PIMA COUNTY
FLOOD CONTROL

MEMORANDUM

DATE: August 21, 2018

TO: All

FROM: Brian Jones, CFM
Chief Hydrologist

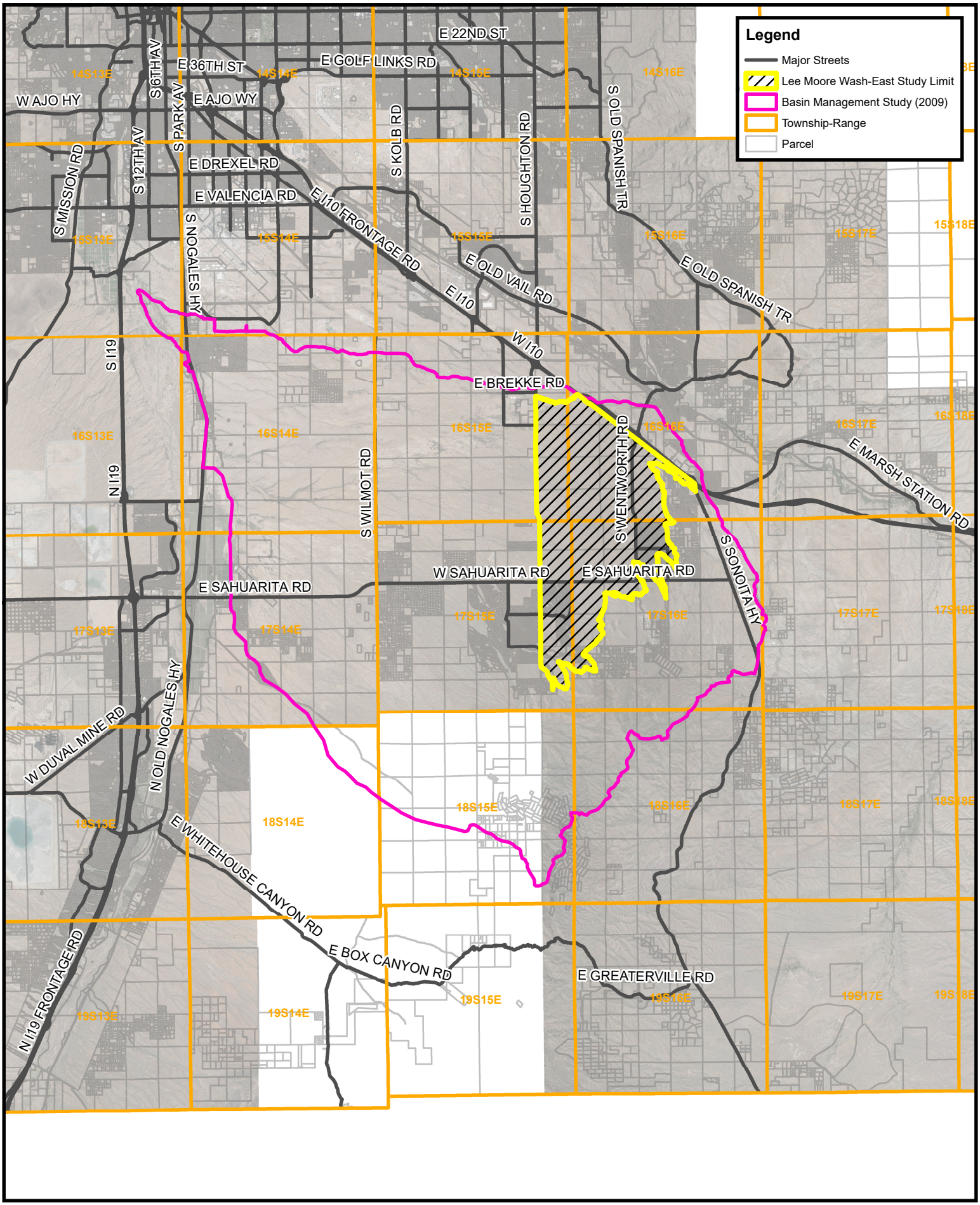
SUBJECT: **Revised floodplain delineations for portions of Lee Moore Basin Management Plan**

On August 15, 2018, Suzanne Shields, P.E., Chief Engineer for Pima County Regional Flood Control District approved the report titled: *Upper Santa Cruz River Watercourse Studies: Technical Support Data Notebook for Hydrologic and Hydraulic Analyses for Lee Moore Wash – East: Upstream of South Houghton Road*. For the project area shown as "Lee Moore Wash-East Study Limit" in Attachment A below, the floodplain delineations in this report supersede the delineations found in the 2009 Lee Moore Basin Management Plan reports.

Specifically, the reports that are partially superseded by the above report are titled *Lee Moore Wash Basin Management Study – Hydrology and Hydraulic Report*, by Stantec dated December 2008, and Two-Dimensional Flow Analysis Report for the Lee Moore Wash Basin Management Study in Pima County Arizona by JE Fuller Hydrology & Geomorphology, Inc., dated December 2008.

Aspects of other reports associated with the 2009 Lee Moore Wash Basin Management Plan may also be made obsolete by the latest report. Further revision of the floodplain delineations for the area west of Houghton Road is expected by early 2019.

Please ensure that you are using the latest information for your area of concern.



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0 5,000 10,000 20,000 Feet

1 in = 20,000 feet

Lee Moore Wash-East
Attachment A - Study Limit

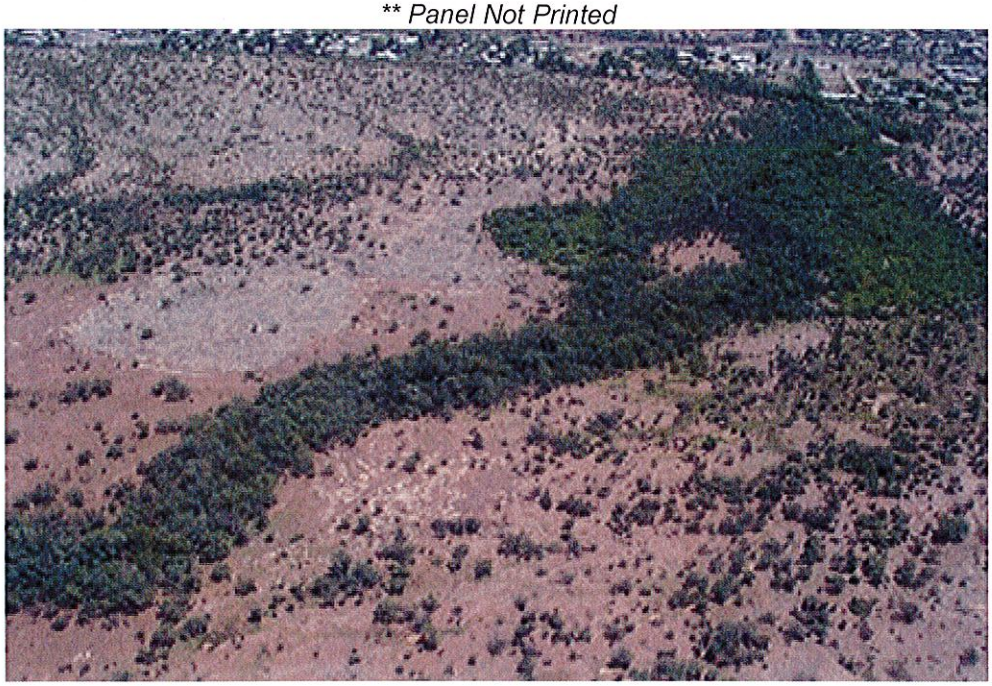
PIMA COUNTY
FLOOD CONTROL

Date: 8/21/2018

Upper Santa Cruz River Watercourse Studies:
Technical Support Data Notebook
for Hydrologic and Hydraulic Analyses for:

Lee Moore Wash – East: Upstream of South Houghton Road

FEMA FIRM Panels:
04019C-2925L
04019C-2940L
04019C-2945L
04019C-3500L**
04019C-3525L
*** Panel Not Printed*



Prepared by

Jacob Prietto, CFM
Principal Hydrologist

Approved by

Suzanne Shields, P.E.
Director

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SUZANNE J.
SHIELDS
ARIZONA U.S.A.
8/15/18

expire
2019

Pima County Regional Flood Control District
201 N. Stone Avenue, 9th Floor
Tucson Arizona, 85701

August 14, 2018

PIMA COUNTY
FLOOD CONTROL

Upper Santa Cruz River Watercourse Studies:
Technical Support Data Notebook
for Hydrologic and Hydraulic Analyses for:

