Hydrologic Modeling
In The
Diamond Bell Ranch Area

Location:
The proposed site is located in portions of:

T15S, R10E, SECT 25, 34-36
T15S, R111E, SECT 21, 22, 27, 28, 31-34
T16S, R10E, SECT 1- 3, 9-16, 21-27, 34-36
T16S, R11E, SECT 3-10, 15-22, 26-36
T17S, R10E, SECT 1-3, 10-15, 25, 26
T17S, R11E, SECT 2-11, 14-23, 27-34
T18S, R11E, SECT 3-6

Gila & Salt River Meridian

Prepared for:

Pima County Regional Flood Control District
97 E. Congress Street, 3rd Floor
Tucson, Arizona 85701

October 12, 2007

Registered Professional Engineer (Civil)
CERTIFICATE NO.
44825
JANICE
HUGHES
DATE SIGNED 10/12/07
ARIZONA U.S.A.
Janice Hughes

Prepared by:
Psomas
800 E. Wetmore Road, Suite 110
Tucson, AZ 85719

Psomas 07015-01

PSOMAS

October 12, 2007

Evan Canfield, PhD, P.E.

Pima County Regional Flood Control District
Planning & Development Division
97 E. Congress Street, 3rd Floor
Tucson, Arizona 85701-1797

Re: Hydrologic Modeling in the Diamond Bell Ranch Area – Draft Submittal Psomas 07015-01-1012

Dear Mr. Canfield:

Thank you for taking the time to review the draft submittal of the Diamond Bell report. In response to your comment letter received September 25, 2007, Psomas has revised the report accordingly.

In reference to your comments we offer the following responses:

- Channel portion of the TR-55 Time of Concentration calculations uses a misinterpretation of "bank full" discharge, leading to high hydraulic radii, fast velocities, short travel times and high discharges.

  Acknowledged. The channel portion of each watershed was revisited. The aerial photographs were evaluated to determine an approximate channel top width. Where channel top width fluctuates through the watershed, more than one top width was delineated to determine an appropriate mean to represent the channel top width of the watershed.

  As within the draft submittal, the stage-discharge analysis for the routing reaches were to determine the hydraulic radius of the TR-55 channel portion. To make use of a larger spectrum of discharge (cfs), a 10 cfs profile was added to replace the discharge just less than "cross section" full. The eight discharge profiles generated a hydraulic radius-top width matrix.

  Initially, the same routing reach in the draft submittal was utilized to determine the hydraulic radius for the TR-55 channel portion. The channel top widths were checked against hydraulic radius-top width matrix. As a function of the top width, the hydraulic radius was linearly interpolated between two known hydraulic radius and top width. Where a reach does not provide a range of top width that does not

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contain that derived from aerial photo investigation, another reach was utilized for the information. Selecting a replacement reach was dependent on geographical location, approximate elevation, and watershed shape/size which the reaches route through.

- The storage/discharge table for the Modified Puls provides too high of discharges.

  Acknowledged. The peak discharge being routed through each reach was reanalyzed. Where the peak discharge was less than that of the lowest discharge in the storage/discharge table, a 10 cfs discharge profile was added to replace the discharge just less than "cross section" full. Reach-8, Reach 31/32(31), and Reach 31/32(32) were reanalyzed with a smaller discharge.

- Editorial Comments:
  - Appendix 1 (Hydrologic Analysis) will be divided into seven (7) appendices of more specific content.
  - Section 2.1: Watershed Delineation. The text was revised to make a statement regarding the LIDAR data utilization for channel geometry.
  - Section 2.4: The text was revised to identify Reference 15,
  - Section 2.4.3: The Lag Time equation was added to the text, stating the lag time is 0.6 of the time of concentration.
  - Section 2.6: the text was revised to properly identify the source of soils information.
  - Section 3.2: The text was revised to accurately describe the watershed characteristics consistent with 'cfs/acre' values.
  - Table 2: revised to reflect the updated hydraulic radius analysis.
  - Table 5: The soil area (acre) for each watershed was added to the table.
  - Table 6: The reach slope was reformatted to show as a percentage (%).
  - Table 6: Flow area (ft2), wetted perimeter (ft), and hydraulic radius (ft) was removed as this information is provided for eight (8) discharge profiles in the appendix.
  - Tables 7, 8, 9, 10: revised to reflect updated hydrologic analysis results.

Thank you for your time in reviewing Diamond Bell. If you have any questions, feel free to contact me at 520.292.2300 or via email.

Sincerely,
Psomas

Janice Hughes

Janice Hughes, P.E.
Project Manager
Water Resources Department
jhughes@psomas.com

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FLOOD CONTROL
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Dear Janice,

Andy Seiger and I have reviewed the Diamond Bell Draft submittal. In general, we recognize that that it represents a tremendous amount of work, and it is well-documented. However, Andy and I think there is a fundamental error in the interpretation of 'channel' in the TR-55 Time of Concentration (TC) calculations, which is best illustrated in the table in the Appendix called 'SCS Time Lag Parameters'.

You will note that the table has velocities up to 14 ft/s that result in shorter travel times than would realistically occur. We believe that this is because the cross-sections assume that bankfull discharge occurs in 'channels' that are several hundred feet wide. Inspection of the channel locations in air photos reveals that sandy-bottom channels with tree-lining are in-fact less than 50 feet wide in most cases. The impact of this mis-interpretation of 'bankfull' is channel Rs that are too high, which result in TC calculations that are too small and discharges that are too high.

Andy calculated a few TCs with what we believe are bankfull channels, and found that selecting the smaller channel for the calculations makes a significant difference in the TC. The following are some specific examples:

Watershed	**R (ft) current**	***R (ft) recalculated***	**Channel Vel. (ft/s) current**	***Channel Vel. (ft/s) recalculated***	**TC (hours) current**	***TC (hours) recalculated***
Watershed 27 XS 900:	1.65	*0.6*	6.38	*3.2*	0.87	*1.7*
Watershed 53A XS 1800:	3.19	*0.85*	9.26	*3.8*	0.21	*0.52*
Watershed 64 XS 200:	1.81	*1.0*	7.48	*5.1*	0.93	*1.4*

A related problem is that the storage-discharge table for the Modified Puls routing includes discharge rates much greater than those calculated on the watersheds. For this reason, the calculated discharge rates are much lower than the values used in the table.

We believe that the TC calculations should be revised to be more realistic. At this point, we are less concerned about the storage-discharge table for the Modified Puls routing, though we would ask that you make sure that the routed peak flow value is between two calculated values on the table. If the modeled discharge is below the first value on the table, please select a lower discharge to augment the table.

I have also made some editorial comments on the hard copy of the report, which I will arrange to have delivered to you.

Please call me if you would like to discuss this further.

Sincerely,

Evan Canfield, PhD, P.E.

Ec

Cc: Andy Seiger, P.E. Engineering Manager, Floodplain Management, FCD
Bill Zimmerman, Division Manager, Planning & Development, FCD

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1.0 INTRODUCTION

1.1 Project Location and Description

This document summarizes the hydrologic analysis of the existing watersheds within Pima County that impact the Diamond Bell Ranch, Valley View Acres, Greenwald Acres and other developments in Townships 16 and 7 South, Ranges 10 and 11 East in unincorporated Pima County, Arizona. Refer to Figure 1A for the Vicinity Map and Figure 1B for the Location Map.

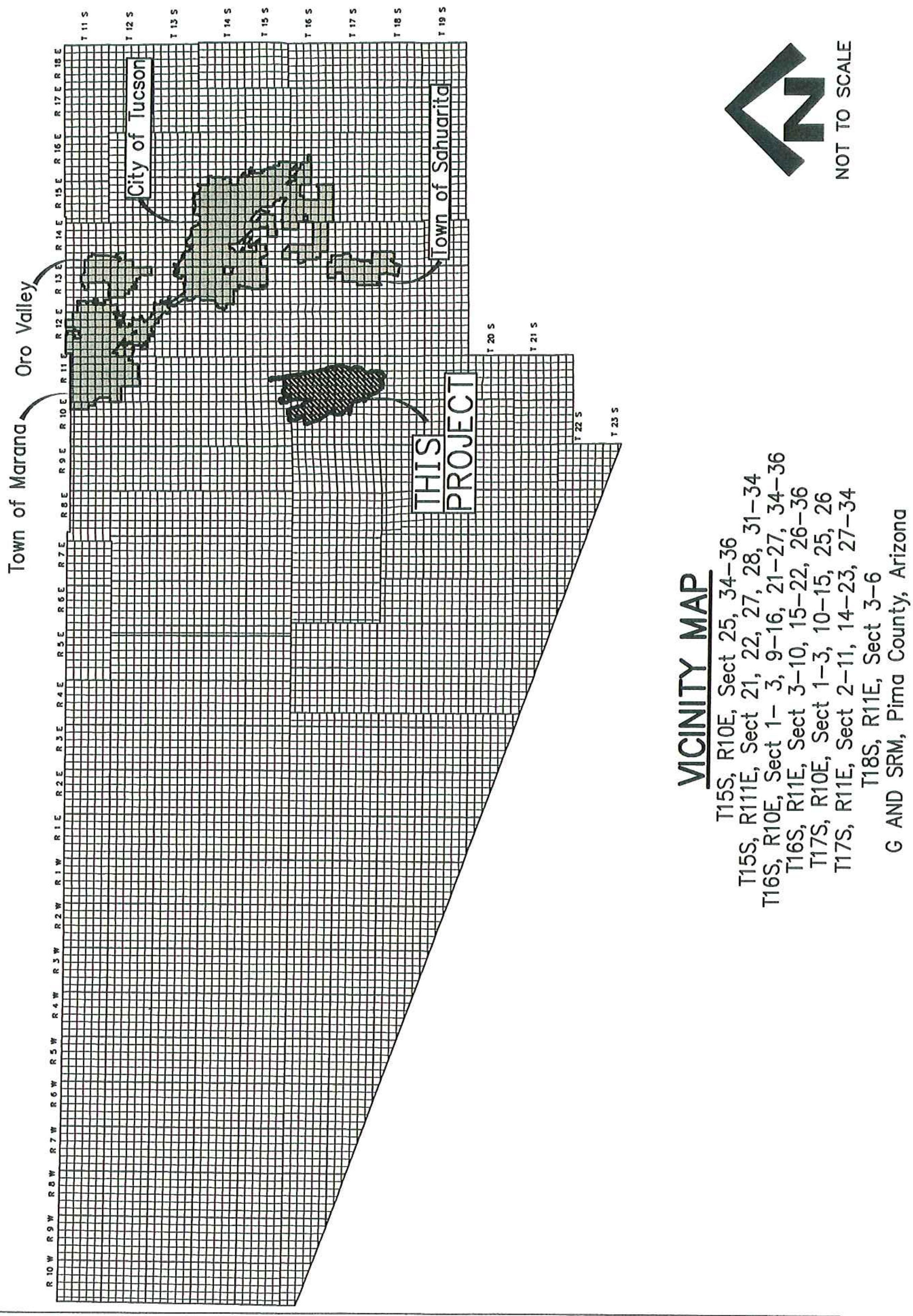
This project was designed to delineate and develop hydrologic modeling to provide the Pima County Regional Flood Control District (PCRFCD) with information for use in this rapidly developing area. As much of the land was platted prior to the adoption of the Pima County Floodplain Ordinance, the regulatory floodplains and associated erosion hazards have not been delineated. This study evaluates the discharges at 68 Concentration Points (CP) identified by PCRFCD.

