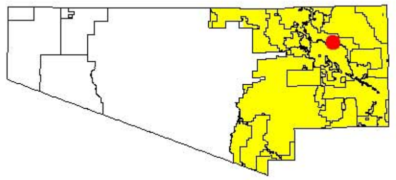


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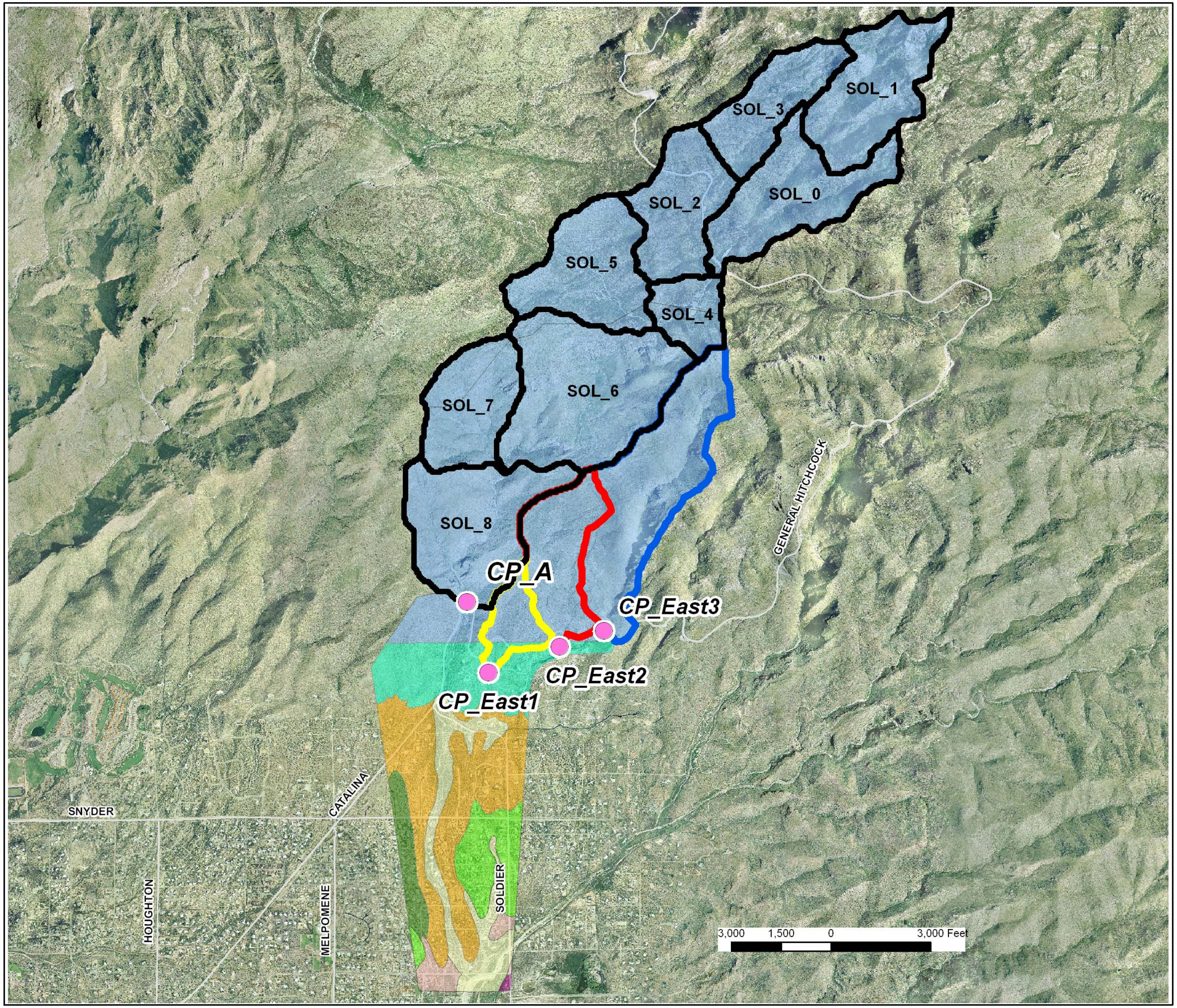
Figure 1.3
Soil Classification Map
Soldier Canyon Wash



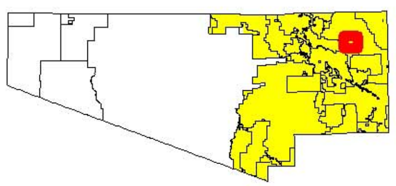
Discharge Point
Soldier Canyon Subbasins
EastSub1
EastSub2
EastSub3

Soil Classification

- Soil Group: A (100%), ARIZO-RIVERWASH COMPLEX, 0 TO 3 PERCENT SLOPES
- Soil Group: B (100%), ANTHONY FINE SANDY LOAM, 0 TO 3 PERCENT SLOPES
- Soil Group: B (100%), HAYHOOK SANDY LOAM, 1 TO 5 PERCENT SLOPES
- Soil Group: B (100%), PINALENO VERY COBBLY SANDY LOAM, 1 TO 8 PERCENT SLOPES
- Soil Group: B (100%), SAHUARITA SOILS, MOHAVE SOILS AND URBAN LAND, 1 TO 5 PERCENT SLOPES
- Soil Group: B (50%) C (50%), PALOS VERDES-SAHUARITA COMPLEX, 2 TO 8 PERCENT SLOPES
- Soil Group: C (50%), D (50%)
- Soil Group: D (100%), CELLAR-LAMPSHIRE-ROCK OUTCROP COMPLEX, 15 TO 60 PERCENT SLOPES