Lee Moore Wash – East: Upstream of South Houghton Road

FEMA FIRM Panels:
04019C-2925L
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04019C-3525L
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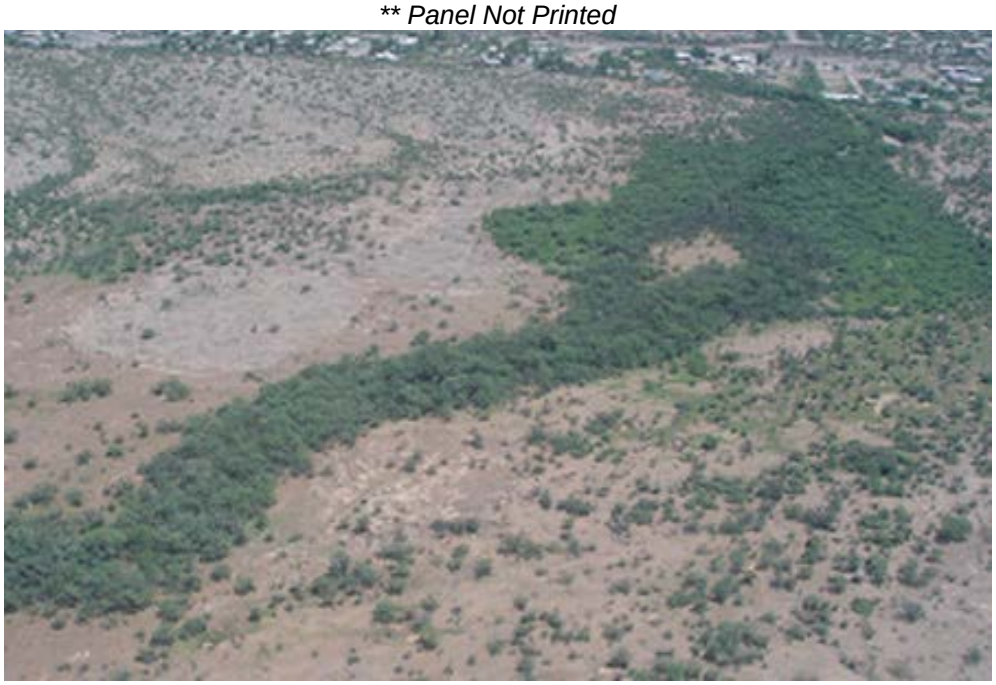

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Suzanne Shields, P.E.
Director

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August 14, 2018

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Exhibit 1B – Maximum Depth Map: 100-year (5 sheets)

Exhibit 2A – Maximum Velocity Map: 10-year (5 sheets)
Exhibit 2B – Maximum Velocity Map: 100-year (5 sheets)

Exhibit 3 – Floodplain Inundation Map: 10-year & 100-year (5 sheets)

Exhibit 4A – Maximum DV^2 Map: 10-year (5 sheets)
Exhibit 4B – Maximum DV^2 Map: 100-year (5 sheets)

Attached CD

TSDN with supporting models, GIS data, and Exhibits.

Appendix A – References
Appendix B – General Documentation and Correspondence
Appendix C – Survey Field Notes (N/A)
Appendix D – Hydrologic Analysis Supporting Documentation
Appendix E – Hydraulic Analysis Supporting Documentation
Appendix F – Erosion, Sediment, Transport, Geometric Analysis Supporting Documentation (N/A)

Section 1: Introduction

1.1 Purpose

The objective of this Technical Support Data Notebook (TSDN) is to provide the peak discharge at concentration points (CP) and cross sections (XS), maximum flow depths, maximum flow velocities, and inundation areas for the 10-year flow-corridor and 100-year floodplain for the portions of the Lee Moore Wash watershed upstream (east) of South Houghton Road.

As part of the 2009 Lee Moore Wash Basin Management Study (Basin Management Study), floodplain data was produced for the entire Lee Moore Wash watershed. The results of this study will replace the results of the 2009 study for the upper portion of the watershed, east of South Houghton Road. The superseding of floodplain data is based on the use of the most up-to-date topographic, hydrologic, and hydraulic data, and the application of current two-dimensional hydraulic modeling guidance.

This TSDN was prepared in accordance with the "Instructions for Organizing and Submitting Technical Documentation for Flood Studies" prepared by the Arizona Department of Water Resources, Flood Mitigation Section (Arizona State Standard, SSA 1) and FEMA Guidelines.

1.2 Project Authority

The State of Arizona has delegated the responsibility to each county flood control district to delineate or require the delineation of floodplains and to regulate development within floodplains (ARS § 48-3609):

1.3 Project Location

The contributing watersheds (Study Area) of the *Lee Moore Wash-East* (LMWE) analyzed include the following Township, Range, and Section, all located within Pima County, Arizona:

- Township 16 South, Range 15 East – Sections 11-14, 23-26, 35, 36
- Township 16 South, Range 16 East – Sections 7, 15-22, 26-35
- Township 17 South, Range 15 East – Sections 1, 2, 11-14, 23-26, 36
- Township 17 South, Range 16 East – Sections 1-35
- Township 17 South, Range 17 East – Section 18, 19, 30
- Township 18 South, Range 16 East – Sections 3-6

The entire contributing drainage area is located within FEMA Zone X (unshaded), as shown on the current Flood Insurance Rate Map (FIRM) numbers:

- 04019C-2925L
- 04019C-2940L
- 04019C-2945L
- 04019C-3500L**
- 04019C-3525L

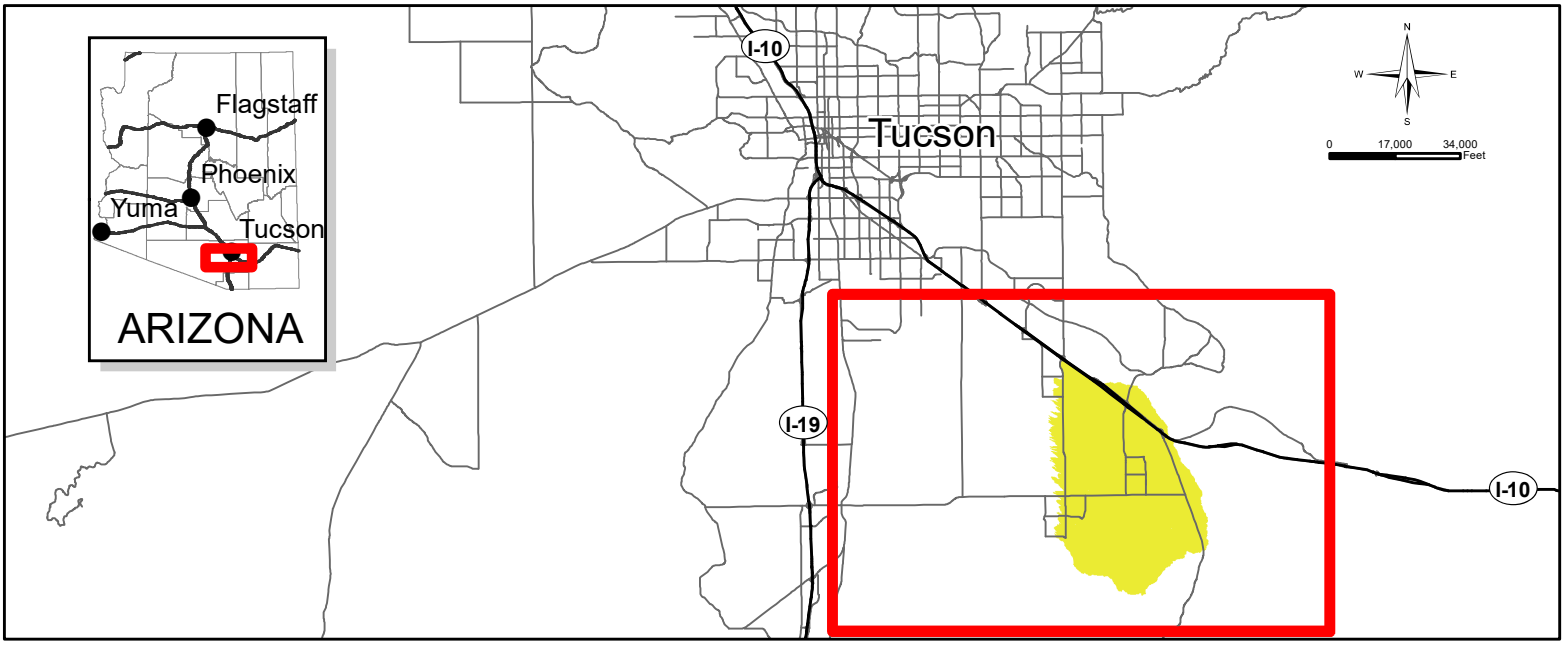
*** Panel Not Printed – Forest area in Zone D; area outside forest in Zone X*

