Catalina Foothills Watercourse Studies:
Technical Data Notebook for Hydrologic and Hydraulic Mapping of the North Manor Wash (incl. Hillcrest Wash),
Pima County Arizona.

FEMA FIRM Panel 04019C-1687L &1680L

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Exhibit

Exhibit 1 100-yr floodplain limit for the North Manor Wash

Section 1 Introduction

1.1 Purpose

The objective of this Technical Data Notebook (TDN) is to provide 100-yr peak discharges at Concentration Points (CPs) for the North Manor Wash (NTM) and the 100-yr floodplain boundary information, using better topographic, hydrologic, and hydraulic data.

This TDN 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 1-97) and FEMA Guidelines. This is a local study and has not been submitted to FEMA.

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):

This study has been prepared by the Pima County Regional Flood Control District (RFCD):

Pima County Regional Flood Control District
97 East Congress, Tucson, AZ 85701

The project was prepared by:

Felipe Ip, P.E., C.F.M., Senior Civil Engineer Assistant
Pima County Regional Flood Control District
97 East Congress, Tucson, AZ 85701

1.3 Project Location

The North Manor (NTM) study was performed to provide drainage information for the North Manor Wash. The site is located within Sections 13 and 24 of Township 13 South, Range 13 East, and Sections 7, 18, and 19 of Township 13 South, Range 14 East, Pima County, Arizona. Entire watershed of the North Manor Wash is in FEMA Zone X and Shaded Zone X, as shown on the current Flood Insurance Rate Map (FIRM) numbers 04019C-1687L and 04019C-1680L.

The watershed is 0.79 square mile. The study watershed was divided into seven sub-basins (Fig.1.1) with six reaches (Fig.1.2). The study area for the North Manor Wash is

from a junction with Rillito Creek to the upstream boundary of the watershed 400 feet south of Orange Grove Rd between N 1st Avenue and E Skyline Drive. (Fig.1.2).

1.4 Hydrologic and Hydraulic Methods

A hydrologic analysis was performed to estimate the 100-year regulatory discharge rate at concentration points along the NTM and at the confluence of NTM and the Rillito Creek using PC-Hydro Version 5.4.3 (PC-Hydro). The parameters for PC-Hydro, such as soil, vegetation, slope, flow path length and roughness were selected in accordance with the PC-Hydro User Guide (Arroyo Engineering, 2007). The proposed regulatory discharges are flow rates that have a 1-percent chance of being equaled or exceeded each year ("100-year" discharge rates). The hydraulic analysis was performed to delineate floodplain limits along the study reaches of the NTM using HEC-GeoRAS, Version 10 (HEC-GeoRAS), HEC-RAS Version 4.0 (HEC-RAS) and FLO2D models in the downstream distributary flow areas. Culverts are located at the NTM crossings with River Road in reaches NTM D and NTM B.

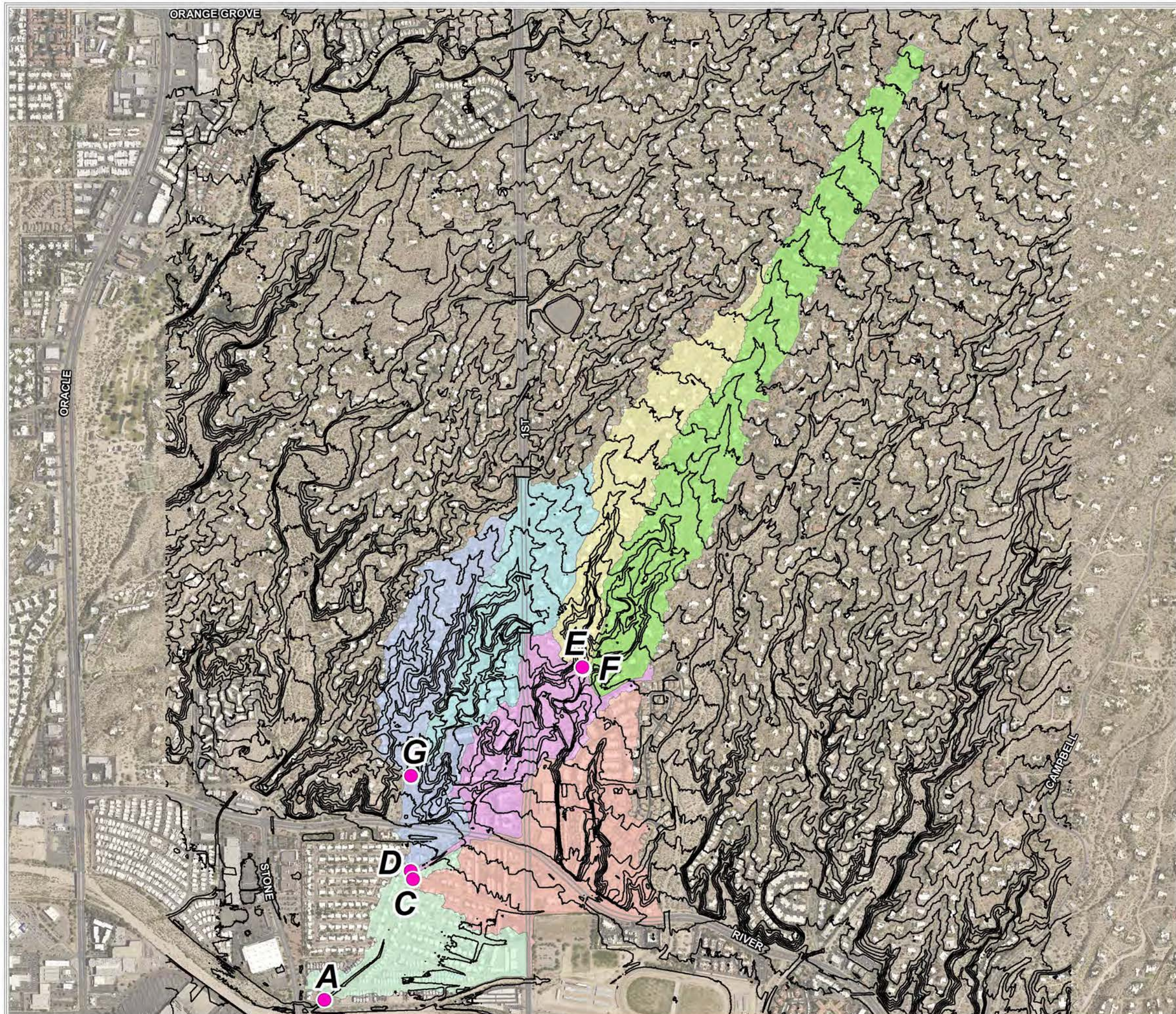
1.5 Acknowledgment

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

1.5 Study Results

The 100-yr discharges were calculated for the North Manor Wash. Subbasin boundaries and corresponding CPs are illustrated in Figure 1.1. Hydrologic characteristics for the studied subbasins are presented in Table 2. The regulatory peak discharge rate was calculated at the confluence of the Rillito Creek (CP A; Fig.1.1). The estimated discharge rate is 1229 cubic feet per second (cfs) with a drainage area of 506.8 acres at CP A. Calculated discharges are summarized in Table 3. The calculated discharges are compared with the USGS Regional Regression Equation (Table 4). The comparison shows that the peak discharges calculated in this study are reasonable. This study found some homes at risk for flooding during the 100-yr flood.

Figure 1.1
Watershed Map
Northmanor Wash



Discharge Point

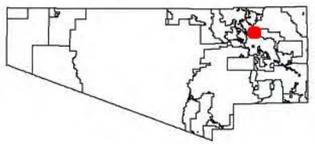
Contour 10ft.

