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DEPARTMENT OF THE ARMY
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SACRAMENTO, CALIFORNIA

CACHE CREEK
HYDRAULIC ANALYSIS
ROAD 94B TO CACHE CREEK
SETTLING BASIN

MBK ENGINEERS

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SECTION 1 -- INTRODUCTION

1.01 Purpose and Scope

The purpose of this report is to present an evaluation of flood problems along Cache Creek from Road 94B to the Cache Creek Settling Basin. To evaluate the potential for flooding, it is necessary to define the existing system of flood protection and compare this to likely alternatives. The alternatives are then evaluated to select the most likely alternatives for further study on final selection.

This report was prepared as required by the Department of the Army, Sacramento District, US Army Corps of Engineers under contract with the City of Woodland.

SECTION 2 -- STUDY AREA DESCRIPTION

2.01 Cache Creek

As part of the Sacramento River Flood Control Project, authorized by the Flood Control Act of 1917, the Corps of Engineers completed construction for the Cache Creek Settling Basin in 1937. The settling basin, located in Yolo County about two miles east of Woodland, is bounded by levees on all sides and covers approximately 3,600 acres. The basin's fundamental purpose is to preserve the floodway capacity of the Yolo Bypass by entrapping the heavy sediment load carried by Cache Creek. Plate 1 is a location map for the study area.

The southern levee of the settling basin along the Sacramento Northern Railroad Track was constructed in 1940, and the "Cobble Weir" was constructed in 1944. A levee was not built on the western boundary of the basin because rights-of-way were acquired only to the 32-foot contour, USGS Datum. This was considered to be the westerly limit to which waters would spread.

In 1943, levees were constructed along Cache Creek from the mouth of the settling basin to Yolo, providing for a capacity of 20,000 cfs. In 1961, the north levees were extended approximately three miles upstream of the town of Yolo, and the entire settling basin levee system was strengthened to convey a design flow of 30,000 cfs. This work was authorized in "Design Memorandum No. 10 for the Sacramento River Flood Control Project, California, Cache Creek Yolo Bypass to High Ground Levee Construction," dated 1 November 1958. Plate 2 is a proposed levee construction plan from October 1958. Due to the proposed Wilson Valley Reservoir and subsequent anticipated flood protection, the south levee upstream of I-5 was not constructed, thus leaving lands south of Cache Creek vulnerable to overflow.

Interstate Highway 5, completed in 1973, forms a barrier to overland flow from Cache Creek, with the potential for diverting flood flows toward the City of Woodland. Although there have been many major floods from Cache Creek, the central City of Woodland has no recorded history of flooding.

During the flood of 1958, the sedimentation basin levees successfully contained flows of 41,400 cfs, but Cache Creek overflowed its banks upstream of the levees and flooded farmlands and roads. Flood damages for the 1958 flood along Cache Creek above the leveed reach and below Clear Lake Dam were estimated at $520,000 (1958 price level). In 1970, limited flooding in the lower basin adjacent to Cache Creek caused approximately $50,000 (1970 price level) in agricultural damages. In January 1983, flooding occurred adjacent to the settling basin due to a levee break on the southern project levee below Road 102. A partial estimate for flood damages in 1983 have totaled approximately $1,800,000 (1983 price level). In March 1995, flooding occurred to the north and south of Cache Creek upstream of I-5. Flooding downstream of I-5 was contained by flood fighting on top of the levee.

SECTION 3 -- HYDROLOGY

3.01 Cache Creek Hydrology

Limited historical runoff data are available for the Cache Creek basin. For this investigation, 60 years of runoff data were available for evaluating flow frequencies and magnitudes. Although this length or record is much better than the length of record for many rivers in California, it is still considered a relatively short period of time. It is important to understand that this study is based on past events that we assume will be equaled in the future; however, significantly greater flood flows may also occur.

The computer program HEC-1 was used for the Cache Creek basin model. Discharge hydrographs were developed for the without-project condition for Cache Creek for the 50-, 100-, 200-, and 500-year flood events. Historical flood stages and cross sections were used to verify the channel capacity of Cache Creek.

A detailed hydrology study was performed and is included as part of the feasibility report. For the hydraulic study, flows developed in the hydrology study were input at Road 94B. Tabulated below are the peak flows and associated frequency.

Table 1
Estimated Cache Creek Peak Flood Flow & Frequency

Return Period (years)	Peak Flow (cfs)
10	31,500
50	53,290
100	63,683
200	70,085
500	78,595

For comparison, historical flows at the Yolo gage are tabulated below in Table 1A. The Yolo Gage is downstream of RD 94B and does not represent flows fully contained by Cache Creek. Natural banks between RD 94B and Yolo begin to overtop between 36,000 and 38,000 cfs.

Table 1A
Cache Creek Historic Flows at Yolo

Location	Date	Flood Peak (cfs)	3-Day Flow Volume (ac-ft)
Cache Creek at Yolo	25 Feb 58	41,400	102,230
	23 Dec 64	26,200	79,360
	6 Jan 65	37,800	97,420
	24 Jan 70	34,600	125,720
	27 Jan 83	33,000	---
	9 Jan 95	32,000	---
	9 Mar 95	36,400	---

SECTION 4 -- SURVEYS and MAPPING

4.01 Surveys

Topographic mapping, field cross sections, and reconnaissance-level survey data were collected in the study area during the spring of 2000. Aerial photography was taken on March 24, 2000, and a GPS control survey was subsequently performed. In addition, DWR surveyed the bridges in mid-April 2000. The aerial topographic data was collected in Digital Terrain Model (DTM) format in a three-dimensional digital file. Planimetric detail was for a two-foot contour interval. Vertical control datum for the survey is NAVD '88.

SECTION 5 -- HYDRAULICS

5.01 Lower Cache Creek Channel Model Flood Plain Delineations

Hydraulic modeling and flood plain delineations were conducted on Cache Creek from Road 94B to the Cache Creek settling basin. Water-surface profiles and overbank flood depths were developed for the existing (pre-project) conditions for Cache Creek using the UNET and FLO-2D computer programs.

UNET is a computer program that models one-dimensional, unsteady flow for open channel hydraulics. The study reach extended from the Cache Creek settling basin to Road 94B. Cross sections for the model used the survey data to develop sections spaced about 500 feet apart. Overbank or levee failure flows were modeled as inflow to storage areas for later input in FLO-2D. Plate 3 shows the study reach and UNET cross section locations.

Manning's "n" values ranged from .04 to .052 for overbank and from .032 to .042 for channel. Contraction and expansion loss coefficients ranged from 0.1 to 0.3 for gradual transitions to 0.3 to 0.5 for some bridge crossing sections.

1. Calibration

The UNET model was calibrated to the January and March 1995 flood events. High water mark (HWM) data was collected from gage data and DWR flood freeboard surveys.

During calibration, thalweg elevations were adjusted from Highway 113 to the settling basin. These adjustments were necessary to account for water depths of up to 10 feet downstream of Road 102 that were not identified in the aerial survey. Manning's "n" values were subsequently adjusted to reasonably simulate historical HWM data. Plate 4 is a profile plot of the modeled March 1995 event with HWM data.

2. Flood Analysis

Once calibration was complete, hydrographs for the 50-year, 100-year, 200-year and 500-year flood events were modeled with the UNET model. The flood flows leaving the Cache Creek Channel were computed using UNET. The overbank flow, results from water escaping the channel upstream of the leveed portion on both the north and south banks, a levee failure on the south bank approximately 1,000 feet upstream of Interstate 5, and levee failures on both the north and south banks approximately 3500 feet downstream of Interstate 5. Embankment failures were defined at locations shown in the table below to simulate levee failures.

Table 2
Embankment Failure Locations

Left Stations	Right Stations
615+00 to 605+00	610+00 to 595+00
540+00 to 515+00	540+00 to 515+00
460+00 to 450+00	460+00 to 450+00
415+00 to 395+00	415+00 to 395+00
375+00 to 370+00	375+00 to 370+00

Embankment failures were defined as 300 feet long and failed to the landside toe elevation.

3. Estimated PFP, PNP and Non-Damaging Channel Capacity

The hydraulic analysis incorporated the estimated existing levee failure locations, including the Probable Non-Failure Point (PNP) and Probable Failure Point (PFP) for the existing Cache Creek levee system. The PNP is defined as the highest vertical elevation on the existing levee where it is determined to be highly unlikely that the levee would fail if the water-surface elevation is at or below this level. The PNP for reaches along Cache Creek is two feet below the top of the existing levees. The PFP is defined as the lowest vertical elevation on the levee where it is determined to be highly likely that the levee would fail. The PFP for reaches along Cache Creek is to the top of the existing levee. These elevations were based on a geotechnical risk-based analysis report (August 2000).

The non-damaging water surface elevations of the non-leveed reaches were assumed to be at the existing bank elevations. The flow calculated below the existing bank elevations and below the PNP is 30,000 cfs. This flow has an exceedance probability of 0.10 (10 year). For the hydraulic model, Cache Creek levees failed at the PFP.

Flows above 30,000 cfs are considered to have a potential result in flooding of developed areas. Historically, the levee system has performed well. The March 1995 flood was approximately a 20-year event (42,000 cfs at RD 94B). Water overtopped the right and left banks above I-5. Water levels also overtopped the levee downstream of I-5, but with the aid of DWR flood fighting did not fail the levee. On the contrary, in 1983, also about a 20-year event, the levee failed downstream of RD 102 and flooded areas in the eastern part of the City of Woodland.