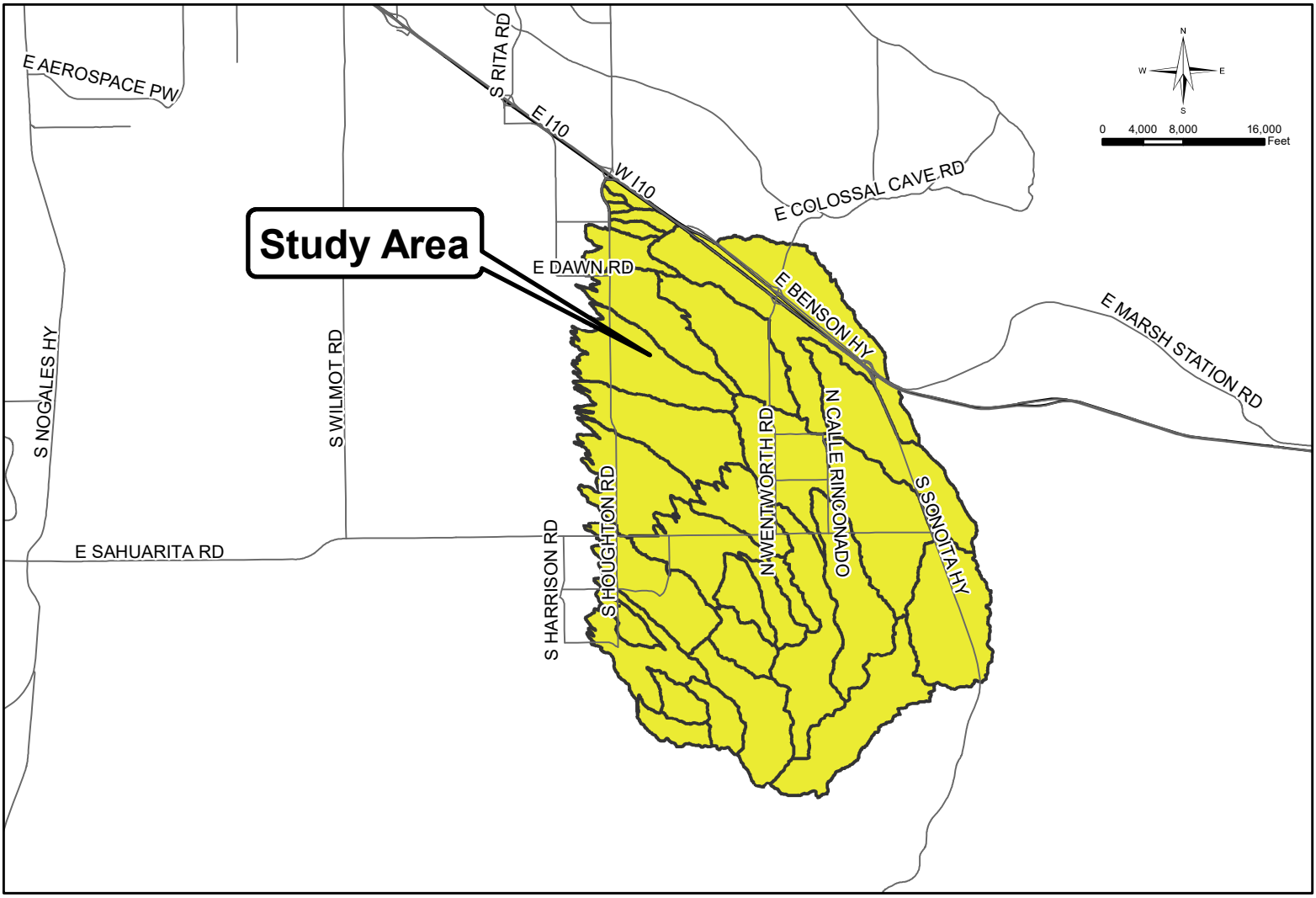
The Study Area is approximately 70.6 square miles, and has been divided into four (4) sub-groups called “Phases”: Phase-0, Phase-1, Phase-2, Phase-3, totaling thirty-seven (37) subbasins. The downstream study limit is South Houghton Road.

A Vicinity Map is provided as Figure 1; A Location Map is provided as Figure 2.

Figure 1 – Vicinity Map

Figure 2 – Location Map





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http://www.rfcd.pima.gov

Lee Moore Wash - East

Figure 1: Vicinity Map (Above)
Figure 2: Location Map (Below)

Date: 4/17/2018

The information depicted on this display is the result of digital analyses performed on a variety of databases provided and maintained by several governmental agencies. The accuracy of the information presented is limited to the collective accuracy of these databases on the date of the analysis. The Pima County Regional Flood Control District makes no claims regarding the accuracy of the information depicted herein.

1.4 Hydrologic and Hydraulic Methods

Using multiple methodologies, hydrologic analyses were performed to estimate 10-year peak discharge (Q_{10}) and 100-year peak discharge (Q_{100}) at concentration points and cross sections. The "10-year" event is identified as the flow rate of having a *ten-percent* chance of being equaled or exceeded in any given annual time period; the "100-year" event is identified as the flow rate of having a *one-percent* chance of being equaled or exceeded in any given annual time period.

Small isolated watersheds (less than 0.5 square miles) immediately upstream of South Houghton Road, were analyzed using the Pima County hydrologic methodology (PC-Hydro, Version 6.0), and are categorized as Phase-0. Selection of PC-Hydro for the hydrologic analysis of Phase-0 subbasins is consistent with Technical Policy 15 (Tech-015, Appendix A) developed by Pima County Regional Flood Control District (RFCD). No downstream routing or hydraulic analysis was performed for Phase-0 subbasins.

A hydrologic analysis for the most upstream subbasins where riverine conditions dominate and distributary/break out flow conditions is highly unlikely, was performed with HEC-HMS Version 4.0 (HEC-HMS), and are categorized as Phase-1 subbasins. Selection of HEC-HMS for the hydrologic analysis of Phase-1 subbasins is consistent with Technical Policy 15 for determining regulatory discharge values for Phase-1 concentration points with contributing watershed areas greater than one-square mile. Regulatory discharge values are not being determined for Phase-1 concentration points with contributing watershed areas less than one-square mile. Parameterization followed Technical Policy 18 (Tech-018, Appendix A) developed by Pima County Regional Flood Control District. No hydraulic analysis was performed for Phase-1 subbasins.

Downstream of the Phase-1 subbasins where distributary/breakout flows have the potential to occur, hydrologic and hydraulic analyses were performed in combination using FLO-2D Pro (F2D), and are categorized as Phase-2 and Phase-3. Parameterization followed Technical Policy 33 (Tech-033, Appendix A) developed by Pima County Regional Flood Control District. The subbasins of Phase-2 and Phase-3, east of South Houghton Road, consist of the Study Limit as both hydrologic and hydraulic analyses were performed. However, some subbasins were extended approximately one-half mile downstream (west) of South Houghton Road to avoid the potential effects of boundary conditions of the hydraulic analysis.

The results of this study will replace the results of the 2009 Basin Management Study for the upper portion of the Lee Moore Wash watershed, east of South Houghton Road.

A watershed map is provided as Figure 3.

1.5 Acknowledgements

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

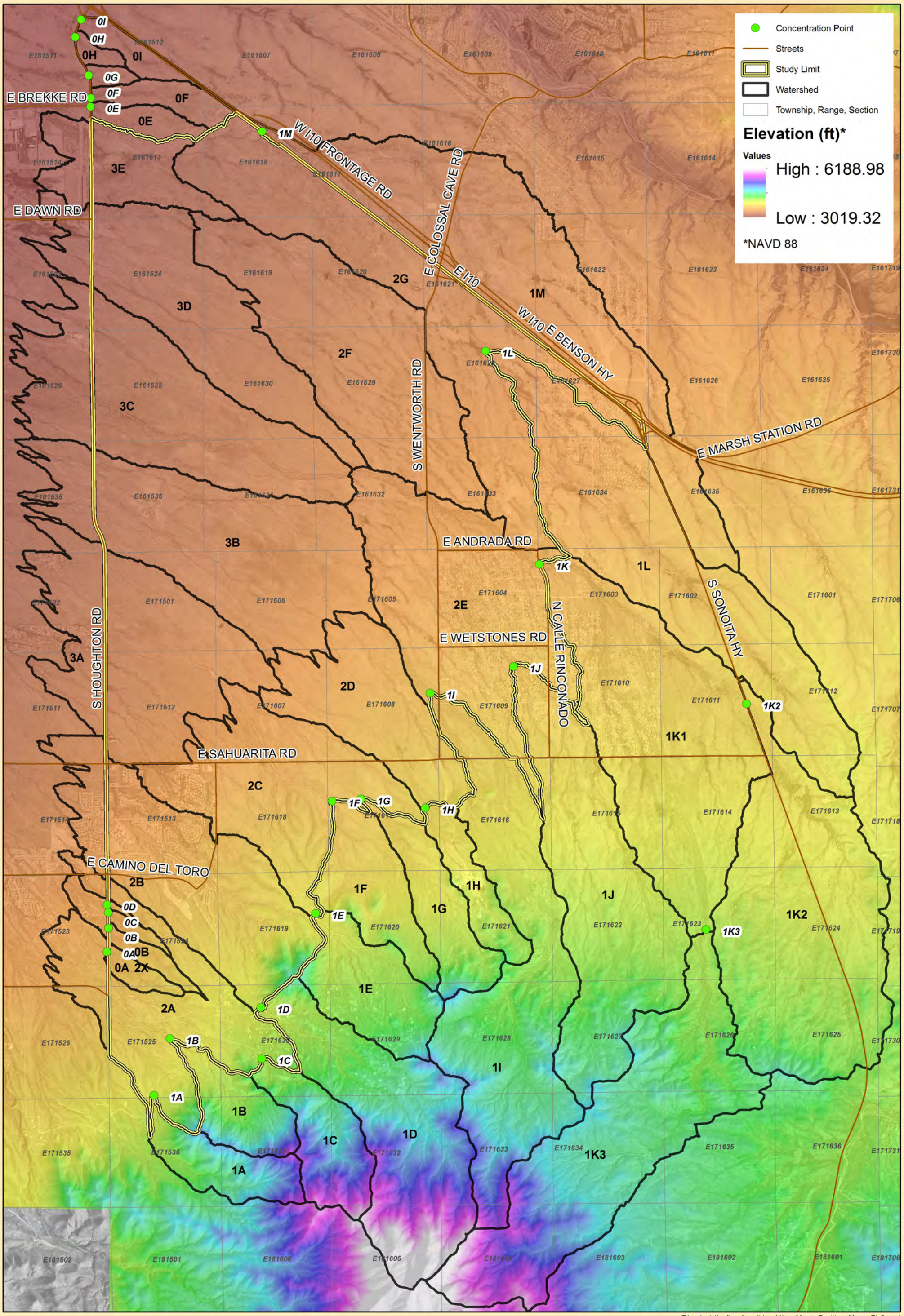
1.6 Study Results

The 10-year and 100-year peak discharges were calculated within the Study Limit at concentration points and cross sections. Selected hydrologic parameters and rainfall characteristics of the Phase-0 (PC-Hydro), Phase-1 (HEC-HMS), and Phase 2 (F2D) and Phase-3 (F2D) subbasins are presented in Table 4.2.1, Table 4.2.2, and Table 4.2.3, respectively.