SUBBASINS

- A
- B
- C
- D
- E
- F
- G

Aerial : 2012 Pictometry Orthophoto Imagery ©
Topo: 2008 Pima Association of Governments
Datum: NAVD 1988

Pima County Index Map



Index Map Scale 1:5,250,000

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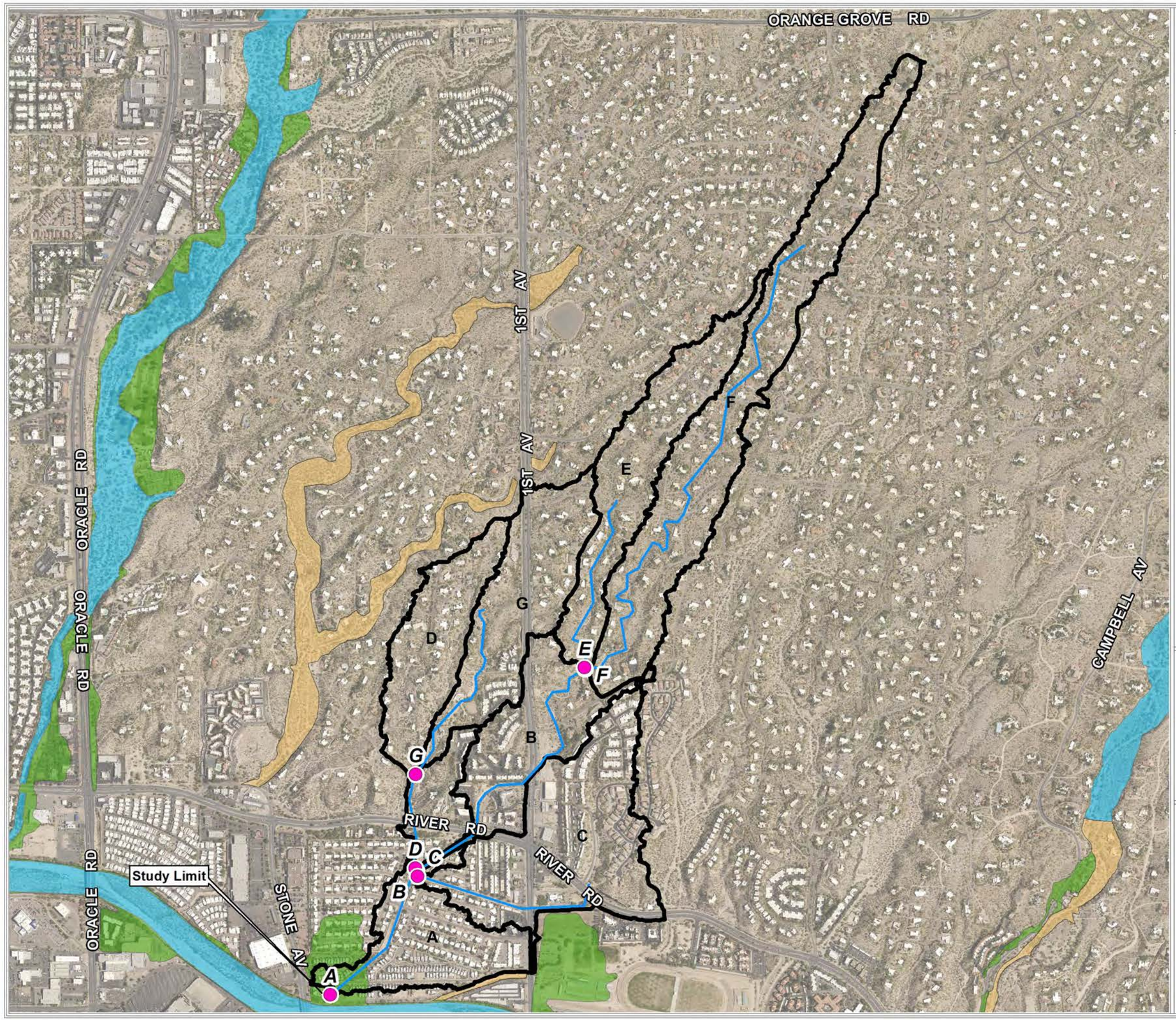
Figure 1.2
Study Limit
Northmanor Wash



Discharge Point

River

Subbasins

Existing FEMA Floodplain

ZONE A

ZONE AE

ZONE X - SHADED

Aerial : 2012 Pictometry Orthophoto Imagery ©

Pima County Index Map

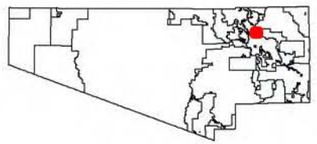


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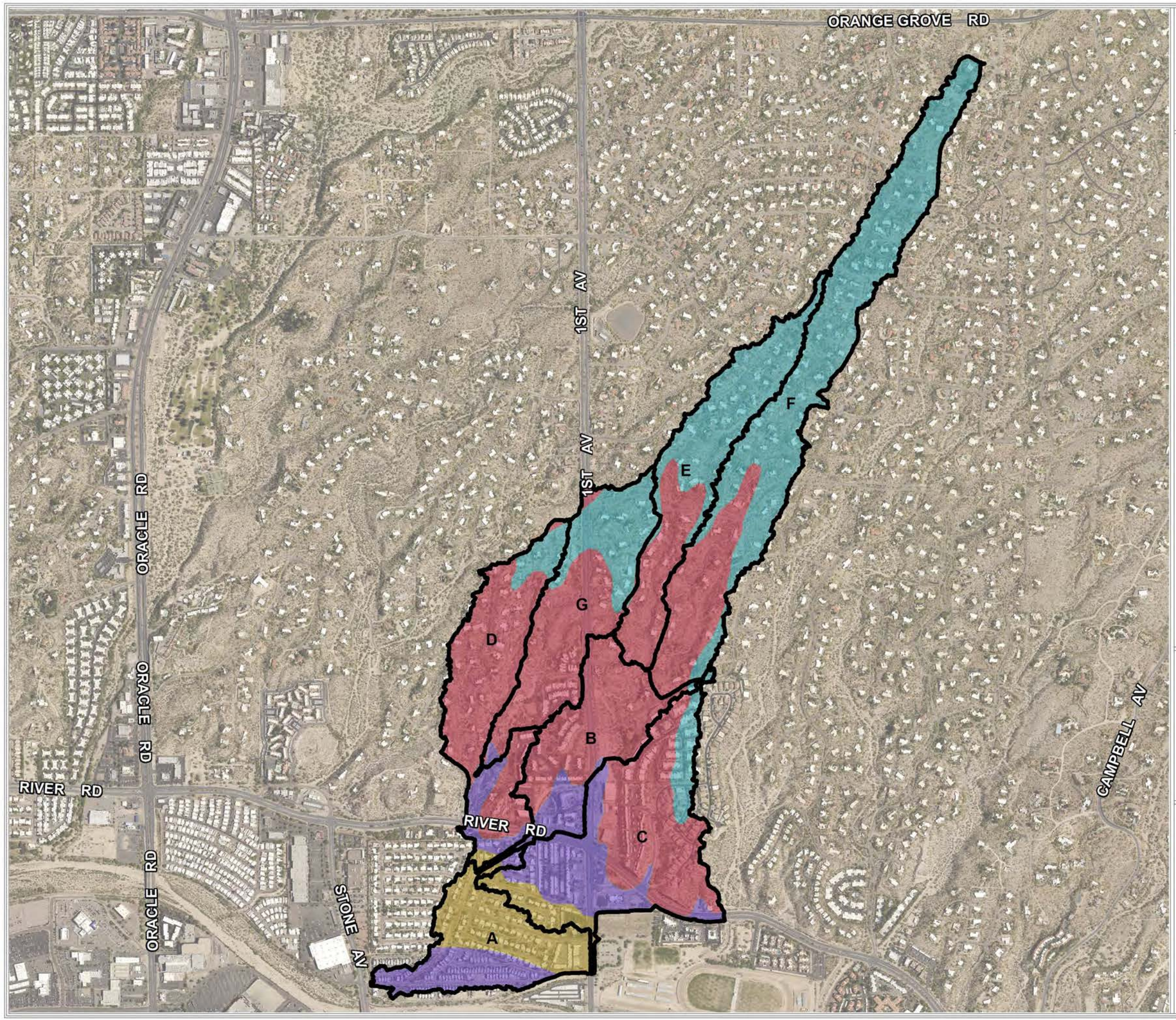
Figure 1.3
Soil Classification
Northmanor Wash