1.2 Report Objectives

The purpose of this report is to provide a detailed analysis of the runoff characteristics of the Diamond Bell Ranch Area. With increasing development in this area, the PCRFCD has identified the need to determine the 100-year discharges in the area. To this end, HEC-HMS models were generated to analyze the runoff under existing watershed conditions. The objectives of the report are to:

- Define sub-watersheds within the overall drainage area for input into the HEC-HMS models;
- Perform a field investigation to supplement document research on watershed characteristics and split/distributary flow conditions within the watershed;
- Determine the peak 100-year discharges at split flow locations, approximate the split percentages at each split flow location and route the flows downstream to concentration points identified by PCRFCD;
- Present the modeling parameters and results, along with digital products to PCRFCD for use in regulatory decisions.

The objectives noted above, and the results of the analyses are presented in the following report.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Oro Valley
City of Tucson
Town of Sahuarita
THIS PROJECT
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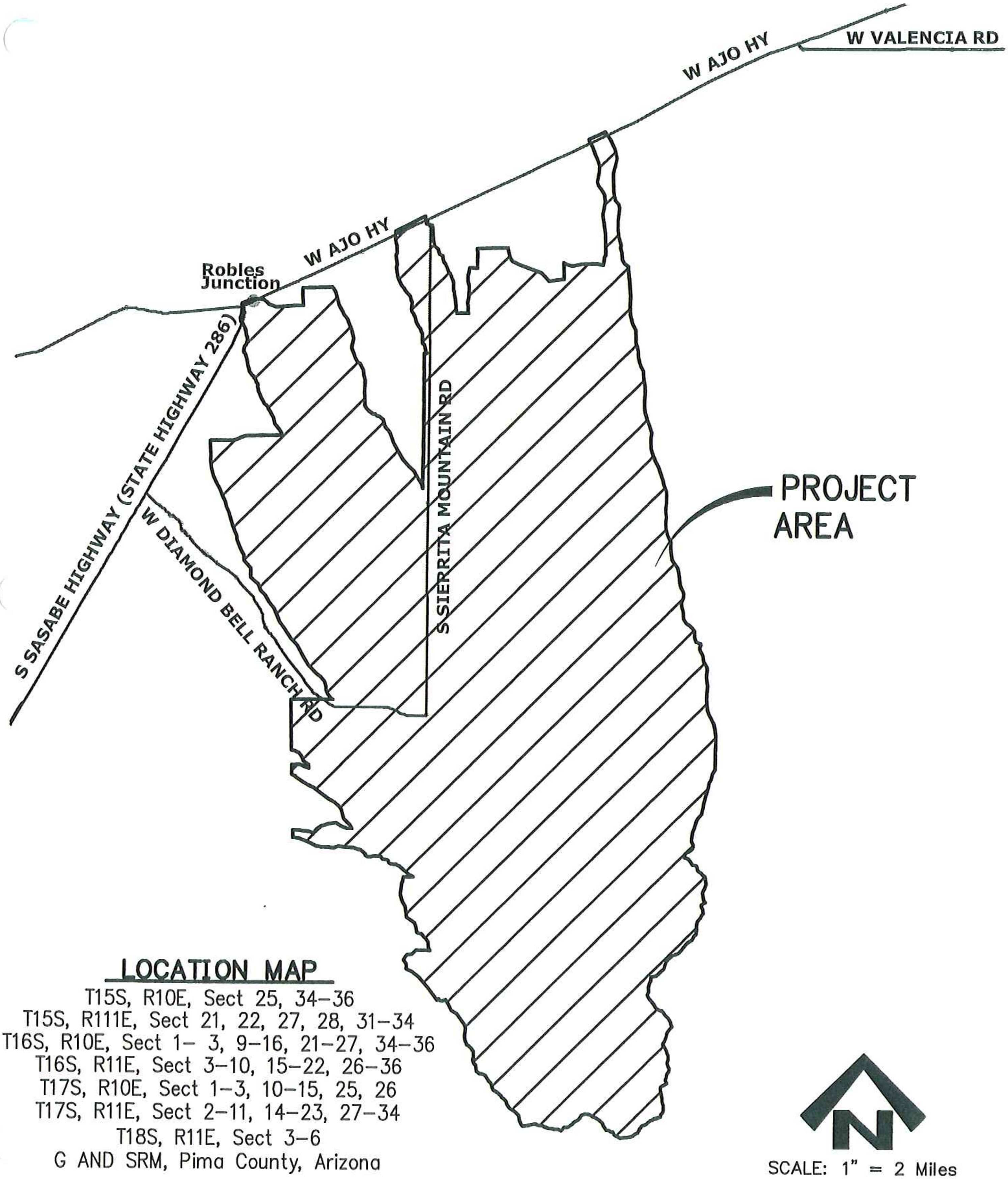

LOCATION MAP

T15S, R10E, Sect 25, 34–36
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2.0 HYDROLOGIC MODELING

Based on PCRFCD Methodology, Psomas developed HMS models to analyze the hydrologic conditions impacting the Diamond Bell Ranch Area. SCS and TR-55 methodology were utilized in combination to determine the watershed parameters. The Modified Puls method was used for the routing portion of the analysis. The Tucson Stormwater Management Study (TSMS) 3-hour rainfall distribution and the 6-hour and 12-hour duration of the SCS Type II storm distribution were used to determine peak discharges per watershed and at concentration points where flows combine. Hydrologic modeling was executed using the HEC-HMS 3.0.1 software, developed by the Army Corps of Engineers. A hydrologic model schematic is provided in Appendix 1.

The modeling parameters are outlined below.

2.1 Watershed Delineation

Sixty-eight (68) point locations were identified by PCRFCD as points of interest. The point locations were provided to Psomas under the Central Arizona State Plane coordinate system (NAD 1983 HARN, international feet) and classified as the primary concentration points (CP). The points of interest are identified as (#68).

Important to note: CP #38 and CP #67 have been deemed identical concentration points. Therefore, CP #67 has been eliminated from further analysis.

Initial watershed delineation for the primary concentration points was done using USGS Quadangle Maps: Stevens Mountain, Arizona (C.I.= 20'); Samaniego Peak, Arizona (C.I.= 40'); Three Points, Arizona (C.I.= 10') and San Xavier Mission, Arizona (C.I.= 20').

Due to the limitations of the quadrangle maps, digital topography was used to improve the watershed delineations. Psomas created one-foot contour interval digital topography for approximately the northern half of the project area based on Digital Elevation Models (DEM) provided by Pima Association of Governments (PAG). The PAG topography was used for watershed delineation. One-foot contour interval topography was also generated by LIDAR data. The LIDAR topography was utilized to for channel geometry.

Concerned with the presence of split flows in the project area, watershed delineations were improved using a series of aerial photographs. One-foot resolution color and 4-foot resolution black/white resolution PAG orthophotos were utilized as available. Watershed boundaries were adjusted to where vegetation densities are low and to where previously platted roadways have been aligned, traditionally on or near watershed ridges and have been assumed to produce ridge-like influences. Where aerial photography could only provide an approximate delineation, the PAG topography was confirmed to finalize the watershed delineations.

Based on final watershed delineations, watershed parameters including area and flow length were compiled for entry into the HMS model. Table 5 in Section 2.9 provides a summary of watershed parameters. Figure 2, Watershed Map, illustrates watershed boundaries, watershed flow lengths and concentration point location.

2.2 Concentration Points

In most cases, the concentration point locations align clearly where plat boundaries and wash crossings intersect. Where CP locations do not clearly align, horizontal adjustments were applied based on the alignment provided by aerial photography. For example, CP #6 was shifted west approximately 1000 feet to align with the defined sandy bottom wash crossing Diamond Bell Ranch Road.

Additional concentration points were identified where the watersheds of primary CP's have an extensive watershed length and flow concentration is evident near the watershed centroid. For example, CP 62A is located near the centroid of watershed associated with CP #62. Based on the aerial photography, flow concentrates at CP 62A and is routed downstream to CP #62 via a defined sandy bottom reach.

2.3 Split Flow

Based on the aerial photography, locations of split flow were located and classified as split flow concentration points, identified as (5/7). The description recognizes the two downstream concentration points to which the split flow is routed downstream. Flows which split and reunite within the same watershed were not analyzed.

Split flow concentration points were assigned to divert 75% of the inflow to each downstream concentration point, producing an artificial 150% of the inflow diverted downstream. Field reconnaissance of split flow locations yielded more approximate percentages as fitting. For example CP 20/26 will divert 100% to CP 20 and 50% to CP 26. The amount of vegetation, the presence of sandy bottoms in the wash and bank stabilization determined the percentage of each split. Concurrence from PCRFCD staff was received for locations with split flow percentages other than 75%. A summary of the split flow concentration points is provided as Table 1.

