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

FEMA FIRM Panel 04019C-1630, 1635, and 1637K

Prepared by

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Approved by

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SHIELDS
DATE SIGNED 1/12/11
ARIZONA U.S.A.

Suzanne Shields, PE
Director

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Pima County Regional
FLOOD CONTROL
DISTRICT

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Addendum

Attached CD

Race Track 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 Race Track 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 Race Track Wash. The site includes Sections 5, 7, 18, and 19 of Township 13 South, Range 14 East, Sections 24 of Township 13 South, Range 13 East, Pima County, Arizona. Entire watershed of the Race Track Wash is in FEMA Zone X, as shown on the current Flood Insurance Rate Map (FIRM) number 04019C-1630, 1635, and 1637K.

The watershed is 1.38 square miles. The study watershed was divided into three sub-watersheds (Fig.1.1). The study limits for the Race Track Wash extends from River Rd. to the south of Sunrise Dr. (Fig.1.2).

1.4 Methodologies Used for Hydrology and Hydraulics

Topographic, hydrologic and hydraulic analyses were performed to determine drainage conditions in Race Track wash. ArcGIS, Version 9.3.1, HEC-HMS version 3.4 (HEC-HMS), Hec-RAS Version 4.0 (HEC-RAS), and HEC-GeoRAS, Version 4.2.93 (HEC-GeoRAS) were used for the analyses.

1.5 Acknowledgements

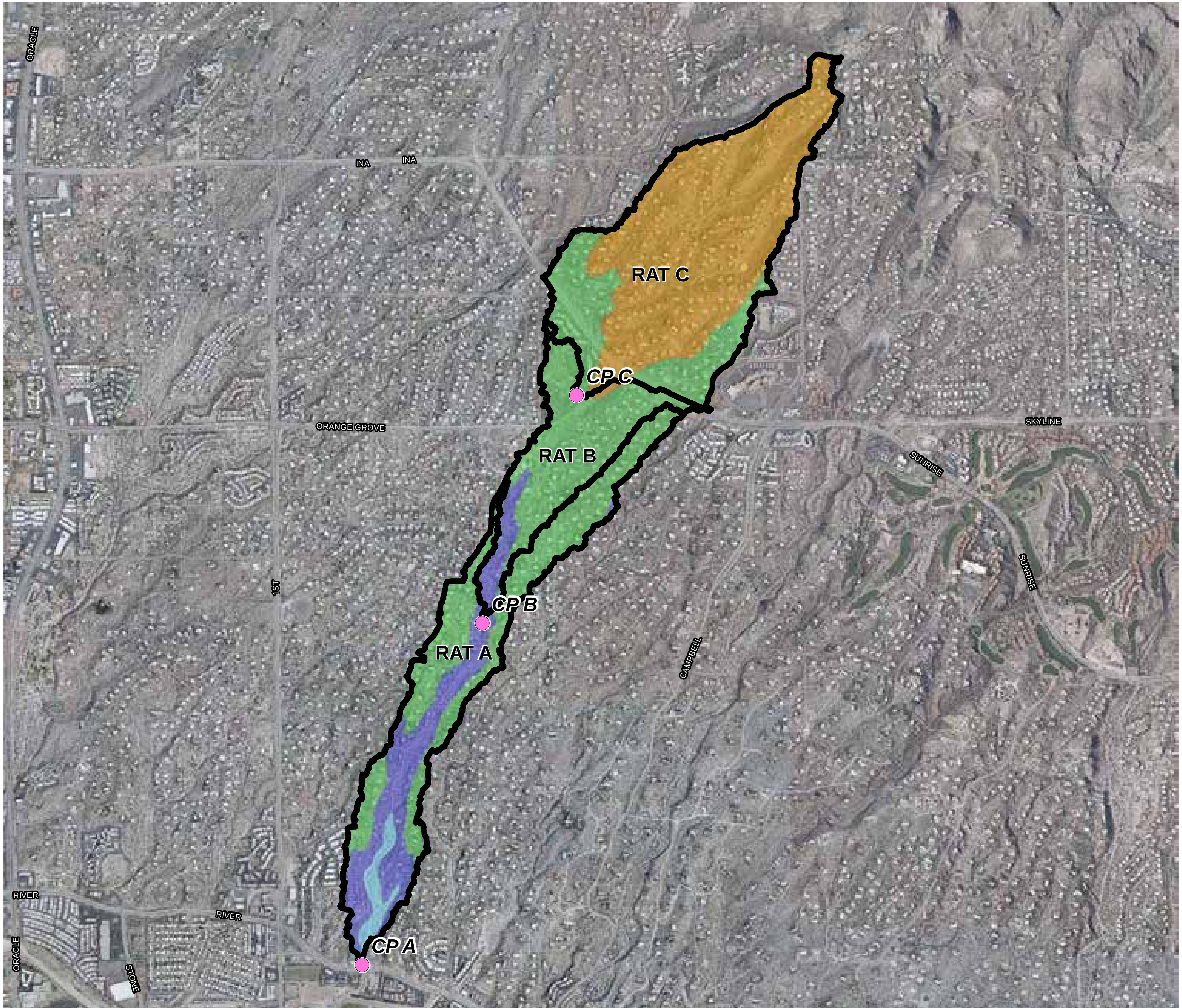
This study relied on assistance of RFCD GIS staff, who were integral to the development of the models and maps.

1.6 Study Results

The modeled discharge for the Race Track Wash on River Rd. is 1883 cfs, where the area is 1.38 square miles.

Floodplain boundary for areas less than one square mile is mapped as part of a future effort to map tributaries smaller than one square mile using the PC Hydro program to determine discharge.
The floodplains for delineation of watersheds greater than one square mile were delineated at part of this study. The study found some homes at risk for flooding during the 100-yr flood. In-general, the footprint of the 500-yr floodplain is slightly wider than the 100-yr floodplain.

Figure 1.3
Soil Classification Map
Race Track Wash



Concentration Point
Subbasins

Soil Classification

Soil Group: A (100%)
Soil Group: B (100%)
Soil Group: B (82%) C (18%)
Soil Group: C (47%) D (53%)