Overbank and embankment failure flows calculated in the UNET model were compiled and the input into the FLO-2D model to determine flood plain routing and depths.

5.02 Lower Cache Creek FLO-2D Model

1. Model Description

The FLO-2D computer program, a two-dimensional flood routing model, was used to model the lower Cache Creek overbank flooding.

FLO-2D models the flood plain using a square grid format. The topography of the study area is defined by a single elevation point at the center of each grid element. Each grid element is also assigned a roughness (Manning's n) value and infiltration parameters. Storage and flow area in grid elements can be limited. Obstructions such as levees, roadways and embankments can also be modeled.

2. Study Area

The study area consists of Cache Creek downstream of Road 94B. The FLO-2D model grid network is shown in Plate 5. Due to the low variability of the topography of the lower Cache Creek overbank, the study area was modeled using a grid spacing of 1000 feet, resulting in a total of 1521 elements. Grid element elevations were generated from digital topography dated March 24, 2000. The areal extent of the modeling was limited by the available digital topography. The topography was sufficient to cover the inundation area of the south (right) bank, but was limited on the north (left) bank.

Obstruction of flow due to structures was modeled by reducing the flow area in the affected elements. Magnitudes of reduction were estimated from aerial photography.

A review of the topography indicated that the following were significant obstructions of overbank flow: Interstate 5 (I-5), Highway 113, Road 98, Road 102 and the Highline Canal. These were all modeled as embankments that could be overtopped if the flow exceeded their crest elevations.

3. Calibration

In March of 1995 flow escaped the Cache Creek channel upstream of I-5 and flooded a small area west of I-5 and north of Woodland. This event was used to calibrate the FLO-2D model. The Cache Creek UNET model was used to determine the flow that escaped from the channel during the 1995 flood event, and that flow (see Plate 6) was used as input to the FLO-2D model.

A Manning's "n" value of 0.08 was used for the overbank, and infiltration parameters, such as soil porosity (0.48) and hydraulic conductivity (0 to 0.1), were selected based on recommended values in the FLO-2D manual and soil types as delineated in the U.S. Soil Conservation Service General Soil Map for Yolo County. Initial saturation and final saturation were set at 0.8 and 1.0, respectively. FLO-2D also allows for surface detention in the grid elements which is defined as the depth of water below which no flood routing will be

performed. This parameter is used to represent ponding of water due to local topographic features that are not directly modeled, such as roadways other than those previously mentioned as significant obstructions to flow and irrigation ditch embankments. A value of 0.5 feet was determined as appropriate through the calibration analysis.

The result of the calibration analysis are provided in Plate 7.

4. Flood Analysis

As noted previously, flood flows that escape the Cache Creek channel in the 50, 100, 200 and 500 year events were calculated using a UNET model. These flow, hydrographs are tabulated in Table 3 and plotted on Plates 8 through 11. These hydrographs were used as inputs to the FLO-2D model.

Flood depth contour maps (see Plates 12 through 15) were derived from the results of the FLO-2D studies. Overbank flood flow velocities did not exceed 3 feet per second in the 50 and 100 year flood events. With the exception of elements in which flow area was constricted due to structures, velocities did not exceed 4 feet per second in the 200 and 500 year flood events.

Table 3. Cache Creek Flood Flows Escaping Channel

	South (Right) Bank								North (Left) Bank							
	50-year		100-year		200-year		500-year		50-year		100-year		200-year		500-year	
	Above I-5	Below I-5	Above I-5	Below I-5	Above I-5	Below I-5	Above I-5	Below I-5	Above I-5	Below I-5	Above I-5	Below I-5	Above I-5	Below I-5	Above I-5	Below I-5
Date/Time	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)
3/9/95 12:00																
3/9/95 13:00																
3/9/95 14:00																
3/9/95 15:00							0								0	
3/9/95 16:00					0		2,803	0					0		1,029	
3/9/95 17:00					112		14,901	1,849					172		4,142	0
3/9/95 18:00			0		8,113	0	22,973	7,933			0		2,116	0	6,927	6,347
3/9/95 19:00			3,989	0	18,362	5,441	25,621	10,204			1,090		4,910	2,418	8,792	9,070
3/9/95 20:00	0		14,474	3,688	22,564	9,662	25,439	9,875			3,356		6,718	7,362	9,958	9,875
3/9/95 21:00	36		19,975	10,105	22,586	10,741	25,539	8,660	0		5,048		7,671	9,114	10,675	8,660
3/9/95 22:00	3,135	0	21,052	13,877	21,639	9,105	25,782	8,293	537		5,829		8,064	9,105	11,058	8,293
3/9/95 23:00	10,303	4,884	19,541	13,924	21,031	8,397	25,862	8,156	1,405		6,024		8,110	8,397	11,172	8,156
3/10/95 0:00	13,699	10,792	18,497	13,069	20,480	8,146	25,715	8,099	2,141		5,895		7,913	8,146	11,096	8,099
3/10/95 1:00	13,462	14,075	17,619	12,758	19,775	8,041	25,429	8,072	2,292		5,563		7,540	8,041	10,922	8,072
3/10/95 2:00	11,364	13,445	16,661	12,634	18,914	7,988	25,115	8,058	2,062		5,094		7,057	7,988	10,730	8,058
3/10/95 3:00	9,805	12,675	15,576	12,574	17,980	7,954	24,839	8,050	1,671		4,532		6,549	7,954	10,562	8,050
3/10/95 4:00	8,523	12,351	14,407	12,534	17,074	7,929	24,603	8,046	1,277		3,924		6,062	7,929	10,418	8,046
3/10/95 5:00	7,339	12,178	13,200	12,498	16,275	7,907	24,355	8,043	975		3,336		5,624	7,907	10,264	8,043
3/10/95 6:00	6,332	12,052	12,057	12,459	15,596	7,888	24,020	8,041	675		2,808		5,252	7,888	10,055	8,041
3/10/95 7:00	5,627	11,930	11,056	12,417	15,030	7,871	23,552	8,039	363		2,350		4,944	7,871	9,766	8,039
3/10/95 8:00	5,064	11,791	10,207	12,374	14,549	7,856	22,943	8,035	89		1,979		4,682	7,856	9,396	8,035
3/10/95 9:00	4,758	11,623	9,520	12,333	14,119	7,843	22,217	8,029	0		1,694		4,447	7,843	8,964	8,029
3/10/95 10:00	4,446	11,415	8,979	12,294	13,708	7,831	21,411	8,020			1,487		4,225	7,831	8,497	8,020
3/10/95 11:00	4,093	11,167	8,547	12,259	13,288	7,820	20,556	8,010			1,339		4,000	7,820	8,004	8,010
3/10/95 12:00	3,705	10,879	8,176	12,228	12,828	7,808	19,666	7,997			1,225		3,757	7,808	7,491	7,997
3/10/95 13:00	3,288	10,557	7,825	12,199	12,309	7,795	18,742	7,982			1,131		3,493	7,795	6,965	7,982
3/10/95 14:00	2,883	10,211	7,460	12,169	11,720	7,780	17,774	7,966			1,038		3,204	7,780	6,438	7,966
3/10/95 15:00	2,483	9,857	7,067	12,137	11,061	7,762	16,775	7,947			933		2,882	7,762	5,890	7,947

Table 3. Cache Creek Flood Flows Escaping Channel

	South (Right) Bank								North (Left) Bank							
	50-year		100-year		200-year		500-year		50-year		100-year		200-year		500-year	
	Above I-5	Below I-5	Above I-5	Below I-5	Above I-5	Below I-5	Above I-5	Below I-5	Above I-5	Below I-5	Above I-5	Below I-5	Above I-5	Below I-5	Above I-5	Below I-5
Date/Time	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)
3/10/95 16:00	2,125	9,505	6,650	12,100	10,345	7,742	15,747	7,925			811		2,533	7,742	5,319	7,925
3/10/95 17:00	1,776	9,161	6,235	12,054	9,569	7,717	14,695	7,900			668		2,164	7,717	4,736	7,900
3/10/95 18:00	1,450	8,811	5,861	11,997	8,734	7,689	13,622	7,872			502		1,788	7,689	4,148	7,872
3/10/95 19:00	1,151	8,471	5,474	11,925	7,860	7,656	12,519	7,842			321		1,432	7,656	3,570	7,842
3/10/95 20:00	900	8,147	5,103	11,835	6,956	7,619	11,402	7,808			142		1,150	7,619	3,026	7,808
3/10/95 21:00	682	7,845	4,857	11,723	6,067	7,576	10,305	7,772			7		912	7,576	2,496	7,772
3/10/95 22:00	486	7,556	4,648	11,583	5,304	7,525	9,218	7,733			0		661	7,525	1,990	7,733
3/10/95 23:00	306	7,268	4,397	11,409	4,733	7,465	8,136	7,690					397	7,465	1,529	7,690
3/11/95 0:00	149	6,975	4,101	11,196	4,228	7,394	7,074	7,644					150	7,394	1,176	7,644
3/11/95 1:00	33	6,677	3,758	10,944	3,945	7,307	6,062	7,592					0	7,307	906	7,592
3/11/95 2:00	0	6,369	3,363	10,646	3,698	7,200	5,237	7,534						7,200	628	7,534
3/11/95 3:00		6,032	2,940	10,302	3,406	7,068	4,634	7,466						7,068	345	7,466
3/11/95 4:00		5,675	2,487	9,923	3,070	6,912	4,148	7,385						6,912	96	7,385
3/11/95 5:00		5,304	2,042	9,514	2,688	6,728	3,886	7,289						6,728	0	7,289
3/11/95 6:00		4,930	1,569	9,070	2,268	6,512	3,620	7,171						6,512		7,171
3/11/95 7:00		4,555	1,123	8,597	1,834	6,273	3,311	7,030						6,273		7,030
3/11/95 8:00		4,181	746	8,126	1,412	6,013	2,960	6,863						6,013		6,863
3/11/95 9:00		3,812	423	7,668	979	5,731	2,564	6,669						5,731		6,669
3/11/95 10:00		3,450	161	7,208	590	5,428	2,152	6,447						5,428		6,447
3/11/95 11:00		3,100	3	6,750	289	5,129	1,725	6,205						5,129		6,205
3/11/95 12:00		2,766	0	6,271	69	4,837	1,321	5,949						4,837		5,949
3/11/95 13:00		2,456		5,772	0	4,541	914	5,672						4,541		5,672
3/11/95 14:00		2,166		5,271		4,239	558	5,384						4,239		5,384
3/11/95 15:00		1,894		4,784		3,927	287	5,105						3,927		5,105
3/11/95 16:00		1,640		4,314		3,614	86	4,837						3,614		4,837
3/11/95 17:00		1,405		3,867		3,308	0	4,571						3,308		4,571
3/11/95 18:00		1,186		3,448		3,012		4,303						3,012		4,303
3/11/95 19:00		990		3,062		2,732		4,035						2,732		4,035

