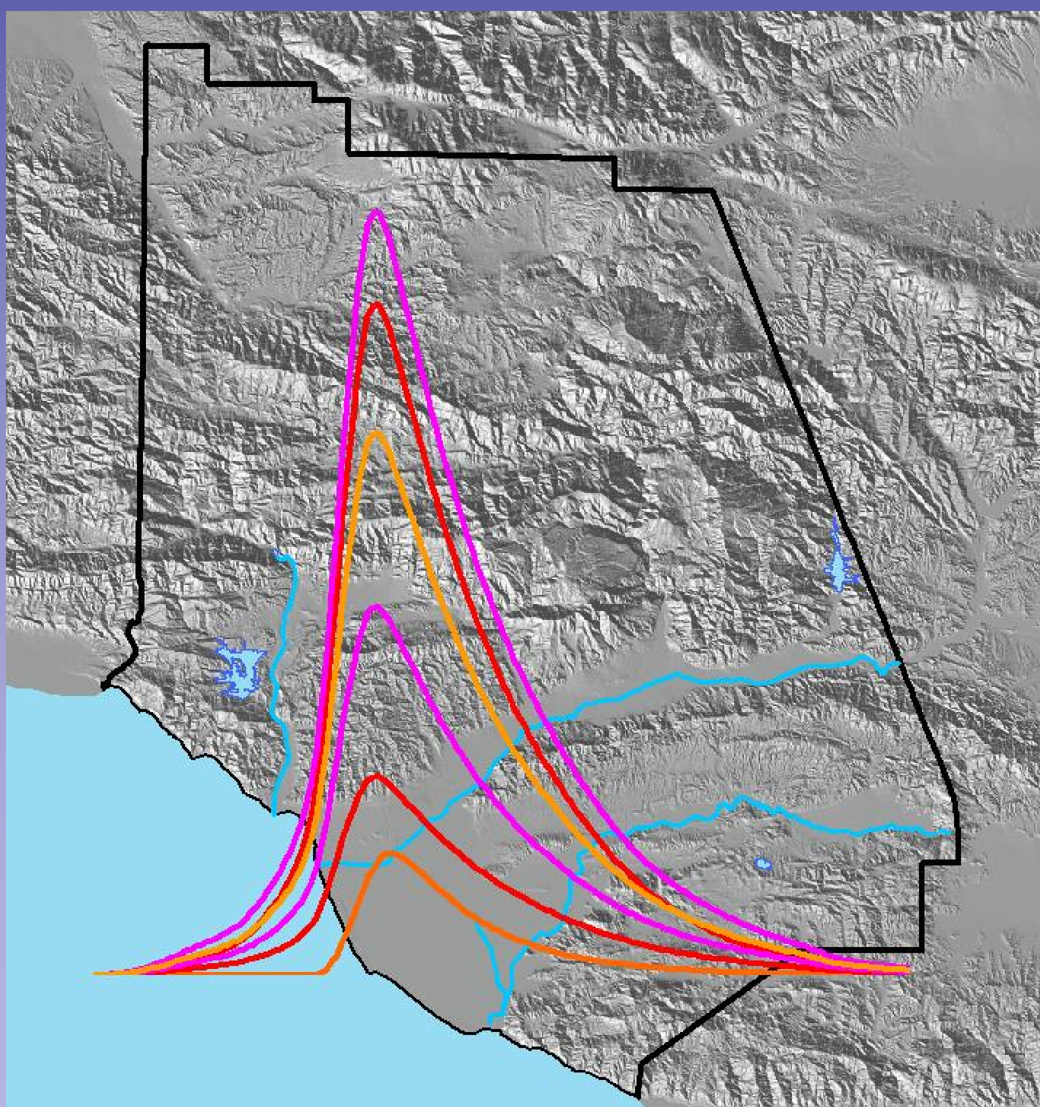
CALLEGUAS CREEK WATERSHED
HSPF DESIGN STORM
DRAFT REPORT



August 2012
Hydrology Section
Watershed Resources and Technology Division
Ventura County Watershed Protection District

Ventura County

Watershed Protection District

Hydrology Section

Project 15042

District Director: Vacant

Engineering Manager: Bruce Rindahl

Author: Mark Bandurraga

Reviewers: Bruce Rindahl, Yunsheng Su, Zia Hosseinipour

EXECUTIVE SUMMARY

This report documents the work done by the Hydrology Section of the Ventura County Watershed Protection District (District) in using the calibrated Calleguas Creek Continuous HSPF Model (Aqua Terra 2005, VCWPD, 2011). The continuous hydrologic model has been used to evaluate historical runoff, TMDLs, and shear stresses affecting stream channel stability in the watershed. The current Design Storm Model provides design storm peaks and hydrographs for use in regional facility design and to evaluate the effects of detention in the watershed.

The continuous model was created by Aqua Terra in 2003 by extending a pilot study model for the City of Simi Valley to cover the entire Calleguas watershed. The Pilot Study model simulated the runoff from the period 1977 through 2000. Because the hydrologic data from the rest of the watershed was not as robust as the data from the Simi Valley area, the extended model only simulated the period from 1987 through 2002. The model was then extended by Larry Walker and Associates (LWA) for their TMDL work for the Calleguas Watershed Management Plan to cover the period through calendar year 2004. Most recently, LWA added hydrologic data to extend the model through Water Year (WY) 2009 as a District consultant.

In 2011 the District updated the model calibration and confirmed that it matched the historical data adequately, and then converted it to run on 5-min timesteps. Design storm rain was applied to the input Watershed Data Module (WDM) file. The wettest antecedent moisture condition in recent memory (December 26, 2004 through January 9, 2005) was used to create saturated conditions in the model before applying the design storm rain starting on January 10, 2005. The design storm peaks and yields were then checked against design storm peaks from flow frequency analysis, other model results, and the NRCS Curve Number methodology.

The results showed that the design storm model provided peaks that matched most stream gage flow frequency analysis peaks to within a few percent through the use of a rainfall calibration factor ranging from 0.78 to 1.10. In some locations the change in the rainfall factor to match the design storm peak data indicated that the design storm peaks may be too conservative. This conclusion was confirmed in many cases by comparing the design storm peak to the historic maximum peak flow for a gage.

The HSPF peaks on ungaged tributaries were generally 20-50% less than the peaks from the District's rational method model. Tributaries with differences greater than 50% were generally due to differences in watershed areas or rainfall intensities for the two models. The HSPF peaks were usually less than the rational method peaks due to the inclusion of channel storage volume in the HSPF model to simulate the effects of homeowner association detention basins and curb inlet limitations on design storm runoff. A number of sensitivity studies were done to improve the understanding of the model results.

This page intentionally left blank.

TABLE OF CONTENTS

This page intentionally left blank.

1. INTRODUCTION

This report documents the work done by the Hydrology Section of the Ventura County Watershed Protection District (District) in using the Calleguas Creek Continuous HSPF Model (Aqua Terra 2005) calibrated with historical data (VCWPD, 2011). A map of the watershed is shown in Figure 1. The continuous model has been used to evaluate historical runoff, TMDLs, and shear stresses affecting stream channel stability in the watershed. The calibrated model can perform long term simulations of historical runoff. The Design Storm Model provides design storm peaks and hydrographs for use in regional facility design and to evaluate the effects of detention in the watershed.

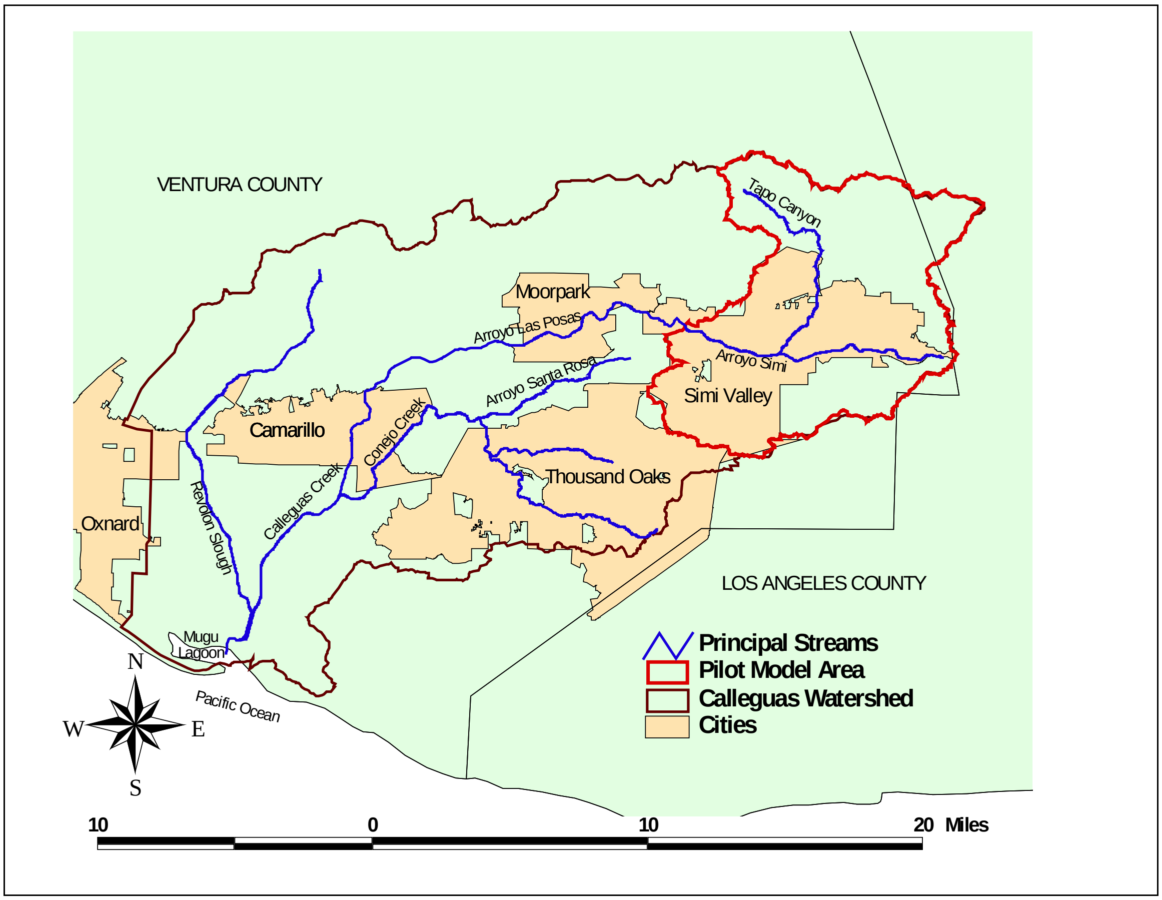


Figure 1. Calleguas Creek Watershed Location, Municipalities, and Major Waterbodies (Aqua Terra, 2005)

The continuous model was created by Aqua Terra in 2003 by extending a pilot study model for the City of Simi Valley to cover the entire Calleguas watershed. The Pilot Study model simulated the runoff from the period 1977 through 2000 with hourly timesteps. Because the hydrologic data from the rest of the watershed was not as robust as the data from the Simi Valley area, the extended model only simulated the period from 1987 through 2002. The model was then extended by Larry Walker and Associates (LWA) for their TMDL work for the Calleguas Watershed Management Plan to cover the period through calendar year 1994. Most recently, LWA added hydrologic data to extend the model through Water Year (WY) 2009 as a District consultant.

In 2011 the District recalibrated the model to confirm that it still matched the historical data adequately (VCWPD, 2011). This report describes the subsequent work to convert the model to provide design storm peaks and hydrographs.

2. DESIGN STORM HSPF MODEL

The calibrated Calleguas Creek HSPF Model (Aqua Terra, 2005) used an hourly timestep because its intended use for water quality simulations did not require matching instantaneous storm peaks but instead was primarily required to match total storm runoff volumes. The work done by the District on the continuous model included changing it to run with a 15-min timestep to adequately resolve the flow hydrographs. The changes included adding 15-minute rainfall data to the model, and converting the units where necessary to transform the input data sets to work correctly at the 15-min level.

In addition, the historic model used the ‘Ftable’ feature in HSPF to provide the stage-storage-discharge data necessary for routing the runoff from the subareas through the channel and detention/debris basin networks. The Ftables were also used to mitigate a limitation inherent in the other design storm models used by the District. This limitation exists because it is difficult to represent the curb inlet constraints and small-scale detention provided by homeowner basins in other models. Previously the design storm model of the Ventura River had added storage to Ftables in two watersheds to match the stream gage frequency analysis results. The amount of additional storage required in that model was about 0.35 inches assumed to occur across the entire developed area in the watershed for flows above the 10-yr peak flow level.

Because the urban areas in Simi Valley are more highly developed than the more rural Ventura River watersheds, the increase in storage as assumed to be double the depth that was used in the Ventura model. The increase in storage was applied as follows:

1. Find the subarea size for the HSPF model for the tributary of interest.
2. Use GIS to find the developed area in acres for that tributary watershed.
3. Find the comparable subarea in the District’s modified rational method model (VCRat) of the Calleguas watershed and extract the 2- to 100-yr flow levels provided in that document.
4. Calculate the increase in storage to be applied to the Ftable by 0.7 inches/12*developed area in watershed.
5. Apply this volume incrementally between the 10- and 100-yr flow levels relative to the increase in depth between these two flow levels in the Ftable.
6. Revise the Ftable data in the HSPF UCI file to reflect the increased storage.

Table 1 shows the area and flow information used to calculate the increase in storage to be applied to the Ftable 11 representing the White Oak watershed in the City of Simi

Valley. Table 2 shows the original and modified Ftable with the extra storage added to the flow between the 10- and 100-yr levels.

Table 1. Ftable Modification Data

HSPF Reach	VCRat Node	VCRat Area ac	2-Yr Peak cfs	5-Yr Peak cfs	10-Yr Peak cfs	50-Yr Peak cfs	100-Yr Peak cfs	500-Yr Peak cfs
11	88b	2361	222	562	914	2,103	2,812	5,025
HSPF Area	Developed Area ac	Undev. Area ac.	Storage Factor in.		Storage Volume af			
2,361	551	1,810	0.7		32.14			

Table 2. Modified Ftable Reach 11

Flow Depth (ft)	Surface Area (ac)	Volume (af)	Disch. (cfs)	Additional Volume Factor	Revised Volume (af)
0.0	0.00	0.00	0.0	0.000	0.00
1.0	3.30	4.05	86.7	0.000	4.05
2.0	4.00	8.50	258.4	0.000	8.50
3.0	4.86	13.70	479.3	0.000	13.70
4.0	5.61	19.19	734.0	0.000	19.19
5.0	6.68	25.12	1,013.4	0.159	30.22
6.0	9.59	32.39	1,311.7	0.317	42.59
7.0	11.52	40.04	1,624.6	0.476	55.35
8.0	15.89	48.51	1,949.3	0.635	68.92
9.0	19.37	57.99	2,283.6	0.794	83.50
10.0	22.55	68.07	2,625.8	0.952	98.68
10.3	27.66	73.63	2,788.3	1.000	105.77
10.5	29.62	80.48	2,991.8	1.000	112.62
10.8	31.73	88.09	3,219.0	1.000	120.23
11.0	33.73	95.74	3,466.3	1.000	127.88
12.0	35.00	105.00	4,000.0	1.000	137.14

2.1. Additional Subarea

Nyeland Drain was previously included in reach/subarea 503 of the Revolon Slough watershed. To be able to use the stream gage on the Nyeland Drain for calibration, the model was refined to model Nyeland Drain as a separate reach/subarea 507. The HSPF model results could then be compared to the gage 778 peak flow results for the years when the gage record was recorded.

2.2. Debris Basin Removal

District design storm hydrology models do not generally include debris basins for the following reasons:

1. Debris basins usually have limited flood storage volumes and operational outlets and so generally do not significantly attenuate the inflow hydrographs.
2. The emergency spillway flow that occurs in the 100-yr storm is difficult to model accurately as it is rapidly varying turbulent flow; therefore, the conservative assumption is made that the basin does not have any effect on the inflow hydrograph.
3. Debris basins generally do not have sufficient capacity for the expected 100-yr debris yield from the watershed so there is a good possibility that in the 100-yr storm some or all of the limited storage capacity will be filled by sediment when the peak flow arrives at the basin. This further limits the amount of attenuation that a basin can have on an inflow hydrograph.

Because of these reasons, only detention basins that are generally designed so that the operating spillway can convey the routed 100-yr outflow peak, with sufficient capacity for 125% of the expected 100-yr watershed sediment yield, are included in design storm runs. Due to this, the following debris basins were removed from the model:

1. South Branch Arroyo Conejo Debris and Bypass Basin- Reach 422
2. Fox Debris Basin- Reach 242
3. Coyote Debris Basin- Reach 232
4. Gabbert Debris Basin- Reach 222
5. West Camarillo Hills Debris Basin, West- Reach 524
6. West Camarillo Hills Debris Basin, East- Reach 523
7. Edgemoor Debris Basin- Reach 525
8. Crestview Debris Basin- Reach 526
9. Ferro Debris Basin- Reach 510
10. Honda Debris Basin- Reach 500
11. Tapo Hills Debris Basin 1- Reach 61
12. Santa Rosa Debris Basin- Reach 443

If the debris basin was represented in the model a short connecting reach with no associated subarea flow (such as Coyote, Fox, and Gabbert) the reach was removed from the run by commenting it out in the OPN SEQUENCE portion of the UCI file and connecting the upstream and downstream reach to each other. The other debris basins in the preceding list were were modeled as the only reaches associated with their respective subareas and so their Ftables were revised to act like channels with minimal storage rather than debris basins.

2.3. Additional Detention Basins

Detention basins built since the extended model was prepared in 2003 were added to the model by either revising their associated Ftables or splitting existing subareas and adding new reaches. These basins included Mt. Sinai (new reach 12), North Simi Drain basin (Ftable altered for reach 91), and Lang Creek (new reach 410). The basins were added to the model so that it would reflect the drainage system that exists in the watershed as of 2011 for use in proposed detention policy studies. Also, the basin locations were not directly upstream of any stream gages and so would not have much effect on the calibration of the model to the historic stream gage data.

The basin in the model in the Erringer Tributary location (reaches 71 and 72) had Ftable data for the historic debris basin. For the design storm run, the debris basin info was replaced by the Erringer Detention basin stage storage discharge data so that the detained flow could be modeled more accurately.

2.4. Other Model Changes

When the continuous model was extended to cover the entire Calleguas Watershed from the pilot study of the City of Simi Valley, the modelers assigned pervious and impervious land use parameter groups (perlnds and implnds in the HSPF input file) with similar characteristics for as many locations as possible in the model. This minimized the number of operations required to calculate runoff in the model, making it more efficient.

This approach led to a number of problems in calibrating the continuous model in that some perlnds were used in more than one watershed but assigned to just one rain gage. Because of this it was difficult to change the rain gage factors or hydrology parameters to calibrate the runoff in one watershed without changing the runoff in the adjacent watershed. Therefore, new perlnd and implnd series were added to the model so that each watershed had a unique set of parameter groups that could be calibrated individually.

Table 3 shows a summary of the reaches and their assigned perlnd parameter groups. Each reach also has an implnd parameter group assigned to it ending in the number 1. For example, the perlnd group with seven land uses starting with 11 and ending in 17 has an associated implnd parameter set designated as number 11.

Table 3. PerlInd Groups Assigned to HSPF Model Reaches

Perlnds											Reaches																																												
	1	2	3	4	5	6	7	8	9	10	11	12	21	23	24	25	26	31	41	42	43	44	45	46	51	52	61	62	63	64	65	71	72	81	82	91	92	101	103	106	107	109	952	964	190	191	192	193	201	202	203	204	205	206	207
11	x	x			x						x	x																																											
21	x	x			x											x																																							
31													x	x																																									
41					x								x	x																																									
51		x			x										x	x																																							
61																		x																																					
71		x	x	x	x													x								x						x	x										x												
81		x	x	x	x											x																																							
91						x															x	x																																	
101						x													x	x																																			
111						x																	x							x						x																			
121		x	x		x											x								x							x																								
131																											x	x	x	x	x					x	x							x											
141					x	x	x																	x		x					x	x	x		x		x																		
151																									x									x																					
161																																			x																				
171										x																															x	x													
181								x																											x		x																		
191																																																							
201																																													x	x									
211																																															x	x		x	x	x			
221																																																				x	x	
231																																																						
241																																																						
251																																																						
261																																																						
271																																																						x
281																																																						
291																																																						
301																																																						
311																																																						
321																																																						
331																																																	x						
341																																						x	x	x	x														
351																																																						
361																																																						
371																																																						
381									x	x																														x		x													
391																																																						
751																																																						
401																																																						

Table 3 (Continued)

Reaches

Perlnds	211	212	221	223	225	227	231	233	241	243	301	302	303	304	305	306	307	311	401	402	403	404	405	406	407	408	411	421	423	431	441	442	443	500	501	502	503	504	505	506	507	510	511	512	513	514	521	522	523	524	525	526	531	541	542
11																																																							
21																																																							
31																																																							
41																																																							
51																																																							
61																																																							
71																																																							
81																																																							
91																																																							
101																																																							
111																																																							
121																																																							
131																																																							
141																																																							
151																																																							
161																																																							
171																																																							
181																																																							
191																														x	x		x																						
201	x		x		x																																																		
211		x	x	x	x																																																		
221																																																							
231																			x	x							x																												
241																					x	x						x	x	x																									
251											x	x	x	x				x																																					
261						x	x		x																																														
271						x	x	x	x	x																																													
281																																				x	x																		
291																																					x	x	x						x	x	x	x	x	x	x	x	x		
301															x	x	x																																						
311																																																							
321																							x									x																							
331																																																							
341																																																							
351																								x	x																														
361																																		x	x																				
371																																			x																				
381																																																							
391																																									x	x	x	x											
751																										x																													
401																																								x														x	x

2.5. Design Storm Rainfall

5-minute design storm rainfall data sets for the rain gages included in the calibrated continuous HSPF were prepared using the approach from the Santa Clara and Ventura River design storm HSPF models. These models used the Balanced Storm Method (also called Alternating Block) commonly used by the Los Angeles District of the Army Corps of Engineers (Corps) as a way of developing design storm hyetographs. For these studies, developing the hyetographs included the following steps:

1. Perform a Pearson III Frequency Analysis of the rainfall data using the annual maxima data at intervals ranging from 5-minutes to 24-hours.
2. Plot the depth-versus-duration data on a log-log plot and fit a power equation trendline through the results.
3. Establish the desired rainfall storm duration. In this study, a 24-hour duration storm was used.
4. Establish a duration interval that divides equally into an hour. For this study, a 5-minute interval was used.
5. Tabulate the duration in increasing values of the interval.
6. Use the regression equation from Step 2 to calculate the rainfall depth for each interval.
7. Calculate the incremental rainfall depth for each time period by subtracting the cumulative rainfall at the previous time step from the cumulative rainfall for the current time step.
8. If the sum of the incremental values is larger than the 24-hour depth from the frequency analysis, reduce the incremental values by a constant factor for each interval so that the sum matches the 24-hour depth.
9. Distribute the incremental depth values. Use time blocks that correlate with the duration intervals. Assign the highest incremental depth to the central time block, and arrange the remaining incremental depth blocks in descending order, alternating between the upper and lower time blocks away from the central time block.