Aerial Photo:
2008 Pima Association of Government

Pima County Index Map

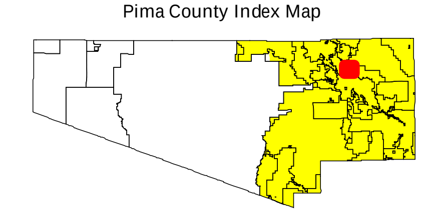


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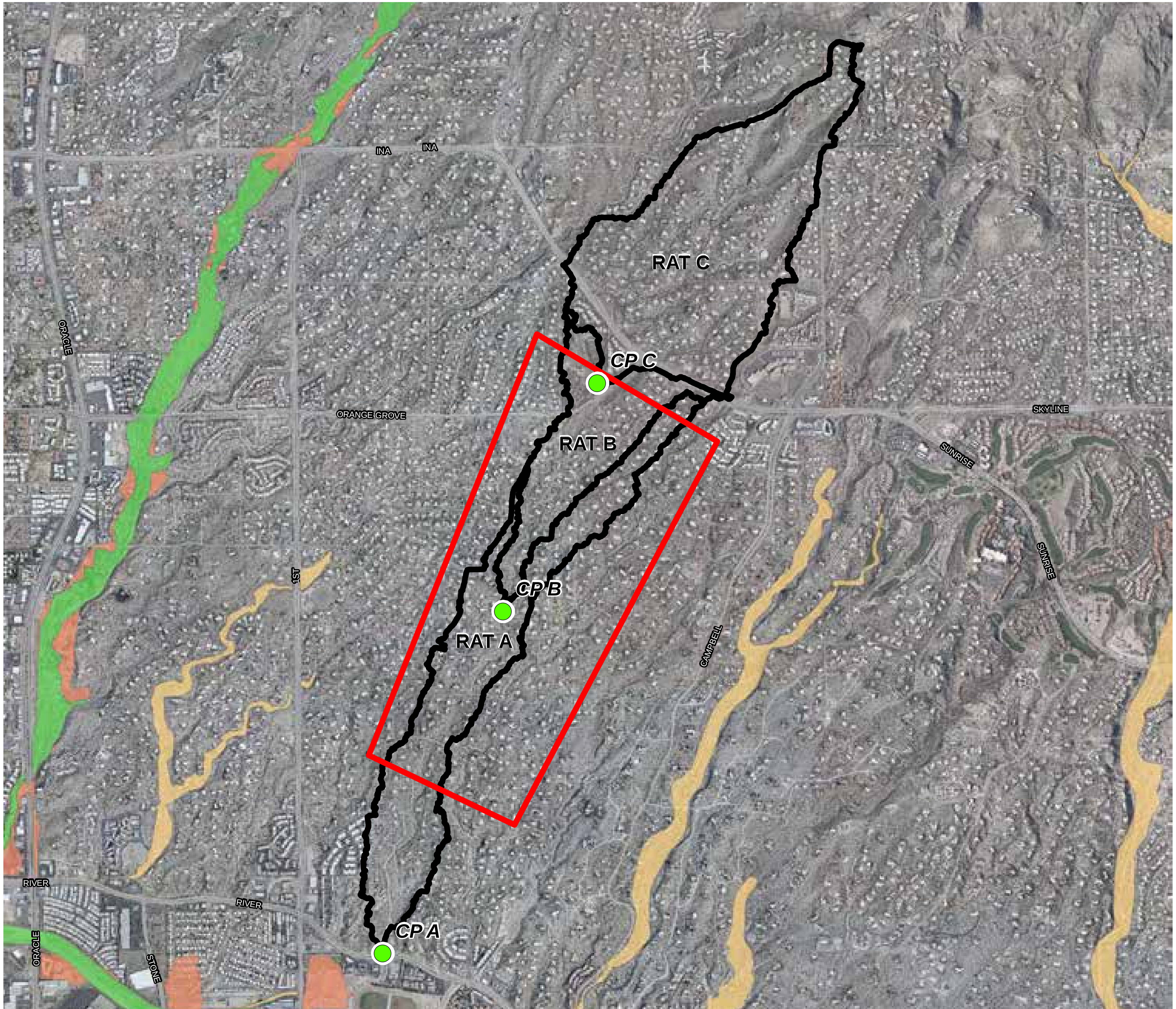
Figure 1.2
Study Limit Map
Race Track Wash
with FEMA Floodplains



Concentration Point
Study Limit
Main Subbasins
Existing FEMA Floodplain
ZONE A
ZONE AE
ZONE X - SHADED

Aerial Photo:
2008 Pima Association of Government

Pima County Index Map

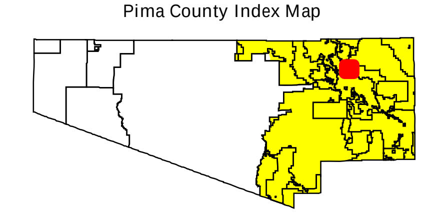


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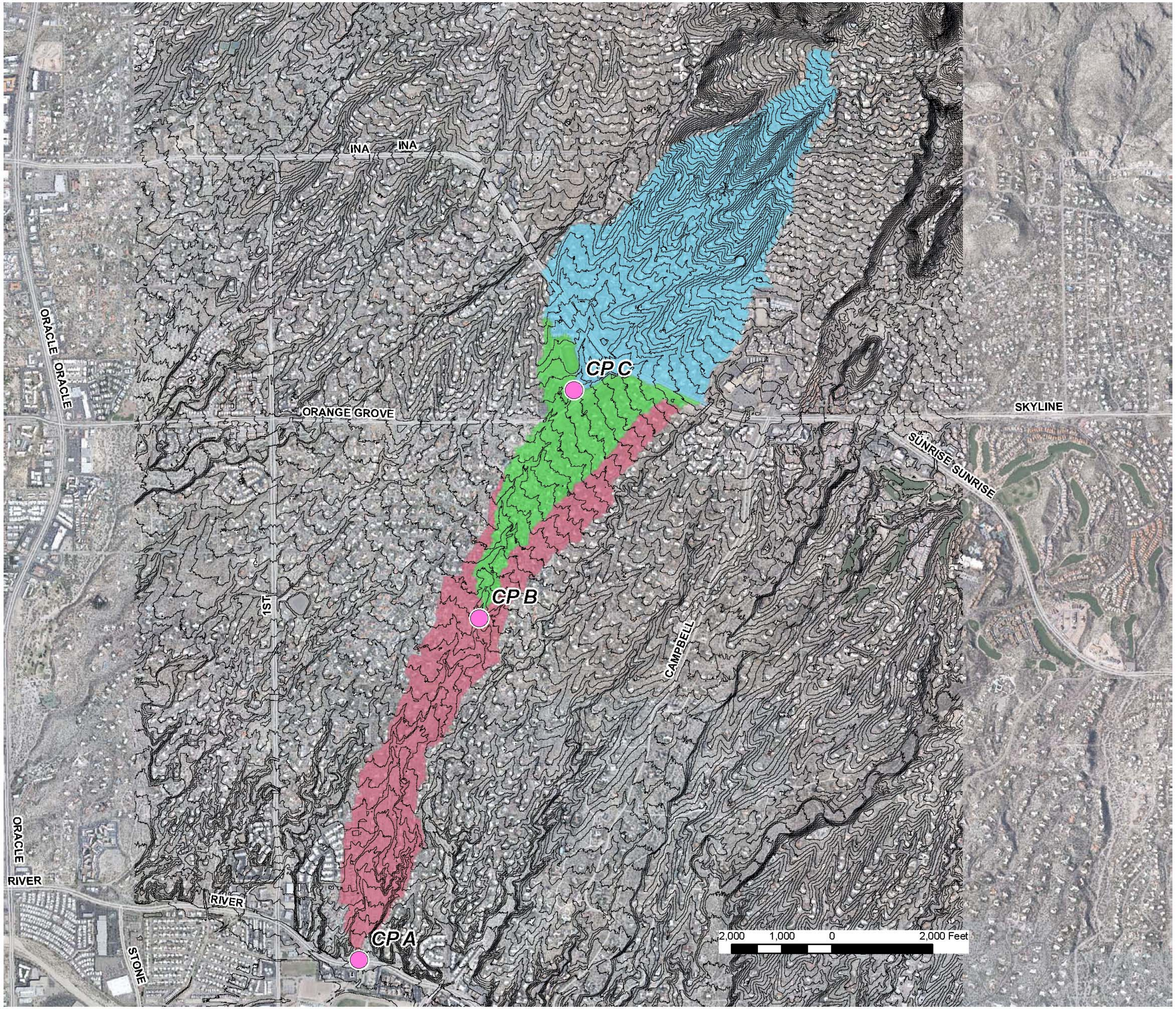
Figure 1.1
Race Track Wash Watershed Map



