

APPENDIX F
SANTA CRUZ RIVER STUDY DATA

SANTA CRUZ RIVER STUDY

The Santa Cruz River floodplain north of Pima Mine Road, an area that is adjacent to the western margin of the LMWBMS study area and ultimately impacted to the north where the Lee Moore channel discharges west underneath Nogales Highway, was investigated with this study. The Santa Cruz River south of Pima Mine Road has been previously mapped in the FEMA FIS study dated February 1999, however only a portion of the subject area north was mapped by approximate methods, precluded because the area is situated predominantly within the Tohono O'Odham reservation. The PCRFC interest in this area also stems from a recent study of the area south of Pima Mine Road by Castro Engineering suggesting that 80% (36,000 cfs) of the peak flow of the Santa Cruz River near this location breaks away from the main river to the northeast into the overbank areas. A map displaying this concept along with email correspondence was provided by staff with the engineering firm, however, the HEC-RAS model documenting this analysis was not provided. Thus, the flow distribution associated with the breakout within areas to the south and north could only be estimated.

In the event that breakout flow from the Santa Cruz River would occur upstream of Pima Mine Road as identified in a preliminary upstream study, it is apparent that flow from the south may overflow both the Nogales Highway to the east and Pima Mine Road to the north. Review of available aerial photography from the 1983 event indicates a situation similar to these circumstances did occur during this flood event. The existing topography to the north of Pima Mine Road and east presents several flow obstructions, and the flow distribution within the eastern overbank of the Santa Cruz River under the given situation is complex, with several areas of divided flow paths. These encroachments include an existing gravel pit northeast of the Pima Mine Road and Nogales Highway intersection, and the Tucson Water recharge ponds to the north and west of Nogales Highway. Thus, in order to estimate existing flood limits, several different models were developed to evaluate hydraulic conditions surrounding these structures. These models were all generated from identical cross-sections developed to characterize the floodplain topography within these areas, with separate topographic constraints employed to isolate specific areas and estimate flooding conditions. The following discussion provides a brief description of the methods employed to separate each model and their base conditions, with the results presented on the accompanying map illustrating the approximate flood limits associated with this study.

