Santa Cruz County, Arizona
DIRM and Map
Modernization Project

TDN Section 5 – Hydraulics

Stantec

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SECTION 5: HYDRAULICS

5.1 Method Description

The watercourses evaluated within this study are all located within the corporate boundary of the County of Santa Cruz, Arizona. The general physical characteristics of these watercourses are exhibited by sand and gravel channel beds with vegetative overbanks that vary in coverage and density.

Standard hydraulic methods, in accordance with USCOE modeling guidelines, were used to determine the 100-year recurrence interval flood boundaries for this study. Analyses reported herein reflect current conditions of the streams. The HEC-RAS River Analysis System computer program was used for all water surface profile modeling.

Due to FEMA floodplain modeling criteria, per *Guidelines and Specifications for Flood Hazard Mapping Partners*, all reaches were modeled using a subcritical flow regime. This produces a higher water surface elevation when a reach or portion thereof is actually below critical depth.

The starting water surface elevation (WSEL) was extracted from other watercourses evaluated within this study where such was encountered. However, where such was not available or could be obtained readably, the starting water surface elevation method used was normal depth based on the existing downstream gradient of a given watercourse. HEC-RAS modeling of the Santa Cruz River was conducted from the Pima County-Santa Cruz County boundary to the International Border, which constitutes a 38-mile study reach. The starting water-surface elevation for the 100-year profile corresponds to Cross Section FF (Section 913) of the effective HEC-2 model for Pima County, which was adjusted from 3034.40 (NGVD29) to 3037.02 (NAVD88) using an adjustment factor of 2.62 ft. However, since the floodway elevation at this section was 3034.2 (NGVD29), which reflects a negative surcharge of 0.2 feet, the starting water-surface elevation for the floodway model was also 3034.4 (NGVD29) or 3037.02 (NAVD88). The starting water-surface elevations for the remaining profiles were estimated by applying the selected discharges to a truncated version of the effective model that started at Cross Section FA (Section 908). The boundary condition at Section FA for the three profiles (10-, 50-, and 500-year) were based on normal depth with an assumed slope of 0.2%. The computed water-surface elevations at Cross Section FF (Section 913) from the truncated model were then assumed to be the known water-surface elevations for the respective profiles.

HEC-RAS modeling of the Potrero Creek was conducted from its confluence with the Santa Cruz River to the upstream limit of the study reach, which constitutes a 7.4-mile study reach. The starting water-surface elevations for all profiles were based on the corresponding water-surface elevations for the Santa Cruz River at the confluence.

The following model names were used for this study:

Table 5-1
Hydraulic Modeling Names

HEC-RAS filename	Reach Name	Type of Study
Aguafria.prj	Agua Fria Canyon	Detailed Study Reach
Aguatrb1.prj	Agua Fria Canyon Tributary 1	Limited Detail Study Reach
Harrison.prj	Al Harrison Wash	Limited Detail Study Reach
Calabasa.prj	Calabasas Canyon	Limited Detail Study Reach
Caralamp.prj	Caralampi Canyon	Limited Detail Study Reach
Carltrib2.prj	Caralampi Canyon Tributary 2	Limited Detail Study Reach
Carltrib3.prj	Caralampi Canyon Tributary 3	Limited Detail Study Reach
Ephraim.prj	Ephraim Canyon Wash	Detailed Study Reach
Lyle_Canyon	Farosa Wash	Detailed Study Reach
Sonoita4.prj	Harshaw Creek	Detailed Study Reach
Josephine_downstream.prj	Josephine Canyon Reach 1	Detailed Study Reach
Josephine_uptream.prj	Josephine Canyon Reach 2	Detailed Study Reach
Kino.prj	Kino Springs Wash	Limited Detail Study Reach
Lyle_Canyon.prj	Lyle Canyon	Detailed Study Reach
Lyle_Canyon.prj	Lyle Canyon	Limited Detail Study Reach
Negro.prj	Negro Canyon	Limited Detail Study Reach
Nogales.prj	Nogales Wash	Detailed Study Reach
Peck.prj	Peck Canyon	Detailed Study Reach
Pecktrb1.prj	Peck Canyon Tributary 1	Limited Detail Study Reach
PT01_HR2.prj	Potrero Creek Reach 1	Detailed Study Reach