Subbasins

Soil Classification

- Soil Group: A (100%), ARIZO-RIVERWASH COMPLEX, 0 TO 3 PERCENT SLOPES
- Soil Group: B (100%), GLENDALE SILT LOAM, 0 TO 3 PERCENT SLOPES
- Soil Group: B (100%), PINALENO VERY COBBLY SANDY LOAM, 1 TO 8 PERCENT SLOPES
- Soil Group: B (82%) C (18%), PINALENO-STAGECOACH-PALOS VERDES COMPLEX, 10 TO 35 PERCENT SLOPES

Aerial : 2012 Pictometry Orthophoto Imagery ©

Pima County Index Map

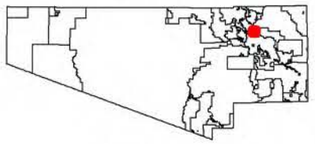


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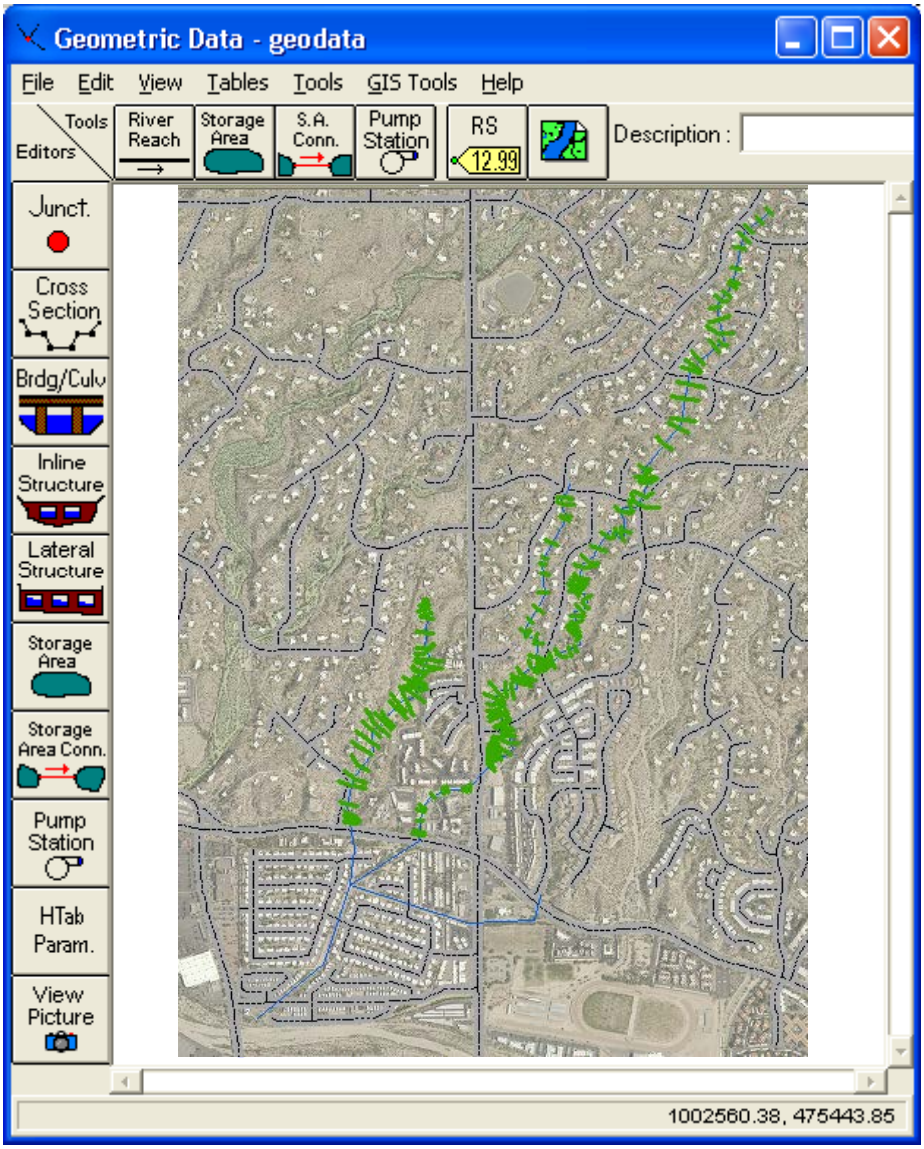
Figure 1.4 (optional). HecRAS model schematic.



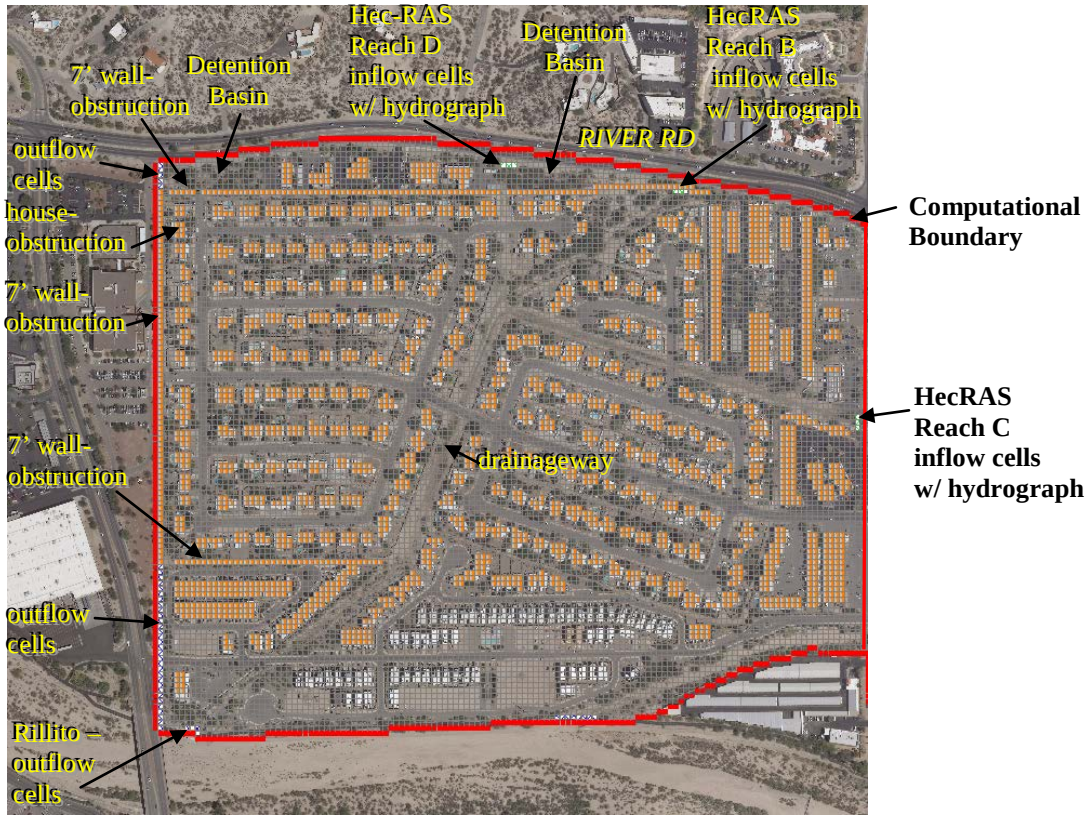


Fig.1.5 (optional) FLO-2D Model south of the River Road

Section 2 Local Government Abstract

2.1 Project Contact Information

Contact Information:
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97E Congress, Tucson, AZ 85705
Terry.Hendricks@pima.gov / Evan.Canfield@pima.gov