Calculated peak discharges for Phase-0 (PC-Hydro) and Phase-1 (HEC-HMS) are summarized in Table 4.5.1 and Table 4.5.2, respectively. Calculated peak discharges for Phase-2 (F2D) and Phase-3 (F2D) are summarized in Appendix D.)

Selected concentration points, where total contributing drainage areas are known and distributary flows or breakout flows are not likely, were compared with the USGS Regional Regression Equation and presented in Table 4.5.3 and Table 4.5.4. The comparisons show that the 10-year and 100-year peak discharges calculated in this study are reasonable.

Figure 3 – Watershed Map



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Lee Moore Wash - East

Figure 3: Watershed Map

1 inch = 4,000 feet

0 2,050 4,100 8,200 Feet

Date: 5/21/2018

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This product is subject to the GIS Division Disclaimer and Use Restrictions.

Section 2 Local Government Abstract

2.1 Project Contact Information

Contact Information:
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Jacob.Prietto@pima.gov

Local Technical Reviewer:
Terry Hendricks
Pima County Regional Flood Control District
201 N. Stone Avenue, 9th Floor, Tucson, AZ 85701
Terry.Hendricks@pima.gov

2.2 General Information

Community: Pima County
County: Pima County
River or Stream Name: Lee Moore Wash-East
Reach Description: tributaries/headwaters
Study Type: Hydrologic and Hydraulics study
Purpose of the Study: Floodplain mapping

2.3 Survey and Mapping Information

Digital Projection Information: PAG 2015 orthophoto
USGS Quad Sheets if available:
Mapping for Hydrologic Study: LiDAR based on 2015 flight used to derive 2-ft contour interval maps using ArcGIS 10.0 and FLO-2D Pro GDS
Mapping for Hydraulic Study: LiDAR based on 2015 flight used to derive a DEM (5-ft cell size) for use with HEC-GeoRAS

2.4 Hydrology

Model(s) or Method(s) Used: Pima County Hydrology Procedures (PC-Hydro), HEC-HMS Version 4.0 (HEC-HMS), FLO-2D Pro (F2D).
Storm Duration: 3 hour, 24-hour
Hydrograph Type(s): SCS Type II 3-hr storm, SCS Type I 24-hr storm
Frequencies Determined: 10-year and 100-year
List of Gages used in Frequency Analysis or Calibration: None
Rainfall Amounts and Reference: NOAA 14 Upper 90% Confidence Interval
Unique Conditions and Problems: multiple hydrologic model types
Coordination of Q's: Comparison with a USGS Regression Equation

2.5 Hydraulics

Model or Method Used: HEC-GeoRAS, Version 10.1 (HEC-GeoRAS) and HEC-RAS Version 4.1.0 (HEC-RAS), FLO-2D Pro (F2D)
Regime: Modeled as subcritical
Frequencies for which Profiles were computed: 10-year 100-year
Method of Floodway Calculation: No Floodway
Unique Conditions and Problems: distributary/breakout flow conditions

2.6 Erosion, Sediment Transport and Geomorphic Analysis

None

2.7 Additional Study Information

None

Section 3: Survey and Mapping Information

3.1 Digital Projection Information

The data below are included in this TDN (see "GIS" folder)
Aerial Photo: PAG 2015 Orthophotos
Contour: NA
Topographic Data: 5-ft DEM

Projection: State Plane, Arizona Central Zone
Horizontal Datum: NAD83-92 (HARN)
Vertical Datum: NAVD-88
Units: International Feet

3.2 Field Survey Information

NA

3.3 Mapping

Digital Elevation Model (DEM) derived from 2015 Light Detection and Ranging (LiDAR) data was used for the HEC-RAS and F2D analyses. A contour interval topographic map was not produced.

Following data are included in this TDN (see "GIS" folder):
Aerial Photo: PAG 2015 Orthophotos
Contour: NA
Topographic Data: 5-ft DEM

Section 4: Hydrology

4.1 Method Description

A 10-year and 100-year peak discharge hydrologic analysie was performed for Phase-0 subbasins using PC-Hydro. The PC-Hydro model requires the parameters as rainfall, topography, soil type, vegetation type, and flow path characteristics to determine runoff volume and peak discharge. Those parameters were determined by following the Pima County Regional Flood Control District Technical Policy 018 (Tech-018). There are nine (9) Phase-0 subbasins: 0A, 0B, 0C, 0D, 0E, 0F, 0G, 0H, 0I.

A 10-year and 100-year peak discharge hydrologic analysis was performed for Phase-1 subbasins using HEC-HMS, version 4.0. The HEC-HMS model requires parameters such as rainfall, topography, soil type, vegetation type, and channel characteristics to determine runoff volume and peak discharge. Those parameters were determined by following the Pima County Regional Flood Control District Technical Policy 018 (Tech-018). There are fifteen (15) Phase-1 subbasins: 1A, 1B, 1C, 1D, 1E, 1F, 1G, 1H, 1I, 1J, 1K1-1K3, 1L, 1M.

A 10-year and 100-year peak discharge hydrologic analysis was performed for Phase-2 and Phase-3 subbasins using FLO-2D Pro. The grid size for all F2D models is 20-ft. The outflow hydrographs from the HEC-HMS Phase-1 models were incorporated into the F2D Phase-2 models as inflow hydrographs, all of which were distributed over ten (10) grid cells. Outflow hydrographs from the F2D Phase-2 models, measured at flow-recording cross sections, were incorporated into the F2D Phase-3 models as inflow hydrographs, distributed over an amount of grid cells to approximately match the inundation width at that location. Breakout flows between subbasins of the same Phase were modeled in similar fashion.

To avoid potential effects of a downstream boundary condition at the Study Limit, Subbasins 2A, 2B, 3A, 3B, 3C, 3D, and 3E extend approximately 0.5 miles west of South Houghton Road. As a result, Subbasin 0A is upstream of and conveys stormwater to a portion of Subbasin 2A. To provide continuity within the hydraulic analysis, Subbasins 0A-0D were analyzed as a single Phase-2 subbasin: 2X. Therefore, the Subbasin 2X hydraulic analysis results dictate the floodplain conditions of the watercourses within this portion of the watershed. However, the hydrologic results of Subbasins 0A-0D dictate the hydrologic conditions at these specific watercourse/roadway-crossings along South Houghton Road, as the PC-Hydro methodology is more appropriately utilized to quantify discharge at roadway crossings of this specific nature.

Subbasin There are seven (8) Phase 2 subbasins: 2A, 2B, 2C, 2D, 2E, 2F, 2G, 2X; there are five (5) Phase-3 subbasins: 3A, 3B, 3C, 3D, 3E.

A conceptual watershed map is provided in Appendix B.

4.2 Parameter Estimation

4.2.1 Drainage Area Boundaries

The Study Area, approximately 70.6 square-miles, is defined as the contributing drainage area where hydrologic analyses occurred. The maximum elevation of the Study Area is approximately 6189'; the minimum elevation of the Study Area is approximately 3048' (NAVD-88). Subbasins of all four Phases are included in the Study Area.

The Study Limit, approximately 25.7 square-miles, is defined as the contributing drainage area where *both* hydrologic and hydraulic analyses occurred. Subbasins of Phase 2 and Phase 3, east of South Houghton Road, are considered the Study Limit.

Subbasins of Phase 0 and Phase 1 are not within the Study Area because no hydraulic analyses were performed within those subbasins. The hydrologic analysis of Phase-1 subbasins contributed to hydraulic analyses of the downstream Phase-2 subbasins.

4.2.2 Watershed Work Maps

A watershed work map with background aerial orthophoto is provided as Figure 3. As mentioned previously, the study watershed was divided into four "Phases", totaling thirty-eight (38) subbasins. The work map includes major roadways, Section boundaries, Phase boundaries, subbasin boundaries, and concentration points.

4.2.3 Gage Data

NA

4.2.4 Statistical Parameters

NA

4.2.5 Precipitation

The NOAA 14 Atlas 90% upper confidence (NOAA) rainfall depth for the centroid of the study watershed was used for hydrologic analysis of all subbasins. Areal reduction (AR) factors were applied to Phase-1 subbasins larger than one square-mile as noted in Tech-018. The 3-hr, SCS Type II rainfall distribution described in Haan et al (1994) was used for Phase-1, Phase-2, and Phase-3 subbasins. Aerial reduction factors were not applied to Phase-0 subbasins, as all of the Phase-0 contributing drainage areas are less than one square-mile. Aerial reduction factors were not applied to Phase-2 and Phase-3 subbasins as instructed by Pima County Regional Flood Control District Technical Policy 033 (Tech-033) for two-dimensional modeling. The point rainfall values for for Phase-0, Phase-1, and Phase-2 and Phase-3 subbasins are summarized in Tables 4.2.1, 4.2.2, and 4.2.3, respectively.