Concentration Point

Contour 10ft

Subbasins

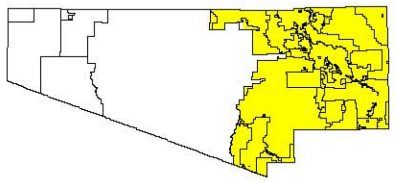
RAT A

RAT B

RAT C

Aerial Photo: 2008 Pima Association of Government

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: Not Accepted
2.1.6 Study Contractor: Pima County Regional Flood Control District
2.1.7 State Technical Reviewer: Not Applicable
2.1.8 Local Technical Reviewer: Suzanne Shields
2.1.9 River or Stream Name: Race Track Wash
2.1.10 Reach Description: Race Track Wash
2.1.11 Study Type: Hydrology and Hydraulics study of a Riverene System

2.2 Mapping Information

2.2.1 FIRM Panels: 04019C-1630, 1635 and 1637K
2.2.2 Mapping for Hydrologic Study: Lidar based on 2008 flight used to derive 2' contour interval maps using ArcGIS 9.3.1
2.2.3 Mapping for Hydraulic Study: Lidar based on 2008 flight used to derive a DEM (5-ft cell size) for use with GeoRAS

2.3 Hydrology

2.3.1 Model or Method Used: HEC-HMS model parameterized using methods of RFCD Draft 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

2.4 Hydraulics

2.4.1 Model or Method Used: HEC-RAS, 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 normal depth.

2.5 Additional Study Information:

None

Section 3: Survey and Mapping Information

3.1 Field Survey Information

No field survey was used.

3.2 Mapping

The 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 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. DEM was also used to characterize the topography along channels used for the floodplain mapping process. 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 Race Track Wash (RAT A, B, and C; Figure 1.1) were calculated using U.S. Army Corps of Engineers Computer Hydrologic Modeling System, (HEC-HMS) version 3.1.0. The HEC-HMS morel requires the 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 are summarized in Table 4.1. The data processing methods are summarized in Fig. 4

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.

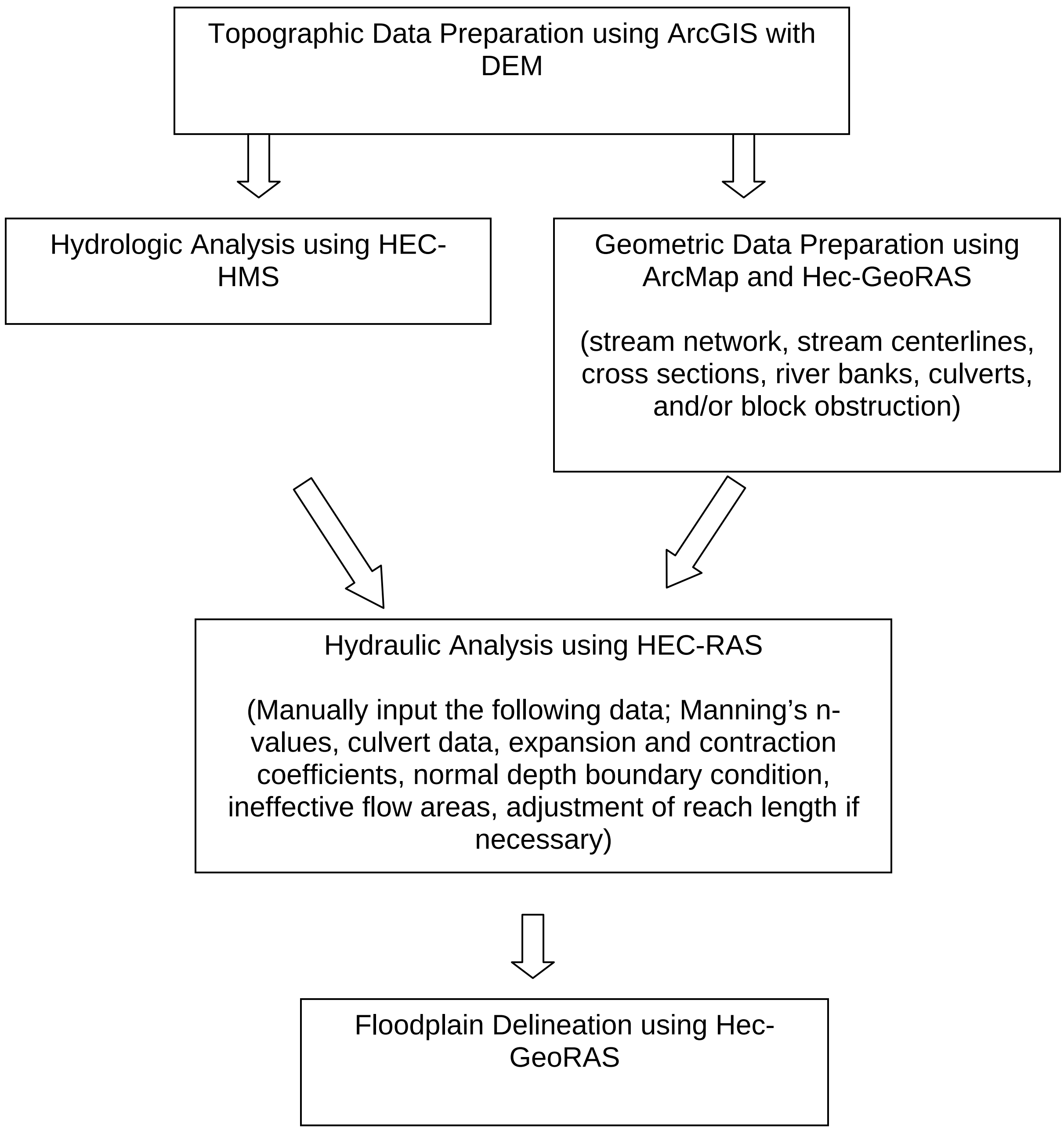
The limits of this study are shown in Fig.1.2. The site includes Sections 5, 7, 18, and 19 of Township 13 South, Range 14 East, Sections 24 of Township 13 South, Range 13 East, Pima County, Arizona. The entire watershed of the Race Track Wash is in FEMA Zone X, as shown on the current Flood Insurance Rate Map (FIRM) number 04019C-1630, 1635, and 1637K.

The watershed is 1.38 square mile. The study watershed was divided into three sub-watersheds (Fig.1.1). The upstream study limits is Sunrise Dr, while the downstream limit is River Rd (Fig.1.2).

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 2008 Lidar. Study reach includes only a main channel. 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, culverts, and other physical attributes of the wash were determined by using the 2-ft interval contour map and 2008 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. The point rainfall depth for the 3-hour storm was obtained, based on the coordinates of the centroid of the watershed (Latitude: 32.317, Longitude: 110.945). Areal reduction factor was applied to watersheds larger than 1 square mile as noted in Tech-018. The 3-hr, SCS Type II rainfall distribution described in Haan et al (1994) was used.

4.2.6 Physical parameters.

A hydrologic soils group map for the study watershed is presented in Fig.1.3. The study watershed is covered with Desert brush. Hydrologic Soil Groups B and C are the dominant soil types in the Race Track Wash watershed. 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. Impervious cover percentage of 10% was 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.