Table 5-1 Continued
Hydraulic Modeling Names

HEC-RAS filename	Reach Name	Type of Study
BASETOPO-RCAD.prj	Potrero Creek Reach 2	Detailed Study Reach
Pot_trib_1.prj	Potrero Tributary 1	Limited Detail Study Reach
Puerto.prj	Puerto Wash	Detailed Study Reach
PuertBO1.prj	Puerto Wash Breakout 1	Limited Detail Study Reach
PuertBO2.prj	Puerto Wash Breakout 2	Limited Detail Study Reach
Ramanote.prj	Ramanote Canyon	Limited Detail Study Reach
Sonoita4.prj	Red Rock Canyon	Detailed Study Reach
BASETOPO-RCAD.prj	Santa Cruz River Reach 1	Detailed Study Reach
SC02_HR.prj	Santa Cruz River Reach 2	Detailed Study Reach
SC03_HR.prj	Santa Cruz River Reach 3	Detailed Study Reach
SCR04.prj	Santa Cruz River Reach 4	Detailed Study Reach
SC05_HR working.prj	Santa Cruz River Reach 5	Detailed Study Reach
SCR06.prj	Santa Cruz River Reach 6	Detailed Study Reach
SCR07.prj	Santa Cruz River Reach 7	Detailed Study Reach
SCRtrb15.prj	Santa Cruz River Tributary 15	Limited Detail Study Reach
Trib14.prj	Santa Cruz Tributary 14	Limited Detail Study Reach
Trib16.prj	Santa Cruz Tributary 16	Limited Detail Study Reach
Trib_17.prj	Santa Cruz Tributary 17	Limited Detail Study Reach
Trib_18.prj	Santa Cruz Tributary 18	Limited Detail Study Reach
Trib_19.prj	Santa Cruz Tributary 19	Limited Detail Study Reach
Trib_21.prj	Santa Cruz Tributary 21	Limited Detail Study Reach
Trib_24.prj	Santa Cruz Tributary 24	Limited Detail Study Reach
Trib_28.prj	Santa Cruz Tributary 28	Limited Detail Study Reach
Trib_29.prj	Santa Cruz Tributary 29	Limited Detail Study Reach
Trib_41.prj	Santa Cruz Tributary 41	Limited Detail Study Reach
Sonover.prj	Sonoita Breakover, East of Railroad	Detailed Study Reach
Son.prj	Sonoita Creek Reach 1	Detailed Study Reach
Son2lower.prj	Sonoita Creek Reach 2	Detailed Study Reach
Son2lower.prj	Sonoita Creek Reach 2 (downstream Patagonia Lake outfall)	Limited Detail Study Reach
Son2upstream.prj	Sonoita Creek Reach 2 (upstream Patagonia Lake outfall)	Limited Detail Study Reach
Patlakewier.prj (sic)	Sonoita Creek Reach 2 Patagonia Lake Spillway	Limited Detail Study Reach
Sonoita3.prj	Sonoita Creek Reach 3	Limited Detail Study Reach
Sonoita4.prj	Sonoita Creek Reach 4	Detailed Study Reach
Sonoita4.prj	Sonoita Creek Reach 4	Limited Detail Study Reach
Sopori.prj	Sopori Wash	Detailed Study Reach
Terunot1.prj	Teruno Canyon Tributary 1	Limited Detail Study Reach
Tinaja.prj	Tinaja Canyon	Limited Detail Study Reach
Tumaccor.prj	Tummaccori Canyon	Limited Detail Study Reach
Lyle_Canyon	Woodyard Canyon	Detailed Study Reach
Falls.prj	Yerba Buena Canyon	Limited Detail Study Reach

5.2 Work Study Maps

The study reach for the Santa Cruz River was subdivided into seven sub-reaches. The study reach for Potrero Creek was divided into two sub-reaches. Sonoita Creek was divided into four sub-reaches. Reach 2 of Sonoita Creek was further divided into 3 sub-reaches due to Patagonia Lake. Josephine Canyon was divided into two sub-reaches. Separate HEC-RAS project files were created for each sub-reach. The sub-reaches are numbered from downstream to upstream. The primary purpose of subdividing the reaches was to facilitate concurrent modeling, thus reducing the time required to complete the overall modeling effort and to facilitate Geo-Ras processing. Each reach includes at least one overlapping section from the adjoining downstream and/or upstream reach. Several reaches include three overlapping sections.