Aerial Photo:
2002 Pima Association og Government

Pima County Index Map



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Section 2.0 Summary of Key Facts

Section 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: 06-11-10
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: Soldier CanyonWash
2.1.10 Reach Description: Soldier Canyon Fan below Apex.
2.1.11 Study Type: Hydrology and Hydraulics study of an Alluvial Fan System

Section 2.2: Mapping Information

2.2.1 FIRM Panels: 04019C-1690K
2.2.2 Mapping for Hydrologic Study: Lidar based on 2008 flight used to derive 2' contour interval maps using ARC-GIS 9.3 for fan mapping. Lidar from 2006 was used to generate topography for the portions of the watershed in the Coronado National Forest.
2.2.3 Mapping for Hydraulic Study: Lidar based on 2008 flight used to derive a DEM (20-ft cell size) for use with FLO-2D.

Section 2.3: Hydrology

2.3.1 Model or Method Used: HEC-HMS (v. 3.4) model parameterized using methods of RFCD Tech Policy 018
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

Section 2.4: Hydraulics

2.4.1 Model or Method Used: FLO-2D.
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: Hydrograph at the apex of the fan was generated with HEC-HMS. Flow on the fan was modeled with FLO-2D including rainfall, infiltration and structures. Boundary set at outflow on Tanque Verde Creek.

Section 2.5: Additional Study Information:

Study mapping reflects flooding from a regional storm. Local flooding on watersheds smaller tributaries to Soldier Wash will need to be delineated using the PC Hydro program to generate peak flows on the tributaries.

Section 3: Survey and Mapping Information

3.1 Field Survey Information

No field survey was used.

3.2 Mapping

The 2006 and 2008 Light Detection and Ranging (LiDAR) data was used for the analysis. 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 2006 LiDAR was used to derive a Digital Elevation Model (DEM) and a contour map. DEM derived on 5’ centers provided the basis for delineating the watershed and sub-basins. A DEM derived from the 2008 LiDAR based on 20’ centers was used to characterize the topography along channels used for the floodplain mapping process in FLO-2D. Contour map derived from the DEM allowed modelers to visualize topographic differences in making decisions on how to model different areas.

Section 4: Hydrology

4.1 Method description.

For the floodplain mapping, a 100-yr discharge is required. The 100-year peak discharges for the sub-basins of the Soldier Canyon Wash (SOL0 to SOL8; and East Sub1, EastSub2 and EastSub 3; Figure 1.1) were calculated using U.S. Army Corps of Engineers Computer Hydrologic Modeling System, (HEC-HMS) version 3.4. The HEC-HMS model requires parameters regarding rainfall, topography, soil, vegetation, and channel characteristics to determine runoff volume and peak discharge. Those parameters were determined according to the Pima County Regional Flood Control District Technical Policy 018 (Tech-018). Tech-018 is included in Appendix A.

4.2 Parameter estimation.

Methods used to determine discharge in the upper watershed are summarized in Table - 4.1. The data processing methods are summarized in Figure 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