4.2.6 Physical Parameters

A hydrologic soils group map for the study watershed is presented as Figure 4.1; there is no dominant hydrologic soil group in the study watershed. A vegetation classification map is presented as Figure 4.2; the study watershed is mostly covered with Desert Brush vegetation type; Mountain Brush vegetation type is dominant within the highest

elevations; Herbaceous vegetation type is dominant in some mid-elevation regions of the study watershed.

An SCS Curve Number (CN) was assigned spatially within the study watershed at the intersections of Hydrologic Soil Type and vegetation type, using *Figure D-1: Hydrologic Soil-Cover Complexes and their Associated SCS Curve Numbers* from the PC-Hydro User Guide (Arroyo Engineering, 2007). Vegetation cover density was assumed to be twenty-percent (20%) for the entire Study Area. A spatial distribution of Curve Numbers is presented as Figure 4.3.

Phase-0 subbasins were modeled using PC-Hydro, implementing a modified rational method. A weighted runoff-coefficient was generated based on the composite of unique CN values and spatial coverage within each subbasin. Table 4.2.1 summarizes the physical and rainfall parameters of Phase-0 subbasins. The 3-hour duration rainfall depths are provided for illustrative purposes, only for relative comparison among subbasins of other Phases.

Table 4.2.1 – Subbasin Characteristics (PC-Hydro)

Basin ID	Area	Length	Mean Slope	Basin Factor	Runoff Coef.*		Time of Concentration*	
					10-Year	100-Year	10-Year	100-Year
	(sq. miles)	(ft)	(ft/ft)	(-)	(-)	(-)	(min)	(min)
0A	0.140	4968	0.036	0.038	0.47	0.65	17	12
0B	0.146	6618	0.040	0.050	0.47	0.66	28	20
0C	0.068	4040	0.045	0.050	0.48	0.66	19	13
0D	0.016	2188	0.045	0.050	0.48	0.66	12	8
0E	0.223	6684	0.008	0.035	0.42	0.63	47	30
0F	0.295	8612	0.005	0.035	0.43	0.64	77	48
0G	0.071	2825	0.011	0.035	0.39	0.60	21	14
0H	0.080	3215	0.013	0.035	0.40	0.61	21	14
0I	0.230	7855	0.009	0.035	0.42	0.62	53	34

**PC-Hydro Output*

Phase-1 subbasins were modeled using HEC-HMS, implementing the SCS Curve Number loss method. A weighted CN was generated for individual subbasins based on the composite of unique CN values and spatial coverage within each subbasin. The CN was not adjusted for rainfall intensity or antecedent moisture conditions in the HEC-HMS model. Impervious cover was estimated using the 2015 PAG orthophotos and *Table D-3: Summary of Approximate Imperviousness Cover Percentages for Various Land Development Types* in the PC Hydro User Guide (Arroyo Engineering, 2007).

The transform method was modeled using the SCS Unit Hydrograph method. The combination of the kinematic wave method and the U.S. Natural Resources Conservation Service (NRCS) segmented Time of Concentration (Tc) calculation method (USDA-

NRCS, 1986) was used to determine Tc, following the recommendation on Tech-018. The Tc was calculated by summing the travel time for sheet flow, shallow concentrated flow and channel flow. The Tc for sheet flow was estimated using the kinematic wave equation. Manning's roughness coefficient for sheet flow was obtained using Table 3-1 in *Technical Release 55, Urban Hydrology for Small Watersheds* (USDA-NRCS, 1986). HEC-GeoRAS and HEC-RAS were used to estimate average velocity of channels. Table 4.2.2 summarizes the physical and rainfall parameters of Phase-1 subbasins.

Runoff from subbasins 1K2 and 1K3 were routed to CP 1K using the Modified-Puls method. Storage-discharge tables for the channel routing were developed using HEC-GeoRAS and HEC-RAS. Six (6) different discharges were used for storage-discharge correlation. Spreadsheets used for the calculations of those parameters are included in Appendix D.

Table 4.2.2 – Subbasin Characteristics (HEC-HMS)

Basin ID	Area	Impervious Cover	Curve Number	Lag Time
	(sq. miles)	(%)	(-)	(min)
1A	0.593	0.0	90.2	19
1B	0.586	0.5	87.4	16
1C	0.751	1.0	91.0	19
1D	2.265	2.0	87.9	31
1E	0.963	0.0	85.2	21
1F	0.876	0.0	86.5	27
1G	0.748	0.0	88.0	27
1H	0.475	0.0	88.6	21
1I	3.085	1.0	87.3	54
1J	2.817	0.5	89.3	41
1K1	3.439	2.0	85.5	39
1K2	3.644	1.0	88.9	40
1K3	3.203	0.0	90.5	45
1L	3.394	2.0	85.7	81
1M	3.432	1.0	86.7	103

Table 4.2.3 – Rainfall Characteristics (HEC-HMS)

Basin ID	10-Year (in.)				100-Year (in.)			
	3-Hour		24-Hour		3-Hour		24-Hour	
	NOAA*	AR**	NOAA*	AR**	NOAA*	AR**	NOAA*	AR**
1A	2.52	2.52	3.32	3.32	3.88	3.88	5.03	5.03
1B	2.51	2.51	3.31	3.31	3.86	3.86	4.99	4.99
1C	2.53	2.53	3.33	3.33	3.89	3.89	5.05	5.05
1D	2.54	2.38	3.34	3.23	3.92	3.67	5.08	4.92
1E	2.44	2.44	3.25	3.25	3.77	3.77	4.84	4.84
1F	2.35	2.35	3.14	3.14	3.63	3.63	4.70	4.70
1G	2.40	2.40	3.20	3.20	3.71	3.71	4.78	4.78
1H	2.37	2.37	3.16	3.16	3.66	3.66	4.73	4.73
1I	2.47	2.26	3.26	3.12	3.81	3.48	4.89	4.68
1J	2.42	2.23	3.21	3.08	3.74	3.45	4.79	4.60
1K	2.42	1.93	3.20	2.84	3.73	2.98	4.77	4.24
1L	2.28	2.06	3.02	2.88	3.53	3.19	4.53	4.31
1M	2.21	2.00	2.94	2.80	3.42	3.09	4.42	4.21

* NOAA Atlas 14, 90% Upper Confidence Interval
** Aerial Reduction

Phase-2 and Phase-3 subbasins were modeled using FLO-2D Pro, implementing the SCS Curve Number infiltration method and utilizing a spatially variable CN. By overlaying the *MGrid* shapefile of the individual subbasins with *Figure 4.3 – Curve Number Map*, and converting each grid to a point at the center of each grid, the spatially variable CN of *Figure 3.3* was extracted and assigned to the MGrid "point" while maintaining its unique grid identification number. It is assumed that the CN at the center of each F2D grid unit is representative of the entire grid-square. Each grid-cell is 20'x 20' in size.

To fully identify and analyze the breakout occurrences of each subbasin without the potential effects of model-boundary conditions, a 500 ft. buffer was applied to each Phase-2 and Phase-3 subbasin in the hydrologic/hydraulic analysis. Rainfall was only applied to the grid cells within each subbasin; rainfall was not applied to grid cells outside of each subbasin, located within the buffer.

The spatially variable CN was not adjusted for rainfall intensity or antecedent moisture conditions in the F2D model. Table 4.2.3 summarizes the physical and rainfall parameters of Phase-2 and Phase-3 subbasins. An average CN for Phase-2 and Phase-3 subbasins are provided in Table 4.3 for illustrative purposes only to provide a qualitative description of the subbasin characteristic.

The impervious cover of roadways was estimated by using the roadway polyline shapefiles from the Pima County GIS Library. Major Roadways were offset 25 ft. in each direction; Minor Roadways were offset 12 ft. in each direction. Similar to the spatially variable CN described above, the MGrid points that intersect the roadway polygons created by the offsets were assigned a CN of 98, consistent with Table 2-2a in *Technical Release 55, Urban Hydrology for Small Watersheds* (USDA-NRCS, 1986).

The impervious surfaces of non-roadway spaces (i.e. existing residential and commercial land developments) were estimated using estimated using the 2015 PAG orthophotos and *Table D-3: Summary of Approximate Imperviousness Cover Percentages for Various Land Development Types* in the PC Hydro User Guide (Arroyo Engineering, 2007). Within the F2D models, the spatially variable Reduction Factor component was implemented for individual grid cells based on developments types.