Table 4.2 - Sub-basin Characteristics

Sub-Basin	Area (sq mi)	CN	Impervious Area (%)	Vegetation Cover (%)	Lag Time (min)
RAT A	0.45	84.0	10.0	30	34.1
RAT B	0.24	83.9	10.0	30	27.1
RAT C	0.69	88.3	10.0	30	16.1

The SCS TR-55 segmental Time of Concentration (Tc) method with a combination of kinematic wave method 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 sheetflow was calculated using kinematic wave method. 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.

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 Modified-Puls method. A storage discharge table for the channel routing was developed using the cross sections and slopes derived from HEC-HMS. Modified puls 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 (sq mi)	Rainfall Depth (in)	Runoff Volume (in)	Peak Discharge (cfs)
RAT A	0.45	3.29	1.75	465
RAT B	0.24	3.29	1.75	293
RAT C	0.69	3.29	2.1	1445

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 Race Track Wash were determined using the HEC-HMS. Six hours were simulated on a 1 minute time step with rainfall occurring in the first three hours. For the hydraulic analysis the following discharges were 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
CP A	River Rd.	1.38	3.16	1.81	1883	2:06
CP B	Between Camino Paore Isidoro and Calle de la Culebra	0.93	3.29	2.01	1680	1:49

Table 4.5 – Summary of 25-yr Peak Discharge Values

Concentration Point	Location	Area (sq mile)	Rainfall Depth (in)	Runoff Volume (in)	Q25 HMS (cfs)	Q25 RRE (cfs)	Time to Peak
CP A	River Rd.	1.38	2.45	1.22	1211	887	2:09
CP B	Between Camino Paore Isidoro and Calle de la Culebra	0.93	2.55	1.37	1130	691	1:51

Table 4.6 – Summary of 500-yr Peak Discharge Values

Concentration Point	Location	Area (sq mile)	Rainfall Depth (in)	Runoff Volume (in)	Q500 HMS (cfs)	Time to Peak
CP A	River Rd.	1.38	4.13	2.66	2830	2:02
CP B	Between Camino Paore Isidoro and Calle de la Culebra	0.93	4.13	2.9	2420	1:49

4.5.2 Verification of results.

Results are reasonable when compared with USGS Regression Equation 13 (Thomas et al, 1997, Table 4.7). 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. Existing regulatory peak discharge for the Race Track Wash is 2100 cfs at First Ave (downstream of CP A). The proposed discharge is around 10% smaller than the existing regulatory peak discharge.

Table 4.7 – Comparison of 100-yr Peak Discharge Values

Concentration Point	Location	Area (sq mile)	Q100 HMS (cfs)	Q100 RRE (cfs)
CP A	River Rd.	1.38	1883	1555
CP B	Between Camino Paore Isidoro and Calle de la Culebra	0.93	1680	1199

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.

5.2 Work study maps

As described above, geometric data for HEC-RAS including stream centerline, cross-sections, and culverts, were obtained from HEC-GeoRAS. The locations of cross sections and channels used for the 100-yr floodplain analysis are show in Exhibit 1. The 100-yr and 500-yr floodplain limits are also shown in Exhibit 1.

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 2008 aerial photo. The roughness used in this study is 0.055 for overbank areas and 0.035-0.04 for a channel. Bank stations were refined by selecting bank stations based on the topography and a 2008 aerial photo.

5.3.2 Expansion and contraction coefficients.

Default HEC RAS expansion (0.3) and contraction (0.1) coefficients were used for the most cross sections. The expansion coefficient of 0.5 and contraction coefficient of 0.3 were used for the cross sections immediately upstream or downstream of culverts.

5.4 Cross section description.

A 2-foot interval contour map derived from 2008 LiDAR data was used to select the location of cross sections. Cross-section locations were determined primarily based on the channel topography. The cross-section lines were drawn to be perpendicular to flow paths in Geo-RAS and ArcGIS.

5.5 Modeling considerations.

5.5.1 Hydraulic Jump and drop analysis.

No Hydraulic Jumps were encountered.

5.5.2 Bridges and culverts.

There are four culverts along the study reach of the Race Track Wash.

5.5.3 Levees and dikes.

None.

5.5.4 Islands and flow splits.

None.

5.5.5 Ineffective flow areas.

Ineffective flow areas were noted on the study reach of the Race Track Wash.
In general these ineffective flow areas were disconnected overbank areas that would not convey flow to the next downstream cross-section or immediately upstream or downstream of culverts.

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.

Lateral structures were used for the cross sections where containment is lost (Reach C2, station# 1865, reach B station# 5289, 5109, 5081). The HEC-RAS model includes the tributaries (RAT A1, B1, C1, C2, C3, C4, C5, and C6). The methods and results of the tributaries were summarized in Addendum.

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 HEC-RAS modeling results were summarized in Appendix E.

5.9.2 Verification of results.

Existing floodplain maps are not available along the Race Track Wash. The new map tends to follow the floodplain topography. The results suggest that the mapping is reasonable.