Table 1 – Split Flow Concentration Points

Concentration Point	Downstream Concentration Point			
	(west)	(%)	(east)	(%)
6/7	6	50	7	100
7/11	6/7	100	11/12A	50
11/12	11	75	12	75
16/17	16	75	17	75
19/20	19	75	20/26	75
20/26	20	100	26	50
23/24	24	75	23	75
28/30	30	75	28	75
30/32	32	75	30	75
31/32	31	75	32	75
34/35	35	75	34	75
35/36	36	75	35	75
36/37	37	75	36	75
38/39	39	75	38	75
41	68	100	39	100
48/50	50	75	48	75
52/53	52	100	53	100
62/63	62	75	63	75
62A	62	100	62/63	100
65/66	65	75	66	75

2.4 Time of Concentration

A primary parameter in the hydrologic model is the Time of Concentration (T_C), which is related to the watershed flow length and land cover conditions. Watershed flow length is the distance from the most hydraulically distant point in the watershed to the watershed CP. Initial delineations of the flow lengths were done using the USGS quadrangle maps and PAG digital topography. Flow length alignments were revised based on the aerial photography. The flow lengths were adjusted to match the presence of dense vegetation and sandy bottom washes. Where flow patterns split and rejoin within the same watershed, the larger, more defined wash was utilized for the flow length distance.

The Time of Concentration (T_C) was calculated using the TR-55 methodology (Reference 15) in which the flow length is divided into three components: sheet flow, shallow concentrated flow, and channel flow. The T_C is the summation of each segment's travel time (T_T):

$$T_C = T_{T\text{-SHEET}} + T_{T\text{-SHALLOW}} + T_{T\text{-CHANNEL}}$$

In the rainfall-runoff model, the SCS Lag Time will be utilized as the transform portion of the model. It is assumed that the lag time (T_{LAG}) is 0.60 T_C, consistent with the SCS lag equation (Reference 3). The Lag Time calculations are summarized in Table 2. The full spreadsheet outlining all parameters of the TR-55 T_{LAG} calculations are provided in Appendix 4.

2.4.1 Sheet Flow

Sheet flow begins at the hydraulically most distant point in the watershed. The travel time of sheet flow is dependent on Manning's roughness coefficient, flow length, the 2-year/24-hour rainfall depth and the hydraulic grade line slope (land slope). The sheet flow travel time is calculated using Manning's kinematic equation (Reference 7, eq. 3-3):

$$T_T = \frac{0.007(nL)^{0.8}}{(P_2)^{0.5}s^{0.4}}$$

Where: T_T = Travel time (hr)
n = Manning's roughness coefficient (Reference 11, table 3-1)
L = flow length (ft)
P_2 = 2-year, 24-hour precipitation (in.)
s = hydraulic grade line slope (land slope) (ft/ft)

The length of sheet flow is initially assumed to be 300 feet, the maximum applicable distance for the Manning's kinematic equation. Where aerial photos indicate flow transitions to channel flow before the maximum allowable 300 feet, that shorter is utilized. Manning's roughness coefficient is assumed to represent the Range (natural) surface description: 0.13 (Reference 15). The 2-year, 24-hour precipitation is 2.46 in. The hydraulic gradeline slope is assumed to be equivalent to the land surface slope. Table 2 provides a summary of $T_{T\text{-SHEET}}$ values. Appendix 4 provides the entire calculation spreadsheet.

2.4.2 Shallow Concentrated Flow

Typically after 300 feet the sheet flow transforms into shallow concentrated flow (shallow concentration flow does not exist where clearly defined channel flow begins before 300 feet of sheet flow). The average velocity of shallow concentrated flow is determined from Figure 3-1 from Reference 15 for unpaved surfaces and paved surfaces, which are represented by the following equations:

$$V = 16.1345(s)^{0.5} \quad \textit{Unpaved}$$
$$V = 20.3282(s)^{0.5} \quad \textit{Paved}$$

Where: V = average velocity (fps)
s = hydraulic grade line slope (watercourse slope) (ft/ft)

It is assumed that all shallow concentrated flow occurs over unpaved surfaces. Aerial photography was utilized to determine where channel flow becomes dominate along the watershed flow length. The most upstream presence of sandy bottom washes is where channel flow is assumed to begin. The travel time of shallow flow is the ratio of flow length and average velocity:

$$T_{T\text{-}SHALLOW} = L_{SHALLOW} / 3600\ V_{SHALLOW}$$

Where $T_{T\text{-}SHALLOW}$ = Travel time of shallow flow (hr)
$L_{SHALLOW}$ = Flow length of shallow flow (ft)
$V_{SHALLOW}$ = Average velocity of shallow flow (fps)

Table 2 provides a summary of $T_{T\text{-}SHALLOW}$ values. Appendix 4 provides the entire calculation spreadsheet.

2.4.3 Channel Flow

Channel flow occurs where flow is within sandy bottom washes along the watershed flow length, typically from the end of shallow concentrated flow to the concentration point.. The average velocity of channel flow is function of the hydraulic radius, hydraulic grade line slope and Manning's roughness coefficient for channel flow (Reference 15, equation 3-4):

$$V = \frac{1.49 r^{2/3} s^{1/2}}{n}$$

Where V = average velocity (fps)
r = hydraulic radius, equal a/p_w
a = cross sectional flow area (sq. ft)
p_W = wetted perimeter (ft)
s = hydraulic grade line slope (mean channel slope) (ft/ft)
n = Manning's roughness coefficient for open channel flow

The Manning's roughness coefficient was assumed to be 0.05, derived from Aldridge and Garrett, *Roughness Coefficients for Stream Channels in Arizona* (Reference 1). The Brawley Wash near Three Points, Ariz. section of Reference 1 is provided in Appendix 4. The hydraulic radius for the channel flow was referenced from the Modified Pulse routing analysis. Where routing reaches traverse through a watershed, the hydraulic radius of that reach was utilized for the channel flow. The travel time of channel flow is the ratio of flow length and average velocity:

$$T_{T\text{-}CHANNEL} = L_{CHANNEL} / 3600\ V_{CHANNEL}$$

Where $T_{T\text{-}CHANNEL}$ = Travel time of flow (hr)
$L_{CHANNEL}$ = Flow length of channel flow (ft)
$V_{CHANNEL}$ = Average velocity of channel flow (fps)

Table 2 provides a summary of $T_{T\text{-}CHANNEL}$ values. The SCS lag time (T_{LAG}), minutes, was assumed to be 0.6 of the Time of Concentration. Appendix 4 provides the entire calculation spreadsheet.

$$T_{LAG} = 0.6\ T_C$$

Table 2 – TR-55 Lag Time Parameters

	TR-55		Sheet Flow			Shallow Flow			Channel Flow			
Watershed	T_C (hr)	T_{LAG} (min)	Flow Length (ft)	Slope (ft/ft)	T_t (hr)	Flow Length (ft)	Slope (ft/ft)	T_t (hr)	Flow Length (ft)	Hydraulic Radius (ft)	Slope (ft/ft)	T_t (hr)
1	1.49	53.71	300	0.47	0.11	2283	0.138	0.11	28544	0.91	0.050	1.27
2	0.81	29.34	300	0.17	0.17	1462	0.003	0.43	3794	0.93	0.030	0.21
3	1.17	42.22	300	0.13	0.19	3428	0.057	0.25	14312	0.93	0.036	0.74
4	0.71	25.47	300	0.50	0.11	4249	0.195	0.17	8756	0.94	0.039	0.43
5	0.71	25.49	300	0.05	0.28	0	--	0.00	7685	0.86	0.034	0.43
6	0.45	16.20	300	0.03	0.33	0	--	0.00	4052	0.86	0.114	0.12
6/7	1.02	36.73	300	0.07	0.25	1449	0.141	0.07	13278	1.42	0.019	0.71
7	1.31	46.99	300	0.02	0.43	6952	0.026	0.74	3071	1.44	0.029	0.13
7/11	0.53	19.08	92	4.88	0.02	0	--	0.00	11819	1.41	0.029	0.51
8	2.15	77.50	300	0.02	0.43	1465	0.048	0.12	9378	0.76	0.004	1.61
9	0.98	35.18	300	0.02	0.38	5895	0.037	0.53	1500	0.76	0.051	0.07
10	1.21	43.58	300	0.06	0.26	5429	0.034	0.50	7316	0.77	0.033	0.45
11	1.67	60.20	300	0.01	0.53	6700	0.036	0.61	6767	0.47	0.038	0.54
11/12	0.98	35.30	300	0.03	0.34	4353	0.082	0.26	5702	0.77	0.028	0.38
11/12A	1.60	57.50	177	0.51	0.07	0	--	0.00	33234	0.77	0.058	1.53
12	1.10	39.74	300	0.03	0.34	2680	0.036	0.24	8788	0.76	0.036	0.52
12A	0.89	31.93	300	0.27	0.14	1819	0.138	0.08	10369	0.76	0.031	0.66
13	0.96	34.63	300	0.03	0.34	2504	0.036	0.23	9378	1.32	0.034	0.40
14	0.89	32.05	300	0.03	0.34	2182	0.035	0.20	6503	0.86	0.037	0.35
15	0.70	25.08	300	0.03	0.33	2628	0.045	0.21	2803	0.86	0.034	0.16
16	1.26	45.51	300	0.03	0.34	1593	0.046	0.13	15081	0.97	0.032	0.80
16/17	3.52	126.83	300	0.10	0.21	3229	0.011	0.53	22192	0.26	0.033	2.78
17	1.19	42.77	300	0.03	0.33	6502	0.033	0.62	4895	0.97	0.036	0.25
18	0.94	33.91	300	0.02	0.38	2460	0.039	0.21	7049	1.21	0.027	0.35
19	0.92	33.22	300	0.02	0.43	2060	0.036	0.19	5051	0.45	0.068	0.31
19/20	1.76	63.36	300	0.49	0.11	664	0.196	0.03	32869	0.75	0.052	1.62
20	0.45	16.07	198	0.03	0.24	0	--	0.00	981	0.26	0.012	0.20
20/26	3.20	115.37	300	0.05	0.29	0	--	0.00	22982	0.27	0.031	2.92
21	1.48	53.12	300	0.05	0.28	653	0.026	0.07	11253	0.47	0.024	1.13
22	0.45	16.23	300	0.03	0.34	0	--	0.00	1470	0.32	0.070	0.11
23	1.97	71.03	300	0.02	0.43	901	0.029	0.09	14253	0.43	0.026	1.45
23/24	1.39	49.88	300	0.03	0.33	447	0.054	0.03	11175	0.47	0.028	1.03
24	2.36	84.80	300	0.03	0.34	1808	0.067	0.12	12954	0.29	0.021	1.90
25	0.75	27.14	300	0.03	0.33	0	--	0.00	2560	0.26	0.019	0.43
26	3.10	111.77	300	0.02	0.43	0	--	0.00	15723	0.29	0.016	2.67
27	3.62	130.29	300	0.03	0.33	735	0.049	0.06	19956	0.23	0.023	3.24
28	1.40	50.35	300	0.02	0.43	0	--	0.00	5339	0.26	0.016	0.97
28/30	1.35	48.54	300	0.03	0.33	2924	0.025	0.32	6081	0.47	0.018	0.70
29	0.87	31.43	300	0.02	0.40	0	--	0.00	1974	0.26	0.009	0.47
30	1.13	40.58	300	0.02	0.38	3467	0.017	0.45	1658	0.26	0.016	0.30
30/32	0.91	32.76	300	0.04	0.31	1088	0.040	0.09	7638	0.68	0.034	0.50
31	2.05	73.93	300	0.03	0.33	445	2.074	0.01	17612	0.47	0.025	1.72
31/32	0.98	35.25	300	0.04	0.31	1737	0.034	0.16	3881	0.26	0.031	0.50
32	1.72	62.02	300	0.03	0.34	2427	0.031	0.24	7394	0.26	0.022	1.15
33	1.83	65.94	300	0.02	0.43	0	--	0.00	11113	0.50	0.014	1.40
34	2.87	103.26	300	0.03	0.36	3354	0.044	0.28	24397	0.52	0.025	2.24
34/35	0.81	29.19	300	0.05	0.27	1759	0.042	0.15	3127	0.24	0.037	0.39
35	2.38	85.60	300	0.04	0.31	2540	0.041	0.22	17589	0.28	0.043	1.85
35/36	1.30	46.71	300	0.03	0.33	2864	0.037	0.26	9470	0.52	0.036	0.72
36	1.72	61.87	300	0.03	0.34	461	0.030	0.05	12120	0.31	0.034	1.33
36/37	1.83	65.88	300	0.04	0.30	545	0.046	0.04	12346	0.26	0.036	1.48