4.2.1 Drainage area boundaries.

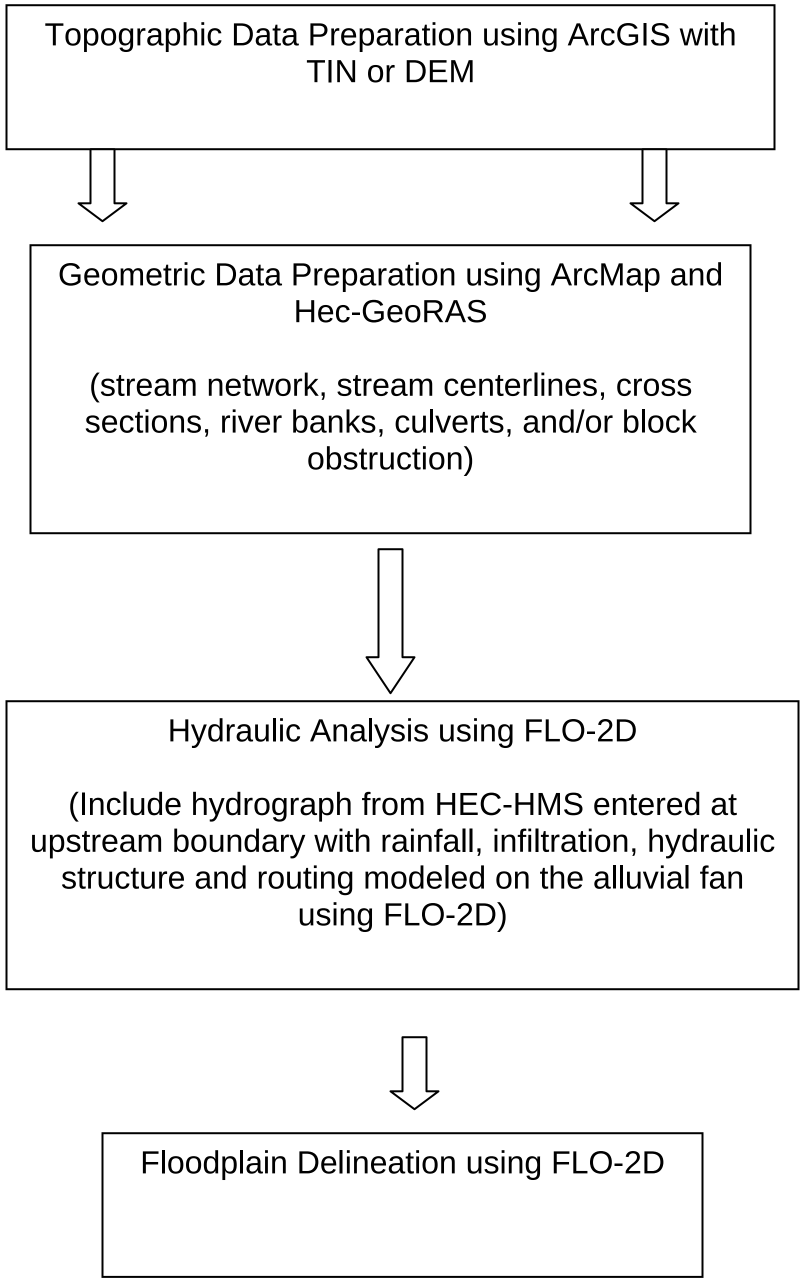
The limits of this study are shown in Fig.1.2. The watershed extends to Sections 27, 28, 32, and 33 of Township 12 South, Range 16 East, and Sections 05-07 of Township 13 South, Range 16 East Pima County, Arizona. Flow on the alluvial fan at the base of this watershed is distibutary and extends over Sections 18 and 19 of Township 13 South, Range 16 East. The current mapping shows an A-Zone over much of the channel below the Mt Lemon Short Rd on the current Flood Insurance Rate Map (FIRM) number 04019C-1690K.

The upper watershed is 3.6 square mile. The study watershed was divided into nine sub-watersheds (Fig.1.1). Below the apex, distributary flow occurs, and the area modeled with FLO-2D was extended outside the expected drainage area to ensure that flow that would enter from other distributary flow paths discharged to Soldier Canyon Wash. The FLO-2D study limit extended from the apex of the fan to the Agua Caliente.

4.2.2 Watershed work maps

The boundary of the watershed and internal sub-basins were determined using Hydrology function in ArcGIS (Fig.1.1) with DEM derived from the 2006 LiDAR. 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 the 2-ft interval contour map and 2002 aerial photo.

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. Values were selected for both the upper and lower watershed. The point rainfall depth of 3.71”for the 3-hour storm on the upper watershed was obtained, based on the coordinates of the centroid of the watershed (Latitude: 32.330, Longitude: 110.730). Areal reduction factor was applied to watersheds larger than 1 square mile as noted in Tech-018, which is 0.87 for the 3.6 sq mile upper watershed, yielding a rainfall depth of 3.23 inches on the upper watershed. For the lower watershed, a value of 3.36 inches (Latitude: 32.285, Longitude: 110.750) was aerially reduced assuming the 3.6 square watershed area, because the true drainage area is not known in distributary flow systems, yielding a rainfall depth of 2.92” for the 3-hr storm. The 3-hr, SCS Type II rainfall distribution described in Haan et al (1994) was used.

4.2.6 Physical parameters.

A CN map derived from cover type, percent impervious and hydrologic soils group for the study watershed is presented in Fig.4.2. About half (47%) is Mountain Brush, about a quarter (27%) is Desert Brush, and the remaining quarter is split approximately evenly between Juniper-Grass (12.9%) and Herbaceous (12.1%). Vegetative cover on the apex is virtually all Desert Brush. The hydrologic soils group (HSG) are D on the watershed. On the apex, HSG B and C dominate (Figure 1.3).

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 (Fig. 4.2). A vegetation cover density of 30% was used to select the SCS Curve Number for the hydrologic calculation of the mountainous watersheds. Impervious cover percentage from 10-20%, were selected based on lot size, the fraction of the sub-basin that is developed and the tables in the PC Hydro manual. Sub-basin characteristics are summarized in Table 4.2 The detail of the CN calculation is included in Appendix D.