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

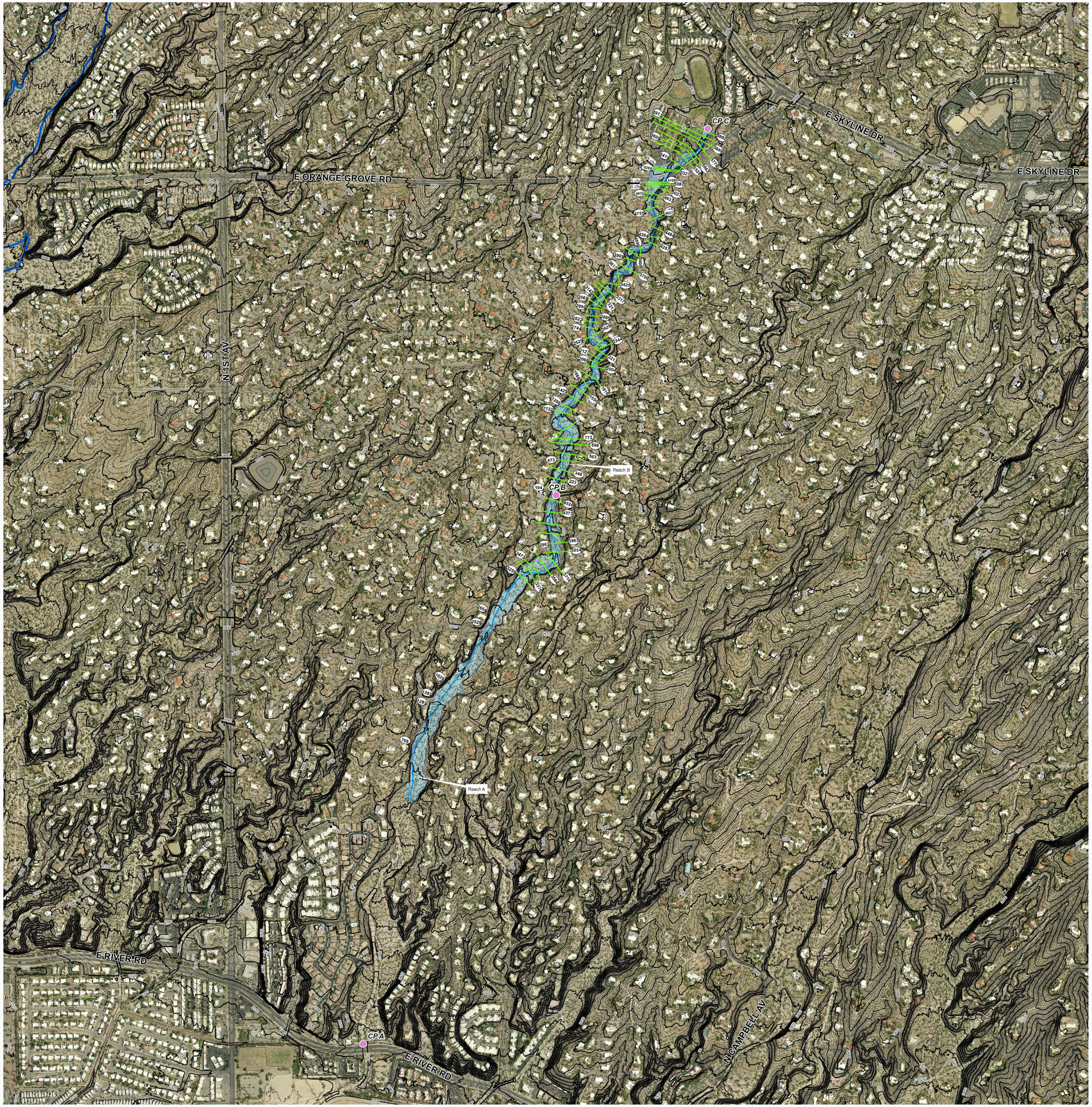


Exhibit 1
100-year Floodplain with cross sections Race Track Wash

- Discharge Points
- contour_10ft
- Contour 2 foot
- River
- Existing Zone A
- Proposed 100yr Flooding

Areial Photo 2010 Pictometry
Topo: 2008 Pima Association of Governments
Vertical Datum: NAVD 1988

Pima County Index Map

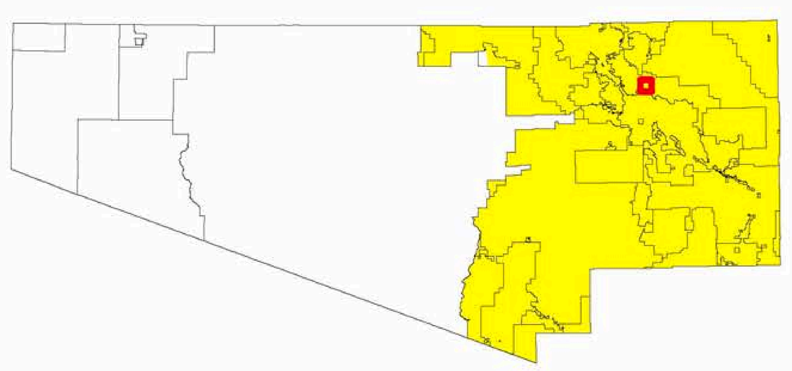


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Exhibit 1
100-year Floodplain with cross sections Race Track Wash Sheet 1 of 2

Discharge Points
contour 10 foot
Contour 2 foot
River
Existing Zone A
Proposed 100yr Flooding

Areial Photo 2010 Pictometry
Topo: 2008 Pima Association of Governments
Vertical Datum: NAVD 1988

Pima County Index Map

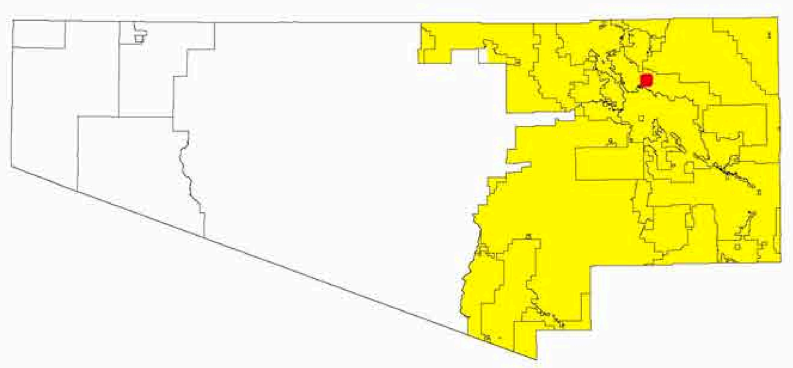

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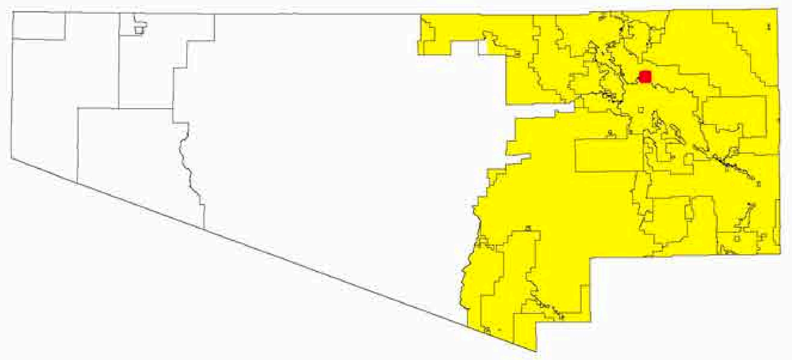
Exhibit 1
100-year Floodplain with cross sections Race Track Wash
Sheet 2 of 2

- Discharge Points
- contour 10 foot
- Contour 2 foot
- River
- Existing Zone A
- Proposed 100yr Flooding

Areial Photo 2010 Pictometry
Topo: 2008 Pima Association of Governments
Vertical Datum: NAVD 1988

Pima County Index Map



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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

Appendix F: Erosion and Sediment Transport Analysis

(None – no sediment transport analysis in this report)

Addendum

Floodplain Analysis for Race Track Wash Tributaries

Introduction

Preliminary floodplain boundaries for areas less than one square mile were shown in the main part of the report. The peak discharge for the Race Track Wash main channels was determined using HEC-HMS. This addendum provides drainage information for the Race Track Wash tributaries. Peak discharge for the tributaries was obtained using Pima County Hydrology Procedures (PC-Hydro, Arroyo Engineering, 2007), Version 5.3.1. Floodplain limits for “regulatory washes” will be shown in this addendum. The assumption that regulatory washes have drainage areas greater than 20 acre was used to determine the upstream end the tributaries.

Description of the watershed

The three subbasins used for HEC-HMS analysis (RAT A, B, and C) were further divided into smaller subbasins to determine peak discharge for the tributaries using PC-Hydro. The eight subbasins (RAT A1, B1, and C1-C6) were delineated for the PC-Hydro analysis (Fig. A1). Study limits are shown on Fig. A2. Hydrologic Soil Map is shown on Fig. A3.

Data processing procedures

ArcGIS, Version 9.3.1, PC-Hydro, Version 5.3.1, HEC-RAS, Version 4.0, and HEC-GeoRas, Version 4.1.1 were used for the analyses. As mentioned in the main part of the report, the 2008 Light Detection and Ranging (LiDAR) data and 2008 PAG aerial photo were used for the analysis. Slope break points were determined using the contour lines. The locations of the stream centerline, cross-sections, river banks, culverts, and other physical attributes of the wash were determined by using a topographic map and aerial photo (Exhibit A1).

