A Feasibility Investigation of Reintroduction of Anadromous Salmonids above Crocker-Huffman Dam on the Merced River

Report prepared for the U.S. Fish and Wildlife Service
Anadromous Fish Restoration Program

December 2007

David A. Vogel
Natural Resource Scientists, Inc.
P.O. Box 1210
Red Bluff, CA 96080

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

Introduction and Background

The Merced River is the southernmost Central Valley stream presently inhabited by anadromous salmonids. The Merced River, its channel, watershed and riparian corridor, have been significantly altered by gold and gravel mining; dam construction for power production, irrigation, and flood control; agriculture; and urbanization (CDFG 1993, USFWS 1995a, USBR 1997). Crocker-Huffman Dam is located at river mile (RM) 52, along with three upstream dams (Merced Falls Dam [RM55], McSwain Dam [RM56], and New Exchequer Dam [RM62] – Figure 1) that regulate flows in the lower Merced River. Compared to their historic access to spawning and rearing habitat in higher elevation river reaches, Chinook salmon (*Oncorhynchus tshawytscha*) are restricted during all of their freshwater life stages to utilize the lower Merced River up to Crocker-Huffman Dam, which is the upstream barrier for fish migration and the location of the Merced River Fish Hatchery (Merced Hatchery). As a result, natural salmon production is affected by limited accessible stream reach and alterations of stream channel, flow and water temperatures. Crocker-Huffman Dam forms a low-head, run-of-the-river diversion serving the Merced Irrigation District's (Merced ID) Main Canal (Figure 1).

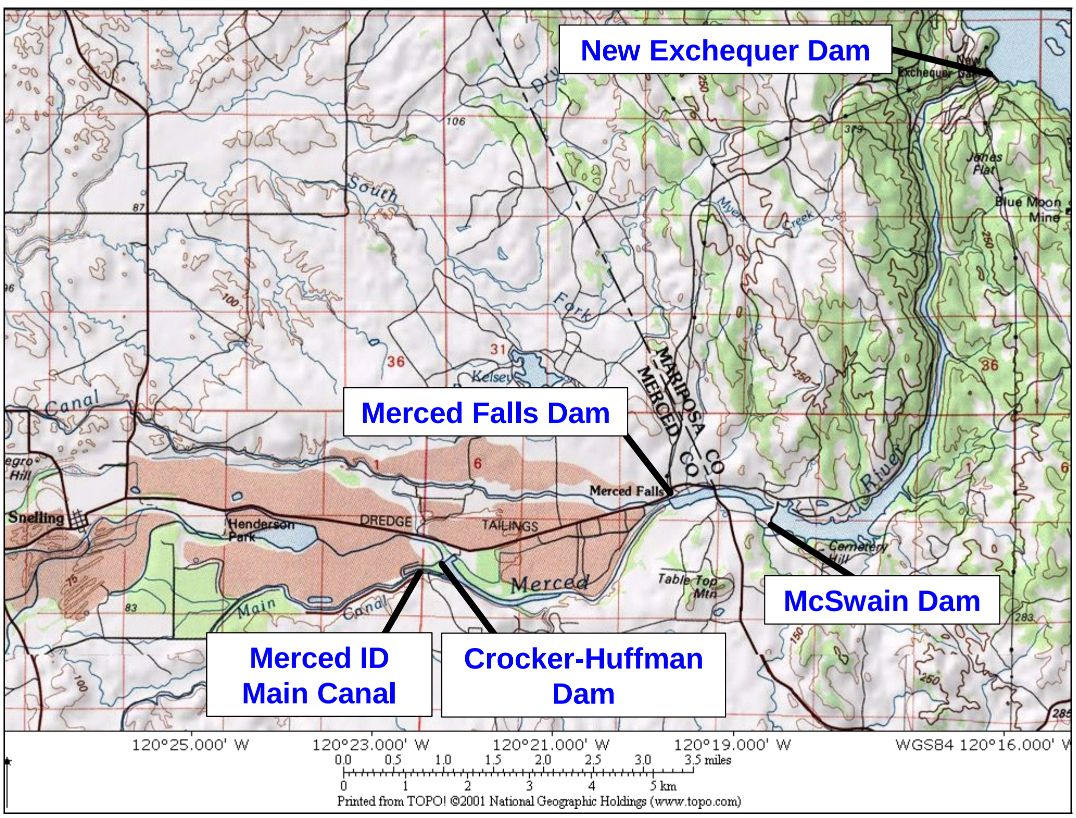


Figure 1. Location of four dams on the Merced River and Merced ID's Main Canal.

The three-mile tailwater river reach between the Crocker-Huffman and Merced Falls dams is both reservoir and riverine in nature, benefits from cool water temperatures, has hypolimnetic reservoir releases throughout its length, and supports a good sport fishery for trout indicating that habitat conditions may be suitable for anadromous salmonid spawning and rearing. However, this reach is currently not accessible to anadromous salmonids because the existing fishway on Crocker-Huffman Dam is non-operational. Due to the proximity of the tailwater reach above Crocker-Huffman Dam to the deep reservoir releases, water temperatures are likely to be cooler and more suitable for salmonid spawning and rearing for longer periods of the year than in river reaches downstream of Crocker-Huffman Dam, particularly during drought years. Additionally, there are no fish screens on the diversions upstream of the dam. Re-establishing anadromous salmonid access to the river reach above Crocker-Huffman Dam has the potential to increase available spawning and rearing habitat and to enhance the natural salmon production of the Merced River. If suitable habitats are available, there may also be the potential to re-establish federally-listed threatened Central Valley ESU (evolutionarily significant unit) steelhead (*O. mykiss*) in the Merced River.

The primary objective for this feasibility study was to examine the biological and physical technical issues associated with the potential for re-establishing migratory passage and fish protection at Crocker Huffman Dam and investigate the biological production potential of the habitat between Crocker-Huffman and Merced Falls dams for anadromous salmonids. An additional and integral objective was to assess the implications for, and interactions of such a restoration action with, ongoing and future planned operations of the California Department of Fish and Game's (CDFG) Merced Hatchery. This investigation examines the opportunities and constraints of anadromous salmonid reintroduction upstream of Crocker-Huffman Dam.

Actions to improve or restore anadromous salmonid accessibility to stream habitat above impassible or marginally passable dams and weirs (due to inadequate or obsolete fishways) are currently taking place on other key salmon-producing Central Valley streams, namely Clear Creek, Battle Creek and Butte Creek, all of which are tributaries to the Sacramento River. These actions have been supported by CALFED, the Central Valley Project Improvement Act's (CVPIA) Anadromous Fish Restoration Program (AFRP) and Anadromous Fish Screen Program (AFSP), and the CDFG's Salmon and Steelhead Restoration Program. Opportunities for restoring anadromous fish above existing dams on Central Valley streams are currently limited but are considered critical opportunities for alleviating several principal environmental stressors thought to contribute to the depressed population status of many at-risk species, including San Joaquin fall-run Chinook salmon which inhabit the Merced River (Myers *et al.* 1998, NMFS 1998, CALFED 1999a, 1999b, 2001). Increasing, or restoring, utilization of spawning and rearing areas above natural and man-made migration barriers in streams is a sound management approach for restoring and enhancing fish runs which has met with considerable success when applied with appropriate ecological and engineering considerations (Calhoun 1966, Huntington *et al.* 1988, Flosi and Reynolds 1991).

Dams can create environmental stress for anadromous fish by blocking migration and eliminating access to suitable habitat, by impeding upstream and downstream migration causing asynchrony between life history events and suitable environmental conditions such as delayed arrival to the spawning grounds for adults or to the estuary for smolts (Vogel *et al.* 1988), and by affecting stream flow and temperature regimes with consequent changes in many biological, ecological, and physical fluvial processes (Leopold *et al.* 1964, Hynes 1970). For most rivers with large dams and deep reservoirs, anadromous fish are completely blocked and habitat is lost due to inundation of the river channel by the reservoir. In some cases, local extinction of salmon and steelhead populations has occurred on streams where large dams blocked fish runs (Warner 1991, Mills *et al.* 1996). Many moderately-sized dams [e.g., Red Bluff Diversion Dam (Sacramento), Anderson-Cottonwood Diversion Dam (Sacramento), Woodbridge Diversion Dam (Mokelumne)] and small seasonal diversions are equipped with fishways to allow anadromous fish passage to suitable upstream habitats.

The CALFED Ecosystem Restoration Program Plan (ERPP) (CALFED 1998) set forth a vision for addressing the adverse effects of dams on fish passage and habitat loss to support the ERPP's Strategic Plan Goals (CALFED 1999a). This vision proposed to improve habitat conditions below dams to enhance salmon and steelhead populations in lower river reaches. These improvements would include those that affect natural processes (e.g., sediment transport), habitat (e.g., riverine and riparian habitat features), and at-risk species requirements (e.g., water temperature, fish passage). The ERPP vision also proposed to address the feasibility of restoring fish above some dams where, consistent with other uses, opportunity and cooperation of local water districts and landowners exist.

Measures to actually increase the amount of physical habitat available for natural production of anadromous fish downstream of dams, such as when degraded channels are re-engineered to spawning riffles or when instream flows are manipulated to provide suitable spawning or rearing habitat, remain limited by the extent of the river reach below the dam. The only other means to increase habitat available to anadromous fish is to restore accessibility to stream reaches with suitable habitat. Access to riverine habitat above Crocker-Huffman Dam may have the potential to expand the river reach distance by about 13% of that currently utilized for natural anadromous salmonid spawning and rearing in the Lower Merced River.

This investigation was a targeted research project to assess the technical biological and physical feasibility issues associated with establishing fish passage at an existing low-head, run-of-the-river diversion dam with a mitigation fish hatchery and reintroducing anadromous salmonids to potentially suitable habitat upstream of the dam, thus enhancing natural salmon production. The principal question addressed in this report is whether habitat between Crocker-Huffman and Merced Falls dams is suitable for natural production of anadromous salmonids and the relative degree of natural production that could be expected. The hypotheses posed in this investigation are that upstream habitats are either not suitable for anadromous salmonid spawning and rearing or that upstream habitats are suitable to varying degrees (e.g., marginal to good) relative to those habitats in downstream reaches. Information generated by this investigation is intended to advance knowledge and address current uncertainties regarding the technical biological and physical feasibility for salmonid reintroduction. Because of the potential impacts on operations of Merced Hatchery, this feasibility study also included an assessment of potential biological impacts, interactions, and integration with hatchery.

Prior to the investigation, it was anticipated that if reintroduction of anadromous salmonids upstream of Crocker-Huffman Dam was ultimately determined to be feasible, stakeholder issues and detailed engineering design associated with providing fish passage and protection would be formulated in a subsequent phase of this project. In that phase, provisions for safe upstream and downstream fish passage would have to be evaluated as to technical feasibility, degree of dam and diversion intake modifications necessary to accommodate appropriate fishway and fish screening structures, and potential costs.

Evaluation of the feasibility of re-establishing access and reintroducing anadromous fish to areas above Crocker-Huffman Dam requires assessing biological issues and habitat and ecological requirements for anadromous fish and, concurrently, impacts to and interactions with Merced Hatchery. Accordingly, physical habitat inventories of the river reach between Crocker-Huffman and Merced Falls dams were studied to define interrelationships between quality and quantity of habitats available for potential Chinook salmon and steelhead production. Field work was composed of multiple processes to evaluate the quantity and quality of potential anadromous salmonid habitats upstream of Crocker-Huffman Dam. The range of factors considered in this study included stream flow regime, water temperature regime, physical habitat availability and quality, and riparian condition. The relevance of these factors to potential salmonid reintroduction, how they were evaluated, and results are provided in subsequent sections of this report.

The Merced River Development Project

Merced ID's Merced River Development Project (Project) has had a profound affect on anadromous salmonid habitats in the river reach between Crocker-Huffman Dam and Merced Falls Dam. Among those effects, Merced ID's Project altered the river's seasonal flow regime, channel geometry, water temperatures, riverbed substrates, riparian vegetation, and aquatic species distribution and abundance. Because of those changes, it is useful for this study to understand the basic infrastructure on the river system.

The present-day Merced ID was originally established as the Robla Canal Company in about 1870, which was succeeded by the Farmers Canal Company in 1876, the year when construction began on a crib dam at the present Crocker-Huffman diversion dam site. In 1883, the Merced Canal and Irrigation Company took over the system, enlarged the original small canal and tunnels, and extended the main irrigation canal. In 1888, the Crocker-Huffman Land and Water Company was incorporated and succeeded to the properties of the Merced Canal and Irrigation Company (Selb 1992). In 1894, a new crib dam was constructed across the Merced River, and in 1910 the present concrete diversion dam was built. In 1919, Merced ID was organized and soon thereafter bought the Crocker-Huffman system. Exchequer Dam, the largest concrete arch dam in the nation at the time, was subsequently built and completed in 1926 forming Lake McClure (Selb 1992) and had a storage capacity of 281,200 acre-ft. (Stillwater 2002). Merced ID's distribution system continued to expand and now consists of about 703 miles of open canals and 89 miles of concrete pipelines, numerous small check dams, siphons and other distribution structures. Prompted by water shortages during summer months causing crop losses, a disastrous flood in 1950, and the anticipated benefits of hydroelectric power, an initiative to construct additional storage facilities to regulate and control flow on the Merced River was undertaken which would be known as the Merced River Development Project, the two main elements which are the New Exchequer Dam, powerhouse and spillway and McSwain dam, powerhouse and spillway. The old Exchequer Dam became a part of the New Exchequer Dam as an immediate upstream supporting structure, and is inundated by Lake McClure (Selb 1992).

Description of Project Facilities

New Exchequer Dam/Lake McClure

New Exchequer Dam, located at RM 62, impounds Lake McClure (Figure 2), a large reservoir in excess of 1 million acre-feet and prone to strong thermal stratification. The dam controls 81 percent of the basin (Stillwater 2002). The reservoir experiences long residence time, has great depth, and possesses modest flow-through volumes during warmer periods of the year; residence time is on the order of one-year. Figure 2 shows a longitudinal schematic of the dam with relative elevations. Note the location of Old Exchequer Dam in relation to the new dam and the water intake elevation. Unlike some Central Valley dams, New Exchequer Dam draws water from the bottom of the reservoir in the hypolimnion and does not have the facilities for water intake from alternative elevations (depths). Physical characteristics of the dam are provided in Table 1.

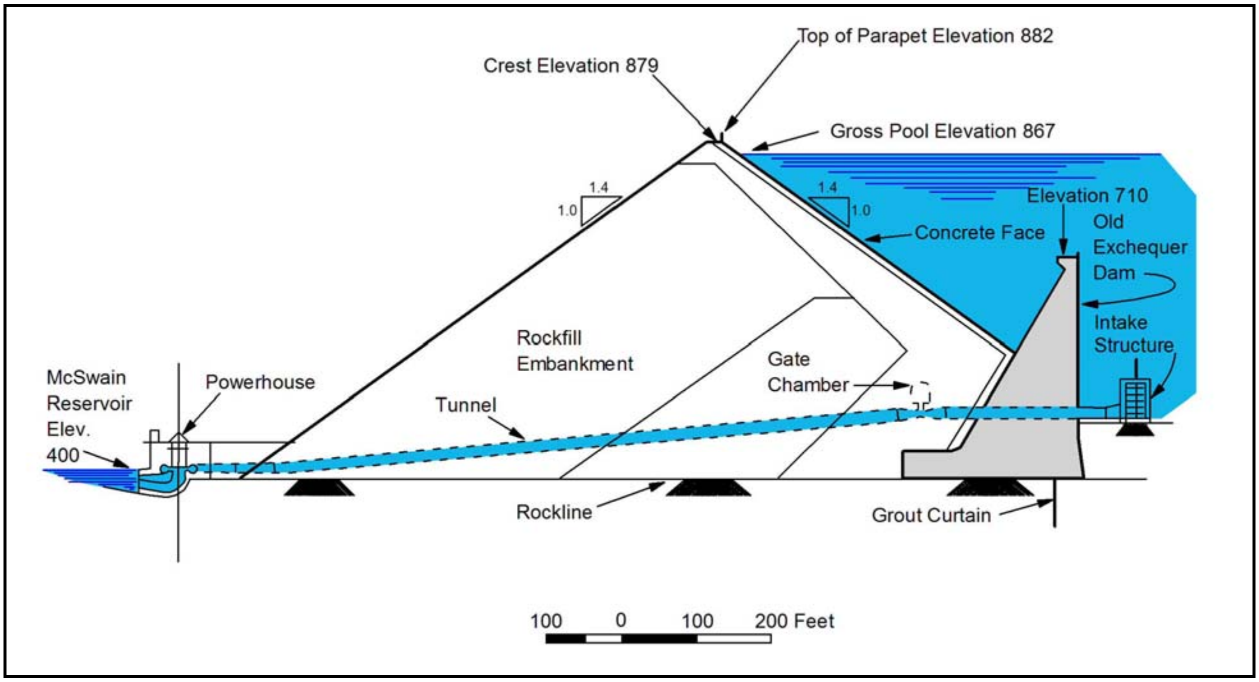


Figure 2. Longitudinal schematic of New Exchequer Dam on the Merced River (source: Merced ID).

McSwain Dam and Reservoir

McSwain Dam, located at RM 56 (Figure 1), and Reservoir re-regulates peaking power releases from New Exchequer Dam. There are no appreciable diversions from this approximately 6-mile-long reservoir with a residence time ranging from less than three days to over three weeks depending on inflow from New Exchequer. This impoundment may exhibit weak to moderate thermal stratification throughout the warmer periods of the year when releases from New Exchequer are modest. Figure 3 shows a longitudinal schematic of McSwain Dam with relative elevations. Physical characteristics of the dam are provided in Table 1.

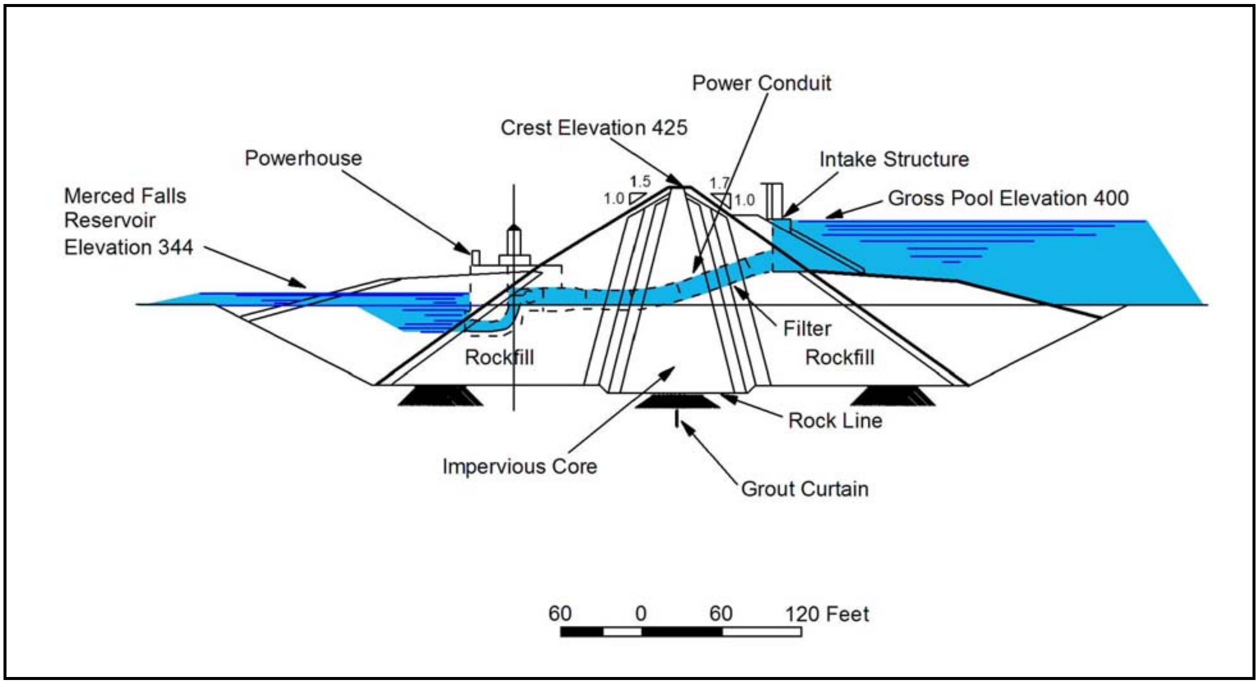


Figure 3. Longitudinal schematic of McSwain Dam on the Merced River (source: Merced ID).

Merced Falls Dam and Forebay

Merced Falls Dam, owned by Pacific Gas & Electric Company, located at RM 55 (Figure 1), and forebay is a diversion point for Merced ID's Northside Canal. This diversion is relatively small compared to the diversions from Crocker-Huffman Dam. This impoundment is approximately one mile long, with a residence time on the order of hours to a few days depending on flow conditions. No schematics or engineering drawings could be obtained for this dam. Physical characteristics of the dam are provided in Table 1.

Crocker-Huffman Dam and Reservoir

Crocker-Huffman Dam, located at RM 52 (Figure 1), impounds water for diversion into Merced ID's Main Canal. This impoundment is three miles long, relatively shallow, and has a residence time on the order of hours to days depending on the flow conditions. The water supply for CDFG's Merced Hatchery as well as a privately owned trout farm (Calaveras Trout) is drawn from the downstream end of the reservoir. Physical characteristics of the dam are provided in Table 1. No schematics or engineering drawings could be obtained for this dam.

Table 1. Description of dams on the Merced River (CDWR 1993).

NAME OF DAM	NAME OF OWNER	COUNTY	LATITUDE (DEG. N)	LONGITUDE (DEG. W)	TYPE	STORAGE CAPACITY (AC. FT.)	DRAINAGE AREA (SQ. MI.)	RESERV. AREA (ACRES)	CREST ELEVATION (FT)	CREST LENGTH (FT)	HEIGHT (FT)	CREST WIDTH (FT)	VOLUME OF DAM (CU. YDS.)	YEAR COMPLETED
Crocker-Huffman	MERCED IRRIGATION DISTRICT	MERCED	37.514	120.371	GRAVITY	300	1,045	56	308	725	22	15	6,224	1910
McSwain	MERCED IRRIGATION DISTRICT	MARIPOSA	37.521	120.310	EARTH & ROCK	9,730	1,037	312	425	1,600	97	15	425,000	1966
Merced Falls	PAC GAS AND ELECTRIC CO	MERCED	37.523	120.329	GRAVITY	620	1,040	65	347	815	37	10	5,300	1901
New Exchequer	MERCED IRRIGATION DISTRICT	MARIPOSA	37.586	120.270	ROCK	1,024,600	1,040.1	7,147	882	1,240	479	18	5,169,000	1967

Water Project Operating Strategies, Requirements, and Agreements

Instream flows through Crocker-Huffman Reservoir are important in determining the potential for reintroduction of anadromous salmonids upstream of Crocker-Huffman Dam. There are a variety of requirements and agreements concerning reservoir operations for the Merced River Development Project that can affect flows through Crocker-Huffman Reservoir and in the lower Merced River. These requirements, therefore, affect potential anadromous salmonid habitats in Crocker-Huffman Reservoir and are described below.

U.S. Army Corps of Engineers Flood Control

According to criteria established by the U.S. Army Corps of Engineers (USCOE 1981), the following are flood control storage limits for Lake McClure and New Exchequer Dam (Figure 4) (MBK 2001):

<u>Rain Flood Space</u>

June 16 to August 31:	1,024,600 acre-feet
September 1 to October 31:	Linear reduction from 1,024,600 acre-feet to 674,600 acre-feet
November 1 to March 15:	674,600 acre-feet
March 16 to June 15:	Linear increase from 674,600 acre-feet to 1,024,600 acre-feet

During the months of March through July, depending on the forecasted runoff and demands, the allowable storage may fall anywhere between the defined Rain Flood Space provided above and the following Maximum Conditional Space (Figure 4) (MBK 2001):

<u>Conditional Space (snow melt flood space)</u>

March 1 to March 31:	Linear reduction from 674,600 acre-feet to 624,600 acre-feet
April 1 to May 15:	624,600 acre-feet
May 16 to July 31:	Linear increase from 624,600 acre-feet to 1,024,600 acre-feet

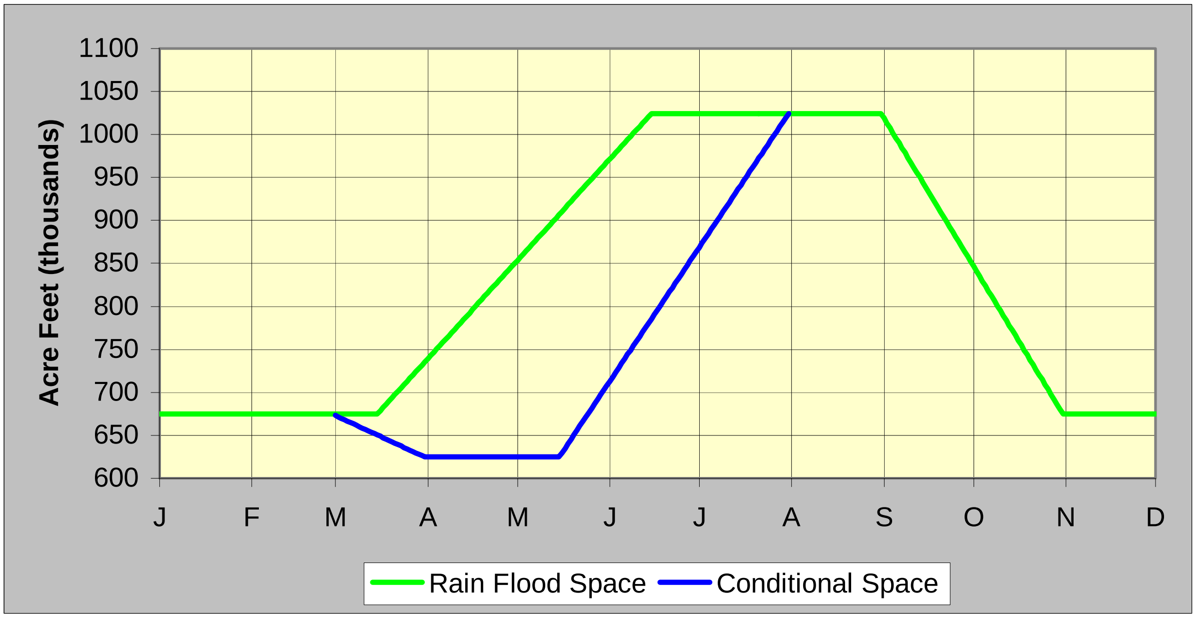


Figure 4. Flood control storage space criteria for Lake McClure/New Exchequer Dam.

Table 2 summarizes the maximum end-of-month flood control storage limits for Lake McClure (MBK 2001):

Table 2. Maximum end-of-month storage (in thousands of acre-feet) in Lake McClure for flood control.

Month	Rain Flood Storage Limit	Maximum Conditional Space Storage Limit
October	674.6	674.6
November	674.6	674.6
December	674.6	674.6
January	674.6	674.6
February	674.6	674.6
March	736.0	624.6
April	850.0	624.6
May	968.0	708.0
June	1024.6	864.0
July	1024.6	1024.6
August	1024.6	1024.6
September	858.0	858.0

Federal Energy Regulatory Commission (FERC)

Merced ID's Federal Energy Regulatory Commission (FERC) license associated with the construction of the New Exchequer Dam calls for Merced ID to provide water for both instream fishery enhancement and to provide up to 15,000 acre feet of water to the Merced National Wildlife Refuge (Selb 1999). Merced ID is required by its FERC power license, issued on April 8, 1964, to release Project water to the Merced River below the Project for fish enhancement (Article 40 & 41, 31 F.P.C. at 901). The FERC fish flow schedule is divided into two (2) categories, a normal year release schedule and a dry year release schedule. A "Dry Year" is defined in the FERC license as a year in which the forecasted April 1 through July 31 unimpaired runoff, as published in the May 1st bulletin of the California Department of Water Resources (CDWR) for the station, "inflow to Exchequer" is less than 450,000 Acre Feet (AF). A "Normal Year" is defined by FERC as a year in which the forecasted April 1 through July 31 unimpaired runoff, as published in the May 1 bulletin of the CDWR for the station "inflow to Exchequer" is more than 450,000 AF. In the "Normal Year" release schedule, 43,734 AF of Project water is released annually to the Merced River downstream of the Project. The "Dry Year" release schedule totals 33,024 AF annually. The monthly flows provided under this FERC license are provided in Table 3 (from CDFG/Merced ID 2002).

Davis-Grunsky Agreement

In October 1967, Merced ID executed a contract with the State of California, known as the Davis-Grunsky ("DG") Contract for State funds in the amount of $8,000,000, to be used for the construction of recreational facilities at the Project, as required by FERC, as well as the construction of fish enhancement facilities operated by CDFG on the Merced River downstream of the Project, in the vicinity of the Crocker-Huffman Dam. The DG also provides for Merced ID to maintain continuous flow of between 180 and 220 cfs in the Merced River spawning area each year during the period October 31 to March 31. The Merced River spawning area is described as a 20 mile (+/-) reach of the Merced River between the Crocker-Huffman Diversion Dam and Shaffer Bridge (Oakdale Road). Annual DG flows for fish enhancement total from 54,269 to 66,326 AF (from CDFG/Merced ID MOU 2002). The monthly flows are provided in Table 3:

Table 3. Annual FERC flows and Davis-Grunsky flows in the Merced River for fish enhancement.										
Month	FERC (Normal/n)		FERC (Dry/d)		Davis -Grunsky		Total Flows (n)		Total Flows (d)	
	cfs	af	cfs	af	cfs	af	cfs	af	cfs	af
Jan	75	4612	60	3689	180–220	11068–13527	180-220	11068-13527	180-220	11068-13527
Feb	75	4165	60	3332	180–220	9997–12218	180-220	9997-12218	180-220	9997-12218
Mar	75	4612	60	3689	180–220	11068–13527	180-220	11068-13527	180-220	11068-13527
Apr	75	4463	60	3570		0	75	4463	60	3570
May	75	4812	60	3689		0	75	4612	60	3689
Jun	25	1488	15	893		0	25	1488	15	893
Jul	25	1537	15	922		0	25	1537	15	922
Aug	25	1537	15	922		0	25	1537	15	922
Sep	25	1488	15	893		0	25	1488	15	893
Oct 01-15	25	744	15	446		0	25	744	15	446
Oct 16-31	25	2380	60	1904		0	75	2380	60	1904
Nov	100	5951	75	4463	180–220	10711–13091	180-220	10711-13091	180-220	10711-13091
Dec	100	6149	75	4612	180-220	11068–13527	180-220	11068-13527	180-220	11068-13527
Total		**43938**		**33024**		**53912 - 65890**		**72161-84139**		**67151-79129**

In terms of actual Project operations, the higher of the two instream flow requirements is implemented for a given month. DG flows are not linked to water year types.

Cowell Agreement Diversions

A water rights adjudication determined that Merced ID must provide water downstream of Crocker-Huffman Dam that could then be diverted from the river at private ditches (Cowell Agreement) (MBK 2001). The flows required to meet the Cowell Agreement Entitlement are provided in Table 4. As described by MBK (2001): "In order to satisfy the flow requirements and the Cowell Agreement, Merced ID operates to a target flow below Crocker-Huffman Diversion Dam equal to the Cowell Agreement adjudicated entitlement plus the FERC/Davis-Grunsky flow requirement. The flow below Crocker-Huffman Diversion Dam must equal the greater of the Davis-Grunsky and FERC flows plus the Cowell Agreement Entitlement."

Stevinson Diversions

Flow entitlements to Stevinson Water District are diverted from the Merced River through Merced ID's Main Canal and rediverted at Merced ID's west boundary to the Stevinson Eastside Canal. Normal year entitlements total 24,000 acre-feet. If in any year the Project does not fill on or before June 15th to the amount of 289,000 acre-feet, then Stevinson Water District water deliveries are curtailed in the same proportion as Merced ID curtailments (Ted Selb, Merced ID, personal communication).

Table 4. Merced ID minimum flow (cfs) requirements for the Cowell Agreement Entitlement and Stevinson entitlement (does not include FERC and Davis-Grunsky flow requirements).		
	Cowell	Stevinson[3]
October 1 – 15	50[1]	0
October 16 – 31	50[1]	0
November	50[1]	0
December	50[1]	0
January	50[1]	0
February	50[1]	0
March	100	0
April	175	30 – 70
May	225	50 - 100
June	250[2]	50 - 100
July	225[2]	50 - 100
August	175[2]	50 - 100
September	150[2]	30 – 70

[1] Entitlement is equal to 50 cfs or the natural flow of the Merced River (inflow to Lake McClure), whichever is less.
[2] If the natural flow of the Merced River falls below 1,200 cfs in the month of June, the entitlement flows are reduced accordingly from that day: 225 cfs flow for next 31 days; 175 cfs flow for next 31 days; 150 cfs for next 30 days; 50 cfs for remainder of September.
[3] Measured at Merced ID westerly boundary

Merced ID Main Canal and Northside Canal Diversions

Merced ID's Main Canal and Northside Canal are the primary water supply conveyance facilities off the Merced River for Merced ID operations. Data on historical diversions and seasonal patterns are provided in a subsequent section of this report.

Vernalis Adaptive Management Plan and San Joaquin River Agreement

Merced ID is a signatory to the San Joaquin River Agreement (SJRA) dated February 1998 which, among other things, implements the Vernalis Adaptive Management Plan (VAMP). The SJRA was developed as an alternative that provides a level of protection equivalent to the San Joaquin River flow objectives contained in the State Water Resources Control Board (SWRCB) 1995 Water Quality Control Plan for the Delta (URS 2001). Under the VAMP, effects of flow and export from the Sacramento/San Joaquin River Delta upon salmon are investigated. The first year of full implementation of VAMP occurred in 2000 (SJRA 2000). As part of that agreement, increased flows in the spring and fall are provided in the Merced, Tuolumne, and Stanislaus Rivers, up to 50 percent of which is supplied by Merced ID. Such flows are provided during an April/May pulse flow. The SJRA specifies the quantity of water from the Project that will be dedicated to meeting the flow needs for VAMP. The SJRA contains two flow components applicable to the Merced River: 1) It provides for Merced ID to sell 12,500 acre-feet above existing flow releases for Chinook salmon during October of all years, and 2) provides for Merced ID to meet a portion of the April/May VAMP flow target under a Division Agreement among San Joaquin River Group Authority (SJRGA) members (discussed below). A Final Environmental Impact Statement/Environmental Impact Report (FEIS/EIR) for "Meeting Flow Objectives for the San Joaquin River Agreement (1999-2010)" was completed on January 28, 1999 (EA 1999). This FEIS/EIR concluded that meeting flow objectives for VAMP through partial use of the Project would result in less-than-significant impacts to anadromous salmonids in the Merced River and will result in beneficial effects.

The reference gage for additional water released downstream of Crocker-Huffman Dam for fishery purposes is the U.S. Geologic Survey/Merced ID gage at Shaffer Bridge. In the event that the annual schedule at any time exceeds 220 cubic feet per second, the CDWR Cressey gage is used (CDFG/Merced ID 2002).

Division Agreement. Pursuant to the SJRA, the SJRGA members[1] (with the exception of Friant Water Users) have agreed to meet specified Vernalis flow requirements for Delta protection and to complete studies over a 12-year period, which requirements were adopted by the SWRCB in Water Right Decision 1641 revised March 15, 2000, in accordance with Order WR-2000-02. The SJRGA executed a Division Agreement dated June 12, 1998 which assigns to each SJRGA member some responsibility for specified target flows at Vernalis on the San Joaquin River (Table 5). Merced ID's responsibility ranges between 50% and 100% of such flows. These specified target flows are provided in the Merced River during the 31-day, April/May, pulse flow period in a manner that: (a) facilitates the studies defined in a CDFG/Merced ID Memorandum of Understanding; and (b) are timed for arrival at Vernalis pursuant to the requirements of the SJRA.

Table 5. Water allocation (in acre-feet) specified in the Division Agreement among water district members within the San Joaquin River Group Authority for use in the Vernalis Adaptive Management Plan.

Priority in Descending Order	First 50,000	Next 23,000	Next 17,000	Next 20,000	Totals
Merced ID	25,000	11,500	8,500	10,000	55,000
Oakdale ID/ South San Joaquin ID	10,000	4,600	3,400	4,000	22,000
Exchange Contractors	5,000	2,300	1,700	2,000	11,000
Modesto ID/Turlock ID	10,000	4,600	3,400	4,000	22,000

[1] As used in the Division Agreement, the SJRGA is a joint powers authority consisting of Merced ID, Modesto ID, Oakland ID, Turlock ID, South San Joaquin ID, San Joaquin River Exchange Contractors Water Authority, and the Friant Water Users Authority.

From approximately February 10th through April 15th of each year of the VAMP, the Hydrology Group of the San Joaquin River Technical Committee meet to determine the volumes of water required to meet the VAMP flows. This volume of water is then used to specify which SJRGA member provides flows to VAMP and the amount of water provided according to the allocation given in Table 5. The SJRGA can provide up to a maximum of 110,000 acre-feet of water annually and can be paid $4 million dollars annually[2] that can be used for construction of projects to make water available for VAMP, increasing funding for habitat restoration and monitoring, and to administer the Division Agreement (from SJRGA 1998).

Supplemental Water above the 110,000 Acre-Feet. Because of the potential need for up to 47,000 acre-feet of water in addition to the 110,000 acre-feet identified in the SJRA for the VAMP April/May pulse flow period in water years 2001 through 2010, a Final Supplemental Environmental Impact Statement/Environmental Impact Report (FSEIS/EIR) was completed on March 13, 2001 (URS 2001). The additional water may be needed to support flows identified for VAMP by providing flows at Vernalis, and to assist the U.S. Bureau of Reclamation (USBR) in meeting the AFRP, Bay-Delta flow objectives as required by SWRCB Water Right Decision 1641, and the USFWS 1995 Biological Opinion on Delta Smelt (USFWS 1995b) (URS 2001). The FEIS/EIR for the 110,000 acre-feet of water noted: "If achieving the double-step requires more than the 110,000 acre-feet of supplemental water, additional water from willing sellers on the San Joaquin, Stanislaus, Tuolumne, and Merced rivers (approximately 50,000 acre-feet) may be acquired by Reclamation for the pulse flow period, and it would require additional [National Environmental Policy Act/California Environmental Quality Act] NEPA/CEQA analysis". Therefore, the FSEIS/EIR was prepared to provide the required environmental documentation for the acquisition of additional water (URS 2001). As with the FEIS/EIR, the FSEIS/EIR concluded that the supplemental water would result in less-than-significant impacts to Chinook salmon in the Merced River and be beneficial to the species (URS 2001).

Merced River Adaptive Management Plan (MRAMP)

In the event that the SJRA is terminated before its expiration as approved by the SWRCB, Merced ID will continue to provide supplemental interim spring flows at such times and in such quantities as are set forth in the Merced River Adaptive Management Plan (MRAMP) agreement between Merced ID, CDFG, CDWR and USBR. The MRAMP will have no effect unless the SJRA is terminated prior to the SWRCB approved expiration date of the SJRA.

Additional 12,500 Acre-Feet October Flows

As part of the 2002 Memorandum of Understanding between Merced ID and CDFG (CDFG/Merced ID MOU) and pursuant to the SJRA, Merced ID agreed to provide additional flows (12,500 acre-feet) above the existing instream flows described above during October every year. The increased October flow each year continues beyond the expiration of VAMP. The

[2] As escalated by the provisions of the SJRA.

following describes how the timing for that additional flow is determined:

Each year CDFG develops a flow schedule for the augmentation of Merced River flow in the month of October of not less than 12,500 acre feet. That schedule is developed and delivered to Merced ID not later than August 15th each year. If CDFG and Merced ID fail to agree on the flow schedule by September 15th of any year, the schedule for delivery of supplemental water is as follows:

October 1-15 2500 acre feet
October 16-31 5000 acre feet
October 7-31 5000 acre feet

In the event that CDFG and Merced ID fail to agree on a pulse flow schedule, the default is level flow of 2500 acre feet between October 10 and 15 inclusive, and 2500 acre feet between October 16 and 20, inclusive (CDFG/Merced ID 2002).