Table 2 – TR-55 Lag Time Parameters (cont.)

Watershed	TR-55		Sheet Flow			Shallow Flow			Channel Flow			
	T_C	T_{LAG}	Flow Length	Slope	T_t	Flow Length	Slope	T_t	Flow Length	Hydraulic Radius	Slope	T_t
	(hr)	(min)	(ft)	(ft/ft)	(hr)	(ft)	(ft/ft)	(hr)	(ft)	(ft)	(ft/ft)	(hr)
37	0.72	25.94	300	0.03	0.33	2273	0.035	0.21	1437	0.25	0.033	0.18
38	1.44	51.78	300	0.69	0.10	455	0.057	0.03	12388	0.33	0.034	1.31
38/39	0.96	34.54	300	0.03	0.33	1364	0.043	0.11	4774	0.33	0.032	0.52
39	0.81	29.10	300	0.03	0.34	0	--	0.00	5811	0.46	0.038	0.47
40	0.84	30.40	300	0.06	0.26	1285	0.044	0.11	8126	0.77	0.035	0.48
41	0.72	25.95	300	0.05	0.28	1172	0.037	0.11	6111	0.76	0.041	0.34
42	0.61	22.12	300	0.07	0.25	1869	0.027	0.20	2051	0.94	0.014	0.17
43	0.80	28.95	300	1.44	0.07	0	--	0.00	12143	0.93	0.026	0.73
44	1.12	40.32	300	0.07	0.25	200	0.050	0.02	12188	0.75	0.026	0.86
45	0.33	11.80	300	1.18	0.08	977	0.266	0.03	3552	0.94	0.025	0.22
46	1.98	71.34	300	0.03	0.34	1308	0.031	0.13	10641	0.32	0.020	1.51
47	0.79	28.47	300	0.02	0.43	0	--	0.00	9989	0.90	0.077	0.36
48	2.80	100.70	300	0.03	0.36	4299	0.017	0.56	9416	0.39	0.008	1.88
48/50	0.86	31.09	300	0.02	0.40	0	--	0.00	6146	0.90	0.018	0.46
49	1.19	42.88	300	0.02	0.40	3065	0.014	0.44	1773	0.25	0.014	0.35
50	1.89	67.97	300	0.02	0.38	3286	0.018	0.42	12667	1.03	0.011	1.09
51	0.62	22.21	300	0.03	0.33	438	0.027	0.05	3378	0.64	0.030	0.25
52	0.40	14.28	300	0.88	0.09	997	0.020	0.12	3099	0.94	0.026	0.19
52/53	0.55	19.77	191	0.10	0.14	964	0.012	0.15	4347	1.28	0.018	0.26
53	0.67	24.18	300	0.05	0.28	1280	0.016	0.18	3580	0.94	0.025	0.22
53A	0.85	30.74	300	0.03	0.33	855	0.103	0.05	7060	0.93	0.021	0.48
54	1.03	36.97	300	0.07	0.24	2219	0.031	0.22	5462	0.61	0.015	0.57
55	1.01	36.20	300	0.13	0.19	1973	0.005	0.48	7833	1.28	0.033	0.34
56	0.19	6.94	300	0.27	0.14	432	0.185	0.02	1268	0.40	0.418	0.03
58	0.93	33.62	300	0.07	0.25	1717	0.006	0.39	4128	0.75	0.024	0.30
59	1.08	38.85	300	0.03	0.33	0	--	0.00	9851	0.61	0.029	0.75
59A	0.82	29.61	300	0.50	0.11	735	0.367	0.02	18806	0.93	0.071	0.69
60	1.05	37.85	300	0.03	0.33	125	0.040	0.01	10692	0.76	0.028	0.71
61	0.82	29.53	300	0.03	0.33	817	0.037	0.07	7148	0.95	0.027	0.42
62	1.19	42.81	300	0.03	0.34	879	0.035	0.08	10736	0.51	0.042	0.77
62/63	1.09	39.11	300	0.01	0.47	3093	0.031	0.30	5787	1.03	0.028	0.32
62A	1.95	70.05	300	0.02	0.43	67	1.015	0.00	21560	0.77	0.025	1.51
63	1.04	37.59	300	0.03	0.34	356	0.031	0.03	9990	0.83	0.025	0.67
64	2.67	96.15	300	0.01	0.53	3904	0.037	0.35	25137	0.68	0.029	1.79
65	0.92	33.06	300	0.03	0.33	1634	0.033	0.15	6528	0.83	0.025	0.44
65/66	1.48	53.18	300	0.03	0.34	1172	0.046	0.09	17064	0.76	0.034	1.04
66	1.12	40.15	300	0.03	0.33	349	0.043	0.03	9562	0.61	0.027	0.76
68	1.89	67.89	300	0.04	0.31	1555	0.033	0.15	25871	1.19	0.023	1.43

2.5 Rainfall

Rainfall data was provided as point precipitation frequency estimates from NOAA Atlas 14, utilizing the upper bound of the 90% confidence interval. For the 1% annual chance event (100-year average return interval), the 3-hr, 6-hr and 12-hr durations were evaluated to determine the critical storm (the duration which produces the highest peak discharge). Point rainfall was derived at three (3) locations, each at a significantly different elevation (2473', 3064', and 3894'). Each watershed draws from the point rainfall which most represents its mean elevation.

The rainfall data at 2473' is identified as 'Lower' within the meteorological model. Watersheds drawing from this point precipitation are: 20, 20/26, 21, 22, 23, 23/24, 24, 25, 26, 27, 28, 28/30, 30, 31, 32, 33, 34, 48, 48/50, 49, and 50.

The rainfall data at 3064' is identified as 'Middle' within the meteorological model. Watersheds drawing from this point precipitation are: 11, 11/12, 12, 12A, 13, 14, 15, 16, 16/17, 17, 18, 19, 30/32, 31/32, 34/35, 35, 36/37, 37, 38, 38/39, 39, 40, 41, 46, 47, 62, 62/63, 63, 64, 65, 65/66, 66, and 68.

The rainfall data at 3894' is identified as 'Upper' within the meteorological model. Watersheds drawing from this point precipitation are: 1, 2, 3, 4, 5, 6, 6/7, 7, 7/11, 8, 9, 10, 11/12A, 19/20, 35/36, 36, 42, 43, 44, 45, 51, 52, 52/53, 53, 53A, 54, 55, 56, 58, 59, 59A, 60, 61, and 62A.

The City of Tucson TSMS (COT) rainfall distribution was utilized to produce the temporal distribution of the 3-hour duration storm (Reference 3). The SCS Type II rainfall distribution was utilized to derive the 6-hour and 12-hour storm durations. Rainfall distributions were produced on a 5 minute time interval.

Table 3 summarizes the rainfall depths utilized for each storm duration analyzed in the meteorological model. The NOAA Atlas 14 precipitation data and the Pima County Design Storm Distribution are provided in Appendix 2.

Table 3 – NOAA Atlas 14 Precipitation

Rainfall Data ID	100-year Precipitation (in.)		
	3-hour COT	6-hour	12-hour
Lower	3.12	3.38	3.91
Middle	3.34	3.67	3.95
Upper	3.79	4.23	4.75

2.6 Soils

Soils information was provided by the Natural Resources Conservation Service: Soil Survey 669. Hydrologic soil group information (A, B, C, D) was provided in the survey. Soil group delineation of the survey was verified against Pima County Map Guide. Delineations of distinct soil groups (100% B) are consistent between the two sources. Delineations of mixed soil groups (25% B, 75%C) are available from Pima County Map Guide and were to incorporate soils analysis. Consistent with the Pima County guidelines, contributing areas of type 'A' soil was assumed to obtain the soil characteristics of type 'B' soil. The soils information, used to determine the SCS Curve Number for each watershed, is summarized in Table 4. The soil survey and a cd-rom containing USGS geological data of the Diamond Bell Ranch area are provided in Appendix 3.