The resulting ordinates of the hyetographs for each rain gage were then used as input to the HSPF Model. For rain gages that only have daily records, the 24-hour value (resulting from a frequency analysis of the daily gage data) was applied to the dimensionless distribution of an adjacent gage concluded to be a good surrogate for the gage of interest. Table 4 summarizes the rain data used in the HSPF Design Storm Modeling. Figure 2 shows the depth-versus-duration data and trendline for Tapo Canyon gage 196. Figure 3 shows the resultant hyetograph for this gage. Figure 4 shows the locations of the rain gages in the watershed.

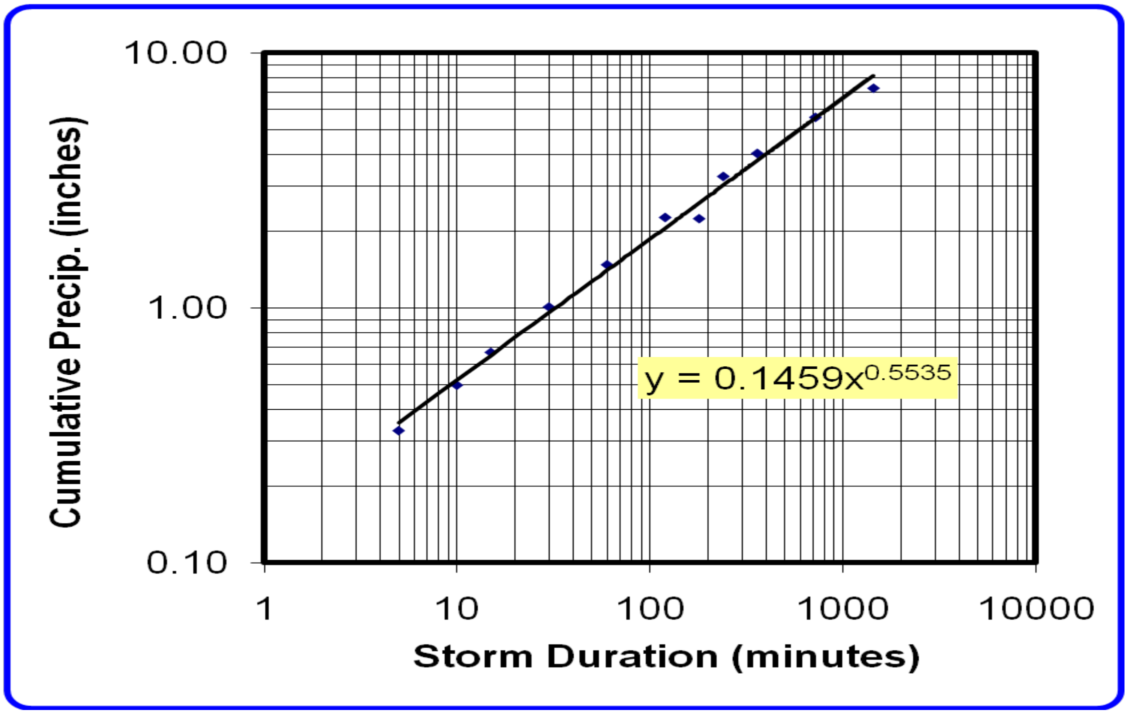


Figure 2. Depth-Duration Data, Tapo Cyn Gage 196

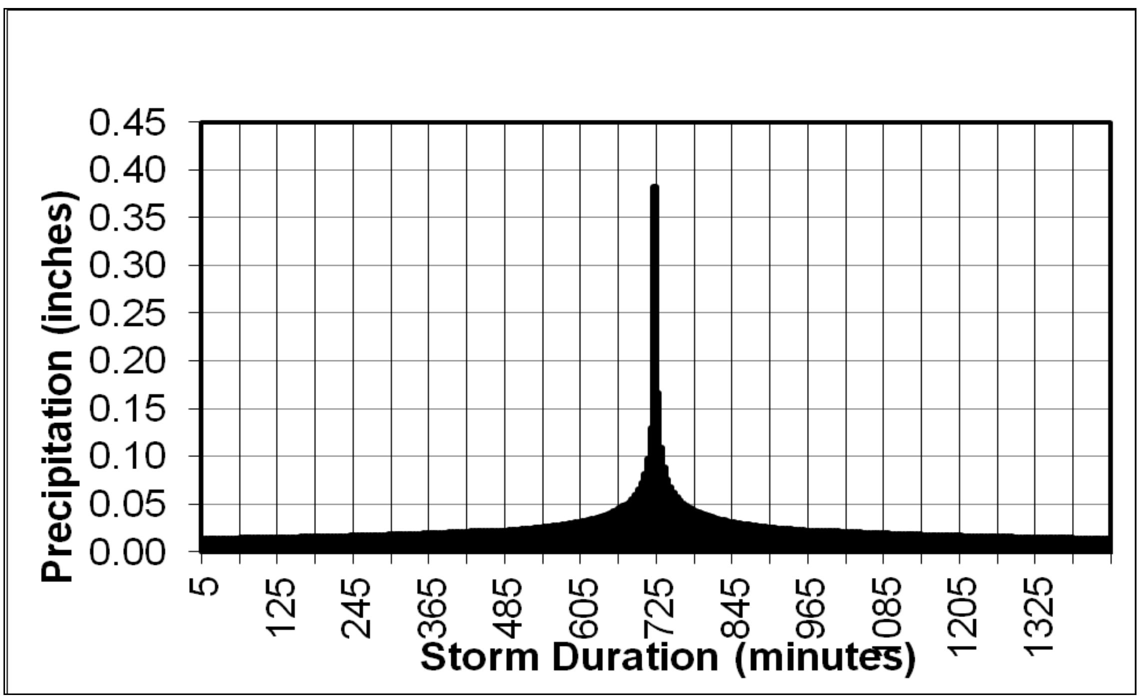


Figure 3. Balanced Hyetograph Tapo Cyn Gage 196

Table 4. Design Storm Rain Gage Data

Gage Number	Name	Tributary	Stream Gage	Perlnd Group(s)	Reaches
234	Las Llajas	Las Llajas, White Oak	Arroyo Simi-White Oak, Stow, Royal	11, 21, 41, 51	1, 11, 12, 2, 21-23, 24, 25
249	Simi Hills	Meier Cyn	Royal	61	31
193	Santa Susana	Dry Cyn, Erringer, Runkle, N. Simi Drn	Madera	71, 81, 141,	52, 952, 71, 72, 3-7, 904, 65, 92, 81
242	Tripas	Tapo Cyn	Tapo, Madera	31,91	41
196	Tapo Cyn	Dry Cyn, Tapo Cyn, N. Simi Drn	Tapo, Madera	101, 111, 121, 131	42-46, 61-63, 91
227	Lake Bard	Bus Cyn, Sycamore Cyn, Tierra Rejada, N Fk Arroyo Conejo	Arroyo Las Posas Hitch, Conejo	161, 181, 171, 331, 341, 381, 191	101-105, 107-109. 82, 8-10, 106, 109, 201, 431, 441, 443
49	Santa Rosa Valley	Arroyo Las Posas, Conejo	Arroyo Las Posas Hitch, Conejo	221, 321	194, 205, 206, 405, 406
194	Camarillo-Adohr	Conejo	Calleguas	251, 751, 351	195, 301-304, 311, 406-408,
250	Happy Camp	Happy Camp	Arroyo Las Posas Hitch	201	190, 191, 211
141	Moorpark	Arroyo Las Posas, Walnut, S. Grimes	Gabbert, Arroyo Las Posas	211	202-204, 212, 221-223, 225
169	1000 Oaks	Lang Ck, Arroyo Conejo	Arroyo Conejo	231	401, 402, 410, 411
188	Newbury Park	SB Arroyo Conejo (SBAC)	SBAC, Conejo	241	403, 404, 421-423
238	S. Mountain	Beardsley	Revolon	261, 361	500
190	Somis-Bard	Arroyo Las Posas, Coyote, Fox, Mahan, Beardsley	Beardsley, Calleguas @ 101	271, 371	207, 227, 231-233, 241-243, 501
175	Saticoy	Beardsley, Ferro, Sta Clara Drn, Nyeland	Nyeland, Sta Clara Drn, Beardsley, Revolon	281, 391	502-504, 512, 507, 510, 511
259	Camarillo PVWD	Camarillo Hills Drn, Revolon	Camarillo Hills Drn, Revolon	291	505, 513, 514, 521-526, 531
177	Camarillo Pacific Sod	Mugu Drn, Calleguas	Calleguas	311, 401	305-307, 541, 542, 506

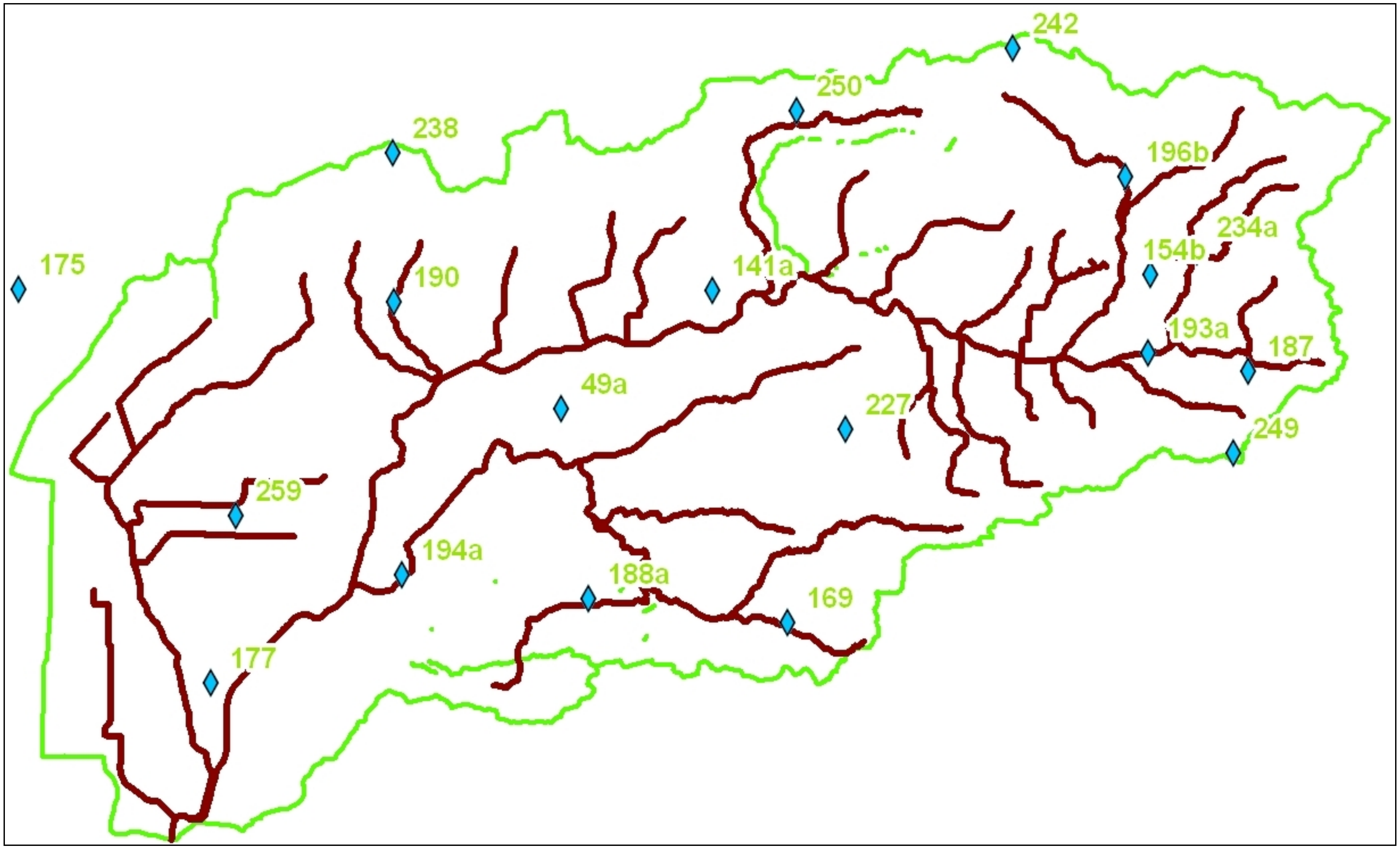


Figure 4. Rain Gage Location- Calleguas Creek Watershed

3. HSPF DESIGN STORM MODEL

The parameters controlling runoff in the HSPF model are shown in Figure 5. The calibration of the model to the historic runoff data was described in the District Calibration Report (2011).

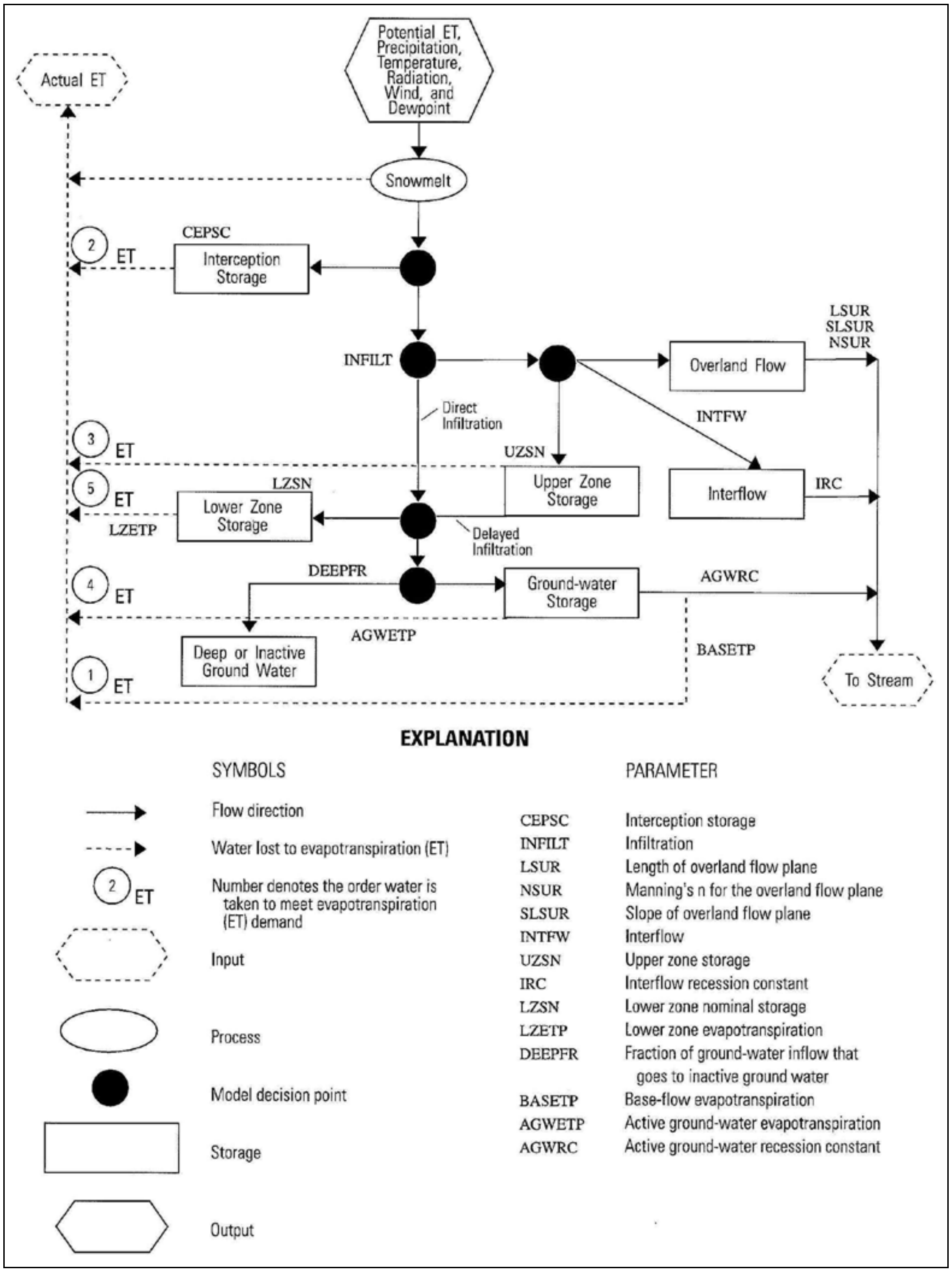


Figure 5. HSPF Parameters and Conceptual Model of Flow

Previous work with HSPF design storm models has shown the results to be relatively insensitive to parameter changes in the infiltration and evapotranspiration data sets.

The HSPF model results appear to be most sensitive to changes in the applied rainfall intensities, initial storage volumes in the channel reaches, and the Ftable data used for routing the data. The following sections will discuss how these were handled in the design storm model preparation and use.

3.1. Design Storm Initial Conditions

The initial conditions in the model were set following the approach used in the Santa Clara and Ventura River HSPF design storm models. The approach consists of running the model to the end of the storm with the most rainfall in recent years and using the storage volumes from the run to provide the initial conditions. The design storm rainfall is then applied to the design model. For the Ventura County models, the most recent period with the highest soil saturations occurred from December 26, 2004 through January 9, 2005. This period led to 50-yr peak flow levels in some of the streams in the Ventura and Santa Clara River watersheds.

Because of the dominant storm direction for this historical storm, antecedent moisture conditions were a little drier in the Calleguas Creek watershed, causing the runoff peaks to be at the 10-yr level or less during the same period. The sensitivity of the design storm peaks to the antecedent moisture conditions was tested to make sure the drier conditions were not biasing the model results. The results of the sensitivity tests will be discussed in the Model Results Section.

For the Calleguas Model, the continuous model was run at 15-min timesteps through the end of the day on January 9, 2005. The storages and fluxes for the perlnd and implnd groups and reaches were then entered into the design storm UCI file as the initial conditions for the design storm run starting at midnight of January 10, 2005.

3.2. Areal Reduction

Because the rain hyetographs used as input to the model were generated from frequency analyses of the rain gages, they represented the highest intensities that can occur in a localized area. In Ventura County, storm cells that can produce these intensities are considered to have a maximum size of about 1 sq mi. For watersheds larger than this, the average intensities during the design storm are reduced by an areal reduction (AR) factor that varies with the size of the watershed. The HEC-HMS Technical Reference Manual (Corps, 2000) provides AR curves for this use as shown in Figure 6. The AR factor is applied to each rain gage data set included in the tributary watershed to reduce the intensities for the design storm run.

Because different AR factors were required for the various watershed sizes associated with the stream gages used in the calibration, a number of design storm runs were required. The runs with different AR factors included the Calleguas CSUCI model, Conejo gage model, Madera gage model, Royal gage model, Calleguas at Hwy 101 gage model, and a Tributary model focusing on tributaries where the AR factor was close to 1.0.