Merced Water Supply Plan

Merced ID recently completed an update of a 1995 study known as the Merced Water Supply Plan (MWSP), a cooperative regional conjunctive use water master plan which was being jointly conducted with the City of Merced and the University of California, Merced. The goal of this study is to identify all sources of water within the study area (the area generally includes all of Merced County east of the San Joaquin River channel not otherwise contained in another water agency), to identify and meet water needs of the same area through the year 2040, which includes balancing the groundwater at 1999 levels. The study contemplates additional water for instream uses, as well as additional uses of applied water. CDFG participated in the early phases of the study as a Technical Committee member. The MWSP has, in addition to conservation and operational improvements, identified the potential diversion of above normal Merced River flows for off stream groundwater storage as a part of a conjunctive use program, as a means to achieve a balanced regional water budget while at the same time providing a larger, more predictable flow for instream use over time. (from CDFG/Merced ID MOU 2002).

Anadromous Salmonid Life History and Habitat Characteristics

The potential anadromous salmonid habitats in Crocker-Huffman Reservoir are a function of the seasonal presence of each freshwater life phase in the river system. Salmonid habitat needs vary with season and life stage (Bjornn and Reiser 1991). The specific habitat needs and the anticipated seasonal timing of each life stage are integral to evaluating availability of potential habitats in the reach upstream of the dam. The following are Chinook salmon and steelhead life history and freshwater habitat characteristics.

Chinook Salmon

Chinook salmon spend 1-1/2 to 5 years rearing in the ocean before returning to their natal stream or river to spawn. The life span and spawning migration timing are primarily genetically controlled (Vogel and Marine 1991). The basic components of salmonid spawning behavior are similar for most salmonids that spawn in streams (Tautz and Groot 1975). Salmonids select sites in the stream or river where suitable water velocities, depth, and substrate are present. To reproduce, female salmon lays eggs in river gravel beds with water depths and velocities sufficient for spawning activities and egg incubation. The eggs are deposited in uncompacted river gravels ranging in size from about 1 to 6 inches in diameter in a nest called a redd; optimal egg survival occurs when the largest fraction of the redd is composed of smaller-sized gravels. Sites selected by salmonids for redd construction are generally located just upstream of riffle crests (Lisle 1989). Redds may be constructed in shallow riffle areas 0.5 to 2 feet deep to deep runs or glides 5 to over 20 feet deep (Vogel and Marine 1991). High water velocities are necessary to provide inducement to spawning salmon and sufficient interstitial flow through salmon redds for egg incubation (Vogel 1983). Water velocities where redds are constructed are usually 1.5 to 2.5 feet per second (ft/s) just above the river bed. Bell (1991) indicated the average spawning velocities should be 1&1/2 feet/second. Flosi *et al*. (1998) describe the criteria as 1 to 3 ft/s. Chinook salmon exhibit low preferences for water velocities less than 1 ft/s or more than 3 ft/s during spawning activities (Vogel 1982).

Briggs (1953) has described in detail how anadromous salmonids construct redds in the river gravels. The female turns on her side and digs vigorously by placing the tail flat against the substrate and suddenly lifting it upward with a powerful muscular contraction. The resultant hydraulic action is strong enough to loosen stones and finer material and to move them several inches upward. This redd-building activity removes fine sediments from the redd prior to spawning (Everest *et al.* 1987). Coarse material is carried downstream a short distance by the current and deposited; fine material is then swept out of the immediate vicinity of the redd. After repeating this process numerous times, a pit is formed, usually oblong in shape with the long axis parallel with the flow. Soon after excavation of the pit, the spawning act takes place when one or more males move along side of the female at the deepest portion of the pit and the gametes are released simultaneously. Once the eggs and milt have been released, the female moves just upstream of the pit and repeats the digging activity which dislodges coarse streambed material back onto the eggs, effectively burying them (Vogel 1989). The process generally continues in a relative upstream direction until several or numerous eggs pockets are buried in the redd. Chinook salmon die upon completion of spawning (Vogel and Marine 1991).

Once laid in the river gravels, eggs and larvae must receive a sufficient supply of oxygenated water of suitable temperature and free from toxic contaminants. After water hardening, the egg capsule allows for the diffusion of oxygen molecules to the embryo but is impervious to water molecules. The delivery rate of oxygen to the egg is a function of intragravel water velocity and the concentration of oxygen (Wickett 1954). Salmon eggs usually hatch in about 40 to 60 days with variability in incubation period controlled by water temperature. Maximum survival of eggs and pre-emergent fry occurs with water temperatures between 40°F and 56°F. Pre-emergent fry remain in the gravels adsorbing the yolk in the yolk sack before emerging from the redd as free-swimming fry, a period lasting approximately 2 to 4 weeks depending on water temperature. Fry seek out shallow near-shore habitats with protective cover and slow current and feed on insects and crustaceans drifting in the current. After growing to a size of approximately 50 to 75 mm in length, juvenile salmon move out into deeper, swifter water but continue to remain near protective cover which reduces predation and minimizes energy expenditure during rearing. Juvenile salmon may migrate downstream at any time from immediately after emergence to after spending over one year in the river. The residence time of juveniles in freshwater depends on a variety of factors including season of emergence, river flow, turbidity, water temperature, and interactions with other species (Vogel and Marine 1991).

The sensitivity and effects of water temperatures vary with life stage (Figure 5).

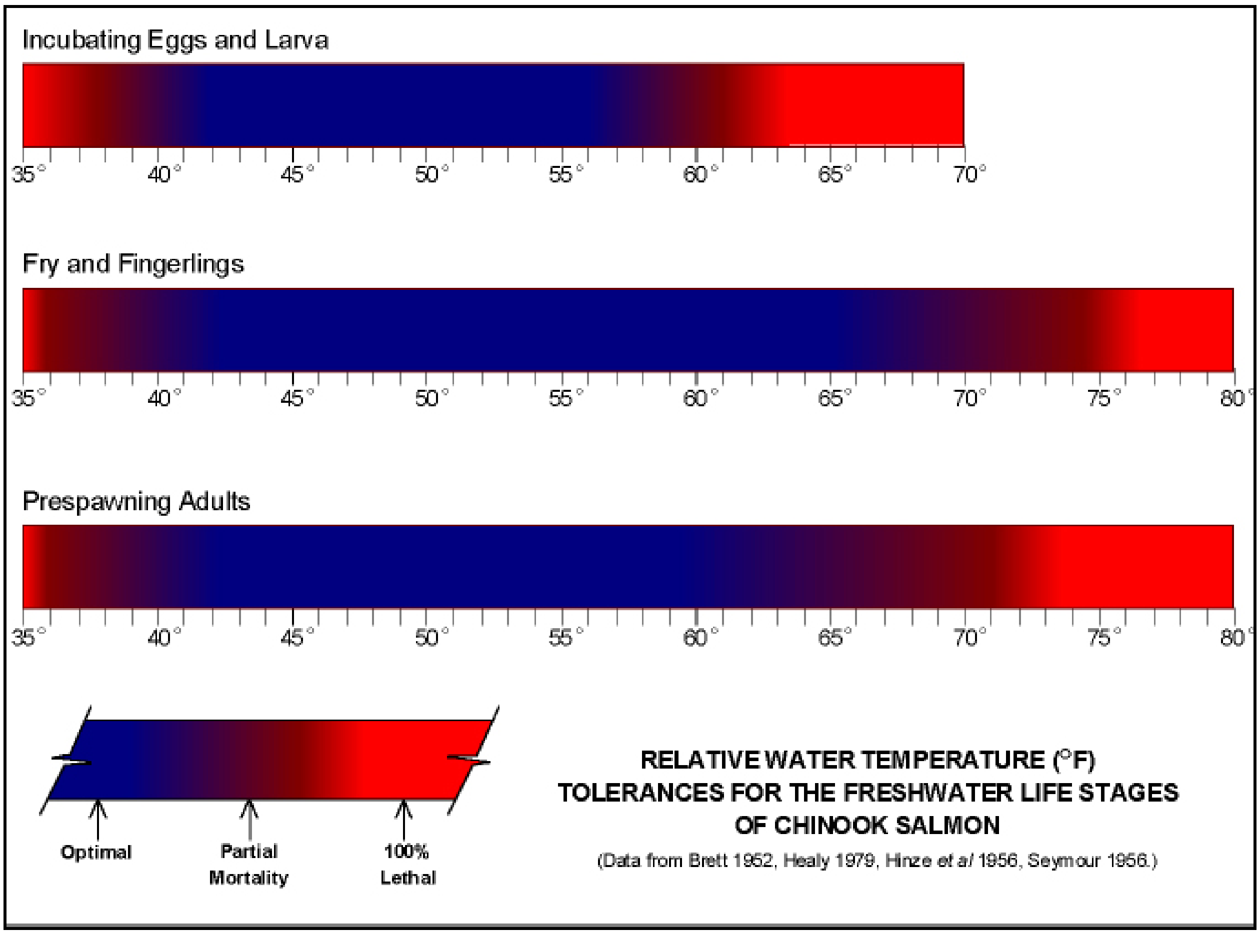


Figure 5. Relative water temperature (°F) tolerances for the freshwater life stages of Chinook salmon. This information was derived from different salmon stocks and represents a composite description for Chinook salmon (from Vogel and Marine 1991).

The life history timing of fall-run salmon in the Merced River is generally characteristic of that for the San Joaquin River basin (Figure 6) (CDFG 1993).

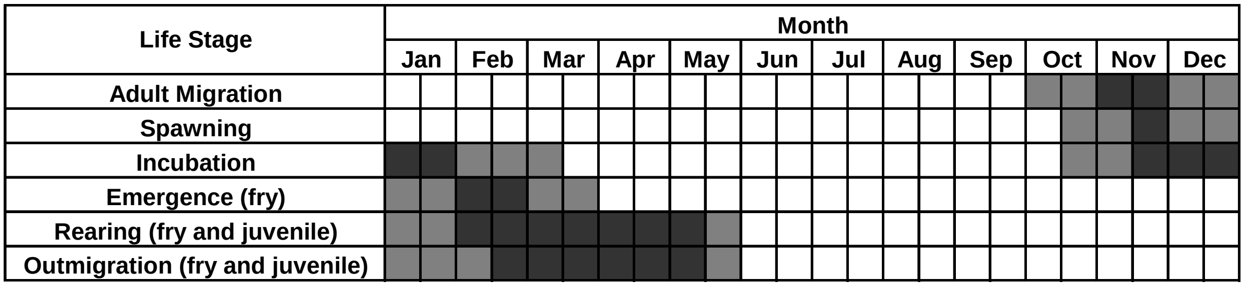


Figure 6. Freshwater life history periodicity for Merced River fall-run Chinook salmon (dark squares denote peak activity (Source: CDFG annual spawning ground surveys and fish trapping by Natural Resource Scientists, Inc.).

Adult Chinook salmon enter the Merced River during mid- to late-October through late December. Spawning activities generally begin in late-October and continue through the end of December with peak activity during mid- to late-November (Figures 7 and 8). Peak spawning periods can vary by one to two weeks between years.

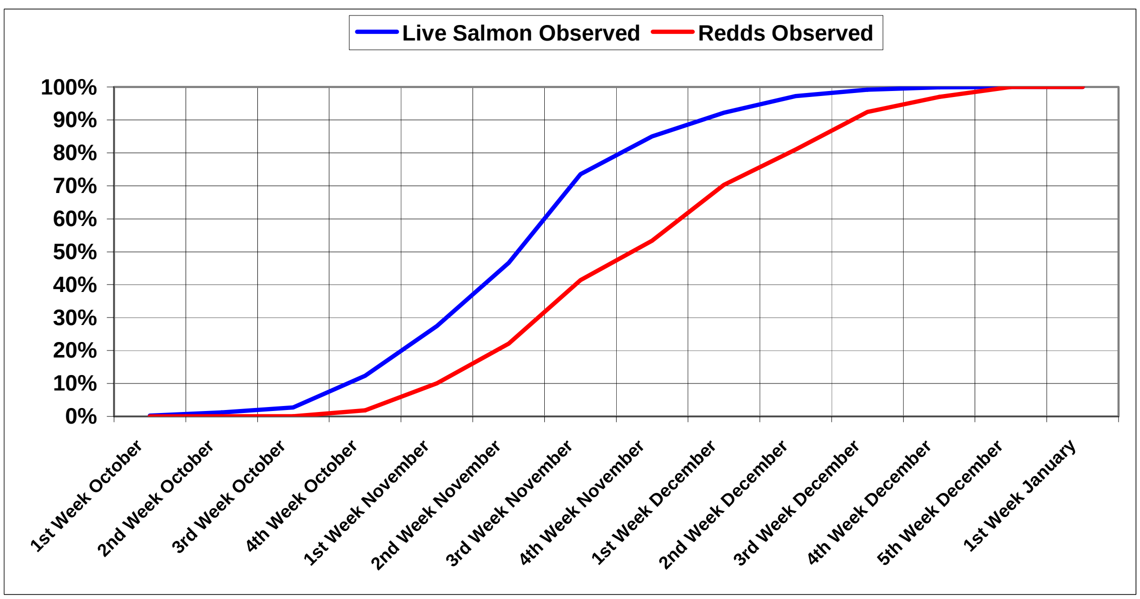


Figure 7. Cumulative percent occurrence of live Chinook salmon and recently-constructed redds observed each week during CDFG annual spawning ground survey in 1999 (Source: CDFG).

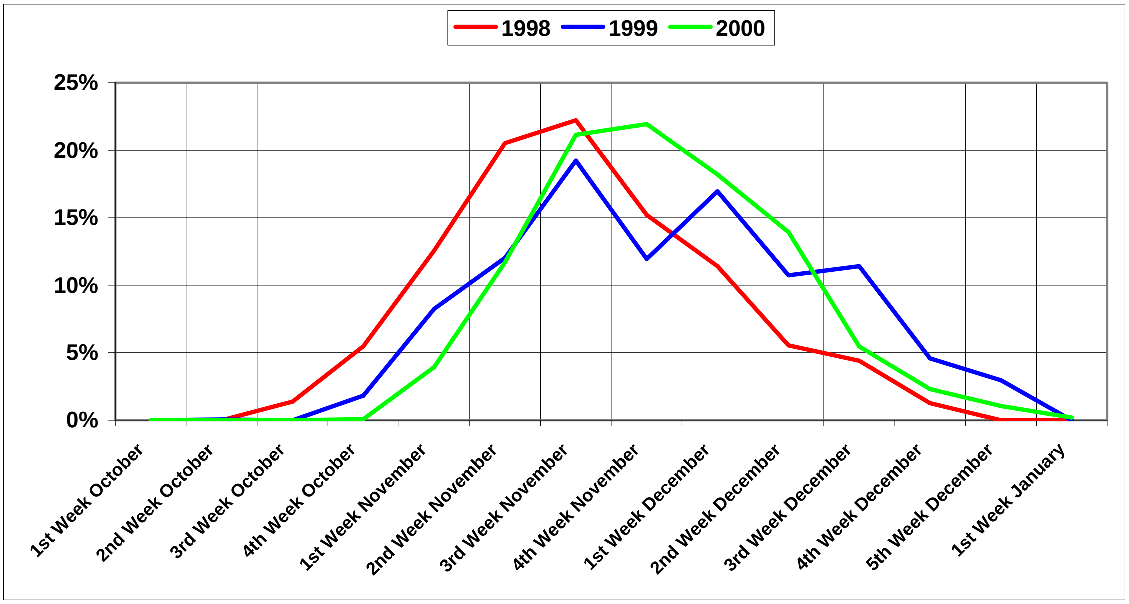


Figure 8. Recently-constructed Chinook salmon redds observed during CDFG's Merced River spawning ground surveys in 1998, 1999, and 2000 (weekly percent of season total) (Source: CDFG)..

Emergence of salmon fry from river gravels in the Merced River usually begins in January and extends through March with peak emergence occurring during February. Fry and juvenile salmon rearing occurs in the Merced River from January through May (Figure 6). Emigration of fry and juveniles from the river can occur during the winter months following storm events which create elevated river flows and high turbidity (fry and parr dispersal) or during April and May when juveniles transform into smolts[3]. The presence of yearling salmon in the Merced River is rare and only occurs during and following very wet hydrologic conditions in the basin causing very high river flows in the lower river during the summer months (Natural Resource Scientists, Inc., unpublished data). The specific timing of natural smolt migration depends on the physiological state of the fish (Vogel 1994a). There are complex morphological, physiological, and behavioral changes associated with the transformation of parr salmon to smolt salmon. The many variables and interactions between variables associated with the migratory behavior of young salmon are complex and not well understood (Kreeger and McNeil 1992). Abiotic factors which may have primary influence on young salmon migration include photoperiod/date, water temperature, and flow. Other abiotic or biotic factors which may affect migration include barometric pressure, turbidity, flooding, rainfall, wind, species, stock, life history stage, degree of smoltification, parental origin (e.g., hatchery or wild), size of juveniles, location (e.g. distance from the ocean), food availability, etc. (Burgner 1991, as cited by Kreeger and McNeil 1992).

[3] EPA (1994) describes a smolt as "... a salmon in the process of acclimating to a change from a fresh water environment to a salt water environment. This occurs when young salmon migrate downstream through the Delta to the ocean.".

Steelhead Life History

The steelhead trout is an anadromous strain of rainbow trout exhibiting a general life cycle similar to Chinook salmon except that not all adults die after spawning and juveniles rear for longer periods in freshwater before migrating to the ocean. Steelhead are important to the Central Valley sport fisheries and their runs are currently highly dependent on hatchery production because of depressed naturally produced populations. Viable naturally produced runs of steelhead are only found in the Sacramento River and some of its tributaries (Mills and Fisher 1994). There is little historical documentation on steelhead distribution in the San Joaquin Basin (McEwan and Jackson 1996). Recent fish trapping in the Stanislaus River indicates that small numbers of steelhead may be present in that tributary. An annual run of steelhead has not been documented in the Merced River although resident rainbow trout are known to reside in the upper reach of the lower Merced River and in its reservoirs; the proportion of these fish that are wild is unknown because the upstream reservoirs are regularly stocked with hatchery trout and some emigration from the reservoirs to the lower river occurs. Freshwater physical habitat needs are similar to Chinook salmon. Spawning habitat for steelhead is similar to that of Chinook salmon except that preferred spawning substrate is usually composed of slightly smaller particle sizes (McEwan and Jackson 1996, Flosi *et al.* 1998).

Specific timing of steelhead migration in the San Joaquin basin is unclear but the upstream migration of steelhead into the Sacramento River occurs from early August through November (Mills and Fisher 1994) and may extend into March in some years (Hallock 1989). Spawning in the Sacramento River basin primarily occurs from January through March (Mills and Fisher 1994), although spawning may occur from late December to April or May (Hallock 1989). Presumably, the life cycle periodicity is generally similar for San Joaquin basin origin steelhead. Spawning, egg incubation, and fry emergence occurs in a manner similar to that previously described for Chinook salmon. Peak emergence of steelhead fry occurs in the late spring or early summer. Unlike Chinook, young steelhead remain in freshwater to rear for one or two years prior to migrating to salt water and adult fish can survive after spawning. A major outmigration of Sacramento River yearling steelhead to the ocean occurs in the spring and a much smaller outmigration occurs in the fall (Hallock 1989). Peak numbers of juvenile steelhead at the south Delta water export facilities (an indication of peak outmigration timing) occur during March and April (USFWS 1995b). Estimated San Joaquin basin steelhead life cycle periodicity as described in the Merced River Corridor Restoration Plan is shown in Figure 9. However, portions of this life cycle would not be reflective for potential steelhead in the Merced River. For example, adult migration into the Merced River would not occur during the summer months because of warm water; a latter migration during the fall and winter could theoretically occur after river water cools to tolerable levels.

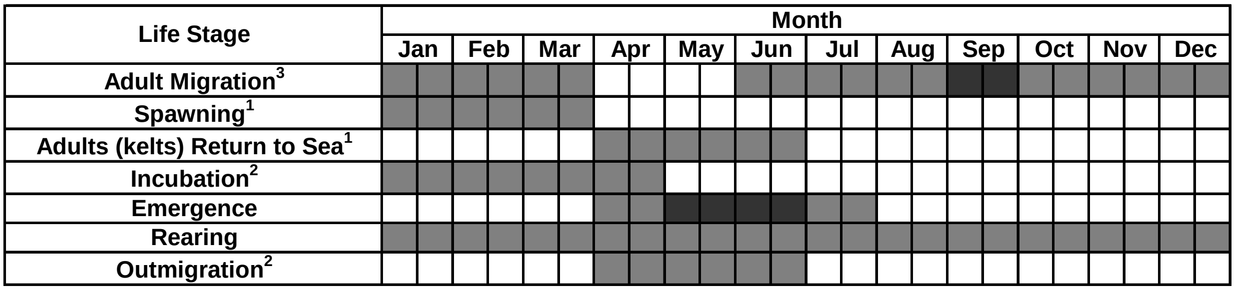


Figure 9. Central Valley winter steelhead life history timing in the San Joaquin Basin [from Stillwater (2002) that used the following sources: Mills and Fisher (1994), Reynolds *et al.* (1993), Hallock *et al.* (1961), and Bailey *et al.* (1954)].

Historical Annual Chinook Salmon Runs

Annual run size estimates for Chinook salmon in the Merced River were initiated in 1954. Total size of annual runs (including hatchery take) have averaged 3,937 salmon with a low of 20 fish in 1963 to a high of 29,749 in 1984 (Figure 10). Note that some salmon spawned at the hatchery during the early years of operation were trapped and transported to the hatchery from out-of-basin locations (e.g., San Joaquin and Stanislaus Rivers).

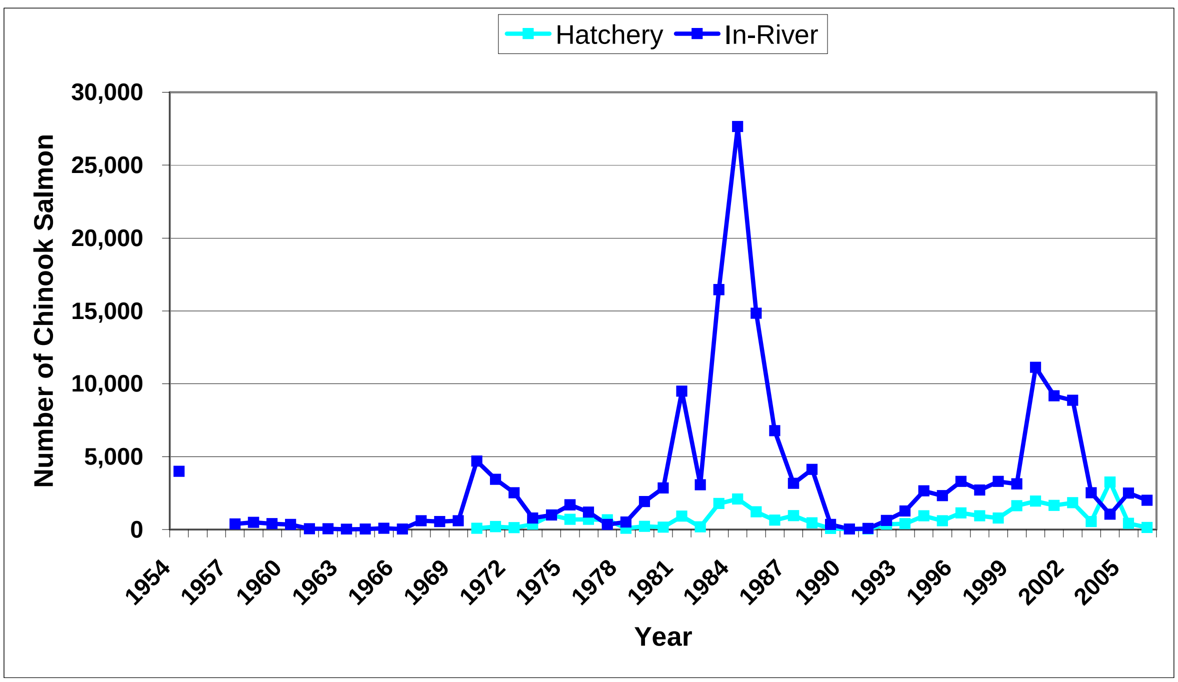


Figure 10. Annual adult Chinook salmon runs to the Merced River, including salmon captured and spawned at Merced Hatchery, 1954 – 2006 (numbers for 2005 and 2006 are preliminary estimates). Source: CDFG's GrandTab, 2007.

Historical Annual Steelhead Runs

An annual steelhead run in the Merced River has not been documented, although steelhead may have been present in the watershed prior to the construction of dams (McEwan 2001).

Characteristics of Crocker-Huffman Reservoir Relevant to Potential Anadromous Salmonid Habitats

Instream Flows

Prior to the construction of dams on the Merced River, the natural flow regime was characterized by low summer and fall base flows, large brief winter peak flows from rain and rain-on-snow events, and extended spring and early summer high flows caused by upper watershed snow melt (Stillwater 2002). Construction of dams on the Merced River have altered hydrologic conditions resulting in reduced frequency of riverbed scour, the river's capacity to transport sediment, and the frequency, duration and magnitude of floodplain inundation (Stillwater 2002). For purposes of this report, recent historical operations of Merced ID's Project are compiled after completion of New Exchequer Dam. Because New Exchequer Dam altered the flow regime of the Merced River (Figure 11), prior years are not relevant for this report. Construction and operation of New Exchequer Dam has, on average, reduced winter and spring flows and increased summer and fall flows in the Merced River downstream of Merced Falls Dam and through most of Crocker-Huffman Reservoir (Figure 11) compared to pre-dam conditions (Vogel 2003). Flows downstream of Crocker-Huffman Dam during summer and early fall are similar to or exceed unregulated flows into Lake McClure (Stillwater 2002).

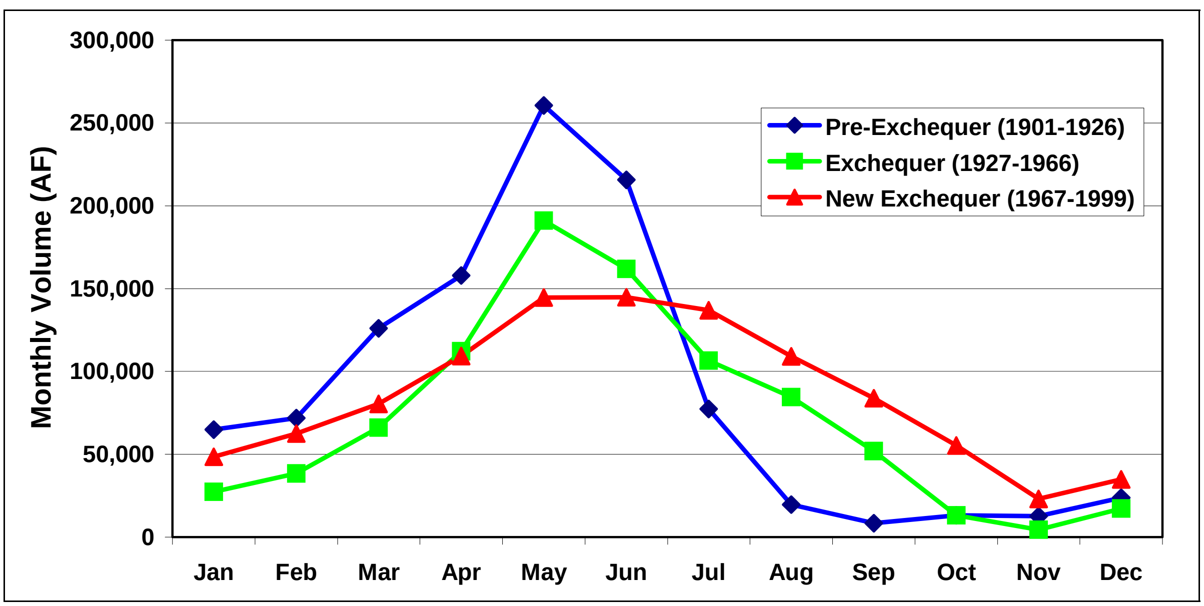


Figure 11. Historical monthly average flow (acre-feet) downstream of Merced Falls Dam prior to the construction of Exchequer Dam, during Exchequer Dam operations, and after construction of New Exchequer Dam.

Figure 12 shows the average monthly diversions into Merced ID's Main Canal off Crocker-Huffman Reservoir for the period 1970 through 2006. The largest annual volume diverted into the Main Canal occurred during 1984 (an above normal water year) and the lowest occurred during 1977 (a severe drought year); the monthly diversions for those years are also provided in Figure 12. The seasonal diversion of water into the Main Canal results in high flows through most of Crocker-Huffman Reservoir during the spring, summer, and early fall months.

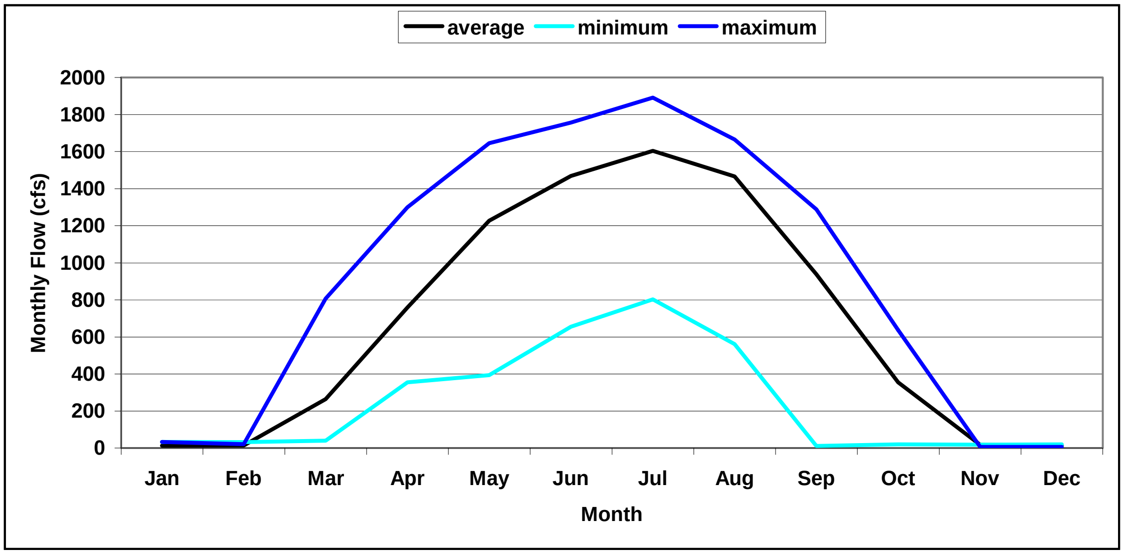


Figure 12. Historical monthly water diversions into Merced ID's Main Canal (average 1970 – 2006, minimum in 1977, maximum in 1984).

Merced ID's North Canal diverts water from the Merced River upstream of Merced Falls Dam and, therefore, those historical data are not provided here.

The seasonal effect of water conveyance through Crocker-Huffman Reservoir into Merced ID's Main Canal is reflected, in part, with average daily flow data provided in Figures 13 - 16. Four recent years in which comparable average daily flows were available at stream gauging stations just downstream of Merced Falls Dam and the Merced ID gauge downstream of Crocker-Huffman Dam were plotted to show how river flows vary between sites. The four water years examined were 2000, 2001, 2005, and 2006 with corresponding hydrologic water year designations of above normal, dry, wet, and wet, respectively. The daily flows measured just downstream of Merced Falls Dam are reflective of the flow through most of Crocker-Huffman Reservoir down to Merced ID's Main Canal (a distance of approximately 14,600 feet or 92% of the length of the reservoir). Flow through the remaining distance of 1,250 feet from the Main Canal to the dam goes to two hatcheries, instream flow for the lower Merced River, and downstream diversions. The large differences in flow evident during the spring, summer, and early fall are attributable to the large diversion into Merced ID's Main Canal during the irrigation season. During the non-irrigation season, the base flows entering Crocker-Huffman

Reservoir are similar to base flows in the Merced River downstream of Crocker-Huffman Dam. Therefore, if anadromous salmonids were reintroduced upstream of Crocker-Huffman Dam, the fish would experience a similar flow regime as those fish spawning in a relatively short distance downstream of the dam. The exception would be riverine conditions further downstream subject to accretions from precipitation where river flows would be higher.

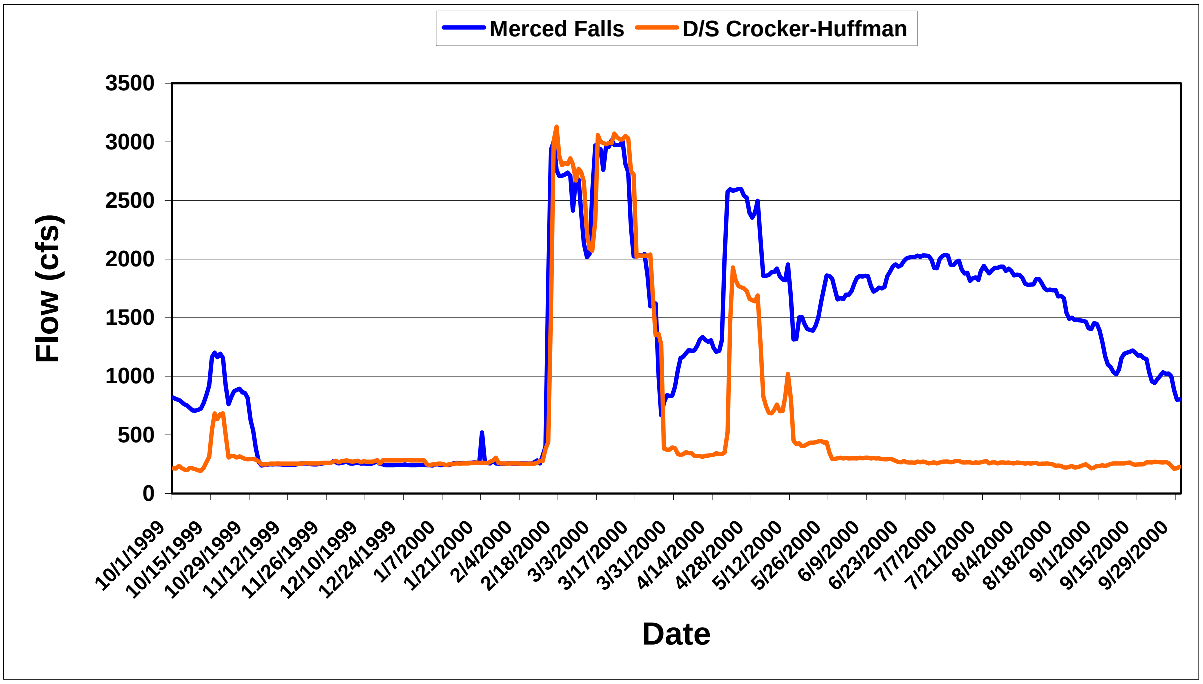


Figure 13. Average Merced River daily flows downstream of Merced Fall dam and downstream of Crocker-Huffman Dam, water year 2000 (above normal hydrologic conditions).

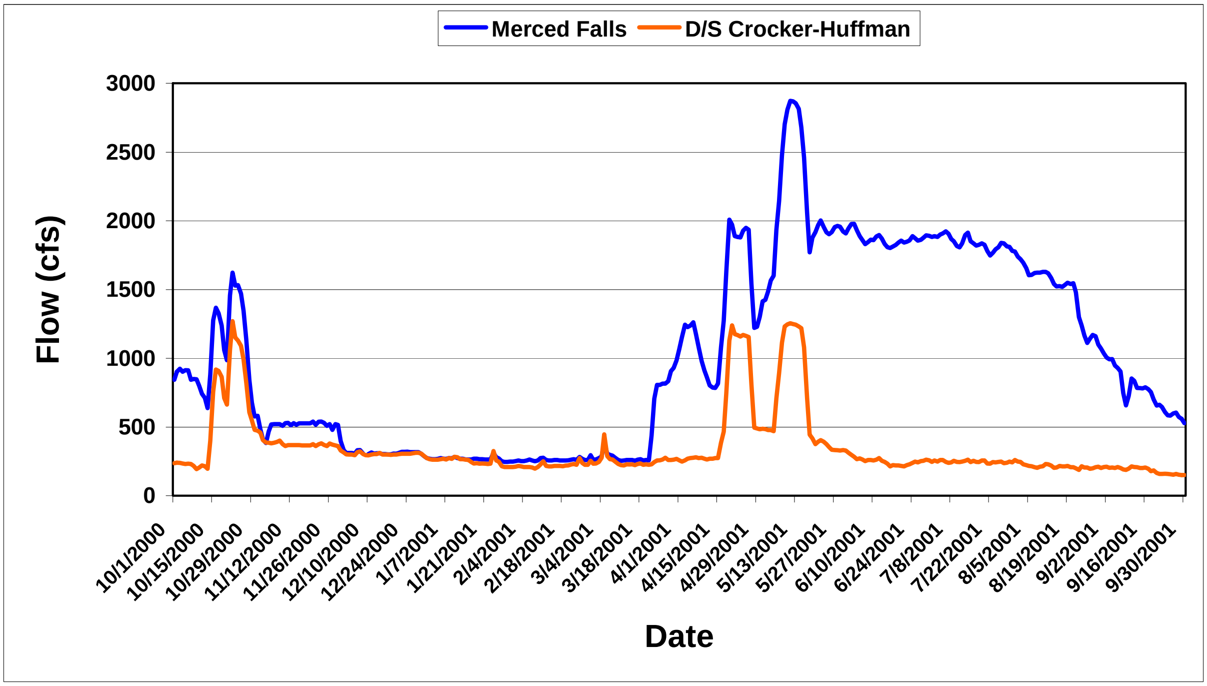


Figure 14. Average Merced River daily flows downstream of Merced Fall dam and downstream of Crocker-Huffman Dam, water year 2001 (provisional data) (dry hydrologic conditions).

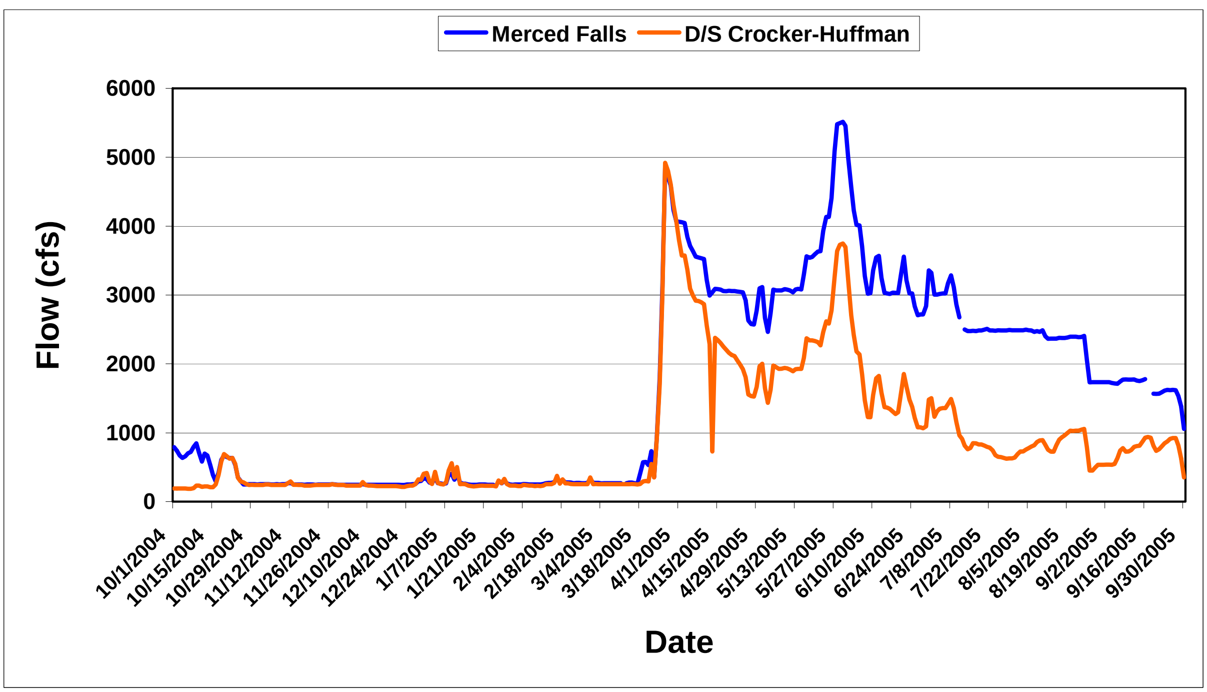


Figure 15. Average Merced River daily flows downstream of Merced Fall dam and downstream of Crocker-Huffman Dam, water year 2005 (provisional data) (wet hydrologic conditions).