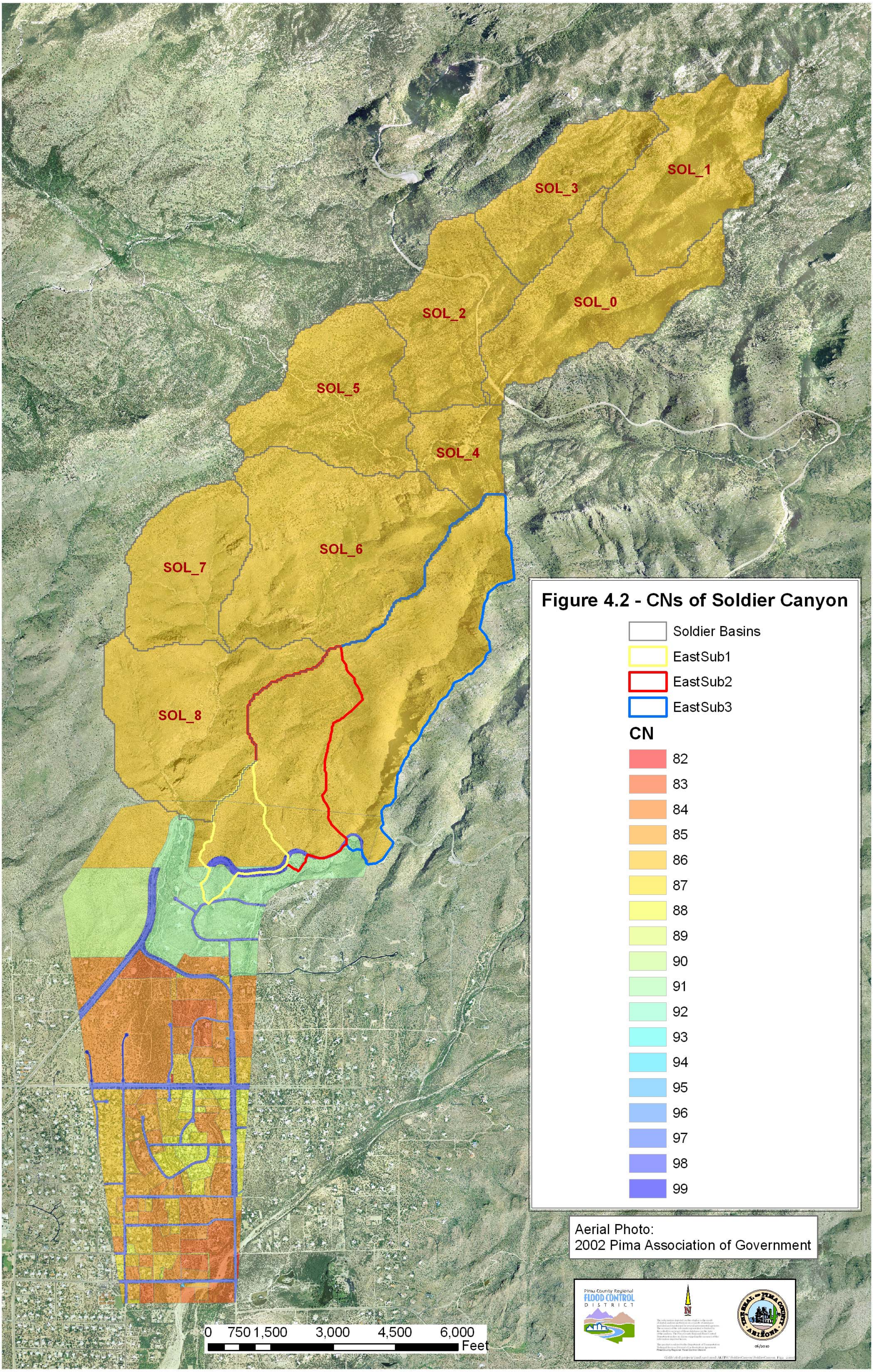


Figure 4.2 - CNs of Soldier Canyon

Table 4.2 - Sub-basin Characteristics

Sub-Basin	Area (sq mi)	CN	Impervious Area (%)	Vegetation Cover (%)	Lag Time (min)
SOL O	0.43	86	0	30	10.3
SOL 1	0.42	86	0	30	8.2
SOL 2	0.35	86	0	30	6.8
SOL 3	0.29	86	0	30	7.1
SOL 4	0.16	86	0	30	6.8
SOL 5	0.42	86	0	30	8.5
SOL 6	0.70	86	0	30	14.7
SOL 7	0.33	86	0	30	6.1
SOL 8	0.51	86	0	30	9.9
EastSub1	0.11	86	0	30	6.7
EastSub2	0.28	86	0	30	11.8
EastSub3	0.58	86	0	30	13.3

The SCS TR-55 segmental Time of Concentration (Tc) method with a channel travel times from HEC-RAS was 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.

Tc is the sum of the travel time for sheetflow, shallow concentrated flow and channel flow. The travel time for shallow concentrated flow was calculated using the methods described in the TR-55 manual (USDA-1986). The travel time for channels used estimates from a HEC-RAS model. The lag time was calculated as 0.6 Tc. The detail of the Tc calculation is included in Appendix D (Table D2).

The SCS unit hydrograph method was used to produce hydrographs at the outlet of the sub-basin in HEC-HMS. Runoff from sub-basins was routed using the kinematic wave method. A storage discharge table for the channel routing was developed using the cross sections and slopes derived from HEC-HMS. Kinematic wave routing employed the methods described in the HMS manual. The detail of the calculation of the number of subreach is included in Appendix D. Sub-basin discharges are summarized on Table 4.3.

Table 4.3 - Sub-basin discharges

Sub-Basin	Area	Rainfall Depth	Runoff Volume	Peak Discharge
	(sq mi)	(in)	(in)	(cfs)
SOL O	0.43	3.23	1.86	935
SOL 1	0.42	3.23	1.86	979
SOL 2	0.35	3.23	1.86	883
SOL 3	0.29	3.23	1.86	721
SOL 4	0.16	3.23	1.86	396
SOL 5	0.42	3.23	1.86	947
SOL 6	0.70	3.23	1.86	1260
SOL 7	0.33	3.23	1.86	853
SOL 8	0.51	3.23	1.86	1119
EastSub1	0.11	3.23	1.86	289
EastSub2	0.28	3.23	1.86	570
EastSub3	0.58	3.23	1.86	1093

4.3 Problems encountered during the study.

None

4.3.1 Special problems and solutions

4.3.2 Modeling warning and error messages

The time interval of the rainfall data used in this study is 5 minutes, while the simulation time interval is 1 minute. The HEC-HMS model interpolated the 5-minute time interval of the rainfall data to 1-minute time interval.