Date Study Submitted: _____

Date Study Approved: _____
12-18-2014

2.2 General Information

Community: Pima County Regional Flood Control
County: Pima County
River or Stream Name: North Manor Wash
Reach Description: Wash in Catalina Foothills
Study Type: Hydrology and Hydraulics study of a Riverine system and a Distributary sheet-flooding system
Purpose of the Study: Estimate regulatory discharges and map floodplain boundaries
Summary of Hydrology and Hydraulic Methods: HEC-GeoRAS, HEC-RAS, FLO2D, PC-Hydro
Brief Summary Description of the Study Results: FLO2D showed shallow flooding along all the streets for the portions of the NorthManor subdivision (Recorded at Book 15 Page 38, Maps and Plats) west of the local drainageway with worse flooding towards to northwest corner of that subdivision. For portions east of the drainageway, shallow flooding is concentrated along Geronimo, Muriel, Los Altos and Lawton Streets. (see Exhibit 1)
Acknowledgements: Akitsu Kimoto, Ann Moynihan, Xavi Amendariz, Terry Hendricks, Evan Canfield

2.3 Survey and Mapping Information

Digital Projection Information: NAD 1983 NAD83-92 **HARN State Plane Arizona Central**
USGS Quad Sheets if available: N/A
Mapping for Hydrologic Study: LiDAR based on 2008 flight used to derive 2-ft contour interval maps using ArcGIS 10.0, PAG 2012 orthophotos
Mapping for Hydraulic Study: LiDAR based on 2008 flight used to derive a DEM (5-ft cell size) for use with HEC-GeoRAS

2.4 Hydrology

Model or Method Used: PC-Hydro Version 5.4.2
Storm Duration: 1-hour
Hydrograph Type: Pima County Dimensionless Hydrograph
Frequencies Determined: 100 yr
List of Gages used in Frequency Analysis or Calibration: None
Rainfall Amounts and Reference: NOAA 14 Upper 90% Confidence Interval
Unique Conditions and Problems: None
Coordination of Q's: Comparison with a USGS Regression Equation and existing regulatory discharges if available

2.5 Hydraulics

Model or Method Used: HEC-GeoRAS, Version 10 (HEC-GeoRAS) and HEC-RAS Version 4.0 (HEC-RAS), FLO-2D Version 2009.06
Regime: Modeled as subcritical
Frequencies for which Profiles were computed: 100 year
Method of Floodway Calculation: No Floodway
Unique Conditions and Problems. 7ft subdivision perimeter wall, detention basin with 2ft-high box culvert outlet, earthern drainageways, shallow flooding

2.6 Erosion, Sediment Transport and Geomorphic Analysis

NA

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 2012 Orthophotos
Contour: 2 feet interval
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 2008 Light Detection and Ranging (LiDAR) data was used for the HEC-RAS analysis. The contour interval of the topographic map is 2 feet.

Following data are included in this TDN (see "GIS" folder):
Aerial Photo: PAG 2012 Orthophotos
Contour: 2 feet interval
Topographic Data: 5-ft DEM

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

Section 4 Hydrology

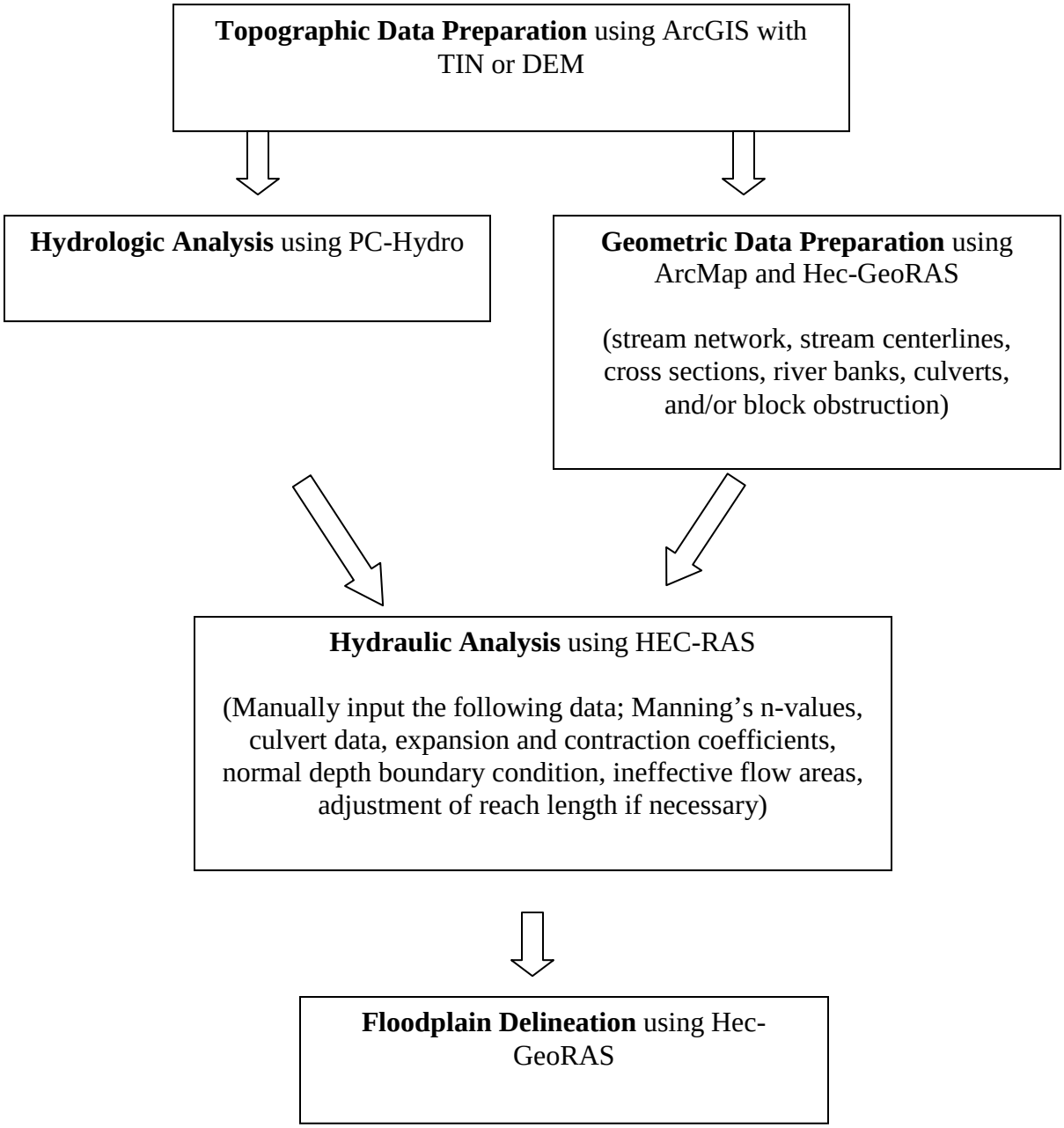
4.1 Method Description

The 100-year peak discharge at NTM concentration points with drainage areas less than 1 mi2 (CP A through G) were calculated using PC-Hydro Version 5.4.3. It uses a semi-empirical method, which is similar to the Rational Formula and is unique to Pima County. Pima County has been using the PC-Hydro method for over 30 years for floodplain management. The method is deemed a FEMA-accepted hydrologic method for prediction of 1% chance 100-yr peak discharge in Pima County. The PC-Hydro method generally produces higher discharge values compared to HEC-HMS or USGS Regression equations. Peak discharge values produced by the PC-Hydro would be conservative, compared to using HEC-HMS or USGS Regression equations. The PC-Hydro model requires the parameters regarding rainfall, topography, soil, and vegetation to determine peak discharge. Those parameters were determined in accordance to the PC-Hydro User Guide (Arroyo Engineering, 2007).