Hydrologic analysis

The 100-year return interval peak discharge rates for the eight subbasins were computed by using PC-Hydro. NOAA Atlas 14 Upper 90% Confidence Interval rainfall data were used for the analysis. Hydrologic soils group map is shown in Fig. A3. The watercourse was divided into segments (Reaches) using slope break points. The basin factor for each segment was determined by using a 2008 PAG aerial photo. Basin Factors were based on the tables in the PC Hydro User Guide. The Basin Factor ranges from 0.034 to 0.036 which corresponds to Suburban-Foothills (< 1 house/acre). A vegetation cover density of 30% was used to select the SCS Curve Number for the hydrologic calculation of the study watershed. Impervious cover percentage was 10%, which was determined using a 2008 PAG aerial photo. The results were summarized in Table A2.

Table A1. Subbasin Characteristics

Sub-Basin	Area (acre)	Impervious Area (%)	Vegetation Cover (%)	Time of Concentration (min)
RAT A1	72.5	10.0	30	14.6
RAT B1	45.1	10.0	30	13.3
RAT C1	118.7	10.0	30	10.2
RAT C2	52.1	10.0	30	17.8
RAT C3	75	10.0	30	8.2
RAT C4	9.4	10.0	30	12.9
RAT C5	120.7	10.0	30	11.1
RAT C6	67.6	10.0	30	8

Table A2. Summary of the results

CP	Area (acre)	Q100 PC-Hydro (cfs)	Q100 RRE (cfs)
A1	72.5	305	238
B1	45.1	191	156
C1	118.7	673	361
C2	324.8	1305	785
C3	75	491	245
C4	197.7	1058	542
C5	120.7	702	366
C6	67.6	447	224

Hydraulic analysis

Steady flow analysis was performed to determine 100-year water surface elevation for the Race Track Wash by using HEC-RAS. There are three culverts in subbasin RAT C1, and two culverts in subbasins RAT A, C2, and C6. No floodplain was mapped between Skyline Dr. and Orange Grove Rd. because there are no outlets between the roads and the flow stays underground.

Manning's roughness coefficients for the main channel and the over-bank areas were determined by using a 2008 PAG aerial photo. The roughness coefficient of 0.04 was assigned for the channel while 0.055 was assigned for the overbank area. Entrance loss coefficient and Manning's roughness coefficient of the culverts are obtained from HEC-RAS Hydraulic Reference Manual version 3.1. Contraction and expansion coefficients are 0.3 and 0.5 for just upstream and downstream of culverts, and 0.1 and 0.3 for other cross sections, which were obtained from HEC-RAS Hydraulic Reference Manual. Normal depth with a slope of 0.028 at the downstream end of the study area for the main channel (River Rd.) was used as a boundary condition for the steady flow analysis. A floodplain limit was shown in Exhibit A1. There are a few houses mapped in a floodplain along the tributaries (Exhibit A1).

References

HEC-RAS Hydraulic Reference Manual version 3.1, US Army Corps of Engineering Center, November 2002.

PC-Hydro User Guide, PC-Hydro V5 Pima County Hydrology Procedures, A couputer program for predicting peak discharge of surface runoff from small semi-arid watersheds in Pima County, Arizona, Arroyo Engineering, LLC, 2007

Phillips J., and Tadayon, S., 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, Flood Control District of Maricopa County, Scientific Investigations Report 2006-5108.

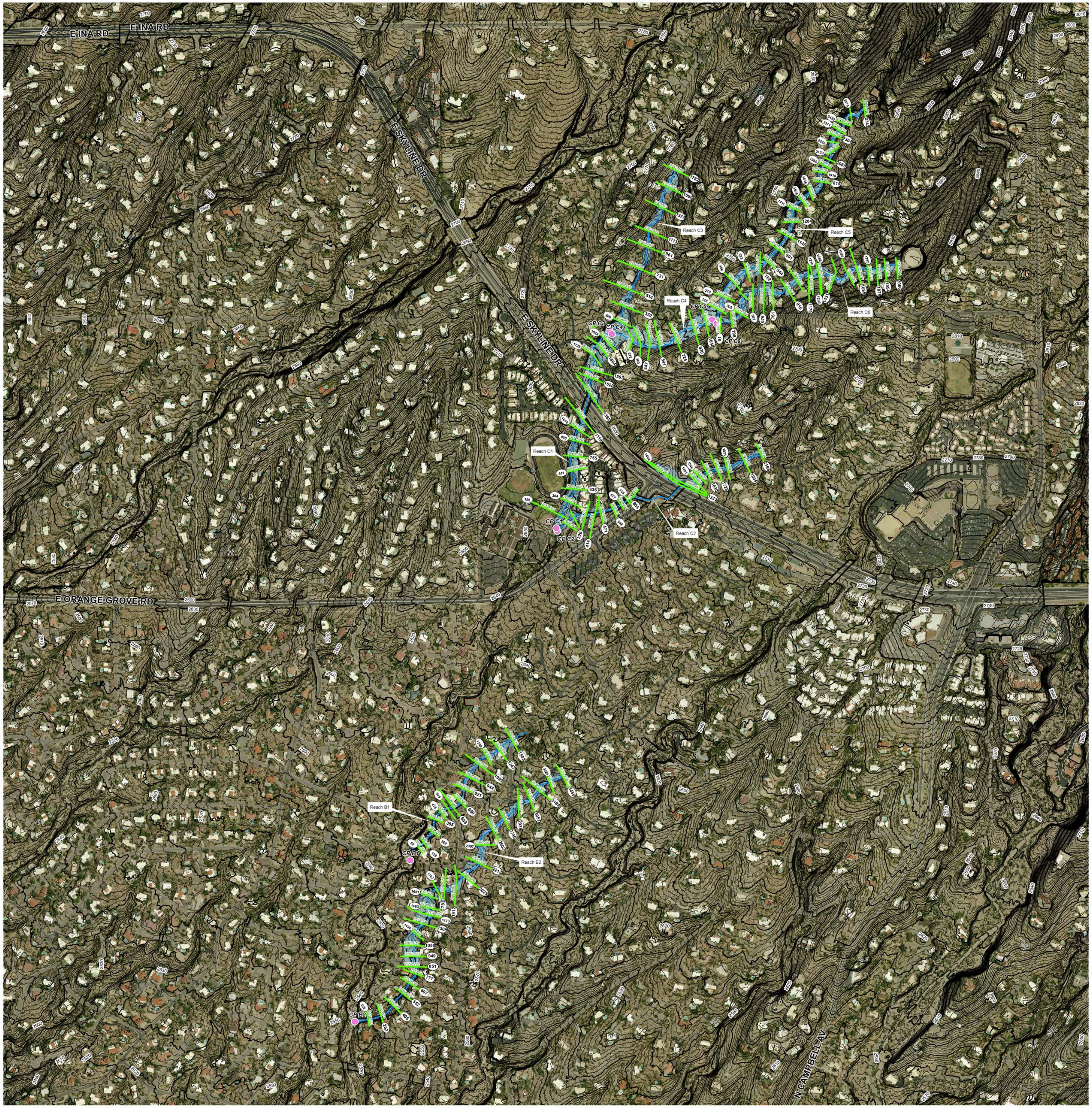
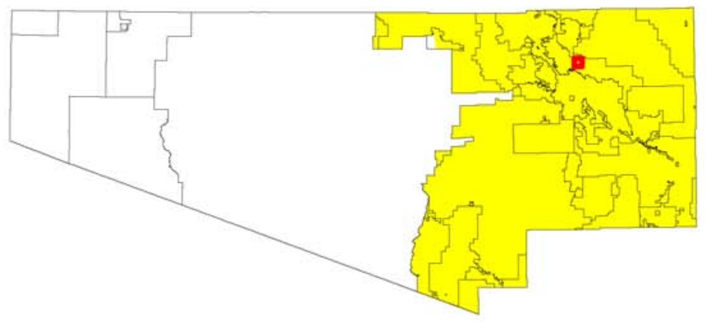