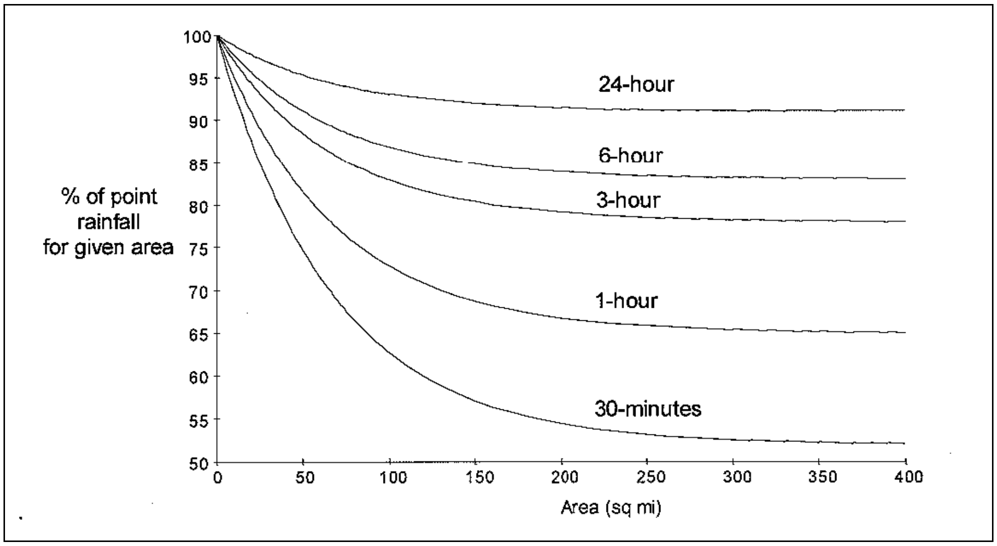


Figure 6. HEC-HMS Areal Reduction Curves for Design Storms

3.3. Rainfall Calibration Factors

In order to match the stream gage calibration data, it was necessary to apply an additional rainfall calibration factor to the design storm rain datasets, in addition to the AR factors and the rainfall factors resulting from the continuous model calibration (MFACT parameter in HSPF input file). The combined rainfall factor used in the design storm model was thus:

(MFACT) x (AR Factor) x (Calibration Factor) = Combined Rainfall Factor

3.4. Stream Gage Calibration Data

Figure 7 shows the locations and numerical designations of the stream gages used in the design storm model calibration. The design storm 100-yr peaks used for many of the stream gage calibration points were obtained from the Corps (2003) HEC-HMS model study of the Calleguas watershed. The Corps did a graphical analysis of the stream gage data for the gages they evaluated because the data sets did not fit the requirements for the standard Bulletin 17b (USGS, 1982) flow frequency analysis due to significant changes in land use and climate in the watershed. The Corps results have been used since 2003 as the design storm peaks in the watershed.

Table 5 shows the stream gage data for the watershed used in the design storm calibration analysis. In some cases, however, the Corps results appear to be conservative when compared to the historic maxima peaks recorded at the stream gages. The historic peak to Bulletin 17b Q100 ratios for the Calleguas gages have a mean of 0.75 with a standard deviation of 0.16. The ratios range from 0.54 to 1.10. The ratios greater than 1.0 (historic peak > Q100) are from smaller urbanized watersheds with relatively short records.

Table 5 – Stream Gage Calibration Data

Gage #	Gage Location	Bulletin 17B Q100 cfs	Corps 2003 Q100 cfs	Hist. Max. Peak cfs	Hist. Peak/ Bull 17 Ratio	Hist. Peak/ Corps Ratio	Record Length yrs	Water-shed Area sq mi
776	REVOLON	16,500	13,900	12,900	0.78	0.93	26	46.0
778	NYELD778	2,560	NA	2,546	0.99	-	18	11.2
780	BEARDSLY	7,790	NA	5,359	0.69	-	12	24.9
781	STACLARA	1,440	NA	1,000	0.69	-	15	7.7
800	CONEJO	17,900	22,500	13,300	0.74	0.59	36	64.0
802	ROYAL	9,540	12,400	5,320	0.56	0.43	37	32.6
803	MADERA	12,200	17,200	10,700	0.88	0.62	62	71.0
805	CC_CSUCI	40,400	38,500	25,900	0.64	0.67	43	248.0
806	CCHWY101	33,500	28,300	18,000	0.54	0.64	36	187.0
830	SBAC830	5,400	6,850	4,240	0.79	0.62	35	12.5
831	ASWO831	1,760	3,170	1,200	0.68	0.38	34	3.2
832	TAPO832	5,070	NA	4,140	0.82	-	36	20.2
833	BUSCA833	1,190	NA	1,200	1.01	-	35	4.9
834	SYCAM834	805	1,250	608	0.76	0.49	21	8.1
835	CAMHL835	3,240	NA	3,580	1.10	-	20	5.3
836	ARCON836	6,540	9,000	4,300	0.66	0.48	30	14.2
838	STARO838	5,250	NA	2,986	0.57	-	18	13.7
839	GABWL839	2,740	NA	1,820	0.66	-	19	6.8
841	ARPOS841	24,900	22,100	16,200	0.65	0.73	14	129.0
				Mean	0.75	0.60		
				St Dev	0.16	0.15		
				Median	0.69	0.62		
NA= Not Analyzed								
841 analyzed by Corps as discontinued upstream gage 801 with 115 sq mi watershed								

The ratio mean using the Corps data is 0.60 and in 4 cases (Royal, Arroyo Simi above White Oak, Sycamore, and Arroyo Conejo) the ratios are less than 0.50. These results will be evaluated in more detail during the discussion of the calibration results.

4. DESIGN STORM MODEL CALIBRATION RESULTS

Table 6 presents a summary of the results from the various design storm models. It also shows available stream gage design peaks and design peaks from the District's modified rational method model of the watershed (VCRat) prepared in 2003. Results from the five design storm models using the different AR factors appropriate for each gage location are provided, along with a column entitled "Selected Model Q100" which repeats the model result with the AR factor that is appropriate for the watershed size being evaluated. The difference calculation subtracts the “Selected Model Q100” from the “Design Q100” for the gaged locations or the “VCRat Outflow” data for ungaged locations.

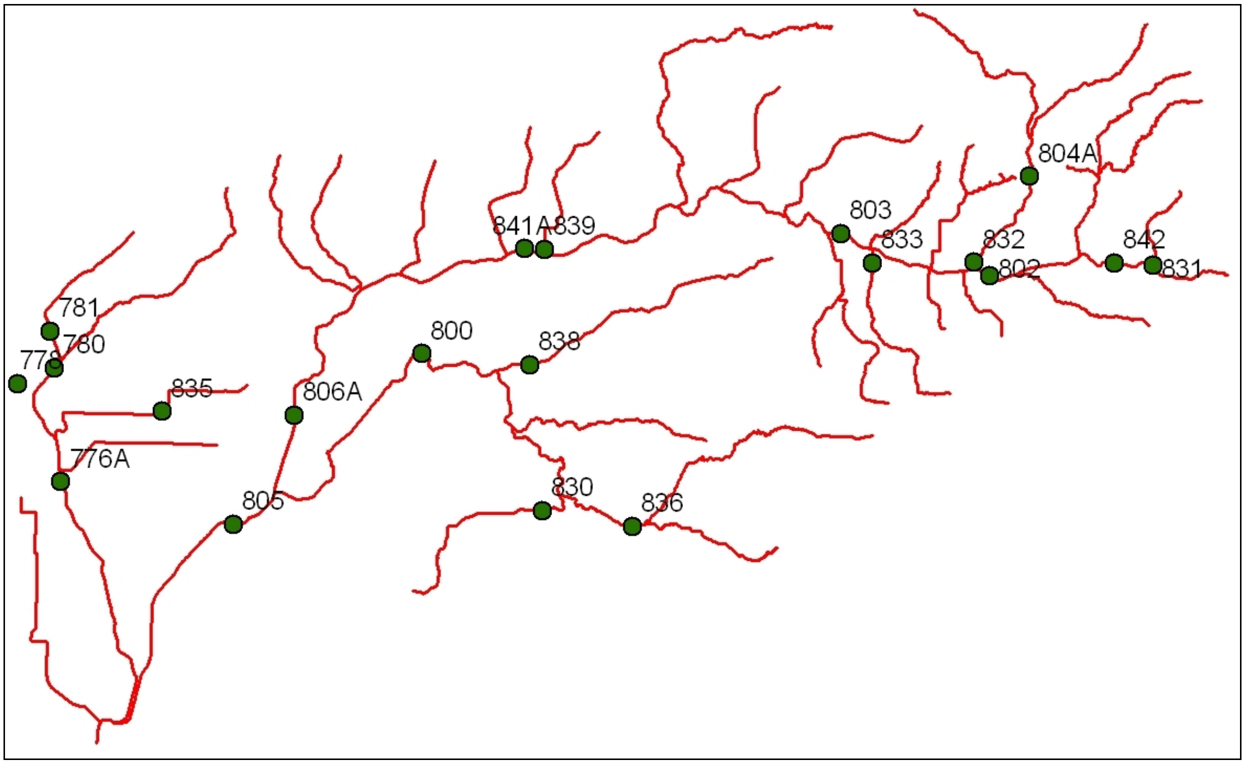


Figure 7. Design Storm Model Stream Gage Locations

Table 6 – Design Storm Model Calibration Results

HSPF ID	HSPF Name	Design Q100 cfs	Hist. Max. cfs	Ratio	2003 VCRat Node	VCRat Area ac	VCRat Inflow cfs	VCRat Outflow	CSUCI Model Q100 cfs	Trib. Q100 cfs	Call101 Model - Q100 cfs	Madera Model Q100 cfs	Royal Model Q100 cfs	Selected Model Q100 cfs	Diff. cfs	% Diff.	Selected Model	Calib Factor	AR Factor	Notes
Gage	REVOLON	13,900	12,900	0.93	5711a	28,199		13,649	13,900	18,300	13,900	13,900	13,900	13,900	-	0%	CSUCI	0.795	0.959	
Gage	NYELD778	2,560	2546	0.99	5401bc	4,855		3,008	2,060	3,130	2,070	2,060	2,060	3,130	(570)	-22%	Trib	1.000	0.990	
Gage	BEARDSLY	7,790	5,359	0.69	5275ac	13,919		8,357	7,760	11,900	7,790	7,760	7,760	7,790	-	0%	Call101	0.783	0.976	
Gage	STACLARA	1,440	1,000	0.69	5264c	1,800		2,189	2,740	4,400	2,750	2,740	2,740	4,400	(2,960)	-206%	Trib	1.000	0.990	
Gage	CONEJO	22,500	13,300	0.59	3630bd	4,170		23,331	15,100	20,100	21,500	17,700	18,100	21,500	1,000	4%	Call101	1.100	0.947	
Gage	ROYAL	12,400	5,320	0.43	319a	20,326		13,691	5,630	8,050	6,540	7,280	7,720	7,720	4,680	38%	Royal	1.000	0.969	
Gage	MADERA	17,200	10,700	0.62	722ab	45,013		17,221	13,300	18,900	15,500	17,200	17,900	17,200	-	0%	Madera	0.985	0.943	
Gage	TAPO804	5,070	4,140	0.82	359b	11,425		11,176	3,610	5,250	4,230	4,720	4,850	5,250	(180)	-4%	Trib	1.000	0.990	Design storm peak from 832
Gage	CC_CSUCI	38,500	25,900	0.67	3850ac	159,771		38,419	38,500	53,500	48,800	48,200	49,400	38,500	-	0%	CSUCI	0.862	0.912	
Gage	CCHWY101	28,300	18,000	0.64	2039a	107,746		27,727	24,800	35,100	28,300	31,200	32,100	28,300	-	0%	Call101	0.950	0.914	
Gage	SBAC830	6,850	4,240	0.62	2690bc	8,637		7,597	3,900	4,850	5,140	4,400	4,460	4,850	2,000	29%	Trib	1.000	0.990	
Gage	ASWO831	3,170	1,200	0.38	40ab	1,736		3,079	929	1,390	1,100	1,250	1,340	1,390	1,780	56%	Trib	1.000	0.990	
Gage	TAPO832	5,070	4,140	0.82	417b	13,109		3,333	4,010	5,760	4,690	5,220	5,340	5,760	(690)	-14%	Trib	1.000	0.990	
Gage	BUSCA833	1,190	1,200	1.01	648b	3,202		2,816	941	1,250	1,050	1,140	1,170	1,250	(60)	-5%	Trib	1.000	0.990	
Gage	SYCAM834	1,250	608	0.49	812b	5,276		1,934	485	593	524	557	565	593	657	53%	Trib	1.000	0.990	
Gage	CAMHL835	3,240	3,580	1.10	5513c	3,013		4,014	2,160	2,770	2,170	2,160	2,160	2,770	470	15%	Trib	1.000	0.990	
Gage	ARCON836	9,000	4,300	0.48	2987c	9,258		10,271	4,670	5,580	6,060	5,210	5,270	5,580	3,420	38%	Trib	1.000	0.990	
Gage	STARO838	5,250	2,986	0.57	3538c	8,419		4,757	2,450	3,700	4,070	3,100	3,180	3,700	1,550	30%	Trib	1.000	0.990	
Gage	GABWL839	2,740	1,820	0.66	1678bd	4,224		3,694	3,310	4,650	3,760	4,150	4,270	4,650	(1,910)	-70%	Trib	1.000	0.990	
Gage	ARPOS841	22,100	16,200	0.73	1683a	82,396		23,330	18,400	26,700	21,700	24,100	24,800	21,700	400	2%	Call101	0.950	0.914	
Gage	ARSTOW84	3,944	1,880	0.48	108ab	5,004		6,404	2,930	4,000	3,340	3,670	3,880	4,000	(56)	-1%	Trib	1.000	0.990	
9003	ASABVWO				306ac	19,765		13,731	4,300	6,090	5,010	5,550	5,870	5,870	7,861	57%	Royal			
9005	ASABVTAP				325a	20,687		13,666	5,760	8,210	6,680	7,430	7,870	7,870	5,796	42%	Royal			
9006	ASABVDRY				448a	35,918		15,644	10,400	14,900	12,100	13,500	14,100	14,100	1,544	10%	Royal			
9007	ASABVBUS				567a	39,465		15,955	11,500	16,500	13,400	14,900	15,500	14,900	1,055	7%	Madera			
9009	ASABVSYC				852ab	51,622		17,141	13,400	19,000	15,500	17,200	17,900	17,200	(59)	0%	Madera			
9010	ASBLWMAD				875ab	52,410		17,174	13,800	19,500	16,000	17,700	18,400	17,700	(526)	-3%	Madera			
9011	WHITEOAK				87bc	2,313		2,817	1,260	1,720	1,450	1,590	1,680	1,720	1,097	39%	Trib			
9012	MTSINAI				56b	911	1,704	930	498	602	543	574	593	602	328	35%	Trib			
9021	UPLLAJAS				159b	4,327		4,545	1,870	2,730	2,220	2,470	2,640	2,730	1,815	40%	Trib			
9022	22LLAJAS				160b	4,327	4,545	543	459	506	477	491	501	506	37	7%	Trib			
9023	CHIVO				166c	2,528		2,180	717	1,080	859	967	1,040	1,080	1,100	50%	Trib			
9024	MARDIVER				182c	381		940	319	489	390	443	474	489	451	48%	Trib			
9025	LWRLLAJA				196b	7,953		3,923	1,350	1,970	1,600	1,780	1,900	1,970	1,953	50%	Trib			
9031	MEIERCYN				304cd	3,869		4,377	1,320	2,040	1,590	1,810	1,940	2,040	2,337	53%	Trib			
9041	WINDMCYN				353c	1,357		2,274	991	1,400	1,140	1,260	1,290	1,400	874	38%	Trib			
9042	LWRGILLI				355c	3,145		3,788	1,130	1,630	1,310	1,460	1,500	1,630	2,158	57%	Trib			

HSPF ID	HSPF Name	Design Q100 cfs	Hist. Max. cfs	Ratio	2003 VCRat Node	VCRat Area ac	VCRat Inflow cfs	VCRat Outflow	CSUCI Model Q100 cfs	Trib. Q100 cfs	Call101 Model - Q100 cfs	Madera Model Q100 cfs	Royal Model Q100 cfs	Selected Model Q100 cfs	Diff. cfs	% Diff.	Selected Model	Calib Factor	AR Factor	Notes
9043	UPRTRIPA				333b	2,556		3,770	1,120	1,690	1,360	1,530	1,570	1,690	2,080	55%	Trib			
9044	LWRTRIPA				347bc	6,888		7,742	2,450	3,540	2,870	3,200	3,280	3,540	4,202	54%	Trib			
9051	51RUNKLE				424b	954	2,200	1,484	226	863	417	614	664	863	621	42%	Trib			
9052	LWRRUNKL				440b	1,782		2,065	576	1,050	748	894	929	1,050	1,015	49%	Trib			
9061	61TAPO_1				460c	110	290	43	21	31	25	28	29	31	12	28%	Trib			
9062	62TAPO_2				452b	140	380	80	48	59	52	56	57	59	21	26%	Trib			
9063	TAPODIVE				465b	385		389	242	355	286	321	329	355	34	9%	Trib			
9064	UPPRDRY				487c	732		1,272	429	696	534	615	633	696	576	45%	Trib			
9065	LWRDRY				520b	2,234		2,685	1,100	1,550	1,280	1,410	1,440	1,550	1,135	42%	Trib			
9071	71ERRING				542CD	333	767	95	79	85	81	83	84	85	10	10%	Trib			
9072	LWRERRIN				552b	874		1,089	246	330	278	304	310	330	759	70%	Trib			
9081	UPRBUS				598b	1,759		2,669	550	729	603	654	671	729	1,940	73%	Trib			
9091	UPRNSIMI				665b	699		1,017	588	758	628	658	664	758	259	25%	Trib			
9092	LWRNSIMI				705b	1,711		1,641	1,030	1,400	1,170	1,280	1,300	1,400	241	15%	Trib			
9101	UPROAK				738bd	1,319		2,083	222	381	273	321	334	381	1,702	82%	Trib			
9102	102OAK								223	380	272	320	333	380	-	-	Trib			HSPF doesn't match VCRat model bdry
9103	103OAK1				739b	1,477		2,228	252	430	307	361	376	430	1,798	81%	Trib			HSPF doesn't match VCRat model bdry
9104	104OAK								255	432	309	364	379	432	-	-	Trib			HSPF doesn't match VCRat model bdry
9105	105OAK							800	251	429	306	362	376	429	371	46%	Trib			HSPF doesn't match VCRat model bdry
9106	LWROAK								395	562	459	506	518	562	-	-	Trib			HSPF doesn't match VCRat model bdry
9107	UPRSYCAM				795bc	4,390		5,108	626	648	909	729	814	835	909	4,199	82%			
9108	108SYCAM				795bc	4,390	5,108	1,249	200	200	200	200	200	200	200	1,049	84%			
9190	ALAMOSCY				1000b	3,804		3,920	1,940	2,750	2,270	2,530	2,580	2,750	1,170	30%	Trib			
9191	CAMPUSRD				1122b	3,223		3,595	3,050	4,320	3,530	3,920	4,010	4,320	(725)	-20%	Trib			VCRat does not include Strathearn, HSPF does
9192	192CASTR				1357b	304	496	496	111	156	133	144	147	156	340	69%	Trib			
9193	193PEACH				1535bd	1,619	2,289	1,486	737	861	786	824	833	861	625	42%	Trib			
9194	MOORPERC								5	5	5	5	5	5	-	-	Trib			Perc pond not in VCRat model
9195	CAMPERC								1	1	1	1	1	1	-	-	Trib			Perc pond not in VCRat model
9201	ASABVALA				1001a	52,947		17,132	13,900	19,100	16,100	17,500	18,100	17,500	(368)	-2%	Madera			
9202	ASABVBIG				1038ab	58,054		17,416	14,800	20,500	17,200	18,700	19,300	18,700	(1,284)	-7%	Madera			
9203	ASABVHAP				1211a	64,834		20,060	15,700	22,300	18,500	20,300	20,900	20,300	(240)	-1%	Madera			
9204	ARRLASPO				1480a	74,905		22,091	16,900	24,400	20,000	22,100	22,800	20,000	2,091	9%	Hitch			
9206	ALP HITC				1717a	88,364		24,242	19,400	28,500	22,900	25,600	26,400	22,900	1,342	6%	Hitch			
9207	ALPSOMIS				1769a	95,721		25,638	21,200	30,800	24,800	27,800	28,600	24,800	838	3%	Hitch			
9211	UPRHAPPY				1324b	6,762		4,025	3,330	4,940	4,010	4,450	4,570	4,940	(915)	-23%	Trib			
9212	LWRHAPPY				1342b	7,553		4,042	2,710	4,620	3,540	4,090	4,220	4,620	(578)	-14%	Trib			
9221	221GABBE				1669c	2,441		1,894	2,350	2,320	2,730	3,020	3,090	2,320	(426)	-22%	Trib			