The PC-Hydro outputs are included in Appendix D.

The 100-year return interval peak discharge rate for the watershed was computed by using PC-Hydro (Arroyo Engineering, 2007). NOAA Atlas 14, upper 90% confidence interval, rainfall data was used for the analysis. Hydrologic soils group map for the watershed is presented in Fig. 1.3. Hydrologic Soil Groups A and B are the dominant soil types in the watershed, which occupies 92.8% of the watershed. The watercourse was divided into six segments (Reaches) using slope break points. Basin factors were based on the tables in the PC Hydro User Guide. The basin factor for each segment was determined by using the 2012 PAG aerial photo. The Basin Factor used for the hydrologic analysis ranges from 0.022 to 0.034. 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 25%, which was determined using a 2012 PAG aerial photo. The results of hydrologic analysis are included in Appendix 1. The 100-year peak discharge rate at Rillito Creek is calculated to be 1229 cubic feet per second (cfs). The Time of concentration (Tc) for the peak discharge is 38 minutes, and the rainfall intensity is 3.71 inches/hr at the time of concentration.

Figure 4.1 Flow Chart of Mapping Process



4.2 Parameter Estimation

4.2.1 Drainage Area Boundaries

The study limit is shown in Fig.1.2. The North Manor Wash watershed is mostly located within residential areas that are FEMA Zone X, except in the downstream areas within the subdivisions 'Northmanor' and 'Miramonte at the River' just before the confluence with the Rillito Creek. Those downstream areas are FEMA Shaded Zone X. The upstream study limits is about 400 feet south of Orange Grove Road midway between N 1st Avenue and E Skyline Drive, while the downstream limit is at the confluence with the Rillito Creek (Fig.1.2). The entire study watershed is 0.79 square mile. The study watershed was divided into seven sub-basins (Fig.1.1).

4.2.2 Watershed Work Maps

A watershed work map is included in Exhibit 1. The work map includes subbasin boundaries, concentration points, flow center lines and cross sections with station numbers and water surface elevations. Soil group boundaries are shown in Fig.1.3. The work map is divided into floodplains delineated by HECRAS and floodplain delineated by FLO-2D.

4.2.3 Gage Data

No gage data were used in this TDN.

4.2.4 Spatial Parameters

No spatial parameters were used in this TDN.

4.2.5 Precipitation

The NOAA 14 Atlas 90% upper confidence rainfall data was used. The rainfall intensity at the time of concentration for the North Manor Wash watershed at CP A is 3.71 in/hr. No area reduction factor was applied.

4.2.6 Physical Parameters

Methods are summarized in Table 1. The PC-Hydro model calculates runoff coefficients using adjusted Curve Number (CN), which was developed based on results from USDA-ARS research. This procedure assumes that high-intensity short-duration storms produce high raindrop impacts that cause the soils on the ground surface to seal up, resulting in reduced infiltration rate of the ground (Caliche Effect). The CN values used in

the PC-Hydro model increase with increasing rainfall depth and intensity. The details of the method are described in the PC-Hydro User Guide (Arroyo Engineering, 2007).

Table 1 Methods used for a PC-Hydro analysis

	Selected Method
Rainfall Depth	NOAA 14, upper 90% Confidence Interval
Rainfall Loss	Adjusted SCS Curve number
Time of Concentration	Pima County Hydrology Procedure

Table 2 Subbasin Characteristics

Sub-Basin	Area (sq mile)	Impervious Area (%)	Vegetation Cover (%)
A	0.076	25	30
B	0.081	15	30
C	0.147	40	30
D	0.106	15	30
E	0.098	10	30
F	0.184	10	30
G	0.07	10	30

4.3 Issues Encountered During the Study

4.3.1 Special Problems and Solutions

There were no problems with the hydrologic modeling.

4.3.2 Modeling Warning and Error Messages

None

4.4 Calibration

No calibration was conducted in this study.

4.5 Final Results

4.5.1 Hydrologic Analysis Results

The 100-year peak discharge at CP A (at confluence with Rillito Creek) was determined using the PC-Hydro. The result is summarized in Table 3.

Table 3 Summary of the Hydrologic Analysis

Concentration Point	Location	Area (acre)	Rainfall Intensity at Tc (in/hr)	Time of Concentration (min)	Q100 (cfs)
A	At confluence w/ Rillito at A	506.8	3.71	38	1229
B	At Junction w/ B	232.5	4.14	32.7	587
C	At Junction w/ C	93.9	8.12	9.3	547
D	At Junction w/ D	132	5.74	18.6	468
E	At Junction w/ E	62.9	6.29	16	234
F	At Junction w/ F	118	4.69	27.3	328
G	At Junction w/ G	64.2	7.06	12.7	270

4.5.2 Verification of results

The estimated peak discharge at CP A was also compared with the peak discharge obtained from USGS Regression Equation 13 (Thomas et al., 1997) (Table 4). The comparison showed that the PC-Hydro-derived peak discharge at CP A is 14.3% higher than the one derived from the Regression Equation.

Table 4 Comparison of a peak discharge

Concentration Point	Location	Area (sq mile)	Q100 PC-Hydro(cfs)	Q100 RRE (cfs)
A	At confluence w/ Rillito at A	0.792	1229	1075
B	At Junction w/ B	0.363	587	613
C	At Junction w/ C	0.247	547	455
D	At Junction w/ D	0.206	468	394
E	At Junction w/ E	0.098	234	210
F	At Junction w/ F	0.184	326	359
G	At Junction w/ G	0.100	270	214

RRE: USGS Regression Equation 13

Section 5 Hydraulics

5.1 Method Description

The hydraulic analysis was performed for the NTM wash study area that includes an area currently mapped as FEMA Shaded Zone X. The modeling was performed using FLO-2D, HECRAS, Version 4.0, and HEC-GeoRAS Version 4.1.1.

2008 LiDAR data was used to create a Triangular Irregular Network (TIN) for the study area of the NTM wash. The locations of the stream centerline, cross-sections, and banks of the NTM wash were determined using ArcGIS and 2012 PAG aerial photos. The physical attributes of the wash were digitized in ArcGIS using the HEC-GeoRAS extension and then exported to HEC-RAS to create geospatially referenced geometric data (cross sections, and reach lengths). Other parameters for the steady-state analysis, such as Manning's n-values, culvert data, expansion and contraction coefficients, boundary condition, and ineffective flow areas were manually input into HEC-RAS. The hydraulic data obtained from HEC-RAS model were then exported back into ArcGIS to delineate a floodplain boundary for NTM Wash using the RAS Mapping floodplain visualization tool. Parameters for the hydraulic analysis were selected following the District Tech Policy 019.

Steady flow analysis with HEC-RAS, Version 4.0 was performed. Normal depth was used as a downstream boundary condition. The model name is Northmanor, and the plan name is Northmanor, which are included in Appendix E.