Table 3. Cache Creek Flood Flows Escaping Channel

	South (Right) Bank								North (Left) Bank							
	50-year		100-year		200-year		500-year		50-year		100-year		200-year		500-year	
	Above I-5	Below I-5	Above I-5	Below I-5	Above I-5	Below I-5	Above I-5	Below I-5	Above I-5	Below I-5	Above I-5	Below I-5	Above I-5	Below I-5	Above I-5	Below I-5
Date/Time	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)
3/11/95 20:00		811		2,714		2,473		3,765						2,473		3,765
3/11/95 21:00		650		2,403		2,236		3,503						2,236		3,503
3/11/95 22:00		507		2,124		2,019		3,253						2,019		3,253
3/11/95 23:00		379		1,872		1,824		3,017						1,824		3,017
3/12/95 0:00		268		1,645		1,652		2,798						1,652		2,798
3/12/95 1:00		173		1,441		1,500		2,595						1,500		2,595
3/12/95 2:00		92		1,254		1,364		2,411						1,364		2,411
3/12/95 3:00		32		1,087		1,242		2,245						1,242		2,245
3/12/95 4:00		0		938		1,132		2,093						1,132		2,093
3/12/95 5:00				800		1,032		1,954						1,032		1,954
3/12/95 6:00				675		939		1,829						939		1,829
3/12/95 7:00				563		852		1,716						852		1,716
3/12/95 8:00				462		771		1,614						771		1,614
3/12/95 9:00				370		697		1,522						697		1,522
3/12/95 10:00				288		629		1,437						629		1,437
3/12/95 11:00				216		565		1,359						565		1,359
3/12/95 12:00				151		506		1,287						506		1,287
3/12/95 13:00				95		450		1,220						450		1,220
3/12/95 14:00				47		399		1,157						399		1,157
3/12/95 15:00				12		350		1,097						350		1,097
3/12/95 16:00				0		305		1,038						305		1,038
3/12/95 17:00						262		982						262		982
3/12/95 18:00						222		927						222		927
3/12/95 19:00						183		875						183		875
3/12/95 20:00						147		824						147		824
3/12/95 21:00						113		776						113		776
3/12/95 22:00						82		729						82		729
3/12/95 23:00						53		684						53		684

Table 3. Cache Creek Flood Flows Escaping Channel

	South (Right) Bank								North (Left) Bank							
	50-year		100-year		200-year		500-year		50-year		100-year		200-year		500-year	
	Above I-5	Below I-5	Above I-5	Below I-5	Above I-5	Below I-5	Above I-5	Below I-5	Above I-5	Below I-5	Above I-5	Below I-5	Above I-5	Below I-5	Above I-5	Below I-5
Date/Time	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)
3/13/95 0:00						28		641						28		641
3/13/95 1:00						9		599						9		599
3/13/95 2:00						0		558						0		558
3/13/95 3:00								518								518
3/13/95 4:00								479								479
3/13/95 5:00								441								441
3/13/95 6:00								405								405
3/13/95 7:00								369								369
3/13/95 8:00								334								334
3/13/95 9:00								300								300
3/13/95 10:00								267								267
3/13/95 11:00								236								236
3/13/95 12:00								206								206
3/13/95 13:00								177								177
3/13/95 14:00								149								149
3/13/95 15:00								122								122
3/13/95 16:00								96								96
3/13/95 17:00								72								72
3/13/95 18:00								49								49
3/13/95 19:00								29								29
3/13/95 20:00								12								12
3/13/95 21:00								1								1
3/13/95 22:00								0								0
3/13/95 23:00																
3/14/95 0:00																
Peak Flow	13,699	14,075	21,052	13,924	22,586	10,741	25,862	10,204	2,292	0	6,024	0	8,110	9,114	11,172	9,875

Table 3. Cache Creek Flood Flows Escaping Channel

	South (Right) Bank								North (Left) Bank							
	50-year		100-year		200-year		500-year		50-year		100-year		200-year		500-year	
	Above I-5	Below I-5	Above I-5	Below I-5	Above I-5	Below I-5	Above I-5	Below I-5	Above I-5	Below I-5	Above I-5	Below I-5	Above I-5	Below I-5	Above I-5	Below I-5
Date/Time	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)
Volume (AF)	10,694	27,861	27,423	41,409	36,955	29,958	55,605	35,196	1,115	0	5,630	0	10,792	29,383	19,767	34,818

February 2002

SECTION 6 – ALTERNATIVE PLANS

6.01 Alternative Planning Assumptions

Described below are the assumptions used to model Cache Creek alternatives. A base HEC-RAS model was developed to model and compare alternatives. HEC-RAS was used in evaluating alternatives because of its ease of model modification for a great number of alternatives, and the alternatives did not include levee failures. Alternatives for the existing flood conditions (attached) were chosen based on discussions with local interest and pervious studies. The HEC-RAS model was compiled from the calibrated existing condition UNET model. Five alternatives were selected for evaluation. These alternatives are:

- Raise existing levees.
- Clear vegetation and line channel.
- Expand existing channel area.
- Set back existing levees.
- Lower Cache Creek Overflow Barrier.

HEC-RAS was used to evaluate all of the alternatives except for the Lower Cache Creek Overflow Barrier. All the alternatives were modeled with the 200-year flow at Road 94B of 70,085 cfs. Routing effects along the creek were estimated with the previously developed UNET model.

1. Raise Existing Levees

The raise existing levees alternative was modeled using the levee option in HEC-RAS. This option allows the insertion of a vertical barrier at a location and elevation set by the user. Manning's n-values developed during calibration were not changed for this alternative. Bridges were not modified under this alternative. The results show that to pass the 200-year flood levee heights would need to be raised from 4 to 8 feet above existing levee heights, plus any required freeboard. Plate 16 is a profile plot of calculated water surface elevations and existing levee heights.

In all cases, the 200-year flow encroached into the bridge decks. Velocities on average increased by 1 to 2 fps in the channel with a maximum increase of about 7 fps (total of 15 fps) under Interstate Highway 5.

2. Clear Vegetation and Line Channel

This alternative considers the effect of cleaning vegetation and, in certain areas, lining the channel with rock riprap. To model channel cleaning, calibrated n-values were multiplied by 0.72 (28% reduction) throughout the study reach. A plot of the 200-year water surface elevation under existing and cleaned channel conditions is attached as Plate 17. For both conditions, the levee is assumed to be confined.

N-values in the cleaned channel range from 0.022 to .031 and from 0.028 to 0.036 in the overbank.

The results show that water surface elevations are reduced from 2 to 3 feet, compared to the existing condition. Existing levees would require raising by 2 to 5 feet and new levees would need to be constructed upstream of I-5.

Channel velocities ranged from 2 to 15 fps with a maximum increase of about 7 fps between the railroad bridge and Interstate Highway 5.

3. Expand Existing Channel Area

This alternative assumed that the width of the existing channel could be increased to contain the 200-year flow within an expanded cross-section. The expansion cut was set at an elevation near the two-year flow. Various widths were tried until the flow was contained at the existing levee heights. It was assumed that actual width expansion would be performed on one side of the creek, similar to the setback alternative.

The results indicate that a 700-foot wide terrace would be required downstream of Highway 113 and a 500-foot wide terrace would be required upstream of Highway 113. In addition, the Road 99 bridge, RR bridge and Highway 113 bridge should be replace due to excessive flow velocities. Attached as Plate 18 is a water surface comparison of the confined levee profile and expanded area profile. Channel velocities ranged from 2 to 25 fps with a maximum increase of 17 fps under the railroad bridge at I-5.

4. Set Back Levees

The set back levee alternative consists of setting back one or both of the existing levees to provide more cross sectional area. Three setback alignments were tested 1,000', 1,500', and 2,000' distance between the levees. Channel and overbank n-values were those developed during calibration runs and were left unchanged. Plate 19 is a drawing showing the alignment of each setback alternative.