HSPF ID	HSPF Name	Design Q100 cfs	Hist. Max. cfs	Ratio	2003 VCRat Node	VCRat Area ac	VCRat Inflow cfs	VCRat Outflow	CSUCI Model Q100 cfs	Trib. Q100 cfs	Call101 Model - Q100 cfs	Madera Model Q100 cfs	Royal Model Q100 cfs	Selected Model Q100 cfs	Diff. cfs	% Diff.	Selected Model	Calib Factor	AR Factor	Notes
9222	222GABBE				1669c	2,441		1,894									Trib			Debris basin not included in design run
9225	GRIMESCY				1703bc	3,526		2,212	2,470	2,910	2,640	2,770	2,810	2,910	(698)	-32%	Trib			HSPF area 4,322 ac
9227	MAHANBAR				1753b	1,385		961	4,810	8,410	5,660	6,320	6,480	8,410	(7,449)	-775%	Trib			HSPF model includes Long, Sand Cyns
9231	231COYOT				1839bc	4,475		3,488	4,130	4,360	5,220	5,980	6,160	4,360	(872)	-25%	Trib			
9232	232COYOT				1839bc	4,475	3,488	3,488	6,310	4,360	6,310	6,310	6,310	4,360	(872)	-25%	Trib			232 reach turned off in design run
9233	COYOTE				1844b	5,015		3,588	4,580	4,940	5,720	6,620	6,830	4,940	(1,352)	-38%	Trib			
9241	241FOX				1896c	3,229		2,664	3,220	3,290	3,770	4,160	4,250	3,290	(626)	-23%	Trib			
9242	242FOX				1896c	3,229	2,664	2,664	4,240	3,290	4,240	4,240	4,240	3,290	(626)	-23%	Trib			242 reach turned off in design run
9243	FOXBLWDB				1897c	3,279		2,663	3,310	3,340	3,870	4,220	4,310	3,340	(677)	-25%	Trib			
9301	CALLSOMI				1904a	104,367		27,626	24,000	33,400	27,400	30,200	31,100	27,400	226	1%	Hitch			
9303	CALBLW10				2087a	109,256		27,659	24,300	34,200	28,100	31,000	31,900	28,100	(441)	-2%	CSUCI			
9305	CALLEG30				3943ab	164,032		38,751	36,500	51,900	46,600	46,200	47,400	36,500	2,251	6%	CSUCI			
9306	CALLEG30				4020a	167,330		37,661	34,500	48,300	43,100	42,800	43,800	34,500	3,161	8%	CSUCI			
9307	CALLEG30				5941ab	205,621		44,465	42,000	58,700	49,500	49,100	50,000	42,000	2,465	6%	CSUCI			
9311	311JOHNS				1957b	228	559	559	147	213	174	194	198	213	346	62%	Trib			
9401	UPRARCON				2974d	5,111		7,869	3,420	3,970	4,400	3,720	3,750	3,970	3,899	50%	Trib			
9403	LOARRCON				3112b	22,302		16,953	9,890	12,500	13,300	11,300	11,500	12,500	4,453	26%	Trib			
9404	LOARRCON				3302b	29,168		22,589	12,300	15,700	16,600	14,100	14,400	16,600	5,989	27%	Con			
9406	CONEJO40				3726b	45,936		22,977	15,500	21,000	22,500	18,500	18,800	22,500	477	2%	Con			
9407	CONEJO40				3772b	48,076		22,716	15,700	21,300	22,900	18,800	19,200	22,900	(184)	-1%	Con			
9408	CONEJO40				3811be	49,677		22,343	15,200	20,600	22,000	18,200	18,500	22,000	343	2%	Con			
9410	LANGBAS				2764ce	2,158	2,837	647	533	604	618	573	577	604	43	7%	Trib			
9411	LANGCK				2807c	3,892		3,351	1,260	1,620	1,680	1,500	1,520	1,620	1,731	52%	Trib			No Lang Basin in VCRat model
9421	421SBAC				2338bc	2,544	3,652	2,387	1,450	2,160	2,360	1,810	1,860	2,160	227	10%	Trib			
9422	422SBAC				2338bc	2,544	3,652	2,387	NA	NA	NA	NA	NA	NA	NA	NA	Trib			Reach 422 turned off in design storm model
9431	NFARRCON				3292c	5,312		6,071	2,430	2,980	3,140	2,730	2,760	2,980	3,091	51%	Trib			
9441	UPRSTARO				3428cd	4,516		4,695	1,040	1,880	2,130	1,470	1,530	1,880	2,815	60%	Trib			
9443	443STARO				3568cd	9,186	4,735	4,735	1,150	1,620	1,750	1,390	1,420	1,620	3,115	66%	Trib			
9500	500HONDA				5007a	817	903	903	846	1,450	851	846	846	1,450	(547)	-61%	Trib			
9501	BEARDS50				5085a	6,056		4,386	3,050	4,610	3,060	3,050	3,050	4,610	(224)	-5%	Trib			
9502	REVLO502				5272ac	13,841		8,352	4,910	7,360	4,930	4,910	4,910	4,930	3,422	41%	Beards			
9503	REVLO503				5406ab	19,003		10,003	9,190	13,000	9,230	9,190	9,190	9,190	813	8%	Rev			
9504	REVLON50				5413a	19,268		9,940	9,480	12,800	9,500	9,480	9,480	9,480	460	5%	Rev			
9506	REVLON50				5921a	37,440		13,781	13,300	16,700	13,400	13,300	13,300	13,300	481	3%	Rev			
9510	510FERRO				5304d	514	820	820	356	593	358	356	356	593	227	28%	Trib			
9512	SCLARADR				5401bc	4,855		3,008	2,860	4,580	2,880	2,860	2,860	4,580	(1,572)	-52%	Trib			
9513	513RAMON				5167b	254	583	131	125	226	125	125	125	226	(95)	-73%	Trib			VCRat imports hydrograph

HSPF ID	HSPF Name	Design Q100 cfs	Hist. Max. cfs	Ratio	2003 VCRat Node	VCRat Area ac	VCRat Inflow cfs	VCRat Outflow	CSUCI Model Q100 cfs	Trib. Q100 cfs	Call101 Model - Q100 cfs	Madera Model Q100 cfs	Royal Model Q100 cfs	Selected Model Q100 cfs	Diff. cfs	% Diff.	Selected Model	Calib Factor	AR Factor	Notes
9514	514LASPO						507	62	57	62	57	57	57	62	0	0%	Trib			
9522	LWRCAMHL				5601cd	5,550		4,610	3,100	3,970	3,100	3,100	3,100	3,970	640	14%	Trib			
9523	523CAMEA	285			5476d	186		473	116	183	116	116	116	183	290	61%	Trib			
9524	524CAMWE	229			5478e	68		211	154	205	154	154	154	205	6	3%	Trib			
9525	525EDGE	250			5491e	101		268	262	356	263	262	262	356	(88)	-33%	Trib			
9526	526CREST	218			5522e	70		191	124	168	124	124	124	168	23	12%	Trib			
9531	PLSNTVAL				5698b	1,132		883	1,330	1,700	1,340	1,330	1,330	1,700	(817)	-93%	Trib			HSPF area 2,241 ac
9541	MUGU541							na	2,660	3,460	2,670	2,660	2,660	3,460	-	-	Trib			Mugu Drn not in VCRat model
9542	MUGU542							na	3,350	4,730	3,360	3,350	3,350	4,730	-	-	Trib			Mugu Drn not in VCRat model
9904	ASATROYA				319a	20,326		13,691	5,630	8,050	6,540	7,280	7,720	7,280	6,411	47%	Royal			
9952	RUNKLE				426b	1,092		1,512	246	892	434	641	698	892	620	41%	Trib			
9964	DRYUSEP				488c	787		1,286	469	755	581	667	687	755	531	41%	Trib			

The results show that a rainfall calibration factor ranging from 0.795 to 0.862 was required to match the peak flow data from the Revolon and Calleguas at CSUCI stream gages, respectively. The Beardsley gage calibration factor was 0.783, while the Calleguas at Hwy 101 and Madera gages required calibration factors of 0.95 and 0.985, respectively. These results show that the Revolon and Calleguas watershed models generally overpredict the peak flows at those stream gage locations and requires a significant calibration factor reduction. The Conejo gage location used a calibration factor of 1.10 and still underpredicted the gage design storm peak by 4%.

Even with a calibration factor of 1.0, the Tributary Model underpredicted about ½ of the gage design storm peaks from small watersheds. Because of this, and because the HSPF Tributary Model generally provided smaller peaks than the design storm peaks from the VCRat model (VCWPD, 2003), the calibration factor was kept at 1.0 for that run. The calibration results will be discussed in more detail below.

4.1. Royal Gage 802, Upper Arroyo Simi

Royal was a recording gage used to provide daily flow data and storm peaks from WY69 through WY05. Because many non-storm days showed no flow, it was converted to an event hydrograph gage at the end of WY05 and now provides 5-min hydrograph data whenever the storm flow is above the level of the gage sensor. From WY01 to WY05 the entire flow record was provided at 5-min intervals.

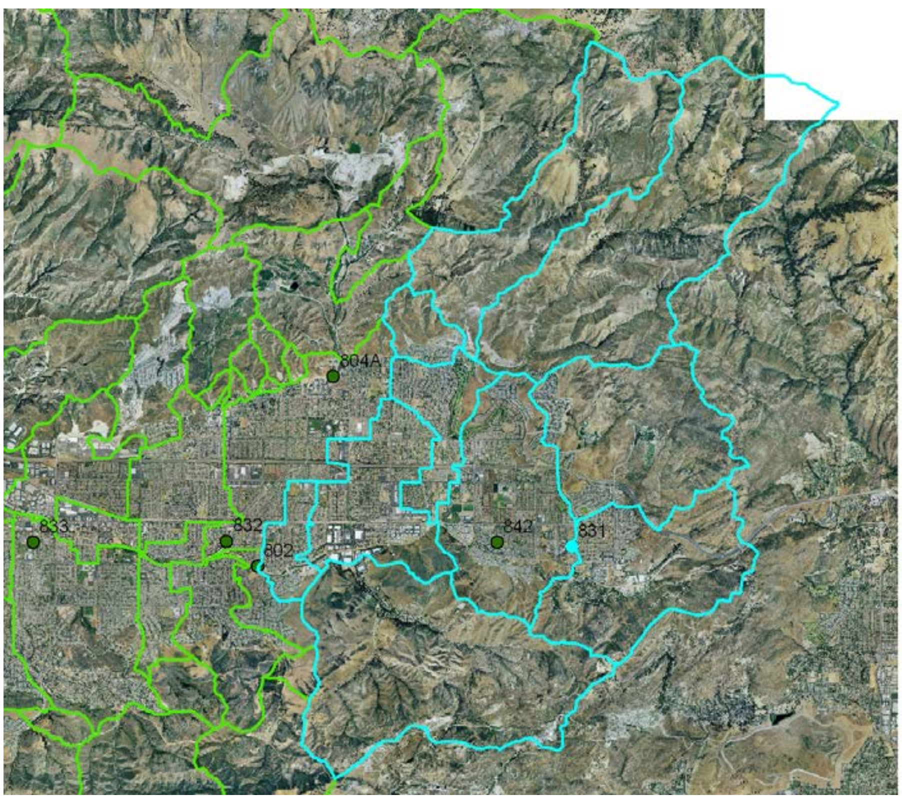


Figure 8.Royal Gage Watershed

4.2. Madera Gage 803, Arroyo Simi

Madera is a recording gage used to provide daily flow data and storm peaks from WY34 through WY09. As a full record gage, it provides 5-min flow data from WY69 to WY09. Figure 9 shows the watershed draining to the gage location.

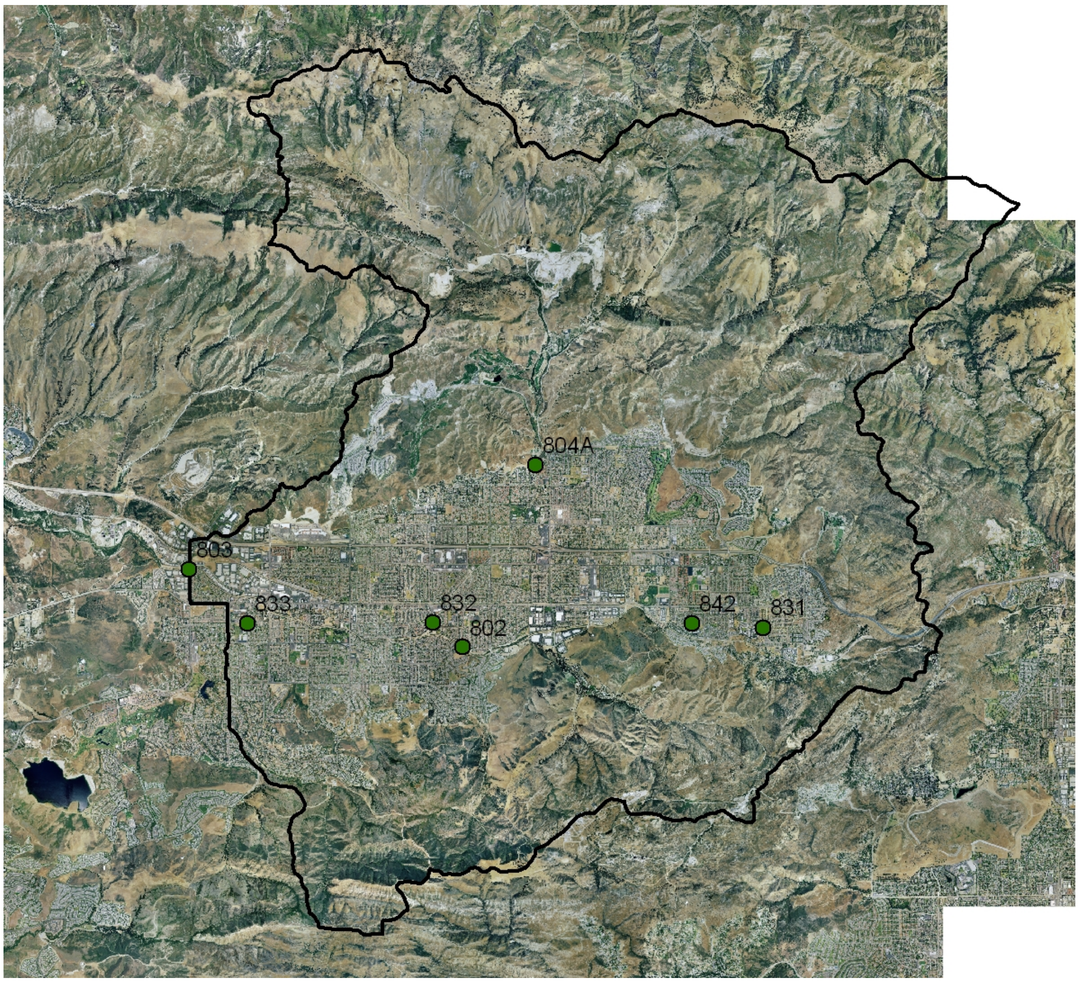


Figure 9. Madera Gage Watershed

The Corps (2003) analyzed the stream gage data from Madera and extrapolated a Q100 peak of 17,200 cfs. The Madera Calibration Model with a calibration factor of 0.985 was able to match this value, which is consistent with the historical maximum peak of 10,700 cfs. The calibrated HSPF peak is about 41% higher than the Bulletin 17b analysis Q100 peak of 12,200 cfs. The Bulletin 17b result is affected by the changing land uses and associated storage in the urbanizing watershed in the past 30 yrs. Figure 9a shows the 100-yr hydrograph at this gage location.

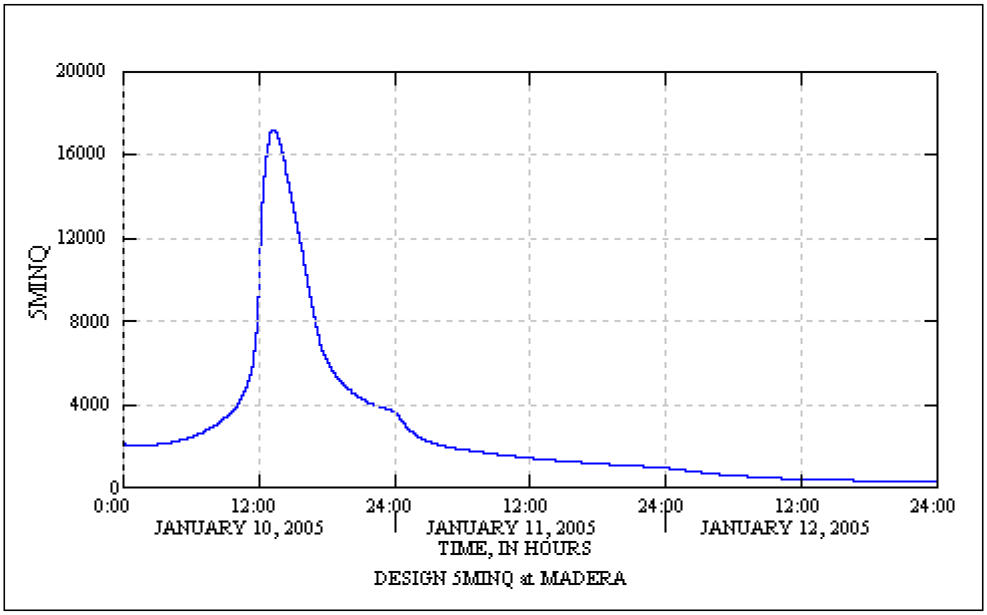


Figure 9a. Madera Gage Hydrograph

4.3. Arroyo Las Posas at Hitch Gage 841, Calleguas Watershed

Arroyo Las Posas (ALP) is a recording gage used to provide daily flow data and storm peaks from WY91 through WY09. As a full record gage, it provides 5-min flow data from WY05 to WY09. The Corps chose to analyze the record from the historic gage 801 located upstream from 1934 through 1983. They extended the record through 2002 by regressing it with the record from the Madera gage 803 and obtained a Q100 peak of 22,100 cfs.

The Calleguas Creek at Hwy 101 Calibration Model with a calibration factor of 0.95 provided a peak within 2% of this value, which is consistent with the historical maximum peak of 16,200 cfs. The Bulletin 17b analysis Q100 peak using only 15 yrs of data from gage 841 was 24,900 cfs which was also consistent with the HSPF results.

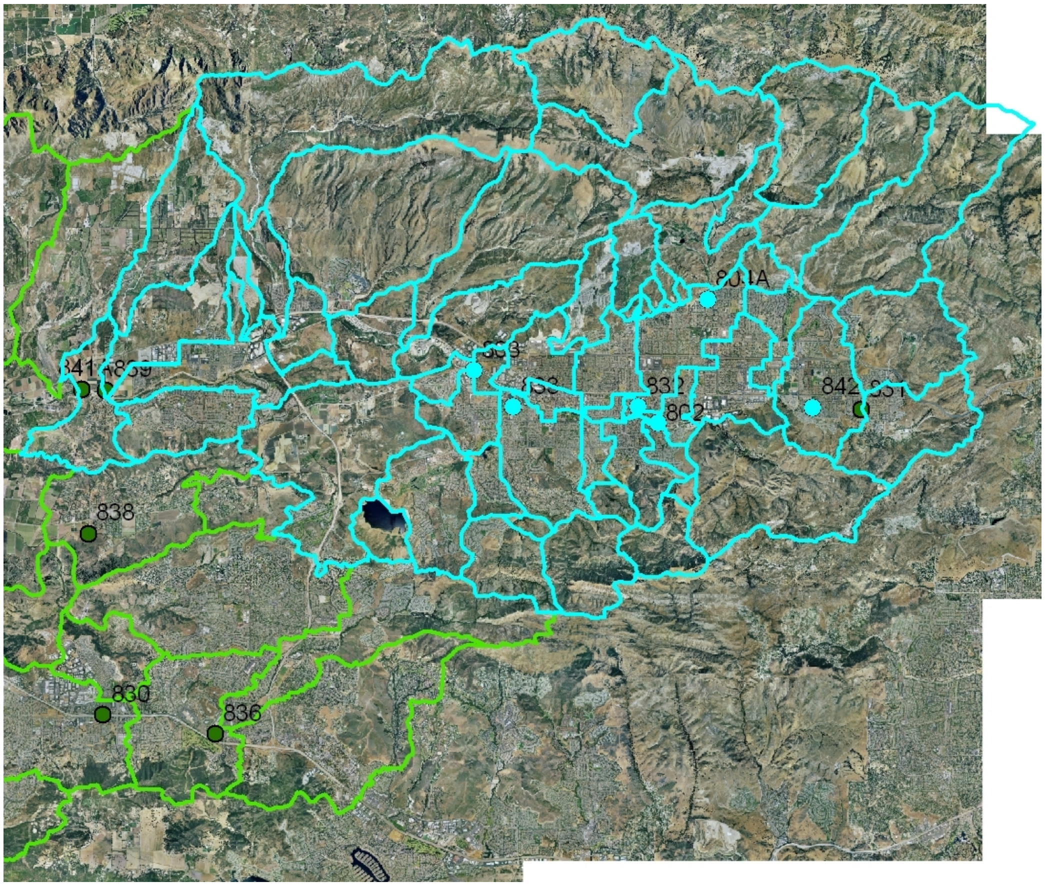


Figure 10. Arroyo Las Posas Gage Watershed

4.4. Calleguas Creek at Hwy 101 Gage 806

Calleguas at Hwy 101was a recording gage used to provide daily flow data and storm peaks from WY71 through WY97. From WY98 through WY07, it provided 5-min flow data. Due to the high infiltration rates in the area, many non-storm periods showed no flow. Because of this, it was converted to an event hydrograph gage beginning in WY07 to provide 5-min data whenever flow is above the gage sensor.

The Corps (2003) analyzed the stream gage data from this gage and obtained a Q100 peak of 28,300 cfs. The Calleguas at Hwy 101 Calibration Model with a calibration factor of 0.95 matched this value, which is consistent with the historical maximum peak of 18,000 cfs. The Bulletin 17b peak using the relatively short record for this gage was 33,500 cfs which appears to be conservative compared to the historical maximum peak.