In earlier HECRAS model runs, the reaches upstream of CP A, B, C, and D were found to flow over bank and leave the channel in areas south of River Road (i.e. the channel/drainageway system in the downstream subdivisions). Thus the HECRAS model extends only to areas north of River Road and for areas south of River Road a FLO2D model was used. Area south of River Road is topographically flat and is representative of distributary sheet-flow flooding regime. The resulting HECRAS model uses normal-depths with a slope of 0.1086 for Reach D and a slope of 0.1174 for Reach B as downstream boundary conditions. The FLO2D model is displayed in Figure 1.5

The NTM wash FLO2D model simulates flow in 2-dimensional and has 20-foot grid cells. Model information such as computational area, inflow/outflow cells, blocked obstructions (both walls and structures), and area/width reduction factors are shown in Fig.1.5. Flows from north of River Road are conveyed to area south of River Road through culverts underneath River Road and are discharged into detention basins which are part of the channel-drainageway system in the south-of-River-Road subdivisions. (DOT Project no. 4BRICA Sheet 19) (Plat Bk15 PG38)

Earlier FLO2D model runs show 100-yr discharge uncontained by the drainageways and resulted in surface sheet-flows in the west and northwest directions towards Stone Avenue. However, later it became evident from the aerial photo and from field visits that there is a 7-foot perimeter wall around the subdivisions that can obstruct the flow at the subdivisions boundary. Thus the wall was modeled as an obstruction. The final FLO-2D floodplain shows some flow ponding up in the basin at the northwest corner of the NorthManor Subdivision (BK15 PG38), and the rest of the flow eventually made it to Rillito Creek through the 15-foot drainageway at the knuckle at the end of East Hyde Street on the southwest corner of the subdivision. Field visit also confirmed the

subdivision is draining into that basin through the local streets. There are other inflow sources to that basin from north of River Rd. Houses are modeled as fully obstructed structures in the FLO2D model. The upstream discharges are entered as inflow cells in FLO2D. For cells that are not modeled as wall obstructions on the western boundary, they are treated as outflow cells. Mannings roughness coefficients used for earthern-channel drainageways, streets and subdivisions are 0.035, 0.011 and 0.065 respectively.

There are three culverts along reach NTM F in subbasin F of the study area [2-2.5'CMP, 1-4'CMP, 1-4'CMP] (Fig. 1.2). From field visit and from culvert hydraulic analysis, it is evident the culverts have the capacity to convey the modeled flows. No signs of past overtopping or erosion were observed in the field (see Field Photos folder). Thus the three culverts were not modeled in HECRAS. Also, without any as-built construction drawings and with only LiDAR background elevations, it will be difficult to input the geometry and elevations of the culverts into the model. The same argument is also used for the 1-5'x7.5'box culvert in subbasin B. The area east of 1st Avenue is not modeled because it is within the City of Tucson limit. The area west of 1st Avenue in subbasin C is modeled in FLO2D.

A work map showing the floodplain limits of the North Manor Wash delineated by HECRAS and by FLO2D is included in Exhibit 1.

5.3 Parameter Estimation

5.3.1 Roughness Coefficients

Manning's n values were determined by a combination of a site visit and 2012 PAG aerial photo. Manning's n value of 0.045 was assigned for entire cross-sections (channel and overbanks) with desert brush along all reaches in the North Manor Wash.

5.3.2 Expansion and Contraction Coefficients

The expansion coefficient of 0.30 and contraction coefficient of 0.10 were used for the entire study reach.

5.4 Cross-Section Description

A 2-foot interval contour map 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 HEC-GeoRAS. The locations of cross sections and channels used for this study are shown in Exhibit 1.

5.5 Modeling Consideration

5.5.1 Hydraulic Jump and Drop Analysis

No hydraulic, drop analyses or adjustment of the floodplain was conducted in this study.

5.5.2. Bridges and Culverts

There are local culverts along the upper reaches of the watershed. However, they are not modeled. There are culverts under River Road and they are not modeled in the final HECRAS-FLO2D models.

5.5.3 Levees and Dikes

There are no levees or dikes located within the study limit.

5.5.4 Non-Levee Embankments

None.

5.5.5 Island and Flow Splits

There were no islands or flow splits modeled.

5.5.5 Ineffective Flow Areas

Ineffective flow option was not modeled in the HEC-RAS model. In general these ineffective flow areas were disconnected overbank areas that would not convey flow to the next downstream cross-section. They are portions of the floodplain that do not actively convey flow.

5.6 Floodway Modeling

No floodway modeling was performed in this study.

5.7 Problems Encountered

5.7.1 Special Problems and Solutions

The Northmanor subdivision has had drainage problems which are reflected in the FL0-2D model. There are no special problems in the study limit.

5.7.2 Model Warnings and Errors

The following warning messages occurred:

Divided flow
Energy loss greater than 1.0
Energy equation could not be balanced and defaulted to critical.
Conveyance ratio is less than 0.7 or greater than 1.4.

5.8 Calibration

The model was not calibrated in this study.

5.9 Final Results

5.9.1 Hydraulic Analysis Results

The 100-year peak discharges at the concentration points along the NTM were determined using PC-Hydro. The results are summarized in Table 4. The HEC-RAS and the FLO2D models are included in Appendix E.

5.9.2 Verification of Results

The proposed floodplain limit appears reasonable. There is no existing floodplain limit except the FEMA shaded-zone X areas close to the wash confluence with Rillito Creek near Stone Ave. The results suggest that the proposed floodplain limit is reasonable based on the topography. FLO2D showed shallow flooding along all the streets for portions of the NorthManor subdivision west of the local drainageway (Bk15 PG38) with worse flooding towards to northwest corner of that subdivision. For portions east of the drainageway, shallow flooding is concentrated along Geronimo, Muriel, Los Altos and Lawton Streets.

Section 6 Erosion and Sediment Transport

No erosion or sediment transport analysis was conducted in this study.

Section 7 Draft FIS Report Data

7.1 Summary of Discharges

Peak discharges at CP A was used for the hydraulic analysis in this study. The estimated regulatory discharge rates are 1229 cubic feet per second (cfs) with a drainage area of 0.79 square mile.

7.2 Floodway Data

Not applicable.