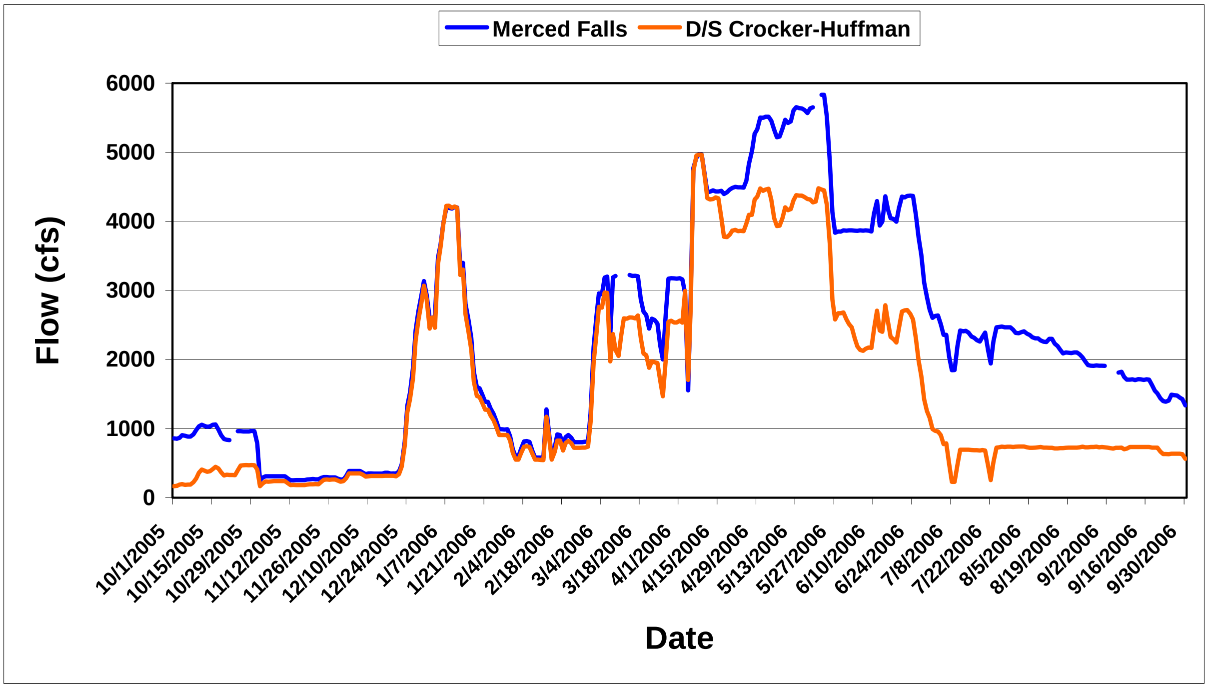


Figure 16. Average Merced River daily flows downstream of Merced Fall dam and downstream of Crocker-Huffman Dam, water year 2006 (provisional data) (wet hydrologic conditions).

If anadromous salmonids were reintroduced upstream of Crocker-Huffman Dam, fish would experience a different seasonal flow regime than fish spawning and rearing downstream of the dam during the spring, summer, and early fall.

In the Merced River, young salmonids have to "voluntarily" migrate out of the stream during the winter or spring months before instream conditions become hostile from warm water conditions naturally occurring in the lower Merced River during the summer months. The timing for downstream migration would be influenced by factors such as time of egg deposition, water temperatures during egg incubation, water temperatures during juvenile rearing, stream flows, turbidity, food supply, and other factors previously discussed. It can be expected that the period of downstream migration would be considerably protracted. For the Merced River, the period can extend from January and February (fry dispersal) to May (smolt outmigration).

Interannual variation in rearing duration and downstream dispersal migrations or emigration of Chinook salmon fry and smolts is of potential importance to management as it appears to be associated with variance in water year hydrology for many stocks of Chinook salmon (Healey 1991, Kjelson *et al.* 1982, Vogel *et al.* 1988, Vogel and Marine 1991). For example, greater fry emigration, or dispersal to downstream riverine or estuarine habitats, appears to occur as an alternative life history strategy for fall Chinook salmon during wet water years in the Sacramento-San Joaquin River system. And, alternatively, upriver rearing to smolt size with subsequent smolt emigrations predominate during drier water years (Kjelson *et al.* 1982, Vogel *et al.* 1988).

The implications of re-introducing anadromous salmonids upstream of Crocker-Huffman Dam is that young fish must emigrate from the river by the end of May before water temperatures become lethal in the lower Merced River and San Joaquin River or remain in Crocker-Huffman Reservoir to rear over the summer and fall months, then emigrate the following year in the winter or spring as yearling salmonids. The yearling life phase of fall-run Chinook salmon in the Central Valley is unusual because the vast majority of emigration throughout the rivers and streams occurs as sub-yearlings. However, young steelhead typically remain in freshwater rearing for one or two years prior to emigration. Presumably, steelhead could benefit from the oversummer flow regime between Crocker-Huffman and Merced Falls dams.

Water Temperatures

Dam construction has altered the flow and water temperature regime in river reaches downstream of the four mainstem dams on the Merced River. These alterations have changed the river's natural ecological processes and affected the habitat available for salmonids. Although water released into the Merced River is released from the hypolimnion at the bottom of Lake McClure, complex hydraulics and thermodynamics in the three downstream reservoirs from New Exchequer Dam significantly affect the ultimate water temperature regime in the salmon spawning and rearing reach of the lower Merced River.

Elevated water temperature, particularly during the early fall and late spring months, has been identified among a set of factors as one principal factor that can limit fall-run Chinook salmon production in the lower Merced River and at Merced Hatchery (CDFG 1993, USFWS 1995a, USBR 1997, NMFS 1998, CALFED 1999a, CALFED 1999b). If river temperatures are too warm, salmon growth and smoltification as well as vulnerability to predation may be negatively affected. However, constraining temperatures too much or cooling long reaches of the river may restrict growth or limit access to relatively warmer conditions for older, more-tolerant juvenile salmon. Size of outmigrant salmon smolts has been implicated in survival and seawater tolerance.

Stream temperatures in some portions of the spawning reach and at Merced Hatchery downstream of Crocker-Huffman Dam can exceed widely recognized temperature tolerances for salmon spawning and egg incubation in October and early November. Elevated water temperatures in the lower Merced River may result in delayed salmon spawning, decreased egg survival, and increased juvenile mortality. Elevated water temperature can affect spawning migration rates, alter the incidence of disease, and delay or accelerate spawning to the detriment of reproductive performance (Marine 1993). In recent drought years, salmon have not spawned until after the first week in November, when water temperatures have cooled, through the effect of reduced day length and concomitant decreased insolation, as well as declining ambient air temperatures, to suitable levels for egg incubation. In more-recent wet years, spawning occurred in October. In late April and May, water temperature often exceeds recognized stressful levels for emigrating smolts. Elevated springtime temperatures are a more frequent and significant problem on the lower Merced River than other Chinook salmon streams, even in the San Joaquin River basin, because of its most southerly latitude in the range of Chinook salmon and consequent higher air temperatures. In these circumstances, salmon have to spawn later and leave the system earlier to be successful. This "compresses" the life cycle into a shorter period and is likely to reduce the level of success fish have in reproducing, as well as reduce diversity in the overall population to only those fish that are successful in following that pattern. To ensure a more robust population it would be valuable to sustain an environment that provided a longer "window" to spawn, incubate, rear, and leave the system, particularly during drought years.

Provision of suitable water temperatures in the Merced River, partially a function of reservoir operations, may be affected by various demands on water supplies including ecosystem management flows such as the previously discussed Vernalis Adaptive Management Plan. Reservoir storage levels, dam operations, and water discharge volumes have important interactive effects on reservoir thermal conditions, and thus directly affect river temperatures along with other environmental conditions such as: solar radiation, air temperatures, riparian shade, accretion volumes and temperatures, depletion or diversions, channel width and depth, wind, humidity, and ground conduction. Identification of effective temperature management measures and complementary restoration actions for the Merced River corridor will require a suite of analytical tools to discern the differential effects of these interactive factors affecting water temperature in the reservoir-river system. Such analytic tools would also help to resolve uncertainties associated with predicting effects of these interactions on potential temperature management measures.

Unlike other large Central Valley reservoirs that are relatively easy to model and control water temperatures in downstream salmon reaches (e.g., Shasta Reservoir), the three re-regulating reservoirs downstream of Lake McClure significantly increase the complexity for controlling and managing water temperatures to benefit salmon in the Merced River. CALFED recently funded the development of a San Joaquin basin water temperature model, including the Merced River. This water temperature model was not complete and therefore unavailable for purposes of this report.

Sufficient cold-water instream flows are necessary to attract salmonids into tributaries prior to spawning activities. For streams, such as the Merced River, these conditions are usually not present until fall when ambient air temperatures cool the river water down to acceptable levels for salmon. Water temperatures should be in the range shown in Figure 5.

A general rule is that salmon require approximately one-half foot of flowing water, at a minimum, for passage over riffles. An established run of salmonids into a river, such as Merced River, explicitly requires that the returning spawning fish were originally hatched in the river several years prior to homing on their natal river upon return. However, it is commonly known that salmon often stray into non-natal areas.

Data were compiled from existing temperature records collected in ongoing river temperature monitoring programs as part of Merced ID and CDFG's fisheries monitoring program and Merced ID's Water Temperature Management Feasibility Study (the latter supported by CALFED in 2000 and funded by the CVPIA AFRP). Data were to be used to assess any temperature limitations based on the biological criteria for anadromous salmonid reproduction.

Lake McClure exhibits strong thermal stratification beginning in the spring and extending through the fall; the winter months of December through February do not show stratification (Figures 17 – 18). Typically, in most months, water released from New Exchequer Dam is cooler than air temperatures and the river water warms in a downstream direction. However, during drought years when Lake McClure is at low levels, substantial warming of the reservoir may occur. For example, during 1992 (a critically dry year), the reservoir reached a minimum elevation of 620 feet (107,000 acre-feet) causing the water released from New Exchequer in the fall to be warmer than the air temperatures and the river temperatures cooled in a downstream direction (Jones and Stokes 1995).

Water temperatures released from the bottom of New Exchequer and McSwain Dams (Figure 2 and 3) are within the thermal tolerances of salmon (Figure 5), except during September to mid-November when excursions may approach lower tolerance levels for egg incubation in some years (Figures 19 – 20). Water released from Crocker-Huffman Reservoir exhibits an extended warming trend during the summer months due, in part, to passage through the reservoir and ambient air conditions. The decline in water temperatures during November follows the seasonal drop on air temperatures during the fall (Figure 21). Figures 22 – 25 show comparisons of average daily water temperatures between New Exchequer, McSwain, and Crocker-Huffman dams for water years 1999 – 2002. Water temperatures downstream of Crocker-Huffman Dam are usually warmer during the late spring to early fall period.

To better characterize thermal characteristics in Crocker-Huffman Reservoir, thermographs were placed immediately downstream of Merced Falls Dam, at the Merced ID Main Canal Intake off of the reservoir, and at Merced Hatchery; data are shown in Figures 26 and 27. During September and early October 2004, water temperatures at the Main Canal intake were slightly (<1^{o}F) warmer than the water released from Merced Falls Dam, but during late fall through the winter, the trend reversed such that the water at the Main Canal intake was slightly (<1^{o}F) cooler than observed at Merced Falls Dam reflecting the effects of seasonal ambient air conditions; in the subsequent spring and summer, the pattern reversed. This temperature pattern was slightly more attenuated at Merced Hatchery except for periods when the thermograph may have been out of the water (Figure 26). In 2006, a very wet year, and reservoir releases were high, water temperatures observed at the Main Canal and the hatchery were very similar until summer when differences were only about ½ ^{o}F to 1^{o}F (Figure 27).

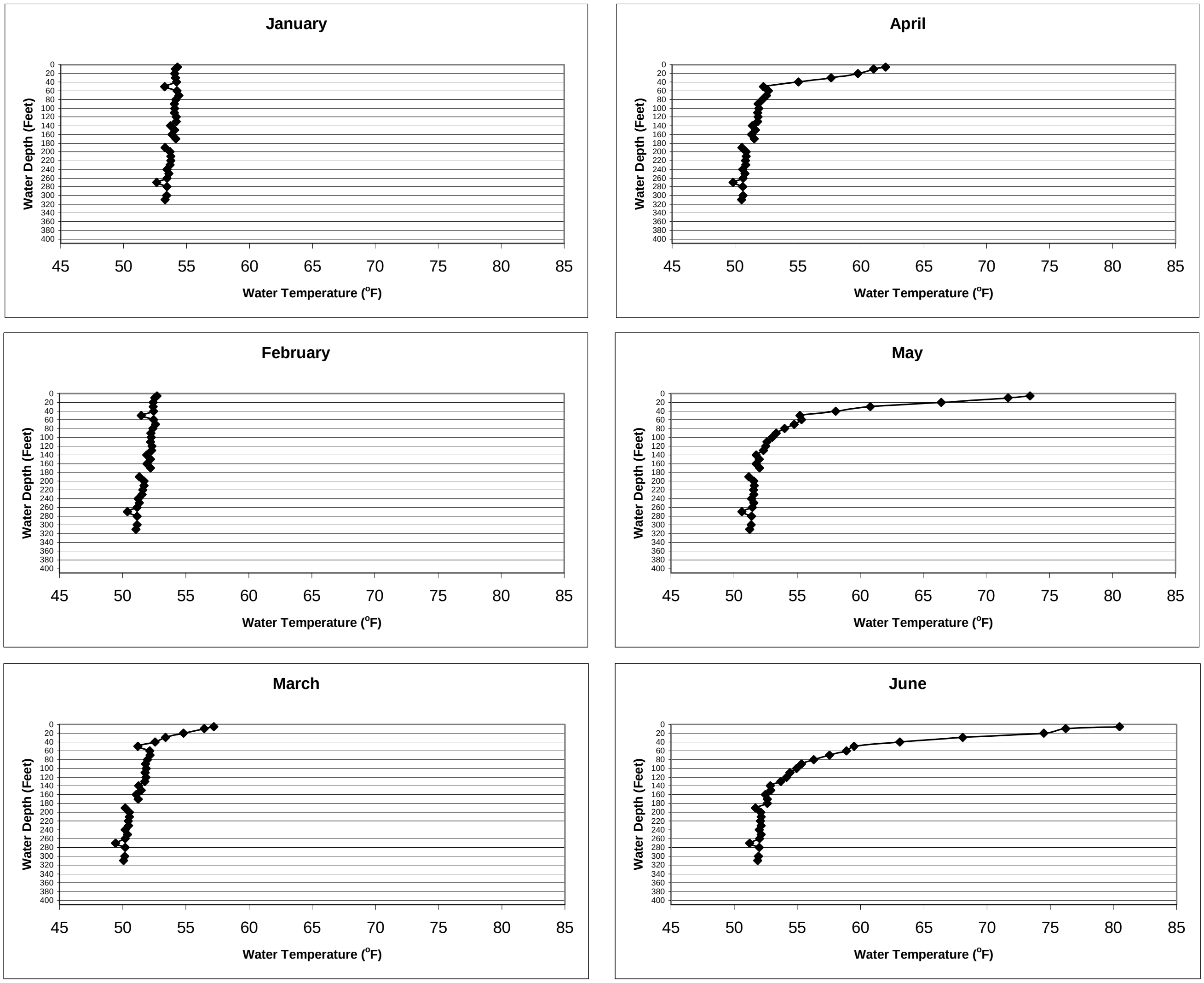


Figure 17. Average monthly water temperatures (°F) and corresponding depths measured upstream of New Exchequer Dam (January – June, 2001).

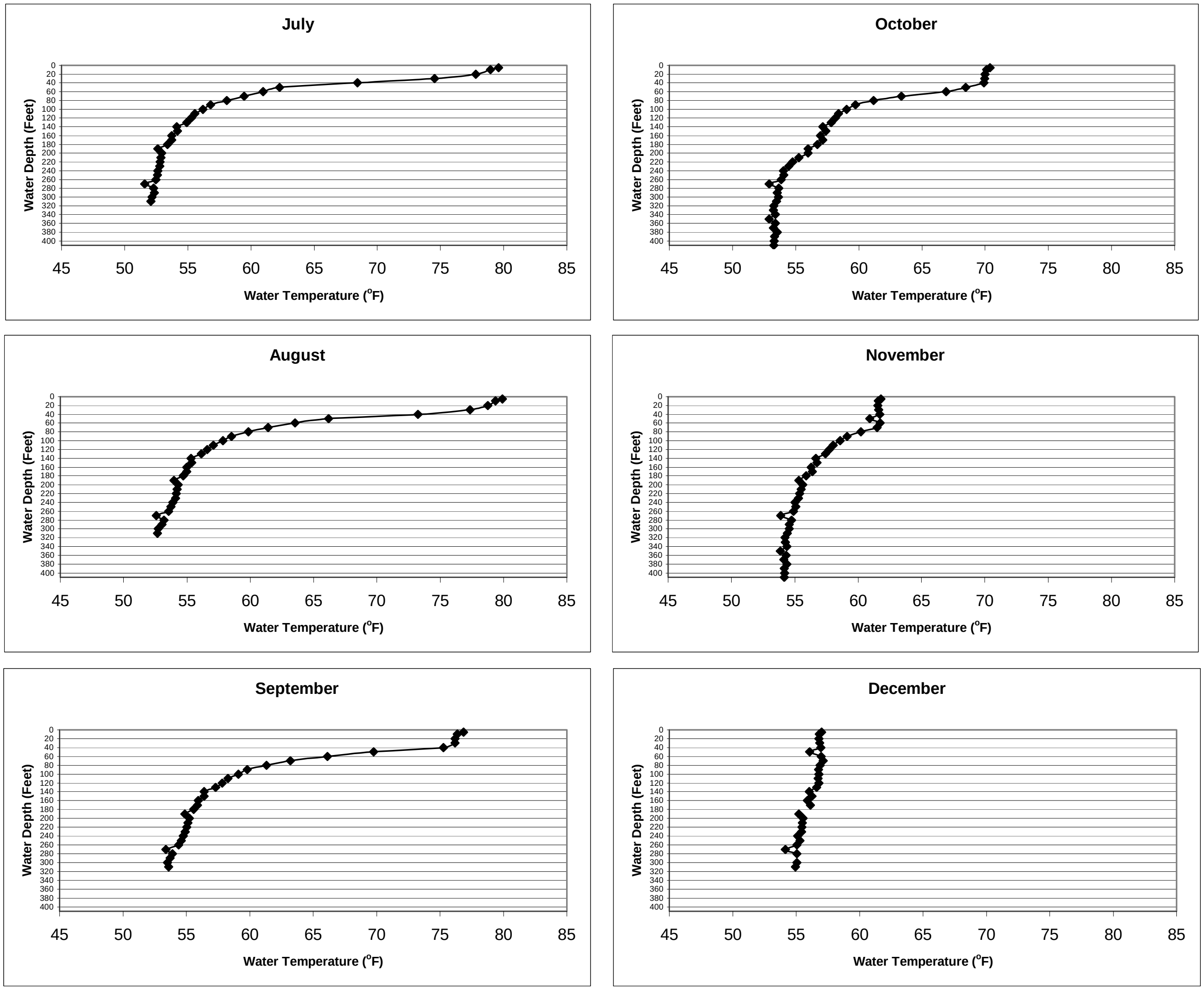


Figure 18. Average monthly water temperatures (°F) and corresponding depths measured upstream of New Exchequer Dam (July - December 2001).

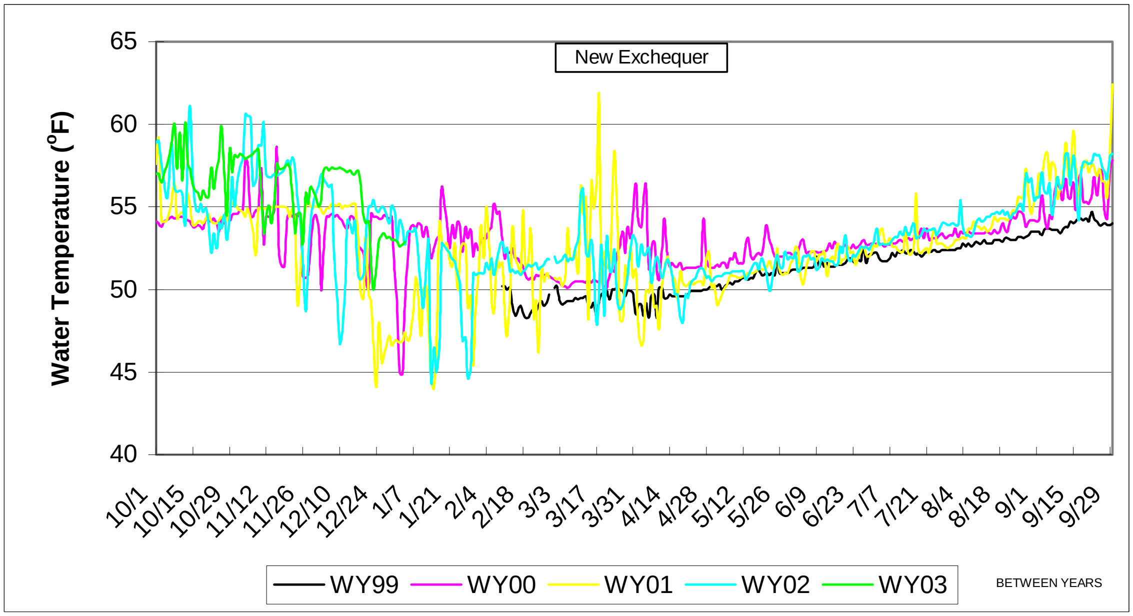


Figure 19. Average daily water temperatures (°F) measured in the Merced River downstream of New Exchequer Dam (water years 1999 – 2003).

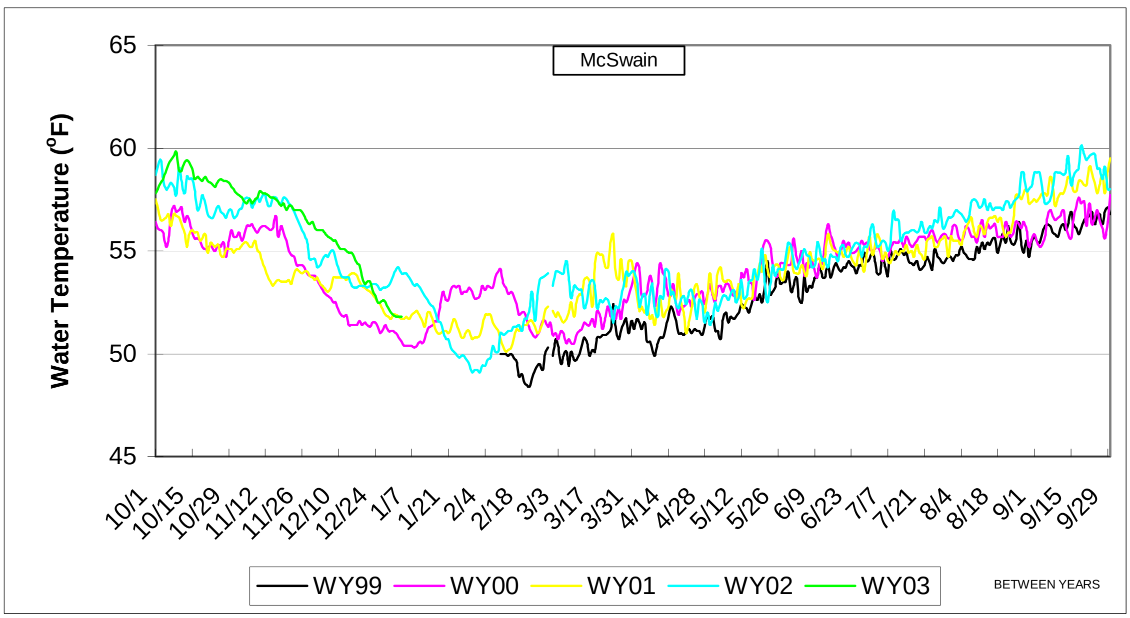


Figure 20. Average daily water temperatures (°F) measured in the Merced River downstream of McSwain Dam (water years 1999 – 2003).

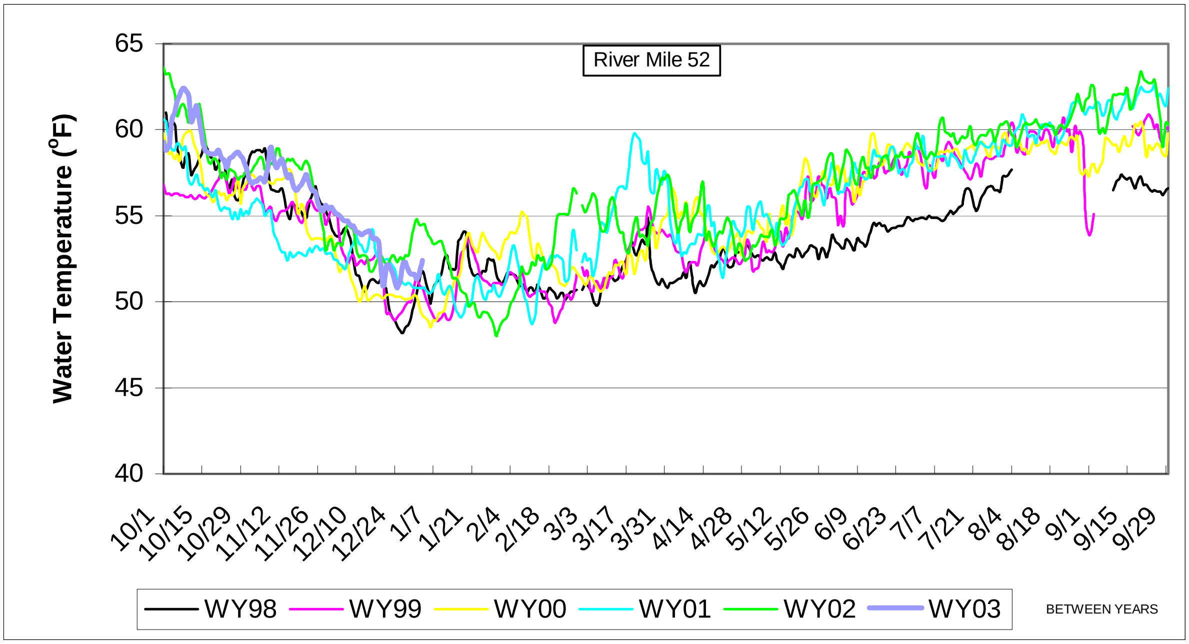


Figure 21. Average daily water temperatures (°F) measured in the Merced River downstream of Crocker-Huffman Dam (water years 1998 – 2003).

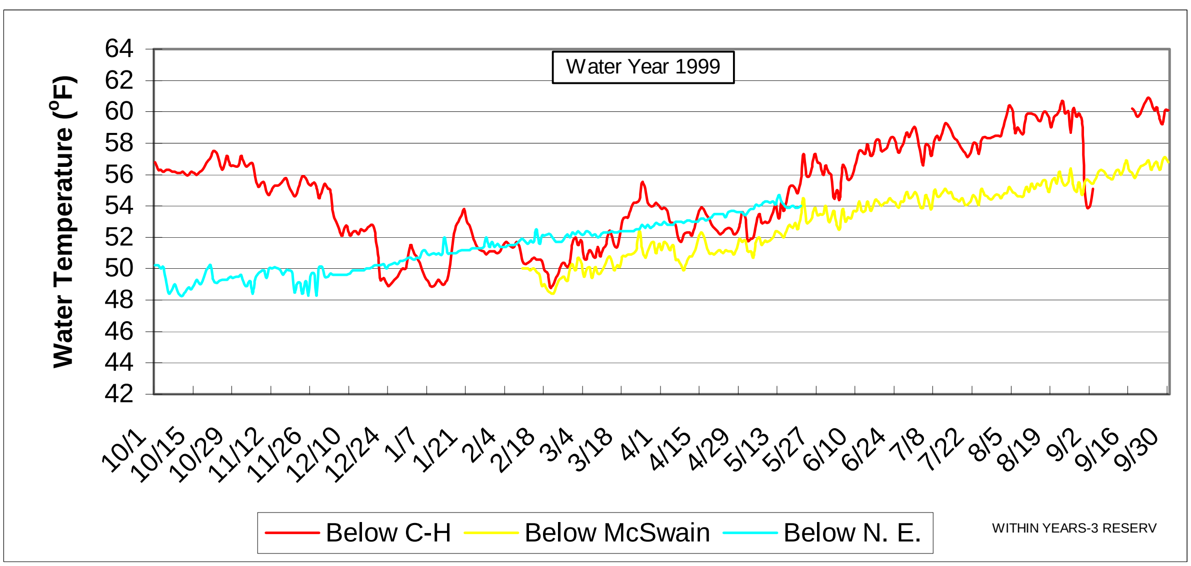


Figure 22. Average daily water temperatures (°F) measured in the Merced River downstream of New Exchequer, McSwain, and Crocker-Huffman dams for water year 1999.

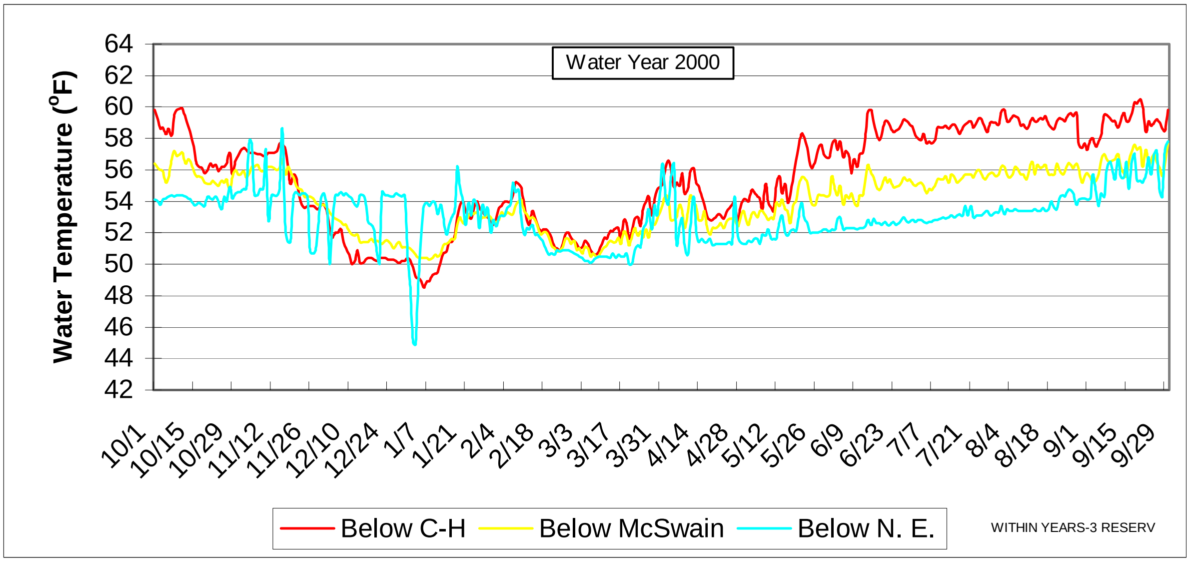


Figure 23. Average daily water temperatures (°F) measured in the Merced River downstream of New Exchequer, McSwain, and Crocker-Huffman dams for water year 2000.

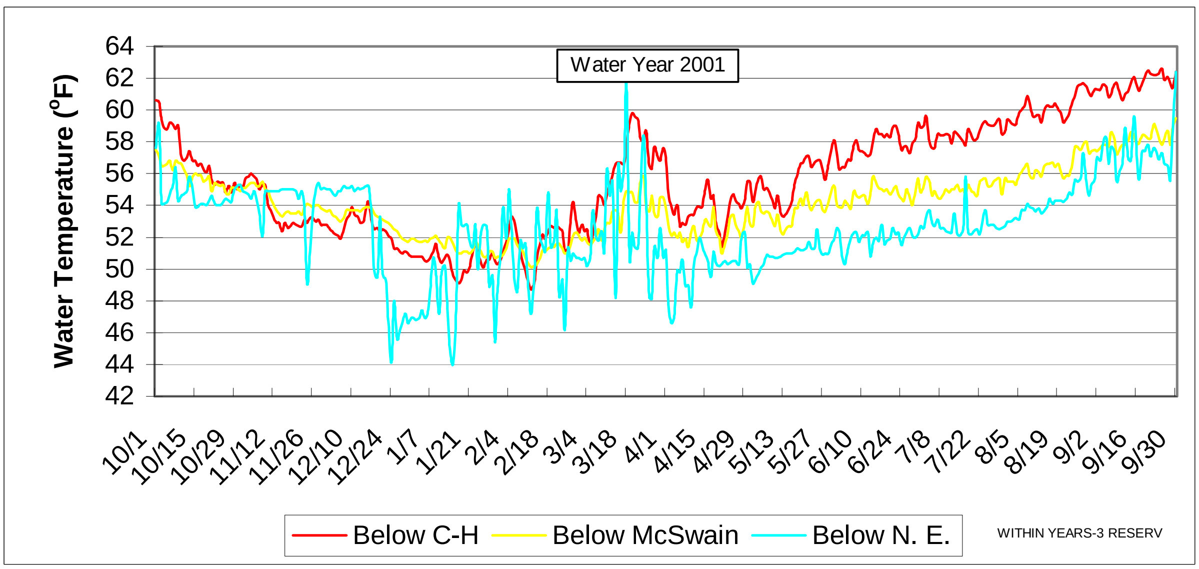


Figure 24. Average daily water temperatures (°F) measured in the Merced River downstream of New Exchequer, McSwain, and Crocker-Huffman dams for water year 2001.

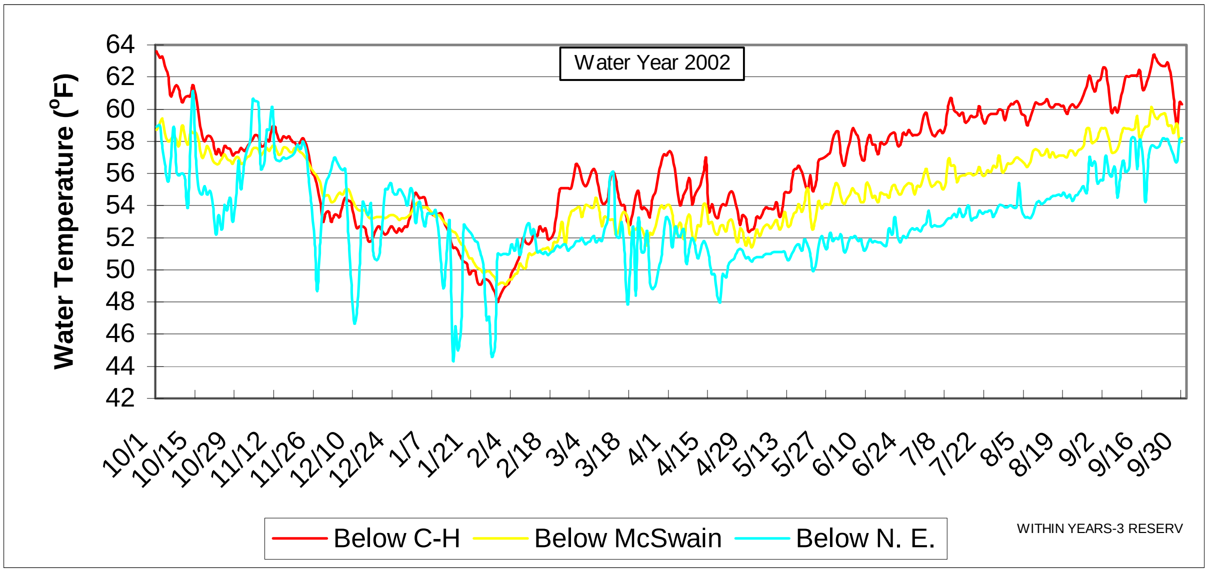


Figure 25. Average daily water temperatures (^{o}F) measured in the Merced River downstream of New Exchequer, McSwain, and Crocker-Huffman dams for water year 2002.

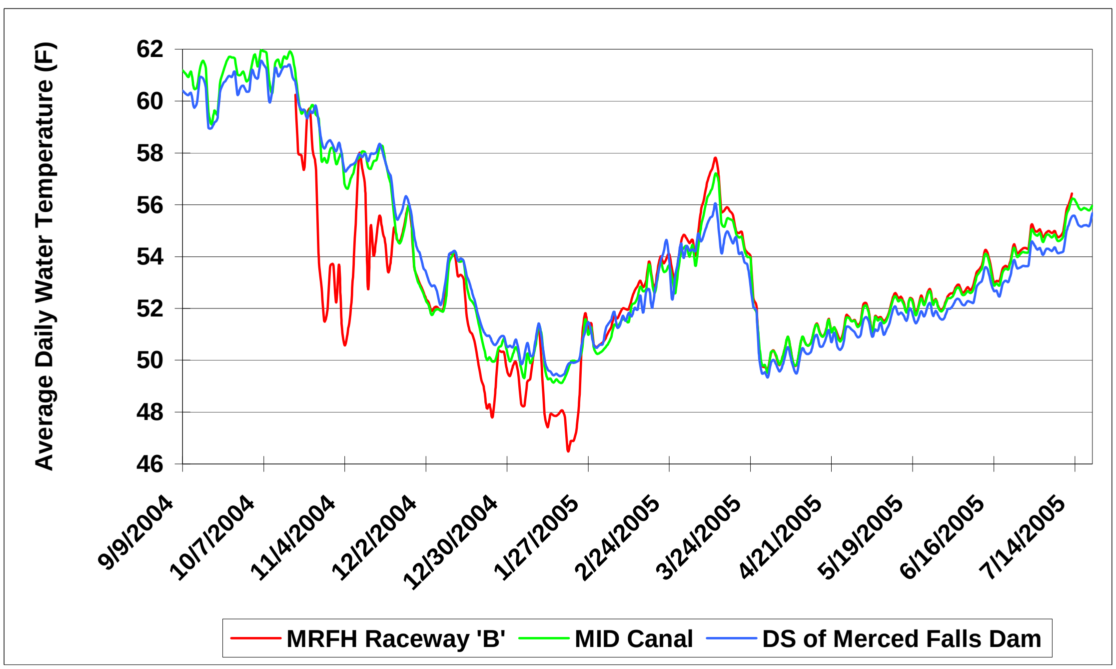


Figure 26. Average daily water temperatures (^{o}F) measured in the Merced River downstream of Merced Falls Dam, the Merced ID Main Canal intake off of Crocker-Huffman Reservoir, and Merced Hatchery, September 2004 – July 2005.

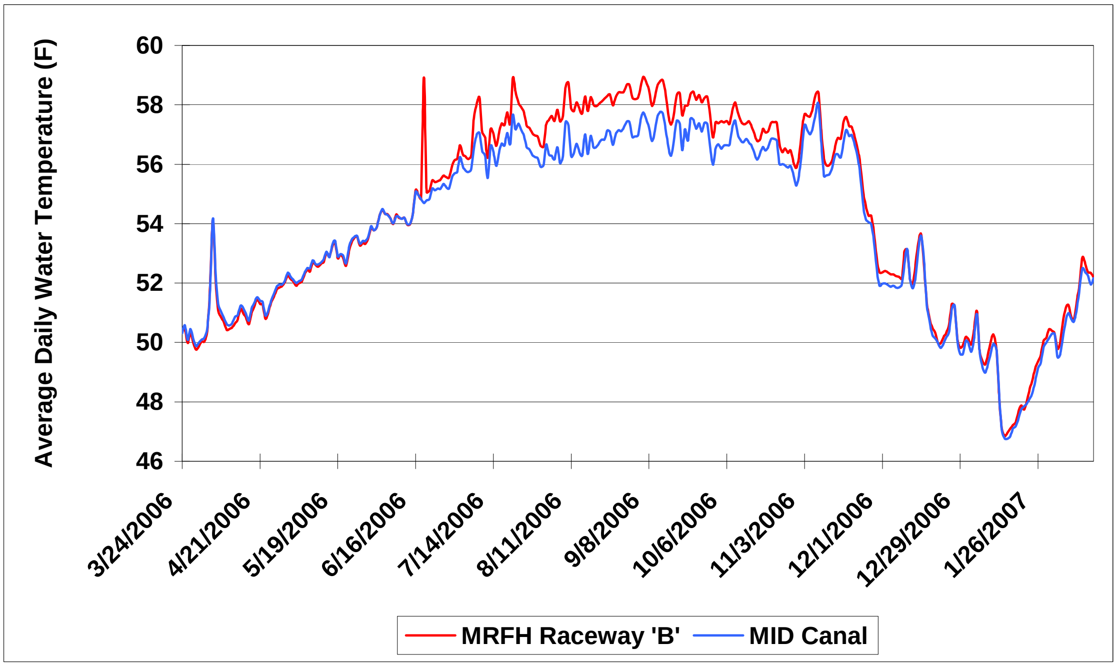


Figure 27. Average daily water temperatures (°F) measured in the Merced ID Main Canal intake off of Crocker-Huffman Reservoir and Merced Hatchery, March 2006 – January 2007.