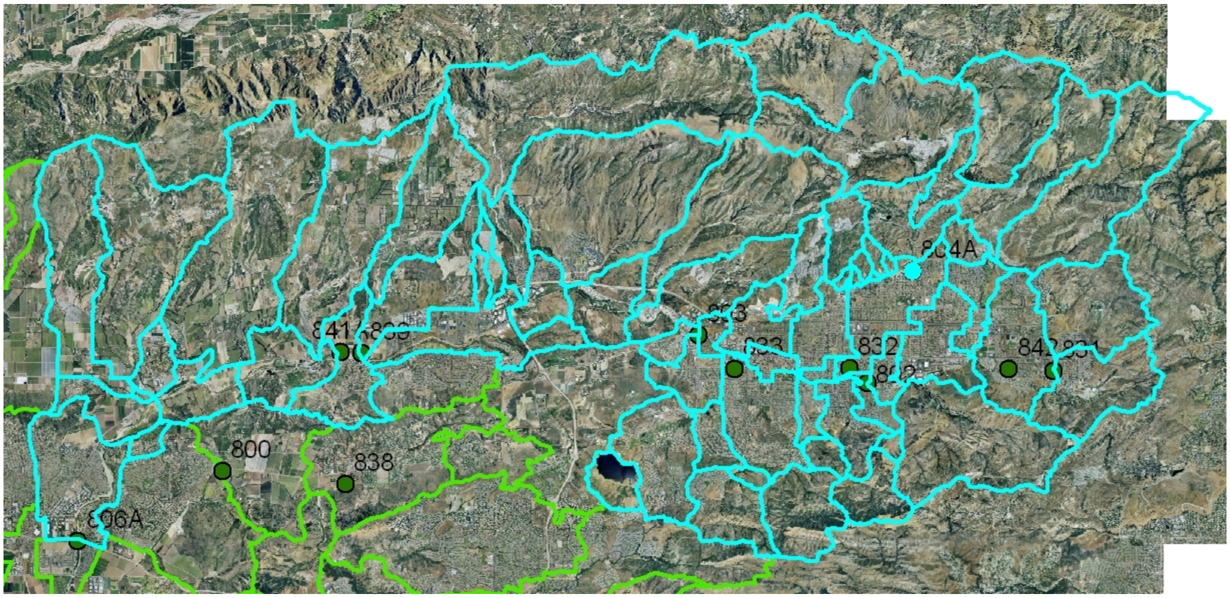


Figure 11. Calleguas Ck at Hwy 101 Watershed

4.5. Conejo Creek near Hwy 101 Gage 800

Conejo Creek near Hwy 101 is a recording gage that provided daily and storm peak data from WY69 through WY90. It has provided 5-min flow data and storm peaks from WY91 through WY09.

The Corps (2003) analyzed the stream gage data from Conejo and obtained a Q100 peak of 22,500 cfs. The Calleguas at Hwy101 Calibration Model with a calibration factor of 1.10 for this watershed calculated a 100-yr peak of 21,500 cfs, or about 4% lower than the Corps value. The Bulletin 17b analysis Q100 value of 17,900 cfs appears to be more consistent with the historical maximum value of 13,300 cfs, and would not require as high of a calibration factor in the model run. Based on these data, it appears that the Corps peak of 22,500 cfs is too conservative.

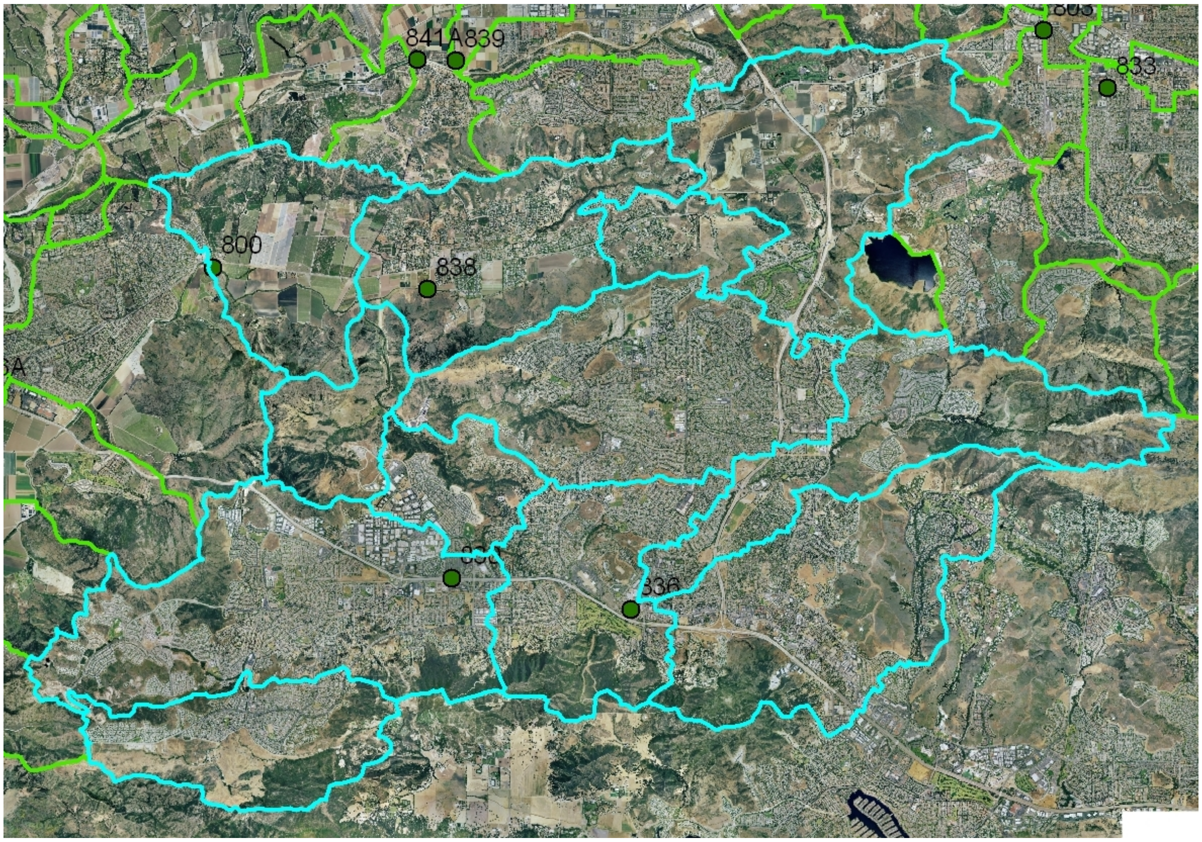


Figure 12. Conejo Ck nr Hwy 101 Watershed

4.6. Calleguas Creek at CSUCI Gage 805

Calleguas Creek near CSUCI is a recording gage used to provide 5-min flow data and storm peaks from WY91 through WY09 and daily flow and peaks from WY55 to WY90. Figure 13 shows the subareas that contribute runoff to the gage location.

The Corps (2003) analyzed the stream gage data from this gage and obtained a Q100 peak of 38,500 cfs. The Calleguas at CSUCI Calibration Model with a calibration factor of 0.862 matched this value, which is consistent with the historical maximum peak of 24,900 cfs. The Bulletin 17b peak for this gage was 40,400 cfs which is also consistent with the historical maximum peak. Figure 13a shows the hydrograph at this location in the model.

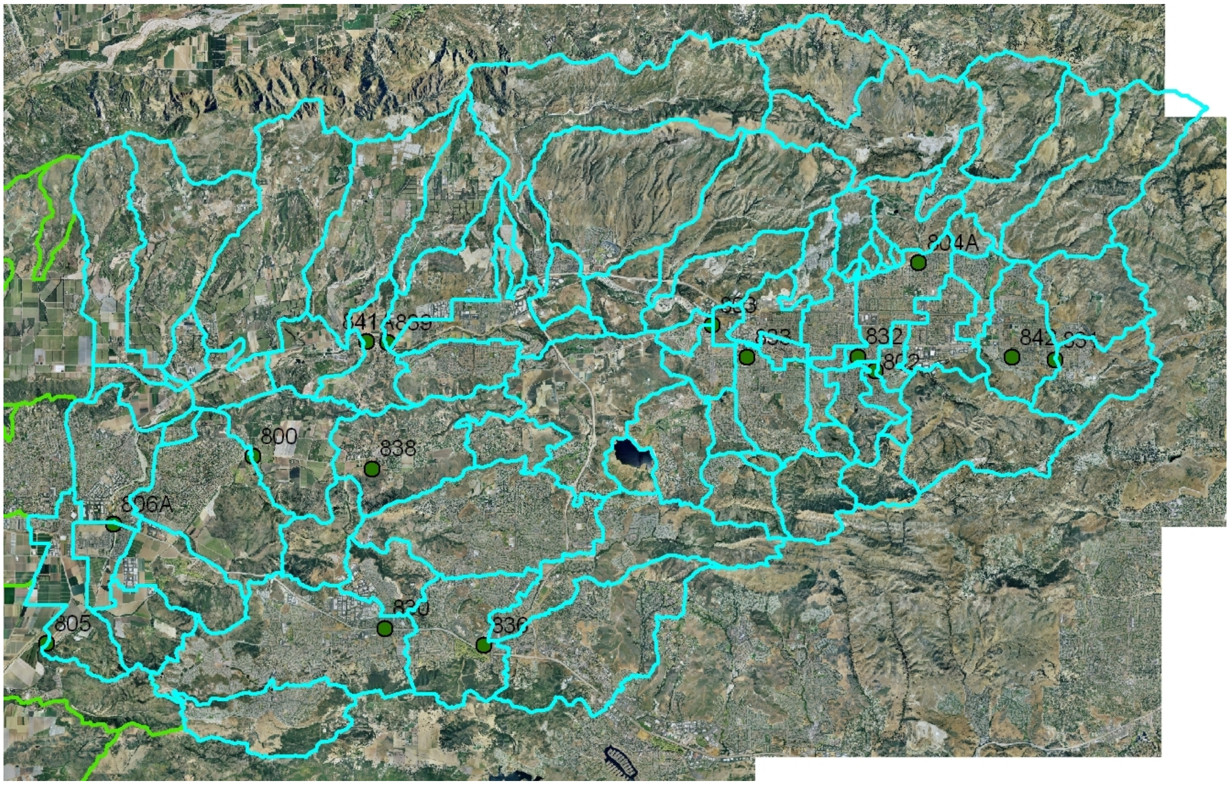


Figure 13. Calleguas Creek at CSUCI Watershed

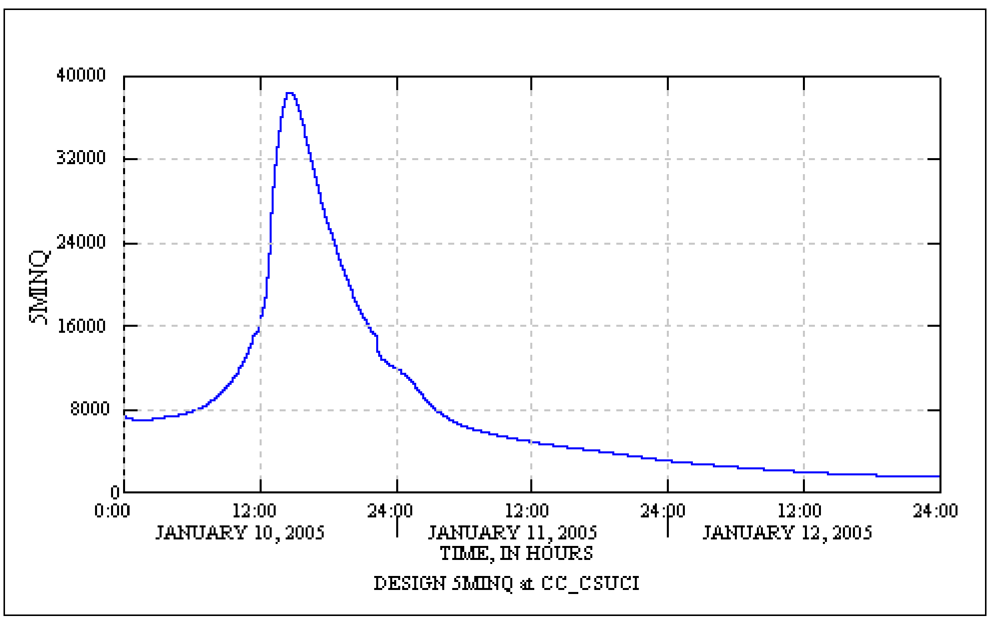


Figure 13a. Calleguas Creek at CSUCI Hydrograph

4.7. Beardsley Wash Gage 780

Beardsley Wash is a recording gage used to provide 5-min flow data and storm peaks from WY95 through WY09. The Corps did not analyze the Q100 for this gage but the Bulletin 17b analysis yielded a Q100 of 7,790 cfs. This value was consistent with the historical maximum peak of 5,360 cfs. The Calleguas at Hwy101 model was used for this calibration and matched the Bulletin 17b value with a calibration factor of 0.783. The calibration factor for this gage was consistent with the Revolon gage factor of 0.795.

Based on these results, it appears that the HSPF design storm model is overestimating the runoff from the Revolon watershed. There are a number of reasons why this may be occurring as follows:

1. The lack of short duration rain gages located in this watershed.
2. The relatively short stream gage records available for use in flow frequency analyses and continuous model calibration.
3. The relatively low slope nature of the watershed that may have significant storage effects that are not represented well in the model.
4. The effects of losing and gaining stream reaches as represented in the model.

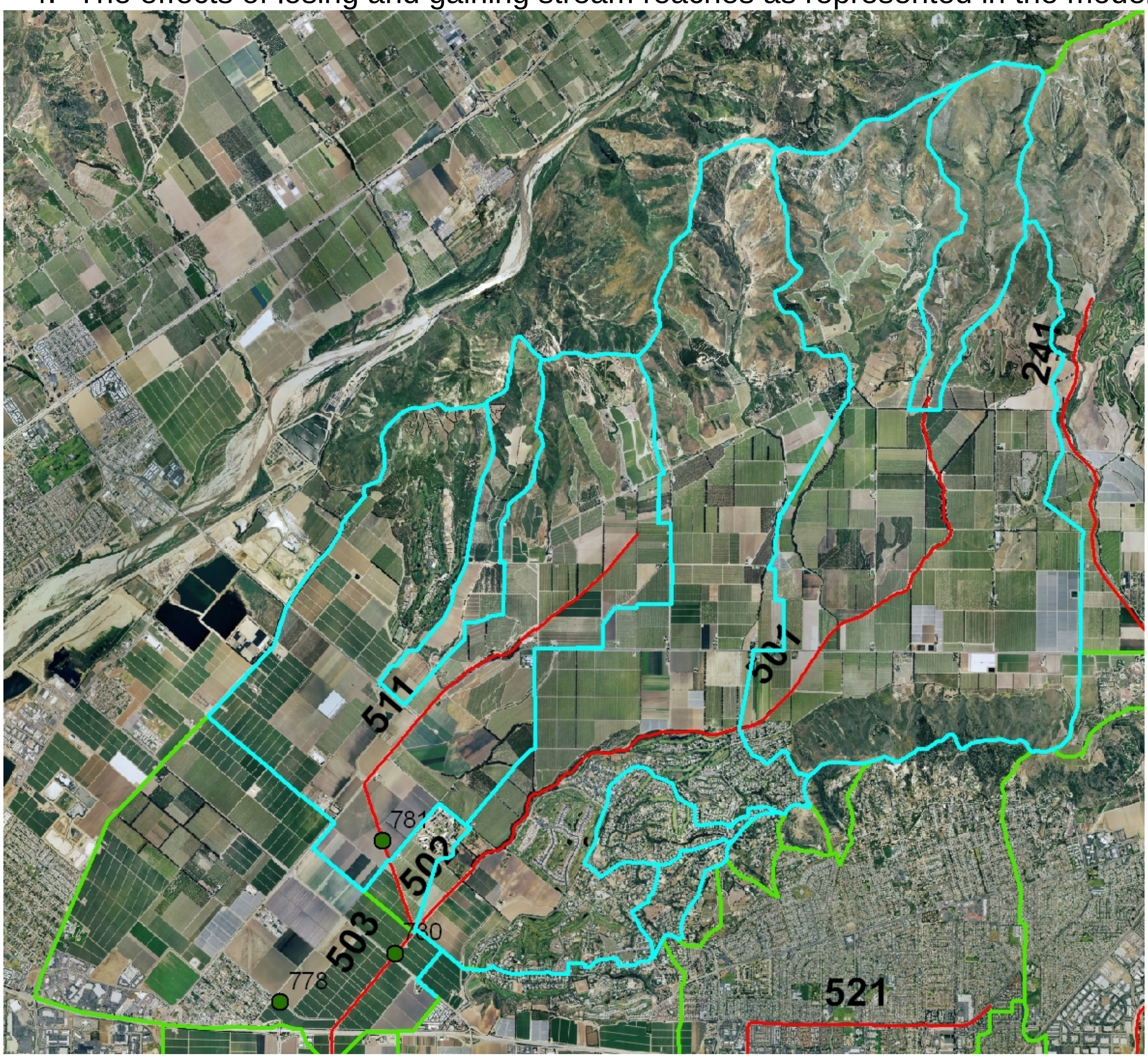


Figure 14. Beardsley Wash Watershed

4.8. Revolon Slough Gage 776

Revolon Slough is a recording gage used to provide 5-min flow data and storm peaks from WY91 through WY09. From WY80 to WY90, the gage provided daily flow data and annual peaks. The Corps analysis of the Q100 for this gage yielded a value of 13,900 cfs which seems low based on the historical maximum peak of 12,900 cfs. This historical maximum is more consistent with the Bulletin 17b peak of 16,500 cfs. If this value had been the calibration target, the HSPF model would not have required a calibration factor of 0.795 in order to match the Corps design storm peak.

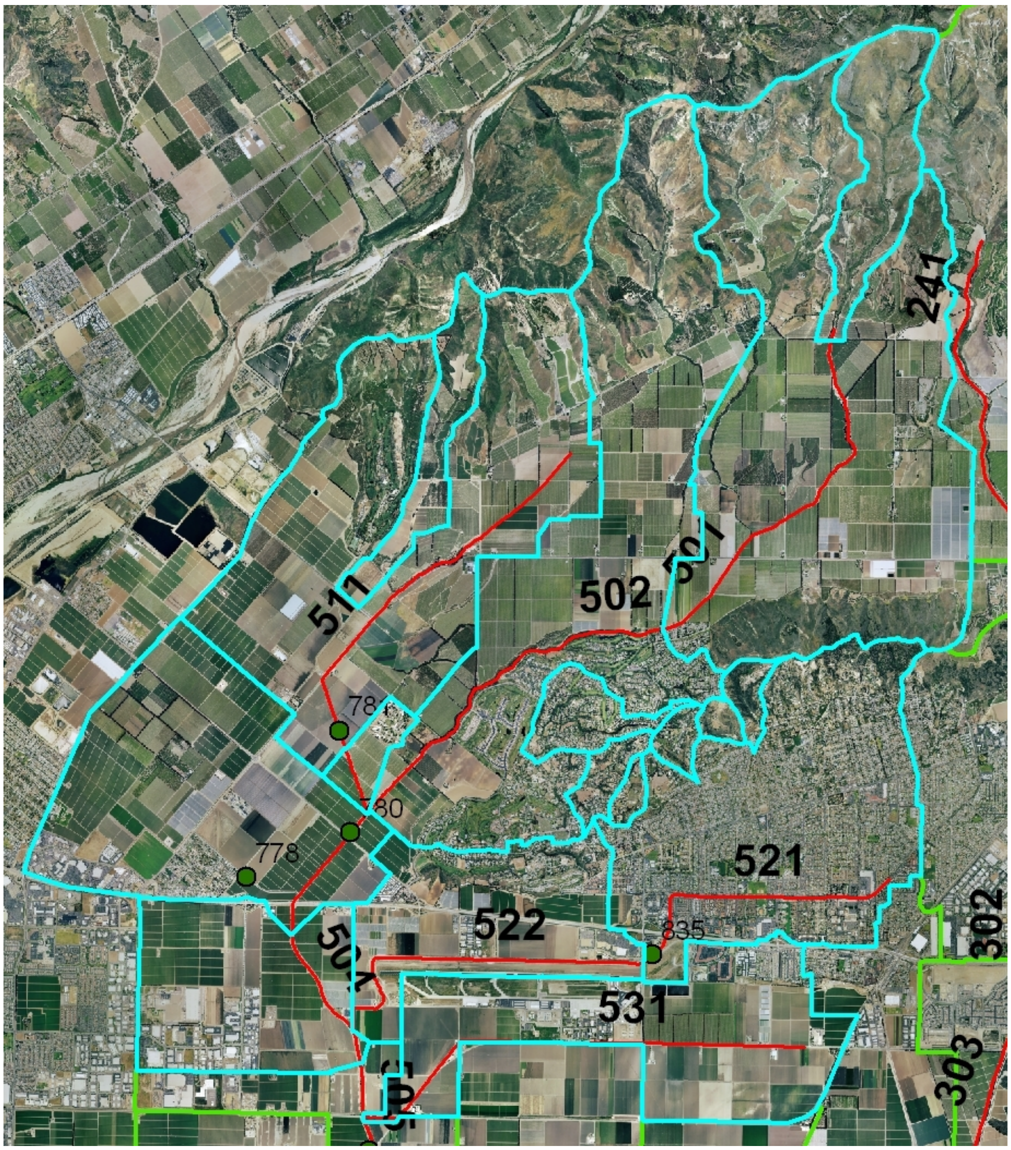


Figure 15 Revolon Slough Watershed

4.9. Arroyo Simi above White Oak 831

Arroyo Simi – White Oak (ASWO) is a recording gage used to provide 5-min flow data and storm peaks from WY05 through WY09. From WY71 to WY04, the gage provided storm event peak data.

The Corps (2003) analyzed the stream gage data from ASWO and provided a Q100 peak of 3,170 cfs. The Tributary Calibration Model with a calibration factor of 1.00 for this watershed calculated a 100-yr peak of 1,780 cfs, or about the same value as the result of a Bulletin 17b analysis of the watershed. The Bulletin 17b peak is also more consistent with the historical peak value of 1,200 cfs reported for this gage. Based on these data, it appears that the Corps peak of 3,170 cfs is too conservative.