A distinct Curve Number (CN) has been determined for each soil group present within each watershed. Where multiple soil groups are present within a watershed, a weighted Curve Number has been calculated based on the arithmetic average of contributing areas.

2.7 Vegetation

Two vegetative cover types are present within the Diamond Bell Ranch Area watersheds.

Desert Brush: includes such plants as mesquite, creosote brush, catlaw, cactus, etc., - desert brush is typical of lower elevations and lower annual rainfall. Maximum elevations generally do not exceed 4000 feet above mean sea level.

Herbaceous: includes short desert grasses with some brush, herbaceous is typical of intermediate elevations and higher annual rainfall than desert areas. Elevations generally range from a minimum of 1500 feet to a maximum of 5000 feet above mean sea level.

Cover type selection for each watershed was primarily based on elevation. Aerial photography was used to determine the presence of short grass, a distinct difference between desert brush and herbaceous cover types, to confirm the selection. Aerial photography was also used to determine the average vegetation densities of each watershed. Density percentages range from 10% - 40%. However, to develop a conservative hydrologic model and account for changes in watershed characteristics with time and season – a maximum cover density of 20% was assumed.

2.8 Curve Number

Figure: Hydrologic Soil – Cover Complexes and Associated Curve Numbers from *Hydrology Manual for Engineering Design and Floodplain Management within Pima County, Arizona for the Prediction of Peak Discharges from Surface Runoff on Small Semi-Arid Watersheds for the 2-year Through 100-Year Flood Recurrence Intervals* (Reference 16) was used to determine the CN of each soil group present within each watershed. The CN is a function of vegetative cover type, soil group and percent cover density. Based on the data analysis, each watershed is assigned a cover type and cover density. For each soil group within the watershed, a CN is assigned. Finally, a weighted CN is applied to represent the individual watershed. Table 4 summarizes the soil group data utilized from Reference 16. The Curve Number information for each watershed is summarized in Table 5.

Table 4 – SCS Soils: Pima County

Herbaceous		
Soil Group	Vegetative Cover Density (%)	
	10	20
B	82	79
C	88	86
D	92	91

Desert Brush		
Soil Group	Vegetative Cover Density (%)	
	10	20
B	84	83
C	89	88
D	92	91

2.9 Loss Method

The SCS Curve Number has been utilized for the Loss Method portion of the rainfall-runoff model. The weighted curve number (CN), initial abstraction (i_a) in inches and percent impervious (%) are the components of the loss method.

Initial abstraction includes all losses before runoff begins, and includes water retained in surface depressions, water taken up by vegetation, evaporation, and infiltration. This value is related to characteristics of the soil and the soil cover. It is calculated using the formula:

$$i_a = 0.2(1000/CN - 10).$$

The percent impervious represents the percentage of the watershed which does not allow infiltration. Impervious surfaces include asphalt, concrete, and other impenetrable surfaces. SCS loss method parameters are provided in Table 5.

Areas platted prior to the Floodplain ordinance were assumed to have their ultimate impervious values. Unplatted land is assumed to have the existing impervious values per current aerial imagery as this land is being held to ordinance requirements for future development.

Table 5 – Watershed Parameters

Watershed	Vegetation Type	Vegetation Density	Area	Soil B			Soil C			Soil D			CN	Initial Abstraction	Imperviousness
		(%)	(ac)	(ac)	(%)	CN	(ac)	(%)	CN	(ac)	(%)	CN	(weighted)	(in)	(%)
1	Herbaceous	20	4692.7	117	2	79	3,848	82	86	727	16	91	86	0.31	0
2	Herbaceous	20	85.6	0	0	79	86	100	86	0	0	91	86	0.33	0
3	Herbaceous	20	1478.6	266	18	79	1,086	73	86	127	9	91	85	0.35	0
4	Herbaceous	20	1016.8	310	30	79	698	69	86	9	1	91	84	0.38	0
5	Herbaceous	10	123.0	94	76	82	30	24	88	0	0	92	83	0.40	0
6	Herbaceous	20	66.7	67	100	79	0	0	86	0	0	91	79	0.53	0
6/7	Herbaceous	20	546.8	144	26	79	403	74	86	0	0	91	84	0.38	0
7	Herbaceous	20	237.2	237	100	79	0	0	86	0	0	91	79	0.53	0
7/11	Herbaceous	20	447.0	22	5	79	415	93	86	10	2	91	86	0.33	0
8	Herbaceous	10	52.7	23	43	82	30	57	88	0	0	92	85	0.34	0
9	Herbaceous	20	167.3	78	46	79	90	54	86	0	0	91	83	0.42	0
10	Herbaceous	20	412.6	153	37	79	260	63	86	0	0	91	83	0.40	0
11	Desert Brush	10	577.9	551	95	84	27	5	89	0	0	92	84	0.37	0
11/12	Desert Brush	20	249.0	183	73	83	66	27	88	0	0	91	84	0.37	0
11/12A	Herbaceous	20	2548.6	704	28	79	1,643	64	86	201	8	91	84	0.37	0
12	Desert Brush	20	406.1	406	100	83	0	0	88	0	0	91	83	0.41	0
12A	Herbaceous	20	590.4	158	27	79	432	73	86	0	0	91	84	0.38	0
13	Desert Brush	20	167.5	168	100	83	0	0	88	0	0	91	83	0.41	0
14	Desert Brush	20	149.2	149	100	83	0	0	88	0	0	91	83	0.41	0
15	Desert Brush	20	92.3	92	100	83	0	0	88	0	0	91	83	0.41	0
16	Desert Brush	20	418.9	385	92	83	34	8	88	0	0	91	83	0.40	0
16/17	Herbaceous	20	652.0	162	25	79	490	75	86	0	0	91	84	0.38	0
17	Desert Brush	20	336.4	336	100	83	0	0	88	0	0	91	83	0.41	0
18	Desert Brush	20	171.0	171	100	83	0	0	88	0	0	91	83	0.41	0
19	Desert Brush	20	298.1	298	100	83	0	0	88	0	0	91	83	0.41	0
19/20	Herbaceous	20	3351.0	358	11	79	2,993	89	86	0	0	91	85	0.35	0
20	Desert Brush	10	17.4	17	100	84	0	0	89	0	0	92	84	0.38	0
20/26	Desert Brush	20	1015.6	1016	100	83	0	0	88	0	0	91	83	0.41	0
21	Desert Brush	20	192.0	184	96	83	9	5	88	0	0	91	83	0.40	0
22	Desert Brush	10	87.9	88	100	84	0	0	89	0	0	92	84	0.38	0
23	Desert Brush	20	302.6	303	100	83	0	0	88	0	0	91	83	0.41	0
23/24	Desert Brush	20	435.0	435	100	83	0	0	88	0	0	91	83	0.41	5
24	Desert Brush	20	441.0	441	100	83	0	0	88	0	0	91	83	0.41	5
25	Desert Brush	10	32.5	33	100	84	0	0	89	0	0	92	84	0.38	0
26	Desert Brush	20	480.7	220	46	83	261	54	88	0	0	91	86	0.33	5
27	Desert Brush	20	1052.3	967	92	83	85	8	88	0	0	91	83	0.40	5
28	Desert Brush	10	134.5	0	0	84	135	100	89	0	0	92	89	0.25	0
28/30	Desert Brush	10	183.5	0	0	84	184	100	89	0	0	92	89	0.25	0
29	Desert Brush	10	25.1	0	0	84	25	100	89	0	0	92	89	0.25	0
30	Desert Brush	10	139.3	0	0	84	139	100	89	0	0	92	89	0.25	10
30/32	Desert Brush	10	135.2	0	0	84	135	100	89	0	0	92	89	0.25	5
31	Desert Brush	20	759.3	720	95	83	39	5	88	0	0	91	83	0.40	5
31/32	Desert Brush	20	44.3	44	100	83	0	0	88	0	0	91	83	0.41	5
32	Desert Brush	10	175.1	159	91	84	16	9	89	0	0	92	84	0.37	0
33	Desert Brush	10	598.6	0	0	84	599	100	89	0	0	92	89	0.25	0
34	Desert Brush	20	441.4	441	100	83	0	0	88	0	0	91	83	0.41	0
34/35	Desert Brush	10	71.9	0	0	84	72	100	89	0	0	92	89	0.25	0
35	Desert Brush	10	798.7	728	91	84	71	9	89	0	0	92	84	0.37	0
35/36	Desert Brush	20	642.5	643	100	83	0	0	88	0	0	91	83	0.41	0
36	Desert Brush	10	207.3	207	100	84	0	0	89	0	0	92	84	0.38	0

Table 5– Watershed Parameters (cont.)