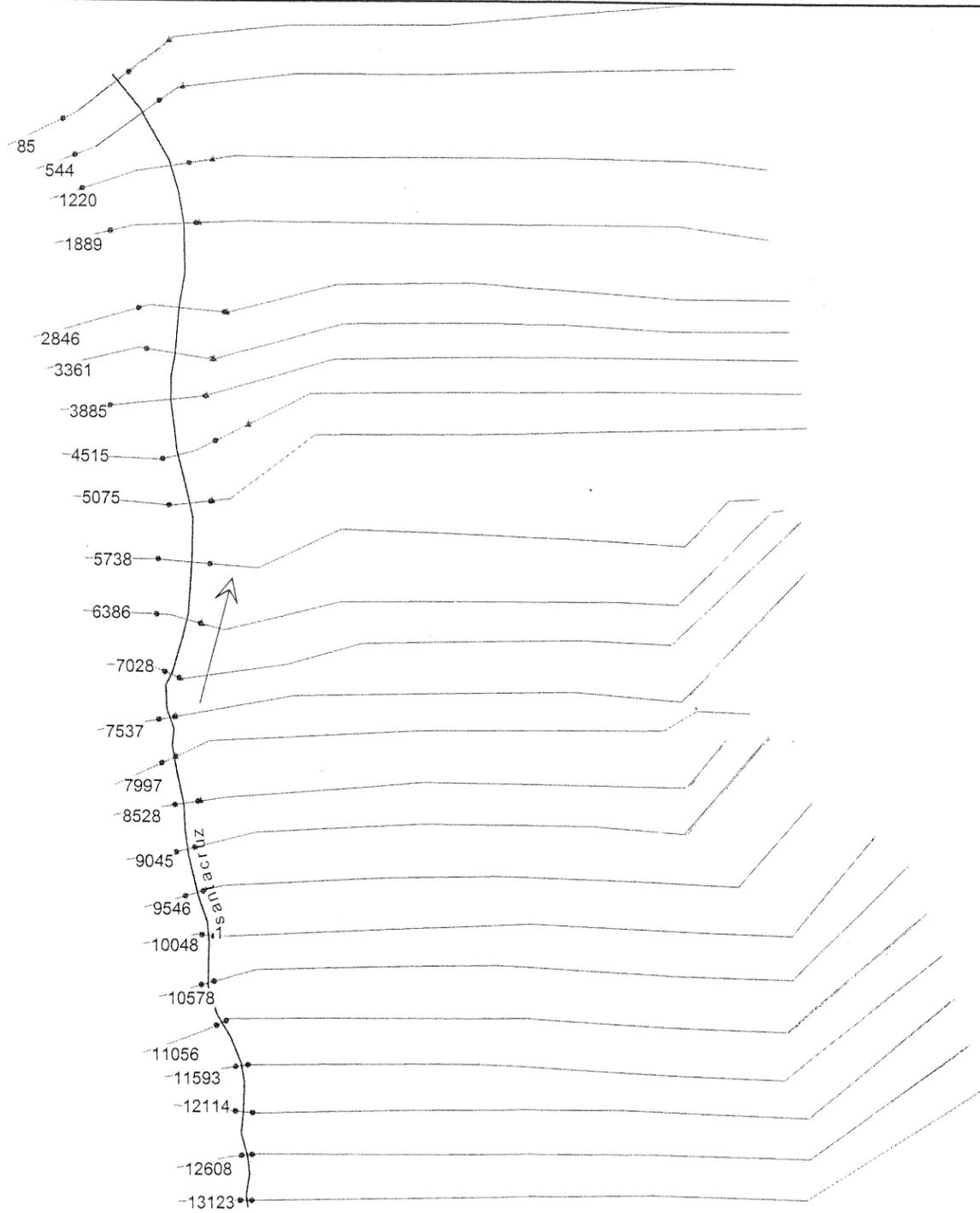
A three-dimensional surface and topography was generated for the study reach north of Pima Mine Road using GEO HEC-RAS computer software, and cross-sections were developed to employ in the HEC-RAS modeling. These sections were extended as much as 1.8 miles from the western overbank of the Santa Cruz River channel eastward to include flooding areas east of the existing gravel pit. From these data, initial HEC-RAS modeling indicated five distinct areas of divided flow, and separate models were developed for each specific reach. These reaches are generally characterized as follows: the Santa Cruz River channel (Model 1), the ROB (right overbank) between the river and recharge ponds (Model 2), the ROB between the recharge ponds and Nogales Highway (Model 3), the ROB between Nogales Highway and the gravel pit (Model 4), and the ROB east of the gravel pit (Model 5). Each model incorporated the same cross-sectional data, and the study reaches were isolated by eliminating portions of the cross-section and/or using the obstruction routine to exclude specific flow areas, i.e. the Santa Cruz River channel was obstructed to develop the right overbank models (Models 2-5), areas east of Nogales Highway were eliminated for Model 3, etc. In this manner, several different hydraulic conditions could be efficiently evaluated, while providing reasonable estimates of potential flooding.

It was also evident from initial modeling efforts that each area of divided flow would have a distinct discharge predominantly dependent on the flow distribution upstream of Pima Mine Road. Since the detailed modeling was not available, a fairly simplified approach was required to determine the potential discharge that might be experienced within each area of divided flow. This was accomplished by developing a simplified cross-section just upstream of Pima Mine Road, and running the HEC-RAS model to determine the capacity of the overbank area between the Santa Cruz and Nogales Highway. The remaining flow was assumed to discharge east of Nogales Highway. On the basis of this analysis, and assuming the Castro breakout estimate of 36,000 cfs, it is estimated that 11,000 cfs discharges immediately north of Pima Mine Road, while 25,000 cfs is assumed to flow within areas east of Nogales Highway. Furthermore, to isolate flows for the two individual models within each of the above-referenced areas, an iterative process was used to balance water-surface elevations and discharges just downstream of Pima Mine Road to estimate the flow distribution within each of the four models. On the basis of these simplified analyses, it is estimated that about 3500 cfs will flow within the Model 2 overbank reach, 7500 cfs within the Model 3 study reach, 12,000 cfs within the Model 4 study reach and 13,000 cfs within the Model 5 reach. The Santa Cruz River

channel flow was estimated as 8800 cfs by the Castro study, and was employed along the reach north of Pima Mine Road.