The water surface calculations for 1,000' setback alternative shows that the 200-year water surface elevation is above the existing levee crown. This means that in addition to constructing a setback levee, the existing levee (on the opposite bank) would also require raising. The 2,000' setback alternative shows that the 200-year water surface elevation is below the existing levee. Some minor existing levee work would be required at isolated locations (bridges) on the existing levee opposite the new setback levee.

At the RR bridge, Highway 113, and I-5, velocities range from 15 fps to 17 fps. The RR bridge and Rd 99 bridge cross-sections have a smaller area than the existing I-5 cross sections and tend to accelerate velocities more so than I-5. Although these velocities are high, water surface elevations are not close to

critical depth. Armoring should be possible for a stable section without removing the bridges.

For all the setback alternatives, water surface elevations for the 200-year flood are below the bridge soffits. Debris impacts were not considered. As the levee is setback further, the extent of work on the existing levee is minimized. Attached as Plate 20 is water surface profile for each alternative setback. Attached as Plate 21 is a velocity profile for each setback alternative.

5. Lower Cache Creek Overflow Barrier

The Lower Cache Creek Overflow Barrier (LCCOB) is essentially backup flood protection in the form of an embankment and/or wall located just north of the City of Woodland. The LCCOB alternative was hydraulically modeled using UNET and FLO-2D. The alignment modeled for preliminary alternative comparisons is shown in Plate 22.

For this alternative, it is assumed that the existing levee system will not be modified and will continue to be maintained. The LCCOB will provide protection from flows coming out of the bank above the existing levees, as well as flows resulting from failures in the existing levees.

A 4,000-foot section of the Settling Basin levee was removed to original ground at the east end of the LCCOB to allow for drainage of overbank flows. The analysis assumed the corresponding section of training levee is also removed.

The analysis assumed the weir connecting the Settling Basin to the Yolo Bypass is at the ultimate crest elevation of 41.0 feet (NAVD 1988).

The resulting inundated area for the 200-year flood event is shown in Plate 22.

No bridge modifications are required for the plan. Cache Creek channel velocities will remain the same as existing conditions.

SECTION 7 – FINAL ALTERNATIVE PLANS

7.01 Alternative Selection

Selection of preliminary alternatives to carry further along in the feasibility process was based upon four general planning criteria: (1) completeness; (2) effectiveness; (3) efficiency; and (4) acceptability. The relative ranking of the preliminary alternatives resulted in the selection of setback levee alternative and Lower Cache Creek Overflow Barrier for further detailed hydraulic analysis.

7.02 Setback Levee Alternative

1. Plan Description

Based on the preliminary alternative plan analysis, a viable setback levee alternative was identified. Setback alignments were further refined and adjusted from the preliminary 1,000 feet (levee to levee) setback levee alternative. Aerial photography and public comments were utilized to minimize impacts to land and facilities. The setback alignment chosen is shown on Plate 23.

2. Flood Analysis

Further flood analysis consisted of running the selected alternative with three flows. The flows were chosen to cover a range of relatively frequent events to rare events. The flows input into the hydraulic model at Road 94B are 50,000 cfs, 70,000 cfs and 91,000 cfs. High flows were evaluated to determine if they would reach Road 94B. Both the 1994 Corps Reconnaissance Study and 1999 FEMA hydraulic models were reviewed. These hydraulic models extend up to Capay Dam. Both models studied up to the 500-year event and show that the Cache Creek will overtop its banks in some locations. However, this overbank flow is localized and because of high adjacent ground elevations, does not leave the creek corridor. Impacts on channel velocities and encroachments were evaluated to determine the need for bank protection, bridge replacement and levee heights. The HEC-RAS model was modified to reflect the expanded sections. Mannings n-values were adjusted for proposed riprap and concrete revetment at bridges (n=0.015). Bridge replacement criteria for existing bridges was coordinated with the various agencies and agreed to be replaced if water surface elevation encroached onto the bridge soffit (pressure flow). Where channel velocities for the alternative were greater than existing conditions (7 to 8 fps), bank protection was included in the model.

A summary table for bridge replacement is shown below.

Table 4
Bridge Replacement
Setback Levee Alternative

Flow	I-5 S	I-5 N	Cty Rd 99	RR Bridge	Hwy 113	RD 102
50,000 cfs	OK	OK	OK	OK	OK	OK
70,000 cfs	OK	OK	OK	OK	OK	OK
91,000 cfs	Lengthen	Lengthen	Lengthen	Replace	Replace	Replace

3. Hydraulic Impacts

Hydraulic impacts evaluated for the alternative include water surface elevations in the project reach and within the settling basin. Summarized in Tables 5, 6, and 7 are hydraulic impacts for each flow profile compared to existing conditions.

Table 5
HEC-RAS Plan: 50K Setback
River: Cache Creek Reach: Cache Creek Profile 50-Year

River Sta. Sec. No.	Q Total (cfs)	W.S. Elev (ft)	Vel Chnl (ft/s)	River Sta. (ft)	Exist W.S. (ft)	Diff. W.S. (ft)
154	53290	95.58	8.62	84499	95.17	0.41
153	53290	95.74	4.2	83996	95.26	0.48
152	53290	95.7	2.76	83496	95.23	0.47
151	53290	95.59	2.81	82997	95.12	0.47
150	53290	95.5	2.73	82497	95.05	0.45
149	53290	95.46	2.06	81999	95.01	0.45
148	53290	95.39	2.25	81499	94.93	0.46
147	53290	95.32	2.32	80999	94.86	0.46
146	53290	95.26	2.2	80498	94.8	0.46
145	53290	95.14	2.73	79999	94.68	0.46
144	53290	94.89	3.88	79499	94.44	0.45
143	53290	94.69	4	78999	94.24	0.45
142	53290	94.59	3.28	78499	94.15	0.44
141	53290	94.45	3.22	77999	94.02	0.43
140	53290	94.29	3.25	77499	93.85	0.44
139	53290	94.24	2.17	76999	93.82	0.42
138	53290	94.18	2.05	76499	93.83	0.35
137	53290	94.11	2.36	75999	93.8	0.31
136	53290	94.06	2.06	75499	93.77	0.29
135	53290	93.94	2.91	74999	93.63	0.31

Table 5

HEC-RAS Plan: 50K Setback

River: Cache Creek Reach: Cache Creek Profile 50-Year

River Sta. Sec. No.	Q Total (cfs)	W.S. Elev (ft)	Vel Chnl (ft/s)	River Sta. (ft)	Exist W.S. (ft)	Diff. W.S. (ft)
134	53290	93.83	3.06	74499	93.51	0.32
133	53290	93.71	2.99	73999	93.39	0.32
132	53290	93.65	2.43	73499	93.35	0.3
131	53290	93.64	1.68	72999	93.36	0.28
130	53290	93.59	1.97	72499	93.32	0.27
129	53290	93.49	2.95	71999	93.25	0.24
128	53290	93.52	1.12	71499	93.25	0.27
127	53290	93.49	1.52	70999	93.22	0.27
126	53290	93.43	2.1	70499	93.17	0.26
125	53290	93.36	2.37	69999	93.14	0.22
124	53290	93.35	1.7	69499	93.11	0.24
123	53290	93.28	2.05	68999	93.06	0.22
122	53290	93.19	2.57	68499	92.98	0.21
121	53290	93.03	3.26	67999	92.86	0.17
120	53290	92.82	3.81	67499	92.7	0.12
119	53290	92.36	5.4	66996	92.36	0
118	53290	92.01	5.25	66499	91.05	0.96
117	53290	91.85	4.11	65999	90.09	1.76
116	53290	91.62	4.44	65501	89.88	1.74
115	53290	90.85	7.2	65001	89.15	1.7
114	53290	89.56	10.02	64498	87.89	1.67
113	53290	89.17	8.33	63994	87.79	1.38
112	53290	88.6	8.43	63497	87.37	1.23
111	53290	88.41	6.95	63000	87.17	1.24
110	53290	87.4	9.27	62499	85.94	1.46
109	53290	86.94	8.45	61999	85.74	1.2
108	53290	86.25	8.74	61499	84.86	1.39
107	53290	86.25	5.43	60999	85.33	0.92
106	53290	86.21	3.96	60501	85.41	0.8
105	53290	86	4.7	59997	85.24	0.76
104	53290	85.26	7.46	59500	84.57	0.69
103	53290	84.68	7.63	58999	84.3	0.38
102	51500	82.25	11.41	58530	83.58	-1.33
101	51500	82.01	11.52	58490	83.53	-1.52
100	51500	82.06	11.25	58430	83.48	-1.42
99	51500	81.9	11.32	58390	83.42	-1.52
98	51500	81.3	12.73	58300	83.21	-1.91