Table 4.2.4 – Subbasin Characteristics (FLO-2D)

Basin ID	Area	Curve Number*
	(sq. miles)	(-)
2A	1.932	84.5
2B	2.491	84.0
2C	2.168	83.8
2D	1.528	83.1
2E	2.905	84.9
2F	2.899	87.8
2G	3.028	86.7
2X	0.483	85.7
3A	2.719	85.2
3B	3.090	84.0
3C	2.878	85.1
3D	2.222	88.3
3E	0.909	87.4

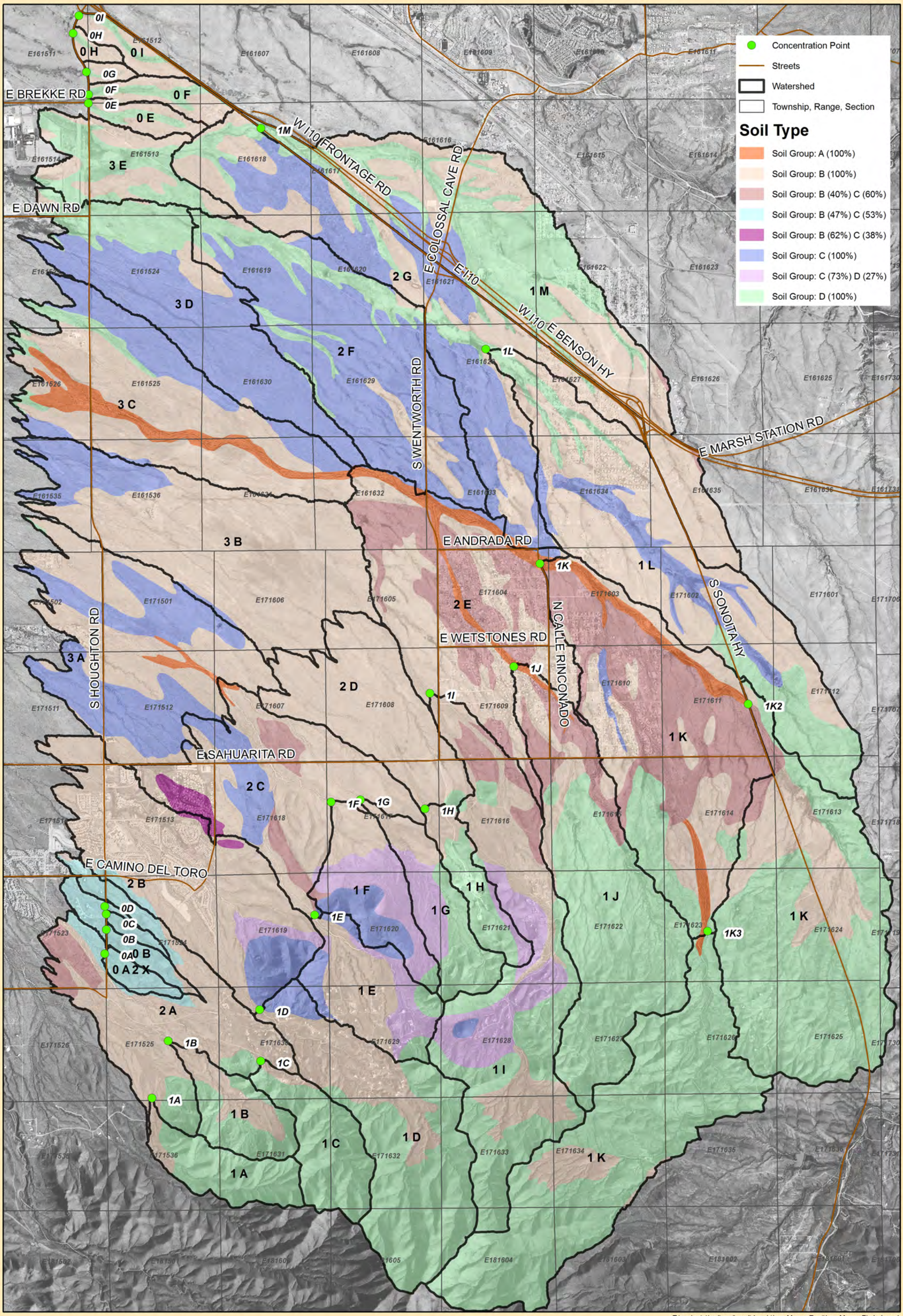
**Average CN, spatially variable*

Table 4.2.5 – Rainfall Characteristics (FLO-2D)

Basin ID	10-Year (in.)*		100-Year (in.)*	
	3-Hour	24-Hour	3-Hour	24-Hour
2A	2.35	3.16	3.64	4.71
2B	2.29	3.09	3.55	4.62
2C	2.28	3.07	3.53	4.59
2D	2.28	3.07	3.53	4.59
2E	2.26	3.02	3.50	4.53
2F	2.19	2.93	3.40	4.40
2G	2.19	2.92	3.40	4.39
2X	2.35	3.16	3.64	4.71
3A	2.20	2.98	3.42	4.45
3B	2.19	2.95	3.39	4.41
3C	2.16	2.90	3.35	4.35
3D	2.16	2.89	3.35	4.34
3E	2.14	2.87	3.32	4.32

**NOAA Atlas 14: Upper 90% CI, no aerial reduction*

Figure 4.1 – Soils Map



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http://www.rfcd.pima.gov

Lee Moore Wash - East

Figure 4.1: Soils Map

1 inch = 4,000 feet

0 2,000 4,000 8,000 Feet

Date: 4/16/2018

The information depicted on this display is the result of digital analyses performed on a variety of databases provided and maintained by several governmental agencies. The accuracy of the information presented is limited to the collective accuracy of these databases on the date of the analysis. The Pima County Regional Flood Control District makes no claims regarding the accuracy of the information depicted herein.

This product is subject to the GIS Division Disclaimer and Use Restrictions.

Figure 4.2 – Vegetation Map

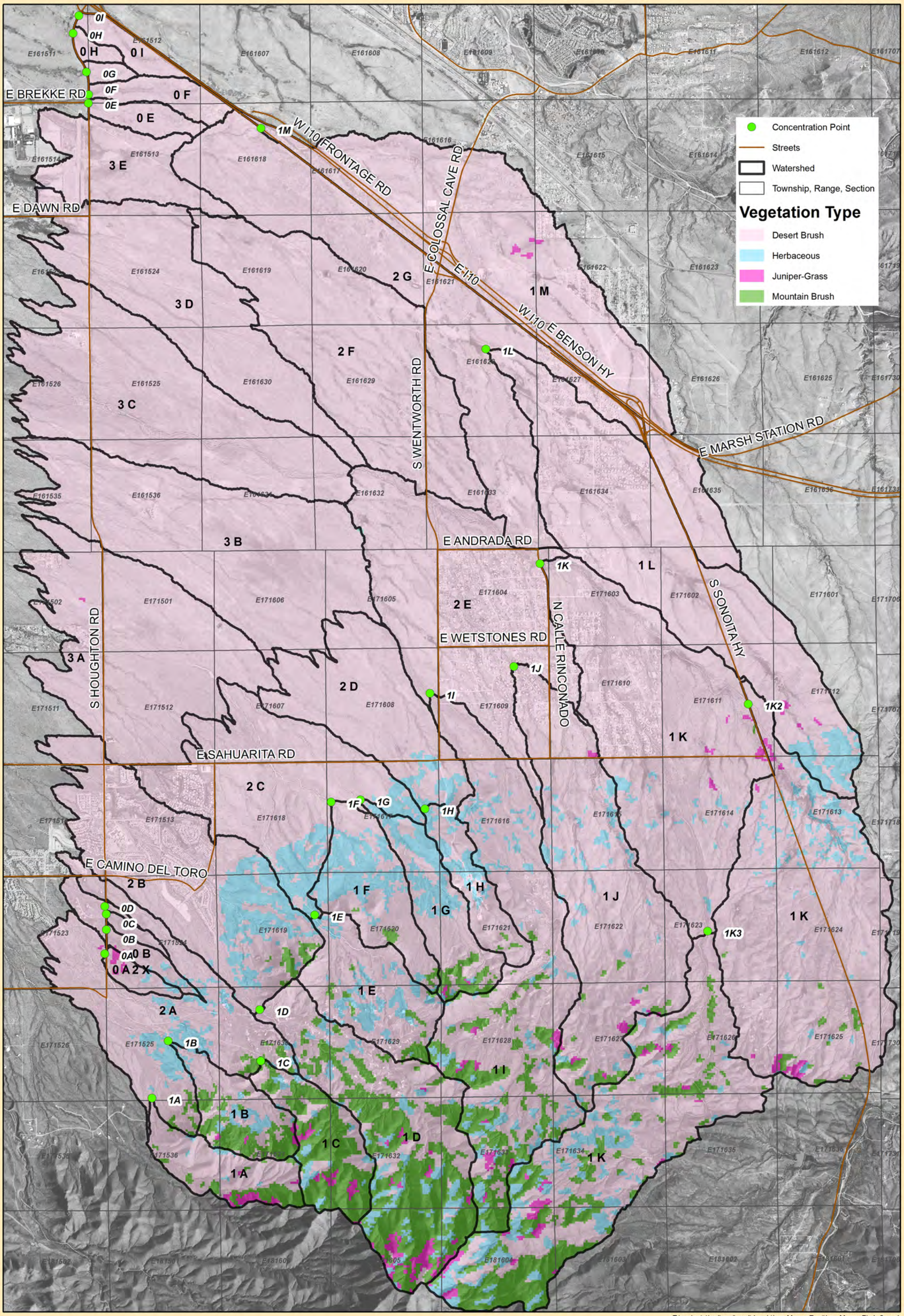

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Figure 4.2: Vegetation Map

1 inch = 4,000 feet

0 2,000 4,000 8,000 Feet

Date: 4/16/2018

The information depicted on this display is the result of digital analyses performed on a variety of databases provided and maintained by several governmental agencies. The accuracy of the information presented is limited to the collective accuracy of these databases on the date of the analysis. The Pima County Regional Flood Control District makes no claims regarding the accuracy of the information depicted herein.