Exhibit A1
100-year Floodplain with cross sections Race Track Wash Tributaries

Discharge Points
Cross Section
River
Contour 2 foot
Contour 10 foot
Existing Zone A
Proposed 100yr Flooding

Areial Photo: 2010 Pictometry
Topo: 2008 Pima Association of Governments
Vertical Datum: NAVD 1988

Pima County Index Map



Index Map Scale 1:1,500,000

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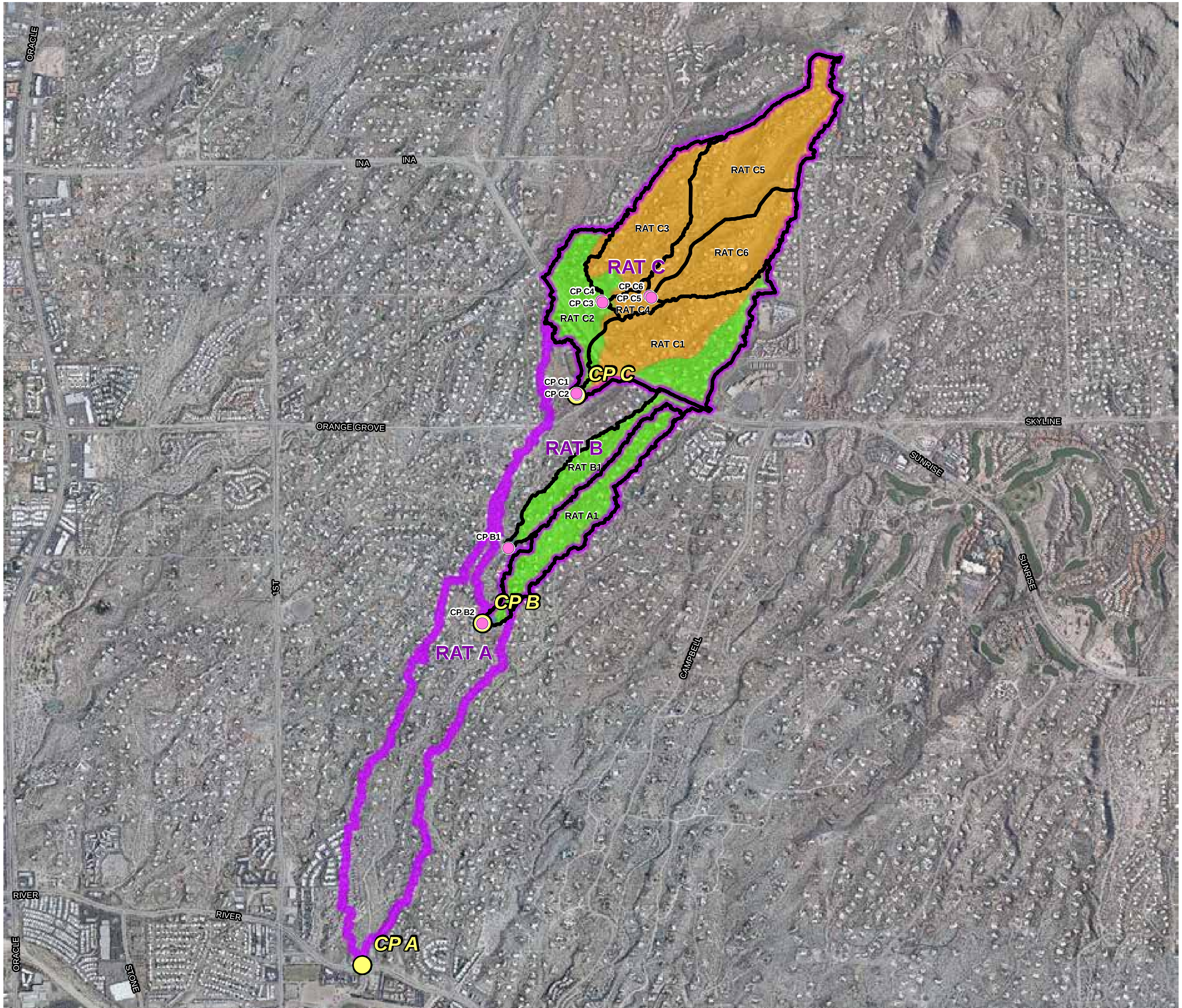


Figure A3
Soil Classification Map
Tributaries Race Track Wash

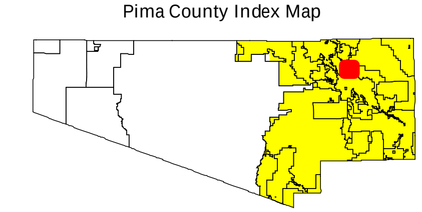
- Tributaries Concentration Point
- Main Concentration Point
- Tributaries Subbasins
- Main Subbasins

Soil Classification

- Soil Group: B (100%)
- Soil Group: B (82%) C (18%)
- Soil Group: C (47%) D (53%)