Table 5

HEC-RAS Plan: 50K Setback

River: Cache Creek Reach: Cache Creek Profile 50-Year

River Sta.	Q Total	W.S. Elev	Vel Chnl	River Sta.	Exist W.S.	Diff. W.S.
Sec. No.	(cfs)	(ft)	(ft/s)	(ft)	(ft)	(ft)
97	51500	81.1	12.83	58276	83.2	-2.1
96	51500	81.15	12.6	58220	83.19	-2.04
95	51500	81.14	12.6	58195	83.18	-2.04
94	51500	80.93	11.64	57999	83.13	-2.2
93	51500	80.18	9.97	57499	82.86	-2.68
92	51500	79.71	8.59	57001	82.78	-3.07
91	51500	79.27	7.88	56499	82.64	-3.37
90	51500	78.7	8.24	56002	82.02	-3.32
89	51500	78.02	8.52	55499	81.61	-3.59
88	51500	77.83	6.37	54996	81.26	-3.43
87	51500	77.46	6.52	54498	80.93	-3.47
86	51500	77.06	6.71	53998	80.46	-3.4
85	51500	76.75	6.21	53499	79.24	-2.49
84	51500	76.32	6.53	53002	76.66	-0.34
83	51500	75.8	7.26	52503	74.89	0.91
82	51500	75.35	6.72	52000	73.85	1.5
81	51500	74.81	7.18	51499	73.03	1.78
80	51500	74.52	6.06	50995	72.25	2.27
79	51500	74.45	4.37	50498	72.33	2.12
78	51500	74.33	4.36	49998	71.62	2.71
77	51500	73.96	5.53	49500	70.72	3.24
76	51500	73.55	6.11	48998	70.34	3.21
75	51500	73.14	6.54	48499	69.75	3.39
74	51500	72.58	6.88	48000	69.27	3.31
73	51500	72.23	6.41	47497	68.95	3.28
72	51500	71.93	6.34	46999	68.53	3.4
71	51500	71.72	5.26	46505	68.17	3.55
70	51500	71.5	5.01	46002	67.79	3.71
69	51500	71.28	4.9	45499	67.25	4.03
68	51500	71.02	5.25	44999	66.72	4.3
67	51500	70.83	4.72	44499	66.1	4.73
66	51500	70.6	4.86	44000	65.84	4.76
65	51500	70.31	5.26	43498	65.16	5.15
64	51500	70.01	5.26	42999	64.51	5.5
63	51500	69.66	5.7	42499	63.92	5.74
62	51500	69.17	6.51	41999	63.17	6
61	51500	67.87	8.96	41499	62.62	5.25

Table 5

HEC-RAS Plan: 50K Setback

River: Cache Creek Reach: Cache Creek Profile 50-Year

River Sta. Sec. No.	Q Total (cfs)	W.S. Elev (ft)	Vel Chnl (ft/s)	River Sta. (ft)	Exist W.S. (ft)	Diff. W.S. (ft)
60	51000	66.22	11.83	41346	62.46	3.76
59	51000	66.01	11.95	41300	62.39	3.62
58	51000	65.74	10.11	41000	61.98	3.76
57	51000	65.66	7.35	40500	61.89	3.77
56	51000	65.32	7.04	40008	61.63	3.69
55	51000	64.14	9.38	39498	61.05	3.09
54	51000	62.74	10.58	39001	60.6	2.14
53	51000	62.24	8.29	38498	60.29	1.95
52	51000	61.51	8.31	37999	59.52	1.99
51	51000	61.28	5.93	37499	59.29	1.99
50	51000	61.06	5.54	36997	58.97	2.09
49	51000	60.66	6.14	36498	58.2	2.46
48	51000	60.23	6.31	35997	57.72	2.51
47	51000	59.76	6.58	35499	57.17	2.59
46	51000	59.48	5.07	35001	56.95	2.53
45	51000	59.11	5.33	34502	56.27	2.84
44	51000	58.73	5.22	33999	55.68	3.05
43	51000	58.35	5.32	33501	55.21	3.14
42	51000	57.92	5.56	33000	54.72	3.2
41	51000	57.51	5.19	32490	54.37	3.14
40	51000	57.25	4.33	31996	53.96	3.29
39	51000	56.95	4.62	31499	53.46	3.49
38	51000	56.76	3.97	30999	53.17	3.59
37	51000	56.49	4.4	30499	52.86	3.63
36	51000	56.11	5.13	29999	52.51	3.6
35	50000	55.56	5.75	29499	52.2	3.36
34	50000	54.86	7.72	29332	52.02	2.84
33	50000	54.79	7.75	29300	51.99	2.8
32	50000	53.62	9.94	28999	51.62	2
31	50000	52.48	9.63	28499	50.47	2.01
30	50000	51.73	7.74	28001	49.52	2.21
29	50000	51.45	5.34	27496	49.14	2.31
28	50000	51.31	3.65	27014	48.53	2.78
27	50000	51.16	3.58	26489	47.84	3.32
26	50000	51.02	3.51	25991	47.02	4
25	50000	50.87	3.42	25506	46.56	4.31
24	50000	50.76	3.33	25002	46.15	4.61

Table 5

HEC-RAS Plan: 50K Setback

River: Cache Creek Reach: Cache Creek Profile 50-Year

River Sta.	Q Total	W.S. Elev	Vel Chnl	River Sta.	Exist W.S.	Diff. W.S.
Sec. No.	(cfs)	(ft)	(ft/s)	(ft)	(ft)	(ft)
23	50000	50.65	3.64	24502	45.72	4.93
22	50000	50.31	5	23990	45.48	4.83
21	50000	50.2	4.57	23503	45.39	4.81
20	50000	49.9	5.33	22997	45.21	4.69
19	50000	49.65	5.51	22499	45	4.65
18	50000	49.4	5.67	21999	44.77	4.63
17	50000	49.15	5.7	21499	44.54	4.61
16	50000	48.85	5.94	20999	44.24	4.61
15	50000	48.57	5.92	20499	43.97	4.6
14	50000	48.37	5.59	20000	43.79	4.58
13	50000	48.18	5.4	19502	43.8	4.38
12	50000	48.04	5.08	18999	43.8	4.24
11	50000	47.64	6.07	18496	43.79	3.85
10	50000	47.35	6	17998	43.79	3.56
9	50000	46.92	6.45	17504	43.78	3.14
8	50000	46.48	6.7	16994	43.78	2.7
7	50000	46.43	5.17	16499	43.77	2.66
6	50000	46.22	5.31	15998	43.76	2.46
5	50000	45.98	5.53	15503	43.76	2.22
4	50000	45.79	5.43	14999	43.75	2.04
3	50000	45.62	5.31	14502	43.75	1.87
2	50000	45.46	5.09	14001	43.75	1.71
1	50000	45.3	4.65	13496	43.74	1.56

Table 6

HEC-RAS Plan: 70K Setback

River: Cache Creek Reach: Cache Creek Profile 200-Year

River Sta.	Q Total	W.S. Elev	Vel Chnl	River Sta.	Exist W.S.	Diff. W.S.
Sec. No.	(cfs)	(ft)	(ft/s)	(ft)	(ft)	(ft)
154	70000	98.12	9.44	84499	96.63	1.49
153	70000	98.42	4.59	83996	96.88	1.54
152	70000	98.41	3.03	83496	96.87	1.54
151	70000	98.31	3.08	82997	96.73	1.58
150	70000	98.21	3.01	82497	96.74	1.47
149	70000	98.19	2.27	81999	96.65	1.54
148	70000	98.11	2.44	81499	96.55	1.56

Table 6

HEC-RAS Plan: 70K Setback

River: Cache Creek Reach: Cache Creek Profile 200-Year

River Sta.	Q Total	W.S. Elev	Vel Chnl	River Sta.	Exist W.S.	Diff. W.S.
Sec. No.	(cfs)	(ft)	(ft/s)	(ft)	(ft)	(ft)
147	70000	98.04	2.54	80999	96.44	1.6
146	70000	97.99	2.44	80498	96.37	1.62
145	70000	97.86	3.02	79999	96.2	1.66
144	70000	97.57	4.34	79499	95.84	1.73
143	70000	97.36	4.44	78999	95.55	1.81
142	70000	97.26	3.65	78499	95.44	1.82
141	70000	97.13	3.51	77999	95.27	1.86
140	70000	96.99	3.46	77499	95.03	1.96
139	70000	96.95	2.44	76999	95.01	1.94
138	70000	96.9	2.32	76499	95.01	1.89
137	70000	96.81	2.69	75999	94.97	1.84
136	70000	96.76	2.41	75499	94.91	1.85
135	70000	96.64	3.26	74999	94.69	1.95
134	70000	96.51	3.38	74499	94.5	2.01
133	70000	96.39	3.25	73999	94.33	2.06
132	70000	96.33	2.71	73499	94.25	2.08
131	70000	96.32	1.93	72999	94.29	2.03
130	70000	96.26	2.3	72499	94.22	2.04
129	70000	96.14	3.33	71999	94.13	2.01
128	70000	96.18	1.36	71499	94.13	2.05
127	70000	96.15	1.73	70999	94.09	2.06
126	70000	96.09	2.32	70499	94.02	2.07
125	70000	96.02	2.6	69999	93.98	2.04
124	70000	96	1.89	69499	93.95	2.05
123	70000	95.93	2.3	68999	93.9	2.03
122	70000	95.82	2.92	68499	93.8	2.02
121	70000	95.64	3.64	67999	93.66	1.98
120	70000	95.4	4.3	67499	93.5	1.9
119	70000	94.89	5.93	66996	93.15	1.74
118	70000	94.52	5.65	66499	91.62	2.9
117	70000	94.35	4.68	65999	90.46	3.89
116	70000	94.09	5.06	65501	90.24	3.85
115	70000	93.38	7.32	65001	89.47	3.91
114	70000	92.66	8.9	64498	88.11	4.55
113	70000	92.46	7.3	63994	88.01	4.45
112	70000	92.04	7.54	63497	87.56	4.48
111	70000	91.75	6.98	63000	87.36	4.39