The lower end of Crocker-Huffman Reservoir between the Main Canal intake and the dam is wide and relatively shallow with abundant aquatic macrophytes (discussed in a subsequent section) allowing solar radiation to warm the surface layer during the spring, summer, and fall. This warmer surface layer is skimmed off in a sheet flow over the dam which can further warm the downstream water, depending on season (Figure 28). These conditions would reverse during the late fall and winter months when ambient air conditions cool the surface layer.

Figure 28. Crocker-Huffman Dam during a flow of approximately 255 cfs.

Channel Geometry, Depths, and Velocities

Physical features of anadromous salmonid riverine habitats are largely controlled by river channel geometry, water depths and velocities, and substrates. These features, in combination, can create a variety of habitat types commonly examined by fisheries biologists to evaluate suitability and quality of fish habitats. McCain *et al.* (1990), Flosi *et al*. (1998), and Arend (1999) describe commonly used different macrohabitat types based on channel features for a stream habitat classification system. Prior to this investigation, there were no data on these physical features for Crocker-Huffman Reservoir. For example, during the development of a water temperature model for the Merced River, the widths and depths of the channel between Merced Falls and Crocker-Huffman dams had to be estimated because empirical data were lacking. Measurements of river channel geometry could improve water temperature model simulations for the Merced River (Jones and Stokes 1995) and, therefore, data collected from this study will be used to improve a recently-funded CALFED project to develop a new water temperature model for the Merced River.

For this study, sixty-four cross-sectional transects across Crocker-Huffman Reservoir were established approximately every 250 feet in the 3-mile reach from Crocker-Huffman Dam up to Merced Falls Dam to measure the reservoir's channel geometry, water depths and velocities, and substrates (Figures 28 - 31). A GPS was used during surveys to record locations of collected field data. Measurements were taken during different seasons to obtain data under a range of high- to low-flow conditions. Water velocities were measured with a Price AA flow meter (upstream of Rattlesnake Bend[4]) and an Acoustic Doppler Current Profiler (ADCP) (downstream of Rattlesnake Bend) under a range of low to high flows to characterize water velocities within the 3-mile reach. Example transects showing water depths and velocities are provided in Figure 32 and 33. Detailed data on each transect are provided in Appendix A. The historical flow regime (magnitude and timing), including diversions into Merced ID's Main Canal, were related to the periods when Chinook salmon or steelhead may be present given their life cycle periodicities in the San Joaquin basin.

Figure 28. Location of transects 1 – 20 among 64 transects established between Crocker-Huffman and Merced Falls dam (river flow is from top right to lower left of picture). Crocker-Huffman Dam is on lower left.

[4] Rattlesnake Bend is a sharp right river bend approximately half the distance between Merced Falls and Crocker-Huffman dams. River features are substantially different upstream and downstream of this location.

Figure 29. Location of transects 20 – 38 among 64 transects established between Crocker-Huffman and Merced Falls dam (river flow is from top right to lower left of picture).

Figure 30. Location of transects 39 – 51 among 64 transects established between Crocker-Huffman and Merced Falls dam (river flow is from top right to lower left of picture).

Figure 31. Location of transects 52 – 64 among 64 transects established between Crocker-Huffman and Merced Falls dam (river flow is from top right to lower left of picture). Merced Falls Dam is on upper right.

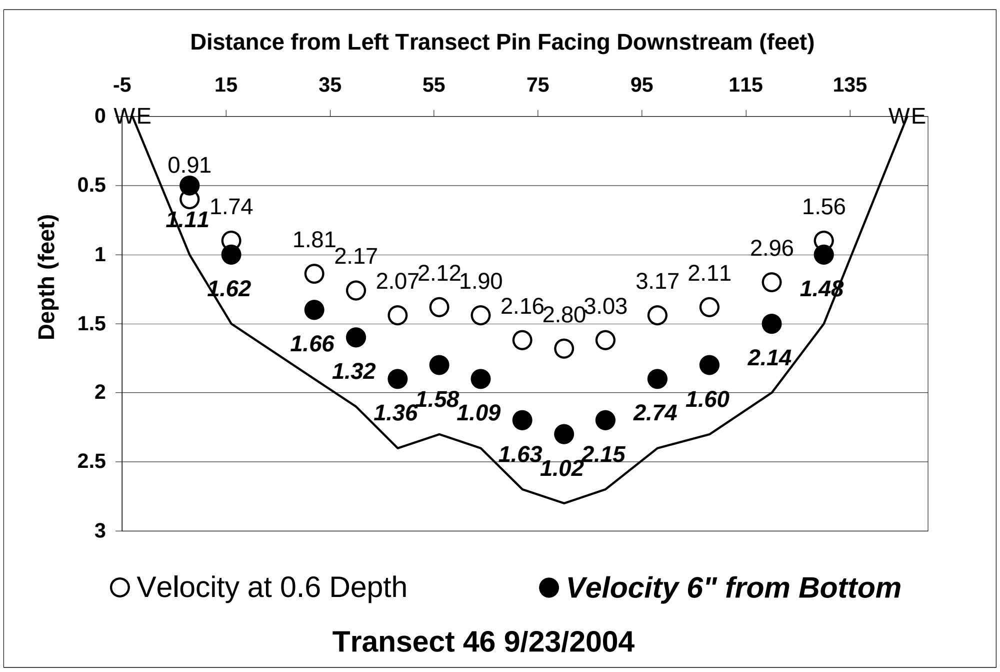


Figure 32. Example cross-sectional transect (no. 46) showing water depths and velocities using a Price AA flow meter.

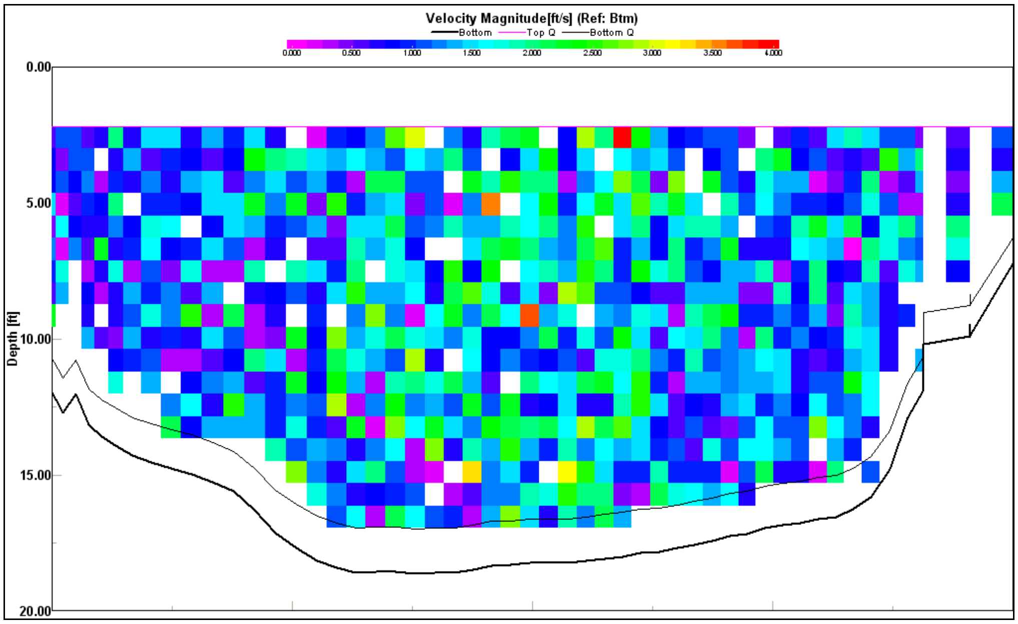


Figure 33. Example cross-sectional transect (no. 10) showing water depths and velocities using an ADCP.

Riverbed Substrates

Riverbed substrates are important features affecting the quantity and quality of anadromous salmonid habitats. Riverbed substrates must be suitable for successful salmonid reproduction and provide habitats for rearing of young fish. Prior to this investigation, there were no data on substrates in Crocker-Huffman Reservoir. Observations of riverbed substrates in the reservoir were made at most of the 64 channel geometry cross-sectional transects. The riverbed substrate was determined using an underwater video camera, through visual observations from the surface where water clarity permitted, or estimated by feel using a stadia rod in areas where the water was too swift and/or clarity was too poor (e.g., silt in weed beds).

In those areas where water velocities could potentially be suitable for salmonid spawning depending on flow conditions, pebble counts (Wolman 1954) were made to determine the particle size distributions of surface substrates. The surface of the riverbed usually possesses lesser fine particles and is coarser relative to the subsurface (Kondolf 1997a, Kondolf 2000). Because pebble counts cannot be used to evaluate the presence of fines less than 2 to 4 mm in diameter on the riverbed surface (Wolman 1954) or the level of fines in subsurface strata, core samples were taken using a 30.5-cm-diameter McNeil sampler. Bulk material from core samples were sieved with ASTM sieves in gradations of sizes to determine the levels of fines present that may affect egg survival. The only area where visually suitable substrates and potentially suitable water velocities for spawning salmon were present was the reach between Merced Falls Dam and Rattlesnake Bend.

Pebble Counts

Within the three-mile reach between Crocker-Huffman and Merced Falls dams, pebble counts were performed only in the reach between Rattlesnake Bend and Merced Falls Dam. Unlike this upstream reach which is riverine in nature, the area between Crocker-Huffman Dam and Rattlesnake Bend is a backwater created by the dam and pebble counts were deemed inappropriate or unfeasible due to factors such as river depth, weeds, silt, etc. During relatively low-flow conditions, pebble counts in the upstream reach were feasible at nearly all transects. Figure 34 provides an example particle size distribution measured at transect no. 49 between Rattlesnake Bend and Merced Falls Dam. Pebble count data for all measured transects are provided in Appendix B. These data were used to determine the d_{50} and d_{84} particle sizes. The median particle diameter, d_{50}, a measure of the central tendency of the distribution, and the d_{84}, the size at which 84% of the sample is finer, are commonly used in hydrology and geomorphic studies (Kondolf 2000). Pebble counts allow comparisons of results from other studies conducted elsewhere (Wolman 1954, Kondolf and Li 1992). The d_{50} particle size for each transect are shown in Figure 35 and both the d_{50} and d_{84} particle sizes measured at each transect are provided in Figure 36. For comparative purposes, pebble counts were also performed at five known salmon spawning riffles downstream of Crocker-Huffman Dam; those results are shown in Figure 37 and provided in Appendix B. The relevance of the surface particle sizes in the reach between Rattlesnake Bend and Merced Falls Dam is discussed in subsequent habitat sections in this report.

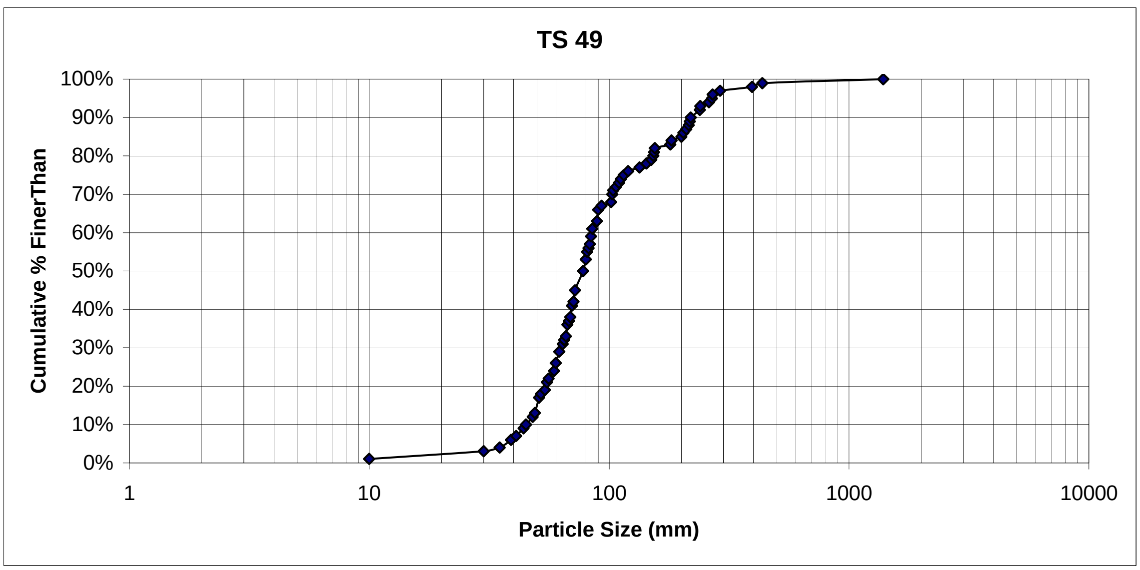


Figure 34. Pebble count at transect No. 49 between Crocker-Huffman and Merced Falls dams.

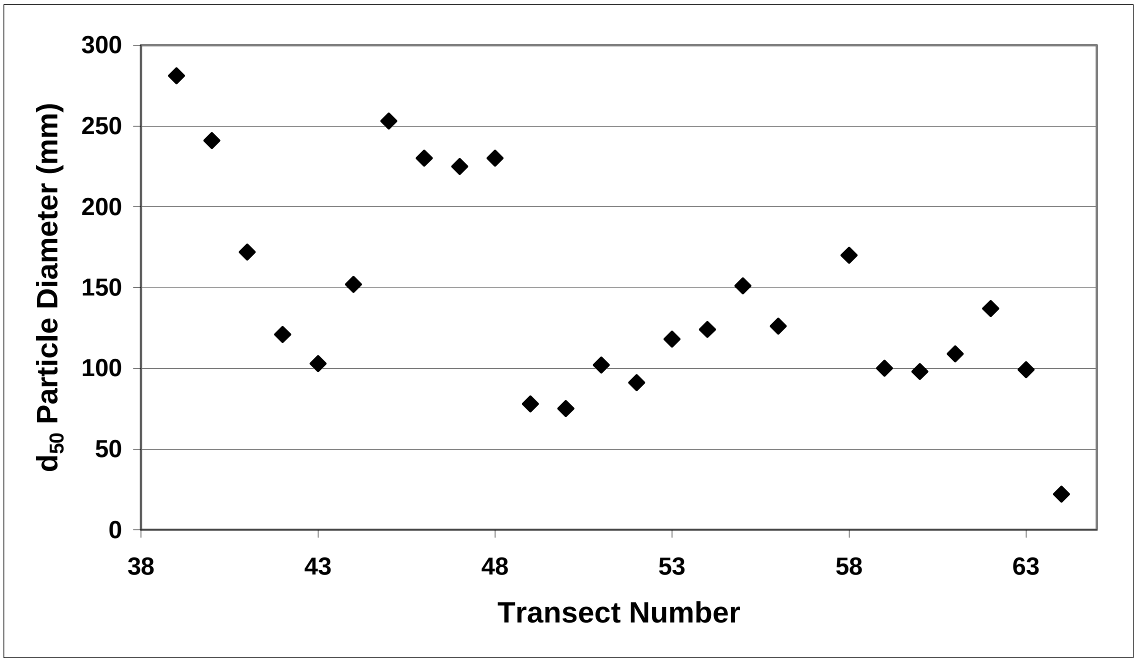


Figure 35. Riverbed surface particle sizes in mm (d_{50}) at transects between Rattlesnake Bend and Merced Falls Dam.

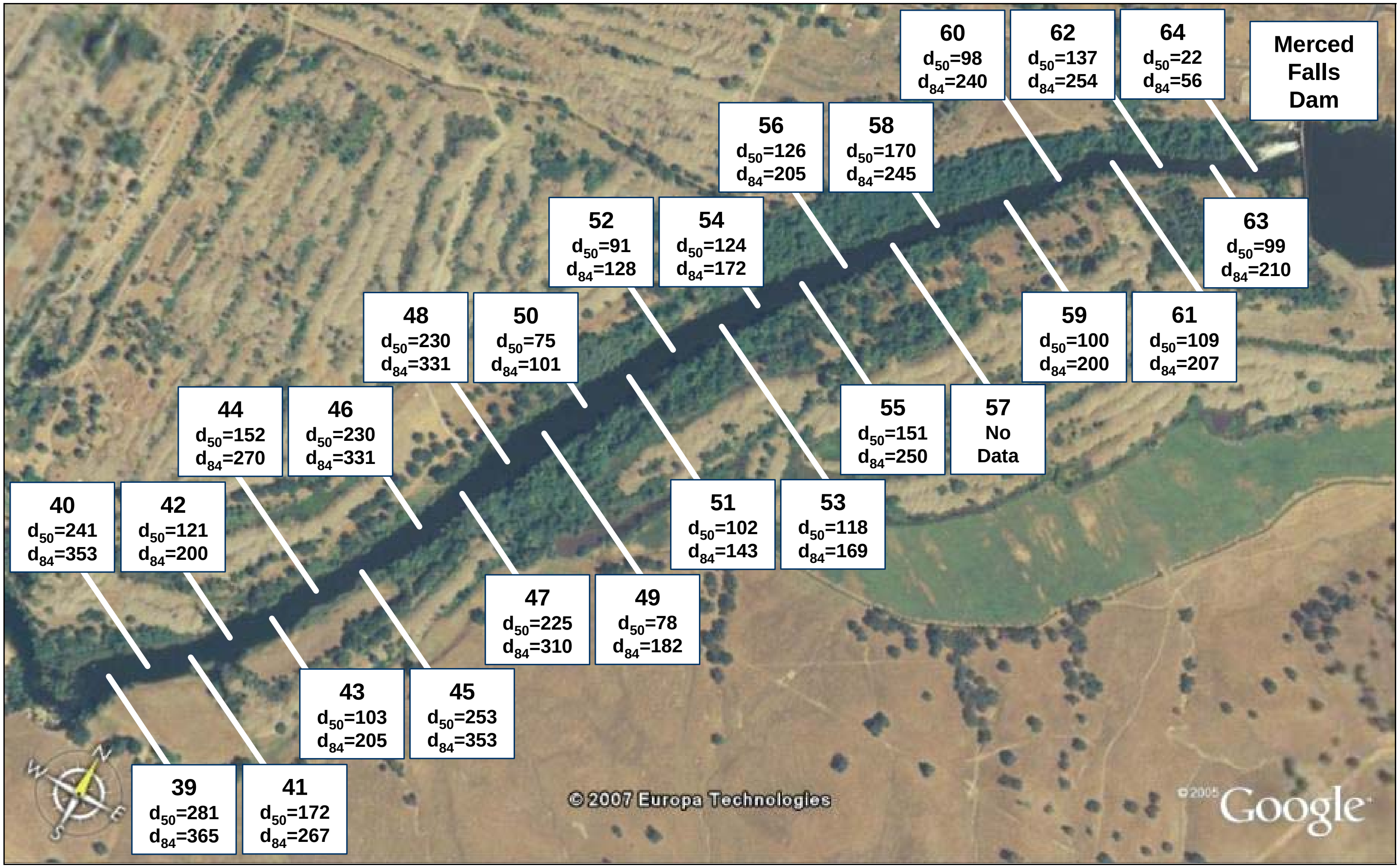


Figure 36. Riverbed particle sizes in mm (d_{50} and d_{84}) determined from pebble counts at transects (nos. 39 – 64) between Rattlesnake Bend (lower left of picture) to Merced Falls Dam (river flow is from upper right to lower left of picture).

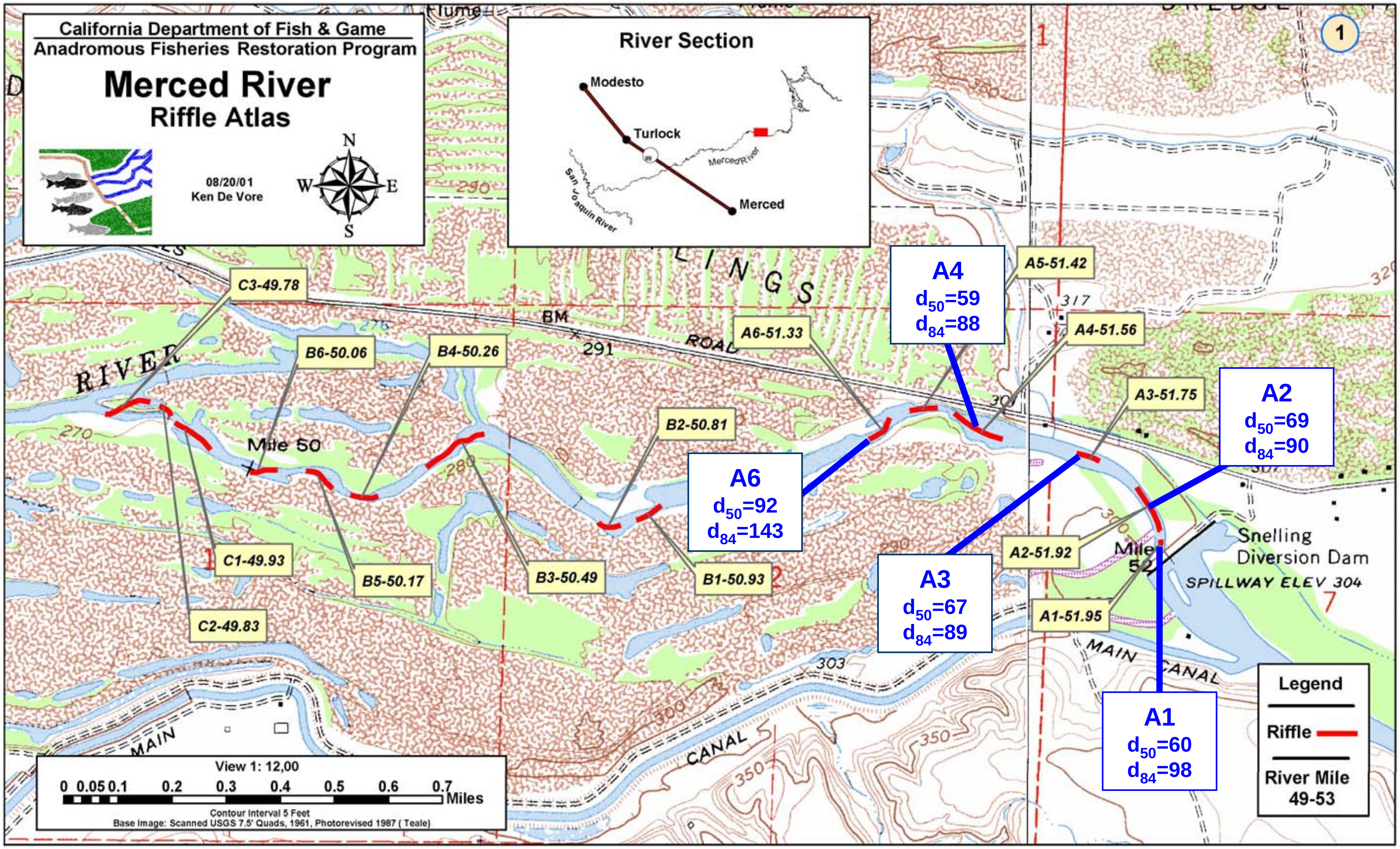


Figure 37. Surface particle sizes (d_{50} and d_{84}) determined from pebble counts at five salmon spawning riffles downstream from Crocker-Huffman Dam.

During recent geomorphological investigations, pebble counts were performed at various locations in the lower Merced River downstream of Crocker-Huffman Dam (Stillwater 2002) which could be used for comparisons to pebble count data collected upstream of the dam for this study. The surface substrate in the reach immediately downstream from Crocker-Huffman Dam ("Dredger Tailings Reach") from RM 52 to RM 45.2 is composed of coarse gravel and cobbles with the D_{50} of the bed ranging from 36 to 128 mm, and the D_{84} ranging from 85 to 270 mm (Vick 1995, CDWR 1994, and Stillwater 2001a, as cited by Stillwater 2002). In the reach from RM 45.2 to RM 32.5 ("Gravel Mining Reach 1"), the D_{50} ranges from 25 to 90 mm and the D_{84} ranges from 48 to 150 mm (Stillwater 2002). In the reach from RM 32.5 to RM 26.8 ("Gravel Mining Reach 2"), the D_{50} ranges from 22 to 85 mm and the D_{84} ranges from 33 to 130 mm (CDWR 1994, Vick 1995, Stillwater 2001b, as cited by Stillwater 2002). (Figures 38 and 39).

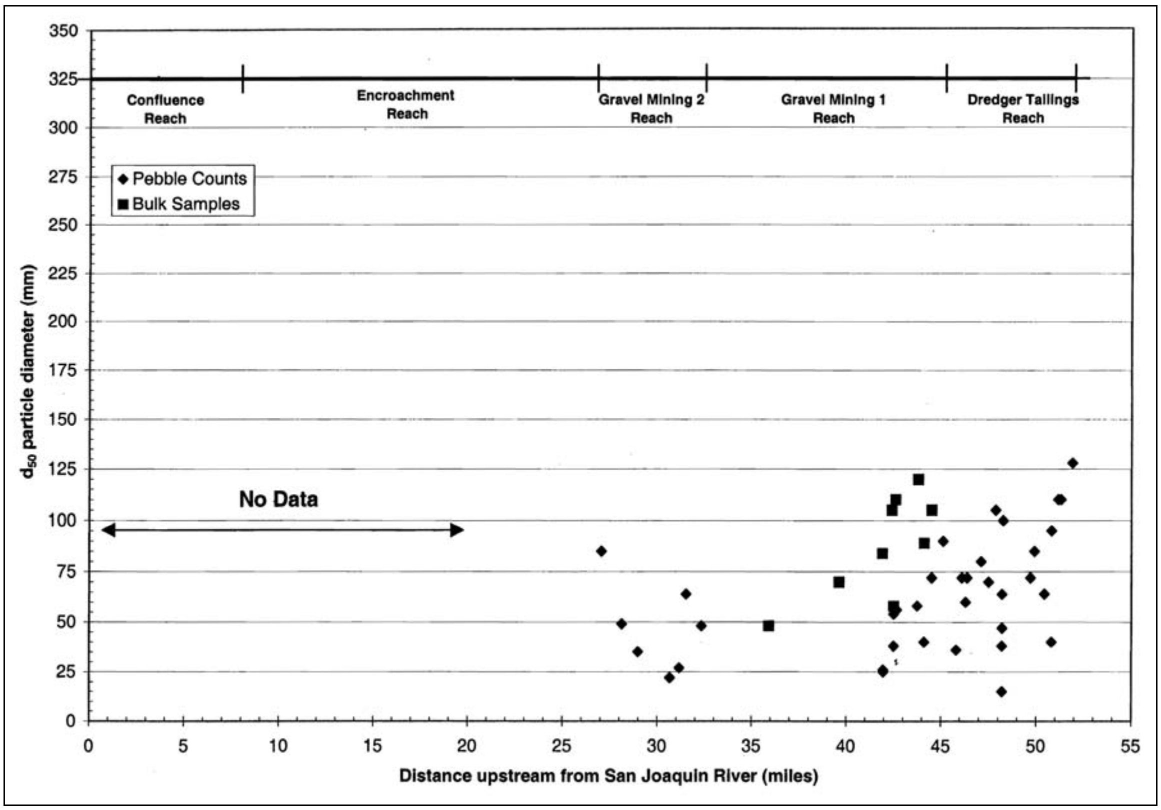


Figure 38. Merced River surface particle size – d_{50} [from Stillwater (2001) using CDWR (1994) and Vick (1995)].

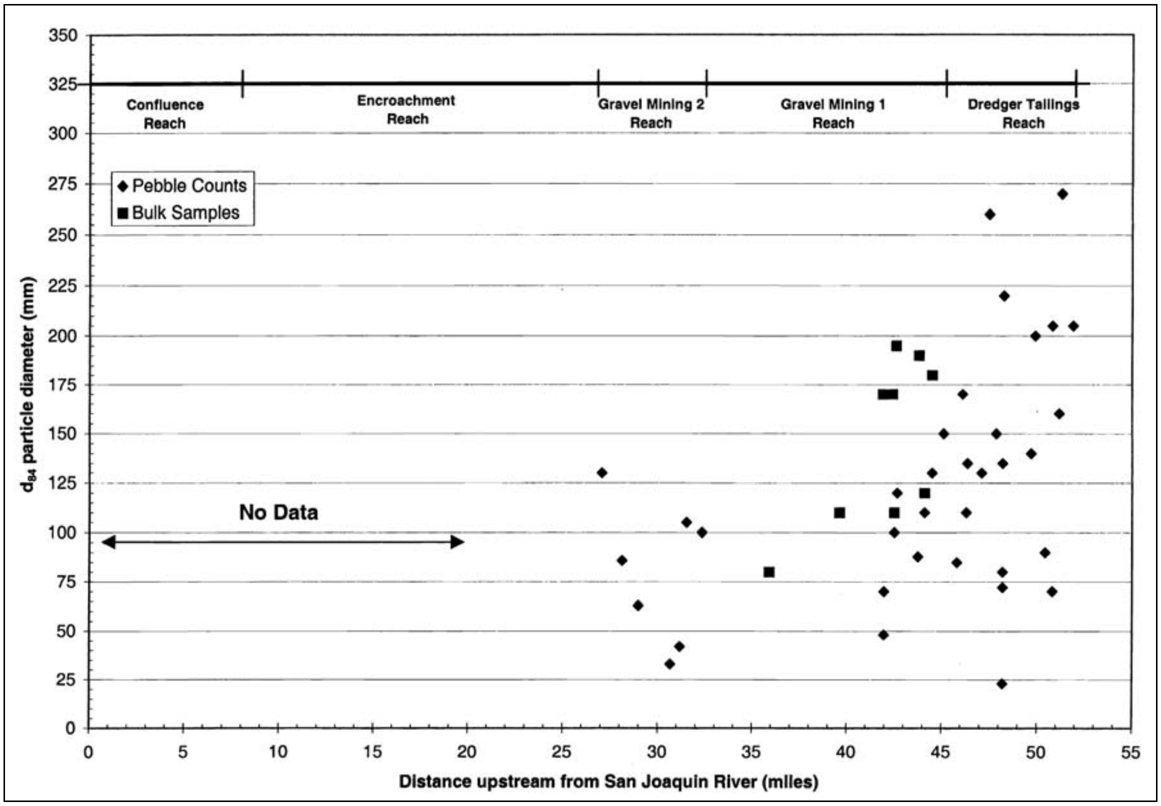


Figure 39. Merced River surface particle size – d_{84} [from Stillwater (2001) using CDWR (1994) and Vick (1995)].

Core Samples

Core samples of riverbed substrate were taken using a 30.5-cm-diameter McNeil sampler. The core sampler was inserted approximately 30 cm into the streambed. Substrate composition for each sample was determined by wet sieving collected streambed material through four U.S. Standard brass sieves (American Society for Testing and Materials - ASTM) of the following sieve sizes:

	Sieve Size Opening	
ASTM Sieve Number	**Millimeters**	**Inches**
1/2	12.5	0.5
4	4.75	0.187
8	2.36	0.0937
20	0.85	0.0331

Fifty-one core samples were able to be taken near 17 transects between Rattlesnake Bend and Merced Falls Dam. At each transect[5], three core samples were taken, processed, and results averaged to represent one composite sample. Results are summarized in Figure 40 and provided in Appendix C. The intent of core sampling was to determine the level of fine material present

[5] Core samples were taken in proximity to the transect but not necessarily on the transect line.

in the sub-surface strata, not the coarse particle central tendency. Others have indicated that bulk samples to assess coarse particle central tendency should be more than 200 kg if the gravels include stones 100 mm in diameter (Church *et al.* 1987, as cited by Kondolf 1997a). Samples taken were less than 200 kg and the largest sieve size was 12.5 mm so these results cannot be used to evaluate coarse particle sizes; pebble counts were used for that purpose.

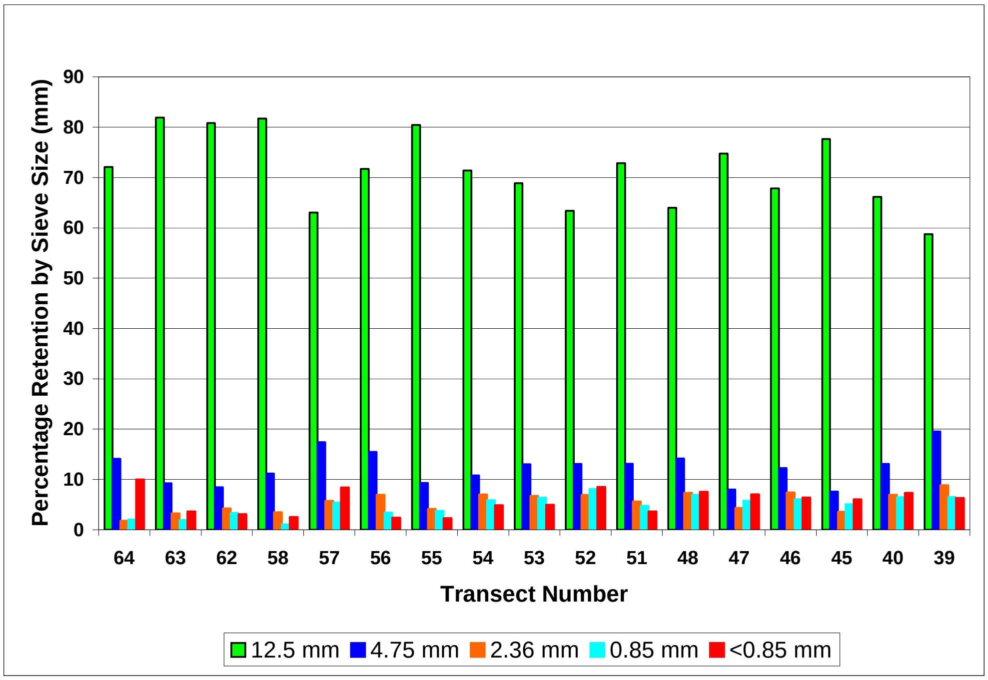


Figure 40. Percent retention of various riverbed particle sizes from core samples collected at 17 transects between Rattlesnake Bend (TS 39) and Merced Falls Dam (TS 64).

Core samples were also taken at five salmon spawning riffles downstream of Crocker-Huffman Dam near locations where pebble counts were also measured. Three core samples were taken at each riffle for a total of 15 samples. Results are summarized in Figure 41 and provided in Appendix C. The relevance of these data to potential salmon spawning habitats upstream of Crocker-Huffman Dam is discussed in a subsequent section.

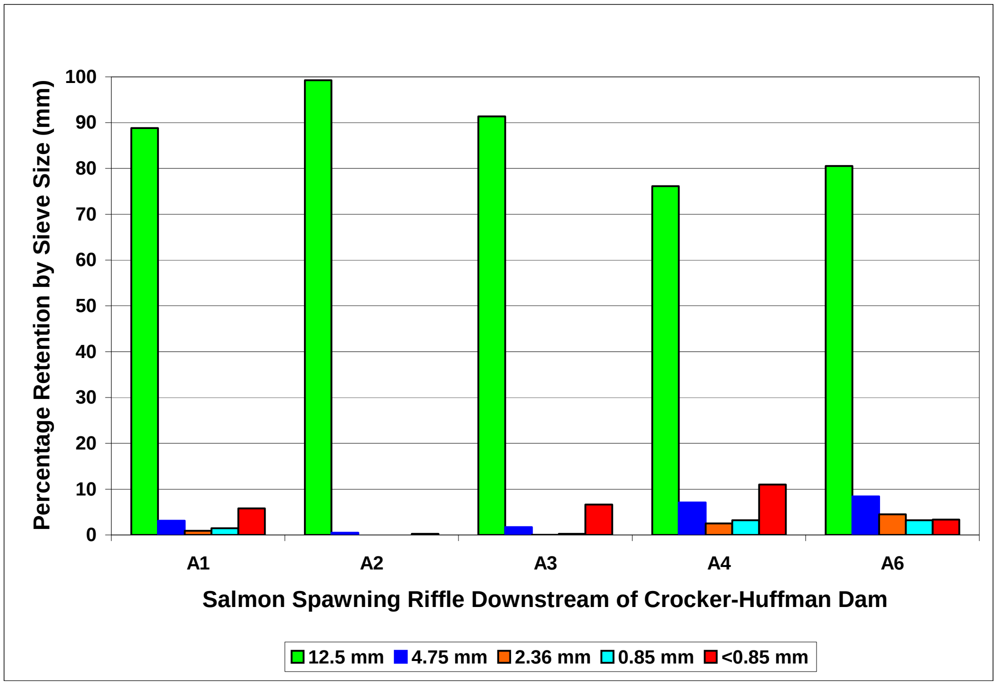


Figure 41. Percent retention of various riverbed particle sizes from core samples collected at five salmon spawning riffles downstream of Crocker-Huffman Dam.

Visual Observations of Substrates

Visual observations of the riverbed substrates were made at each of the 64 transects between Crocker-Huffman and Merced Falls dams. In a cross-sectional perspective, observations were made every 10 feet across the wetted perimeter of the stream channel. In deep water, an underwater video camera was used; in shallow water, observations from the surface were made. In those areas where water clarity did not allow observations (e.g., in weeds or silt), a stadia rod was used to feel the substrate. Table 6 provides the substrate classifications used for the surveys.

Table 6. Substrate classifications used in the riverbed surveys of Crocker-Huffman Reservoir.

Substrate	Substrate Size
Silt	*
Sand	< 0.08 inch
Gravel	0.08 inch – 2.5 inch
Small Cobble	2.5 inch – 5 inch
Large Cobble	5 inch – 10 inch
Small Boulder	10 inch – 20 inch
Medium Boulder	20 inch – 40 inch
Large Boulder	> 40 inch
Bedrock	*

* Based on observer's judgment.

Figures 42 - 44 show summarized results of the surveys. For readability, substrate classifications were grouped (e.g., small and large cobble = cobble) and data collected every 10 feet were averaged for the entire transect. The substrate in the lower third of Crocker-Huffman Reservoir (Transects 1 – 19) is dominated by silt (Figure 42) obviously caused by the back-water influence of Crocker-Huffman Dam. Large particle substrates (cobbles and boulders) were dominant in transects 20 – 38 up to Rattlesnake Bend, but still exhibited a high proportion of silt that diminishes in an upstream direction (Figure 43). The reach between Rattlesnake Bend and Merced Falls Dam (transects 39 – 64) is dominated by cobbles and boulders (Figure 44). Appendix D provides detailed data collected every 10 feet at each of the 64 transects.