5.3 Parameter Estimation

5.3.1 Roughness Coefficients

In general, channel bottoms are relatively smooth sand and gravel channel beds and were assigned a base coefficient of between 0.028 and 0.045. These base values were adjusted to account for other factors such as density of vegetation, channel irregularity, effects of obstructions, variations in channel cross-section and degree of channel meandering.

Portions of the channel overbanks are densely vegetated with grasses, bushes and trees and were assigned an appropriate additional roughness value. In highly urbanized areas, an n-value of 1.0 was utilized to represent the in-effective flow characteristics of the overbank areas.

Aerial photography and site investigations were used in conjunction with two USGS publications and Chapter 5 of the *Arizona Department of Transportation Highway Drainage Design Manual, Hydrology* to estimate the channel roughness coefficients along the study reaches. The two USGS publications are: (1)

Roughness Coefficients for Stream Channels in Arizona, Open-File Report, February 1973, and (2) *Verification of Roughness Coefficients for Selected Natural and Constructed Stream Channels in Arizona*, Profession Paper 1584.

5.3.2 Expansion and Contraction Coefficients

Commonly applied expansion and contraction coefficients as outlined in the HECRAS Hydraulic Reference manual were used along all study reaches.

5.4 Cross-Section Description

Following completion of reproducible topographic mapping, stream thalwegs were sketched on work prints. Cross-section locations for a given reach were then selected and adjusted to account for the perceived direction of flow. Criteria for selection included:

- Representative of the local stream reach
- Orient sections perpendicular to the anticipated flow direction
- Avoid inclusion of non-effective areas such as major tributary washes and regions outside of parallel embankment and large ponding areas
- Include the entire predicted 100-year floodplain or 500-year where necessary.
- Cross-section spacing for detailed study reaches was made at approximately 500-foot intervals or as needed to account for stream variations or other features.
- Cross-section spacing for limited detail study reaches was made at approximately 1,000-foot intervals or as needed to account for stream variations or other features.

5.5 Modeling Considerations

The following hydraulic modeling considerations were made during this study and are listed for the 100-year recurrence event.

5.5.1 Hydraulic Jump and Drop Analysis

Hydraulic jumps were noted to occur within the subject study reaches. Such features, in general, occur outside the transition zone of flow regimes (i.e., outside of the Froude number range of 0.85 and 1.25).

A review of these features and their associated influence on the water surface elevations found that no additional attention, adjustment or modification of the associated base flood elevation was necessary.

5.5.2 Bridges and Culverts

Bridges and culverts were modeled using special bridge and special culvert routines in HEC-RAS. Standard modeling approaches were applied. The following table summarizes where such features occur.

Table 5-2
Bridges and Culverts

Reach Name	River Mile Section	Plan Number (date)	Type of Structure	Structure Name Structure Data Number
Agua Fria Canyon	0.468	field survey	Bridge	West Frontage Road 4
	0.257	field survey	Bridge	Interstate 19 5A
	0.236	field survey	Bridge	Interstate 19 5B
Calabasas Canyon	3.011	field survey	Culvert	SR 289 (Ruby Road) 1
	0.44	field survey	Culvert	Interstate 19 2
Caralampi Canyon	0.335	field survey	Culvert	Interstate 19 3A
	0.309	field survey	Culvert	East Frontage Road 3B
Peck Canyon	0.227	field survey	Bridge	West Frontage Road 12A
	0.165	field survey	Bridge	Interstate 19 12B

Table 5-3 Continued
Bridges and Culverts

Reach Name	River Mile Section	Plan Number (date)	Type of Structure	Structure Name Structure Data Number
	0.144	field survey	Bridge	Interstate 19 12C
Puerto Wash	1.081	field survey	Culvert	West Frontage Road 10A
	1.039	field survey	Culvert	Interstate 19 10B
	1.014	field survey	Culvert	East Frontage Road 10C
Puerto Wash Breakout 1	0.886	field survey	Culvert	West Frontage Road 10A
	0.843	field survey	Culvert	Interstate 19 10B
	0.818	field survey	Culvert	East Frontage Road 10C
Tummaccori Canyon	0.416	field survey	Culvert	Interstate 19 9A
	0.233	field survey	Culvert	East Frontage Road 9B
Negro Canyon	0.11	field survey	Culvert	Interstate 19 & East Frontage Road 7
Santa Cruz River Tributary 15	0.34	field survey	Culvert	Interstate 19 6A
	0.201	field survey	Culvert	East Frontage Road 6B
Sopori Wash	1.219	field survey	Bridge	West Frontage Road 11A
	1.108	field survey	Bridge	Interstate 19 11B, 11C
Tinaja Canyon	0.108	field survey	Culvert	Interstate 19 8
Santa Cruz	9.128	9968 (1986)	Bridge	River Ave. (Tubac) Bridge