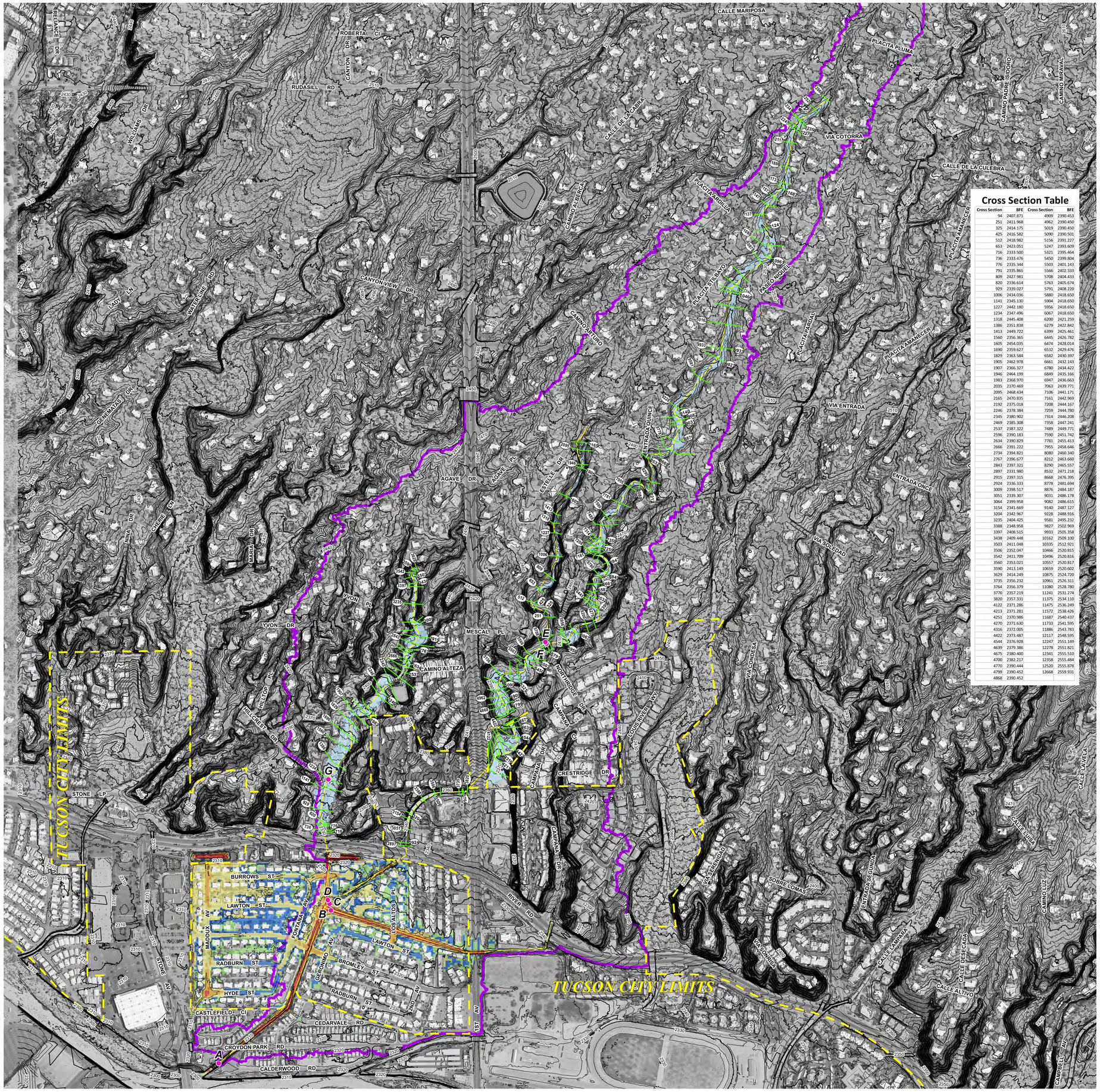
7.3 Annotated Flood Insurance Rate Map

Not applicable.

7.4 Flood Profiles

Flood profiles are included in the HEC-RAS model in Appendix E.

Exhibit 1
100-year Floodplain with cross sections Northmanor Wash



Cross Section Table

Cross Section	BFE	Cross Section	BFE
94	2407.871	4909	2390.453
251	2411.968	4962	2390.450
325	2414.175	5019	2390.450
425	2416.582	5090	2390.501
512	2418.982	5156	2391.227
653	2423.051	5247	2393.609
716	2333.500	5321	2395.464
736	2333.476	5450	2399.804
776	2335.344	5503	2401.143
791	2335.865	5566	2402.333
809	2427.981	5708	2404.433
820	2336.614	5763	2405.674
929	2339.027	5791	2408.220
1006	2434.036	5880	2418.650
1141	2345.130	5904	2418.650
1227	2442.180	5956	2418.650
1234	2347.496	6067	2418.650
1318	2445.408	6200	2421.259
1386	2351.838	6279	2422.842
1413	2449.722	6399	2425.461
1560	2356.365	6445	2426.782
1605	2454.035	6474	2428.014
1690	2359.627	6532	2429.476
1829	2363.584	6582	2430.397
1905	2462.978	6661	2432.143
1907	2366.327	6780	2434.422
1946	2464.199	6849	2435.166
1983	2368.970	6947	2436.663
2035	2370.469	7063	2439.771
2095	2468.434	7106	2441.171
2165	2470.835	7161	2442.969
2192	2375.018	7208	2444.167
2246	2378.384	7259	2444.780
2345	2380.902	7314	2446.208
2469	2385.308	7358	2447.241
2537	2387.322	7489	2449.771
2596	2390.183	7590	2451.742
2634	2390.829	7781	2455.413
2666	2391.222	7955	2458.646
2734	2394.821	8080	2460.340
2767	2396.677	8212	2463.660
2843	2397.321	8290	2465.557
2897	2331.980	8532	2471.218
2915	2397.315	8668	2476.395
2924	2336.333	8778	2481.694
3009	2398.517	8876	2484.187
3051	2339.307	9031	2486.178
3064	2399.958	9082	2486.615
3154	2341.669	9140	2487.127
3204	2342.967	9228	2488.916
3235	2404.425	9581	2495.232
3388	2348.958	9827	2502.969
3397	2408.515	9933	2505.358
3438	2409.448	10162	2509.100
3503	2411.048	10335	2512.921
3506	2352.047	10466	2520.815
3542	2411.709	10496	2520.816
3560	2353.021	10557	2520.817
3590	2413.149	10659	2520.602
3629	2414.249	10875	2524.720
3735	2356.232	10961	2526.311
3764	2356.379	11080	2528.780
3776	2357.219	11241	2531.274
3820	2357.331	11375	2534.110
4122	2371.286	11475	2536.249
4213	2371.281	11572	2538.426
4251	2370.986	11687	2540.437
4270	2371.630	11733	2541.595
4316	2372.005	11886	2543.783
4422	2373.487	12117	2548.595
4544	2376.928	12247	2551.149
4639	2379.386	12278	2551.821
4675	2380.400	12341	2555.510
4700	2382.217	12358	2555.484
4770	2390.444	12520	2555.878
4799	2390.452	12668	2559.931
4868	2390.452		

- Discharge Point
- Cross Section
- Contour 2ft.
- River
- Streets
- City of Tucson Limits
- Northmanor Watershed
- 100yr. Floodplain

Final Flow Depth at Cell

- => 0.200
- => 0.500
- => 1.000
- => 2.000
- => 3.000

Aerial : 2011 Pictometry Orthophoto Imagery ©
Topo: 2008 Pima Association of Governments
Datum: NAVD 1988

Pima County Index Map

Index Map Scale 1:1,500,000

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 Department of Transportation Technical Services Division makes no claims regarding the accuracy of the information depicted herein.This product is subject to the Department of Transportation Technical Services Division's Disclaimer and Use Restrictions.

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PIMA COUNTY
FLOOD CONTROL

Pima County Regional Flood Control
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Tucson, Arizona 85701-1207
(520)243-1800 - FAX (520)243-1821
http://www.rfcd.pima.gov

08/2013

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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.

Arizona Department of Water Resources, Flood Mitigation Section
"Instruction for Organization and Submitting Technical Document for Flood Studies" SSA1-97, November 1997

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

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

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"Pima County Mapguide Map", 2008

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

A 2. Referenced Documents

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.

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.

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

APPROVED BY:

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

Appendix

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:

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

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.)

Appendix B FEMA MT-2 Form, General Documentation and Correspondence

C. REVIEW FEE

Has the review fee for the appropriate request category been included? ☐ Yes Fee amount: $_____

☒ No, Attach Explanation

Please see the DHS-FEMA Web site at http://www.fema.gov/plan/prevent/fhm/frm_fees.shtm for Fee Amounts and Exemptions.

D. SIGNATURE

All documents submitted in support of this request are correct to the best of my knowledge. I understand that any false statement may be punishable by fine or imprisonment under Title 18 of the United States Code, Section 1001.