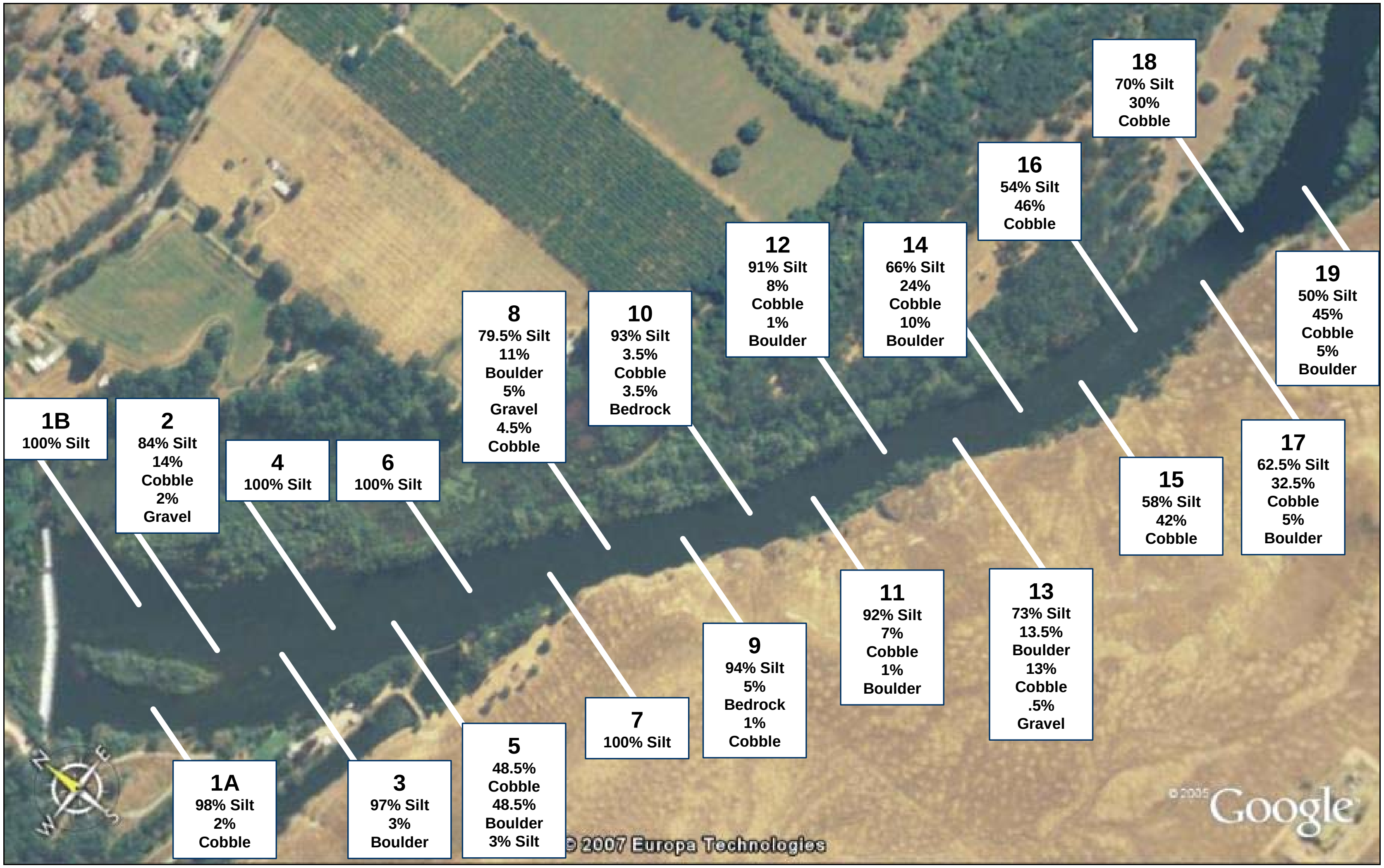


Figure 42. Observations of the riverbed substrate at transects in approximately the lower third of Crocker-Huffman Reservoir.

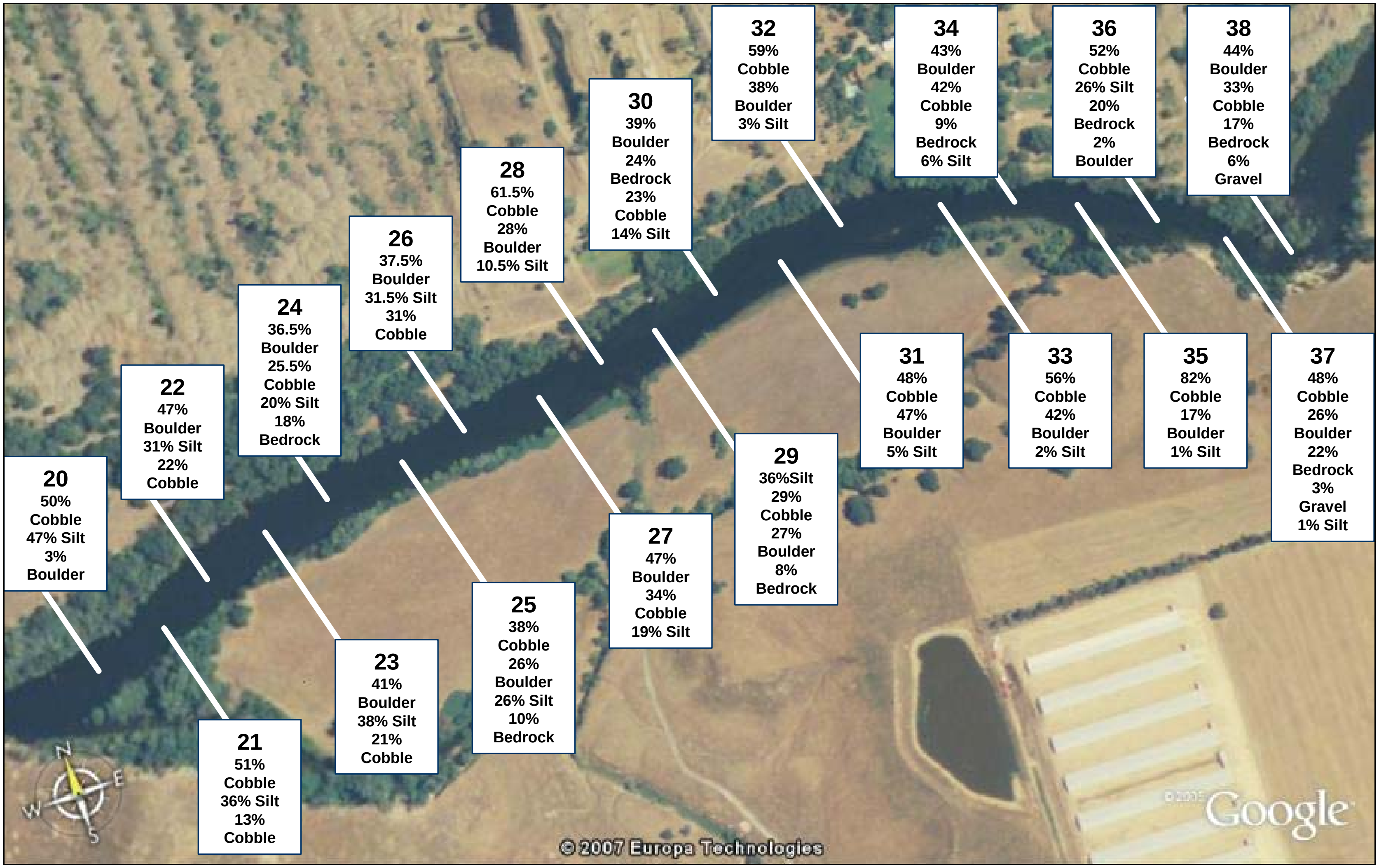


Figure 43. Observations of the riverbed substrate at transects in approximately the middle third of Crocker-Huffman Reservoir.

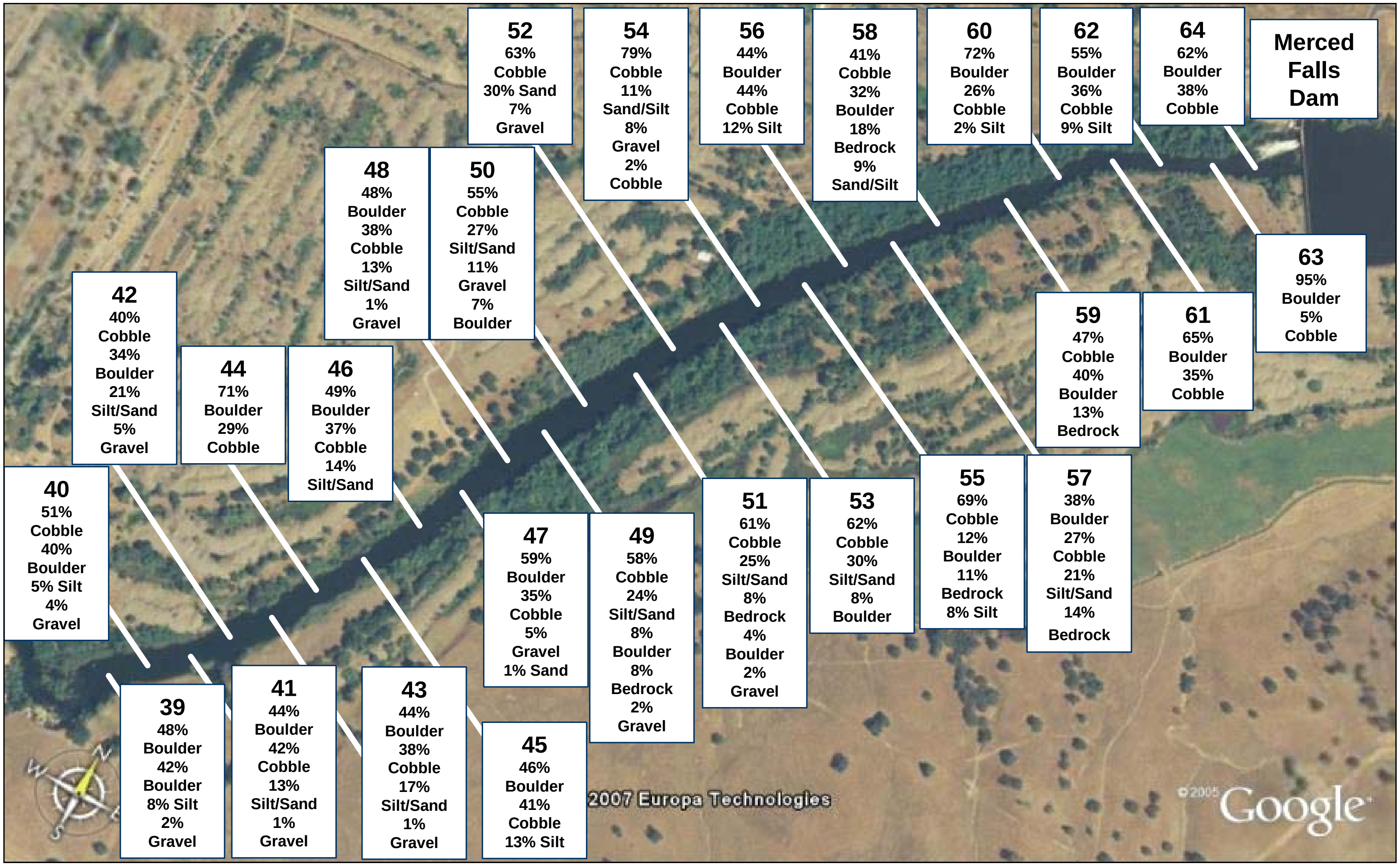


Figure 44. Observations of the riverbed substrate at transects in approximately the upper third of Crocker-Huffman Reservoir.

Riparian Vegetation

Riparian vegetation can provide important habitat elements for anadromous salmonid rearing. Shade provided by stream bank vegetation can provide cooling effects on river water. Terrestrial insects from riparian vegetation provide food to rearing salmonids. Rootwads, woody debris recruitment into the stream channel margins, and undercut banks increase protective cover for fish from predators. Riparian vegetation also provides stream bank stability helping to alleviate erosion of deleterious fine sediments into the river.

The dredging piles from historical gold dredging in the lower Merced River have replaced much of the riparian forests with piles of cobbles and boulders, creating a confined, river channel corridor (Stillwater 2002). Riparian vegetation has encroached[6] into the river channel and was identified as one of the most difficult issues to address in the restoration of the lower Merced River corridor (Stillwater 2001a). Riparian encroachment has also occurred in the reach between Crocker-Huffman and Merced Falls dams.

As part of this feasibility study, characteristics of riparian vegetation between Crocker-Huffman and Merced Falls dams were assessed because of potential importance to anadromous salmonids. Between each of the 64 cross-sectional transects, visual estimates of coverage for the overstory (upper canopy - trees) and understory (tall grasses and shrubs) were made for left and right riverbanks. Coverage was estimated by percent of coverage for the approximate 250-ft longitudinal distance between left- and right-bank transects and ranked as low (0% – 33%), medium (34% – 67%), or high (68% - 100%). Results are provided in Appendix E and summarized in Figures 45 - 48. The same demarcation between the upstream reach and downstream reach from Rattlesnake Bend for channel features was used to segregate riparian characteristics.

[6] "In natural alluvial river systems, geomorphic processes such as flooding, erosion, and sediment deposition maintain the channel shape and cross section width. Through these processes, the river maintains a multistaged channel (which includes the low flow, active, and bankfull channels) and a floodplain. With reduced flow magnitude, scour of alluvial bars in the active channel is reduced, which allows riparian trees to become established in the former (pre-dam) active channel. The process is referred to as 'riparian encroachment'" (Stillwater 2001a).

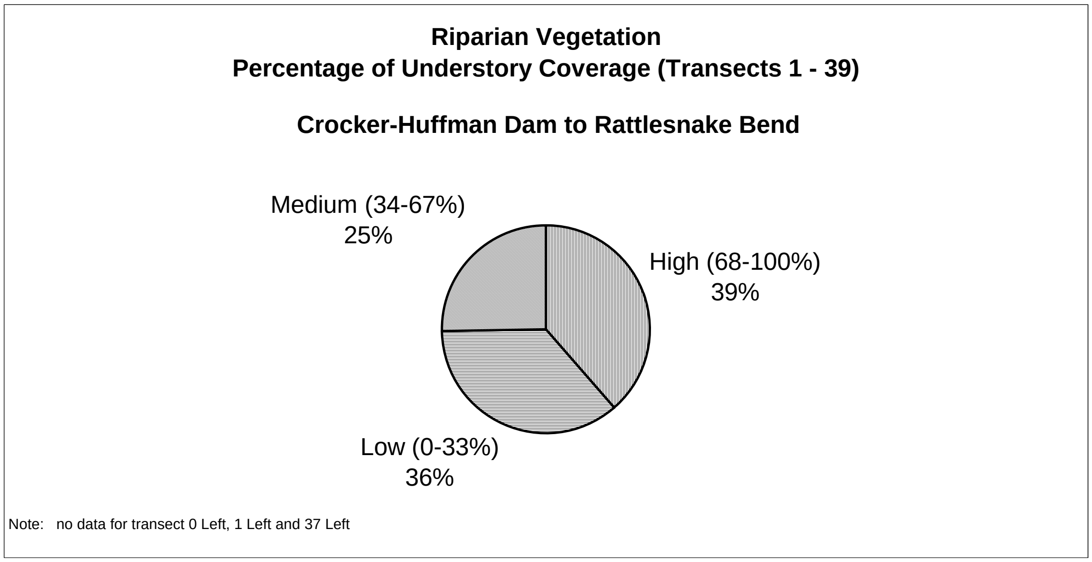


Figure 45. Percentage of riparian understory coverage between transects 1 – 39 from Crocker-Huffman Dam to Rattlesnake Bend (including left and right banks).

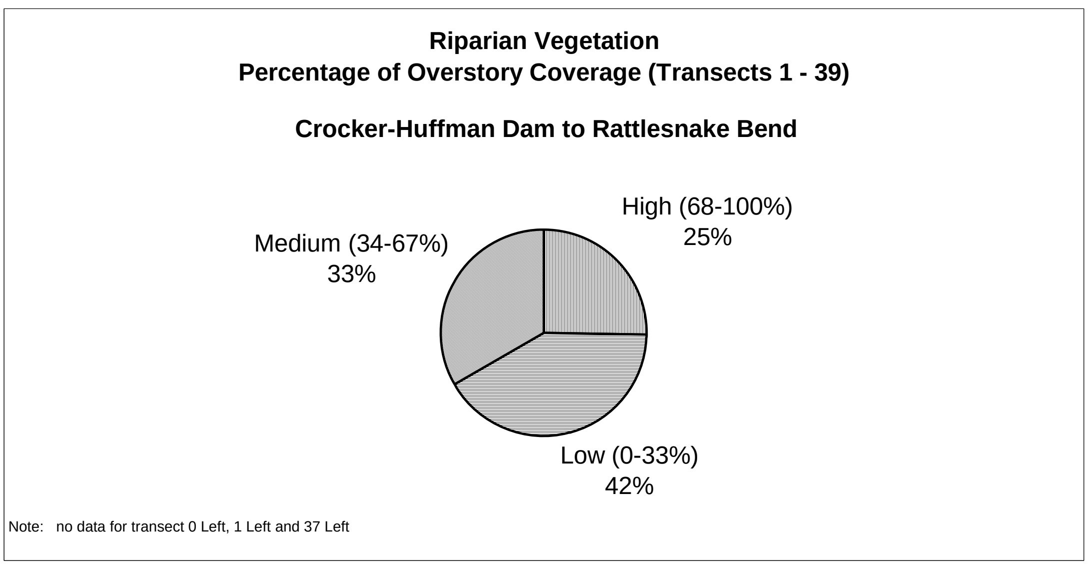


Figure 46. Percentage of riparian overstory coverage between transects 1 – 39 from Crocker-Huffman Dam to Rattlesnake Bend (including left and right banks).

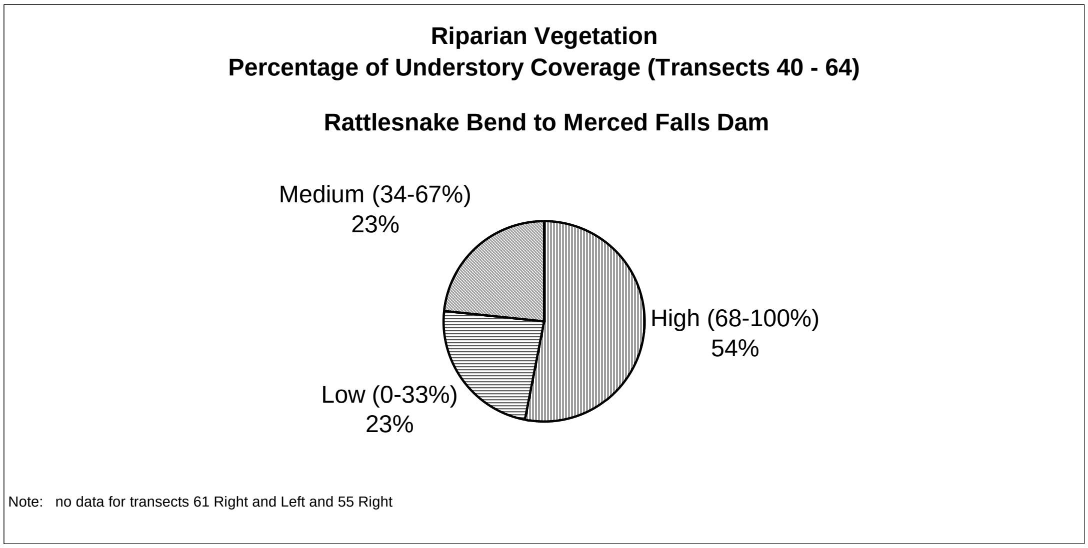


Figure 47. Percentage of riparian understory coverage between transects 40 – 64 from Rattlesnake Bend to Merced Falls Dam (including left and right banks).

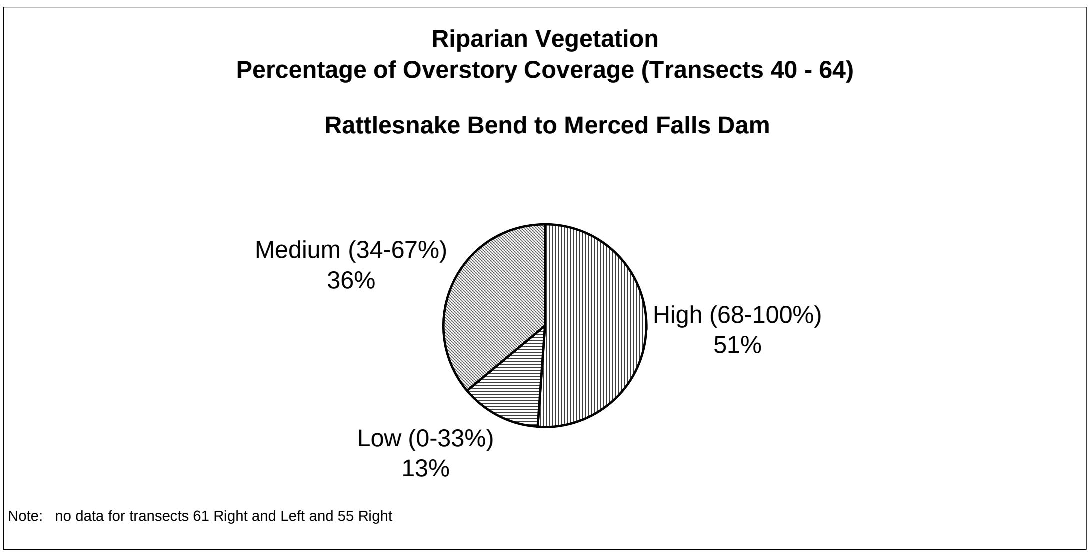


Figure 48. Percentage of riparian overstory coverage between transects 40 – 64 from Rattlesnake Bend to Merced Falls Dam (including left and right banks).

Much of the riparian vegetation upstream of Crocker-Huffman Dam overhangs the water's edge. Because of the potential importance for juvenile salmonid rearing, the amount of vegetation hanging five feet[7] or more over the water's edge was also estimated during the surveys. Those results are provided in Appendix E and summarized in Figures 49 - 52.

[7] The distance of five feet was arbitrarily chosen.

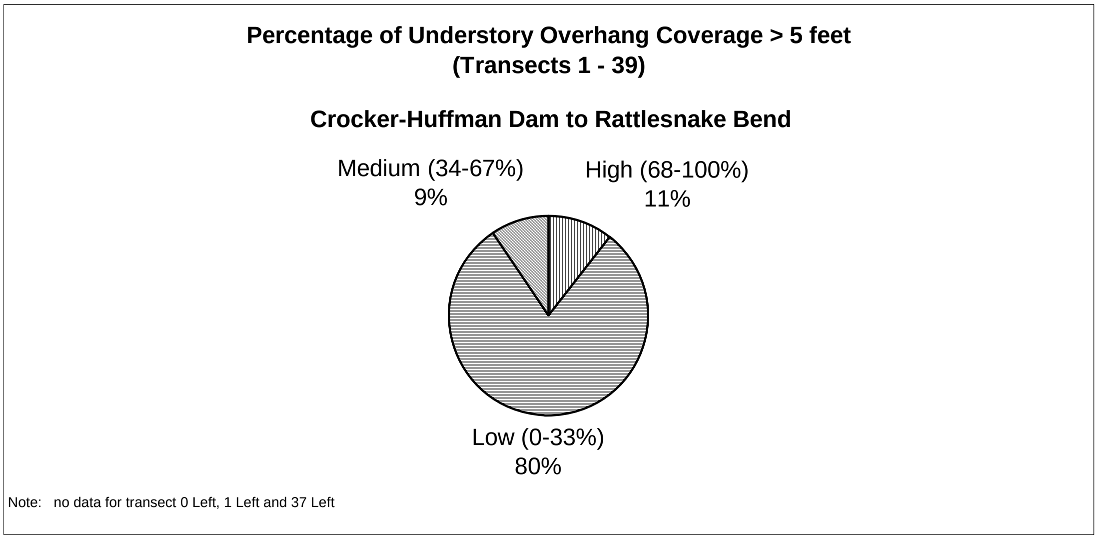


Figure 49. Percentage of riparian understory overhang coverage greater than 5 feet between transects 1 – 39 from Crocker-Huffman Dam to Rattlesnake Bend (including left and right banks).

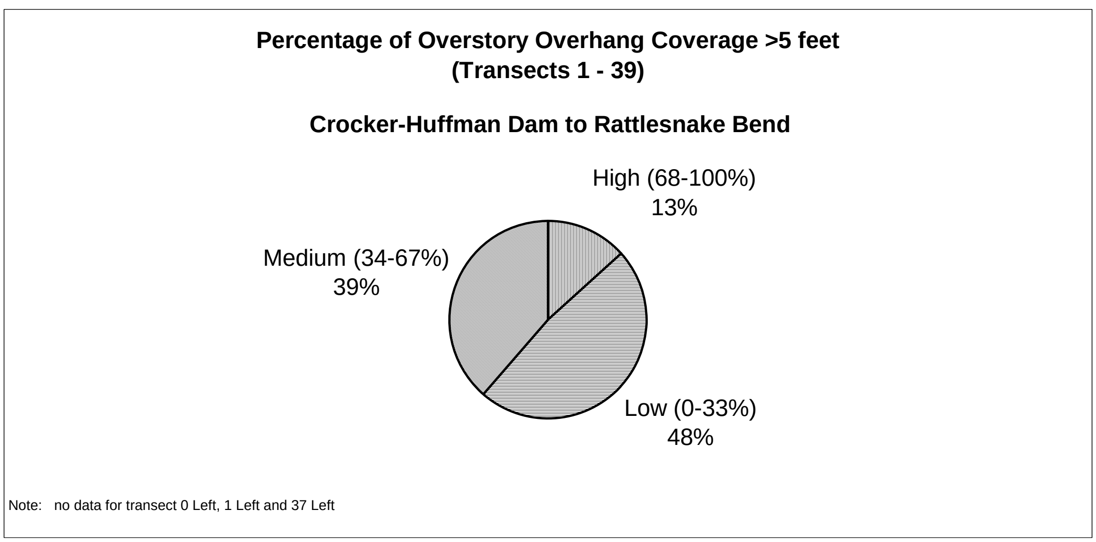


Figure 50. Percentage of riparian overstory overhang coverage greater than 5 feet between transects 1 – 39 from Crocker-Huffman Dam to Rattlesnake Bend (including left and right banks).

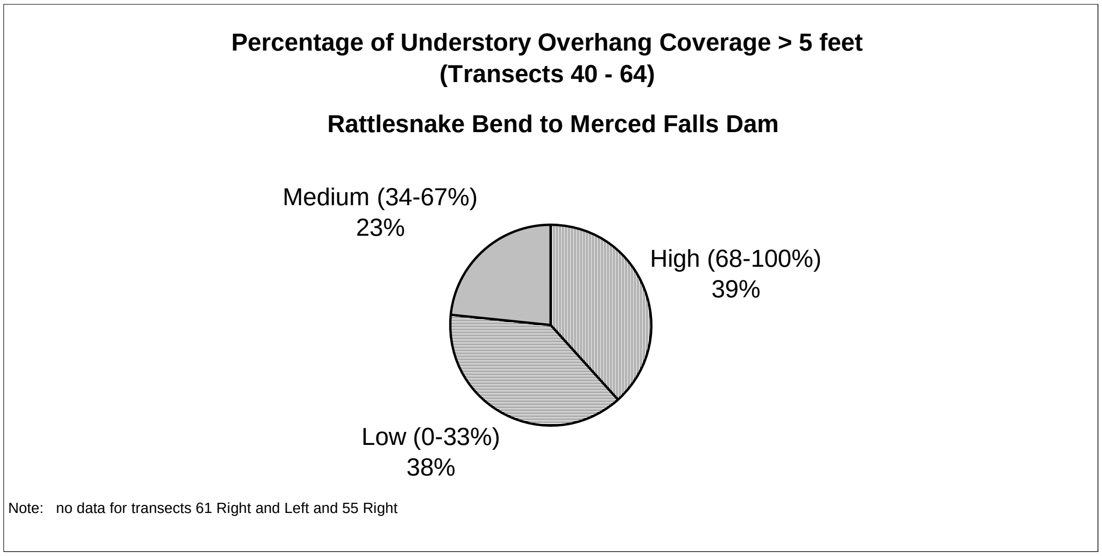


Figure 51. Percentage of riparian understory overhang coverage greater than 5 feet between transects 40 – 64 from Rattlesnake Bend to Merced Falls Dam (including left and right banks).

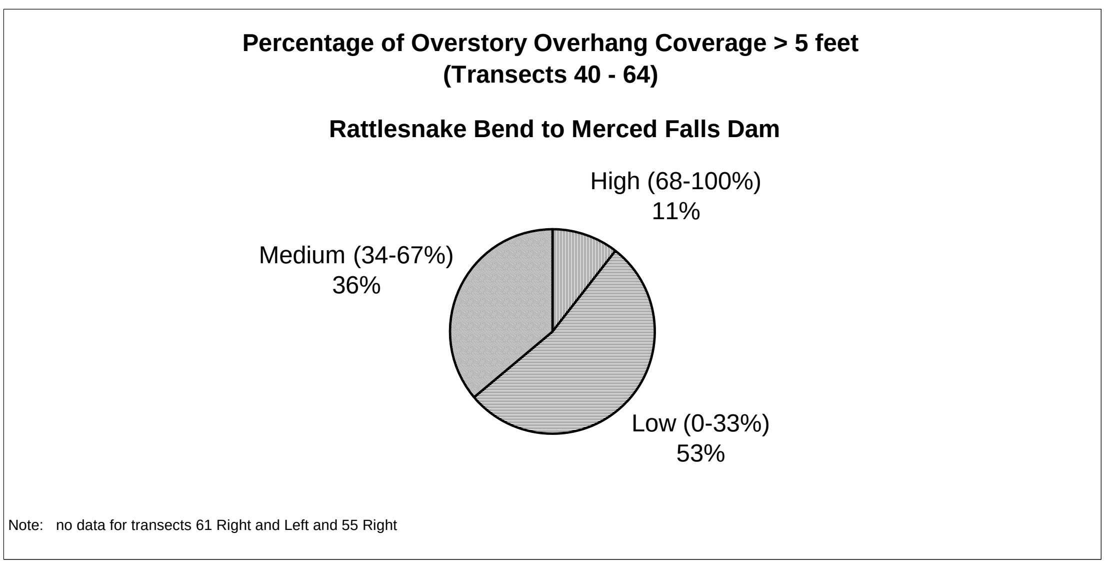


Figure 52. Percentage of riparian overstory overhang coverage greater than 5 feet between transects 40 – 64 from Rattlesnake Bend to Merced Falls Dam (including left and right banks).

Aquatic Vegetation and Instream Cover

As part of the in-channel surveys between Crocker-Huffman and Merced Falls dams, the presence of aquatic vegetation (macrophytes) was recorded every 10 feet across each of the cross-sectional transects. Those results are provided in Appendix D. The dominant aquatic macrophytes included elodea, Eurasian watermilfoil, water primrose, and coontail. Instream cover on the channel margins (e.g., woody debris, terrestrial vegetation in the water) between left- and right-bank transects was also recorded. Those results are provided in Appendix F and summarized in Figures 53 - 54.

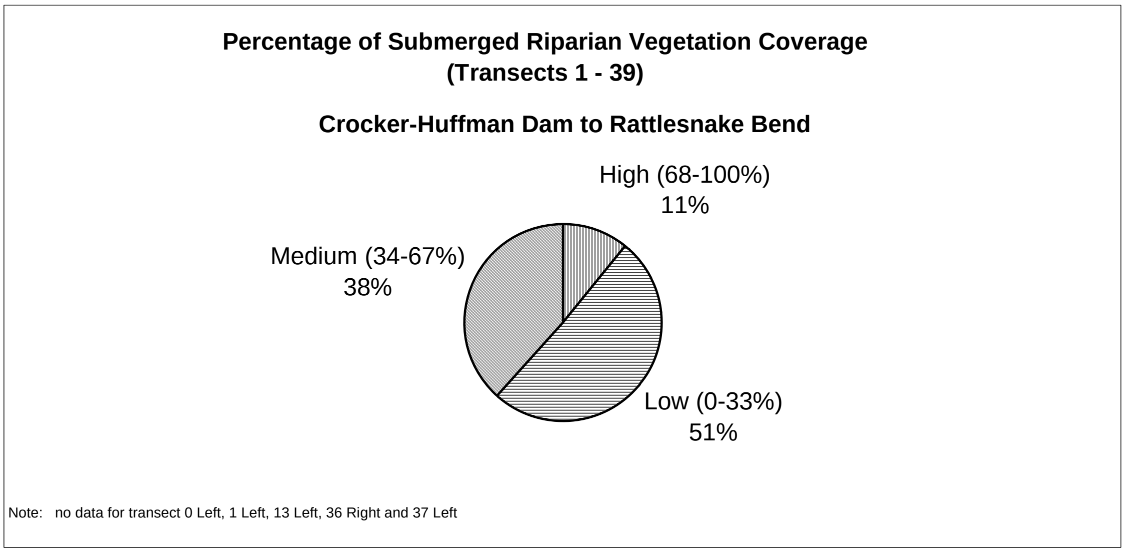


Figure 53. Percentage of submerged riparian vegetation coverage on channel margins between transects 1 – 39 from Crocker-Huffman Dam to Rattlesnake Bend (including left and right banks).

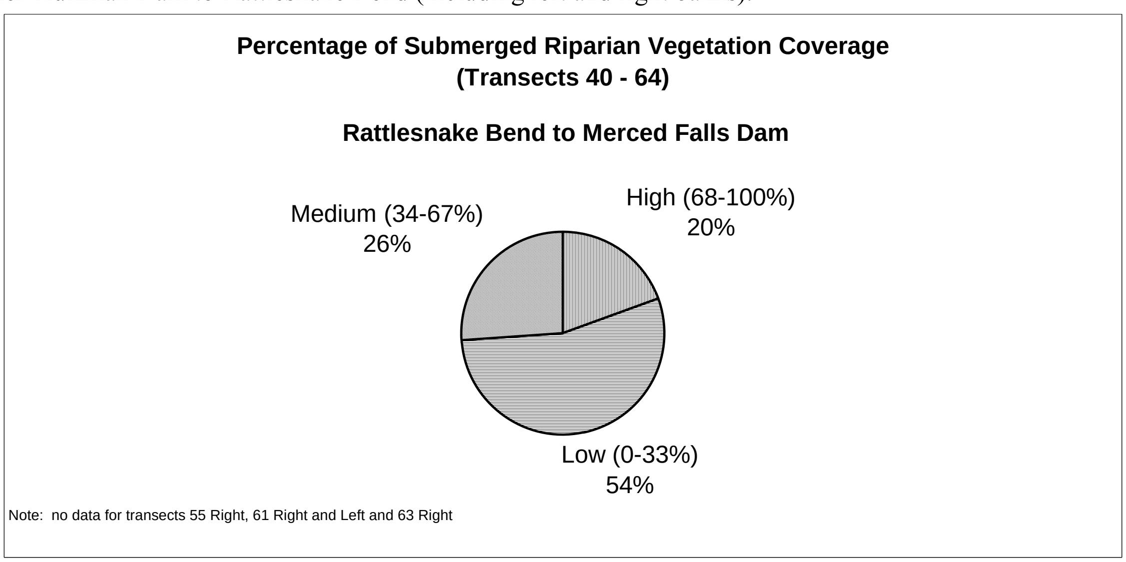


Figure 54. Percentage of submerged riparian vegetation coverage on channel margins between transects 1 – 39 from Crocker-Huffman Dam to Rattlesnake Bend (including left and right banks).

Spawning Habitat

Chinook salmon spawn in a mixture of gravel and small cobbles (Moyle 2002), the requirements of which are fairly rigid for successful reproduction (Allen and Hassler 1986). Substrate particle sizes for optimal redd construction and egg development have been described by numerous researchers. Bell (1991) indicated that the spawning gravels should be 80 percent ½-inch to 1&1/2 inch to 2 inches, with the remaining balance up to 4 inches. Flosi *et al*. (1988) describe the criteria as 0.5 to 10 inches dominated by 1- to 3-inch cobble. USFWS (1997) concluded that lower Merced River Chinook salmon preferred spawning substrate 2 – 4 inches in diameter and velocities between 1 and 2.5 ft/s. The substrate must allow for good intragravel flow which is important for egg incubation (Allen and Hassler 1986, Healey 1991, Moyle 2002).

Visual, qualitative observations of riverbed surface substrates are commonly made by fisheries biologists to assess suitability for salmon spawning. For example, SCUBA divers evaluating the suitability of Chinook salmon spawning substrate in the 3.5-mile reach of the Sacramento River immediately downstream of Keswick Dam and in other areas of the Sacramento River used the following qualitative spawning substrate suitability classification (Vogel and Taylor 1987, Vogel 2000, Vogel 2001):

Good: Substrate of good to excellent quality for Chinook redd construction because of expected ease in redd construction, expected good structural integrity, and probable high egg survival. Substrate predominately composed of gravel and cobble (approximately 90 - 100 percent). Substrate size range from approximately 1 to 6 inches in mean diameter with most substrate 2 to 4 inches in diameter. Boulders or fines scarce or absent.

Fair: Substrate of less than optimal quality for Chinook redd construction because of some expected difficulty in redd construction and/or probable lower than optimal egg survival. Substrate predominately composed of gravel and cobble (approximately 50 – 90 percent). Substrate in this classification generally of a larger than optimal size for salmon spawning (i.e., large cobbles). Proportion of gravels to cobbles smaller than that observed for the “good” classification.

Poor: Substrate of only marginal usefulness for Chinook redd construction because of expected great difficulty in redd construction and/or probable low egg survival. Substrate composed almost entirely of large cobbles (larger than approximately 6 inches in mean diameter) or of gravels with a large amount of fines present.

Not Present: Substrate not meeting the criteria for good, fair, or poor. Substrate composed of one or more of the following: bedrock, sand, very large rocks, boulders.

Such classifications are subject to the experience of those individuals making the observations and may not be reproducible and comparable between observers in different studies.

Much of the research on spawning gravel has focused on the deleterious effects caused by varying degrees of sediments on egg incubation and fry emergence. Very fine sediments (e.g., silt) can adversely impact egg incubation, whereas coarse fine sediments (e.g., sand) can adversely impact the ability of hatched salmon to emerge from the gravel interstices (Kondolf 2000). The amount of fine sediment which may be detrimental to naturally spawning salmonids is related to particle size, specific composition and spatial distribution of the spawning gravels, species or stock of fish, timing and amount of deposition, locations of the eggs and egg pockets in redds, and numerous other complex processes and interrelationships not entirely understood. Once laid in the river gravels, eggs and larvae must receive a sufficient supply of oxygenated water of suitable temperature (Figure 5) and free from toxic contaminants. The delivery rate of oxygen to the egg is a function of intragravel water velocity and the concentration of oxygen. The intragravel flow is controlled both by gravel permeability and hydraulic gradient (Kondolf 2000). Heavy siltation on the eggs can reduce intragravel water flow to lethal levels (Wickett 1954). Fine sediment has a large influence on gravel permeability; finer sediments can be more effective in reducing intragravel flow than coarser sediments (Cooper 1965). Of particular concern are fines smaller than 1 mm in diameter (Beschta and Jackson 1979). The principal benefits resulting from adequate water velocity to incubating salmonid embryos are the concurrent functions of transferring sufficient dissolved oxygen to the surface of the egg membrane and the removal of the egg's metabolic waste products (Brannon 1965; Hausle and Coble 1976).

Excessive fines in spawning gravels can also obstruct movements of alevins within the gravel at the time of emergence (Hausle and Coble 1976). Reduction in emergence of salmonid embryos can occur when spawning gravels contain more than 20 percent sand (Hausle and Coble 1976; and Hall and Lantz 1969, as cited by Hausle and Coble 1976). Bjorn (1969) found that Chinook salmon fry readily emerged from gravel with less than 20 percent sand, experienced difficulty in 20-40 percent sand, and that few emerged from more than 40 percent sand. He also found that most steelhead fry emerged from gravel with up to 30 percent sand. In his review of variables used to define effects of fines in salmonid redds, Chapman (1988) inferred that some fines aid salmonid survival by reducing intrusion of smaller fines and organic debris into the egg pocket. Reiser and White (1988) also believed that coarser sediments, to some degree, may actually benefit egg survival by filtering out some of the finer sediments. Bjorn and Reiser (1991) stated that such a layer can be beneficial if it prevents deposition of fine inorganic or organic materials in the egg pocket, detrimental if it impedes alevin emergence, or both. Platts *et al.* (1979) also proposed that fine sediments in the correct amounts can be important to salmonid embryo survival.

Lisle and Eads (1991) state that the threshold of concern for fine sediment content in salmonid spawning gravel vary between species and grain size of fine sediment, but most commonly is around 20 percent. The California Department of Fish and Game's threshold of concern for fines in spawning gravel in streams along the northern California coast is 15 percent (Vogel 1994b). Kondolf (2000) estimates that the threshold of adverse egg incubation effects from fines < 1 mm is 12 - 14%. Importantly, in estimating the effects of both very fine and coarser fine sediments, consideration must be given to the fact that salmonids cleanse some of the fine material from redd during spawning activities (Kondolf 2000).