4.4 Calibration.

No Calibration

4.5 Final results.

4.5.1 Hydrologic analysis results

The 100-year peak discharges at the concentration points along the Soldier Canyon Wash were determined using the HEC-HMS. Twelve hours were simulated on a 1 minute time step with rainfall occurring in the first three hours. For the hydraulic analysis the following discharge was used:

Table 4.4 – Summary of 100-yr Peak Discharge Values

Concentration Point	Location	Area (sq mile)	Rainfall Depth (in)	Runoff Volume (in)	Q100 HMS (cfs)	Time to Peak (hr:min)
CP A	**Catalina Highway**	3.61	3.23	1.86	5562	1:50
CP East 1	**Catalina Highway**	0.11	3.23	1.86	289	1:30
CP East 2	**Catalina Highway**	0.28	3.23	1.86	570	1:35
CP East 3	**Catalina Highway**	0.58	3.23	1.86	1093	1:35

4.5.2 Verification of results.

The modeled discharge of 5562 cfs is in good agreement with the accepted regulatory discharge of 5050 cfs for Soldier Wash at Mt Lemmon Short Rd. Results are also reasonable when compared with USGS Regression Equation 13 (Thomas et al, 1997, Table 4.5). 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 at the sub-basin scale, and routing would favor runoff converging at the apex of the fan from three different areas (the main part of Soldier to the northeast, a smaller area to the north, and a sub-basin contributing from the east).

Table 4.5 – Comparison of 100-yr Peak Discharge Values

Concentration Point	Location	Area (sq mile)	Q100 HMS (cfs)	Q100* Regulatory (cfs)	Q100 RRE (cfs)
CP A	**Catalina Highway**	3.61	5562	5050	2789

* at Mt Lemmon Short Rd

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 FLO-2D with the discharge obtained from HEC-HMS at the Catalina Highway. On the fan, the 3-hr rainfall was used with runoff generated using the CN method on a 20’ grid. Channel flow was not specifically modeled, and the area was modeled as ‘floodplain’ in FLO-2D. Two versions of the FLO-2D model was prepared, one with an existing berm on the old Soldier Trail alignment, and one without the berm. This second version was prepared, because the berm changes the flow path, so that it may be advisable to remove it.

5.2 Work study maps

Geometric data for the FLO-2D model were derived from the 20’ DEM prepared based on the 2008 LiDAR data. The GDS tool in FLO-2D parameterized the model.

5.3 Parameter estimation.

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

5.3.1 Roughness coefficients.

The Manning coefficient of 0.065 for grid cells was used in the FLO-2D model for all cells except those along visible channels, which were set to 0.04. If flow approached critical, the roughness could go as high as 0.15 in accordance with model-specified parameters.

5.3.2 Expansion and contraction coefficients.

Expansion and contraction were not modeled, because FLO-2D is a grid based model.

5.4 Cross section description.

No flow-recording cross-sections

5.5 Modeling considerations.

5.5.1 Hydraulic Jump and drop analysis.

No Hydraulic Jumps were encountered.

5.5.2 Bridges and culverts.

There is a large box culvert over the Soldier Canyon Wash at the Catalina Highway, and a smaller bridge over the Soldier Canyon Wash at Mt Lemmon Short Rd. These two were modeled using depth discharge tables developed in HEC-RAS. In the FLO-2D model, flow entered into an upstream grid cell, and discharged to a downstream cell downstream of the bridge or culvert. The depth discharge tables used for modeling bridges and culverts are included in Appendix E.

5.5.3 Levees and dikes.

None.

5.5.4 Islands and flow splits.

There are numerous flow splits. The largest is downstream of the Mt Lemmon Short Rd, where the flow splits into two major flow paths. At 100-yr flood stage, these two splits connect near the Agua Caliente Wash.

5.5.5 Ineffective flow areas.

Ineffective flow was not modeled, because the ability of FLO-2D to model flow in the overbanks implicitly includes the modeling of ineffective flow areas.

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 significant errors occurred. Individual grid cells required extensive iteration to solve the dynamic wave equations, which slowed down the computation time.

5.8 Calibration.

None.

5.9 Final results.

5.9.1 Hydraulic analysis results.

The FLO-2D modeling results are included in Appendix E. The versions of the model with and without the berm yielded similar results except immediately downstream of the berm. A single version of the floodplain limit map was prepared showing the most conservative of the two cases. The results were used to prepare the workmaps in Exhibits 1.1 and 1.2. The flow depth is shown on a flow depth grid, and a floodplain map was derived using the 'Flow Inundation Map' function set with a flow depth of 0.1 foot and a smoothing value of 30. The floodplain map was then further refined so that it represented the flooding on the major flow paths. The flow depth grid indicates flow depths greater than 0.1 foot that are not in the floodplain. However these were smaller flow paths, or local depressions and were not included in the 100-yr floodplain.