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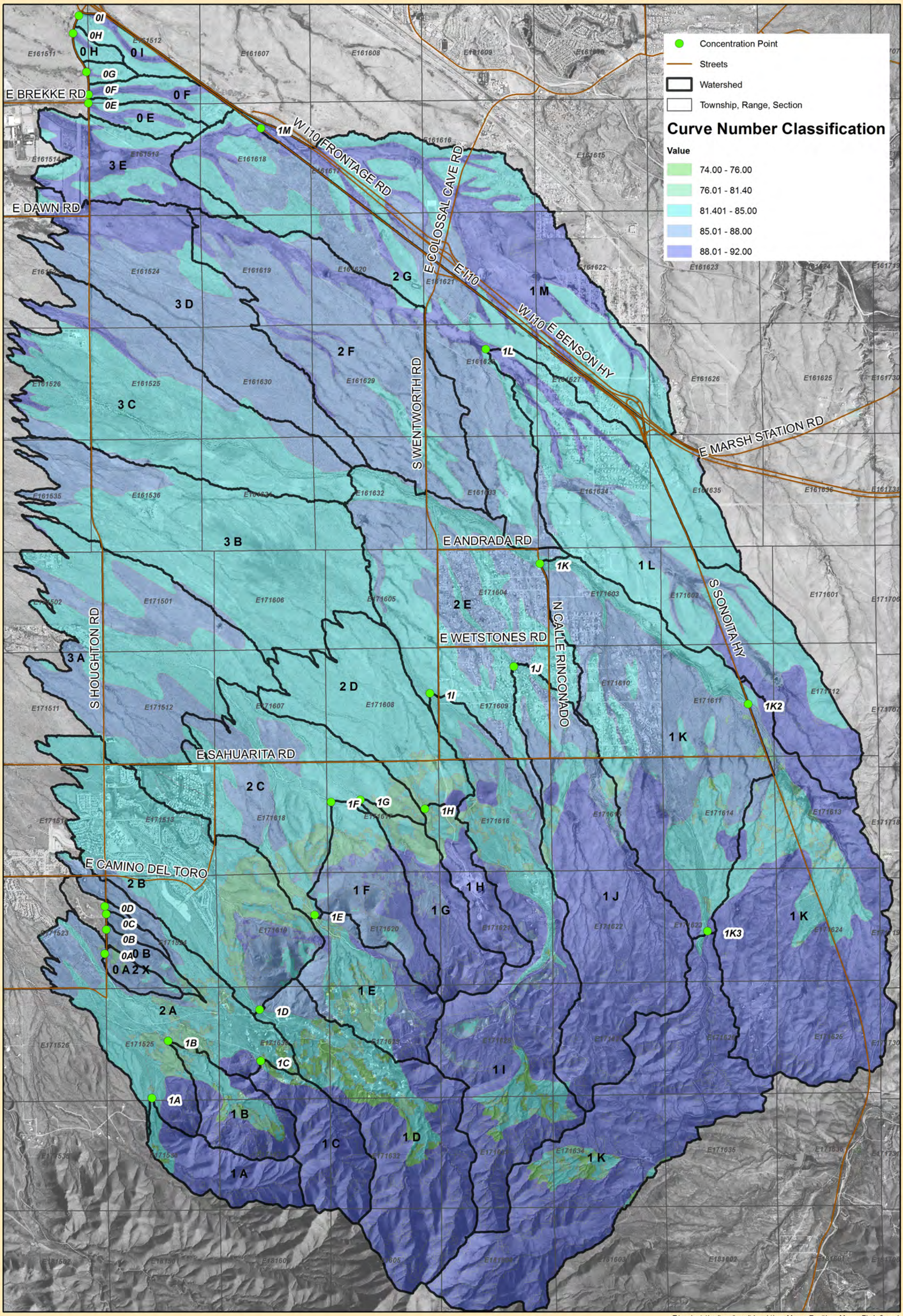
Figure 4.3 – Curve Number Map



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Lee Moore Wash - East

Figure 4.3: Curve Number Map

1 inch = 4,000 feet

0 2,000 4,000 8,000 Feet

Date: 4/16/2018

The information depicted on this display is the result of digital analyses performed on a variety of databases provided and maintained by several governmental agencies. The accuracy of the information presented is limited to the collective accuracy of these databases on the date of the analysis. The Pima County Regional Flood Control District makes no claims regarding the accuracy of the information depicted herein.

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4.3 Issues Encountered During the Study.

4.3.1 Special problems and solutions
NA

4.3.2 Modeling Warning and Error Messages
No warning or error messages were received for the modeling of Phase-0 subbasins.

For the Phase-1 HEC-HMS hydrologic analysis, Warning #41784 was encountered for both the 10-year and 100-year simulation: *Simulation time interval is greater than 0.29*lag for subasin "B" [1B]; reduce simulation time interval.* The simulation time interval is five (5) minutes; the rainfall distribution time interval is five (5) minutes; no adjustment for the warning was conducted.

For Phase-2 and Phase-3 F2D hydrologic/hydraulic analyses, "no data input errors were encountered". However, multiple "potential errors" were encountered and provided as warning messages. The F2D ERROR.CHK files are provided in the attached CD.

4.4 Calibration

No calibration was performed.

4.5 Final Results

4.5.1 Hydrologic Analysis Results
The 10-year and 100-year peak discharges calculated for Phase-0 subbasins are summarized in Table 4.5.1. No areal reduction of rainfall was applied to estimate the peak discharges for Phase-0 subbasins.

Table 4.5.1 – Peak Discharge Results (PC-Hydro)

Basin ID	Area	Peak Discharge	
		10-Year	100-Year
	(sq. miles)	(cfs)	(cfs)
0A	0.140	196	500
0B	0.146	155	399
0C	0.068	90	232
0D	0.016	27	64
0E	0.223	134	421
0F	0.295	125	401
0G	0.071	64	196
0H	0.080	76	225
0I	0.230	126	394

The 10-year and 100-year peak discharges calculated for Phase-1 subbasins are summarized in Table 4.5.2. Areal reduction of rainfall was applied to subbasins larger than 1.0 square-mile: 1D, 1I, 1J, 1K1-1K3, 1L, and 1M.

Table 4.5.2 – Peak Discharge Results (HEC-HMS)

Basin ID	Area	Peak Discharge (cfs)			
		10-Year		100-Year	
	(sq. miles)	3-Hour	24-Hour	3-Hour	24-Hour
1A	0.593	770	389	1401	667
1B	0.586	739	370	1396	658
1C	0.751	1023	512	1825	865
1D	2.265	1745	1010	3350	1813
1E	0.963	844	459	1712	843
1F	0.876	662	373	1326	681
1G	0.748	652	358	1255	630
1H	0.475	491	259	929	451
1I	3.085	1413	926	2775	1667
1J	2.817	1729	1068	3294	1847
1K	10.285	3501	2399	7134	4628
1K1	3.439	1364	979	2890	1839
1K2	3.644	1774	1224	3491	2156
1K3	3.203	1583	1087	3013	1863
1L	3.394	893	641	1835	1212
1M	3.432	754	565	1529	1061

The 10-year and 100-year peak discharges were calculated for Phase-2 and Phase-3 subbasins. Due to the distributary nature of Phase-2 and Phase-3 subbasins, peak discharges were calculated at multiple flow recording cross sections for each subbasin. The peak discharges recorded at F2D cross sections for Phase-2 and Phase-3 subbasins are summarized in Appendix D.

4.5.2 Verification of Results

Results were compared with USGS Flood Region 5 (Southeastern Basin and Range) regression equations (USGS Scientific Investigations Report 2014-5211, Table 9). The USGS regression results were generally lower than the PC-Hydro results for Phase-0 subbasins and HEC-HMS results for Phase-1 subbasins. These are expected results because the steep watersheds characteristics should be expected to produce higher than average discharge on average.

Table 4.5.3 and Table 4.5.4 summarize the regression equation comparisons with Phase-0 and Phase-1 subbasins, respectively. The regression equations are provided in Appendix B. Phase-2 and Phase-3 subbasins were not compared to USGS regression equations, as distributary flow characteristics and lesser known contributing drainage areas exist.

Table 4.5.3 – Comparison of Peak Discharge Values (PC-Hydro)

Basin ID	Area	Peak Discharge (cfs)			
		10-Year		100-Year	
	(sq. miles)	PC-Hydro	USGS Table 9	PC-Hydro	USGS Table 9
0A	0.140	196	87	500	207
0B	0.146	155	89	399	215
0C	0.068	90	48	232	103
0D	0.016	27	13	64	21
0E	0.223	134	124	421	314
0F	0.295	125	154	401	399
0G	0.071	64	50	196	108
0H	0.080	76	55	225	121
0I	0.230	126	127	394	323

Table 4.5.4 – Comparison of Peak Discharge Values (HEC-HMS)

Basin ID	Area	HEC-HMS	USGS Table 9	HEC-HMS	USGS Table 9
	(sq. miles)	(cfs)	(cfs)	(cfs)	(cfs)
1A	0.593	770	254	1401	702
1B	0.586	739	252	1396	696
1C	0.751	1023	299	1825	841
1D	2.265	1745	614	3350	1833
1E	0.963	844	354	1712	1012
1F	0.876	662	332	1326	944
1G	0.748	652	298	1255	839
1H	0.475	491	217	929	590
1I	3.085	1413	742	2775	2239
1J	2.817	1729	702	3294	2113
1K	10.285	3501	1475	7134	4567
1K1	3.439	1364	792	2890	2398
1K2	3.644	1774	819	3491	2486
1K3	3.203	1583	759	3013	2293
1L	3.394	893	786	1835	2378
1M	3.432	754	791	1529	2395

Section 5: Hydraulics

5.1 Method Description

A hydraulic analysis was performed to determine the existing floodplain conditions (Existing Conditions) within the Study Limit, which includes the Phase-2 and Phase-3 subbasins. The hydraulic analysis was performed for the 100-year event using F2D in combination with the hydrologic analysis. No hydraulic analysis was performed for Phase-0 or Phase-1 subbasins.