Prior to this field study, we speculated that deep-water spawning habitats may exist in the reservoir. For example, the USFWS found that that majority of Chinook salmon redds in a survey just downstream of Keswick Dam on the Sacramento River were in water depths of 8 to 12 feet (Vogel and Taylor 1987). In contrast, based on data collected in this study, the deeper water areas upstream of Crocker-Huffman Dam either possess unsuitable substrates, unsuitably low velocities, or (mostly) combinations of both.

Based on comparisons where suitable velocities and potentially suitable substrates were present in the surveys upstream of Crocker-Huffman Dam, the only reach with sufficient gradient where fish could theoretically spawn is upstream of Rattlesnake Bend. Results of core samples of riverbed substrates in that reach demonstrated that the level of very fine sediment (<0.85 mm) is relatively low (Figure 40). Most samples showed a percentage of very fine sediments below the level of concern for incubating eggs. Additionally, the level of coarser fine material (<4.75 mm and >0.85 mm) is also relatively low and is generally below the range where deleterious effects on fry emergence could occur. However, core samples collected a substantial amount of large-sized substrate material (refer to pebble counts) and the dominance of large particle sizes in the core samples reduces the remaining finer fractions as a proportion of the total samples. The core samples collected above Crocker-Huffman Dam were compared to 15 samples collected downstream of the dam at five known salmon spawning riffles (Figure 41) which were also, on average, found to be below the level of concern for egg incubation and fry emergence. Comparisons of these Merced River substrate samples with those collected in potential salmon spawning areas in five northern California streams show that the levels of very fine and coarse fine material in Merced River samples were similar or lower to those streams (Figure 55).

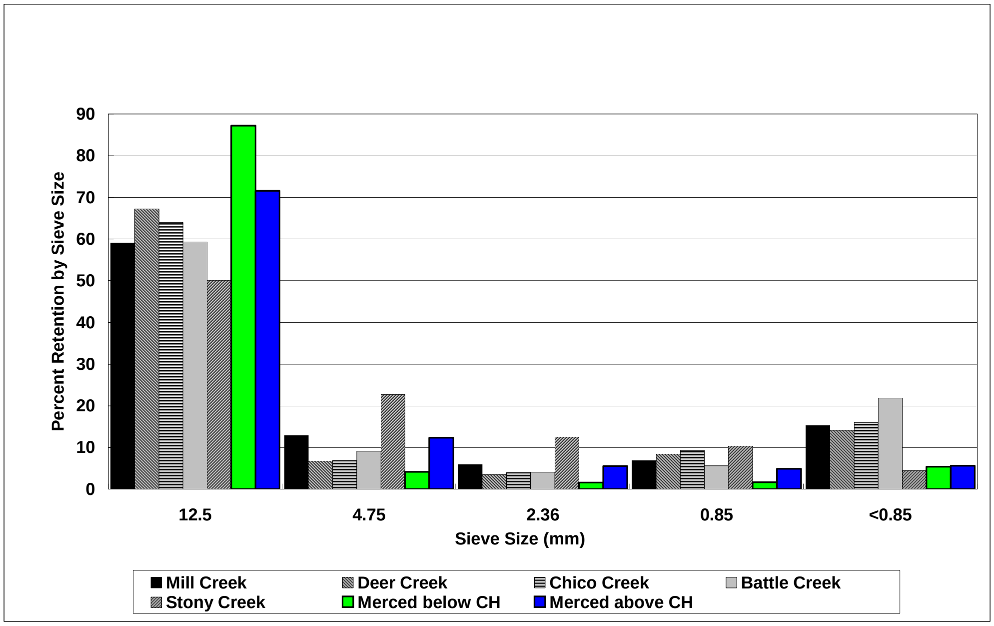


Figure 55. Comparison of substrate composition in potential salmon spawning areas for five northern California streams with Merced River substrate samples (unpublished data, Natural Resource Scientists, Inc.).

The core samples collected surface and subsurface material in its natural setting. Because spawning activities would further cleanse the substrate of fines, the levels of fines determined from this study indicate that this factor would probably not limit salmonid production if fish were reintroduced above Crocker-Huffman Dam. If salmonids were to successfully spawn in the reach downstream of Merced Falls Dam, an advantage of that location is the low probability of fine sediments (e.g., silt) entering the reach and being deposited in the redds due to the upstream reservoirs catching fine, settleable material following precipitation runoff events. However, an exception may occur when PG&E temporarily drains Merced Falls Reservoir for maintenance activities (Figure 56). When the reservoir is drained, some mobilization of silt and sand may move fine material downstream into the reach below Merced Falls Dam.

Figure 56. Merced Falls Reservoir after it had been drained.

Pebble count data revealed that the surface particle sizes in potential spawning areas upstream of Rattlesnake Bend are relatively large. Visual assessment of spawning suitability based on the previously-described qualitative criteria indicated fair to poor classification in most areas primarily due to the presence of large cobbles or boulders (Figure 44). There were some isolated areas from transect no. 51 to no. 55 where the surface substrate (cobbles) appeared suitable for spawning based on visual observation. However, the median particle sizes (d_{50}) at most transects (Figures 35 and 36) are substantially larger than those observed in areas downstream of Crocker-Huffman Dam (Figure 38) and in known salmon spawning areas below the dam (Figure 37). Kondolf and Wolman (1993), as cited by Kondolf (1997a), and Kondolf (2000) suggested that salmonids can spawn in surface median particle sizes (d_{50}) up to 10 percent of their body length. Most sampling sites had d_{50} particle sizes larger than 100 mm indicating that the substrate is too large for suitable salmon spawning. Adult Chinook salmon are usually much smaller than 100 cm in length. In a comprehensive database of adult Chinook salmon returning to the Mokelumne River over 10 years, the average length of salmon each year ranged from 73 cm to 79 cm with a mean of 75 cm for a sample size of 28,115 salmon (Marine and Vogel 2000). Using the 10 percent criterion, a 75-cm salmon would be capable of moving d_{50} particle sizes of 75 mm or much smaller than most particle sizes observed in the reach between Rattlesnake Bend and Merced Falls Dam. Because steelhead utilize smaller cobbles and gravels than Chinook salmon, that species would be expected to have greater difficulty spawning in the large substrates. However, d_{50} particle sizes observed downstream of Crocker-Huffman Dam are in the ranges suitable for most salmon (using the 10 percent criterion) (Figures 37 and 38). Adult Chinook salmon construct redds of a size approximately 6 square yards, but accounting for a defense area, a spawning pair should have a total area of 24 square yards. In contrast, rainbow trout/steelhead can spawn in small pockets of gravel (Flosi *et al*. 1998). Trout redds are only about 0.3 square yards with a total defense area of 2 square yards [Burner (1951) as cited by Bell (1991)]. It is unknown if the rainbow trout in Crocker-Huffman Reservoir are of wild or hatchery origin; if wild, it would suggest that some areas downstream of Merced Falls Dam possess suitable spawning habitat for steelhead, but those areas are probably small.

Among the spawning requirements for substrate, temperature, flow regime, and water velocities, the lack of smaller substrate particles in the range preferred by spawning salmon would likely be a primary, significant factor limiting anadromous salmonid reproduction upstream of Crocker-Huffman Dam. However, water temperatures are not likely to be limiting based on data examined for this study. During the period when salmon and steelhead would be expected to spawn and during the period of egg incubation, temperatures are below lethal levels. Temperatures for both salmon and steelhead are largely more favorable for spawning upstream of Crocker-Huffman Dam compared to downstream reaches, a circumstance attributable to closer proximity to hypolimnetic releases from Lake McClure. Additionally, based on water velocities measured in the reach between Merced Falls Dam and Rattlesnake Bend (Appendix A) and the required regulatory flow regime conveyed through this reach to downstream areas (previously discussed), flow, by itself, would not likely be a limiting factor for spawning. In some areas of the low-gradient riffles and runs, water velocities were found to be within the range preferred for spawning. The measured near-bed velocities were sometimes affected by the large particle substrate upstream of Rattlesnake Bend (e.g., backeddys behind boulders) so it's difficult to predict how velocities would change if smaller-sized substrates (gravels and small cobbles) were present. Chinook salmon undoubtedly spawned in this reach prior to closure of the fish ladder on Crocker-Huffman Dam. In 1970, about 100 adult salmon inadvertently got into the reservoir when a physical barrier at the upstream end of the artificial spawning channel below Crocker-Huffman Dam was displaced; some of these fish spawned in the upstream reach (Menchen 1972). However, the success of the spawning activity was unknown. In the nearly four decades since salmon were allowed to spawn in this area, the substrate quality would have deteriorated due to the continual loss of smaller-sized substrate preferred for spawning caused by high-flow events. Hydraulic and physical habitat simulation modeling (e.g., PHABSIM[8]) would be necessary to predict available spawning habitat following the addition of good spawning substrate.

Reservoirs can trap the downstream movement of gravels and release clear water which may cause the winnowing of smaller particles in reaches downstream of dams resulting in progressively coarser particles over time. This "armoring" process may render the riverbed to be unsuitable for salmon spawning (Kondolf 1997b, Kondolf 2000). This phenomenon has occurred in the reach downstream of Merced Falls Dam and partially occurred in some areas downstream of Crocker-Huffman Dam. Additionally, the large-scale removal of spawning-sized gravels from the active channel resulting from historical gold dredging in the area greatly impacted the present-day fish habitats downstream of Merced Falls Dam. The river channel downstream of Crocker-Huffman Dam in the Dredger Tailings Reach is armored and is scoured to bedrock in numerous areas. State agencies have implemented several gravel augmentation projects within this reach to increase spawning habitat for salmon. Additional large-scale and long-term gravel augmentation has been recommended to increase Chinook salmon habitats (Stillwater 2001a). Among other measures, large-scale gravel replenishment downstream of Merced Falls Dam would have to occur prior to reintroduction of anadromous salmonids upstream of Crocker-Huffman Dam. However, gravel supplementation downstream of Merced Falls Dam would ultimately result in movement of the material downstream into the deeper, slower water of the reservoir where it would become unavailable for spawning salmon. Analyses of coarse bedload transport through the reservoir would have to be conducted to ensure continual gravel additions do not result in filling in the reservoir.

[8] PHABSIM is "an integrated collection of hydraulic and microhabitat simulation models designed to quantify the amount of microhabitat available for a target species over a wide range of discharges. PHABSIM combines empirical descriptions of the structural features of the channel, simulated distributions of depth and velocity, and habitat suitability criteria for the target species. This combination reveals a functional relationship between streamflow and the area of microhabitat available for the target species, per unit length of stream." (Bovee *et al*. 1998)

Anadromous Salmonid Rearing Habitats

Anadromous salmonid fry are particularly vulnerable at emergence and the initiation of feeding because the fish leave the secure, low energy environment in the interstices of streambed gravels and enter the high energy environment of the river. Upon emergence, fry either swim or are displaced downstream; large downstream movements are typical of most populations (Healey 1991). Fry seek shallow water and low water velocities during the final stages of yolk sac absorbance (Moyle 2002). As fish grow, they continually shift their distribution to deeper, faster water. The mechanisms affecting dispersal can be highly variable. Downstream movements of Chinook fry may continue as the fish move out of the river or fry may take up residency in the river (Healey 1991). When young salmon move from spawning areas to rearing areas, complex factors may cause downstream or upstream movements (or both) which may be environmentally and genetically controlled. Downstream dispersal could be a function of high velocities, turbidity, search for food, a genetic basis, density, temperature, aggression, and competitive interactions. Many factors may interact to produce these complex instream movements. There is only very limited knowledge of these factors affecting Central Valley Chinook salmon (Vogel 1993).

Instream habitat complexity is important for fry and juvenile Chinook salmon. Habitat complexity provided by instream structure such as large woody debris (e.g., fallen trees and rootwads) and large rocks or boulders gives young salmonids areas to rear and protection from predatory fish. Proximity of a low-velocity region (for a fish's holding position) to a high velocity region (for feeding), or the proximity of predators and competitors can have overriding influences on how young salmon take up residency at particular locations in a river. The occupation of a sheltered place in the stream in close proximity to high velocities (and consequently substantial food drift) minimizes the energy expenditure associated with the fish maintaining position in the currents while maximizing food availability. The fish must do so while avoiding predators (e.g., bass, squawfish, or birds) and minimizing interactions with competitors. Cover habitat for rearing Chinook has been described as the characteristics associated with: water depth, water turbulence, large-particle substrates, overhanging or undercut banks, overhanging riparian vegetation, woody debris, and aquatic vegetation (Bjornn and Reiser 1991). The needs of Chinook salmon for cover habitats vary diurnally, seasonally, and by size of the fish (Vogel 1993).

Cover is important for rearing but it is difficult to accurately define and measure. Most researchers have measured mean column water velocity, "nose" velocity, depth, and substrate and incorporate this information into models. However, the utility of these models has been questioned because additional factors, such as proximity of a low-velocity area (for a holding position) to a high velocity area (for feeding), or the proximity of predators and competitors could have overriding influences on how Chinook take up residency at particular locations in a river. Furthermore, it is very difficult to accurately measure and quantify the rearing habitat diversity associated with localized velocity shear zones. If a fish has a known utilization or affinity to cover, that utilization is likely to vary depending on stream flow conditions. With low stream flow conditions, the cover attributes (e.g., velocity breaks, turbulence, bubble curtain, depth, etc.) may dictate a relatively close proximity of a fish to the cover feature. For example, Hampton (1988) found that surface turbulence served as cover for fry and juvenile steelhead, Chinook, and coho in the Trinity River and was particularly important for steelhead and Chinook juveniles. As stream flow increases, the cover characteristics change, extending the probable range of the fish's utilization to the cover structure through an expanded range of the cover attributes (e.g., greater turbulence, increase in bubble curtain, depth, etc.).

Studies in large rivers indicate that rearing habitat for Chinook salmon fry decreases with increased flow because of a combination of undesirable depths at channel margins, unsuitably high water velocities, and reduction in lateral slope areas utilized by young fish (Tiffan *et al.* 2002). In the Hanford Reach of the Columbia River, Tiffan *et al.* (2002) found that decreases in near-shore lateral slope and water velocities associated with decreased flow increased the probability of habitat use and actual Chinook fry observed. Additionally, they found that high flows inundated many islands thereby reducing or eliminating rearing habitat that had been present at lower flows. No relationship was noted between Chinook fry usage and submerged terrestrial vegetation in the Hanford Reach of the Columbia River (based on observations and underwater videography) prompting Tiffan *et al.* (2002) to conclude that its importance for Chinook rearing remains unknown. The Alaska Department of Fish and Game estimated that over 80 percent of ideal juvenile Chinook salmon rearing habitat was found within a 6-foot wide corridor adjacent to the banks of the Kenai River and was described as "water velocities less than 1.0 feet per second, undercut banks with overhanging vegetation, and gravel/cobble substrates" (Liepitz 1994).

Figures 57 - 59 show typical portions of the river channel in Crocker-Huffman Reservoir. The encroached riparian vegetation is abundant throughout the three-mile reach and provides what could be characterized as a good overstory and understory with numerous areas of overhanging vegetation (Appendix E). More than half of the reach between Crocker-Huffman Dam and Rattlesnake Bend possessed medium to high coverage between transects for both overstory and understory (Figures 45 and 46); medium or high coverage was even greater (>75% combined) between transects upstream of Rattlesnake Bend (Figures 47 and 48). Approximately half of the riparian vegetation between transects had medium or high coverage extending over five feet from the channel margins (Figures 49 – 52). Additionally, the riparian corridor provides continual recruitment of terrestrial vegetation into the river channel margins. Nearly half of all estimates between transects had medium to high instream cover resulting from woody debris (e.g., dead branches) or live vegetation. These attributes are generally considered as favorable for rearing anadromous salmonids, in particular because rearing salmonids require some protective cover and a constant food supply from "drift" organisms and this supply may be in the form of aquatic invertebrates or terrestrial invertebrates introduced into the stream from overhanging riparian vegetation (Vogel 1993).

Figure 57. Crocker-Huffman Reservoir approximately one-half mile above the dam (looking upstream).

Figure 58. Crocker-Huffman Reservoir approximately one-half mile above the dam (looking downstream).

Figure 59. Merced River downstream of Merced Falls Dam (looking upstream).

Overall, the habitat types in the three-mile reach above Crocker-Huffman Dam are relatively simple, lacking channel complexity. A recent aerial reconnaissance survey of the Merced River in 2005 identified only several stream habitat classifications between Crocker-Huffman and Merced Falls dams (80% pool, 12% low gradient riffle, and 7% run) compared to numerous and varied habitat types downstream of Crocker-Huffman dam. The entire reach from Crocker-Huffman Dam to Rattlesnake Bend and approximately one half of the reach between Rattlesnake Bend and Merced Falls Dam were classified as a pool habitat type (Figure 60) (Stillwater 2006).

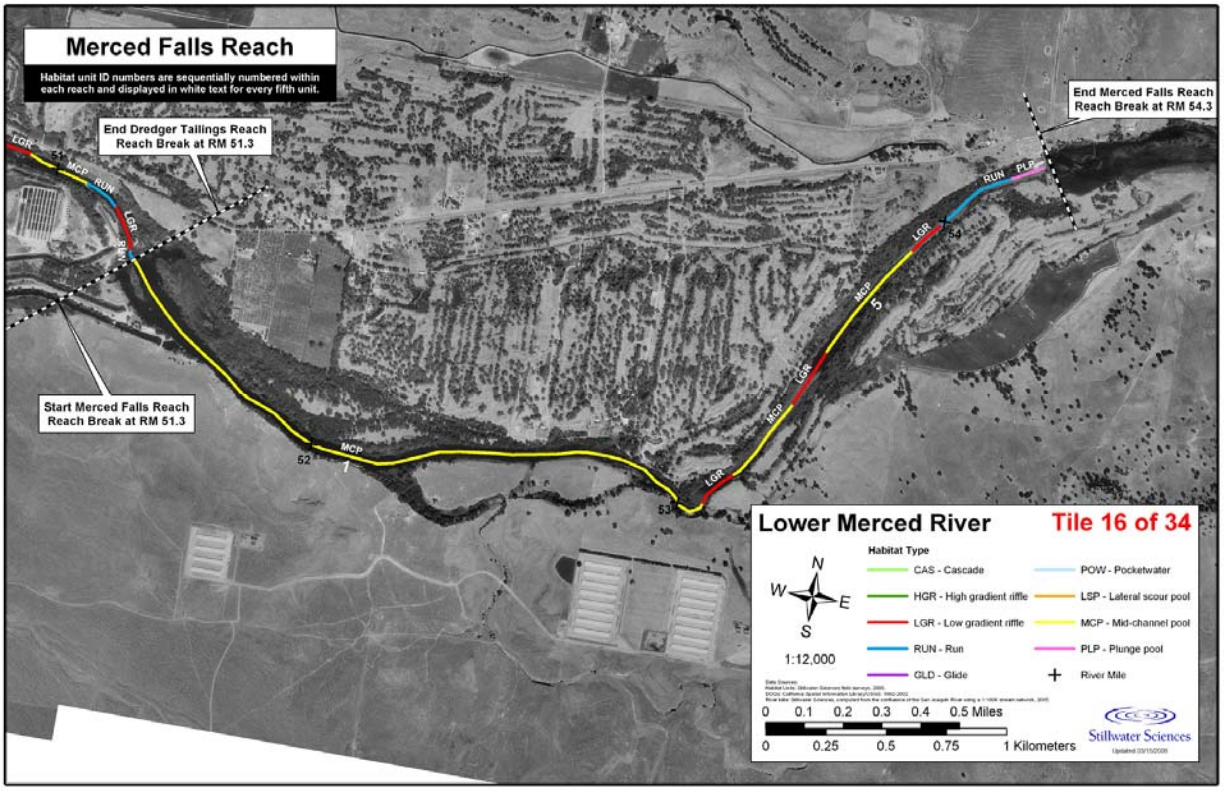


Figure 60. Stream habitat types in Crocker-Huffman Reservoir based on aerial surveys conducted in 2005 (source: Stillwater 2006).

In this study, we also found that the three-mile reach was dominated by three stream macrohabitat types: low-gradient riffle, run, and dammed pool. The reach from Crocker-Huffman Dam to Rattlesnake Bend was principally pool habitat and the reach upstream of Rattlesnake Bend was dominated by a largely indeterminate blend between riffle and run habitats that changes with flow conditions. McCain *et al*. (1990) described these channel features as follows:

Low-Gradient Riffle: Shallow reaches with swiftly flowing, turbulent water with some partially exposed substrate. Gradient <4%, substrate is usually cobble dominated.

Run: Swiftly flowing reaches with little surface agitation and no major flow obstructions. Often appears as flooded riffles. Typical substrates are gravel, cobble and boulders.

Dammed Pool: Water impounded from a complete or nearly complete channel blockage (debris jams, rock landslides or beaver dams). Substrate tends toward smaller gravels and sand.

The dammed pool habitat channel feature in Crocker-Huffman Reservoir is obviously not natural and is due to the concrete dam. Crocker-Huffman Dam's backwater influence extends approximately 1.7 miles upstream of the dam to the bottom of the riffle just upstream of

Rattlesnake Bend creating a dammed pool encompassing 57% of the habitat. The channel margins in this region are deeper than that preferred by salmonid fry and probably inferior rearing habitat as compared to the river downstream of Crocker-Huffman Dam.

The principal area where Chinook salmon fry may find suitable rearing habitats is the narrow, near-bank fringe between Rattlesnake Bend and Merced Falls Dam. This reach is dominated by low-gradient riffle habitats and runs, depending on flow conditions (i.e., release from Merced Falls Dam). A short high-gradient riffle is present immediately upstream of Rattlesnake Bend and is the only macrohabitat of that type present in the three-mile reach between the dams. Due to the encroached channel upstream of Rattlesnake Bend and the relatively small amount of shallow, quiet water, that area could limit fry production even though riparian vegetation and instream channel margin cover is abundant. Because of the riparian encroachment and the confined channel, the typical fry rearing habitats are probably limiting and lower in quality as compared to the lower Merced River. High-flow events during emergence can cause fry dispersal downstream (Moyle 2002). High flows in this reach commonly occur in the winter months for upstream reservoir flood control operations during above normal or wet hydrologic conditions and could easily displace fry into downstream lake-like areas of the reservoir where salmon fry rearing habitats are probably poor. Additionally, increased reservoir releases conveyed to the Merced ID Main Canal usually begin in March (Figure 12) resulting in high flows, and therefore high velocities, through the confined, encroached reach that may displace fry to downstream areas (Figure 61).

Figure 61. Merced River channel immediately downstream of Merced Falls Dam during a release of 1,226 cfs (preliminary data).

If salmon could successfully reproduce upstream of Crocker-Huffman Dam, the resulting progeny must avoid predators that reside in Crocker Huffman Reservoir. Large adult rainbow trout and large numbers of introduced, non-native predatory Centrachids (e.g., bass) may pose considerable threats to salmon fry and smolts. The reach between Crocker-Huffman Dam and Merced ID's Main Canal intake has abundant growth of macrophytes filling up much of the water column (Figures 62 – 64). Rearing salmonids inevitably have to migrate through the prolific, dense vegetation which may harbor predatory fish species. Young salmon successfully navigating this lower-most reach would subsequently pass over the dam and could be lost to predatory fish downstream of the dam (e.g., striped bass). The combination of accumulation of predatory fish below a barrier and juvenile salmon becoming disoriented passing over the barrier create ideal conditions for predation. A fish population study was not conducted as part of this investigation. Prior to reintroduction of anadromous salmonids above the dam, it would be valuable to evaluate the relative abundance of fish species in the reservoir, particularly fish that may prey on young salmonids.

Figure 62. Crocker-Huffman Reservoir looking upstream from Crocker-Huffman Dam.

Figure 63. Aquatic vegetation in Crocker-Huffman Reservoir (adjacent to Merced ID Main Canal looking downstream).

Figure 64. Aquatic vegetation in Crocker-Huffman Reservoir (adjacent to Merced ID Main Canal looking upstream).

The Dredger Tailings Reach downstream of Crocker-Huffman Dam has historically provided most of the habitats for anadromous salmonid production in the Merced River. Although the

Merced River Corridor Plan did not include the reach upstream of Crocker-Huffman Dam, the document identified the following anthropogenic changes to the Dredger Tailings Reach:

- Removal of riparian forests;
- Flow regulation;
- Interception of sediment in Lake McClure, which intercepts sediment supply from the upper 81 percent of the watershed;
- Direct removal of sediment from the channel and floodplain through dredger mining;
- Placement of mined sediment on the floodplain in irregular tailings piles; and
- Potential input of nutrients and contaminants (Stillwater 2002).

With the major exceptions of the construction of Crocker-Huffman Dam, creation of a reservoir, and the conveyance of water through its reservoir to Merced ID's Main Canal, the anthropogenic changes in the reach between Merced Falls Dam and Crocker-Huffman Dam are similar to those described for the Dredger Tailings Reach. The lower Merced River and floodplain were dredged for gold from 1907 through 1952 which, combined with sediment storage in upstream reservoirs, depleted coarse sediments in the dredged river reaches and is characterized by long, deep pools (Stillwater 2002). The anthropogenic changes in the Dredger Tailings Reach have resulted in a change from a complex, multiple-channel system to a simplified, single-thread system with a narrow floodplain adjacent to the channel; the channel is typified by long, deep pools that are scoured to bedrock or to a coarse cobble armor layer (Stillwater 2002). The lower Merced River channel width from Crocker-Huffman Dam (RM 52) to RM 15 has been reduced by an average of 85 feet, or 33 percent of the mean 1937 channel width due to riparian encroachment into the active channel; consequently, the aquatic habitat has been reduced with a channel now characterized by a simplified cross section with no active bars (Vick 1995, as cited by Stillwater 2002). Similarly, the reach between Crocker-Huffman and Merced Falls dams also presently possesses a simplified cross section with no active bars.

After completion of a long-term instream flow evaluation on the Trinity River in northern California, the USFWS found that Chinook salmon fry habitat was restricted by morphological features of the river channel, not terrestrial vegetation on the river banks. In the Trinity River, long-term decreased flows due to a large trans-basin diversion to the Sacramento River caused riparian vegetation (e.g., willows) to encroach into the previously active river channel and reduced shallow edge habitats utilized by salmon fry (Figure 65).[9]

[9] "Construction and operation of the Trinity River Diversion resulted in a change in channel morphology from one of gently sloping point bars to a narrow trapezoidal channel contained within steep riparian berms. This change in channel morphology eliminated most of the gently sloping point bars of the pre-dam alluvial channel that provided open, shallow, low-velocity gravel bar habitats for rearing salmonid fry." (USFWS and Hoopa Valley Tribe 1999)

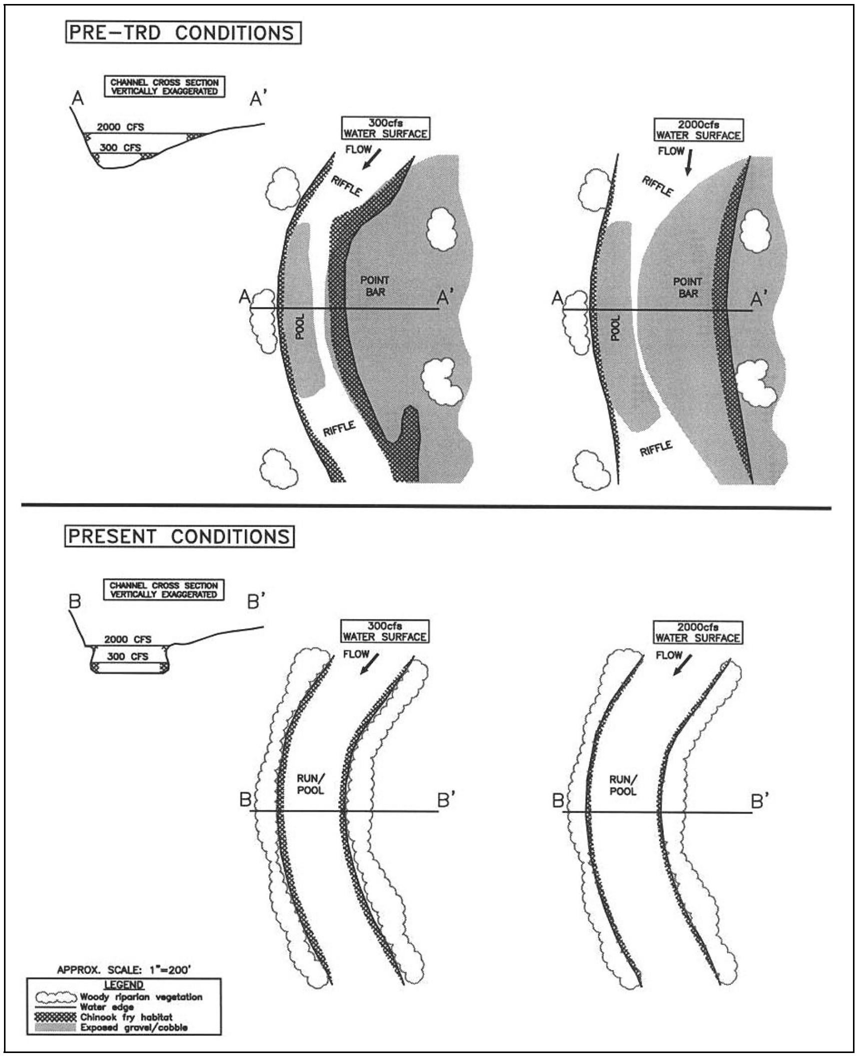


Figure 65. Idealized pre-Trinity River Diversion (TRD) point bar showing relative surface area of fry Chinook rearing habitat in comparison with present conditions of riparian encroachment and narrow channel configuration (original figure from USFWS and Hoopa Valley Tribe 1999).

To overcome this limitation, the USFWS recommended mechanical measures (e.g., bulldozers) to eliminate riparian berms and expand shallow edge habitats preferred by salmon fry for rearing (Figure 66).

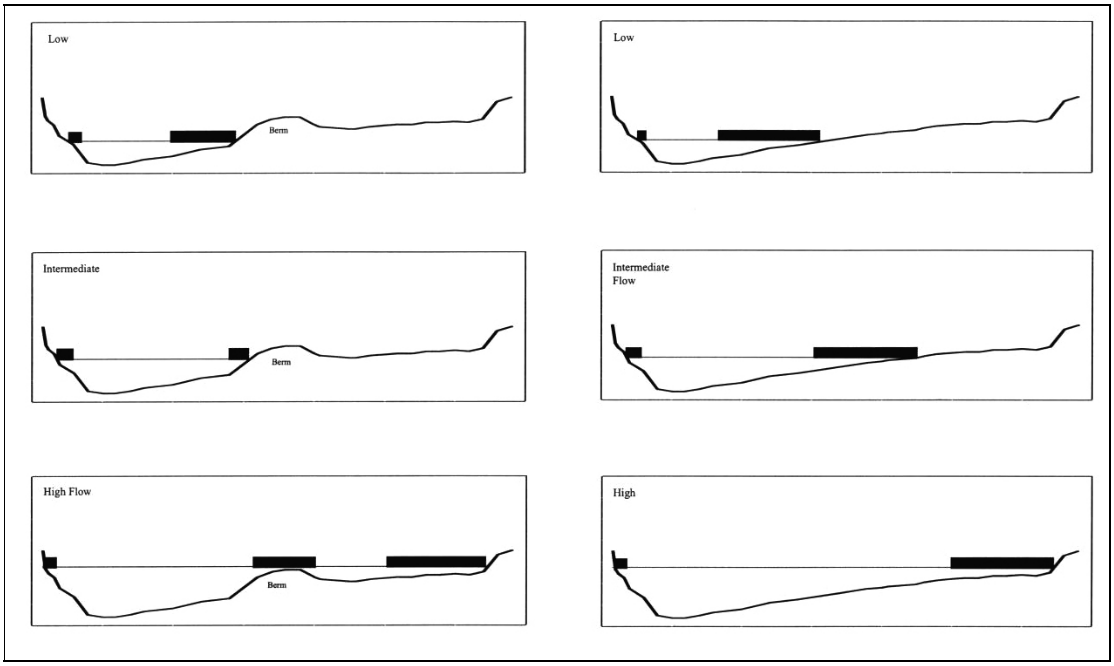


Figure 66. Representation of the existing Trinity River channel with a riparian berm and the rehabilated channel with salmonid fry rearing habitat (represented by the boxes) at low, intermediate, and high flows (original figure from USFWS and Hoopa Valley Tribe 1999).

In the Trinity River Flow Evaluation Final Report, the USFWS and Hoopa Valley Tribe (1999) concluded:

> "The broadening and gradual sloping of the narrow trapezoidal channel allowed the river flows to spread out and water velocities to decrease, providing suitable depths and velocities for rearing salmonids regardless of flow magnitude. Bands of suitable habitat along the stream margin were relatively consistent at all flows and migrated up and down the gently sloping bank relative to changes in flow. Because the river often experiences substantial changes in flow during winter storms, providing suitable habitat throughout a range of flows is necessary to prevent habitat bottlenecks."

Opportunities to implement such measures between Crocker-Huffman and Merced Falls dams are limited due to the steep topographic relief on the left side of the river (facing downstream) and the private property on the right side of the river.

Crocker-Huffman Dam Fish Ladder

Included in this study was an examination of the presently non-functional fishway on Crocker-Huffman Dam to determine measures that would be necessary to modify or replace the fishway should suitable anadromous salmonid habitats be found upstream of the dam and fish were reintroduced into upstream areas. Both Crocker-Huffman and Merced Falls dams have fish ladders but are currently inoperable (Figures 67 - 70). The ladders were blocked by CDFG in the early 1970s in association with the construction of the salmon spawning channel just downstream of Crocker-Huffman Dam (Stillwater 2001a).

Figure 67. Non-operational fish ladder on Crocker-Huffman Dam.

Figure 68. Non-operational fish ladder on Crocker-Huffman Dam.

Figure 69. Non-operational fish ladder on Merced Falls Dam (left side of picture).

Figure 70. Non-operational fish ladder on Merced Falls Dam.

The existing Crocker-Huffman Dam ladder is a weir-and-pool design with seven weirs and six small pools and is approximately 56 feet long and 14 feet high. Each irregularly-shaped pool is approximately 6-feet long by 7-feet wide by 2-feet deep, with variations in these dimensions between each pool. Detailed dimensions of the ladder are shown in Figures 71 and 72. The ladder is positioned approximately 140 feet from the dam's right-side abutment.

The Crocker-Huffman Dam fish ladder does not meet present-day criteria for fish passage. For example, modern fish ladders commonly have one foot or less head between pools (Bates 1994, Clay 1995), whereas the pools in the Crocker-Huffman fish ladder would have about two feet of head between pools if it were made operational. Fish ladders are usually constructed on the banklines (Bates 1994), not out in the channel. Also, the Crocker-Huffman Dam fishway does not incorporate a design feature for the provision of auxiliary attraction flow for the fish entrance which is commonly constructed in modern fishways (Bates 1994, Clay 1995).

A combination of the existing Crocker-Huffman Dam's fish ladder entrance location, entrance configuration, and insufficient water discharge would all likely contribute to suboptimal upstream fish passage conditions. An appropriate entrance to a fish ladder is the single most important part of any fishway system (Powers *et al.* 1985, Bates 1994, Clay 1995). Location and hydraulics are two factors which are considered in the design of fish ladder entrances (Powers *et al.* 1985). The shallow water conditions at the fish entrance and extended distance away from

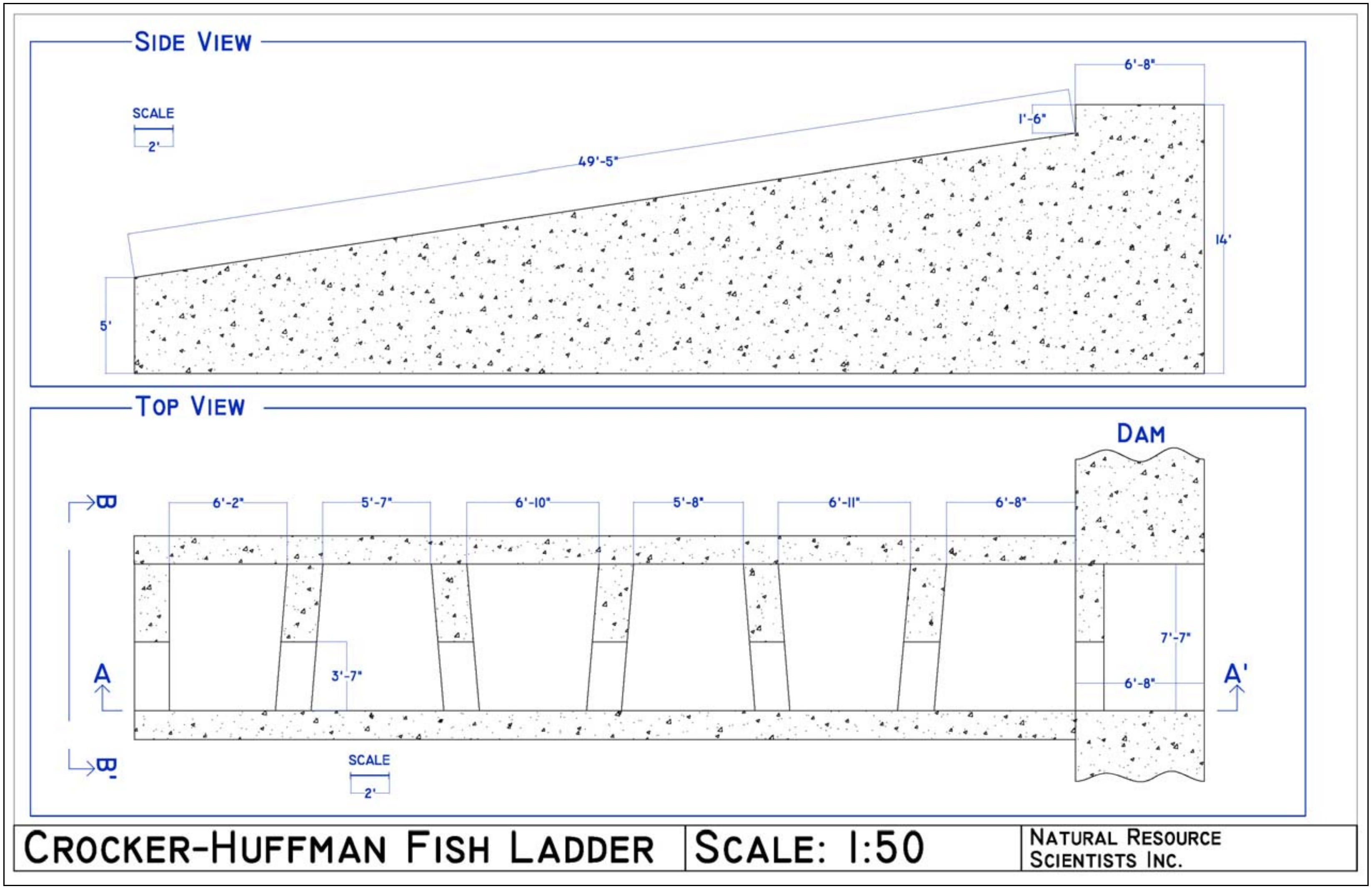


Figure 71. Top and side view of the Crocker-Huffman Dam fish ladder.