An annotated FIRM map showing the relationship of this local study to the FEMA maps is included in Exhibits 2.1 and 2.2.

A velocity map was also prepared to better understand the hazards associated with velocities such as erosion hazard setbacks. The velocity grid map is included in Exhibits 3.1 and 3.2. This map shows similar trends to the flow depth map, with the greatest velocities occurring at the deepest flow areas.

5.9.2 Verification of results.

Existing floodplain maps are available along the Soldier Canyon Wash. The new map tends to follow the floodplain topography, and the split observed in the topography and aerial photos, while the existing map did not follow these features. The results suggest that the mapping is reasonable. It also suggests that the existing FEMA A-Zone is inaccurate.

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

A.1 Data Collection Summary

Aldridge, B. and J. Garrett. 1973. Roughness Coefficients for Stream Channels in Arizona. US Department of the Interior Geological Survey. Tucson, AZ.

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A 2. Referenced Documents

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PIMA COUNTY REGIONAL FLOOD CONTROL DISTRICT
TECHNICAL POLICY
(DRAFT)

POLICY NAME: Acceptable Model Parameterization for Determining Peak Discharge

POLICY NUMBER: Technical Policy, TECH-018

EFFECTIVE DATE: To be Determined
(comment period from October 1, 2008 to March 1, 2009)

PURPOSE

To standardize the parameterization of hydrologic models.

BACKGROUND

When peak discharges need to be established or revised, a computer-based hydrologic model or previously-accepted discharge value may be used. Technical Policy 015 describes which models are acceptable for determining peak discharges. Once a model is selected, this policy describes which parameterization shall be used for submittals to the Pima County Regional Flood Control District (District).

POLICY

A. **Watershed Delineation:** The accuracy of watershed delineation and flow path identification is critical in hydrologic modeling. The District requires the use of 2-foot contour interval (or finer where available) contour maps, such as the Pima Association of Governments (PAG) contour maps for delineation of basin boundaries and flow paths in all areas other than steep terrain. In areas of steep terrain, or where 2-foot or finer contour interval maps are not available, U.S. Geologic Survey (USGS) contour maps (7.5 minute series) may be used. At the discretion of the District, it may be necessary to acquire topographic data that has been sealed by a Professional Civil Engineer (PE), or Registered Land Surveyor (RLS) registered in the State of Arizona. In regulatory sheetflood areas, both 2-foot or finer contour interval maps and aerial photos with a resolution sufficient to determine flow paths and watershed boundaries shall be used. If Geo-HMS (COE, 2003) is used, Digital Elevation Models (DEMs) or Digital Terrain Models (DTMs), or DEMs derived from lidar data from PAG or other reputable vendors, may be used. With the approval of the District, alternative topographic data, such as stereo photography may be used.

B. **Pima County Hydrology Procedures:** Peak discharges calculations performed using the Pima County Hydrology Procedures shall follow the guidance for parameterization provided in the PC- Hydro User Guide (Arroyo Engineering, 2007).

C. **<u>HEC-1 and HEC-HMS:</u>** Peak discharges calculated using HEC-HMS (COE, 2006) or HEC-1 (COE, 1998) shall employ the following parameterization:

a. ***Rainfall Loss Method:*** Models shall employ the U.S Soil Conservation Service (SCS) Curve Number method using the Curve Number tables and Hydrologic Soils Group maps associated with the PC Hydro User Guide (Arroyo Engineering, 2007). The Curve Number shall not be adjusted for rainfall intensity or antecedent moisture conditions.

b. ***Time of Concentration Calculation:*** The U.S. Natural Resources Conservation Service (NRCS) segmented Time of Concentration (T_c) calculation shall be employed (USDA-NRCS, 1986). The Tc shall be calculated by summing the travel time for overland flow, shallow concentrated flow and channel flow, along the primary flow path. Manning's roughness coefficient for sheet flow shall be obtained using Table 3-1 in Technical Release 55, Urban Hydrology for Small Watersheds (USDA-NRCS, 1986). Maximum slope length for sheet flow shall be 100 feet. Manning's roughness coefficient for concentrated flow shall be determined using the method described in the District's Technical Policy 019.

c. ***Transform:*** The SCS Unit Hydrograph method shall be used.

d. ***Channel Routing:***

i. ***Routing in Natural Channels:*** Runoff can be routed using the Modified-Puls method for natural channels with the slope less than 1%. If HEC-1 is used, an 8-point cross-section may be used. A storage discharge table must be developed if HEC-HMS is used. Such a table can be developed using cross-sections and slopes derived from a Manning normal depth analysis or HEC-RAS (COE, 2001). The number of subreaches shall be calculated using the methods described in the HEC-HMS User's Manuals. Selection of Manning's n values shall conform to the guidance in Technical Policy 019.

ii. ***Routing in Constructed Channels and Steep Channel:*** Shall use the kinematic wave for constructed channels and channels with the slope greater than 1%. Reach length, slope, bottom of width and side slope may be obtained using the data utilized for watershed delineation (e.g. 2-foot contour interval contour maps, Digital Elevation Models (DEMs) or Digital Terrain Models (DTMs), or DEMs). Selection of Manning's n values shall conform to the guidance in Technical Policy 019. The number of subreaches shall be calculated using the methods described in the HEC-HMS User's Manuals.