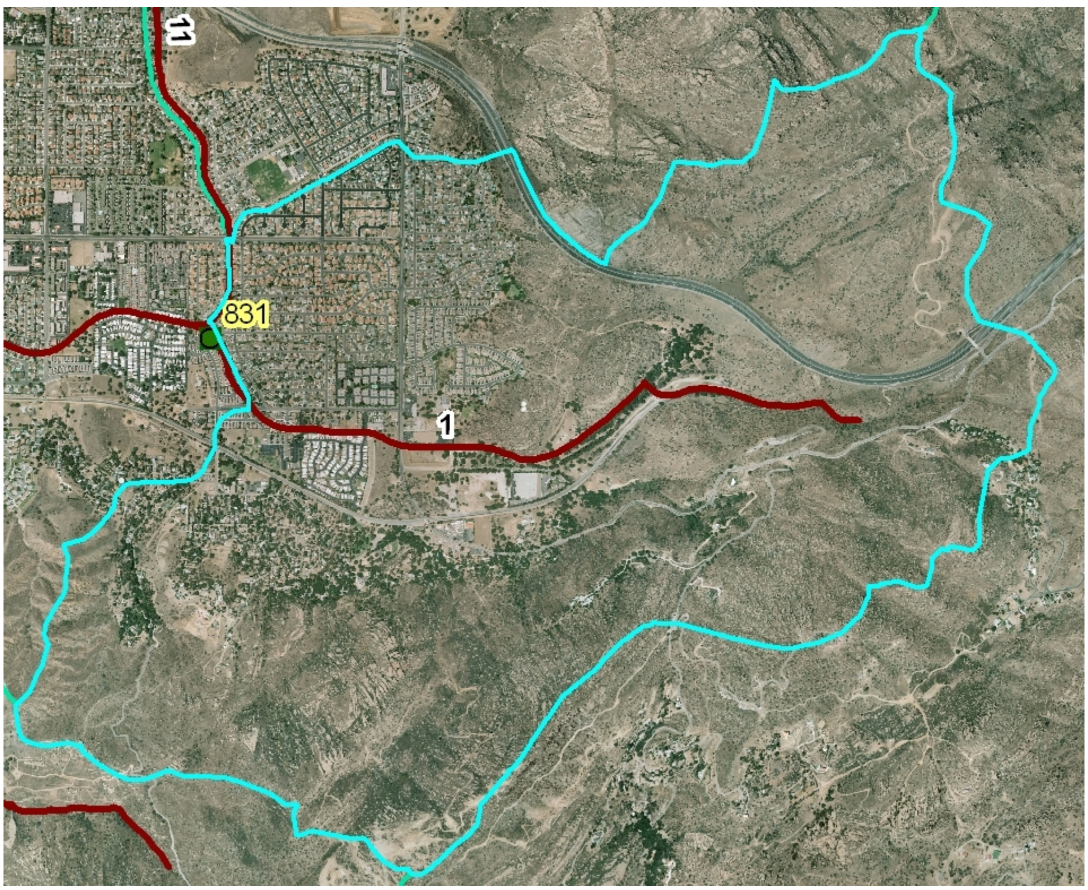


Figure 16. Arroyo Simi – White Oak Watershed

4.10. Upper Arroyo Simi- Stow Gage 842

Arroyo Simi – Stow is a recording gage used to provide 5-min flow data and storm peaks from WY03 through WY09. This gage was not analyzed by the Corps as the record did not start until after their study was finished. The Bulletin 17b analysis of the extremely short record gives a Q100 of about 3,900 cfs with a relatively large 90% confidence range. This Q100 is also inconsistent with the reported historical maximum peak of 1,880 cfs observed during WY2005. However, the HSPF model design storm peak from the Tributary Model with a rainfall calibration factor of 1.00 provided a peak of 4,000 cfs, which supports the Bulletin 17b result.

Based on these results, it appears that more continuous data from wet years like 2005 should be collected to improve the model calibration. Also, the HSPF model boundaries should be revised so that they coincide with the gage location as currently the model subareas in this area include additional areas that do not drain to the stream gage.

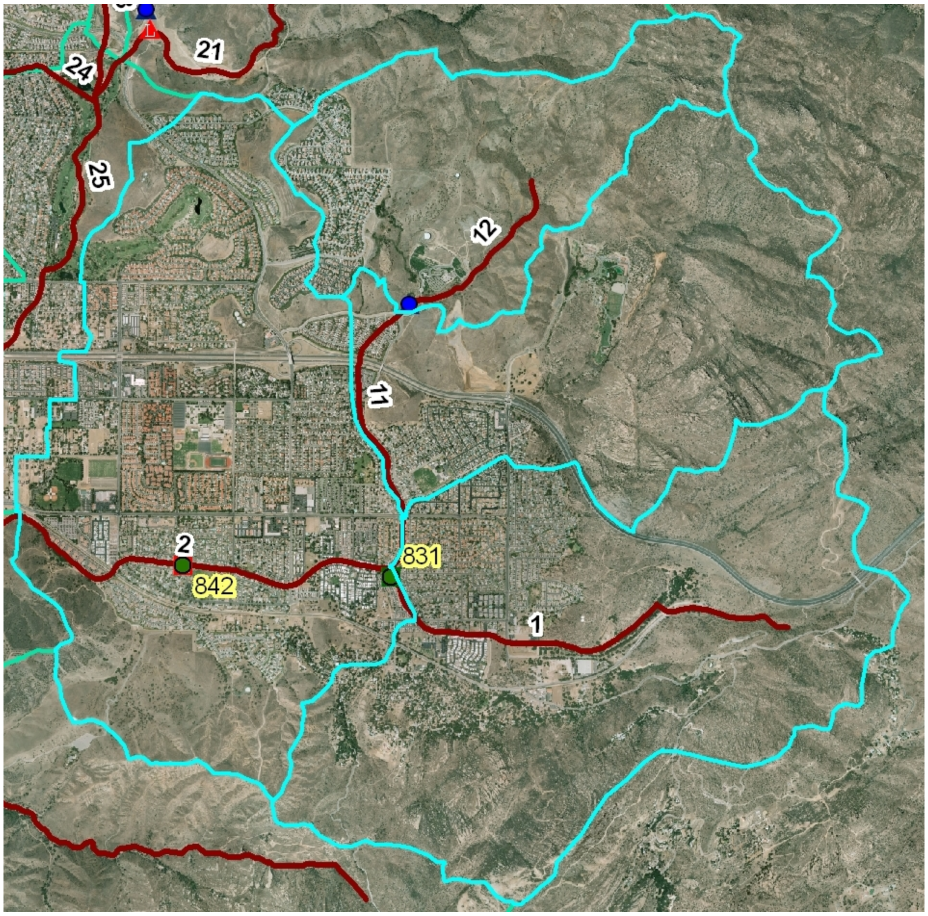


Figure 17. Arroyo Simi – Stow Watershed

4.11. Tapo Canyon Gages 804 and 832

The Tapo Canyon gage 832 located in the downstream developed area of the watershed provided peak flow data beginning in 1970. Gage 804 was installed at the beginning of Water Year 2005 at the developed/undeveloped boundary and provides 5-min data from the extensive upstream undeveloped area during storm events. This gage is used primarily as a storm monitoring location and so less time is spent on the record ensuring that the flows are as accurate as possible compared to the full record locations.

The Corps did not analyze the Q100 for these gages but the Bulletin 17b analysis for gage 832 provided a Q100 of 5,070 cfs. This value was consistent with the historical maximum peak of 4,140 cfs. These data are also assumed to apply to gage 804 although the existing road crossings upstream of gage 832 have a theoretical maximum capacity of 3,500 cfs and may have truncated the actual storm peaks to an unknown extent. The Tributary Model provided Q100 peaks of 5,250 and 5,760 cfs for these gages, or about -4 to -14% higher than the Bulletin 17b peak.

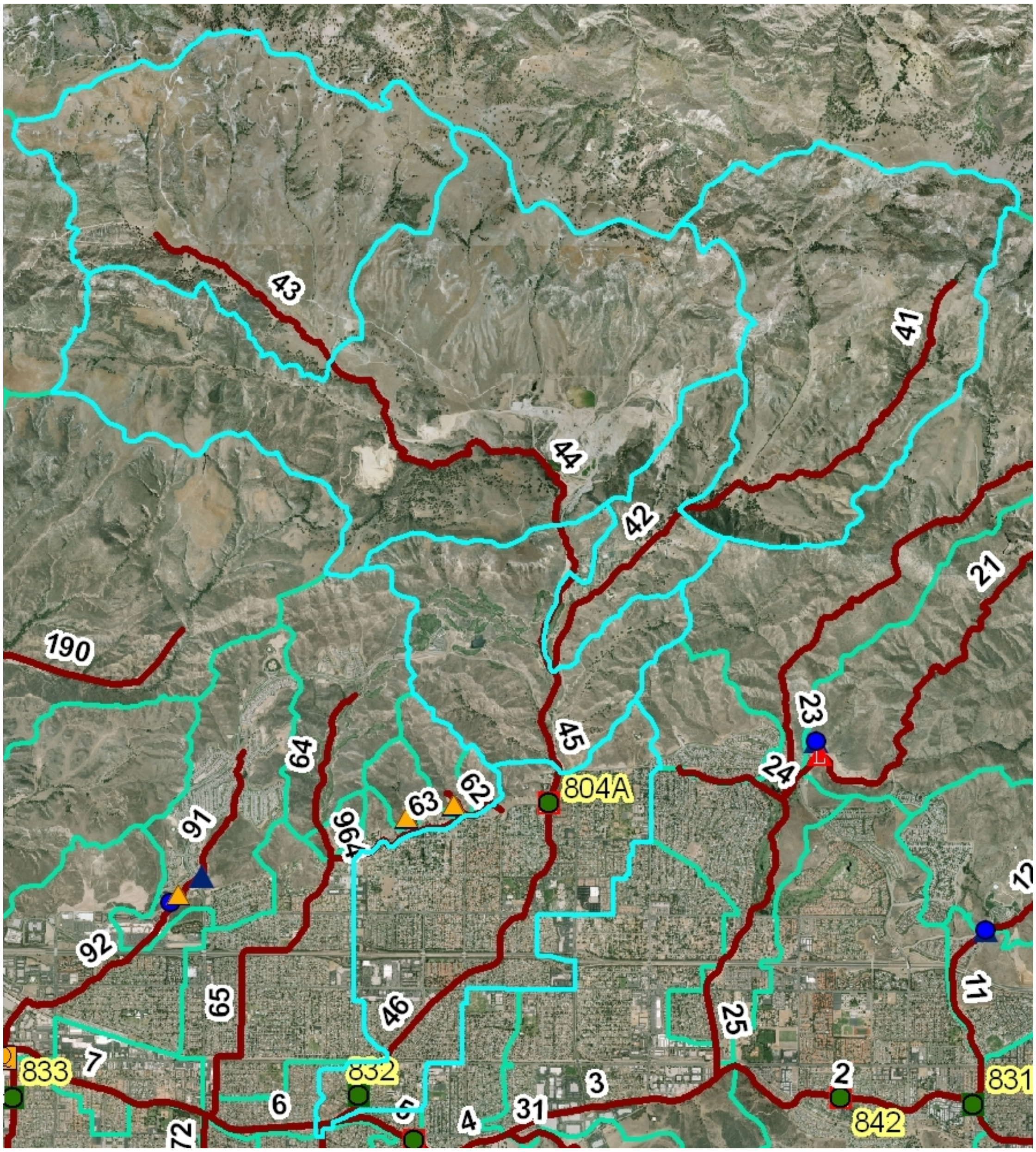


Figure 18. Tapo Cyn Watershed

4.12. Bus Canyon Gage 833

The Bus Canyon gage 833 located in the downstream developed area of the watershed has provided peak flow data since 1970. The record was processed beginning in WY05 to provide 5-min data during storm events.

The Corps did not analyze the Q100 for this gage but the Bulletin 17b analysis provided a Q100 of 1,190 cfs. This value was inconsistent with the historical maximum peak of 1,200 cfs. The Tributary Model provided a peak of 1,250 cfs or about 5% higher than the Bulletin 17b result. Because the stream gage is only used for peak flows and storm hydrographs there are very few measurements to confirm the rating, especially at high flow levels. However, the gage is located in a rectangular concrete channel with a uniform cross-section and slope so the uniform flow assumption used to create the rating table should be fairly accurate. Another issue with design storm rainfall for this watershed is that the rain gages assigned to the HSPF model are relatively far away from the watershed.

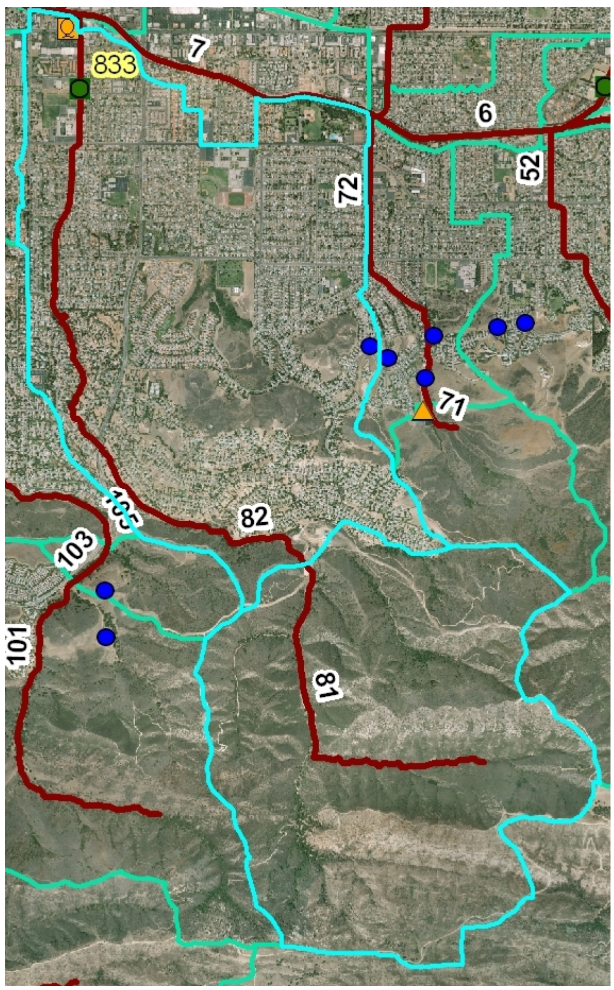


Figure 19. Bus Cyn Watershed

4.13. Gabbert-Walnut Cyn Gage 839

The Gabbert-Walnut gage 839 located downstream of the City of Moorpark has provided peak flow data since 1987. After Water Year 2005 the record was processed to provide 5-min data during storm events. The Gabbert portion of the watershed has a debris basin that controls runoff from the 3.8 sq mi Gabbert subarea and attenuates peaks from smaller storms. Depending on how much sediment has accumulated in the basin, the degree of attenuation can vary. The Walnut portion of the watershed has one regional basin and several smaller homeowner peak flow mitigation basins that are not included in the HSPF model as it is represented in the model with just one subarea and one reach.

The Corps did not analyze the Q100 for this gage but Bulletin 17b analysis shows a Q100 of 2,740 cfs. This value was consistent with the historical maximum peak of 1,820 cfs. However, because the debris and detention basins are not modeled explicitly in the model, the Tributary Model provided a peak of 4,650 cfs or about 70% higher than the Bulletin 17b result. One of the issues with this result could be that the stream gage is only used for peak flows and storm hydrographs so there are very few measurements to confirm the rating, especially at high flow levels. However, it is more likely that the detention facilities and additional hydraulic constrictions above the 0.7 inches of assumed storage need to be included in the HSPF model of the watershed.

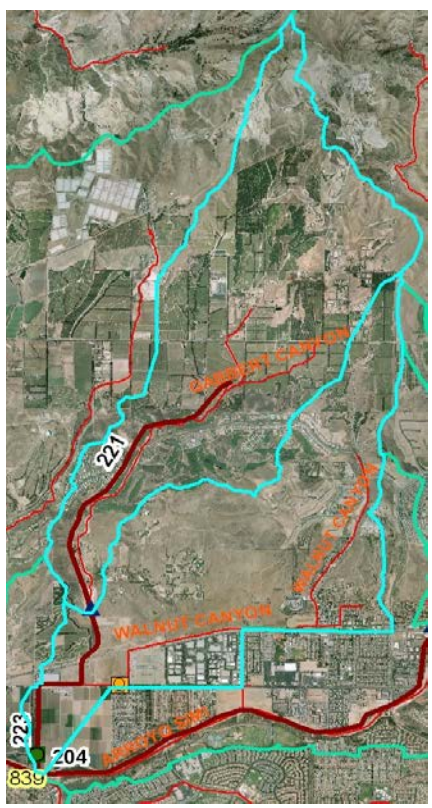


Figure 20. Gabbert Walnut Watershed

4.14. <u>Santa Clara Drain Gage 781</u>

The Santa Clara Drain gage 781 located in the Revolon Slough Watershed provided peak flow data from WY96-09, with daily average data available from WY96-WY07. The record was processed for 5 min data starting in WY01. After WY07, only storm hydrographs were processed. This subarea has a debris basin that controls runoff from the 1.1 sq mi Ferro Ditch subarea that attenuates peaks from smaller storms. Depending on how much sediment has accumulated in the basin, the degree of attenuation can vary.

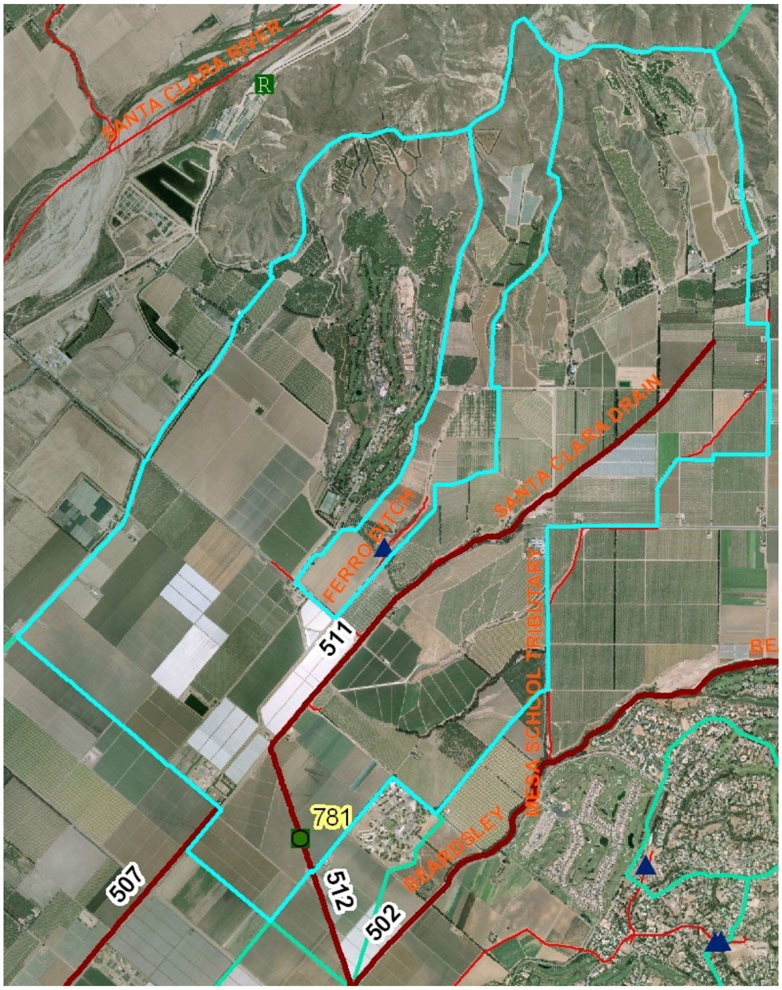


Figure 21. Santa Clara Drain Watershed

The Corps did not analyze the Q100 for this gage but Bulletin 17b analysis shows a Q100 of 1,440 cfs. This value was consistent with the historical maximum peak of 1,000 cfs. A higher peak of 1,424 cfs is part of the historical record but based on the data set the Bulletin 17b analysis identified this point as a high outlier and did not use it to provide the Q100. Due to the issues discussed previously for the Beardsley gage, the Tributary Model overestimated the peak for this gage by over 200% with a flow of 4,400 cfs. One approach to mitigate this apparently high peak would be to use a rainfall calibration factor for this gage similar to the Revolon and Beardsley factors although this is not required to improve the Nyeland gage match.

4.15. Nyeland Drain Gage 778

The Nyeland Drain gage 778 provided peak flow data beginning in 1987. The Corps did not analyze the Q100 for this gage but a Bulletin 17b analysis for this relatively short record extrapolated a Q100 of 2,560 cfs. This value was inconsistent with the historical maximum peak of 2,546 cfs. However, the Tributary Model calculated a peak of 3,130 cfs, which is about 22% higher than the Bulletin 17b result. This is a fairly reasonable result for a hydrology model so it is not concluded that a rain calibration factor should be used for this gage. The differences may be due to some extent to the issues discussed previously for the Beardsley gage.