Table 5-3 Continued
Bridges and Culverts

Reach Name	River Mile Section	Plan Number (date)	Type of Structure	Structure Name Structure Data Number
	21.403	8170 (1978)	Bridge	Rio Rico Drive
	23.152	no plans, field measurements	Bridge	Railroad bridge crossing
	26.142	8483 (1977)	Bridge	Ruby Rd
	31.639	8166 (1916)	Bridge	River Rd Bridge
	31.735	no plans, field measurements	Bridge	Highway 82 (Patagonia Highway) Bridge
	34.572	8643 (1979)	Bridge	Xavier Way Bridge (Kino Springs Dr.)
Potrero Creek	1.093	no plans, field measurements	Bridge	Railroad bridge crossing
(d/s Nogales)	1.558	8482 (1977)	Bridge	Pena Blanca Road (Ruby Rd.)
	2.035	8171 (?)	Bridge	Tucson Road Bridge (Potrero)
	4.47	8167 (?)	Bridge	Tucson Road Bridge (Nogales)
Potrero Creek	4.859	no plans, field measurements	Bridge	4.859 (US 89/93 bridge Grand Avenue)
(u/s Nogales)	5.124	no plans, field measurements	Bridge	5.124(I-19 bridge)
	5.211	I-19-1-507 (1988)	Box Culvert (buried, modeled as at grade crossing)	Country Club Rd
	5.5	no plans, field measurements	Pipe Culverts	5.5 (W. Meadow Hill Drive)
Ephraim	8000	field survey	Arch Box Culvert	Western Ave.
	7788	field survey	Pedestrian Bridge	Pedestrian Bridge
	24	field survey	Tressel	Railroad

Table 5-3 Continued
Bridges and Culverts

Reach Name	River Mile Section	Plan Number (date)	Type of Structure	Structure Name Structure Data Number
	400	field survey	Box Culvert	Grand Avenue
	3040	field survey	Box Culvert	Bautista St.
	3157	field survey	Pedestrian Bridge	Pedestrian Bridge
	4800	field survey	Box Culvert	Western Ave.
	7274	field survey	Pedestrian Bridge	Pedestrian Bridge
	7280	field survey	Pedestrian Bridge	Pedestrian Bridge
	7418	field survey	Pedestrian Bridge	Pedestrian Bridge
	7507	field survey	pedestrian bridge	Pedestrian Bridge
	7600	field survey	Bridge	Single Lane Bridge
	7680	field survey	Bridge	Single Lane Bridge
	7800	field survey	Bridge	Single Lane Bridge
	9500	field survey	Pipe Culverts	I-19
	15000	field survey	Pipe Culverts	Hwy 189
Yerba Buena Canyon	75	field survey	Box Culvert	75
	500	field survey	Box Culvert	500
Josephine Canyon	513	field survey	Railroad Tressel	Railroad
	2930	Rio Rico Ranchettes (1978)	Box Culvert	Pendelton Dr.
	19730	Rio Rico Ranchettes (1978)	Box Culvert	Calle De Provinica
Tributary 39.1	240	field survey	Pipe Culverts	240
Tributary 39.3	4400	field survey	Pipe Culverts	4400

Table 5-3 Continued
Bridges and Culverts

Reach Name	River Mile Section	Plan Number (date)	Type of Structure	Structure Name Structure Data Number
Lyle	18315	SC Co. B-95-02 (1995)	Bridge	Cimarron Rd. Bridge
Nogales	7120	field survey	Box culvert	Mesa Verde
	8220	field survey	Bridge	railroad bridge crossing
	9935	field survey	Bridge	Produce Row
	10715	field survey	Bridge	Escondido Crossing
	14250	field survey	Bridge	Baffert
	15665	field survey	Bridge	Mariposa Rd.
	21270	field survey	Bridge	Doe
	25100	field survey	Bridge	Morley Ave.
Potrero Tirbutary 1	100	field survey	Bridge	R/R Bridge
	750	field survey	Box culvert	I-19
Sonoita Creek	2968	field survey	Railroad Tressel	Railroad
	102129	field survey	Bridge	Highway 82 Bridge
Harshaw	5087	BRZ-984 (21) P (1992)	Bridge	Harshaw Rd.
Tributary 14	50	field survey	Bridge	50 (Railroad)

5.5.3 Levees and Dikes

Given recent direction by FEMA, all levee-like features within the study area must be certified in order to be considered a levee under floodplain mapping requirements. As no certification records could be found or obtained from their respective owner, all such levees were considered to fail during preparation of the floodplain mapping limits.