Aerial Photo:
2008 Pima Association of Government

Pima County Index Map



Index Map Scale 1:5,250,000

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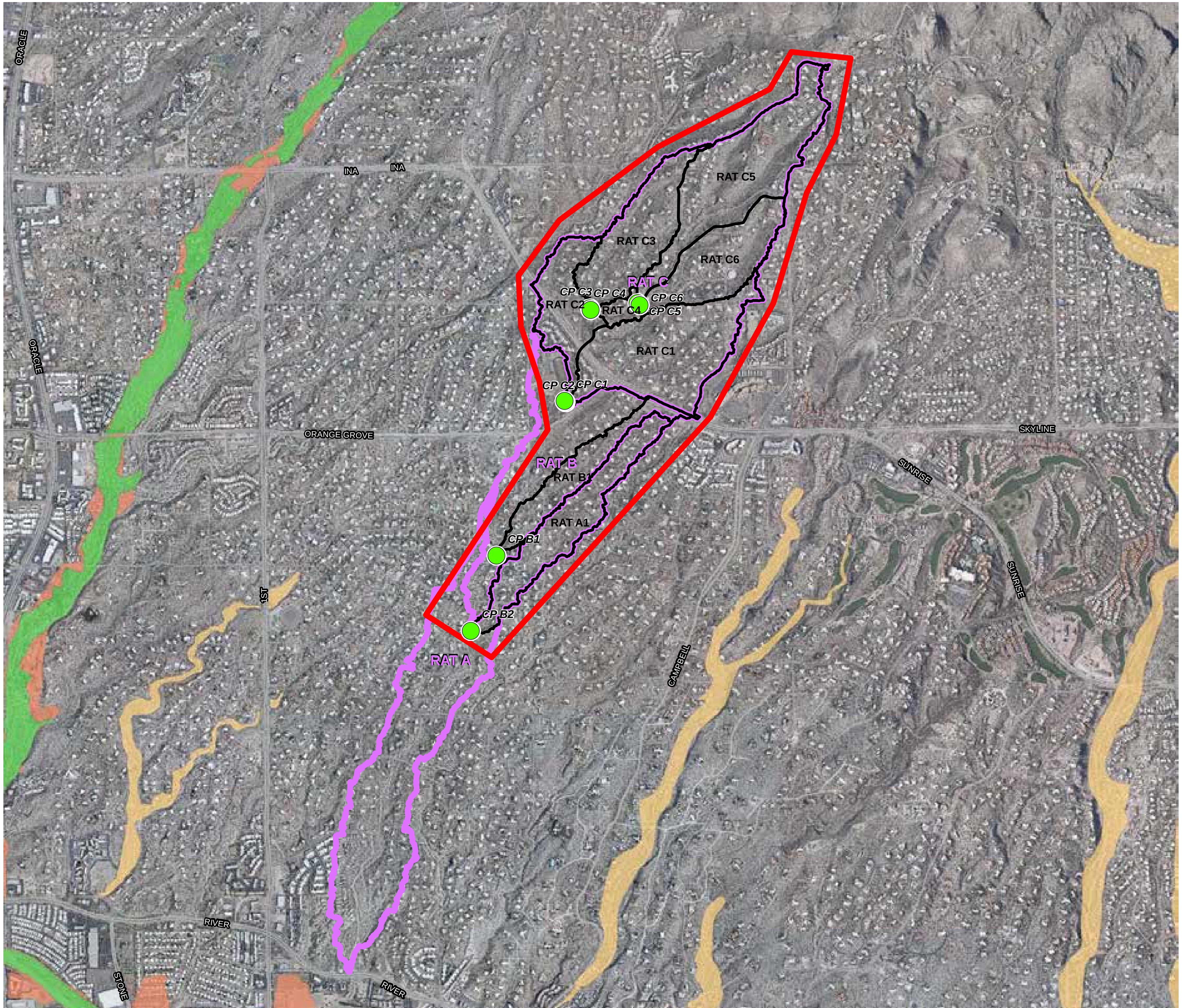
Figure A2
Study Limit Map
Tributaries Race Track Wash
with FEMA Floodplains



Concentration Point

Study Limit

Tributaries Subbasins

Main Subbasins

Existing FEMA Floodplain

ZONE A

ZONE AE

ZONE X - SHADED

Aerial Photo:
2008 Pima Association of Government

Pima County Index Map

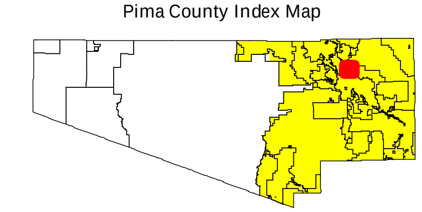


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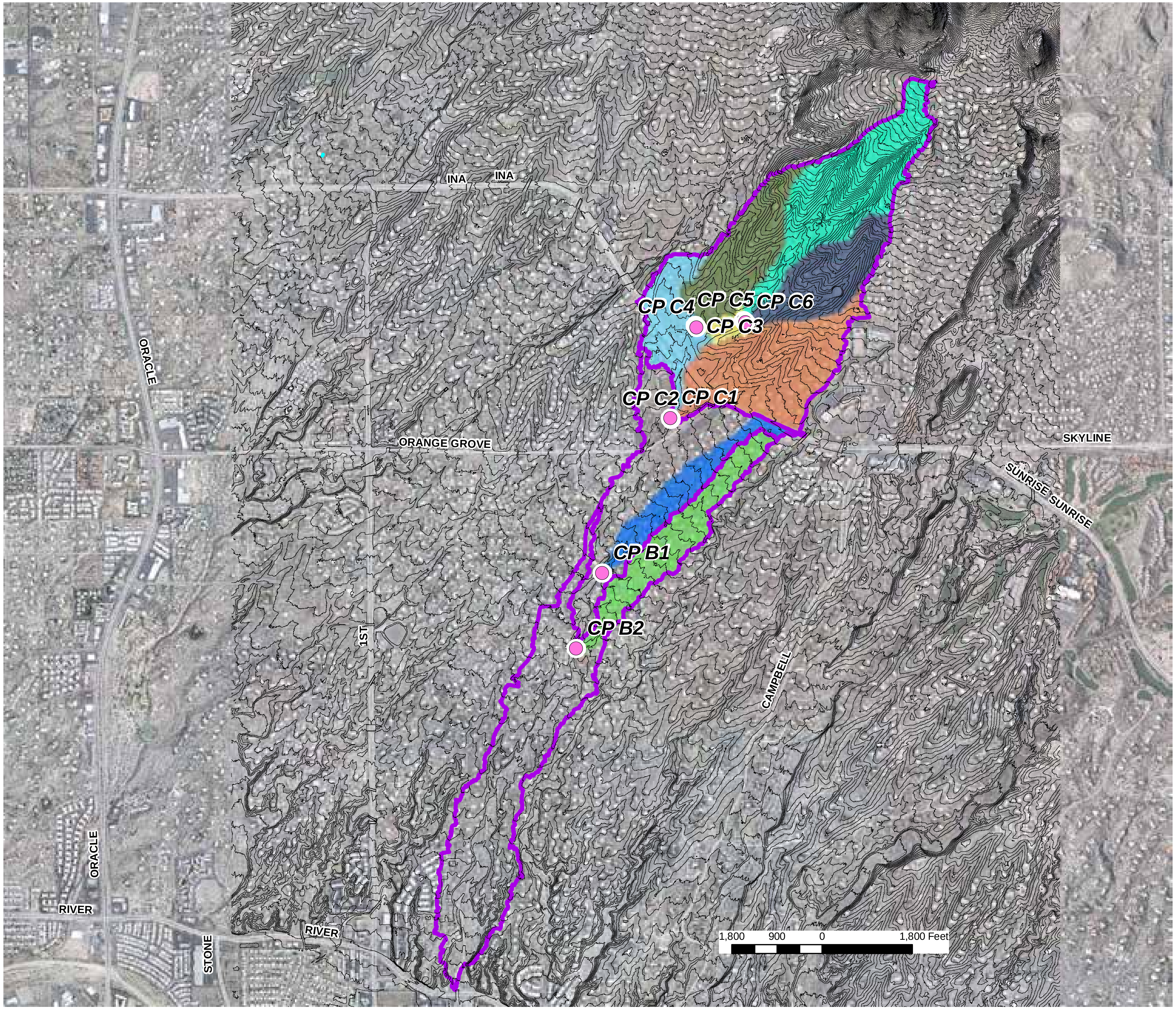
Figure A1
Race Track Tributaries Watershed Map



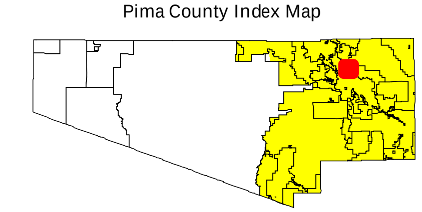
Concentration Point
Contour 10 Foot
Main Subbasins

Tributaries Subbasins

RAT A1
RAT B1
RAT C1
RAT C2
RAT C3
RAT C4
RAT C5
RAT C6

Aerial Photo: 2008 Pima Association of Government

Pima County Index Map



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