Given these discharges, each individual model was evaluated using specific cross-section modifications to best simulate the divided flow study reach for each model. During these analyses, it became apparent that specific areas would not contain their associated discharge, and the split flow routine was employed as appropriate. Based on this analysis, it is evident that should the 12,000 cfs between the gravel pits and Nogales Highway be a reasonable estimate, approximately 5000 cfs will spill over Nogales Highway to the west and flow north within the Model 3 study reach. An additional area displaying split flow is Model 5, where flow just north of the existing gravel pit will spill over into the existing Lee Moore Wash channel at this location. It should be noted that one additional model was required to complete the floodplain delineation, consisting of the Lee Moore channel north of the gravel pit where flows associated with Models 4 and 5 converge, and north to the existing bridge at Nogales Highway. This reach was modeled employing a discharge of 20,000 cfs, as 5000 cfs spills west over Nogales Highway as noted above. The Lee Moore channel west of Nogales Highway was incorporated within Model 3.

Flood limits based on the results of these five models were delineated, and are displayed on the accompanying map along with the estimated discharges used with the modeling. These results indicate that the majority of the area east of Nogales Highway and north of Pima Mine Road may experience shallow flooding, as well as the areas west of the highway to the Santa Cruz River. It is also worthy to note that the Lee Moore channel as studied in the overall LMWBMS hydraulic analysis has marginal capacity for the estimated 100-year flow of 22,000 cfs generated by the Lee Moore Wash, however, the estimated 32,500 cfs associated with this analysis may induce flooding within residential areas located along the Lee Moore overbank areas to the north.



MODEL 1 | MODEL 2 | MODEL 3 | MODEL 4 | MODEL 5
 APPROXIMATE MODEL LIMITS

HEC-RAS Plan: p10 River: santacruz Reach: 1 Profile: PF 1

Reach	River Sta	Profile	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Crit W.S. (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Vel Chnl (ft/s)	Flow Area (sq ft)	Top Width (ft)	Froude # Chl
1	13123	PF 1	8800.00	2635.46	2648.37		2649.76	0.002489	9.46	930.39	89.90	0.52
1	12608	PF 1	8800.00	2633.70	2644.91		2647.71	0.006081	13.44	654.87	70.58	0.78
1	12114	PF 1	8800.00	2632.02	2644.67		2645.60	0.001911	7.74	1136.25	128.01	0.46
1	11593	PF 1	8800.00	2630.64	2642.14		2644.11	0.003987	11.25	782.56	84.27	0.65
1	11056	PF 1	8800.00	2629.22	2640.02		2641.95	0.004008	11.14	790.22	84.30	0.64
1	10578	PF 1	8800.00	2627.97	2637.48		2639.64	0.005800	11.78	746.90	104.28	0.78
1	10048	PF 1	8800.00	2626.36	2635.21		2636.91	0.004184	10.47	840.15	106.43	0.66
1	9546	PF 1	8800.00	2624.75	2633.62		2634.84	0.003526	8.87	991.62	145.41	0.60
1	9045	PF 1	8800.00	2622.66	2631.67		2633.04	0.003584	9.40	936.27	127.58	0.61
1	8528	PF 1	8800.00	2620.93	2630.12	2627.60	2631.28	0.003041	8.63	1019.46	296.15	0.57
1	7997	PF 1	8800.00	2618.75	2628.03	2625.82	2629.47	0.003705	9.65	912.34	295.68	0.62
1	7537	PF 1	8800.00	2616.04	2626.92	2623.93	2627.96	0.002518	8.16	1078.84	243.48	0.51
1	7028	PF 1	8800.00	2614.84	2622.91	2622.76	2625.55	0.009528	13.06	673.97	154.96	0.96
1	6386	PF 1	8800.00	2613.25	2620.66	2619.19	2621.42	0.003635	6.97	1262.21	297.86	0.58
1	5738	PF 1	8800.00	2611.57	2618.44		2619.07	0.003503	6.37	1382.31	341.25	0.56
1	5075	PF 1	8800.00	2609.27	2617.70	2614.41	2617.94	0.000852	3.90	2256.41	523.41	0.29
1	4515	PF 1	8800.00	2606.56	2617.28	2612.14	2617.46	0.000804	3.43	2562.31	627.84	0.28
1	3885	PF 1	12300.00	2603.78	2615.45	2612.02	2616.27	0.004242	7.28	1689.74	511.28	0.62
1	3361	PF 1	12300.00	2601.50	2612.11	2610.13	2613.60	0.005883	9.82	1252.68	327.71	0.75
1	2846	PF 1	12300.00	2599.92	2610.61	2607.62	2611.52	0.002540	7.69	1599.24	332.15	0.52
1	1889	PF 1	12300.00	2596.73	2607.29	2604.42	2607.84	0.006042	5.94	2070.75	932.53	0.67
1	1220	PF 1	12300.00	2594.04	2604.87	2601.71	2605.14	0.002740	4.14	2969.55	1233.34	0.46
1	544	PF 1	12300.00	2591.58	2602.66	2598.81	2603.01	0.003617	4.78	2575.25	1109.78	0.53
1	85	PF 1	12300.00	2590.00	2601.02	2597.19	2601.42	0.003306	5.05	2436.56	888.53	0.52