The HEC-RAS levee function was used on occasion to remove conveyance from a given cross-section or range of sections so that a more realistic modeling of the study reaches would be obtained. For example, along Calabasas Canyon (limited detail study reach) from RM 3.332 to 3.267 there appears a low point within the cross-sections. However, upon review of the field conditions and the topographic mapping this area is a tributary and therefore does not convey flow within the Calabasas Canyon. Use of the levee function, although this is not a levee, allowed for a higher resulting base flood elevation and likely is more realistic of the conditions that occur within this watercourse during flooding.

Railroad embankments located within the eastern overbank area of the Santa Cruz River floodplain parallels the main channel from just downstream of the Potrero Creek (Nogales Wash) confluence to the Santa Cruz/Pima County line. The embankment was modeled as an ineffective flow boundary that confined 100% of the flow to the channel side of the embankment. This approach produced the most conservative water-surface elevations. The area on the landward side of the embankment was mapped using these water-surface elevations. Several agricultural levees that projected a short distance into the floodplain fringe area (perpendicular to the direction of flow) were mapped as rigid constrictions to provide the most conservative estimate of the water-surface elevations. Agricultural levees that paralleled the direction of flow were ignored in the modeling.

The embankments surrounding the Nogales International Wastewater Treatment Facility, which is located at the confluence of the Santa Cruz River and the Potrero Creek, was also treated as an ineffective flow area. The entire facility was mapped as being located in the regulatory floodplain.

5.5.4 Islands and Flow Splits

The HECRAS split-flow routine was applied along the left bank of the Potrero Creek just upstream of its confluence with the Santa Cruz River. The Nogales International Wastewater Treatment Facility, which was constructed at the confluence, acts as an overbank island in the Potrero Creek floodplain. The split-flow routine was used to estimate the discharge that could potentially weir over the top of the left bank. Overtopping flows do not return to the main channel of the Potrero Creek, which joins the Santa Cruz River a short distance downstream. Overtopping flows are conveyed along the west side of the facility in a constructed earthen section that outlets into the Santa Cruz River at the northern boundary of the facility. The split-flow routine was only applied to the 10-, 50-, and 100-year models. The facility was treated as an island in the 500-year model. The model for the western overflow channel is included in the Potrero Creek, Reach 01 project file.

A second split flow area in the immediate vicinity of the wastewater treatment facility was recognized during the preliminary stages of model development. This area is located on the east (right overbank) of the Santa Cruz River immediately upstream of the railroad bridge. The right bank in this area is too low to contain the backwater profile associated with the railroad bridge during the 100-year and 500-year events. Overtopping flows will enter the Sonoita Creek floodplain. However, the final mapping assumes no loss of flow, which provides the most conservative water-surface elevations for the short reach located downstream along the Santa Cruz River between the railroad bridge and the Sonita Creek confluence.

At the downstream reach of Sonoita Creek, at Pendleton Road, flow splits and drains north, east of the of the Union Pacific Railroad track. A separate profile was modeled for this flow which ultimately joins with the 100-year floodplain for the Santa Cruz River, south of Rio Rico Dr.

On the upstream portion of Tributary 41, a flow split condition was modeled. After field investigation, it was determined that flow split did not occur. However, given the flatness of the terrain and close proximity of the two streamlines, it was determined that using a split flow analysis was the most accurate way to model this streamline.

5.5.5 Ineffective Flow Areas

Areas such as roadway embankments at bridges and culverts, localized depressions, levees, tributary features, buildings and natural encroachments (e.g. hills) were modeled as ineffective flow using the standard modeling guidelines outlined in the HEC-RAS user's manual.

As previously noted, the most significant ineffective flow area was the area located along the east side of the railroad embankment that parallels the Santa Cruz River from the Potrero Creek confluence to the Santa Cruz/Pima County line.