Watershed	Vegetation Type	Vegetation Density	Area	Soil B			Soil C			Soil D			CN	Initial Abstraction	Imperviousness
		(%)	(ac)	(ac)	(%)	CN	(ac)	(%)	CN	(ac)	(%)	CN	(weighted)	(in)	(%)
36/37	Desert Brush	10	173.3	168	97	84	6	3	89	0	0	92	84	0.38	0
37	Desert Brush	10	55.7	56	100	84	0	0	89	0	0	92	84	0.38	0
38	Desert Brush	20	277.9	234	84	83	44	16	88	0	0	91	84	0.39	0
38/39	Desert Brush	20	80.5	31	39	83	49	61	88	0	0	91	86	0.32	0
39	Desert Brush	20	143.1	143	100	83	0	0	88	0	0	91	83	0.41	0
40	Desert Brush	20	248.2	98	40	83	150	60	88	0	0	91	86	0.33	0
41	Desert Brush	20	194.5	116	59	83	79	41	88	0	0	91	85	0.35	0
42	Desert Brush	10	53.2	0	0	84	53	100	89	0	0	92	89	0.25	0
43	Herbaceous	10	291.2	291	100	82	0	0	88	0	0	92	82	0.44	0
44	Herbaceous	10	332.1	270	81	82	62	19	88	0	0	92	83	0.41	0
45	Herbaceous	20	256.0	0	0	79	256	100	86	0	0	91	86	0.33	0
46	Desert Brush	20	287.3	243	85	83	44	15	88	0	0	91	84	0.39	0
47	Desert Brush	20	1512.8	372	25	83	1,141	75	88	0	0	91	87	0.30	0
48	Desert Brush	10	263.9	149	56	84	115	44	89	0	0	92	86	0.32	0
48/50	Desert Brush	20	249.8	250	100	83	0	0	88	0	0	91	83	0.41	5
49	Desert Brush	10	127.6	101	79	84	27	21	89	0	0	92	85	0.35	0
50	Desert Brush	20	1049.0	765	73	83	284	27	88	0	0	91	84	0.37	5
51	Herbaceous	20	85.0	0	0	79	85	100	86	0	0	91	86	0.33	0
52	Herbaceous	20	55.0	40	73	79	15	27	86	0	0	91	81	0.47	0
52/53	Herbaceous	20	88.4	0	0	79	88	100	86	0	0	91	86	0.33	0
53	Herbaceous	20	130.2	99	76	79	31	24	86	0	0	91	81	0.48	0
53A	Herbaceous	10	202.9	152	75	82	51	25	88	0	0	92	83	0.40	0
54	Herbaceous	10	87.5	58	67	82	29	33	88	0	0	92	84	0.38	0
55	Herbaceous	20	171.7	0	0	79	172	100	86	0	0	91	86	0.33	0
56	Herbaceous	10	22.1	3	13	82	19	87	88	0	0	92	87	0.29	0
58	Herbaceous	10	157.5	0	0	82	107	68	88	50	32	92	89	0.24	0
59	Herbaceous	20	343.9	197	57	79	147	43	86	0	0	91	82	0.44	0
59A	Herbaceous	20	2265.7	0	0	79	1,792	79	86	474	21	91	87	0.30	0
60	Herbaceous	20	367.7	70	19	79	298	81	86	0	0	91	85	0.36	0
61	Herbaceous	10	200.9	0	0	82	154	77	88	47	23	92	89	0.25	0
62	Desert Brush	20	680.90	486.6	71	83	194	29	88	0	0	91	84	0.37	0
62/63	Desert Brush	20	135.80	135.80	100	83	0	0	88	0	0	91	83	0.41	0
62A	Desert Brush	20	836.10	449.1	54	83	387	46	88	0	0	91	85	0.34	0
63	Desert Brush	20	211.20	211.2	100	83	0	0	88	0	0	91	83	0.41	0
64	Desert Brush	20	2011.90	1185.1	59	83	827	41	88	0	0	91	85	0.35	0
65	Desert Brush	20	232.30	232.30	100	83	0	0	88	0	0	91	83	0.41	0
65/66	Desert Brush	20	776.30	194.2	25	83	582	75	88	0	0	91	87	0.31	10
66	Desert Brush	20	269.00	241.60	90	83	27	10	88	0	0	91	84	0.39	10
68	Desert Brush	10	1206.40	######	89	84	134	11	89	0	0	92	85	0.37	10

2.10 Routing

Hydrographs generated within the watersheds are routed downstream by reaches, utilized the Modified-Puls method. LIDAR data, converted to one-foot contour interval digital topography, was utilized to produce eighteen (18) representative cross sections within the project area. Each of the seventy-seven (77) reaches drew from the cross section which is most representative by geographical location. Stage-discharge relationships were created for each reach under normal depth conditions using HEC-RAS. Reach parameters include: uniform Manning's n of 0.050, a representative cross section, mean reach slope (ft/ft). Eight discharges (cfs) were analyzed, including a bank full discharge. The cross sectional flow area (ft^2) of each discharge was multiplied by the reach length (ft) to produce the storage (acre-ft) portion of the storage-discharge relationship. The stage-discharge and storage-discharge relationships were applied to each reach to execute the Modified Puls routing method. A subreach of one (1) was applied to each reach.

Maps depicting the locations of the representative cross sections are provided in Appendix 5. The 'River' ID indicates the representative cross section. The 'Reach' ID indicates the reach. Table 6 summarizes the reach parameters. The stage-discharge-storage calculations are provided in Appendix 5. The HEC-RAS output files are provided in Appendix 6.

2.11 Control Specifications

The control specifications establish the window of time in which the model is executed. The control specification was specified to contain the entire duration of precipitation and the peak discharge of runoff for each of the storm durations analyzed for each individual watershed.

Table 6 – Reach Parameters

Reach ID	Length (ft)	Slope (%)	Cross Section ID
Reach-2	8090	2.68	1800
Reach-3	20731	2.75	200
Reach-4	26049	2.79	200
Reach-5	26969	2.85	200
Reach-6	28759	3.02	200
Reach-6/7div(6)	4503	3.11	1500
Reach-6/7div(7)	4241	3.77	1500
Reach-7	18156	3.39	1400
Reach-7/11 div(11)	15560	3.68	1700
Reach-7/11 div(7)	9800	4.18	1500
Reach-8	17465	3.38	1400
Reach-9	8348	3.65	1400
Reach-10	7168	3.36	1400
Reach-11	18556	2.53	700
Reach-11/12A	6514	3.02	1700
Reach-11/12div(11)	6880	4.24	1700
Reach-11/12div(12)	9106	3.91	1700
Reach-12	14774	2.74	700
Reach-12A	9230	3.52	1700
Reach-13	18874	2.59	900
Reach-14	16510	2.96	900
Reach-15	14510	2.65	1600
Reach-16	14942	2.67	1600
Reach-16/17div(16)	5202	3.73	1600
Reach-16/17div(17)	4423	4.05	1600
Reach-17	12162	2.92	1600
Reach-18	10656	2.67	1600
Reach-19	11191	2.48	1000
Reach-19/20div(19)	7336	2.39	1600
Reach-19/20div(20)	18139	0.46	1100
Reach-20/26div(20)	956	2.20	1100
Reach-20/26div(26)	12002	1.39	1100
Reach-23/24div(23)	2539	2.44	1000
Reach-23/24div(24)	2884	2.05	1000
Reach-24	4870	1.21	900
Reach-28/30div(28)	3757	1.30	800
Reach-28/30div(30)	2007	1.54	800
Reach-30	1764	1.02	800
Reach-30/32div(28/30)	7447	1.89	800
Reach-30/32div(32)	5574	2.03	800
Reach-31	8547	1.24	700
Reach-31/32div(31)	6919	2.15	700
Reach-31/32div(32)	2269	1.23	800
Reach-32	4666	2.12	800
Reach-34	3902	1.08	700
Reach-34/35div(34)	20541	2.17	700
Reach-34/35div(35)	2164	2.82	1200
Reach-35/36div(35)	9193	3.59	1200
Reach-35/36div(36)	8363	3.72	1200
Reach-36/37div(36)	5204	2.86	1200
Reach-36/37div(37)	2586	3.21	1200
Reach-38	6790	0.15	600
Reach-38/39div(38)	9841	3.66	1300
Reach-38/39div(39)	12625	3.45	1300
Reach-39	22759	2.17	1300
Reach-40	27143	2.35	600
Reach-41div(39)	3798	3.74	1300
Reach-41div(68)	3678	3.81	1300
Reach-48/50div(50)	9085	1.42	500

Table 6 – Reach Parameters (cont.)

Reach ID	Length (ft)	Slope (%)	Cross Section ID
Reach-48/50div(48)	7536	1.57	500
Reach-51	19055	2.82	100
Reach-52/53div(52)	3860	2.85	1800
Reach-52/53div(53)	4497	2.80	1800
Reach-53A	3405	3.26	1800
Reach-59	12122	4.50	1800
Reach-59A	10039	7.04	1800
Reach-60	953	2.94	1800
Reach-61	1682	0.59	1800
Reach-62/63div(62)	6792	2.04	100
Reach-62/63div(63)	5523	2.29	100
Reach-62Adiv(62/63)	6872	2.94	100
Reach-62Adiv(62)	13729	2.48	100
Reach-64	12889	1.48	200
Reach-65	7065	1.53	400
Reach-65/66div(65)	8040	2.64	300
Reach-65/66div(66)	6891	2.70	300
Reach-66	7274	1.50	400

3.0 RESULTS

3.1 Critical Storm

HMS models were run throughout the Diamond Bell Ranch Area for the 3, 6 and 12 hour storm durations to evaluate the 100-year critical storm for each watershed. Based on the Time of Concentration and watershed parameters, the critical storm for the each individual watershed was determined. Table 7 summarizes the Critical Storm analysis for individual watersheds. Table 8 identifies the Critical Storm and the cfs/acre of that duration storm.

Table 7 – Watershed Critical Storm Analysis: Q_{100}

Watershed	Drainage Area (acres)	Q_{100} (cfs)		
		3-hour COT	6-hour	12-hour
1	4692.5	6256	7199	7303
2	85.8	163	196	197
3	1478.4	2186	2581	2624
4	1017.0	1908	2355	2382
5	122.9	221	275	279
6	66.6	119	160	163
6/7	546.6	839	1009	1030
7	237.4	251	304	319
7/11	446.7	1066	1279	1272
8	52.5	52	59	61
9	167.0	250	304	312
10	412.8	575	675	689
11	577.9	536	609	593
11/12	249.0	335	392	377
11/12A	2548.5	2979	3458	3547
12	406.4	460	547	532
12A	590.7	796	959	927
13	167.7	205	247	240
14	149.1	190	231	224
15	92.2	134	166	160
16	419.2	441	516	503
16/17	652.2	354	390	382
17	336.6	365	431	420
18	170.9	212	256	248
19	298.2	373	452	438
19/20	3351.0	3816	4382	4485
20	17.3	29	35	33
20/26	1015.7	505	547	532
21	192.0	164	185	179
22	87.7	146	179	168
23	302.7	212	235	228
23/24	435.2	383	436	422
24	441.0	274	300	292
25	32.6	48	55	52
26	480.6	304	321	308
27	1052.2	531	562	540
28	134.4	159	175	166
28/30	183.7	222	245	232
29	25.0	39	45	42
30	139.5	201	219	205
30/32	135.0	237	267	253
31	759.0	550	599	577
31/32	44.2	57	67	64
32	175.4	142	159	153
33	598.4	590	640	609
34	441.6	238	259	252
34/35	71.7	131	150	142
35	798.7	582	648	634
35/36	642.6	816	970	998
36	207.4	230	266	273

Table 7 – Watershed Critical Storm Analysis: Q_{100} (cont.)