Table 6

HEC-RAS Plan: 70K Setback

River: Cache Creek Reach: Cache Creek Profile 200-Year

River Sta. Sec. No.	Q Total (cfs)	W.S. Elev (ft)	Vel Chnl (ft/s)	River Sta. (ft)	Exist W.S. (ft)	Diff. W.S. (ft)
110	70000	91.05	8.7	62499	86.06	4.99
109	70000	90.66	8.22	61999	85.86	4.8
108	70000	90.23	8.01	61499	84.95	5.28
107	70000	90.24	5.26	60999	85.45	4.79
106	70000	90.21	4.01	60501	85.54	4.67
105	70000	90.06	4.57	59997	85.38	4.68
104	70000	89.5	7.06	59500	84.69	4.81
103	70000	89.02	7.38	58999	84.42	4.6
102	70000	85.25	13.85	58530	83.68	1.57
101	70000	84.86	14.04	58490	83.62	1.24
100	70000	85	13.7	58430	83.57	1.43
99	70000	84.69	13.85	58390	83.52	1.17
98	70000	83.62	15.83	58300	83.3	0.32
97	70000	83.21	16.07	58276	83.28	-0.07
96	70000	83.24	15.95	58220	83.28	-0.04
95	70000	83.23	15.96	58195	83.26	-0.03
94	70000	83.2	14.07	57999	83.22	-0.02
93	70000	82.33	11.41	57499	82.94	-0.61
92	70000	81.85	9.68	57001	82.86	-1.01
91	70000	81.38	8.79	56499	82.72	-1.34
90	70000	80.86	8.6	56002	82.09	-1.23
89	70000	80.32	8.61	55499	81.68	-1.36
88	70000	80.14	6.42	54996	81.32	-1.18
87	70000	79.82	6.55	54498	80.99	-1.17
86	70000	79.43	6.88	53998	80.51	-1.08
85	70000	79.13	6.31	53499	79.25	-0.12
84	70000	78.77	6.42	53002	76.63	2.14
83	70000	78.4	6.86	52503	74.83	3.57
82	70000	78.03	6.42	52000	73.78	4.25
81	70000	77.58	6.94	51499	72.95	4.63
80	70000	77.37	5.71	50995	72.15	5.22
79	70000	77.3	4.32	50498	72.24	5.06
78	70000	77.21	4.07	49998	71.51	5.7
77	70000	76.91	5.3	49500	70.55	6.36
76	70000	76.56	5.85	48998	70.13	6.43
75	70000	76.21	6.39	48499	69.5	6.71
74	70000	75.72	6.79	48000	68.98	6.74

Table 6

HEC-RAS Plan: 70K Setback

River: Cache Creek Reach: Cache Creek Profile 200-Year

River Sta. Sec. No.	Q Total (cfs)	W.S. Elev (ft)	Vel Chnl (ft/s)	River Sta. (ft)	Exist W.S. (ft)	Diff. W.S. (ft)
73	70000	75.43	6.43	47497	68.65	6.78
72	70000	75.15	6.36	46999	68.24	6.91
71	70000	74.98	5.29	46505	67.89	7.09
70	70000	74.79	5.07	46002	67.51	7.28
69	70000	74.59	5.04	45499	66.99	7.6
68	70000	74.37	5.38	44999	66.46	7.91
67	70000	74.22	4.75	44499	65.85	8.37
66	70000	74.02	4.88	44000	65.59	8.43
65	70000	73.78	5.29	43498	64.92	8.86
64	70000	73.53	5.36	42999	64.26	9.27
63	70000	73.23	5.89	42499	63.67	9.56
62	70000	72.84	6.7	41999	62.93	9.91
61	70000	71.55	9.47	41499	62.39	9.16
60	70000	68.73	14.35	41346	62.24	6.49
59	70000	68.29	14.66	41300	62.17	6.12
58	70000	68.16	11.47	41000	61.76	6.4
57	70000	68.2	8.17	40500	61.67	6.53
56	70000	67.86	7.76	40008	61.41	6.45
55	70000	66.54	10.41	39498	60.84	5.7
54	70000	64.87	11.94	39001	60.41	4.46
53	70000	64.45	8.78	38498	60.1	4.35
52	70000	63.86	8.3	37999	59.34	4.52
51	70000	63.68	5.86	37499	59.11	4.57
50	70000	63.52	5.5	36997	58.8	4.72
49	70000	63.16	6.04	36498	58.03	5.13
48	70000	62.74	6.36	35997	57.56	5.18
47	70000	62.28	6.77	35499	57.02	5.26
46	70000	62.01	5.36	35001	56.79	5.22
45	70000	61.65	5.58	34502	56.11	5.54
44	70000	61.3	5.52	33999	55.54	5.76
43	70000	60.95	5.6	33501	55.08	5.87
42	70000	60.58	5.74	33000	54.59	5.99
41	70000	60.2	5.44	32490	54.24	5.96
40	70000	59.98	4.58	31996	53.83	6.15
39	70000	59.7	4.86	31499	53.33	6.37
38	70000	59.52	4.32	30999	53.03	6.49
37	70000	59.23	4.82	30499	52.72	6.51

Table 6

HEC-RAS Plan: 70K Setback

River: Cache Creek Reach: Cache Creek Profile 200-Year

River Sta. Sec. No.	Q Total (cfs)	W.S. Elev (ft)	Vel Chnl (ft/s)	River Sta. (ft)	Exist W.S. (ft)	Diff. W.S. (ft)
36	70000	58.84	5.61	29999	52.38	6.46
35	70000	58.22	6.51	29499	52.06	6.16
34	70000	56.91	9.75	29332	51.89	5.02
33	70000	56.76	9.81	29300	51.86	4.9
32	70000	54.86	12.75	28999	51.5	3.36
31	70000	53.09	12.59	28499	50.35	2.74
30	70000	51.27	11.53	28001	49.42	1.85
29	70000	50.35	8.53	27496	49.04	1.31
28	70000	49.9	5.88	27014	48.44	1.46
27	70000	49.43	5.9	26489	47.75	1.68
26	70000	48.95	5.99	25991	46.95	2
25	70000	48.37	6.04	25506	46.5	1.87
24	70000	47.9	6.05	25002	46.09	1.81
23	70000	47.53	6.22	24502	45.67	1.86
22	70000	47.45	4.39	23990	45.43	2.02
21	70000	47.38	3.36	23503	45.34	2.04
20	70000	47.31	3.05	22997	45.16	2.15
19	70000	47.24	2.95	22499	44.96	2.28
18	70000	47.17	2.85	21999	44.73	2.44
17	70000	47.1	2.79	21499	44.5	2.6
16	70000	47.03	2.8	20999	44.21	2.82
15	70000	46.95	2.86	20499	43.95	3
14	70000	46.9	2.7	20000	43.77	3.13
13	70000	46.84	2.7	19502	43.78	3.06
12	70000	46.78	2.73	18999	43.78	3
11	70000	46.72	2.6	18496	43.77	2.95
10	70000	46.67	2.67	17998	43.77	2.9
9	70000	46.61	2.6	17504	43.76	2.85
8	70000	46.55	2.6	16994	43.75	2.8
7	70000	46.5	2.77	16499	43.75	2.75
6	70000	46.45	2.83	15998	43.74	2.71
5	70000	46.4	2.85	15503	43.74	2.66
4	70000	46.35	2.75	14999	43.73	2.62
3	70000	46.3	2.77	14502	43.73	2.57
2	70000	46.25	2.69	14001	43.72	2.53
1	70000	46.2	2.46	13496	43.72	2.48

Table 7

HEC-RAS Plan: 91K Setback

River: Cache Creek Reach: Cache Creek Profile 91K

River Sta. Sec. No.	Q Total (cfs)	W.S. Elev (ft)	Vel Chnl (ft/s)	River Sta. (ft)	Exist W.S. (ft)	Diff. W.S. (ft)
154	91000	100.24	10.63	84499	97.93	2.31
153	91000	100.71	5.14	83996	98.42	2.29
152	91000	100.72	3.42	83496	98.44	2.28
151	91000	100.61	3.47	82997	98.26	2.35
150	91000	100.51	3.4	82497	98.3	2.21
149	91000	100.49	2.58	81999	98.17	2.32
148	91000	100.41	2.73	81499	98.05	2.36
147	91000	100.33	2.86	80999	97.92	2.41
146	91000	100.26	2.77	80498	97.82	2.44
145	91000	100.11	3.43	79999	97.6	2.51
144	91000	99.74	4.96	79499	97.09	2.65
143	91000	99.51	5.05	78999	96.69	2.82
142	91000	99.41	4.16	78499	96.54	2.87
141	91000	99.27	3.96	77999	96.41	2.86
140	91000	99.12	3.88	77499	96.04	3.08
139	91000	99.09	2.82	76999	96.03	3.06
138	91000	99.03	2.69	76499	96.04	2.99
137	91000	98.92	3.1	75999	95.96	2.96
136	91000	98.86	2.85	75499	95.87	2.99
135	91000	98.71	3.75	74999	95.57	3.14
134	91000	98.57	3.84	74499	95.28	3.29
133	91000	98.44	3.67	73999	95.02	3.42
132	91000	98.37	3.12	73499	94.92	3.45
131	91000	98.37	2.27	72999	94.98	3.39
130	91000	98.29	2.72	72499	94.88	3.41
129	91000	98.13	3.87	71999	94.75	3.38
128	91000	98.18	1.65	71499	94.76	3.42
127	91000	98.15	2.02	70999	94.7	3.45
126	91000	98.07	2.66	70499	94.62	3.45
125	91000	97.99	2.97	69999	94.57	3.42
124	91000	97.98	2.18	69499	94.54	3.44
123	91000	97.89	2.68	68999	94.48	3.41
122	91000	97.74	3.41	68499	94.37	3.37
121	91000	97.52	4.22	67999	94.21	3.31
120	91000	97.22	5.01	67499	94.05	3.17
119	91000	96.62	6.75	66996	93.7	2.92