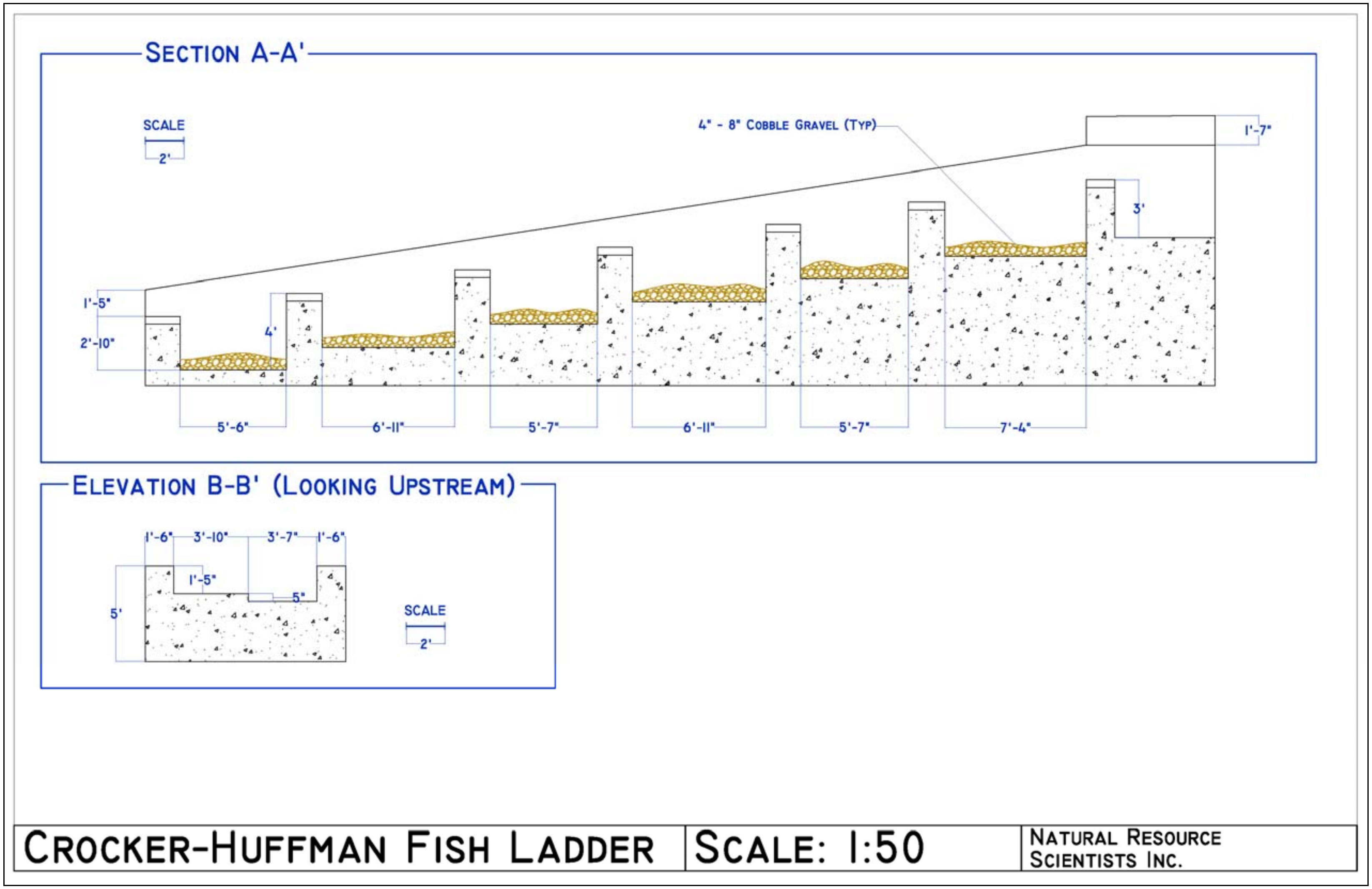


Figure 72. Longitudinal, sectional profile of the Crocker-Huffman Dam fish ladder.

the dam and shoreline would probably provide poor attraction for fish into the ladder, particularly when spill occurs across the entire face of the dam. Rainey (1991) recommended avoidance of shallow, high-velocity conditions near a fish ladder entrance and suggested that a minimum of a 5-foot pool depth outside the entrance is essential because it provides excellent holding water, aids in reducing spill turbulence, and reduces fish passage delay. Extensive evaluations of fish ladders in France during the 1980s found that, in most cases, failure in fish facilities' efficiency resulted from the lack of attraction into the fish ladder, due to a an unsuitable location of the entrance or an insufficient water discharge (Larinier 1990). Vogel *et al*. (1988) concluded that fish ladder entrance configurations at the Red Bluff Diversion Dam (RBDD) on the Sacramento River were contributing factors to reduction in performance for adult salmon passage.

Depending on flow conditions at Crocker-Huffman Dam, the orientation of the fish ladder away from the river bank and off the base of the dam would probably make it difficult for salmon to find the entrance (Figure 73). Because the proportion of flow from the fish ladder would be low relative to total flow passing over the dam, the attraction to the ladder would probably be poor. During low-flow conditions, the fish ladder flow could be a large component of the entire flow downstream of the dam and, therefore, flow by itself would not likely be a significant factor limiting fish passage under those conditions. The existing flow regime during the fall is relatively low at Crocker-Huffman Dam during the first half of the salmon migration season (up to late November) but may increase due to pulse flows during October or November (refer to prior discussion on flow requirements) or increased reservoir releases later in the season (e.g., December). Under moderate- to high-flow conditions, the relatively low flow through the existing ladder (should it be made operable) would probably be a limiting factor for fish attraction. Such circumstances are why modern fish ladders often include a feature to supplement the flow at the fish entrance (auxiliary, attraction flow). The auxiliary water added above the normal ladder flows is needed to extend the area of intensity of velocity of outflow from the ladder entrance for fish and to provide velocities in the ladder sufficiently high to encourage upstream migration (Clay 1995). In recent fish ladder projects constructed on tributaries to the Columbia River, total attraction flows from fishways ranged up to 10 percent of the total stream flow at mid- to high-river stages (Rainey 1991). Vogel *et al*. (1990) found that radio-tagged Chinook salmon downstream of RBDD exhibited the least delay in fish passage when the total fish ladder flow was 8 to 10 percent of the total flow past the dam and led them to recommend additional fishway flow during high-flow periods to approximate 10 percent of the total river flow.

The existing Crocker-Huffman Dam fish ladder is an outdated design and would probably limit upstream migration of anadromous salmonids if the ladder were made operational (i.e., opening up flow into the ladder). Because operation of the existing ladder would probably cause fish delay or blockage leading to stress or injury, it is likely that one or more new fish ladders meeting modern-day criteria would have to be added to the dam. The design considerations for a fish ladder would include a thorough understanding of the following five components:

1) immediate reach of the river downstream of the ladder,
2) entrance to the fish ladder,
3) passage structure itself,
4) ladder's exit, and
5) reach of the river where fish exit the ladder (Odeh and Haro 2000).

The design considerations for potential types of fishways are many and not intended to be described here. Among numerous sources, "Introduction to Fishway Design" by Katopodis (1992), "Fishway Design Guidelines for Pacific Salmon" by Bates (1994) and "Design of Fishways and Other Fish Facilities" by Clay (1995) provide an exhaustive description of design features to accommodate upstream fish passage.

Figure 73. The Crocker-Huffman Dam fish ladder during moderate to high flow conditions past the dam (approximately 1963 cfs – preliminary data).

Potential Effects on Merced Hatchery

One of the objectives of this feasibility study was to assess the implications for and interactions of reintroduction of salmon upstream of the dam with ongoing and future Merced Hatchery operations. Merced Hatchery, located immediately downstream of Crocker-Huffman Dam, is the only hatchery in the San Joaquin River basin that utilizes San Joaquin basin Chinook salmon broodstock (CDFG 1998). Merced Hatchery, operated by CDFG, provides annual economic benefit from sport and commercial harvest, educational opportunities on environmental topics, a critically important safeguard to protect and sustain wild salmon runs during years of low natural production (e.g., droughts or floods), yearly supplementation and subsequent boosting of in-river natural production of wild salmon, replacement of natural fish production from lost habitats resulting from dam construction, and juvenile salmon for numerous scientific experiments (e.g., VAMP and Merced River biological investigations). Annual returns to the hatchery are shown in Figure 10.

The original facility was designed as a Chinook salmon spawning channel (Ruben E. Schmidt Salmon Spawning Channel) to enhance salmon runs in the Merced River. In 1967, it was anticipated that the combination of salmon production from the spawning channel and in-river production would eventually result in 27,600 adult salmon returning to the Merced River annually (Brittan and Trice 1967). The spawning channel was built by Merced ID using Davis-Grunsky Act funds received for recreation and fish enhancement. The facility was constructed on pasture land Merced ID owned downstream of Crocker-Huffman Dam; spawning gravel was obtained from dredger tailings on nearby land (295 acres) the District purchased using DG funds (McSwain 1977). It was completed in the summer of 1970 and went into operation in the fall of that year. Because the salmon runs were low at the time, the original broodstock was obtained from the Stanislaus River (CDFG 2000). The original facility also included an off-channel rearing pond to raise juvenile salmon to a yearling size (Menchen 1972). Water supply quantity, water quality, and design specifications of the original channel and subsequent modifications are provided below based on communications with Mike Cozart and Tim Heyne, CDFG.

Initially, measuring along the inside perimeter from the head gates to the fishway, the Merced River spawning channel was 4,372 lineal feet long, with a bottom width of 63 feet (Figure 74). The loop was 3,830 feet long, and the remaining 460 feet provided a resting pool 4.5 feet deep. A mixture of ¾-inch to 5-inch gravel formed a 3-foot layer on the bottom of the channel, providing 241,900 ft^2 of spawning area; estimates as sufficient for 6,000 female salmon. The rearing pond was 250 feet long and 15 feet wide. A diversion from the reservoir created by Crocker-Huffman Dam supplied the water for the operation (Figure 74).

Figure 74. Aerial photo of the original Merced River spawning channel (loop at the bottom of the picture). Water supply intake is from Crocker-Huffman Reservoir at lower right. Calaveras Trout Farm is in the middle of the picture.

Water entered the channel through two flumes leading into diffusion chambers and welled up with a vertical velocity of ½ ft/sec. From the beginning to the end of the spawning season (generally from mid October until early January), the flow through the spawning channel was maintained between 150 and 200 cfs. At the end of the season, it was reduced to just less than 100 cfs, where it remained until the following spawning season. The average velocity of the water flowing through the channel during spawning season was 2 ft/sec, and the average depth of the channel was 1.5 ft. The spawning channel operated in this manner for two years before expanding.

The first modifications to the channel took place in 1972 and 1974, when two additional rearing ponds, each 275 x 30 -feet, with a capacity to raise around 100,000 salmon to yearling size before release into the Merced River, were completed. From 1974 through 1976, the rearing ponds were also used to raise coho salmon (*O. kisutch*) for release in San Diego County. During the 1970s, coho salmon were periodically released by CDFG in the lower Merced River and stocked in upstream reservoirs (McSwain 1977). In 1979, the issue of warm water in the channel during summer months was resolved by drawing cold water directly from the bottom of the Crocker-Huffman Reservoir through a newly installed water supply pipe capable of delivering 20 cfs. The following year, the hatchery began capturing a large portion of the returning females and artificially spawning them. This marked a major change in the hatchery's mode of operation.

The facility was converted to a conventional fish hatchery (i.e., artificial spawning and rearing) through gradual facility changes during the 1980s and 1990s. The changes were implemented to increase fish production efficiency (Loudermilk 1998). In 1997, CDFG formally identified the production goals and objectives for the hatchery: "to effectively supplement natural production of Chinook salmon in the Merced River to help restore and maintain healthy runs that sustain sport and commercial fisheries" with an objective to achieve an annual average egg take of two million eggs and 960,000 smolt production (CDFG 1997). The switch from primarily natural spawning to artificial spawning required significant modifications to the hatchery's configuration. In 1980, a temporary hatchery shed with six double stacks of Heath® incubator trays capable of incubating and hatching approximately 900,000 Chinook salmon eggs were installed, as well as four temporary nursery tanks (3 x 6 feet). The tanks each had a capacity of approximately 40,000 – 50,000 "swim-up"-size Chinook salmon. Water was supplied to the temporary hatchery through a new 8-inch PVC gravity-flow pipeline. The temporary hatchery used 12 to 13 cfs when incubating eggs and hatching fry. No water was used in the temporary hatchery after fry were transferred to the rearing ponds. In addition to hatchery modifications, a permanent adult salmon trapping facility was constructed. Located adjacent to the fish ladder of the channel (Figure 75), it consists of a "fyke" trap entrance, two basket hoists, anesthetic tank, sorting table and holding pen.

Figure 75. Merced Hatchery fish trapping and spawning building located adjacent to the lower end of the old spawning channel immediately downstream from Crocker-Huffman Dam.

Further modernization took place in 1991, resulting in the hatchery's current configuration. An Aquafine® ultraviolet (UV) filtration system was installed but is currently not in use.

Additionally, the installed sand filtration system which is needed to remove debris prior to entering the UV filter currently needs repairs and adjustment. It also does not meet the flow requirements of the hatchery and cannot sterilize the entire water supply to the hatchery (CDFG 2000). The hatchery has four filter systems installed. One is located at the head of each raceway and two filters flow to the hatchery building. The two units dedicated for the hatchery building do not work as intended. The earth ponds were replaced with two concrete raceways with a shared interior wall (Figure 76). Each raceway has five 100-foot long ponds which can be subdivided into 25-foot compartments. As a deterrent, a bird net canopy was installed (Figure 76). A permanent hatchery building replaced the temporary hatchery and 30 double stacks of Heath® type incubator trays were installed. Outside the main hatchery building, twelve nursery tanks with varying capabilities were installed. A new 24-inch diameter main water supply line runs from the bottom of the Crocker-Huffman reservoir and underneath the hatchery parking lot. It branches into a 12-inch diameter pipe to provide increased volume to the hatchery building, and a 20-inch diameter pipe to provide more consistent volume to the raceways. The modernized hatchery uses an average of 6.5 cfs. Actual water use varies from under 1 cfs in the off season (June through early October) to 6.5 cfs in February when the fry begin to emerge. The branch pipe valves can be closed during the off season, minimizing the water diversion. Routine tests are performed to ensure that both influent and effluent water conforms to Federal standards.

Figure 76. Merced Hatchery raceways.

Water quality monitoring began in 1975. Influent water was tested for suspended matter (mg/l), settled matter (ml/l), biological oxygen demand (mg/l) (BOD), conductivity (μmhos/cm), turbidity (NTU), pH and flow (mgd). Currently, settled matter, conductivity, pH, and flow are tested weekly while suspended matter, BOD, and turbidity are tested monthly. In addition to the influent and effluent water quality testing, the river water immediately downstream of the effluent release pipe is tested for dissolved oxygen, suspended matter, turbidity, conductivity, pH and temperature. The quantity, function and disposal method of any chemicals used by the hatchery must also be reported monthly along with the water quality test results.

The future of Merced Hatchery is one of improvements. A new shop and main office are planned. There are also plans to install double concrete raceways 150 feet long south of the existing raceways promoting more growth space for salmon. The number of salmon will remain the same. The only means to increase salmon smolt production are to enlarge the raceways and improve the water delivery system (CDFG 2000). If more changes were to happen, it would result from the addition of rearing steelhead.

Calaveras Trout Farm

The Calaveras Trout Farm is on the south bank of the Merced River downstream of Crocker-Huffman Dam adjacent to Merced Hatchery, on approximately fifty acres of land leased from Merced ID (Figure 77). It was constructed in 1968 and is currently a commercial hatchery under private ownership and management. It has a production goal of 400,000 pounds of fish annually. The hatchery rears several species of fish such as rainbow trout, white sturgeon, brook, and brown trout. It supplies fish mainly to the sports industry. Its main source of income is from the sale of rainbow trout. Due to the current market, the hatchery plans on increasing production to meet market demands.

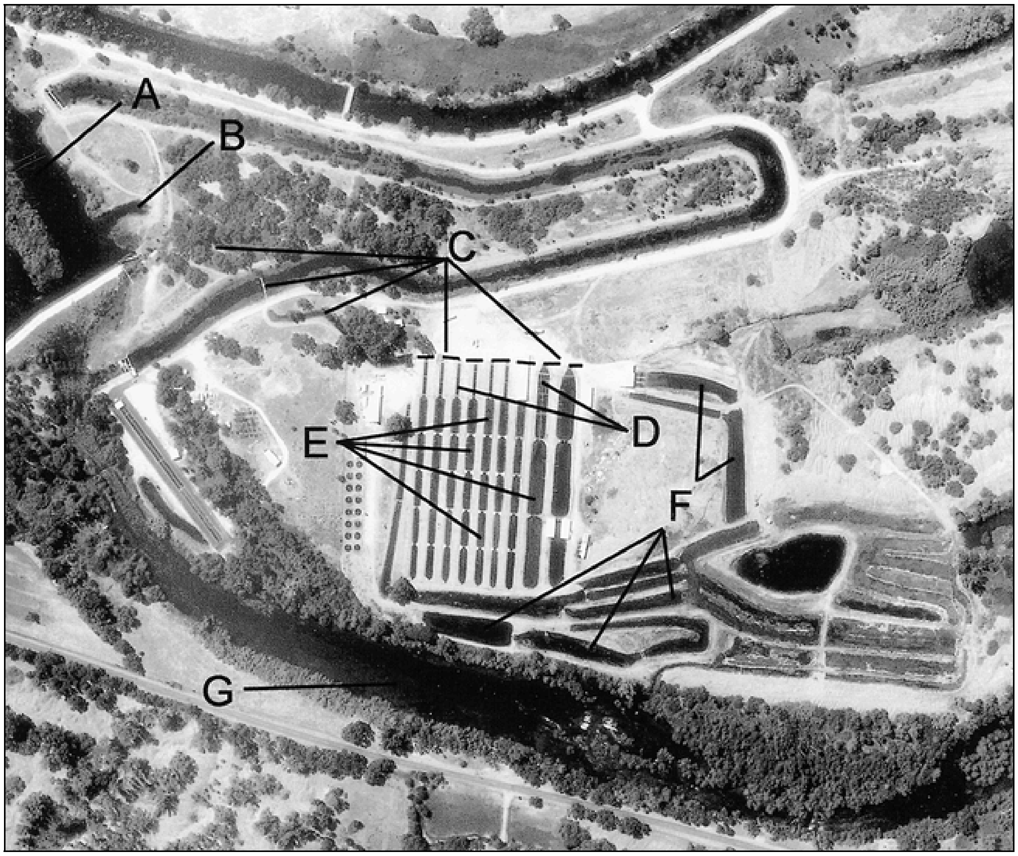


Figure 77. Calaveras Trout Farm and labeled features: (A) Crocker-Huffman Reservoir and water supply, (B) water intake, (C) 1,000-ft-long canal and underground distribution system supplying water to the facility, (D) brook trout ponds, (E) rainbow trout production ponds, (F) settling ponds, and (G) receiving waters of the lower Merced River. (source and photo credit: afs.allenpress.com)

Calaveras Trout Farm diverts water from the Merced River. The hatchery's water supply is gravity-fed from a head gate located upstream of Crocker-Huffman Dam. The head gate is located on the left bank downstream from the abandoned salmon spawning channel (Figure 77). The water delivery system is a combination of canal and pipeline. The intake supplies approximately 50 cfs to the hatchery. In low-flow years, the volume lowers to about 40-42 cfs. It is initially piped from the river to a canal and then piped over the spawning channel and under the road leading to Merced Hatchery in a three-foot diameter pipeline. Once it crosses under the road it is converted back to a canal before being diverted to various areas of the hatchery.

The first diversion of flow leads to sixteen 18-ft-diameter circular tanks used to grow out white sturgeon. The sturgeon vary in size from one to seven feet in length. The rest of the flow is divided into two three-foot diameter pipes that are routed to the top of the raceways. One of the pipes is a combination of pipe and canal to feed the first six raceways. The second pipe runs parallel to the first pipe underground to the top of the old hatchery building and the remaining unused raceways. The remaining water is piped into an 18" pipe that feeds the current hatchery building.

The hatchery building consists of nineteen tanks and six concrete raceways. It is currently capable of raising 300,000 fry. Well water is used for the trout while they are housed in the tanks. River water is used once they are transferred to the raceways. Filter fish (brook trout) of same size are housed immediately upstream of the fry to guard the rainbow trout from copepod infestations (Figure 77). The fry remain in the hatchery building until they are fingerlings (two inches). Once the fry reach fingerling size, they are moved out into a raceway for further grow out. After the water passes through the tanks or raceways it is then plumbed down to settling ponds (Figure 77).

Calaveras Trout Farm currently has ten outdoor raceways/ponds. Each raceway uses approximately 5 cfs and supports 70,000 rainbow trout. The top of each raceway is stocked with brook and brown trout for filtration from copepods. Each raceway has five compartments for growing out the fish to "catchable" size. Once the water flows through the raceways it continues over to a settling basin. All flow is directed to seven settling ponds, where it is treated, with the processed wastewater discharged to the Merced River (Figure 77). Based on discharge monitoring reports from 2001-2003, flow through the facility does not vary from 27 mgd. BOD, suspended solids and settling solids in effluent are consistently at or below analytical detection limits and pH of effluent is consistently in the range of 7.0 – 7.2. Effluent monitoring includes: flow (mgd) collected and recorded weekly; total suspended solids (TSS) (mg/L), net TSS (mg/L), settleable solids (ml/L), pH, and specific conductance at 25°C (μmhos/cm) which are recorded on a monthly basis; zinc (total) (μg/L) and hardness (as $CaCO_3$) (mg/l) which are recorded on a quarterly basis. Samples are taken at the intake pipe and 100 feet downstream of the point of discharge, along the path of the effluent plume (CVRWQCB 2004).

Potential Disease Introduction to the Hatcheries

Anadromous salmonids that are allowed to migrate above Crocker Huffman Dam may pose a serious risk to Merced Hatchery and Calaveras Trout Farm. This potential problem is in the form of disease that may be introduced into the system via fish eggs or carcasses. If salmon were allowed to migrate above the dam, it is expected the fish would introduce one or more pathogens in that reach which would likely adversely affect water supply to the two fish hatcheries. Pathogens such as columnaris disease, infectious hematopoietic necrosis (IHN), bacterial kidney disease (BKD), and proliferative kidney disease (PKD) are described below.

> **Columnaris disease**: This is a skin and gill infection caused by the bacteria *Flexibacter columnaris*. It is common in hatcheries but is usually treatable unless warm water (>56F°) temperatures or other stressors are present. Warm water temperatures create conditions in the natural and hatchery environment that are conducive to pathogens resulting in diseases or infections that reduce fitness or cause mortality (Piper *et al.* 1982, Marine 1993, Fagerlund *et al.* 1995, NMFS 1998). This is most evident in hatchery populations but can occur in wild fish.

Infectious hematopoietic necrosis (IHN): The virus known as IHN attacks the liver of salmon or steelhead. The fish are more susceptible to IHN when water temperatures are cold. The disease is "vertically transmitted" which means that it can be passed from fluids within the gut of the female fish then to the eggs. It is known that IHN is on the surface of the eggs but it may be found on the inside of the egg as well. If IHN were transferred from one basin to another, its virulence could be substantially increased (pers. comm.., Mark Atkinson, CDFG, 2007). Juvenile salmonid mortality in large northern California hatcheries has been high due to IHN outbreaks.

Bacterial kidney disease (BKD): BKD results from infection by a bacterium (*Renibacterium salmonarium*) which attacks the kidney of salmonids. This disease can be transmitted "horizontally" from fish to fish through fecal material, as well as vertically from one generation to the next. BKD, like IHN, is more pathogenic in cold-water conditions. Steelhead are more resistant to BKD than are other salmonid species. Juvenile salmon or steelhead may survive well during freshwater emigration but are unable to successfully transition to seawater.

Proliferative kidney disease (PKD): PKD is characterized by a swollen kidney and spleen, bloody asictes (fluid in the visceral cavity), and pale gills (which indicate anemia). These signs occur with many systemic diseases of fish. PKD is caused by a parasite that infects the kidney, spleen, and other organs. PKD has been detected in both wild and hatchery salmon in the Merced River and could be a significant contributor to smolt mortality (Nichols 2002, Nichols and Foott 2002).

Brown Blood Disease: Brown blood disease is not really a disease but it can be very detrimental to hatcheries. Brown blood disease is caused by high concentrations of nitrites. Nitrites enter a fish culture system after feed is digested by fish and the excess nitrogen is converted into ammonia, which is then excreted as waste into the water. Total ammonia nitrogen (TAN; NH^3 and NH4+) is then converted to nitrite (NO_2) that, under normal conditions, is quickly converted to nontoxic nitrate (NO_3) by naturally occurring bacteria. Uneaten (wasted) feed and other organic material also break down into ammonia, nitrite, and nitrate in a similar manner. Brown blood disease occurs in fish when water contains high nitrite concentrations. Nitrite enters the bloodstream through the gills and turns the blood to a chocolate-brown color. Hemoglobin, which transports oxygen in the blood, combines with nitrite to form Methemoglobin, which is incapable of oxygen transport. Brown blood cannot carry sufficient amounts of oxygen, and affected fish can suffocate even in oxygen laden waters. This accounts for the gasping behavior often observed in fish with brown blood disease, even when oxygen levels are relatively high. Nitrites could pose a problem if many adult salmon carcasses are allowed to sequester behind the dam after reintroduction into upstream areas.

Hatcheries can reduce some of their losses due to diseases by practicing good disease management; however, there is no cure for the virus IHN. Major fish losses occurred from IHN at the Nimbus Fish Hatchery (located on the American River) during the 2006 salmon rearing season and also in the mid 1980s (Sacramento Bee May 16, 2006). IHN cannot be killed by a UV filter, only an ozone filter.

During this feasibility investigation, CDFG fish pathologists recommended that salmon should not be provided access to river reaches above the dam because of potential impacts caused by fish diseases (primarily IHN) (pers. comm., M. Adkinson, CDFG, fish pathologist). Additionally, Joe Maret, Senior Fish Pathologist, provided the following opinion concerning potential reintroduction of salmon above the dam:

> "My biggest concern is with Merced River Hatchery, and with an adjacent, private, trout facility called Calaveras Trout. Anadromous fish commonly carry a variety of diseases which CDFG has worked hard to keep out of our inland waters, most notably infectious hematopoietic necrosis virus (IHNV), and bacterial kidney disease (BKD). If fish carrying these diseases are allowed to pass above Crocker-Huffman dam, this is likely to cause disease problems at Merced River Hatchery and Calaveras Trout. IHN and BKD are listed in our title 14, California Code of Regulations, as serious diseases, and CDFG takes regulatory action based on the presence of these diseases in inland waters. If trout at the Calaveras Trout facility become diseased with IHNV or BKD, CDFG would deny stocking permits to Calaveras Trout. This would essentially put them out of business. I'm not familiar enough with the Merced River drainage to speculate on effects on wild fish, but these diseases could have serious impacts on wild fish populations as well." (Joe Maret, DVM, Senior Fish Pathologist, CDFG, Fish Health Laboratory, Rancho Cordova, CA)

The infrastructures for both Merced Hatchery and Calaveras Trout Farm are entirely dependent on water supply intake from Crocker-Huffman Reservoir. If anadromous salmonids were reintroduced upstream of the dam without safeguards for the hatcheries, both facilities could experience major losses to their fish production due to diseases. Safeguards to the hatcheries could include alternative water supplies (e.g., piping from Merced Falls Reservoir or 100% well water) or 100% ozonation of the facilities' water supplies. Any one of these remedial measures would be very expensive and need to be thoroughly evaluated prior to implementation.

In recent years, Merced Hatchery has been unable to reach its salmon production goals due to below-average returns of salmon to the river and the hatchery. If salmon were allowed to be reintroduced above the dam, a potential fishery management dilemma could occur in low-return years. Fishery management agencies would have to determine if reduced hatchery production is more desirable than allowing salmon returning to the area just downstream of the dam access upstream of the dam instead of selecting broodstock for the hatchery.

Fish Screening Issues

The unscreened intake to Merced ID's Main Canal off the impoundment created by Crocker-Huffman Dam (Figures 78 - 79) would have to be screened should the recommendation of reintroduction of anadromous salmonids above the dam be implemented. If the Main Canal was not screened, most emigrating juvenile salmonids would be lost in the canal system when irrigation diversions begin in late winter and spring (Figure 12) which coincides with the period when most downstream migration occurs (Figure 6). Modern-day fish screens in California must be designed and built according to criteria developed by CDFG and NMFS. If a fish screen was designed for the Main Canal intake, it would probably be a V-flat-plate wedge-wire screening facility with a fish bypass to route fish downstream of Crocker-Huffman Dam. A fish screen of this design was recently constructed at the 1,000 cfs A-Canal irrigation intake off of Upper Klamath Lake in Oregon at a cost of $14,000,000 (pers. comm.., D. Solem, Klamath Irrigation District) (Figure 80). Because the Merced ID Main Canal capacity is nearly twice that of the A-Canal, fish screens for the Main Canal would undoubtedly be much higher. An alternative water supply intake from Merced Falls Reservoir to the Main Canal would undoubtedly be prohibitively expensive. Also, although much smaller than the Main Canal, the intakes to the Merced Hatchery and Calaveras Trout Farm would have to be screened if their water supplies were maintained from the reservoir, to prevent juvenile salmonid entrainment into their water supplies. These measures would have to be thoroughly evaluated prior to a decision on reintroduction of salmon.

Figure 78. Merced ID's Main Canal intake (foreground) off of Crocker-Huffman Reservoir (background). A floating debris boom is at the inlet.

Figure 79. Merced ID's Main Canal intake (foreground) off of Crocker-Huffman Reservoir (photo credit: valley-music.com)

Figure 80. V-shaped flat-plate fish screens on the A-Canal, a 1,000 cfs irrigation water diversion in Oregon.

Conclusions

Limiting factors of a stream system are species-specific and are defined as the habitat required to support a particular fish species life history stage that is in shortest supply relative to the habitats required to support other life history stages and thus results in a "bottleneck" for the fish population (Nickelson 1985). The environmental characteristic of the stream system, (e.g., specific habitat type for a particular life history stage) that most constrains the target fish species population is likely to be the most important limiting factor needing enhancement attention. However, if there are several factors which cause a high degree of constraining influence on the fish population, a large level of effort focused only on the most important factor may produce only a very small population gain (Buell 1985). The identification of limiting factors is a comparison of the ecological requirements of the fish species life history stage to the existing seasonally available habitat in the stream. This may seem simple; in practice it is a difficult and complex task (Buell 1986).

This study examined the three-mile reach between Crocker-Huffman and Merced Falls dams to determine if habitats were suitable to support anadromous salmonids and potential factors that may limit fish production. This effort included a comparison of the spawning and rearing habitat requirements for the species to the flow regime (including flow requirements), thermal regime, channel geometry, water velocities, substrates, and aquatic and riparian vegetation. The study also examined potential effects on downstream hatcheries that may result from salmonid reintroduction.

There are numerous legal and regulatory flow requirements for the lower Merced River that result in conveyance of water released from New Exchequer Dam through Crocker-Huffman Reservoir. The purposes include flood control, power production, instream flows for fish, irrigation supplies, and other beneficial uses. The flow regime through Crocker-Huffman

Reservoir during the late fall through winter periods is similar to the flow immediately downstream of the reservoir. This period corresponds to the time when spawning, egg incubation, and initial fry rearing for salmonids occur. However, during the spring, summer, and early fall months, the seasonal diversion of irrigation water into Merced ID's Main Canal results in higher flows through most of Crocker-Huffman Reservoir than occurs downstream of the dam. Therefore, if anadromous salmonids were reintroduced upstream of Crocker-Huffman Dam, the fish would experience a similar flow regime as those fish spawning and rearing in a relatively short distance downstream of the dam during late fall and winter, but a different (higher) flow regime during the spring, summer, and early fall. Young fish must emigrate from the river by the end of May before water temperatures become lethal in the lower Merced River and San Joaquin River or remain in Crocker-Huffman Reservoir or the upper reach of the lower river to rear over the summer and fall months, then emigrate the following year in the winter or spring as yearling salmonids. The yearling life phase of fall-run Chinook salmon is unusual because the vast majority of emigration throughout the Central Valley occurs as sub-yearlings. However, young steelhead typically remain in freshwater rearing for one or two years prior to emigration. Presumably, steelhead could benefit from the oversummer flow regime between Crocker-Huffman and Merced Falls dams. Overall, the flow regime would not be expected to limit fish production in the reach between Crocker-Huffman and Merced Falls dams.

Data were compiled from existing temperature records collected in ongoing river temperature monitoring programs to assess any temperature limitations that could occur upstream of Crocker-Huffman Dam and compared to biological criteria for anadromous salmonids. Based on those analyses, the thermal regime in the three-mile reach would not be expected to limit salmonid production. During the period when salmon and steelhead would be expected to spawn and during the period of egg incubation, temperatures are below lethal levels. Water temperatures during the rearing phase are within optimal levels. Temperatures for both salmon and steelhead are largely more favorable for spawning and rearing upstream of Crocker-Huffman Dam compared to downstream reaches, a circumstance attributable to closer proximity to hypolimnetic releases from Lake McClure.

Based on comparisons where suitable velocities and potentially suitable substrates for spawning were present in the surveys upstream of Crocker-Huffman Dam, the only reach with sufficient gradient where fish could theoretically spawn is upstream of Rattlesnake Bend. The deeper water areas upstream of Crocker-Huffman Dam either possess unsuitable substrates, unsuitably low velocities, or (mostly) combinations of both. Results of core samples of riverbed substrates upstream of Rattlesnake Bend demonstrated that the level of very fine sediment (<0.85 mm) is relatively low and most samples showed a percentage of very fine sediments below the level of concern for incubating eggs. Additionally, the level of coarser fine material (<4.75 mm and >0.85 mm) is also relatively low and is generally below the range where deleterious effects on fry emergence could occur. However, surface particle sizes in potential spawning areas upstream of Rattlesnake Bend are relatively large. Visual assessment of spawning suitability indicated fair to poor classification for spawning in most areas primarily due to the presence of large cobbles or boulders. There were some isolated areas where the surface substrate (cobbles) appeared suitable for Chinook salmon spawning but the substrates at most transects are substantially larger than those observed in areas downstream of Crocker-Huffman Dam and in known salmon spawning areas below the dam. Because steelhead utilize smaller cobbles and gravels than Chinook salmon, that species would be expected to have greater difficulty spawning in the large substrates. Among the spawning requirements for substrate, temperature, flow regime, and water velocities, the lack of smaller substrate particles in the range preferred by spawning salmon would likely be a primary, significant factor limiting anadromous salmonid reproduction upstream of Crocker-Huffman Dam. This circumstance is attributable to the lack of gravel recruitment from upstream reaches, past gold dredging in the reach, and winnowing of smaller particles in reaches downstream of the dams resulting in progressively coarser particles over time. Overall, potential spawning habitats upstream of Crocker-Huffman Dam were judged to be inferior to those habitats downstream of the dam. Among other measures, large-scale gravel replenishment downstream of Merced Falls Dam would have to occur prior to reintroduction of anadromous salmonids. However, gravel supplementation downstream of Merced Falls Dam would ultimately result in movement of the material downstream into the deeper, slower water of the reservoir where it would become unavailable for spawning salmon. Analyses of coarse bedload transport through the reservoir would have to be conducted to ensure that continual gravel additions do not result in filling in the reservoir.

There are some areas between Crocker-Huffman and Merced Falls dams where rearing habitats for juvenile salmonids may be favorable, largely due to the presence of abundant cover in stream-side margins provided by riparian vegetation. The principal area where Chinook salmon fry may find suitable rearing habitats is the narrow, near-bank fringe between Rattlesnake Bend and Merced Falls Dam. This reach is dominated by low-gradient riffle habitats and runs, depending on flow conditions. However, riparian encroachment throughout the three-mile reach has resulted in deterioration of some of the habitat quality such that very shallow near-bank habitats and complexity of macrohabitats preferred for rearing are largely unavailable. Additionally, because of the confined channel upstream of Rattlesnake Bend, emergent fry would likely be quickly displaced to downstream areas of the reservoir. More than half of the three-mile reach is a relatively deep, lake-like environment and considered poor habitat for fry rearing. Crocker-Huffman Reservoir would be an unusual environment for rearing young Chinook salmon and is uncharacteristic of customary habitats utilized by salmon downstream of the dam and in other rivers. The lower-most area of the reservoir possesses abundant aquatic macrophytes throughout the water column. Rearing salmonids inevitably have to migrate through the prolific, dense vegetation which may harbor predatory fish species. Because of riparian encroachment, a confined channel, low amount of shallow, near-shore habitats, and deep lake-like environment through the lower reservoir, fry rearing habitats are probably limiting and lower in quality as compared to the lower Merced River where more-typical habitats are present.

The Crocker-Huffman Dam fish ladder does not meet present-day criteria for fish passage. A combination of the fish ladder entrance location, entrance configuration, and insufficient water discharge would all likely contribute to suboptimal upstream fish passage conditions. The fishway would probably limit upstream migration of anadromous salmonids if the ladder were made operational (i.e., opening up flow into the ladder). Because operation of the existing ladder would probably cause fish delay or blockage leading to stress or injury, it is likely that one or more new fish ladders meeting modern-day criteria would have to be added to the dam.

The infrastructures for both Merced Hatchery and Calaveras Trout Farm are entirely dependent on water supply intake from Crocker-Huffman Reservoir. If anadromous salmonids were reintroduced upstream of the dam without safeguards for the hatcheries, both facilities could experience major losses to their fish production due to diseases. Safeguards to the hatcheries could include alternative water supplies (e.g., piping from Merced Falls Reservoir or 100% well water) or 100% ozonation of the facilities' water supplies. Any one of these remedial measures would be very expensive and need to be thoroughly evaluated prior to implementation. Also, in recent years, Merced Hatchery has been unable to reach its salmon production goals due to below-average returns of salmon to the river and the hatchery. If salmon were allowed to be reintroduced above the dam, a potential fishery management dilemma could occur in low-return years. Fishery management agencies would have to determine if reduced hatchery production is more desirable than allowing salmon returning to the area just downstream of the dam to have access to upstream areas.

The unscreened intake to Merced ID's Main Canal off the impoundment created by Crocker-Huffman Dam would have to be screened should reintroduction of anadromous salmonids above the dam be implemented. If the Main Canal was not screened, most emigrating juvenile salmonids would be lost in the canal system when irrigation diversions begin in late winter and spring because most downstream migration occurs during the same period. The technology to screen the Main Canal exists, but doing so would be very expensive (est. tens of millions of dollars).

In conclusion, reintroduction of anadromous salmonids upstream of Crocker-Huffman Dam would be a very difficult measure to successfully implement; the opportunities are few and the constraints are many. Adult fish passage at Crocker-Huffman Dam could be accomplished through installation of one or more new fish ladders built according to modern-day standards. Although the small reach upstream of the dam between Rattlesnake Bend and Merced Falls Dam may be able to provide a relatively small amount of spawning and rearing habitat for both Chinook salmon and steelhead, it would require major management actions to "rehabilitate" those habitats. Additionally, long-term maintenance of those habitats would be required to prevent eventual deterioration of the habitat quality. Even if such measures were implemented, there are no assurances that improved habitats would translate into increased fish production as compared to underutilized areas downstream of Crocker-Huffman Dam where greater opportunities for increased natural fish production exist.

Acknowledgements

This project was funded by the USFWS Anadromous Fish Restoration Program and appreciation is extended to staff of the USFWS for management of the project. Thanks are due to Merced ID staff and MBK Engineers for providing valuable data and information on the Merced River Development Project. Without the cooperation of the landowners along Crocker-Huffman Reservoir, this project would not have been possible. We also appreciated the cooperation of the CDFG staff at LaGrange, Merced Hatchery, and Fish Pathology Laboratory for provision of information on the operations of Merced Hatchery and the operators of Calaveras Trout Farm for information on that facility. The NRS, Inc. field staff comprised of Emily McDonald, Christopher Vallee, Mary Serr, Paul Harvey, Kip Dali, and Chad Dale are especially thanked for their dedication and hard work in often difficult field conditions to collect data for this study. Gratitude is expressed to Rick Burmester, Tim Heyne, Steve Tsao, Ted Selb, Art Godwin, Ken Robbins, and Mary Serr for reviewing a draft of this report.

Literature Cited

Allen, M.A. and T.J. Hassler. 1986. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (Pacific Southwest). Chinook salmon. U.S. Fish and Wildlife Service, California Cooperative Fishery Research Unit. Biological Report 82(11.49). 26 p.

Arend, K.K. 1999. Macrohabitat identification. Pages 75-93 *in* M.B. Bain and N.J. Stevenson, eds. Aquatic habitat assessment: common methods. American Fisheries Society, Bethesda, Maryland.

Bailey, E.D. 1954. Time pattern of 1953-54 migration of salmon and steelhead into the upper Sacramento River. Unpublished report. California Department of Fish and Game.

Bates, K.M. 1994. Fishway design guidelines for Pacific salmon. Washington Department of Fish and Wildlife. Working paper 1.5. November 1994.