SANTA CRUZ RIVER STUDY
MODEL 1

HEC-RAS Plan: p7 River: santacruz Reach: 1 Profile: PF 1

Reach	River Sta	Profile	Q Total (cfs)	Min Ch El (ft)	W. S. Elev (ft)	Crit W. S. (ft)	E. G. Elev (ft)	E. G. Slope (ft/ft)	Vel Chnl (ft/s)	Flow Area (sq ft)	Top Width (ft)	Froude # Chl
1	13123	PF 1	3500.00	2658.10	2660.18		2660.23	0.001593	1.82	1923.36	1185.44	0.25
1	12608	PF 1	3500.00	2656.96	2659.23		2659.29	0.002120	2.06	1835.26	1518.82	0.29
1	12114	PF 1	3500.00	2655.64	2657.63	2657.09	2657.75	0.005018	2.29	1363.02	1469.11	0.43
1	11593	PF 1	3500.00	2653.66	2655.80		2655.89	0.002653	2.85	1566.06	1349.09	0.32
1	11056	PF 1	3500.00	2650.69	2652.75	2652.58	2652.95	0.016720	3.58	977.66	1273.38	0.72
1	10578	PF 1	3500.00	2647.54	2650.40		2650.46	0.002454	1.95	1814.55	1479.67	0.30
1	10048	PF 1	3500.00	2645.24	2648.84	2648.19	2648.92	0.003464	2.21	1603.23	1506.00	0.35
1	9546	PF 1	3500.00	2639.12	2645.65	2644.86	2646.45	0.006986	7.33	577.08	723.00	0.74
1	9045	PF 1	3500.00	2635.78	2644.07		2644.53	0.002218	5.55	737.08	498.26	0.42
1	8528	PF 1	3500.00	2635.01	2642.52		2643.00	0.004132	5.62	657.18	286.14	0.54
1	7997	PF 1	3500.00	2633.60	2640.33	2638.55	2640.90	0.003778	6.05	589.36	292.10	0.52
1	7537	PF 1	3500.00	2631.71	2637.89		2638.79	0.005453	7.64	458.32	97.07	0.62
1	7028	PF 1	3500.00	2629.83	2635.85		2636.39	0.003787	5.90	617.62	188.32	0.51
1	6386	PF 1	3500.00	2625.20	2632.87		2633.73	0.004414	7.46	468.95	86.89	0.57
1	5738	PF 1	3500.00	2622.69	2631.83		2632.11	0.001349	4.24	825.46	148.74	0.32
1	5075	PF 1	12300.00	2618.12	2625.90	2625.90	2627.60	0.015260	10.46	1175.69	786.61	0.99
1	4515	PF 1	12300.00	2606.56	2622.84	2622.84	2622.89	0.000115	1.86	6605.46	1085.39	0.13
1	3885	PF 1	12300.00	2603.78	2615.45		2616.27	0.004231	7.27	1691.31	393.38	0.62
1	3361	PF 1	12300.00	2601.50	2612.08		2613.59	0.005963	9.87	1246.15	236.36	0.76
1	2846	PF 1	12300.00	2599.92	2610.52		2611.46	0.002631	7.79	1579.76	231.46	0.53
1	1889	PF 1	12300.00	2596.73	2607.46	2604.43	2607.94	0.005001	5.54	2220.51	883.02	0.62
1	1220	PF 1	12300.00	2594.04	2604.60	2601.71	2604.94	0.003944	4.62	2660.75	1162.97	0.54
1	544	PF 1	12300.00	2591.58	2601.30	2598.81	2602.12	0.004254	7.28	1689.64	393.82	0.62
1	85	PF 1	12300.00	2590.00	2598.75	2597.19	2599.97	0.005001	8.85	1389.82	273.24	0.69