Table 7

HEC-RAS Plan: 91K Setback

River: Cache Creek Reach: Cache Creek Profile 91K

River Sta. Sec. No.	Q Total (cfs)	W.S. Elev (ft)	Vel Chnl (ft/s)	River Sta. (ft)	Exist W.S. (ft)	Diff. W.S. (ft)
118	91000	96.2	6.46	66499	92.03	4.17
117	91000	95.98	5.52	65999	90.66	5.32
116	91000	95.64	6	65501	90.42	5.22
115	91000	94.9	8.11	65001	89.6	5.3
114	91000	94.24	9.57	64498	88.21	6.03
113	91000	94.04	7.9	63994	88.11	5.93
112	91000	93.56	8.32	63497	87.64	5.92
111	91000	93.12	8.12	63000	87.43	5.69
110	91000	92.2	10.21	62499	86.09	6.11
109	91000	91.63	9.86	61999	85.9	5.73
108	91000	91.01	9.71	61499	84.96	6.05
107	91000	91.05	6.42	60999	85.48	5.57
106	91000	91	4.92	60501	85.58	5.42
105	91000	90.84	5.32	59997	85.42	5.42
104	91000	90.27	7.69	59500	84.73	5.54
103	91000	89.81	7.76	58999	84.45	5.36
102	91000	86.6	13.86	58530	83.71	2.89
101	91000	86.36	13.6	58490	83.66	2.7
100	91000	86.36	13.58	58430	83.6	2.76
99	91000	86.1	13.84	58390	83.55	2.55
98	91000	85.39	15.37	58300	83.33	2.06
97	91000	85.2	14.98	58276	83.31	1.89
96	91000	85.59	12.85	58220	83.31	2.28
95	91000	85.54	12.9	58195	83.29	2.25
94	91000	85.07	12.65	57999	83.25	1.82
93	91000	84.58	10.16	57499	82.97	1.61
92	91000	83.83	9.96	57001	82.89	0.94
91	91000	83.19	9.64	56499	82.74	0.45
90	91000	82.7	9.05	56002	82.11	0.59
89	91000	82.2	8.91	55499	81.7	0.5
88	91000	82.02	6.66	54996	81.34	0.68
87	91000	81.7	6.79	54498	81.01	0.69
86	91000	81.25	7.29	53998	80.53	0.72
85	91000	80.94	6.63	53499	79.28	1.66
84	91000	80.58	6.74	53002	76.66	3.92
83	91000	80.21	7.21	52503	74.86	5.35

Table 7

HEC-RAS Plan: 91K Setback

River: Cache Creek Reach: Cache Creek Profile 91K

River Sta. Sec. No.	Q Total (cfs)	W.S. Elev (ft)	Vel Chnl (ft/s)	River Sta. (ft)	Exist W.S. (ft)	Diff. W.S. (ft)
82	91000	79.85	6.87	52000	73.81	6.04
81	91000	79.38	7.51	51499	72.98	6.4
80	91000	79.17	6.02	50995	72.19	6.98
79	91000	79.1	4.73	50498	72.27	6.83
78	91000	79.02	4.41	49998	71.55	7.47
77	91000	78.69	5.78	49500	70.59	8.1
76	91000	78.3	6.46	48998	70.17	8.13
75	91000	77.9	7.1	48499	69.54	8.36
74	91000	77.33	7.64	48000	69.02	8.31
73	91000	76.99	7.31	47497	68.7	8.29
72	91000	76.66	7.28	46999	68.29	8.37
71	91000	76.46	6.09	46505	67.93	8.53
70	91000	76.23	5.89	46002	67.56	8.67
69	91000	75.99	5.89	45499	67.03	8.96
68	91000	75.7	6.3	44999	66.51	9.19
67	91000	75.52	5.58	44499	65.9	9.62
66	91000	75.27	5.76	44000	65.64	9.63
65	91000	74.95	6.26	43498	64.97	9.98
64	91000	74.61	6.39	42999	64.31	10.3
63	91000	74.18	7.12	42499	63.73	10.45
62	91000	73.48	8.26	41999	62.98	10.5
61	91000	72.16	10.65	41499	62.45	9.71
60	91000	70.85	12.37	41346	62.29	8.56
59	91000	70.7	12.47	41300	62.23	8.47
58	91000	70.46	11.58	41000	61.81	8.65
57	91000	70.3	9.04	40500	61.72	8.58
56	91000	69.96	8.55	40008	61.47	8.49
55	91000	68.47	11.52	39498	60.89	7.58
54	91000	66.71	12.87	39001	60.46	6.25
53	91000	66.22	9.41	38498	60.15	6.07
52	91000	65.66	8.67	37999	59.39	6.27
51	91000	65.49	6.14	37499	59.16	6.33
50	91000	65.34	5.83	36997	58.84	6.5
49	91000	64.97	6.48	36498	58.08	6.89
48	91000	64.53	6.92	35997	57.61	6.92
47	91000	64.02	7.43	35499	57.06	6.96

Table 7

HEC-RAS Plan: 91K Setback

River: Cache Creek Reach: Cache Creek Profile 91K

River Sta. Sec. No.	Q Total (cfs)	W.S. Elev (ft)	Vel Chnl (ft/s)	River Sta. (ft)	Exist W.S. (ft)	Diff. W.S. (ft)
46	91000	63.74	5.96	35001	56.83	6.91
45	91000	63.35	6.18	34502	56.16	7.19
44	91000	62.96	6.17	33999	55.58	7.38
43	91000	62.58	6.27	33501	55.12	7.46
42	91000	62.15	6.42	33000	54.63	7.52
41	91000	61.72	6.17	32490	54.28	7.44
40	91000	61.47	5.22	31996	53.87	7.6
39	91000	61.14	5.57	31499	53.37	7.77
38	91000	60.92	5.02	30999	53.07	7.85
37	91000	60.56	5.66	30499	52.76	7.8
36	91000	60.05	6.62	29999	52.42	7.63
35	91000	59.3	7.43	29499	52.11	7.19
34	91000	58.12	10.23	29332	51.93	6.19
33	91000	57.99	10.36	29300	51.9	6.09
32	91000	57.13	10.92	28999	51.54	5.59
31	91000	54.53	13.91	28499	50.39	4.14
30	91000	52.73	12.33	28001	49.45	3.28
29	91000	51.84	9.19	27496	49.08	2.76
28	91000	51.4	6.51	27014	48.47	2.93
27	91000	50.9	6.6	26489	47.78	3.12
26	91000	50.35	6.71	25991	46.98	3.37
25	91000	49.71	6.82	25506	46.52	3.19
24	91000	49.16	6.88	25002	46.11	3.05
23	91000	48.77	7.01	24502	45.69	3.08
22	91000	48.71	4.83	23990	45.45	3.26
21	91000	48.63	3.75	23503	45.36	3.27
20	91000	48.55	3.46	22997	45.18	3.37
19	91000	48.46	3.36	22499	44.98	3.48
18	91000	48.38	3.26	21999	44.75	3.63
17	91000	48.3	3.2	21499	44.52	3.78
16	91000	48.21	3.22	20999	44.23	3.98
15	91000	48.13	3.28	20499	43.96	4.17
14	91000	48.06	3.12	20000	43.78	4.28
13	91000	47.99	3.13	19502	43.79	4.2
12	91000	47.92	3.17	18999	43.79	4.13
11	91000	47.85	3.03	18496	43.78	4.07

Table 7

HEC-RAS Plan: 91K Setback

River: Cache Creek Reach: Cache Creek Profile 91K

River Sta. Sec. No.	Q Total (cfs)	W.S. Elev (ft)	Vel Chnl (ft/s)	River Sta. (ft)	Exist W.S. (ft)	Diff. W.S. (ft)
10	91000	47.77	3.11	17998	43.78	3.99
9	91000	47.7	3.03	17504	43.77	3.93
8	91000	47.63	3.03	16994	43.77	3.86
7	91000	47.57	3.23	16499	43.76	3.81
6	91000	47.51	3.3	15998	43.75	3.76
5	91000	47.45	3.32	15503	43.75	3.7
4	91000	47.39	3.21	14999	43.74	3.65
3	91000	47.32	3.23	14502	43.74	3.58
2	91000	47.26	3.12	14001	43.74	3.52
1	91000	47.2	2.87	13496	43.73	3.47

The hydraulic model shows that water surface impacts in the settling basin range from 1.50 feet to 3.40 feet for flows between 53,000 cfs and 91,000 cfs. Table 8 below summarizes the impacts at the settling basin. This stage impact is due to confining flows within the setback levee. At RD 94B, the models show water surface impacts of 0.40 feet to 2.31 feet for the 53,000 cfs (50-year event) to 91,000 cfs (1,000-year event), respectively.