5.5.6 Supercritical Flow

Supercritical flow (Froude number greater than 1.00) for the 100-year event occurs at isolated cross-sections throughout the study reaches, generally at some bridges and in steeper and narrow sections of the streams. Supercritical flow does not occur at three consecutive cross-sections or at more than 40% of cross-sections in a reach.

5.6 Floodway Modeling

Floodway determination was employed for detailed study reaches. Encroachment methodology is based on FEMA guidelines and is the standard of care and practice within Arizona. Encroachment into floodplains, such as artificial fill, reduces the flood carrying capacity, increases flood heights of streams, and increases flood hazards in areas beyond the encroachment itself. One aspect of floodplain management involves balancing the economic gain from floodplain development against the resulting increase in flood hazard.

For purposes of the National Flood Insurance Program, the concept of a floodway is used as a tool to assist local communities in this aspect of floodplain management. Under this concept, the area of the 100-year flood is divided into a floodway and a floodway fringe. The floodway is the channel of a stream plus any adjacent floodplain areas that must be kept free of encroachment in order that the 100-year flood can be carried without substantial increase in flood height. The area between the floodway and the boundary of the 100-year flood is termed the floodway fringe. Minimum federal standards limit such increase in flood height to one foot, provided that hazardous velocities are not produced. The floodway fringe thus encompasses the portion of the floodplain that could be completely obstructed without increasing the water surface elevation of the 100-year flood by more than one foot at any point.

Several encroachment methods are available to determine the extent of floodway limits. For the purposes of this project, two methods were employed. This approach does not apply to Peck Canyon.

1. *Method 4* – Encroachment Method 4 was initially employed to determine the left and right encroachment stations such that the conveyance within the encroached cross-section at a higher surface elevation (i.e., target value) is equal to the conveyance of the natural cross-section at the original water surface elevations. This approach is sometimes called the equal loss of conveyance method. For this study, as required by the Arizona Department of Water Resources State Standard[9] 2-96, a target value change of no more than one (1) foot in the hydraulic grade line is used. This method is used to establish a base encroachment model.
2. *Method 1* – Once the base encroachment models have been performed, encroachment method 1 is used to insure target values have not exceeded the floodway model.

The analysis of Peck Canyon was found to result in critical depth occurring at three or more consecutive cross-sections (such occurred several times within this reach) and in accordance with Arizona Department of Water Resources State Standard[10] 3-94 the method used to determine the floodway is as follows:

1. *Method 6* – Encroachment Method 6 (Method 6 when using HEC-2 or Method 5 when using HEC-RAS) was initially employed to determine the left and right encroachment stations and is used for reaches that exhibit supercritical flow regimes. For this study, as required by the Arizona Department of Water Resources State Standard[10] 3-94, a target value of no more than one (1) foot in the energy grade line is used. This method is used to establish a base encroachment model.
2. *Method 1* – Once the base encroachment models have been performed, encroachment method 1 is used to insure target values have not exceeded the floodway model.

Portions of Nogales Wash and Ephraim Canyon are fully concrete lined and negative surcharges were allowed in these reaches.

5.7 Problems Encountered During the Study

The following problems or special considerations were noted to occur within the reaches evaluated within this study.

5.7.1 Agua Fria

An active in-stream mine was noted during field investigation (commencing near RM 2.351) and affects the resulting floodplain through this region. Although there may be a slight possibility that upstream flow could breakout within the left overbank and, after careful consideration, was deemed to be contained within the resulting floodplain limits. The watercourse profile was noted to change dramatically (from sudden steep slopes to nearly flat slopes) across this region.

During the less frequent events there appears to be a possibility that flow may leave the system at or near RM 0.257 due to a low profile point within Interstate 19. However, the amount of discharge through this area (initially modeled with a lateral weir modeling feature) was relatively minor and therefore it was assumed that the main channel would contain the entire flow downstream.

5.7.2 Agua Fria Tributary 1

Near RM 1.293 there appears to be a possibility that flow may enter the extreme right overbank and therefore the modeler recommends that this region be considered as a shallow depth floodplain.

5.7.3 Calabasas Canyon

Commencing at RM 1.151 there appears to be a possibility that flow may enter the extreme right overbank and therefore the modeler recommends that this region be considered as a shallow depth floodplain to a location just downstream of RM 0.986.