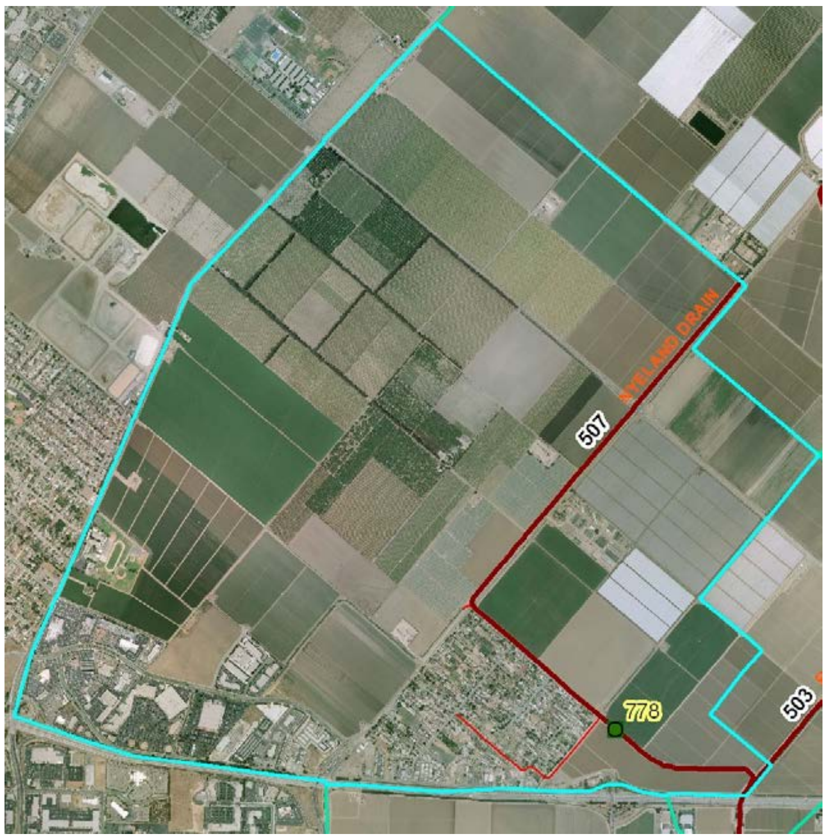


Figure 22. Nyeland Drain Watershed

4.16. Camarillo Hills Drain Gage 835

The Camarillo Hills Drain gage 835 has provided peak flow data since 1977. There are four relatively small debris basins that attenuate the peak flows to a limited extent depending on the magnitude of the storm and how much debris has accumulated in the basins. A hydraulic constriction above the gage was fixed in 1985 so that data since then can be used in flow frequency analyses of the gage data.

The Corps did not analyze the Q100 for this gage but a Bulletin 17b analysis for this relatively short record shows a Q100 of 3,240 cfs. This value was inconsistent with the historical maximum peak of 3,580 cfs, resulting in the highest historical peak to Bulletin 17b peak ratio for all gages in the Calleguas watershed. However, the

Tributary Model calculated a peak of 2,770 cfs, which is about 15% lower than the Bulletin 17b peak. This is a fairly reasonable match for different hydrology methods so it is not concluded that a rain calibration factor should be used for this gage. The differences in the HSPF model results to the design peak may be due to some extent to the issues discussed previously for the Beardsley gage. Another possible reason for this result could be that the stream gage is only used for peak flows and storm hydrographs so there are very few measurements to confirm the rating, especially at high flow levels.

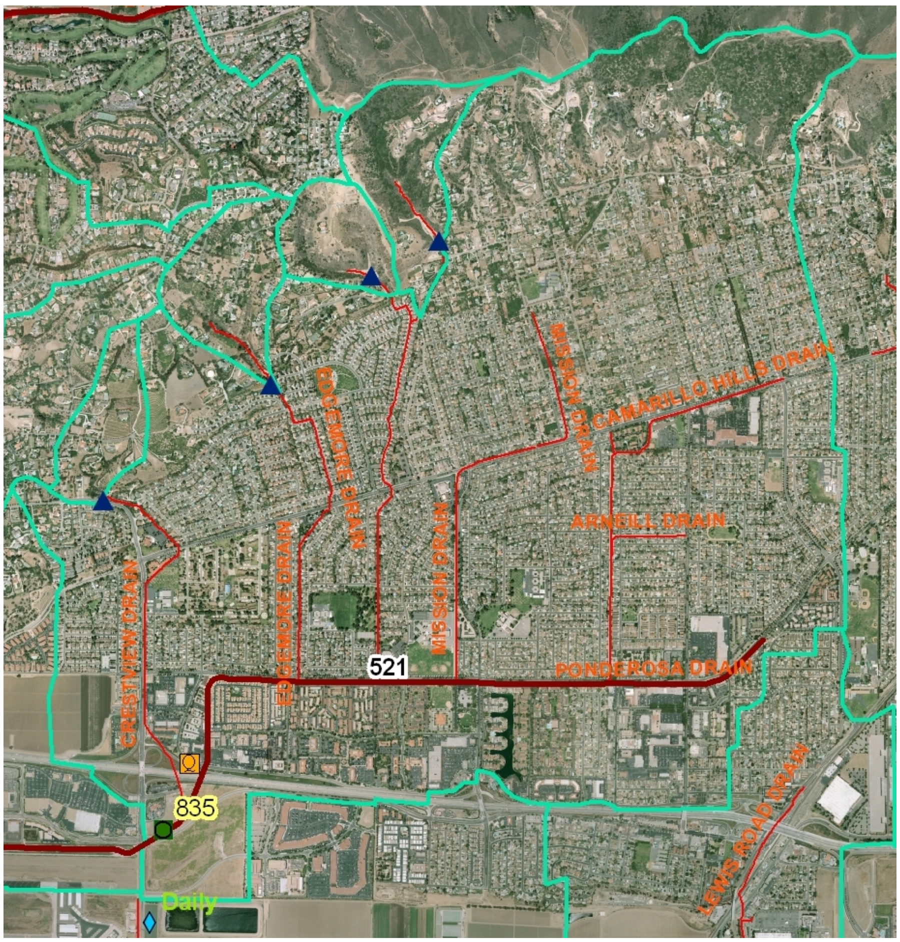


Figure 23. Camarillo Hills Drain Watershed

4.17. Santa Rosa Creek Gage 838

The Santa Rosa gage 838 has provided peak flow data since 1985. There is one debris basin that attenuates the peak flows to a limited extent depending on the magnitude of the storm and how much debris has accumulated in the basin. There are some culverts and drainage facilities in the upper Tierra Rejada watershed (subarea 441) that provide detention to attenuate peaks.

The Corps did not analyze the Q100 for this gage but a Bulletin 17b analysis for this relatively short record showed a Q100 of 5,250 cfs. This value appears to be a bit high as compared to the historical maximum peak of about 2,990 cfs. However, the Tributary Model calculated a peak of 3,700 cfs, which is about 30% lower than the Bulletin 17b peak. The differences in the HSPF model results to the design peak may be due to some extent to the issues discussed previously for the Beardsley gage. Another possible reason for this result could be that the stream gage is only used for peak flows and storm hydrographs so there are very few measurements to confirm the rating, especially at high flow levels. Extensive vegetation is often found in the channel which can alter the boundary roughness values and affect the flow rating table results. The continuous model did not match the historic data very well during calibration and this was attributed to the lack of rain gage coverage in the watershed.

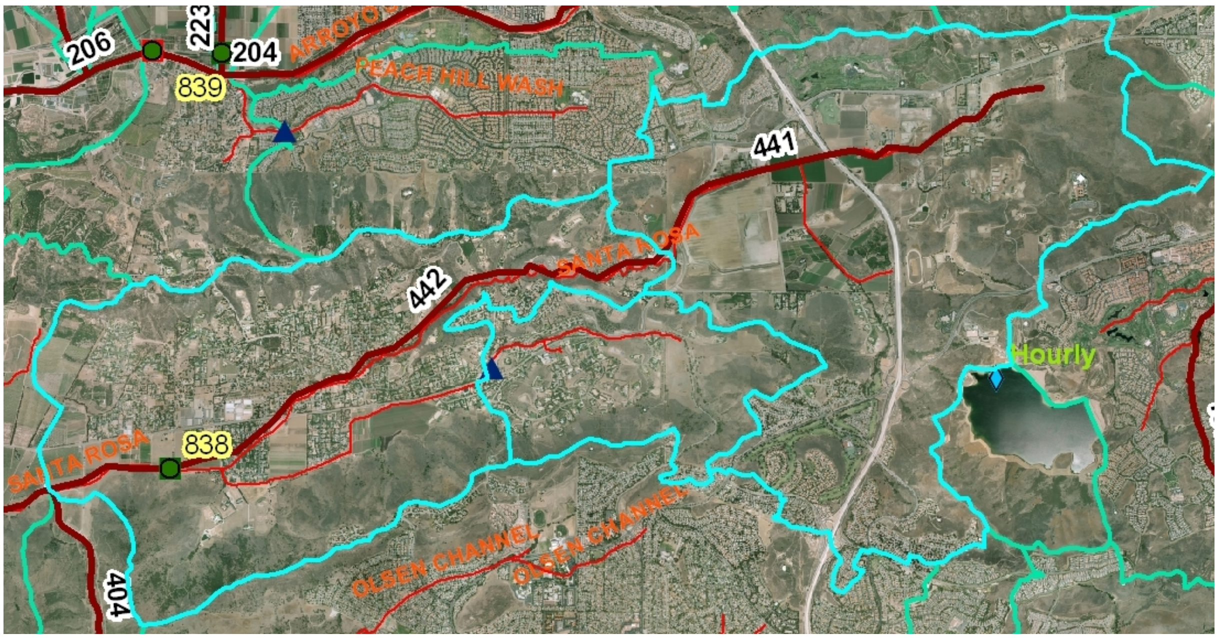


Figure 24. Santa Rosa Creek Watershed

4.18. South Branch Arroyo Conejo Gage 830

The South Branch Arroyo Conejo (SBAC) gage 830 has provided peak flow data since 1970. There are five detention basins in series in the upper watershed along the Conejo Mtn Creek tributary, and two other detention basins along the SBAC, that are all represented in the Modified Rational Method model of the area. The only basin that is currently included in the HSPF model is the South Branch Arroyo bypass basin (Reach 422 in model) that diverts a portion of the flow into a basin.

The Corps (2003) analyzed the stream gage data from the SBAC gage and extrapolated a Q100 peak of 6,850 cfs. A Bulletin 17b analysis of the relatively short record gage resulted in a Q100 peak of 5,400 cfs. The Tributary Calibration Model with a calibration factor of 1.00 for this watershed calculated a 100-yr peak of 4,850 cfs. This result is about 29% less than the Corps Q100, and about 10% less than the Bulletin 17b result. Both design peaks are fairly consistent with the historical peak value of 4,240 cfs reported for this gage.

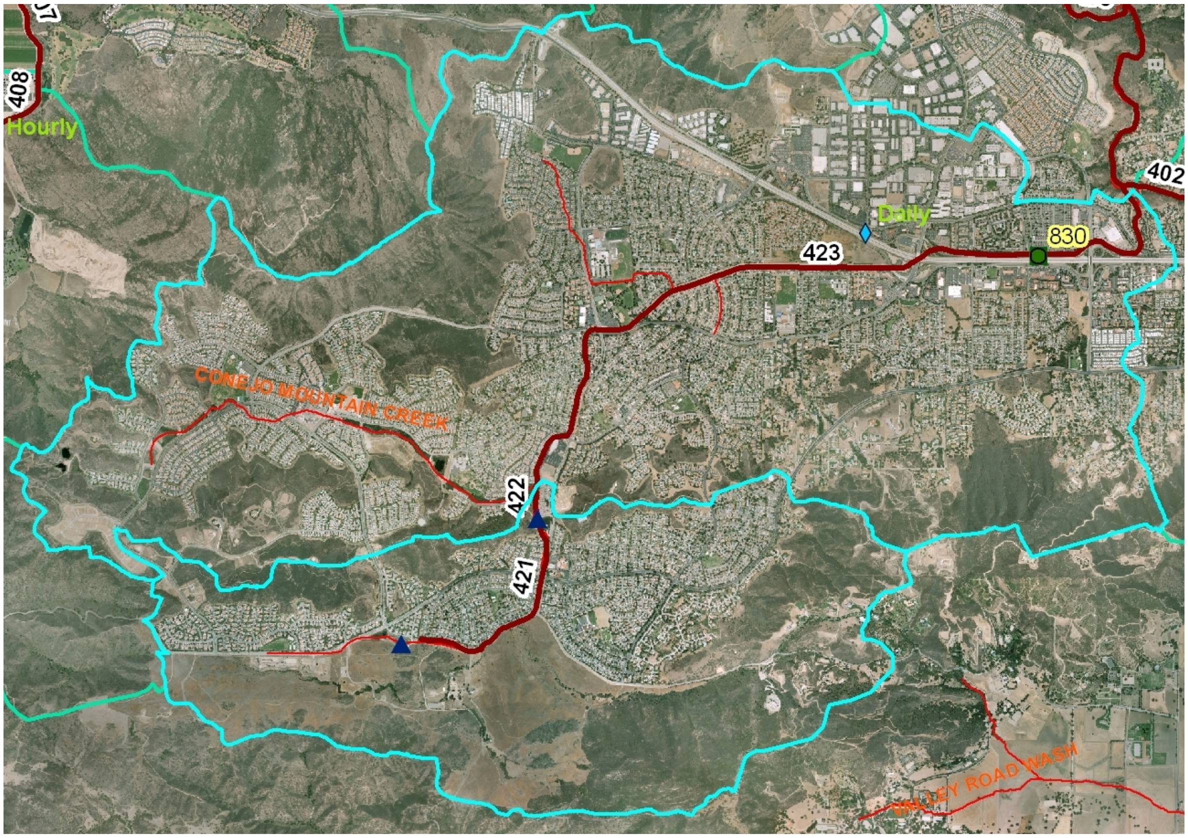


Figure 25. South Branch Arroyo Conejo Watershed

4.19. Arroyo Conejo Gage 836

The Arroyo Conejo gage 836 has provided peak flow data since WY1977. One major detention basin was completed in 2004 on the Lang Creek Tributary that controls 3.6 sq mi of the watershed. Although peaks prior to 2004 were not attenuated by the basin, the percent of area controlled by the basin is relatively small and so the calibration was done with the basin in the model.

The Corps (2003) analyzed the stream gage data from the SBAC gage and provided a Q100 peak of 9,000 cfs. A Bulletin 17b analysis of the relatively short record gage resulted in a Q100 peak of 6,540 cfs. The Tributary Calibration Model with a calibration factor of 1.00 for this watershed calculated a 100-yr peak of 5,580 cfs. The Tributary Model peak is about 15% less than the Bulletin 17b Q100 and both of these results are consistent with the historic maximum peak of 4,300 cfs. Based on these data, it appears that the Corps Q100 is overly conservative for this gage.

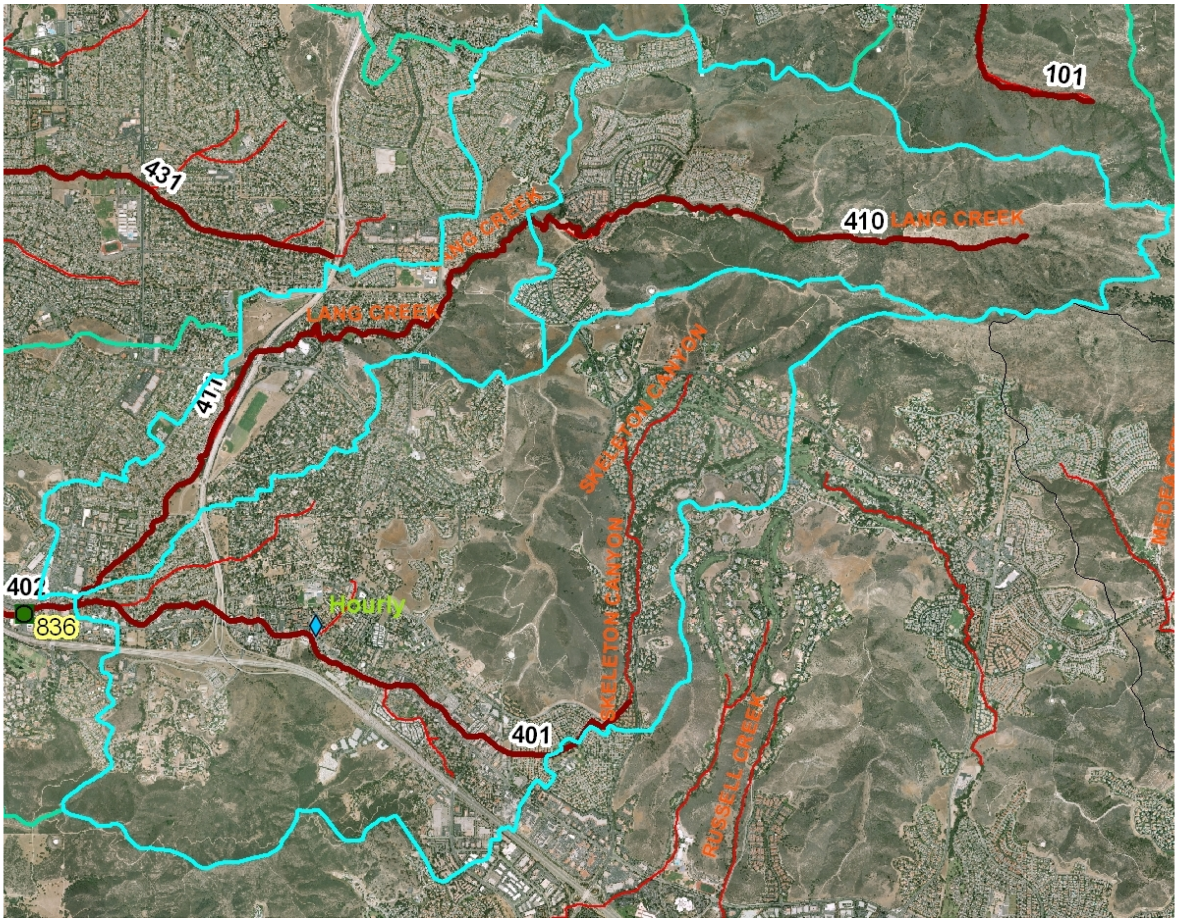


Figure 26. Arroyo Conejo Watershed

4.20. <u>Comparison to VCRat Design Storm Results</u>

In 2003 the District prepared a model of the watershed based on their modified rational method program VCRat. The Corps 2003 report using their HEC-HMS model provided the calibration data and supporting data for the VCRat model results that were eventually used by the Federal Emergency Management Agency (FEMA) to update the floodplain maps for a large portion of the watershed.

One of the assumptions embedded in the VCRat modeling is that all runoff can be conveyed as open channel flow in the local storm drain system and so it does not account for the effects of small homeowner detention basins or curb inlet limitations (commonly limited to the 10-yr peak) on the design storm peaks. Also, the runoff coefficients used for undeveloped watersheds are relatively high, leading to conservative peaks for these watersheds. Other modeling studies have shown that the VCRat model has very little attenuation in undeveloped channels due to the modified Puls routing scheme used in the model.
Because the HSPF model can accounts for local storage effect if they are included in the Ftables used for channel routing, it is expected that the HSPF peaks would be generally lower than the VCRat model results. This general result is confirmed by the results shown in Table 6. Based on the results, it appears that the VCRat model

results that represent the official hydrology for the District are fairly conservative, especially for undeveloped areas. An explanation of the general results for various reaches is provided in the following sections.

4.20.1 Stream Gage Results

The stream gages that were used in the calibration of the VCRat model such as Revolon, Calleguas CSUCI, Madera, Arroyo Simi above White Oak, and Conejo, have VCRat 100-yr peaks that are within 4% or less than the Corps design storm peaks. The other gages that were not used in the VCRat model calibration are have design storm peaks that are different (lower) than the VCRat results by as much as -140%. The exceptions to this are as follows:

1. Tapo gage 832- the VCRat peak at the gage location of 3,333 cfs is 7,843 cfs lower than the VCRat peak at the upstream gage 804 location due to the hydraulic constrictions at the road crossings estimated to have a capacity of 3,500 cfs. The peak at this location has been significantly affected by the flow diversion assumptions used in the VCRat model.
2. Arroyo Santa Rosa gage 838- the VCRat peak at the gage location of about 4,750 cfs is about 500 cfs lower than the Bulletin 17b extrapolated design storm peak.

4.20.2 Upper Arroyo Simi

The VCRat peaks in this portion of the watershed are as much as 57% higher than the HSPF model results (HSPF model reach 3 above the Royal gage). Undeveloped watersheds consistently have HSPF peaks that are 50% lower than the VCRat peaks. The HSPF inflow peak to Sycamore Dam is 80% lower than the VCRat result and does not show any spill over the emergency spillway as in the VCRat model. However, the 2012 study done to develop an updated HSPF model of the Sycamore watershed have not been incorporated into the Calleguas HSPF model.

4.20.3 Simi Valley to Calleguas Gage at CSUCI

The high intensities from the Happy Camp rain gage cause this canyon to have HSPF peaks that are higher than the VCRat peaks. Reach 191 has an HSPF peak that is higher than the VCRat peak because the HSPF model combines Canyon No. 2 and Strathearn Canyon while the VCRat model evaluates them separately. This is also the case with Mahan Barranca (227), while Grimes Canyon (225) subarea is about 800 ac larger in the HSPF model than the VCRat model. The Coyote (231-233) and Fox (241-243) watersheds have HSPF peaks larger than the VCRat peaks by as much as 38%, likely due to the way that the Ftables for those vegetated watersheds were defined.