SANTA CRUZ RIVER STUDY
MODEL 2

HEC-RAS Plan: p6 River: santacruz Reach: 1 Profile: PF 1

Reach	River Sta	Profile	Q Total (cfs)	Min Ch El (ft)	W. S. Elev (ft)	Crit W.S. (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Vel Chnl (ft/s)	Flow Area (sq ft)	Top Width (ft)	Froude # Chl
1	13123	PF 1	7500.00	2657.50	2660.37		2660.45	0.002189	2.28	3284.72	1827.30	0.30
1	12608	PF 1	7500.00	2656.42	2658.62		2658.78	0.002556	3.15	3284.16	1582.16	0.45
1	12114	PF 1	7500.00	2654.11	2656.91	2655.86	2657.02	0.002557	2.56	2932.60	2248.69	0.33
1	11593	PF 1	7500.00	2652.88	2655.64	2654.61	2655.73	0.002387	2.49	3013.25	2303.72	0.32
1	11056	PF 1	8000.00	2650.84	2653.09	2652.73	2653.33	0.010287	3.93	2033.62	2295.18	0.61
1	10578	PF 1	10200.00	2646.66	2651.20		2651.32	0.002485	2.75	3705.59	1713.33	0.33
1	10048	PF 1	11700.00	2646.31	2649.65		2649.80	0.003276	3.13	3762.92	1809.03	0.38
1	9546	PF 1	12400.00	2644.73	2647.81		2647.97	0.004066	3.18	3904.87	2107.58	0.41
1	9045	PF 1	12400.00	2643.32	2646.44	2645.22	2646.54	0.002055	2.55	4860.78	2544.85	0.30
1	8528	PF 1	12400.00	2642.32	2644.78	2644.07	2644.95	0.005035	3.32	3729.53	2562.35	0.45
1	7997	PF 1	12400.00	2640.26	2643.32		2643.41	0.001839	2.42	5115.02	2285.22	0.29
1	7537	PF 1	12400.00	2638.15	2641.67	2641.14	2641.90	0.007459	3.83	3241.46	2601.83	0.54
1	7028	PF 1	12400.00	2627.97	2640.33	2638.79	2640.40	0.001458	2.12	5814.92	2645.27	0.25
1	6386	PF 1	12400.00	2626.21	2638.22	2634.18	2638.51	0.008412	4.30	2883.45	2407.22	0.58
1	5738	PF 1	12400.00	2623.89	2634.28		2634.64	0.004454	4.82	2573.05	792.31	0.47
1	5075	PF 1	32500.00	2609.53	2633.44	2625.83	2633.80	0.000918	6.03	9707.99	3208.31	0.27
1	4515	PF 1	32500.00	2608.17	2627.13	2626.64	2632.21	0.007327	18.10	1812.77	175.30	0.94
1	3885	PF 1	32500.00	2607.12	2629.05		2629.61	0.000901	6.25	6915.78	1980.28	0.33
1	3361	PF 1	32500.00	2606.17	2624.95		2628.39	0.004906	14.91	2202.44	212.98	0.77
1	2846	PF 1	32500.00	2605.31	2623.46		2626.01	0.003486	12.83	2545.65	232.97	0.66
1	1889	PF 1	32500.00	2603.79	2623.71		2624.15	0.000658	6.00	7518.28	1135.74	0.29
1	1220	PF 1	32500.00	2601.93	2620.71	2617.06	2623.10	0.003476	12.41	2619.62	233.43	0.65
1	544	PF 1	32500.00	2598.65	2619.40	2612.65	2621.09	0.002119	10.51	3544.54	1253.93	0.52
1	85	PF 1	32500.00	2596.48	2617.03	2613.32	2619.73	0.003707	13.53	3249.77	1395.56	0.68