e. ***Rainfall:*** The NOAA 14 Upper 90% rainfall shall be used as described in the District's Technical Policy 010. Point rainfall depth shall be evaluated for each basin or subbasin, based on the latitude and longitude of the centroid of the basin or subbasin.

f. ***Rainfall Distribution:*** Pima County is evaluating rainfall data to determine if the following rainfall distributions are reasonable. In the interim, the higher peak discharge calculated using the following two distributions shall be used:

   i. **SCS Type II 3-hr Storm:** The 3-hr distribution shall be used as the local storm. In general, this includes watersheds with a time of concentration (T_c) equal to or less than three hours (see Haan et al 1994).

   ii. **SCS Type I (24 hr):** The SCS Type I rainfall (NRCS, 1986) may apply for general storms on watersheds with times of concentration (T_c) greater than three hours.

g. ***Rainfall Aerial Reduction:*** Aerial reduction shall be estimated using Hydro-40 (National Weather Service, 1984) for the watershed and event of interest (i.e. same tables as Arizona State Standard). Aerial reduction shall be applied to watersheds larger than 1 square mile.

D. **Comparison of peak discharge**: Recommend to compare the peak discharge calculated using the Pima County Hydrology Procedures and the peak discharge obtained from USGS Regression Equation 13 (Thomas et al., 1997) and/or the equation developed by Eychaner (1984) (See Appendix).

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APPROVED BY:

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Suzanne Shields, P.E. **Date**
Director and Chief Engineer

Appendix for Tech-018

1.) USGS Regression Equation 13: The current regional regression relationship for southern Arizona is regression equation 13 from Thomas et al (1994). This method predicts peak discharge in cfs (Qp) as a function of watershed Area (square miles) only. It has the form:

$$Qp100 = 10^{(5.52 - 2.42 * A^{-0.12})}$$

2.) Eychaner 1984 (rural): This is a USGS publication that was prepared in cooperation with the City and County. It presents a series of regression equations that rely on watershed area (sq. miles), main channel slope (%), channel length (miles) and a shape factor to account for the differences in runoff noted between long watersheds and more traditionally-shaped watersheds. The equation for the 100 year peak discharge is:

$$Qp100 = 10^{(3.044 + 0.646(\log A) - 0.49(\log A)^2 + 0.706(\log S) - 0.367(\log S)^2 - 0.614(\log S)(LogSh))}$$

The shape factor (Sh) is calculated as (channel length)2/(Area)

3.) Eychaner 1984 (urban): This equation adjusts Eychaner's rural equation to account for the amount of impervious area, channel lining and channel modification. It is:

$$Qp100 = 7.7 A^{0.15} (13 - BDF)^{-0.32} Qp100^{0.82}$$

The Basin Development Factor (BDF) is a scoring factor to account for the degree of urbanization. The specific scoring is based on four factors described in pages 10-13 of the manual.The lower, middle and upper portions of a watershed are scored separately and the results are summed. The maximum BDF score is 12, and a score of 0 indicates that the rural equation should be used. (The Qp100 in the equation is the Qp100 calculated using Eychaner's rural method described in section 2 above.)

PIMA COUNTY REGIONAL FLOOD CONTROL DISTRICT
TECHNICAL POLICY

POLICY NAME: Acceptable Model Parameterization for Determining Peak Discharges

POLICY NUMBER: Technical Policy, TECH-018

EFFECTIVE DATE: May 1, 2010

PURPOSE

To standardize the parameterization of hydrologic models.

BACKGROUND

When determining peak discharges, a computer-based hydrologic model or previously-accepted discharge value may be used. Technical Policy *TECH-015, Hydrologic Model Selection for Peak Discharge Determination,* describes which models are acceptable for determining peak discharges. The Pima County Hydrology Procedures shall be used for riverine watersheds with an area less than 1 square mile. Peak discharges calculations performed using the Pima County Hydrology Procedures shall follow the guidance for parameterization provided in the PC- Hydro User Guide (Arroyo Engineering, 2007). Technical Policy *TECH-018* shall be applied to riverine watersheds with an area larger than 1 square mile but smaller than 20 square mile. This policy describes which parameterization shall be used for submittals to the Pima County Regional Flood Control District (District).

POLICY

A. **Watershed Delineation:** The accuracy of watershed delineation and flow path identification is critical in hydrologic modeling. The District requires the use of 2-foot contour interval (or finer where available) maps, such as the Pima Association of Governments (PAG) contour maps for delineation of basin boundaries and flow paths in all areas other than steep terrain. In areas of steep terrain, or where 2-foot or finer contour interval maps are not available, U.S. Geologic Survey (USGS) contour maps (7.5 minute series) may be accepted. At the discretion of the District, topographic data that has been sealed by an Arizona registered civil engineer (PE), or land surveyor (RLS) may be required. In regulatory sheetflood areas, both 2-foot or finer contour interval maps and aerial photos with a resolution sufficient to determine flow paths and watershed boundaries shall be used. If Geo-HMS (COE, 2003) is used, Digital Elevation Models (DEMs) or Digital Terrain Models (DTMs), or DEMs derived from lidar data from PAG or other reputable vendors, may be used. With the approval of the District, alternative topographic data, such as stereo photography may be used.