Commencing at or near RM 0.442 (Interstate 19) the highway overtops and therefore a large portion of the upstream flow does not continue downstream within the main channel, however, within the right overbank and through a developed commercial region. Based on discussions with Flood Control District (FCD) staff and the modeler of the Santa Cruz River (JE Fuller) the resulting floodplain limits as shown were determined along with flow depths of less than two feet across the overbank.

5.7.4 Caralampi Canyon

Commencing at RM 5.365 there is an existing pond that was not taken into consideration, as such this might result in a conservative estimate of the base flood elevation across this feature, during modeling.

During modeling it was noted that distributary flow patterns exist downstream of Interstate 19 (RM 0.335) and that a large portion of the flow would overtop I-19 and not return to the main channel, yet confluence with the Santa Cruz River. Based on discussions with FCD staff and the Santa Cruz River modeler, it was determined that the floodplain boundary resulting from the levee failure methodology would supersede any resulting detailed floodplain analyses in this region.

5.7.5 Caralampi Canyon Tributary 3

The resulting base flood elevation at RM 0.134 is less than the minimum channel elevation for this section. Flow appears to pond within an existing pond and is conveyed downstream within the left overbank and re-enters the main channel at RM 0.010. The reported flow depth for this location and RM 0.114 were manually changed to report realistic values (otherwise the values were negative). Adjusting the location of the main channel path for these sections did not appear reasonable based on review of the flow patterns across this area.

5.7.6 Peck Canyon Tributary 1

As this tributary nears the main channel (i.e., Peck Canyon), the channel depicts features of distributary flow patterns. Therefore, the main channel stem of this tributary has been shown within the floodplain mapping along with a shallow floodplain designation for the region around the main flow, to a point downstream until it's confluence with Peck Canyon. The results appear reasonable for this area.

5.7.7 Puerto Wash

The entire region, downstream of RM 1.001, results in extensive distributary flow patterns. This effect was modeled within HEC-RAS via the lateral weir function. Based on the modeler's recommendations and discussions with Santa Cruz County, it was determined that outside of the main channel (i.e., Puerto Wash) this area would result in a shallow depth floodplain. This condition was also noted to occur downstream of the East Frontage Road for Puerto Wash Breakout 1. A similar approach was used for this limited detail study reach as well.

5.7.8 Puerto Wash Breakout 1

An additional special problem was revealed while evaluating Puerto Wash (detailed study reach). This watercourse exhibits numerous "breakout" features (flow leaving the main channel and not returning as would under a split flow condition, hence distributary flow). Given the type of study level assigned to this watercourse it was determined that such breakout features would be analyzed using HEC-RAS's lateral weir feature. This feature allows the program to determine and remove the breakout flow from the main wash. This information was then used to conduct limited detailed study floodplain analyses along these breakout subreaches. An evaluation of the largest channel breakout flow revealed that under the condition the main channel were to convey the entire discharge (no flow breakout) the change in the water surface elevation along the main channel did not increase by more than one foot and therefore did not appear to require this special consideration. Under the condition where the main channel or breakout flow features exhibits true distributary flow conditions the same approach (i.e., discussions with Santa Cruz County staff and the modeler's recommendations) was employed.

5.7.9 Tumaccori Canyon

The entire region, downstream of the East Frontage Road at RM 0.223, results in extensive distributary flow patterns. However, based on discussions with Santa Cruz County it was determined that resulting floodplain from the levee failure methodology would supersede that resulting from the normal channel hydraulic model.

5.7.10 Negro Canyon

A similar approach, as that used for Tumaccori Canyon, was employed for this watercourse (i.e., distributary flows and the levee failure methodology).

5.7.11 Santa Cruz River Tributary 15

A unique case whereby, downstream of and at RM 0.190, runoff appears to run along the highway interchange, however, flow patterns suggest that the main channel will proceed directly until its confluence with the Santa Cruz River. It is recommended that the floodplain resulting from the levee failure methodology supersede the floodplain resulting from the channel model.

5.7.12 Sopori Wash

A special consideration for Sopori Wash was made as the floodplain limit, when nearing the West Frontage Road, crosses outside the study area and into Pima County. Under this condition it was determined that to provide a conservative estimate of the base flood elevation, it would be assumed that the Santa Cruz/Pima County boundary would serve as a virtual flood wall.