SANTA CRUZ RIVER STUDY
MODEL 3

HEC-RAS Plan: p4 River: santacruz Reach: 1 Profile: PF 1

Reach	River Sta	Profile	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Crit W.S. (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Vel Chnl (ft/s)	Flow Area (sq ft)	Top Width (ft)	Froude # Chl
1	13123	PF 1	12000.00	2649.54	2659.89		2660.70	0.003152	8.58	2050.99	522.11	0.52
1	12608	PF 1	12000.00	2647.87	2658.57		2659.25	0.002921	7.78	2183.70	544.05	0.49
1	12114	PF 1	12000.00	2647.50	2657.12		2657.76	0.003076	7.76	2198.90	542.23	0.50
1	11593	PF 1	12000.00	2646.46	2656.00		2656.55	0.002648	7.13	2321.78	547.71	0.47
1	11592.9		Lat Struct									
1	11056	PF 1	11547.81	2644.80	2655.06		2655.43	0.001503	5.98	2744.93	562.23	0.36
1	10578	PF 1	9334.18	2646.71	2652.53		2653.64	0.011056	10.57	1281.20	534.42	0.88
1	10048	PF 1	7840.35	2641.85	2650.37		2650.87	0.002697	6.66	1730.41	578.61	0.46
1	9546	PF 1	7307.22	2640.70	2649.33	2647.93	2649.66	0.001725	5.57	1979.40	606.80	0.37
1	9045	PF 1	7111.40	2639.12	2644.83	2644.83	2647.18	0.019267	13.13	613.18	223.21	1.14
1	8528	PF 1	7111.40	2634.90	2641.70	2637.65	2641.90	0.000919	3.63	1991.03	341.54	0.29

SANTA CRUZ RIVER STUDY
MODEL 4

HEC-RAS Plan: p2 River: santacruz Reach: 1 Profile: PF 1

Reach	River Sta	Profile	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Crit W.S. (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Vel Chnl (ft/s)	Flow Area (sq ft)	Top Width (ft)	Froude # Chl
1	13123	PF 1	13000.00	2656.73	2659.83		2659.92	0.002182	2.29	5688.87	2698.81	0.28
1	12608	PF 1	13000.00	2655.49	2658.72		2658.82	0.002728	2.50	5201.46	2549.42	0.31
1	12114	PF 1	13000.00	2654.19	2657.59		2657.68	0.002360	2.43	5358.26	2467.33	0.29
1	11593	PF 1	13000.00	2653.18	2656.37		2656.47	0.002588	2.65	5060.42	2334.54	0.31
1	11592.9		Lat Struct									
1	11056	PF 1	12922.88	2651.51	2655.21		2655.31	0.002544	2.59	4981.70	2188.41	0.30
1	10578	PF 1	12890.64	2650.85	2653.87		2653.99	0.003065	2.89	4569.62	2067.15	0.33
1	10048	PF 1	12057.72	2649.63	2652.29		2652.45	0.003782	3.21	3803.17	1951.12	0.40
1	9546	PF 1	7722.29	2646.80	2649.38	2648.49	2649.53	0.003334	3.33	2527.80	1288.43	0.39

SANTA CRUZ RIVER STUDY
MODEL 5

HEC-RAS Plan: p1 River: santacruz Reach: 1 Profile: PF 1

Reach	River Sta	Profile	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Crit W.S. (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Vel Chnl (ft/s)	Flow Area (sq ft)	Top Width (ft)	Froude # Chl
1	7997	PF 1	20000.00	2624.39	2641.39		2641.61	0.000291	3.79	5318.74	483.98	0.19
1	7537	PF 1	20000.00	2623.93	2640.19		2641.34	0.001787	8.62	2323.41	238.92	0.46
1	7028	PF 1	20000.00	2621.93	2640.20		2640.48	0.000610	4.76	6669.95	2195.59	0.27
1	6386	PF 1	20000.00	2620.45	2634.53	2634.53	2639.36	0.008977	17.64	1133.74	118.59	1.01
1	5738	PF 1	20000.00	2618.70	2636.00	2629.18	2636.26	0.000549	5.04	6011.23	935.71	0.26

SANTA CRUZ RIVER STUDY
 LEE MOORE CHANNEL
 DOWNSTREAM OF MODELS 4/5
 TO HWY BRIDGE