Name: Akitsu Kimoto, Ph.D., C.F.M.	Company: Pima County Regional Flood Control	
Mailing Address: 97 E. Congress, Tucson AZ, 85701, Tucson AZ 85705	Daytime Telephone No.: 520 243 1800	Fax No.: 520 243-1821
	E-Mail Address: Akitsu.Kimoto@rfcd.pima.gov	
Signature of Requester (required):	Date:	

As the community official responsible for floodplain management, I hereby acknowledge that we have received and reviewed this Letter of Map Revision (LOMR) or conditional LOMR request. Based upon the community's review, we find the completed or proposed project meets or is designed to meet all of the community floodplain management requirements, including the requirement that no fill be placed in the regulatory floodway, and that all necessary Federal, State, and local permits have been, or in the case of a conditional LOMR, will be obtained. In addition, we have determined that the land and any existing or proposed structures to be removed from the SFHA are or will be reasonably safe from flooding as defined in 44CFR 65.2(c), and that we have available upon request by FEMA, all analyses and documentation used to make this determination.

Community Official's Name and Title: Keith Brann, Town Engineer	Community Name: Town of Marana	
Mailing Address: 11555 W. Civic Center Drive Marana, AZ 85653	Daytime Telephone No.: 520-382-1999	Fax No.: 520-382-1998
	E-Mail Address: kbrann@marana.com	
Community Official's Signature (required):	Date: 6-16-2010	

CERTIFICATION BY REGISTERED PROFESSIONAL ENGINEER AND/OR LAND SURVEYOR

This certification is to be signed and sealed by a licensed land surveyor, registered professional engineer, or architect authorized by law to certify elevation information data, hydrologic and hydraulic analysis, and any other supporting information as per NFIP regulations paragraph 65.2(b) and as described in the MT-2 Forms Instructions. All documents submitted in support of this request are correct to the best of my knowledge. I understand that any false statement may be punishable by fine or imprisonment under Title 18 of the United States Code, Section 1001.

Certifier's Name: Howard Evan Canfield	License No.: 41917	Expiration Date: 3/31/2011
Company Name: Pima County Regional Flood Control	Telephone No.: 520 243 1836	Fax No.:
Signature:		Date:

Ensure the forms that are appropriate to your revision request are included in your submittal.

Form Name and (Number)	Required if ...
☒ Riverine Hydrology and Hydraulics Form (Form 2)	New or revised discharges or water-surface elevations
☐ Riverine Structures Form (Form 3)	Channel is modified, addition/revision of bridge/culverts, addition/revision of levee/floodwall, addition/revision of dam
☐ Coastal Analysis Form (Form 4)	New or revised coastal elevations
☐ Coastal Structures Form (Form 5)	Addition/revision of coastal structure
☐ Alluvial Fan Flooding Form (Form 6)	Flood control measures on alluvial fans

Seal (Optional)

C. REVIEW FEE

Has the review fee for the appropriate request category been included? ☐ Yes Fee amount: $_____

☒ No, Attach Explanation

Please see the DHS-FEMA Web site at http://www.fema.gov/plan/prevent/fhm/frm_fees.shtm **for Fee Amounts and Exemptions.**

D. SIGNATURE

All documents submitted in support of this request are correct to the best of my knowledge. I understand that any false statement may be punishable by fine or imprisonment under Title 18 of the United States Code, Section 1001.

Name: Akitsu Kimoto, Ph.D., C.F.M.	Company: Pima County Regional Flood Control	
Mailing Address: 97 E. Congress, Tucson AZ, 85701, Tucson AZ 85705	Daytime Telephone No.: 520 243 1800	Fax No.: 520 243-1821
	E-Mail Address: Akitsu.Kimoto@rfcd.pima.gov	
Signature of Requester (required):	Date: 6/17/2010	

As the community official responsible for floodplain management, I hereby acknowledge that we have received and reviewed this Letter of Map Revision (LOMR) or conditional LOMR request. Based upon the community's review, we find the completed or proposed project meets or is designed to meet all of the community floodplain management requirements, including the requirement that no fill be placed in the regulatory floodway, and that all necessary Federal, State, and local permits have been, or in the case of a conditional LOMR, will be obtained. In addition, we have determined that the land and any existing or proposed structures to be removed from the SFHA are or will be reasonably safe from flooding as defined in 44CFR 65.2(c), and that we have available upon request by FEMA, all analyses and documentation used to make this determination.

Community Official's Name and Title: Suzanne Shields, PE Chief Engineer	Community Name: Pima County Flood Control	
Mailing Address: 97 E Congress Tucson AZ, 85701	Daytime Telephone No.: 520 243 1800	Fax No.: 520 243 1821
	E-Mail Address: suzanne.shields@rfcd.pima.gov	
Community Official's Signature (required):	Date: 6/17/2010	

CERTIFICATION BY REGISTERED PROFESSIONAL ENGINEER AND/OR LAND SURVEYOR

This certification is to be signed and sealed by a licensed land surveyor, registered professional engineer, or architect authorized by law to certify elevation information data, hydrologic and hydraulic analysis, and any other supporting information as per NFIP regulations paragraph 65.2(b) and as described in the MT-2 Forms Instructions. All documents submitted in support of this request are correct to the best of my knowledge. I understand that any false statement may be punishable by fine or imprisonment under Title 18 of the United States Code, Section 1001.

Certifier's Name: Howard Evan Canfield	License No.: 41917	Expiration Date: 3/31/2011
Company Name: Pima County Regional Flood Control	Telephone No.: 520 243 1836	Fax No.:
Signature:		Date:

Ensure the forms that are appropriate to your revision request are included in your submittal.

Form Name and (Number)	Required if ...
☒ Riverine Hydrology and Hydraulics Form (Form 2)	New or revised discharges or water-surface elevations
☐ Riverine Structures Form (Form 3)	Channel is modified, addition/revision of bridge/culverts, addition/revision of levee/floodwall, addition/revision of dam
☐ Coastal Analysis Form (Form 4)	New or revised coastal elevations
☐ Coastal Structures Form (Form 5)	Addition/revision of coastal structure
☐ Alluvial Fan Flooding Form (Form 6)	Flood control measures on alluvial fans

Seal (Optional)

Appendix C: Survey Field Notes

Terry Hendricks

From: Curtis, Edward [mailto:Edward.Curtis@dhs.gov]
Sent: Tuesday, November 10, 2009 2:44 PM
To: Manny M. Rosas
Cc: Terry Hendricks; Lucero, Andrew; Caldwell, Jason; Akl, Pascal
Subject: RE: PAG 2008 Orthos/Lidar

Mr. Rosas –

I apologize for the delay in responding to you regarding the Sanborn LiDAR report. Pascal Akl of Michael Baker, Jr. reviewed the updated July 2009 report on behalf of FEMA and advised me that all of the concerns raised in his May 18, 2009 memorandum titled "Pima County, CA [sic] Sanborn LiDAR Report Items" were addressed in the updated report except the comment that the original report lacked a sufficient number of checkpoints in urban areas and dense vegetation areas. No additional checkpoints were surveyed in such arease to permit analysis of data accuracy in these land cover categories. However, in the data voids analysis section of the updated report (p. 16), Sanborn states the following: "*Specific areas, dense vegetation or undergrowth near small streams, for example, prevents the LiDAR pulses to fully penetrate to the true ground surface. Thus, for mapping products such as floodplain or contour mapping, LiDAR data must often be manually supplemented with breaklines and mass-points to accurately model the terrain surface.*" As long as the data is used with caution and supplemented with additional ground survey data where necessary in accordance with this statement, I am satisfied that the terrain data meets FEMA standards for use in detailed flood studies.

Please contact me if you have any questions regarding our review and comments.

Ed Curtis, P.E., CFM
Risk Analysis Branch
FEMA Region IX
(510) 627-7207 - office
(510) 295-5249 - mobile

Appendix D: Hydrologic Analysis Supporting Documentation

(models, spreadsheets and supporting information is provided digitally in the TDN disk)

Appendix E: Hydraulic Analysis and As-Built Drawings for Hydraulic Structures

(models, spreadsheets and supporting information is provided digitally in the TDN disk)

Appendix F: Erosion and Sediment Transport Analysis Supporting Documentation

None