5.2 Work Study Maps

Work study maps of the Study Limit have been provided. The 10-year maximum flood depth map is provided as Exhibit 1A and the 100-year maximum flood depth map is provided as Exhibit 1B; the 10-year maximum flood velocity map is provided as Exhibit 2A and the 100-year maximum flood velocity map is provided as Exhibit 2B.

5.3 Parameter Estimation

5.3.1 Roughness Coefficients

Phase-2 and Phase-3 subbasins were modeled with F2D with the Flow Rougness n-value for shallow overland (SHALLOWN, CONT.DAT) turned off (-99). Produced in the similar fashion to the spatially variable CN described above, the F2D grids representing roadways were assigned a Manning's n coefficient of 0.016; all other grids were assigned a Manning's n coefficient of 0.040.

5.3.2 Expansion and Contraction Coefficients

NA

5.4 Cross Section Description

Flow recording cross sections were utilized in the F2D hydraulic analysis to identify peak discharge values at various locations. The cross section locations, illustrated in all Exhibits, are approximate as they are representative of the F2D grids that the flow recordings are based from. The 10-year and 100-year peak discharges at flow recording cross sections for Phase-2 and Phase-3 subbasins, are summarized in Appendix D.

5.5 Modeling Considerations

5.5.1 Hydraulic Jump and Drop Analysis

No hydraulic jumps were encountered.

5.5.2 Bridges and Culverts

Existing culverts were identified by aerial photography, construction plans, and confirmed with field observations. Rating tables were generated for the existing culverts using HY-8 and incorporated into the F2D modeling. No bridges were considered in the hydraulic analyses. The existing culverts modeled in Phase 2 and Phase 3 subbasins are summarized in Table 5.5.1, illustrated in Figure 3, and are provided in Appendix E.

Table 5.5.1 – Existing Culverts

Subbasin ID	Culvert ID	Culvert Type
2A	2A-01	4-36" CMP
	2A-02	8-48" CMP
	2A-03	3-36" CMP
	2A-04	3-36" CMP
2B	2B-01	6-10'x4' RCBC
	2B-02	8-10'x5' RCBC
	2B-03	1-30"x19" HERCP
	2B-04	1-30"x19" HERCP
	2B-05	1-24" RCP
	2B-06	1-30" RCP
	2B-07	2-48" CMP
	2B-08	1-36" CMP
	2B-09	1-36" CMP
	2B-10	2-8'x4' RCBC
	2B-11	6-10'x4' RCBC
	2B-12	1-48" RCP
	2B-13	3-12'x8' RCBC
	2B-14	7-24" HDPE
	2B-15	Concrete Arches (upstream)
	2B-16	Concrete Arches (downstream)
	2B-17	2-36" SRMP (w/ Catchbasin)
	2B-18-1	1-36" SRMP (w/ Catchbasin)
	2B-18-2	1-30" SRMP (w/ Catchbasin)
	2B-19	3-36" CMP
2C	2C-01	1-42" CMP
	2C-02	2-42" CMP
	2C-03	2-30" HDPE
	2C-04	1-48" RCP
	2C-05	3-38"x24" HECMP
	2C-06	2-36" CMP
	2C-07	1-36" CMP
	2C-08	3-49"x32" HECMP
	2C-09	2-45"x29" HECMP
2G	2G-01	2-9'x5' RCBC
2X	2X-0C	1-24” CMP
	2X-0D	2-36” CMP
3A	3A-01	1-48" CMP
	3A-02	1-48" CMP
	3A-03	1-48" CMP
	3A-04	1-48" CMP
	3A-05	3-36" RCP

5.5.3 Levees and Dikes
None.

5.5.4 Non-Levee Embankments
Non-levee embankments exist within the Study Limit. These embankments were modeled in the hydraulic analyses as the digital topography presents them.

5.5.5 Islands and Flow Splits
Islands and flow splits were encountered in the hydraulic analysis of Phase-2 and Phase-3 subbasins. Distributary flow areas, like those evaluated in this study, are dynamic in nature. Changes in watershed delineation and flow path are subject to change over time.

5.5.6 Ineffective Flow Areas
No consideration for ineffective flow areas was taken in the hydraulic analyses.

Aerial Reduction Factors (ARF.DAT) were implemented in the F2D models where land development has occurred. Evaluation of aerial photography and residence-per-acre (RAC) estimates were utilized to assign ARF values. IRAINBUILDING (RAIN.DAT) was turned on (set to 1) to direct the rainfall on the ARF portions of the land-developed grid cells to contribute to the surface water runoff for that element.

The *Surface Detention* parameter (DEPTOL, TOLER.DAT) of the F2D models was assigned to 0.004 ft.

5.5.7 Supercritical Flow
No supercritical modeling was performed. Phase-2 and Phase-3 subbasins were modeled with F2D using a *Limiting Froude Number* (FROUDL, CONT.DAT) of 0.95

5.6 Floodway Modeling
NA

5.7 Issues Encountered during the Study.

5.7.1 Special Problems and Solutions.
None.

5.7.2 Modeling Warning and Error Messages.
For Phase-2 and Phase-3 F2D hydrologic/hydraulic analyses, “no data input errors were encountered”. However, multiple “potential errors” were encountered and provided as warning messages. The F2D ERROR.CHK files are provided in the attached CD.

5.8 Calibration.
None.

5.9 Final Results.

5.9.1 Hydraulic Analysis Results.
The inundation areas of the *10-year flow-corridor* and the *100-year floodplain* within the Study Limit are illustrated in Exhibit 3. The delineations of the inundation areas are based on the 20 ft. grid spacing of the F2D hydrologic/hydraulic analysis. In order to present suitable delineations, the inundation areas have been subject to GIS "smoothing" algorithms and manual drafting edits.

The distributary nature of LMWE creates additional complexities when delineating flood inundation areas. The following summarizes the guidelines followed to delineate the LMWE flood inundation areas:

1. The inundation area boundaries generally encompass the areas of maximum flood depths equal to or greater than 0.2 ft., as illustrated in Exhibit 1A and Exhibit 1B.
2. The *10-year flow-corridor* is generally defined as the 10-year flood inundation area where a watercourse generates a regulatory discharge (100-year peak discharge equal to or greater than 100 cfs).
3. The *100-year floodplain* is generally defined as the 100-year flood inundation area where a watercourse generates a regulatory discharge. Watercourses downstream of a regulatory discharge, whether regulatory or not based on the magnitude of the 100-year peak discharge, are included within the 100-year floodplain inundation area.
4. The boundaries between regulatory and non-regulatory discharge watercourse reaches are based on the F2D flow recording cross sections. The delineation of an inundation area boundary between a regulatory discharge cross section and an upstream non-regulatory discharge cross section is based on approximate linear interpolation. As the hydraulic analysis was performed in unison with the hydrologic analysis using F2D, and the inundation area delineations are based on maximum flood depths (not discharge), distinction between regulatory and non-regulatory inundation areas at watercourse confluences, including the effects of backwater inundation and non-regulatory tributary contributions, is subjective and is based on sound engineering judgement.
5. Inundation areas generated <u>solely</u> by the contribution of onsite developed watersheds (i.e. residential subdivisions) were not mapped, as the site specific hydrologic/hydraulic analyses of the post-development watershed may likely be more accurate.
6. Inundation areas generated by contributing offsite watersheds and conveying flow to developed watersheds were mapped, as the two-dimensional capabilities of the FLO-2D hydraulic analysis may be more accurate.

The maximum DV^2 (depth*velocity^2) within the Study Limit is illustrated in Exhibit 4A and Exhibit 4B, for the 10-year event and 100-year event, respectively. The product of depth and velocity-squared is utilized to support Section 16.26.050 (Appendix X), Part G.1, of the Floodplain and Erosion Hazard Management Ordinance.

The F2D modeling results are provided in the attached CD.

5.9.2 Verification of Results.
Floodplain maps were generated as part of the 2009 Lee Moore Wash Basin Management Study (Basin Management Study). Portions of the Basin Management Study coincide with the Study Area. Similar to the floodplain mapping done with the Basin Management Study, the floodplain results of this study generally follow the floodplain topography. The results suggest that the mapping is reasonable.

In addition, preliminary models were reviewed by *JE Fuller/Hydrology & Geomorphology, Inc. (JE Fuller)*. Downstream of this study, west of South Houghton Road, is Lee Moore Wash – West (LMWW, DO 18*22393). As part of the LMWW, one of the initial tasks was to "*provide a quality check review of the models provided by the District and report any significant issues, if any*" (Task 1.5).

One finding of the review revealed an inflow hydrograph for Basin 3A (3-hour, 10-year and 100-year) being duplicated at nodes #11224 and #11225; the duplication was subsequently revised. In all the review "*concluded that the models are adequate and are superior to the previous generation of FLO-2D model (LMWBMS)*". The JE Fuller review is provided in Appendix B.

Section 6: Erosion and Sediment Transport

Not available in this study

Section 7: Ratio of the Top Width of 100-yr and 25-yr Floodplain

Not available in this study