4.20.4 Conejo Creek Watershed

The VCRat peaks are consistently higher than the HSPF peaks by as much as about 60%. The HSPF model includes the Lang Detention basin while the VCRat model does not.

4.20.5 Revolon Slough Watershed

A number of the subareas in this portion of the model have HSPF peaks higher than the VCRat peaks from the Tributary Model with a rainfall calibration factor of 1.0. Not all of the gages or subareas have higher peaks, however, so it is not clear that the HSPF model is biased in one direction. The Pleasant Valley channel subarea (531) has a HSPF peak higher than the VCRat peak because the HSPF subarea is much larger than the VCRat watershed area.

4.21. Ftable storage sensitivity

As discussed previously, urban storage occurs due to curb inlet limitation and small homeowner basins. It is simulated in the HSPF model by adjusting the Ftables for the developed areas. For reach 11 downstream of the Mt. Sinai Detention Basin, the total tributary area is about 2,361 ac with about 551 ac developed. A storage depth of 0.7 inches across the developed area corresponds to about 32.1 af of extra storage to be added to the Ftable between the 10- and 100-yr flow levels. This represents about 30% extra storage in the Ftable. Figure 27 shows that applying this Ftable in the model results in decreasing the peak from the watershed from 2,060 to 1,720 cfs, a decrease of about 17%. The volume of runoff is not affected.

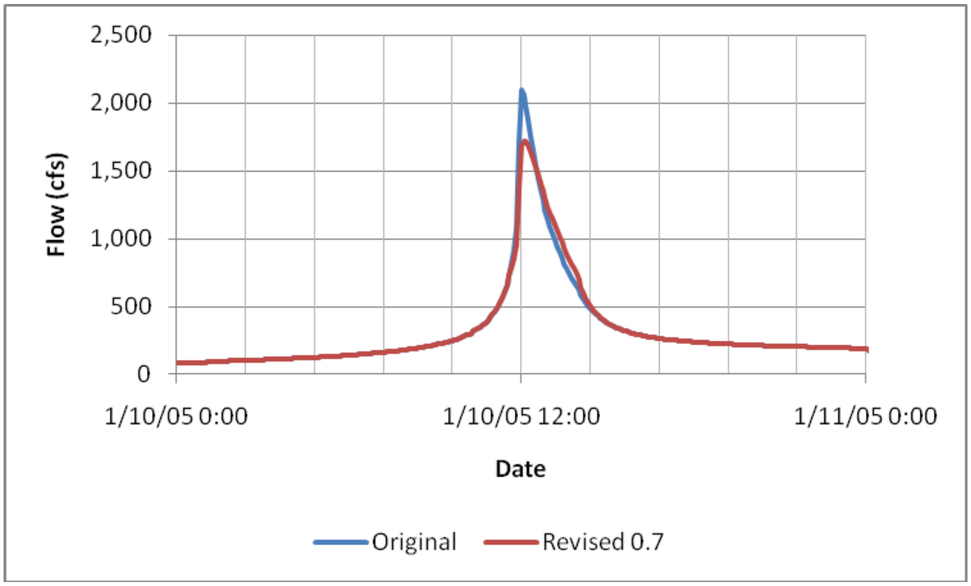


Figure 27. Reach 11 Ftable Storage Effects

Because the changes in the Ftable do not affect the runoff volumes, just the peaks, changing the storage volume is not expected to result in significant changes in peaks at gage locations downstream in the watershed. To verify this, the additional storage volumes included in the developed subareas upstream from the Madera gage were reduced by 50% from 0.70 to 0.35 inches. The 50% reduction in storage increased the peak at the Madera gage from 17,200 to 17,800 cfs, or a little more than 3%.

4.22. Data Parameter Sensitivity

The continuous HSPF model calibration study (VCWPD, 2011) found that the parameters that most affected the model calibration to the historic data were the infiltration rate (INFILT), the lower zone storage (LSZN) and the delayed interflow from the upper storage zone to the stream (INTFW). The sensitivity of the model results to these parameters once the initial conditions are established was investigated by increasing the three parameters by 10%. Increasing these parameters is expected to lower the peak in the model. For the Arroyo Simi above White Oak subarea (Reach 1), the calibrated design storm model had a peak of 1,390 cfs. When the parameters were changed, the peak was reduced to 1,220 cfs, or a decrease of about 12%.

4.23 Initial Conditions Sensitivity

As discussed previously, the antecedent moisture (AM) conditions in the Calleguas for the period of December 26, 2004 through January 9, 2005 were not as saturated as in the Santa Clara and Ventura River watersheds for the same period. An evaluation of the rain gage data showed that in the Santa Clara watershed the 15-day rain totals had recurrence intervals for most gages of 100-yrs or more. In the Calleguas watershed for most rain gages the 15-day totals had recurrence intervals of 100-yrs or less.

To test the sensitivity of the design storm results to the AM conditions in the watershed, the Atmospheric River 1000 Storm (ARkStorm, 2011) data set developed for Ventura County was used to provide hourly rain data for 10 days for input to the HSPF model. The ARkStorm data set rain totals have recurrences intervals of 100-yrs or more.

Most of the ARkStorm rain occurs by the end of the 8th day. Therefore, the rain through the end of the 8th day was inserted into the HSPF input file by setting all the rain values from 12/26/04 through 1/9/05 to zero. Next the hourly data disaggregated to 15-min timesteps was copied into the continuous model input file starting on 12/31/2004 and ending on 1/7/05. The storages in the perlnds, implnds, and reaches at the end of 1/7/05 were then used to set the initial conditions in a design storm sensitivity run.

The ARkStorm model run showed that the peak flow at the Calleguas CSUCI gage location decreased from 38,500 cfs in the calibrated HSPF model to 36,800 cfs in the ARkStorm model, a difference of about 4%. Therefore, it is concluded that the design storm results obtained by using the historic rain through 1/9/05 to set the initial conditions in the model did not lead to an underestimate of the design storm peaks due to dry AM conditions in the model.

5. DESIGN STORM DATA

5.1. 100-Yr Hydrograph Yields

It is often necessary to use hydrographs for facility design and floodplain mapping where volumetric concerns are important. Hydrograph volumes are important for detention facility design and where hydraulic constraints exist in the drainage system. One advantage of the HSPF model over the previous modeling efforts using VCRat or HEC-HMS is that the HSPF hydrographs have reasonable volumes as compared to those other models. VCRat has a method that can be used to adjust the hydrograph volumes to a more reasonable level but it cannot be used on watersheds greater in size than about 80 sq mi.

The hydrograph yields for the HSPF design storm model were checked by exporting the hydrographs, subtracting off the baseflow from a baseflow model run, and then calculating the volume in the net hydrograph. Then the NRCS Curve Number (CN) method was used to estimate an areally-weighted CN for the watershed of interest. The CN was then applied to the 100-yr 24-hr weighted rain depth at the centroid of the watershed to estimate the watershed yield. A comparison of the hydrograph yields resulting from the HSPF model and the CN approach showed that the results were consistent and the HSPF yields were reasonable and generally a higher than the yields obtained from the CN approach. Table 7 shows a summary of the hydrograph yield data resulting from this effort.

5.2. Design Storm Ratios

The hydraulic analyses for floodplain mapping and design require discharges for the 10-, 50-, 100-, 200-, and 500-year storms. It is likely that storms at the 50-year level or higher represent saturated conditions where much of the rain that falls on the land surface occurs as runoff. However, the 10-year design storm is conceptualized as occurring in an unsaturated watershed at the start of the design storm. It is difficult to quantify infiltration rates and available storage capacity for these smaller design storms. In addition, overbank storage effects would become very important for the 200- and 500-year storms. These two factors would require significant additional model calibration to provide reasonable results that is not in the project scope or budget at this time.

Because of this, it was decided to use the results of flow frequency analyses of Ventura County stream gages to develop design storm ratios to convert the Q100 results from the HSPF modeling to the other recurrence intervals of interest.

The ratios from developed and undeveloped watersheds used to develop the design storm ratios for this study are shown in Table 8. These results are applicable to peaks from channels that do not have significant detention basin storage upstream from the point of interest. If such detention storage exists, such as in Sycamore, Lang, or Las Llajas watersheds, the appropriate flow multipliers should be evaluated on a case by case basis.

Table 7. Yield Analysis Results

HSPF Reach	Net Hydro-graph Vol. af	Stream	Down-stream Gage	Reach Name or **Gage**	NRCS 100-yr Yield in.	Hydro-graph Yield in.	Diff. in.	% Diff
1	660	White Oak	White Oak	**White Oak**	**4.579**	**3.80**	**0.78**	**17%**
2	2,236	Stow	Stow	**Stow**	**4.757**	**4.10**	**0.66**	**14%**
23	914	Las Llajas	Royal	Chivo US	3.842	4.42	-0.58	-15%
21	1,589	Las Llajas	Royal	Llajas US	4.212	4.47	-0.25	-6%
25	2,963	Las Llajas	Royal	Llajas	3.971	4.62	-0.64	-16%
31	1,388	Meier Cyn	Royal	Meier US	3.368	4.34	-0.97	-29%
4(904)	7,416	Royal	Royal	**Royal**	**4.150**	**4.46**	**-0.31**	**-7%**
43	717	Tapo Cyn	Tapo	Tapo US	3.672	3.42	0.25	7%
41	549	Tapo Cyn	Tapo	Gillebrand	4.080	2.65	1.43	35%
46	3,525	Tapo Cyn	Tapo	**Tapo**	**3.516**	**3.23**	**0.29**	**8%**
81	449	Bus Cyn	Bus	Bus US	2.869	3.45	-0.58	-20%
82	1,146	Bus Cyn	Bus	**Bus**	**3.421**	**3.90**	**-0.48**	**-14%**
51	270	Runkle	Madera	Runkle US	3.182	3.48	-0.30	-9%
52	682	Runkle	Madera	RunkleDS	3.416	4.00	-0.58	-17%
71	82	Erringer	Madera	Erringer US	2.505	3.06	-0.56	-22%
72	241	Erringer	Madera	Erringer DS	3.301	4.14	-0.84	-25%
61	34	Dry Cyn	Madera	Dry US	2.550	3.65	-1.10	-43%
62	43	Dry Cyn	Madera	Dry US	2.698	3.70	-1.00	-37%
64	187	Dry Cyn	Madera	Dry US	2.755	3.07	-0.32	-12%
65	775	Dry Cyn	Madera	Dry DS	3.325	4.41	-1.09	-33%
91	312	N Simi	Madera	N Simi US	3.756	4.30	-0.54	-14%
92	740	N Simi	Madera	N Simi DS	4.103	4.80	-0.69	-17%
8	15,520	Madera	Madera	**Madera**	**3.830**	**4.19**	**-0.36**	**-9%**
221	1,021	Gabbert	Gabbert	Gabbert US	4.120	5.03	-0.91	-22%
223	1,770	Gabbert	Gabbert	**Gabbert**	**4.231**	**4.67**	**-0.44**	**-10%**
101	202	Live Oak	Hitch	Live Oak US	2.726	1.84	0.88	32%
107	458	Sycamore	Hitch	Sycamore US	3.362	2.75	0.61	18%
109	1,065	Sycamore	Hitch	Sycamore DS	3.291	2.61	0.68	21%
190	1,646	Alamos	Hitch	Alamos	4.025	5.02	-1.00	-25%
192	69	Castro	Hitch	Castro	3.122	2.63	0.50	16%
193	522	Peach	Hitch	Peach	3.934	3.82	0.12	3%
211	2,578	Happy Camp	Hitch	Happy Camp US	3.271	4.60	-1.33	-41%

HSPF Reach	Net Hydro-graph Vol. af	Stream	Down-stream Gage	Reach Name or **Gage**	NRCS 100-yr Yield in.	Hydro-graph Yield in.	Diff. in.	% Diff
212	2,776	Happy Camp	Hitch	Happy Camp	3.205	4.41	-1.21	-38%
205	28,113	Hitch	Hitch	**Hitch**	**3.705**	**4.14**	**-0.43**	**-12%**
241	1,389	Fox	Call101	Fox US	5.127	5.19	-0.06	-1%
243	1,410	Fox	Call101	Fox DS	5.111	5.19	-0.08	-2%
231	1,995	Coyote	Call101	Coyote US	4.033	5.10	-1.07	-27%
233	2,250	Coyote	Call101	Coyote DS	4.100	5.11	-1.01	-25%
311	85	Call101	Call101	St Johns	4.475	4.50	-0.03	-1%
225	1,592	S. Grimes	Call101	S. Grimes	4.213	4.42	-0.21	-5%
227	2,772	Mahan	Call101	Mahan	4.389	5.41	-1.02	-23%
302	38,600	Call101	Call101	**Call101**	**3.826**	**4.34**	**-0.51**	**-13%**
401	2,465	ArrCon	ArrCon	ArrCon US	5.086	5.89	-0.80	-16%
402	4,217	ArrCon	ArrCon	**ArrCon DS**	**5.148**	**6.14**	**-0.99**	**-19%**
410	984	LangBasin	ArrCon	Lang Basin	3.583	5.24	-1.65	-46%
411	1,752	Lang Ck	ArrCon	Lang Ck	4.188	5.31	-1.12	-27%
441	1,068	Sta Rosa	StaRosa	Sta Rosa US	2.579	2.84	-0.26	-10%
443	334	Sta Rosa	StaRosa	Sta Rosa Trib	3.413	3.61	-0.20	-6%
442	2,718	Sta Rosa	StaRosa	**Sta Rosa DS**	**3.057**	**3.52**	**-0.46**	**-15%**
431	1,807	NFAC	Conejo	NFArrCon	4.877	4.10	0.78	16%
421	838	SBAC	Conejo	SBAC US	3.656	3.93	-0.27	-7%
423	3,343	SBAC	Conejo	**SBAC**	4.433	4.67	-0.24	-5%
405	15,696	Conejo	Conejo	**Conejo**	**4.178**	**4.57**	**-0.39**	**-9%**
304	58,043	CSUCI	CSUCI	**CSUCI**	**3.876**	**4.37**	**-0.49**	**-13%**
500	286	Beards	Beards	Beards US	4.328	4.20	0.12	3%
502	5,456	Beards	Beards	**Beardsley**	**4.360**	**5.98**	**-1.62**	**-37%**
510	157	Ferro	StaClara	StaClara US	4.322	3.67	0.65	15%
512	1,693	StaClaraDS	Beards	StaClara DS	4.433	4.15	0.28	6%
507	982	Nyeland	Nyeland	**Nyeland**	**4.623**	**5.09**	**-0.46**	**-10%**
526	30	CamHills	CamHills	Basin	3.729	5.20	-1.47	-39%
525	43	CamHills	CamHills	Basin	4.107	5.11	-1.00	-24%
524	29	CamHills	CamHills	Basin	4.318	5.06	-0.74	-17%
523	39	CamHills	CamHills	Basin	2.873	4.03	-1.16	-40%
522	2,216	Revolon	Revolon	CamHills DS	3.777	5.27	-1.50	-40%
531	965	Plsnt Vall	Revolon	Plsnt Vall	4.220	5.17	-0.95	-22%
505	11,439	Revolon	Revolon	**Revolon**	**4.311**	**4.68**	**-0.36**	**-8%**
307	79,431	Mugu	None	Mugu	3.916	4.48	-0.57	-14%

Table 8. Ventura County Design Storm Ratios

Stream Gage Station District Number	Yrs	Area Sq. Miles	2-yr Ratio	5-yr Ratio	10-yr Ratio	25-yr Ratio	50-yr Ratio	100-yr Ratio	200-yr Ratio	500-yr Ratio
UNDEVELOPED WATERSHEDS										
Ventura Watershed										
606 Santa Ana Creek nr Oak View	37	9.1	0.049	0.154	0.274	0.495	0.718	1.000	1.230	1.897
600 Coyote Creek near Oak View	43	13.2	0.047	0.146	0.261	0.480	0.705	1.000	1.367	1.994
604 North Fork Matilija Creek	72	15.6	0.048	0.158	0.281	0.507	0.727	1.000	1.324	1.842
605 San Antonio Creek at Casitas Springs	55	51.2	0.039	0.126	0.233	0.448	0.683	1.000	1.416	2.160
608 Ventura River Near Ventura	73	187	0.032	0.127	0.245	0.474	0.707	1.000	1.349	1.913
Santa Clara Watershed										
707 Santa Clara at County Line	52	410	0.037	0.126	0.236	0.454	0.689	1.000	1.401	2.102
701 Hopper Creek near Piru	70	23.6	0.048	0.148	0.264	0.482	0.708	1.000	1.359	1.974
709 Santa Paula Creek near Santa Paula	71	40	0.032	0.116	0.222	0.440	0.680	1.000	1.402	2.168
711 Sespe Creek near Wheeler Springs	52	50	0.026	0.107	0.216	0.440	0.683	1.000	1.403	2.089
710 Sespe Creek near Fillmore	63	251	0.062	0.190	0.324	0.549	0.756	1.000	1.274	1.681
708 Santa Clara River at Montalvo	68	1624	0.057	0.185	0.322	0.552	0.761	1.000	1.265	1.650
Average Ratio to 100 yr			0.043	0.144	0.262	0.484	0.711	1.000	1.345	1.952
Standard Deviation			0.011	0.027	0.037	0.040	0.028	0.000	0.064	0.177
Historic District Multipliers			0.058	0.167	0.362	0.507	0.725	1.000	NA	NA
Urban										
733 Oxnard West Drain	35	3.2	0.231	0.423	0.560	0.739	0.871	1.000	1.129	1.293
833 Bus Canyon Drain	35	4.9	0.199	0.357	0.484	0.670	0.827	1.000	1.185	1.462
830 Arroyo Conejo South Branch	35	12.5	0.173	0.322	0.448	0.640	0.809	1.000	1.217	1.546
836 Arroyo Conejo	30	14.2	0.134	0.277	0.405	0.608	0.791	1.000	1.242	1.606
802 Arroyo Simi at Royal Avenue	37	32.6	0.137	0.282	0.410	0.612	0.792	1.000	1.237	1.604
803 Arroyo Simi near Simi	63	71	0.124	0.318	0.476	0.688	0.844	1.000	1.139	1.500
Average Ratio to 100 yr			0.166	0.330	0.464	0.660	0.822	1.000	1.191	1.502
Standard Deviation			0.042	0.054	0.057	0.050	0.031	-	0.049	0.117
Historic District Multipliers			0.133	0.375	0.567	0.692	0.833	1.000	NA	NA
Coyote Creek										
Casitas Dam Outflow Multipliers		38.7	**0.005**	**0.030**	**0.048**	**0.110**	**0.143**	**1.000**	**1.191**	**1.448**
Coyote Creek blw Dam Multipliers		41.3	**0.005**	**0.100**	**0.200**	**0.400**	**0.580**	**1.000**	**1.191**	**1.416**

NA = Not Available/Not Applicable

Because hydraulic modeling of the tributaries may require design storm discharges at points upstream from the locations provided in Table 6, it is recommended that the regression equations developed by the Jennings and others (1994) be used to apply discharge transfer techniques to the design storm model results for this purpose.

5.3. Peak Flow Bulking

Because the HSPF design storm model was calibrated to historic stream gage data, the peak flows incorporate some bulking effects including increased runoff due to fires in the watersheds. Fires or slope failures in the watershed may add more sediment to the flow locally and increase the bulking of the design peaks. However, this study is focused on the peaks occurring due to intense design storm rainfall. If a design peaks are required for emergency projects in response to fires or slope failures in the watershed, then the bulking factors should be increased following the District's historic practices to reflect those relatively short term impacts on the watershed.

6. CONCLUSIONS

The HSPF model provides another tool to evaluate design storm peaks in the Calleguas Creek watershed. The design storm model provided peaks that could be calibrated to the available stream gage flow frequency analysis peaks to within a few percent or less using a rainfall calibration factor. In some locations the change in the rainfall factor to match the design storm peak data indicated that the design storm peaks may be too conservative. This conclusion was confirmed in many cases by comparing the design storm peak to the historic maximum peak flow for a gage.

The HSPF peaks on ungaged tributaries were generally 20-50% less than the peaks from the District's rational method model. Tributaries with differences greater than this were generally due to differences in watershed areas or rainfall intensities for the two models. The HSPF peaks were generally less than the rational method peaks due to the presence of storage in the HSPF model to simulate the effects of homeowner association detention basins and curb inlet limitations on design storm runoff.

7. REFERENCES

ARkStorm, 2011. Atmospheric River 1000 Storm Data Set.

Aqua Terra Consultants, 2005. Hydrologic Modeling of the Calleguas Creek Watershed with the U.S. EPA Hydrologic Simulation Program – FORTRAN (HSPF)- Final Report. March 2005.

Corps, 2000. Hydrologic Modeling System HEC-HMS Technical Reference Manual. US Army Corps of Engineers Hydrologic Engineering Center. March, 2000.

Jennings, M. E.; Thomas W. O., Jr.; Riggs, H. C., U. S. Geological Survey Water-Resources Investigations Report 94-4002, Nationwide Summary of U.S. Geological Survey Regional Regression Equations for Estimating Magnitude and Frequency of Floods for Ungaged Sites (1994).

USGS, 1982. Guidelines for Determining Flood Flow Frequency, Bulletin #17B of the Hydrology Subcommittee USGS (United States Geological Survey 1982).

VCWPD, 2003. Calleguas Creek Watershed Hydrology Study. Ventura County Public Works Agency Watershed Protection District, March 2003.

VCWPD, 2011. Calleguas Creek Watershed HSPF Model Calibration Draft Report. Ventura County Watershed Protection District. October, 2011.