B. **<u>Pima County Hydrology Procedures:</u>** Peak discharges calculations performed using the Pima County Hydrology Procedures shall follow the guidance for parameterization provided in the PC- Hydro User Guide (Arroyo Engineering, 2007).

C. **<u>HEC-1 and HEC-HMS:</u>** Peak discharges calculated using HEC-HMS (COE, 2006) or HEC-1 (COE, 1998) shall employ the following parameterization:

a. ***Rainfall Loss Method:*** Models shall employ the U.S Soil Conservation Service (SCS) Curve Number method using the Curve Number tables, Vegetation map and Hydrologic Soils Group map associated with the PC Hydro User Guide (Arroyo Engineering, 2007) shall be used. The default vegetation cover percent provided in the PC- Hydro User Guide (Arroyo Engineering, 2007) shall be used. unless additional justification is provided. The Curve Number shall not be adjusted for rainfall intensity or antecedent moisture conditions.

b. ***Time of Concentration Calculation:*** The modified U.S. Natural Resources Conservation Service (NRCS) segmented Time of Concentration (T_c) calculation shall be employed (USDA-NRCS, 1986). The Tc shall be calculated by summing the travel time for sheet flow, shallow concentrated flow and channel flow, along the primary flow path.

i. *For sheet flow segment:*

1. Manning's roughness coefficient for sheet flow shall be obtained using Table 3-1 in Technical Release 55, Urban Hydrology for Small Watersheds (USDA-NRCS, 1986).
2. Maximum slope length for sheet flow shall be 100 feet.
3. The Kinematic wave method shall be used to estimate the travel time for sheet flow.

ii. *For shallow concentrated flow segment:*

1. The travel time for shallow concentrated flow using the velocity determined from Figure 3-1 of Technical Release 55, Urban Hydrology for Small Watersheds (USDA-NRCS, 1986).

iii. *For channel flow*

1. Manning's roughness coefficient for channel flow shall be determined using the method described in the District's Technical Policy *TECH-019, Standards for Floodplain Hydraulic Modeling*.
2. HEC-RAS velocity or the Manning's equation may be used to estimate the travel time for channel flow.
3. The discharge used to calculate velocity shall be estimated by integrating the Regional Regression Equation 13 (Thomas et al., 1997) with respect to area (which is 0.667 x the discharge value calculated with Regional Regression Equation 13).

c. ***Transform:*** The SCS Unit Hydrograph method shall be used.

d. ***Channel Routing:***

1.) ***Routing in Natural Channels:*** Runoff shall be routed using the Modified-Puls method for natural channels with the slope less than 1.5%. A storage discharge table is required if HEC-HMS is used. Such a table can be developed using cross-sections and slopes derived from a Manning normal depth analysis or HEC-RAS (COE, 2001). The number of subreaches shall be calculated using the methods described in the HEC-HMS User's Manual. Initial discharge to estimate HEC-RAS velocity for channel flow should be determined using discharge calculated with USGS Regression Equation 13 (Thomas et al., 1997).

2.) ***Routing in Constructed Channels and Steep Channel:*** Kinematic wave may be used for constructed channels and natural channels with slopes greater than 1%. Reach length, slope, bottom width and side slope may be obtained using the data utilized for watershed delineation (e.g. 2-foot contour interval contour maps, Digital Elevation Models (DEMs) or Digital Terrain Models (DTMs), or DEMs). Selection of Manning's n values shall conform to the guidance in Technical Policy *TECH-019, Standards for Floodplain Hydraulic Modeling*.. The number of subreaches shall be calculated using the methods described in the HEC-HMS User's Manuals.

e. ***Rainfall:*** The NOAA 14 Upper 90% rainfall shall be used as described in the District's Technical Policy *TECH-010, Rainfall Input for Hydrologic Modeling*. Point rainfall depth shall be evaluated for a watershed, based on the latitude and longitude of the centroid of the watershed. If appreciable elevation change occurs on a watershed, users should use different values for higher and lower elevations.

f. ***Rainfall Aerial Reduction:*** Aerial reduction shall be applied to watersheds larger than 1 square mile. Aerial reduction shall be estimated using Hydro-40 (National Weather Service, 1984) for the watershed and event of interest (i.e. same tables as Arizona State Standard).

g. ***Rainfall Distribution:*** The following rainfall distributions shall be used, with the highest peak discharge selected in order to determine the critical (i.e. storm that produces the highest discharge) :

1. **SCS Type II 3-hr Storm:** The 3-hr distribution shall be used as the local storm. In general, this includes watersheds with a time of concentration (T_c) equal to or less than three hours (Haan et al 1994).

3. **SCS Type I (24 hr):** The SCS Type I rainfall (NRCS, 1986) may apply for general storms on watersheds with times of concentration (T_c) greater than three hours.

D. **<u>Comparison of peak discharge</u>**: The peak discharge shall be compared with the peak discharge obtained from USGS Regression Equation 13 (Thomas et al., 1997) and/or the equation developed by Eychaner (1984) (See Appendix), and existing regulatory discharge estimate.

REFERENCES

Aldridge, B. and J. Garrett. 1973. *Roughness Coefficients for Stream Channels in Arizona.* US Department of the Interior Geological Survey. Tucson, AZ.

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Suzanne Shields, P.E. **Director and Chief Engineer**	**Date**

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