Watershed	Drainage Area	Q_{100} (cfs)		
	(acres)	3-hour COT	6-hour	12-hour
36/37	173.4	151	171	166
37	55.7	84	103	99
38	277.8	280	324	315
38/39	80.6	115	136	130
39	143.4	193	236	229
40	248.3	380	451	432
41	194.6	309	374	358
42	53.1	136	156	154
43	291.2	466	582	596
44	332.2	461	555	570
45	256.0	763	865	848
46	287.4	235	265	259
47	1513.0	2529	2977	2838
48	263.7	168	181	175
48/50	249.6	305	357	342
49	127.4	137	156	150
50	1049.0	843	919	883
51	85.1	188	227	227
52	55.0	116	149	150
52/53	88.3	207	249	248
53	129.9	215	276	283
53A	202.9	330	406	414
54	87.7	134	161	165
55	171.5	290	343	347
56	21.8	85	83	80
58	157.4	319	367	364
59	343.7	466	566	584
59A	2265.6	4503	5335	5338
60	368.0	581	692	702
61	201.0	438	506	501
62	678.4	778	911	883
62/63	134.4	154	183	178
62A	838.4	895	1021	1046
63	211.2	247	295	287
64	2009.6	1403	1551	1515
65	230.4	289	350	340
65/66	774.4	951	1048	1002
66	268.8	349	397	382
68	1209.6	1163	1276	1231

Table 8 – Watershed Critical Storm Results: cfs/acre

Watershed	Critical Storm (hr)	Drainage Area (acres)	Q_{100} (cfs)	Q_{100} (cfs/acre)
1	12	4692.5	7303	1.56
2	6	85.8	196	2.29
3	12	1478.4	2624	1.78
4	12	1017.0	2382	2.34
5	6	122.9	275	2.24
6	6	66.6	160	2.40
6/7	12	546.6	1030	1.88
7	6	237.4	304	1.28
7/11	6	446.7	1279	2.86
8	6	52.5	59	1.12
9	6	167.0	304	1.82
10	12	412.8	689	1.67
11	6	577.9	609	1.05
11/12	6	249.0	392	1.57
11/12A	12	2548.5	3547	1.39
12	6	406.4	547	1.35
12A	6	590.7	959	1.62
13	6	167.7	247	1.47
14	6	149.1	231	1.55
15	6	92.2	166	1.80
16	6	419.2	516	1.23
16/17	6	652.2	390	0.60
17	6	336.6	431	1.28
18	6	170.9	256	1.50
19	6	298.2	452	1.51
19/20	12	3351.0	4485	1.34
20	6	17.3	35	2.05
20/26	6	1015.7	547	0.54
21	6	192.0	185	0.96
22	6	87.7	179	2.04
23	6	302.7	235	0.78
23/24	6	435.2	436	1.00
24	6	441.0	300	0.68
25	6	32.6	55	1.68
26	6	480.6	321	0.67
27	6	1052.2	562	0.53
28	6	134.4	175	1.30
28/30	6	183.7	245	1.33
29	6	25.0	45	1.78
30	6	139.5	219	1.57
30/32	6	135.0	267	1.98
31	6	759.0	599	0.79
31/32	6	44.2	67	1.51
32	6	175.4	159	0.90
33	6	598.4	640	1.07
34	6	441.6	259	0.59
34/35	6	71.7	150	2.09
35	6	798.7	648	0.81
35/36	12	642.6	998	1.55
36	12	207.4	273	1.32

Table 8 – Watershed Critical Storm Results: cfs/acre (cont.)

Watershed	Critical Storm (hr)	Drainage Area (acres)	Q_{100} (cfs)	Q_{100} (cfs/acre)
36/37	6	173.4	171	0.98
37	6	55.7	103	1.84
38	6	277.8	324	1.17
38/39	6	80.6	136	1.68
39	6	143.4	236	1.65
40	6	248.3	451	1.82
41	6	194.6	374	1.92
42	6	53.1	156	2.94
43	12	291.2	596	2.05
44	12	332.2	570	1.72
45	6	256.0	865	3.38
46	6	287.4	265	0.92
47	6	1513.0	2977	1.97
48	6	263.7	181	0.69
48/50	6	249.6	357	1.43
49	6	127.4	156	1.22
50	6	1049.0	919	0.88
51	6	85.1	227	2.67
52	6	55.0	149	2.71
52/53	6	88.3	249	2.82
53	12	129.9	283	2.18
53A	12	202.9	414	2.04
54	6	87.7	161	1.84
55	6	171.5	343	2.00
56	3 COT	21.8	85	3.92
58	6	157.4	367	2.33
59	12	343.7	584	1.70
59A	12	2265.6	5338	2.36
60	12	368.0	702	1.91
61	6	201.0	506	2.52
62	6	678.4	911	1.34
62/63	6	134.4	183	1.36
62A	12	838.4	1046	1.25
63	6	211.2	295	1.40
64	6	2009.6	1551	0.77
65	6	230.4	350	1.52
65/66	6	774.4	1048	1.35
66	6	268.8	397	1.48
68	6	1209.6	1276	1.05

3.2 HEC-HMS Results

With the critical storm determined for each individual watershed, additional HEC-HMS models were generated, routing flows downstream though the network of junctions, reaches and diversions observed in the Diamond Bell Ranch area.

Where split flow occurs upstream of a concentration point, diversions were incorporated into the model. As previously mentioned, artificial flow was produced at split flow locations, creating a sum of 150% of the flow, at most locations. Where split flows occur in series, multiple models were run, beginning with the most upstream and applying the appropriate percentage diversion. To determine the highest peak discharge at a concentration point, the model incorporated the highest splits of upstream concentration points which would contribute to flow.

The results of the hydrologic analysis are summarized in Tables 9. A 'cfs/acre' calculation is provided for each concentration point in Table 10. The cfs/acre for Diamond Bell concentration points range from 3.9 cfs/acre for small-steep watercourses to 0.5 for long-shallow sloped watercourses.

Figure 3, Hydrologic Analysis Map, illustrates split flow location, reach delineation, watershed ID, and 100-peak discharge. HMS summary outputs are provided in Appendix 7.

The 100-year peak discharges and associated HEC-HMS hydrologic models and parameters are intended to be utilzied by Pima County Regional Flood Control District to enable decisions regarding regulatory watercourses within the Diamond Bell Ranch area. As the area develops, additional analyses will be necessary to further refine the hydrology and hydraulics of the Diamond Bell watersheds.

Table 9 –Hydrologic Analysis Results: Q_{100}

Concentration Point	Contributing Watersheds	Drainage Area (acres)	Q_{100} (cfs) 3-hour COT	6-hour	12-hour
1	1	4692.5	6256	7199	7303
2	2	85.8	163	196	197
3	3	1478.4	2186	2581	2624
4	4	1017.0	1908	2355	2382
5	5	122.9	221	275	279
6	6, 50%(6/7, 100%(7/11))	563.3	723	842	862
6/7	6/7, 100%(7/11)	993.3	1486	1783	1819
7	7, 100%(6/7, 7/11)	1230.7	1499	1730	1773
7/11	7/11	446.7	1066	1279	1272
8	8	52.5	52	59	61
9	9	167.0	250	304	312
10	10	412.8	575	675	689
11	11, 75%(11/12, 11/12A, 50%(7/11))	2843.5	2551	2916	2985
11/12	11/12, 11/12A, 50%(7/11)	3020.9	3065	3513	3609
11/12A	11/12A, 50%(7/11)	2771.9	3170	3681	3780
12	12, 12A, 75%(11/12, 11/12A, 50%(7/11)	3262.7	2620	2951	3022
12A	12A	590.7	796	959	927
13	13	167.7	205	247	240
14	14	149.1	190	231	224
15	15	92.2	134	166	160
16	16, 75%(16/17)	908.4	472	550	543
16/17	16/17	652.2	354	390	382
17	17, 75%(16/17)	825.8	395	463	459
18	18	170.9	212	256	248
19	19, 75%(19/20)	2811.5	2843	3238	3318
19/20	19/20	3351.0	3816	4382	4485
20	20, 100%(20/26, 75%(19/20))	3546.3	1950	2183	2252
20/26	20/26, 75%(19/20)	3529.0	1948	2181	2251
21	21	192.0	164	185	179
22	22	87.7	146	179	168
23	23, 19, 75%(19/20, 23/24, 17, 18, 75%(16/17))	4188.0	3201	3626	3709
23/24	23/24, 17, 18, 75%(16/17)	1431.9	659	758	747
24	24, 15, 16, 75%(16/17, 23/24, 17/18,	2270.9	1036	1158	1141
25	25	32.6	48	55	52

Table 9 –Hydrologic Analysis Results: Q_{100} (cont.)