Table 8

Setback Levee

Settling Basin Hydraulic Impacts

	Settling Basin Data [2/]	
Flow (cfs) [1/]	Existing Condition Flow / Stage	Setback Levee Flow / Stage
50,000	25,300 / 43.8	46,900 / 45.3
70,000	25,000 / 43.8	67,200 / 46.2
91,000	25,100 / 43.8	87,300 / 47.2

[1/] Flow at Road 94 B

[2/] Assumes ultimate weir height of 41.0 (NAVD88).

Peak stages for the 91,000 cfs flow (1,000-year) do not fail the settling basin levee, but do encroach into the freeboard. Settling basin rehabilitation maybe required once the R & U flow is analyzed.

There are several gravel mining operations from Station 740+00 to 830+00, between I-5 and Road 94B. The operations are protected by levees built and

maintained by the respective operator. Table 8A shows the increase in water surface elevations within the mining reach.

Table 8A
Water Surface Increases
Station 740+00 to 840+00

Frequency	Flow	Stage Increase
50-year	53,290 cfs	0.32 to 0.41
200-year	70,000 cfs	2.06 to 1.49
1,000-year	91,000 cfs	3.42 to 2.31

These flow increases reduce the existing freeboard for the local levees.

Hydraulic impacts for existing bridges were evaluated using the UNET model existing condition compared to each alternative. These impacts, both stage and velocity are presented below in Table 8B.

Table 8B

Pre & Post Project

Calculated Hydraulic Bridge Data 1/

50,000 cfs 2/

	Existing	Condition	Flood Barrier		Narrow Max. W.S. Elev.	Setback Levee
Bridge Location	Max. W.S. Elev. 3/	Max. Velocity	Max.W.S. Elev.	Max. Velocity	Max. W.S. Elev.	Max. Velocity 4/
RD 94B	95.27	4.78	75.27	4.78	94.85	4.73
I-5 South Upstream	83.60	9.56	83.60	9.56	81.85	12.07
I-5 North Downstream	83.50	9.44	83.50	9.44	81.65	11.90
RD 99 Upstream	83.24	10.05	83.24	10.05	80.82	13.12
SP Railroad Upstream	83.22	9.75	83.20	9.75	80.84	12.69
SP Railroad Downstream	83.20	9.75	83.22	9.75	80.80	12.67
Hwy 113 Upstream	62.46	7.31	62.46	7.31	66.42	11.25
Hwy 113 Downstream	62.40	7.34	62.40	7.34	66.24	11.35
RD 102 Upstream	52.02	4.71	52.02	4.71	54.63	8.15
RD 102 Downstream	52.00	4.72	52.00	4.72	54.08	7.73

Calculated Hydraulic Bridge Data 1/

70,000 cfs 2/

	Existing	Condition	Flood Barrier		Narrow	Setback Levee
Bridge Location	Max. W.S. Elev. 3/	Max. Velocity	Max.W.S. Elev.	Max. Velocity	Max. W.S. Elev.	Max. Velocity 4/
RD 94B Downstream	96.88	5.10	96.88	5.10	97.44	5.05
I-5 South Upstream	83.68	10.31	83.68	10.31	83.96	14.75
I-5 North Upstream	83.57	10.21	83.57	10.21	83.68	14.62
RD 99 Upstream	83.30	10.91	83.30	10.91	82.17	16.72
SP Railroad Upstream	83.28	10.65	83.28	10.65	82.20	16.11
SP Railroad Downstream	83.26	10.66	83.26	7.25	81.97	16.15
Hwy 113 Upstream	62.24	7.25	62.24	7.28	68.48	14.00
Hwy 113 Downstream	62.17	7.28	62.17	4.66	68.15	14.10
RD 102 Upstream	51.90	4.66	51.90	4.66	56.89	9.84
RD 102 Downstream	51.86	4.67	51.86	4.67	56.70	9.86

1/ UNET Results

2/ Flow @ RD94B

3/ NAVD '88
4/ No Bridge Modifications

7.03 Lower Cache Creek Overflow Barrier

1. Plan Description

Based on the preliminary alternative plan analysis, the Lower Cache Creek Overflow Barrier was identified for further analysis. Levee alignments were further refined and adjusted from the preliminary levee alignment alternative. Aerial photography and public comments were utilized to minimize impacts to land and facilities. The levee alignment chosen is shown on Plate 24 & 25.

2. Flood Analysis

Further flood analysis consisted of running the selected alternative with three flows. The flows were chosen to cover a range of relatively frequent events to rare events. The flows input into the hydraulic model at Road 94B are 50,000 cfs, 70,000 cfs and 91,000 cfs. Impacts on channel velocities and encroachments were evaluated to determine the need for bank protection, bridge replacement and levee heights. The FLO-2D model was modified to reflect the proposed flood barrier along the northern city limit. Overland flow obstructions such as I-5 and Hwy 113 were field reviewed and included in the model. A 4,000-foot section of the west levee of the settling basin was removed to allow overland flow into the settling basin.

The Lower Cache Creek Overflow Barrier (LCCOB) consists of a flood barrier (combination of levee and floodwalls) north of the City of Woodland that ties into the west levee of the settling basin. A portion of the settling basin west levee is removed to allow flood waters to pass into the settling basin. Initial studies assumed a 4,000-foot wide opening, with levee removed to ground. Review and analysis indicated that with this configuration, the area north of the LCCOB on the west side of the settling basin west levee, including Road 102, would be inundated by flows in Cache Creek as low as the two-year event. In an effort to prevent Road 102 from flooding in events smaller than the 10-year event (largest event during which flow in Cache Creek would remain confined within the creek and, therefore, discharge into the settling basin), two alternatives were developed. Details of the study alternative configurations are summarized below.

Plan A:	Construct Weir in West Levee Opening
Weir crest elevation:	45.0 feet (NAVD88)
Opening width:	2,000 feet (50 kcfs and 100-year studies) 3,000 feet (70 kcfs and 91 kcfs studies)
Plan B:	Raise Road 102
Elevation:	48 feet (NAVD88)
Opening width:	4,000 feet in west levee

Plates 26 and 27 compare the innundation boundaries north of the LCCOB for the 50 and 100-year floods with and without the LCCOB. Innundation boundaries for the LCCOB are shown for the initial configuration (existing Road 102 and not west levee weir) and Plans A and B. Table 9 summarizes peak stage for the alternatives.

Table 9
Peak W.S. Elevations
between
Road 102 and West Levee

Flow (cfs) [1/]	Existing Condition (ft)	Plan A Weir @ West Levee	Plan B Raise Road 102
50,000	42.65	48.68	45.84
70,000	43.42	49.41	46.62
91,000	44.33	50.64	47.60

[1/] Flow at Road 94 B

The Cache Creek channel was assumed to remain in existing condition for this alternative. Overbank flow and potential levee failures, downstream of I-5, criteria remained the same. No bridge replacement is required for this alternative. Velocities along the LCCOB are low and do not require riprap. However, geotechnical analysis indicates that riprap is required east of RD 102 for wind and wave hydraulic forces.

3. Hydraulic Impacts

Hydraulic impacts evaluated for this alternative show that water surface increases in the flood plain south of Cache Creek and north of the flood barrier, range from 0 to 6 feet. Plates 28 and 29 show the flood depth differences between the proposed flood barrier alternative and the existing conditions.

Hydraulic impacts at the settling basin for this alternative are less than the impacts under the setback levee plan. The water surface elevations increase for the flood barrier alternative range from 0.8 to 2.1 feet in the settling basin. Rating curves for the settling basin impacts are shown on Plate 31.

Table 10 below summarizes the impacts at the settling basin.

Table 10
Lower Cache Creek Overflow Barrier
Settling Basin Hydraulic Impacts

	Settling Basin Data	
Flow (cfs) [1/]	Existing Condition Flow (cfs) / Stage	LLCOB Flow (cfs) / Stage [2/]
50,000	25,300 / 43.8	37,000 / 44.6
70,000	25,000 / 43.8	45,600 / 45.2
91,000	25,100 / 43.8	57,900 / 45.9

[1/] Flows at Road 94B.
[2/] Data for worst case scenario (Plan A or Plan B). All stages are in NAVD '88.

To evaluate the flood barrier alternatives, stage impacts within the effected lands, depth duration curves were prepared to compare existing conditions to project conditions. Six locations were chosen that represent typical impacts within specific areas. Plate 30 shows the chosen FLO-2D grid locations and Plates 32 to 37 are plots of the overbank flood depth duration. In general, the comparisons show significant impacts near the west levee of the Settling Basin. The hydraulic impacts decrease, moving westerly away from the west levee location.

The preferred flood barrier plan (Plan A) chose an inlet weir elevation of 45, based on no backflow from the settling basin prior to potential flooding. As discussed under non-damaging flows section, the 10-year event was used in the initial evaluation of inlet weir heights. The 10-year event is the non-damaging flow and the goal for choosing an inlet weir elevation is to not increase flood frequency west of the proposed inlet weir. Subsequent evaluation shows (50-year, 100-year, 200-year and 1,000-year hydrograph analysis) that the settling basin does not flow over the proposed inlet weir prior to flooding of the area between Road 102 and the inlet weir. Plates 38, 39, 40 and 41 are stage hydrographs for the studied flows, showing the sequence of flooding.

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