5.7.13 Potrero Creek

The Chula Vista reach, which is located along Potrero Creek at the Nogales Wash confluence, required special mapping considerations. Downstream of Grand Avenue, the Potrero Creek parallels the Nogales Wash for approximately 3300 feet before the two physically join to become the Potrero Creek. Along this reach, flood flows from both the Potrero Creek and the Nogales Wash begin to commingle at the upstream end. Consequently, the floodplain confluence occurs at the upstream end, even though the physical confluence is at the downstream end. In addition, midway along the reach, a single-span bridge (Old Tucson Road) was constructed over the Nogales Wash. Downstream of the crossing, the main channel section for the Nogales Wash is significantly wider than the upstream section. When the downstream section is included in the model, no flow conveyance occurs along the parallel Potrero Creek reach. However, the backwater profile associated with the bridge shows significant conveyance along the Potrero Creek reach. To offset this disparity between the upstream and downstream reaches, a second model was created that assumed that the Nogales Wash was an ineffective conveyance area. The results of the two models were compared and the higher water-surface elevations were used to map the floodplain along this reach.

5.7.14 Nogales Wash

Nogales Wash runoff crosses the International border via two underground channels (Arroyo Blvd. and Nogales Wash covered floodways). Runoff in excess of the underground channel capacities flows overland. Overland flow which crosses the border at the Port of Entry at Grand Ave required separate analysis because this area is higher in elevation than the main flow path of the Nogales Wash.

5.7.15 Josephine Canyon

The downstream portion of Josephine Canyon displayed alluvial fan characteristics just before its confluence with the Santa Cruz River. An expansion reach ratio of 2:1 was applied to the model by modifying cross section lengths accordingly. This change in modeling provided a more realistic flow pattern through that area. This 2:1 expansion ratio was also applied to the downstream end of Tributaries 14, 17, 18, and 19.

5.7.16 Tributary 14

At cross section number 1840, a portion of the flow broke away from the main channel and diverted into the channel to the northwest. The break out flow was blocked at each applicable cross section and the subsequent water surface elevation (WSE) was calculated. The WSE elevation for the blocked break out flow model was compared to the non-blocked break out flow model. The greatest difference in WSE was 0.31 feet. Based on that negligible difference, no further analysis was conducted for the break out flow.

5.7.13 Modeling Warning and Error Messages

Numerous warning messages, the majority relating to the possible need for additional wash cross-sections, resulted from all limited detail study analyses. These warning messages are generally indicative of the limited detail study modeling approaches and are merely to alert the modeler that careful review of the information used should be undertaken. The modeler reviewed each of these messages and found that the results and modeling assumptions and parameters used were reasonable for each condition.

Similar warning message were also encountered for the detailed study analyses. These warnings and notes were reviewed by the modeler and the results found to be reasonable for the conditions that exist. Additional channel cross-sections were not evaluated given the resulting average cross-section spacing for each detailed study reach (less than 500 feet) and review of each noted location. The results were found to be reasonable for watercourses occurring within Arizona.

Also revealed during model was the note "multiple critical depths determined". This is a common warning where during flow depth computations there is a large change in the hydraulic radius between minor changes in the hydraulic depth. These typically occur at or near the crest of levees or other similar shaped features. All such notes were reviewed against the topography and the resulting cross-sections and found that all such data was reasonable and therefore did not appear to warrant any adjustments.

Several channel cross-sections were noted to require the program to extend the cross-section vertically. This occurs within noted regions of distributary flow or flow that confluences a main channel (e.g., where Tumaccori Canyon confluences with the Santa Cruz River) and was permitted to occur to allow the downstream controlling water surface and due to the Santa Cruz River in the above example, to govern in these regions. Each noted occurrence of this warning was reviewed against the topography mapping. The results of the Santa Cruz River analyses and tributary results were discussed with Santa Cruz County, and deemed satisfactory.

All other modeling notes, warning and messages were reviewed and found to be reasonable for the types (limited versus detailed analyses and mapping) of modeling performed.

5.8 Calibration

No calibration was performed for this study as data was limited and unverifiable.

5.9 Final Results

5.9.1 Hydraulic Analysis Results

Complete hydraulic modeling results can be found in the Appendix.

5.9.2 Verification of Results

The hydraulic results in all reaches are considered reasonable and accurate, per accepted modeling techniques and practices within Arizona and when compared to previous floodplain delineations. The applied discharges for the Santa Cruz River and Potrero Creek are significantly greater than those previously used for the effective mapping; however, the new delineations appear reasonable on a reach by reach basis when compared to the previous delineations.