Concentration Point	Contributing Watersheds	Drainage Area (acres)	Q_{100} (cfs) 3-hour COT	6-hour	12-hour
26	26, 50%(20/26, 75%(19/20))	2245.1	1052	1172	1196
27	27, 13, 14, 24, 15, 16, 75%(16/17, 23/24, 17/18, 25%(16/17))	2587.7	1593	1730	1688
28	28, 75%(28/30, 75%(30/32))	348.1	308	337	323
28/30	28/30, 75%(30/32)	285.0	310	342	326
29	.29, 30, 32, 30/32, 75%(28/30, 31/32)	645.8	530	580	557
30	30, 32, 30/32, 75%(28/30, 31/32)	620.8	529	581	559
30/32	30/32	135.0	237	267	253
31	31, 11, 12, 12A, 11/12, 11/12A, 50%(7/11)	5354.9	3057	3463	3550
31/32	31/32	44.2	57	67	64
32	32, 75%(30/32, 31/32)	309.8	284	320	308
33	33, 31, 34, 11, 12, 12A, 11/12, 11/12A, 50%(7/11), 75%(34/35)	6448.7	3251	3669	3734
34	34, 75%(34/35)	495.4	264	287	279
34/35	34/35	71.7	131	150	142
35	35, 75%(35/36, 34/35)	1334.4	1056	1197	1203
35/36	35/36	642.6	816	970	998
36	36, 75%(36/37, 35/36)	819.4	758	878	906
36/37	36/37	173.4	151	171	166
37	37, 75%(36/37)	185.8	128	145	140
38	38, 75%(38/39)	338.3	326	376	366
38/39	38/39	80.6	115	136	130
39	39, 100%(41), 75%(38/39)	398.5	699	790	797
40	40, 9	415.4	480	573	567
41	41, 10	607.4	578	646	656
42	42	53.1	136	156	154
43	43, 59, 59A	2900.5	3437	4032	4165
44	44	332.2	461	555	570
45	45	256.0	763	865	848
46	46	287.4	235	265	259
47	47	1513.0	2529	2977	2838
48	48, 75%(48/50, 65, 66, 65/66, 7, 8, 100%(6/7, 7/11))	2368.5	1653	1814	1818
48/50	48/50, 65, 66, 65/66, 7, 8, 100%(6/7, 7/11)	2806.4	2219	2428	2434

Table 9 –Hydrologic Analysis Results: Q_{100} (cont.)

Concentration Point	Contributing Watersheds	Drainage Area (acres)	Q_{100} (cfs) 3-hour COT	6-hour	12-hour
49	49	127.4	137	156	150
50	50, 64, 4, 5, 6, 75%(48/50, 65, 66, 65/66, 7, 8, 100%(6/7, 7/11)), 50%(6/7, 100%(7/11))	6866.6	3470	3822	3833
51	51	85.1	188	227	227
52	52, 100%(52/53, 60, 61, 2)	709.7	1139	1333	1351
52/53	52/53, 60, 61, 2	654.7	1035	1228	1242
53	53, 100%(52/53, 60, 61, 2)	784.6	1495	1769	1803
53A	53A	202.9	330	406	414
54	54	87.7	134	161	165
55	55	171.5	290	343	347
56	56	21.8	85	83	80
58	58	157.4	319	367	364
59	59, 59A	2609.3	4005	4775	4853
59A	59A	2265.6	4503	5335	5338
60	60	368.0	581	692	702
61	61, 2	286.7	502	586	586
62	62, 75%(62/63), 100%(62A, 3, 51)	3181.1	1837	2078	2162
62/63	62/63, 100%(62A, 3, 51)	2536.3	1986	2254	2345
62A	62A, 3, 51	2401.9	2050	2392	2501
63	63, 75%(62/63, 100%(62A, 3, 51))	2113.4	1448	1648	1713
64	64, 4, 5, 6, 50%(6/7)	3489.4	2252	2528	2551
65	65, 75%(65/66, 7, 8, 100%(6/7, 7/11))	1773.6	1637	1793	1802
65/66	65/66, 7, 8, 100%(6/7, 7/11)	2057.6	2219	2462	2467
66	66, 75%(65/66, 7, 8, 100%(6/7, 7/11))	1812.0	1745	1911	1914
68	68, 38, 39, 40, 38/39, 9, 10	2539.5	2113	2341	2314

Table 10 –Hydrologic Analysis Results: cfs/acre

Concentration Point	Contributing Watersheds	Critical Storm	Drainage Area	Q_{100}	
		(hr)	(acres)	(cfs)	(cfs/acre)
1	1	12	4692.5	7303	1.56
2	2	6	85.8	196	2.29
3	3	12	1478.4	2624	1.78
4	4	12	1017.0	2382	2.34
5	5	6	122.9	275	2.24
6	6, 50%(6/7, 100%(7/11))	12	563.3	862	1.53
6/7	6/7, 100%(7/11)	12	993.3	1819	1.83
7	7, 100%(6/7, 7/11)	12	1230.7	1773	1.44
7/11	7/11	6	446.7	1279	2.86
8	8	6	52.5	59	1.12
9	9	12	167.0	304	1.82
10	10	12	412.8	689	1.67
11	11, 75%(11/12, 11/12A, 50%(7/11))	12	2843.5	2985	1.05
11/12	11/12, 11/12A, 50%(7/11)	12	3020.9	3609	1.19
11/12A	11/12A, 50%(7/11)	12	2771.9	3780	1.36
12	12, 12A, 75%(11/12, 11/12A, 50%(7/11)	12	3262.7	3022	0.93
12A	12A	6	590.7	959	1.62
13	13	6	167.7	247	1.47
14	14	6	149.1	231	1.55
15	15	6	92.2	166	1.80
16	16, 75%(16/17)	6	908.4	550	0.61
16/17	16/17	6	652.2	390	0.60
17	17, 75%(16/17)	6	825.8	463	0.56
18	18	6	170.9	256	1.50
19	19, 75%(19/20)	12	2811.5	3318	1.18
19/20	19/20	12	3351.0	4485	1.34
20	20, 100%(20/26, 75%(19/20))	12	3546.3	2252	0.64
20/26	20/26, 75%(19/20)	12	3529.0	2251	0.64
21	21	6	192.0	185	0.96
22	22	6	87.7	179	2.04
23	23, 19, 75%(19/20, 23/24, 17, 18, 75%(16/17))	12	4188.0	3709	0.89
23/24	23/24, 17, 18, 75%(16/17)	6	1431.9	758	0.53
24	24, 15, 16, 75%(16/17, 23/24, 17/18,	6	2270.9	1158	0.51
25	25	6	32.6	55	1.68

Table 10 –Hydrologic Analysis Results: cfs/acre (cont.)

Concentration Point	Contributing Watersheds	Critical Storm (hr)	Drainage Area (acres)	Q_{100} (cfs)	Q_{100} (cfs/acre)
26	26, 50%(20/26, 75%(19/20))	12	2245.1	1196	0.53
27	27, 13, 14, 24, 15, 16, 75%(16/17, 23/24, 17/18, 25%(16/17))	6	2587.7	1730	0.67
28	28, 75%(28/30, 75%(30/32))	6	348.1	337	0.97
28/30	28/30, 75%(30/32)	6	285.0	342	1.20
29	29, 30, 32, 30/32, 75%(28/30, 31/32)	6	645.8	580	0.90
30	30, 32, 30/32, 75%(28/30, 31/32)	6	620.8	581	0.94
30/32	30/32	6	135.0	267	1.98
31	31, 11, 12, 12A, 11/12, 11/12A, 50%(7/11)	12	5354.9	3550	0.66
31/32	31/32	6	44.2	67	1.51
32	32, 75%(30/32, 31/32)	6	309.8	320	1.03
33	33, 31, 34, 11, 12, 12A, 11/12, 11/12A, 50%(7/11), 75%(34/35)	12	6448.7	3734	0.58
34	34, 75%(34/35)	6	495.4	287	0.58
34/35	34/35	6	71.7	150	2.09
35	35, 75%(35/36, 34/35)	6	1334.4	1203	0.90
35/36	35/36	12	642.6	998	1.55
36	36, 75%(36/37, 35/36)	12	819.4	906	1.11
36/37	36/37	6	173.4	171	0.98
37	37, 75%(36/37)	6	185.8	145	0.78
38	38, 75%(38/39)	6	338.3	376	1.11
38/39	38/39	6	80.6	136	1.68
39	39, 100%(41), 75%(38/39)	6	398.5	790	1.98
40	40, 9	6	415.4	573	1.38
41	41, 10	12	607.4	646	1.06
42	42	6	53.1	156	2.94
43	43, 59, 59A	12	2900.5	4165	1.44
44	44	12	332.2	570	1.72
45	45	6	256.0	865	3.38
46	46	6	287.4	265	0.92
47	47	6	1513.0	2977	1.97
48	48, 75%(48/50, 65, 66, 65/66, 7, 8, 100%(6/7, 7/11))	6	2368.5	1818	0.77
48/50	48/50, 65, 66, 65/66, 7, 8, 100%(6/7, 7/11)	12	2806.4	2434	0.87

Table 10 –Hydrologic Analysis Results: cfs/acre (cont.)

Concentration Point	Contributing Watersheds	Critical Storm	Drainage Area	Q_{100}	
		(hr)	(acres)	(cfs)	(cfs/acre)
49	49	6	127.4	156	1.22
50	50, 64, 4, 5, 6, 75%(48/50, 65, 66, 65/66, 7, 8, 100%(6/7, 7/11)), 50%(6/7, 100%(7/11))	12	6866.6	3833	0.56
51	51	6	85.1	227	2.67
52	52, 100%(52/53, 60, 61, 2)	12	709.7	1351	1.90
52/53	52/53, 60, 61, 2	12	654.7	1242	1.90
53	53, 100%(52/53, 60, 61, 2)	12	784.6	1803	2.30
53A	53A	6	202.9	414	2.04
54	54	6	87.7	161	1.84
55	55	6	171.5	343	2.00
56	56	3 COT	21.8	85	3.92
58	58	6	157.4	367	2.33
59	59, 59A	12	2609.3	4853	1.86
59A	59A	6	2265.6	5338	2.36
60	60	6	368.0	702	1.91
61	61, 2	6	286.7	586	2.04
62	62, 75%(62/63), 100%(62A, 3, 51)	12	3181.1	2162	0.68
62/63	62/63, 100%(62A, 3, 51)	12	2536.3	2345	0.92
62A	62A, 3, 51	12	2401.9	2501	1.04
63	63, 75%(62/63, 100%(62A, 3, 51))	12	2113.4	1713	0.81
64	64, 4, 5, 6, 50%(6/7)	12	3489.4	2551	0.73
65	65, 75%(65/66, 7, 8, 100%(6/7, 7/11))	6	1773.6	1802	1.02
65/66	65/66, 7, 8, 100%(6/7, 7/11)	6	2057.6	2467	1.20
66	66, 75%(65/66, 7, 8, 100%(6/7, 7/11))	6	1812.0	1914	1.06
68	68, 38, 39, 40, 38/39, 9, 10	6	2539.5	2341	0.92

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