Bell, M.C. 1991. Fisheries Handbook of Engineering Requirements and Biological Criteria. Fish Passage Development and Evaluation Program. North Pacific Division, U.S. Army Corps of Engineers. Portland, OR.

Beschta, R.L. and W.L. Jackson. 1979. The intrusion of fine sediments into a stable gravel bed. J. Fish. Res. Board Can. Vol. 36:204-210.

Bjorn, T.C. 1969. Embryo survival and emergence studies, salmon and steelhead investigations. Job No. 5, Federal Aid in Fish and Wildlife Restoration. Job Completion Report, Project F-49-R-7. Idaho Fish and Game Department. 11 p.

Bjornn, T.C. and D.W. Reiser. 1991. Habitat requirements of salmonids in streams. American Fisheries Society Special Publication 19:83-138.

Bovee, K.D., B.L. Lamb, J.M. Bartholow, C.B. Stalnaker, J. Taylor, and J. Hendrickson. 1998. Stream habitat analysis using the instream flow incremental methodology. U.S. Geological Survey, Biological Resources Division Information and Technology Report USGS/BRD/ITR-1998-0004. 131 p.

Brannon, E.L. 1965. The influence of physical factors on the development and weight of sockeye salmon embryos and alevins. International Pacific Salmon Fisheries Commission. Progress Report No. 12. 26 p.

Briggs, J.C. 1953. The behavior and reproduction of salmonid fishes in a small coastal stream. Calif. Dept. Fish and Game. Fish Bulletin No. 94. 62 p.

Brittan, M.R. and A.H. Trice. 1967. California's Merced River Project: a case history of state and local cooperation in fishery and recreational improvement. Pages 499-516 *in* Reservoir Fishery Resources Symposium, American Fisheries Society, Athens, Georgia. April 5-7, 1967.

Buell, J. W. 1985. The determination of limiting factors for the production of anadromous salmonids in streams. Buell and Associates, Inc., Beaverton, OR, U.S.A. Technical Memorandum (unpublished). 5 p.

Buell, J. W. 1986. Stream habitat enhancement evaluation workshop: a synthesis of views. Level I Workshop. March 1986. Hood River, Oregon. Bonneville Power Administration, Division of Fish and Wildlife. Contract No. DE-AP79-86BP61982, Project No. 86-107. September 1986. 51 p.

Burgner, C.J. 1951. Characteristics of spawning nests of Columbia River salmon. Fishery Bulletin 52(61):97-110.

Burgner, R.L. 1991. Life history of sockeye salmon (*Oncorhynchus nerka*). pp. 3-117. In C. Groot and L. Margolis (Eds.). Pacific Salmon Life Histories. Univ. British Columbia Press. Vancouver.

CALFED Bay-Delta Program. 1998. Ecosystem Restoration Program Plan. Draft Programmatic EIS/EIR Technical Appendix. March 1998.

CALFED Bay-Delta Program. 1999a. Ecosystem Restoration Program Plan, Strategic Plan for Ecosystem Restoration. Draft Programmatic EIS/EIR Technical Appendix. June 1999.

CALFED Bay-Delta Program. 1999b. Multi-species Conservation Strategy. Draft Programmatic EIS/EIR Technical Appendix. June 1999.

CALFED Bay-Delta Program. 2001. Ecosystem Restoration Program, Draft Stage 1 Implementation Plan. August 2001.

Calhoun, A. 1966. Habitat protection and improvement. Pages 40-48 *in* A. Calhoun (ed.). *Inland Fisheries Management.* California Department of Fish and Game. Sacramento, CA.

California Department of Fish and Game. 1993. Restoring Central Valley Streams: A Plan for Action. November 1993.

California Department of Fish and Game. 1997. Merced River Hatchery production goals and objectives. 4 p.

California Department of Fish and Game. 1998. Genetic concerns related to use of out-of-basin fall-run Chinook salmon for studies in the lower San Joaquin River. Presented to the State

Water Resources Control Board Public Hearing; Phase 2, regarding “The responsibilities of the parties who are jointly proposing the San Joaquin River Agreement.” CDFG Exhibit 20. CDFG Region 4. June 1998. 6 p.

California Department of Fish and Game. 2000. San Joaquin River Basin Anadromous Fishery Management Program Overview. CDFG. Fresno, CA.

California Department of Fish and Game and Merced Irrigation District. 2002. Memorandum of Understanding between California Department of Fish and Game and Merced Irrigation District regarding October instream flows, other interim instream flows, and fishery studies in the lower Merced River.

California Department of Water Resources. 1993. Dams within the jurisdiction of the state of California. Bulletin 17-93. June 1993. 125 p.

California Department of Water Resources. 1994. San Joaquin River tributaries spawning gravel assessment: Stanislaus, Tuolumne, and Merced Rivers. Memorandum Report. Northern District, Red Bluff, California.

Central Valley Regional Water Quality Control Board. 2004. Order No. R5-2004-0119, NPDES No. CA0081752. Waste discharge requirements for Calaveras Trout Farm, Inc. and Merced Irrigation District trout rearing facility, Merced County. September 10, 2004.

Chapman, D.W. 1988. Critical review of variable used to define effects of fines in redds of large salmonids. Trans. Amer. Fish. Soc. 117:1-21.

Church, M.A., D.G. McLean, and J.F. Wolcott. 1987. River bed gravels: sampling and analysis. Pages 43-79 *in* Sediment Transport in Gravel Bed Rivers, C.R. Thorne, J.C. Bathurst, and R.D. Hey (Editors). John Wiley and Sons, Chichester, United Kingdom.

Clay, C.H. 1995. Design of Fishways and Other Fish Facilities. Second Edition. CRC Press, Inc. 248 p.

Cooper, A.C. 1965. The effect of transported stream sediments on the survival of sockeye and pink salmon eggs and alevin. Internat. Pacific Salmon Fish. Comm., Bulletin 18. 71 p.

EA Engineering, Science, and Technology. 1999. Meeting Flow Objectives for the San Joaquin River Agreement, 1999-2010. Final Environmental Impact Statement/Environmental Impact Report. Prepared for the U.S. Bureau of Reclamation and the San Joaquin River Group Authority. January 28, 1999.

Everest, F.H., R.L. Beschta, J.C. Scrivener, K.V. Koski, J.R. Sedell, and C.J. Cederholm. 1987. Fine sediment and salmonid production - a paradox. Pages 98-142 *in* E. Salo and T. Cundy, editors. Streamside management: forestry and fishery interactions. University of Washington, College of Forest Resources, Contribution 57, Seattle.

Fagerlund, U.H.M., J.R. McBride, and I.V. Williams. 1995. Stress and tolerance. Pages 459-504 in C. Groot, L. Margolis, and W.C. Clarke (eds.). Physiological Ecology of Pacific Salmon. University of British Columbia Press. Vancouver, B.C. Canada.

Flosi, G. and F.L. Reynolds. 1991. California Salmonid Stream Habitat Restoration Manual. California Department of Fish and Game, Inland Fisheries Division. Sacramento, CA.

Flosi, G., S. Downie, J. Hopelain, M. Bird, R. Coey, and B. Collins. 1998. California Salmonid Stream Habitat Restoration Manual. California Department of Fish and Game, Inland Fisheries Division. Sacramento, CA.

Hall, J.D. and R.L. Lantz. 1969. Effects of logging on the habitat of coho salmon and cutthroat trout in coastal streams. Pages 355-375 *in* T.G. Northcote, ed. Symposium on salmon and trout in streams. Univ. British Columbia, Vancouver, B.C.

Hallock, R.J. 1989. Upper Sacramento River steelhead, *Oncorhynchus mykiss*, 1952-1988. Report to the U.S. Fish and Wildlife Service. September 15, 1989. 86 p.

Hallock, R.J., W.F. Van Woert, and L. Shapovalov. 1961. An evaluation of stocking hatchery-reared steelhead rainbow trout (Salmo gairdnerii gairdnerii) in the Sacramento River system. Fish Bulletin 114. California Department of Fish and Game.

Hampton, M. 1988. Development of habitat preference criteria for anadromous salmonids of the Trinity River. U.S. Dept. Int., Fish Wildl. Serv., Div. Ecol. Serv., Sacramento, California. 93 p.

Hausle, D.A. and D.W. Coble. 1976. Influence of sand in redds on survival and emergence of brook trout (*Salvelinus fontinalis*). Trans. Amer. Fish. Soc. 105(1):57-63.

Healey, M.C. 1991. Life history of Chinook salmon (*Oncorhynchus tshawytscha*). Pages 311-393 *in* Pacific Salmon Life Histories. C. Groot and L. Margolis (eds.). UBC Press, Vancouver, Canada.

Huntington, C.W. and Seton, Johnson, and Odell, Inc. 1988. Orofino Creek passage project biological and engineering feasibility report. U.S. Department of Energy, Bonneville Power Administration. Portland, OR.

Hynes, H.B.N. 1970. The Ecology of Running Waters. University of Toronto Press. Toronto, Ontario, Canada.

Jones and Stokes Associates, Inc. 1995. Temperature and gravel investigations for fisheries enhancement on the lower Merced River, Merced County, California. April 1995. (JSA 92-211) Sacramento, CA. Prepared for State of California, The Resources Agency, Department of Fish and Game, Sacramento, CA.

Katopodis, C. 1992. Introduction to fishway design. Freshwater Institute, Department of Fisheries and Oceans, Canada. January 1992. 325 p.

Kjelson, M.A., P.F. Raquel, and F.W. Fisher. 1982. Life history of fall-run juvenile chinook salmon , *Oncorhynchus tshawytscha*, in the Sacramento-San Joaquin estuary, California, pp. 393-411 *in* V.S. Kennedy (ed.) Estuarine comparisons. Academic Press, New York, NY.

Kondolf, G.M. 1997a. Application of the pebble count: notes on purpose, method, and variants. Journal of the American Water Resources Association 33(1):79-87.

Kondolf, G.M. 1997b. Hungry water: effects of dams and gravel mining on river channels. Environmental Management 21(4):533-551.

Kondolf, G.M. 2000. Assessing salmonid spawning gravel quality. Transactions of the American Fisheries Society 129:262-281.

Kondolf, G.M. and S. Li. 1992. The pebble count technique for quantifying surface bed material size in instream flow studies. Rivers 3(2):80-87.

Kondolf, G.M. and M.G. Wolman. 1993. The sizes of salmonid spawning gravels. Water Resources Research 29(7):2275-2285.

Kreeger, K.Y. and W.J. McNeil. 1992. A literature review of factors associated with migration of juvenile salmonids. Unpublished manuscript for Direct Service Industries, Inc. October 23, 1992. 46 p.

Larinier, M. 1990. Experience in fish passage in France: fish pass design criteria and downstream migration problems. Pages 65-74 *in* Proceedings of the International Symposium on Fishways ’90 in Gifu, Japan. October 8-10, 1990.

Leopold, L.B., M.G. Wolman, and J.P. Miller. 1964. Fluvial Processes in Geomorphology. W.H. Freeman. San Francisco, CA.

Liepitz, G.S. 1994. An assessment of the cumulative impacts of development and human uses on fish habitat in the Kenai River. Alaska Dept. of Fish and Game, Habitat and Restoration Division. Technical Report No. 94-6.

Lisle, T.E. 1989. Sediment transport and resulting deposition in spawning gravels, north coastal

California. Water Resources Research 25(6):1303-1319.

Lisle, T.E. and R.E. Eads. 1991. Methods to measure sedimentation of spawning gravels. U.S. Forest Service. Research Note PSW-411. 7 p.

Loudermilk, W.E. 1998. Can we satisfy existing management and the Vernalis Adaptive Management Program salmon smolt survival study needs with production at Merced River Hatchery? Information paper prepared by the VAMP policy and technical groups and other interested parties. CDFG Region 4, Fresno, CA. January 25, 1998. 12 p. plus attachments.

Marine, K.R. 1993. A background investigation and review of the effects of elevated water temperature on reproductive performance of adult Chinook salmon (*Oncorhynchus tshawytscha*), with suggestions for approaches to the assessment of temperature induced reproductive impairment of Chinook salmon stocks in the American River, California. October 1992. University of California, Davis. Prepared for the American River Technical Advisory Committee, Sacramento, CA. 30 p.

Marine, K.R. and D.A. Vogel. 2000. Upstream migration monitoring at Woodbridge Dam during August 1999 through March 2000, Lower Mokelumne River Fisheries Monitoring Program. A technical report prepared by Natural Resource Scientists, Inc. for East Bay Municipal Utility District. September 2000. 44 p. plus appendices.

MBK. 2001. Merced River Simulation Model Documentation. Developed by MBK Engineers for Merced Irrigation District. August 2001.

McCain, M., D. Fuller, L. Decker, and K. Overton. 1990. Stream habitat classification and inventory procedures for northern California. Fish Habitat Relationships Currents, Technical Bulletin 1. USDA Forest Service, Pacific Southwest Region.

McEwan, D. 2001. Central Valley steelhead. Pages 1-70 *in* Contributions to the Biology of Central Valley Salmonids, Volume 1. CDFG Fish Bulletin 179.

McEwan, D. and T.A. Jackson. 1996. Steelhead restoration and management plan for California. Inland Fisheries Division, California Department of Fish and Game. February 1996. 234 p.

McSwain, K.R. 1977. History of the Merced Irrigation District, 1919 – 1977. Merced Irrigation District. 372 p.

Menchen, R.S. 1972. Merced River king (Chinook) salmon spawning channel annual report for 1970-71 season. CDFG Anadromous Fisheries Branch Administrative Report No. 72-6. 9 p.

Mills, T.J. and F. Fisher. 1994. Central Valley anadromous sport fish annual run-size, harvest, and population estimates, 1967 through 1991. Inland Fisheries Technical Report. California Department of Fish and Game.

Mills, T.J., D.R. McEwan, and M.R. Jennings. 1996. California salmon and steelhead: Beyond the crossroads. Pages 91-11 *in* D. Stouder, P. Bisson, and R. Naiman (eds.). Pacific Salmon and their Ecosystems: Status and Future Options. Chapman and Hall Publishers, New York.

Moyle, P.B. 2002. Inland Fishes of California. University of California Press. Berkeley, CA. 502 p.

Myers, J.M., R.G. Kope, G.J. Bryant, D. Teel, L.J. Lierheimer, T.C. Wainwright, W.S. Grant, F.W. Waknitz, K. Neely, S.T. Lindley, and R.S. Waples. 1998. Status review of Chinook salmon from Washington, Idaho, Oregon, and California. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-NWFSC-35.

National Marine Fisheries Service. 1998. Endangered and Threatened Species: Proposed endangered status for two Chinook salmon ESU's and proposed threatened status for five Chinook salmon ESU's; Proposed redefinition, threatened status, and revision of critical habitat for one Chinook salmon ESU; Proposed designation of Chinook salmon critical habitat in California, Oregon, Washington, Idaho. March 9, 1998. Federal Register 63 (45):11482- 11520.

Nickelson, T. E. 1985. A model for determining factors limiting abundance, and thereby estimating carrying capacity of fishes in stream systems. Oregon Department of Fish and Wildlife, Corvallis, OR. U.S.A. (unpublished).

Nichols, K. 2002. Merced River PKD survey, spring 2002. Memorandum to San Joaquin Basin fish health information distribution list. U.S. Fish and Wildlife Service, California-Nevada Fish Health Center, Anderson, California. December 6, 2002. 3 p.

Nichols, K. and J.S. Foott. 2002. Health monitoring of hatchery and natural fall-run Chinook salmon juveniles in the San Joaquin River and tributaries, April – June 2001. U.S. Fish and Wildlife Service, California-Nevada Fish Health Center, Anderson, California. November 2002. 21 p.

Odeh, M. and A. Haro. 2000. Developments in fish passage engineering and technology. Pages 1 – 11 *in* Odeh, M., ed. Advances in Fish Passage Technology: Engineering Design and Biological Evaluation. American Fisheries Society, Bethesda, Maryland.

Piper, R.G., I.B. McElwain, L.E. Orme, J.P. McCraren, L.G. Fowler, J.R. Leonard. 1982. Fish Hatchery Management. U.S. Fish and Wildlife Service. Washington, D.C. 517 p.

Platts, W.S., M.A. Shirazi, and D.H. Lewis. 1979. Sediment particle sizes used by salmon for spawning with methods for evaluation. EPA-600/3-79-043. 33 p.

Powers, P.D., J.F. Orsborn, T.W. Bumstead, S. Klinger-Kingsley, and W.C. Mih. 1985. Fishways – an assessment of their development and design. Final Project Report, Part 3 of 4. Bonneville Power Administration. Project No. 82-14. Contract No. DE-AI79-82BP36523. August 1985. 161 p.

Rainey, W.S. 1991. Recent adult fish passage projects on tributaries of the Columbia River. American Fisheries Society 10:278 – 288.

Reiser, D.W. and R.G. White. 1988. Effects of two sediment size-classes on survival of steelhead and chinook salmon eggs. N. Amer. J. Fish. Mgmt. 8:432-437.

Reynolds, F.L., T.J. Mills, R. Benthin, and A. Low. 1993. Restoring Central Valley streams: a plan for action. California Department of Fish and Game, Inland Fisheries Division, Sacramento, California.

San Joaquin River Group Authority. 1998. Final Division Agreement for the San Joaquin River Agreement. June 12, 1998.

San Joaquin River Agreement. 2000. Technical Report for the Vernalis Adaptive Management Plan. 84 p.

Selb, T. 1992. Testimony of Ted Selb, Assistant General Manager for Water Resources, Merced Irrigation District, at the 1992 Bay-Delta Water Rights Hearings.

Selb, T. 1999. Testimony of Ted Selb, Assistant General Manager for Water Resources, Merced Irrigation District, at the 1998 Bay-Delta Water Rights Hearings. June 28, 1999.

Stillwater Sciences. 2001a. Merced River Restoration Plan Phase II. Volume II: Baseline evaluations; geomorphic and riparian vegetation investigations. Prepared by Stillwater Sciences, Berkeley, California for CALFED, Sacramento, California.

Stillwater Sciences. 2001b. Merced River Restoration Plan Phase III. Task 2 Technical Memorandum: Channel and floodplain design guidelines for Technical Advisory Committee Review. Prepared by Stillwater Sciences, Berkeley, California for CALFED, Sacramento, California.

Stillwater Sciences. 2002. Merced River Corridor Restoration Plan. Berkeley, CA. 245 p.

Stillwater Sciences. 2006. Aerial survey of the Merced River in 2005. Berkeley, CA.

Stillwater Sciences. 2007. Interim biological monitoring and assessment report. Prepared for East Merced Resource Conservation District and State Water Resources Control Board.

Stillwater Sciences, Berkeley, CA. April 2007.

Tautz, A.F. and C. Groot. 1975. Spawning behavior of chum salmon (*Oncorhynchus keta*) and rainbow trout (*Salmo gairdneri*). J. Fish. Res. Board Can. 32(5):633-642.

Tiffan, K.F., R.D. Garland, and D.W. Rondorf. 2002. Quantifying flow-dependent changes in subyearling fall Chinook rearing habitat using two-dimensional spatially explicit modeling. N. Amer. J. Fish. Mgmt. 22:713-726.

URS. 2001. Acquisition of Additional Water for Meeting the San Joaquin River Agreement Flow Objectives, 2001-2010. Final Supplemental Environmental Impact Statement/Environmental Impact Report. Prepared for the U.S. Bureau of Reclamation and the San Joaquin River Group Authority. March 13, 2001.

U.S. Army Corps of Engineers. 1981. Water control manual for New Exchequer Dam and Reservoir, Appendix VII to Master Water Control Manual, San Joaquin River Basin, California. October 1981. Sacramento District, U.S. Army Corps of Engineers.

U.S. Fish and Wildlife Service. 1995a. Working paper on restoration needs: Habitat restoration actions to double natural production of anadromous fish in the Central Valley of California. Three volumes. May 1995. Prepared for the U.S. Fish and Wildlife Service under the direction of the Anadromous Fish Restoration Program Core Group. Stockton, CA.

U.S. Fish and Wildlife Service. 1995b. Biological opinion on the operation of the Central Valley Project and State Water Project effects on threatened Delta smelt, Delta smelt critical habitat, and proposed threatened Sacramento splittail. March 6, 1995. Sacramento, CA

U.S. Fish and Wildlife Service. 1997. Identification of the instream flow requirements for fall-run Chinook salmon spawning in the Merced River. Instream Flow Assessments Branch, Ecological Services, Sacramento, CA Field Office. March 19, 1997. 66 p.

U.S. Fish and Wildlife Service and Hoopa Valley Tribe. 1999. Trinity River Flow Evaluation. Final Report. A Report to the Secretary of the U.S. Department of the Interior. Washington, D.C. June 1999. 308 p. plus appendices.

U.S. Bureau of Reclamation. 1997. Central Valley Project Improvement Act, Draft Programmatic Environmental Impact Statement, Technical Appendix vol. 3: Fisheries. September 1997. Sacramento, CA.

Vick, J.C. 1995. Habitat rehabilitation in the lower Merced River: a geomorphological perspeceive. Master's thesis. University of California, Berkeley, California.

Vogel, D.A. 1982. Preferred spawning velocities, depths, and substrates for fall Chinook salmon in Battle Creek, California. U.S. Fish and Wildlife Service Technical Report. 8 p. November 1982.

Vogel, D.A. 1983. Evaluation of the Tehama-Colusa Fish Facilities. Cal-Neva Wildlife Transactions, pp. 20-25.

Vogel, D.A. 1989. Sacramento River Salmon Restoration. Sacramento Valley Landowners Magazine. pp. 10-13.

Vogel, D.A. 1993. Chinook salmon rearing in the Central Valley. Central Valley Chinook Salmon Workshop, University of California, Davis. January 4-5, 1993.

Vogel, D.A. 1994a. Considerations on the Use of Fish Survival Indices as a Tool to Develop Fish and Wildlife Standards in the Sacramento - San Joaquin Delta. Testimony Presented to the California State Water Resources Control Board. Natural Resource Scientists, Inc. July 14, 1994. 16 p.

Vogel, D.A. 1994b. Evaluation of streambed substrate in anadromous salmonid spawning habitat in Little River, California, 1993. Vogel Environmental Services. 45 p. plus appendices.

Vogel, D.A. 2000. Results of a November 2000 Riverbed Survey of the Sacramento River in the Vicinity of Deschutes Bridge. Natural Resource Scientists, Inc. Technical Memorandum. December 30, 2000.

Vogel, D.A. 2001. Results of an August 2001 Riverbed Survey of the Sacramento River in the Vicinity of Jellys Ferry Bridge. Natural Resource Scientists, Inc., Technical Memorandum. August 30, 2001.

Vogel, D.A. 2003. Merced River water temperature feasibility investigation, reconnaissance report. Prepared for the U.S. Fish and Wildlife Service Anadromous Fish Restoration Program by Natural Resource Scientists, Inc. December 29, 2003. 89 p.

Vogel, D.A. and G. Taylor. 1987. Survey of the Chinook salmon spawning substrate in the Sacramento River from the Highway 273 Bridge to Keswick Dam, July-August, 1987. Contract Report for the Federal Energy Regulatory Commission Request for information concerning the proposed Lake Redding Hydroelectric Project (FERC No. 2828). Joint report by the U.S. Fish and Wildlife Service Fisheries Assistance Office, Red Bluff, CA and Division of Ecological Services, Sacramento, CA. 13 p.

Vogel, D.A. and K.R. Marine. 1991. Guide to upper Sacramento River Chinook salmon life history. Prepared for the U.S. Bureau of Reclamation, Central Valley Project. July 1991. 53 p. plus appendices.

Vogel, D.A., K.R. Marine, and J.G. Smith. 1988. Fish Passage Action Program for Red Bluff Diversion Dam. Final Report on Fishery Investigations. U.S. Fish and Wildlife Service Report No. FR1/FAO-88-19. October 1988. 77 p. plus appendices.

Vogel, D.A., K.R. Marine, and J.G. Smith. 1990. A summary of evaluations of upstream and downstream anadromous salmonid passage at Red Bluff Diversion Dam on the Sacramento River, California, U.S.A. Pages 275-281 *in* Proceedings of the International Symposium on Fishways '90 in Gifu, Japan. October 8-10, 1990.

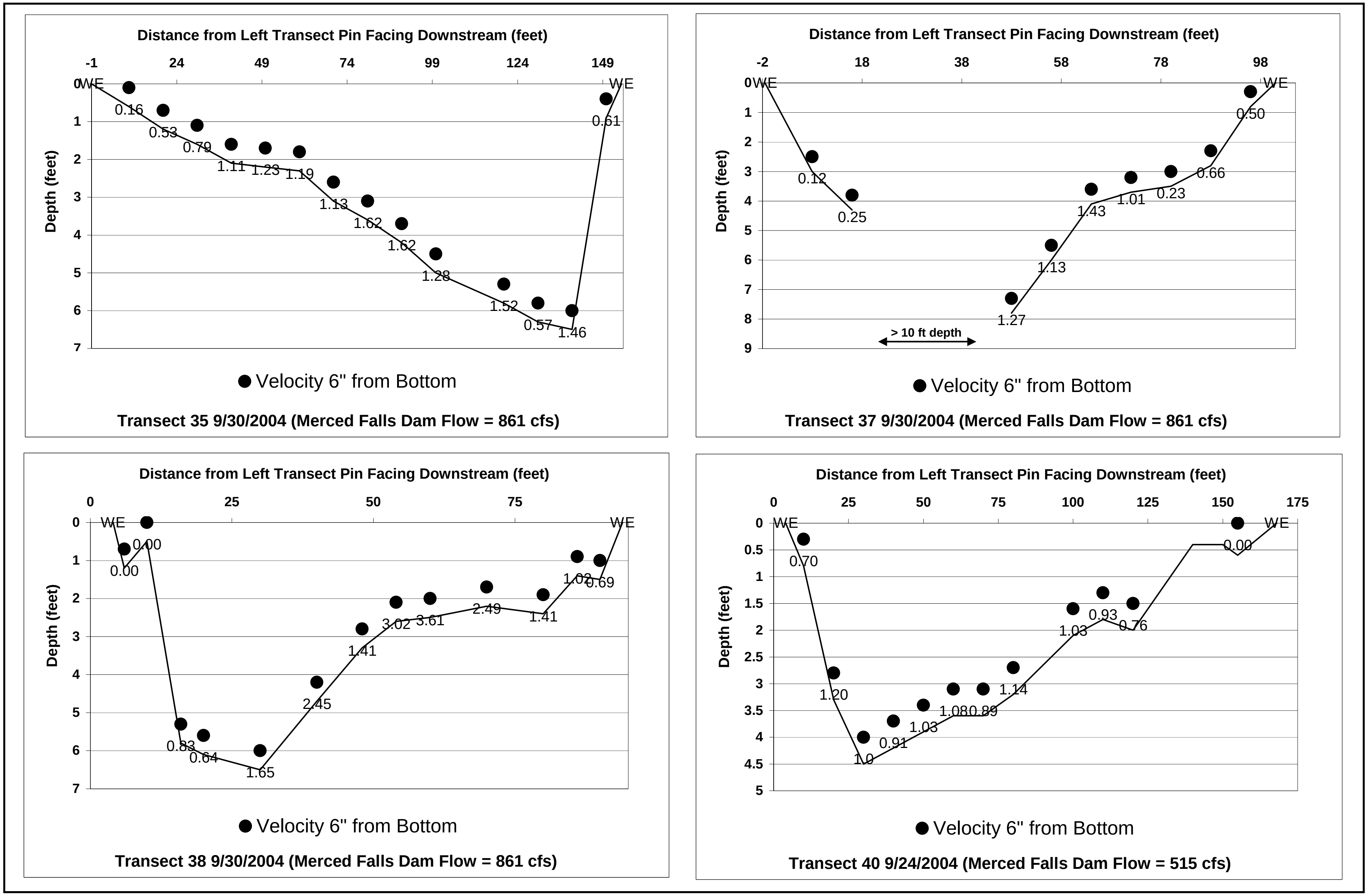
Warner, G. 1991. Remember the San Joaquin. Pages 61-69 *in* A. Lufkin (ed.). California's Salmon and Steelhead. University of California Press, Berkeley, CA.

Wickett, W.P. 1954. The oxygen supply to salmon eggs in spawning beds. J. Fish. Res. Bd. Can. Vol. 11(6):933-953.

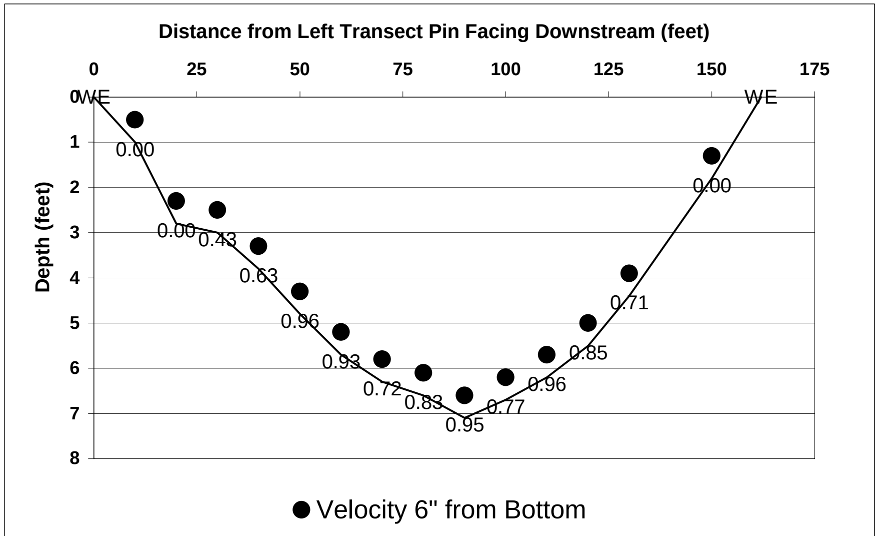
Wolman, M.G. 1954. A method of sampling coarse river-bed material. Transactions of the American Geophysical Union 35(6):951-956.

APPENDICES

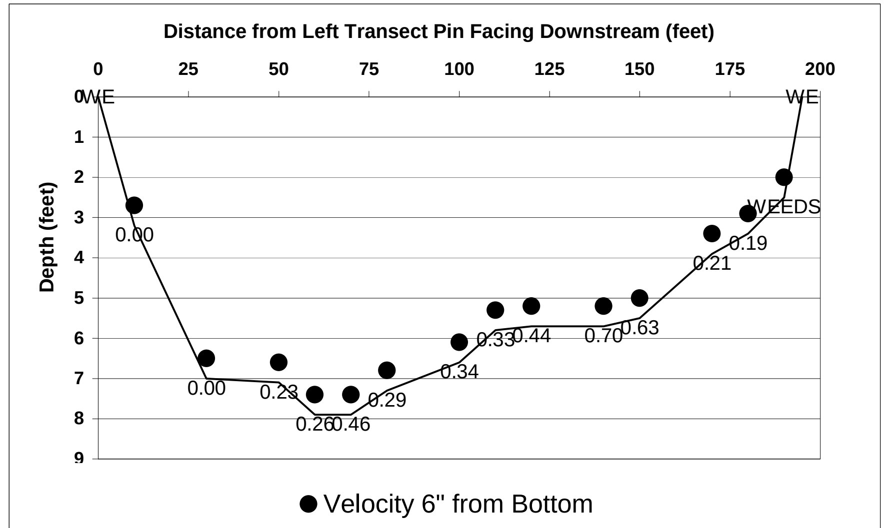
Appendix A. Cross-sectional velocity profiles measured at transects in the Merced River between Crocker-Huffman and Merced Falls dams.



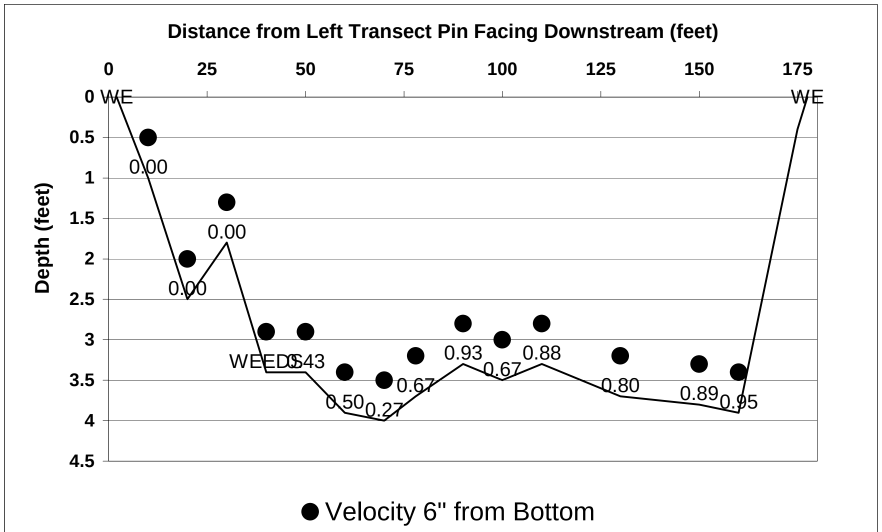
Appendix A. Cross-sectional velocity profiles measured at transects in the Merced River between Crocker-Huffman and Merced Falls dams.



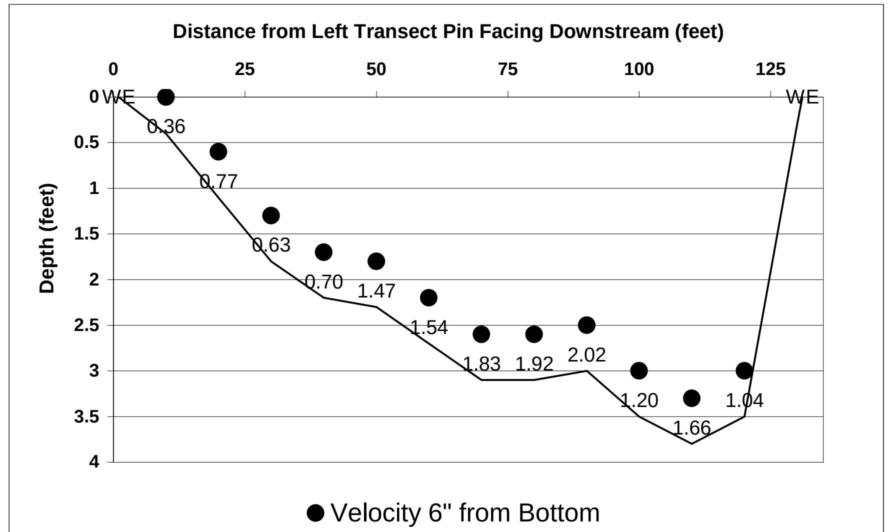
Transect 41 9/27/2004 (Merced Falls Dam Flow = 658 cfs)



Transect 42 9/24/2004 (Merced Falls Dam Flow = 515 cfs)

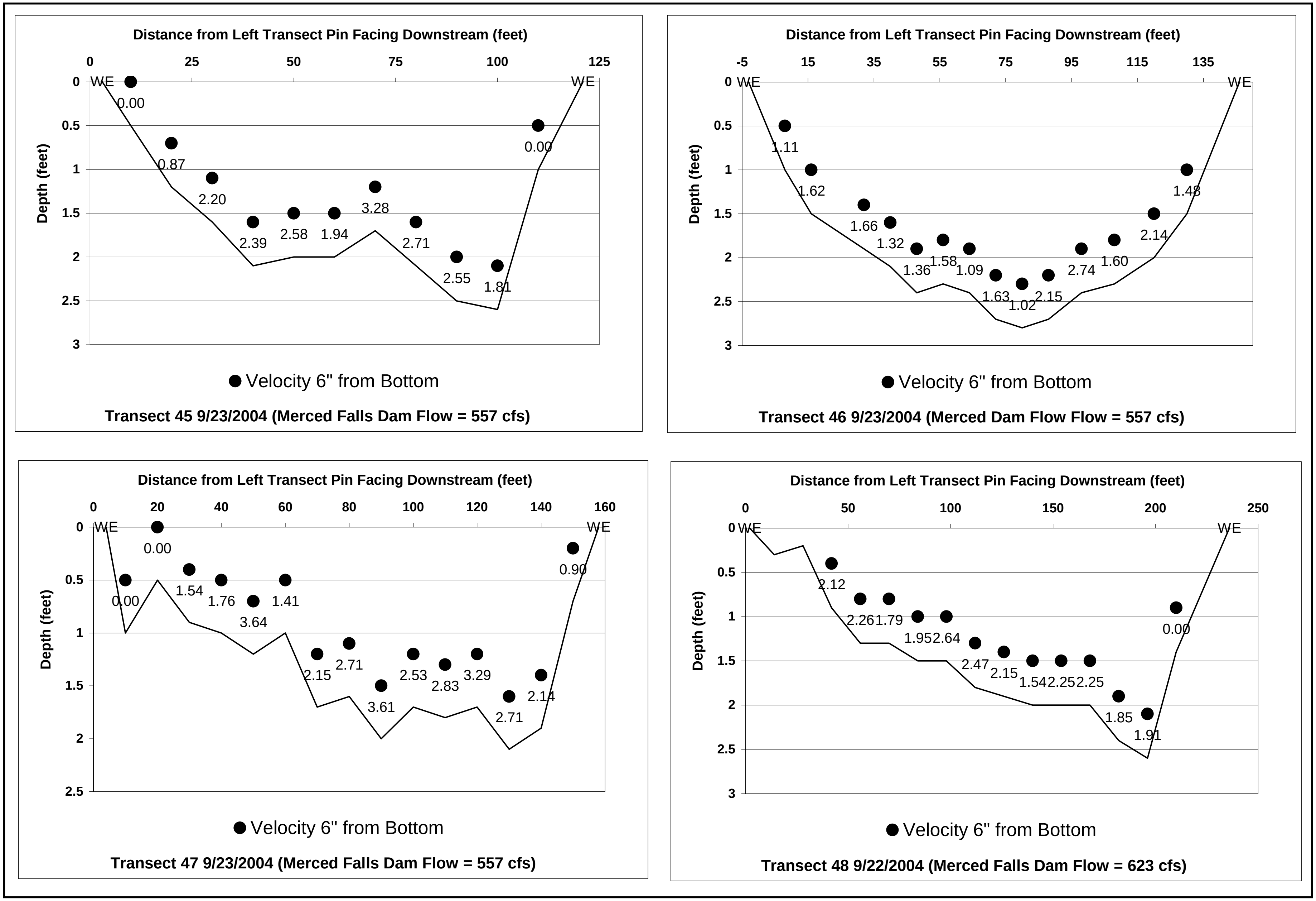


Transect 43 9/24/2004 (Merced Falls Dam Flow = 515 cfs)

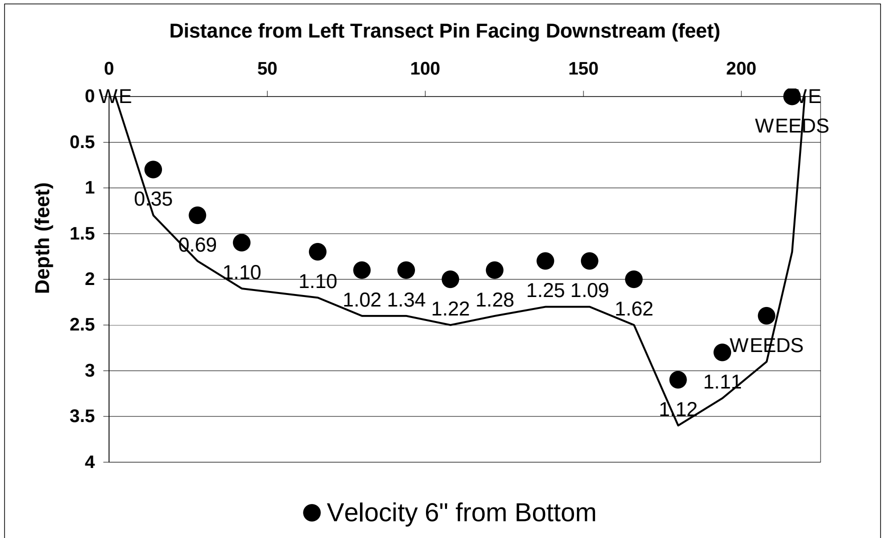


Transect 44 9/24/2004 (Merced Falls Dam Flow = 515 cfs)

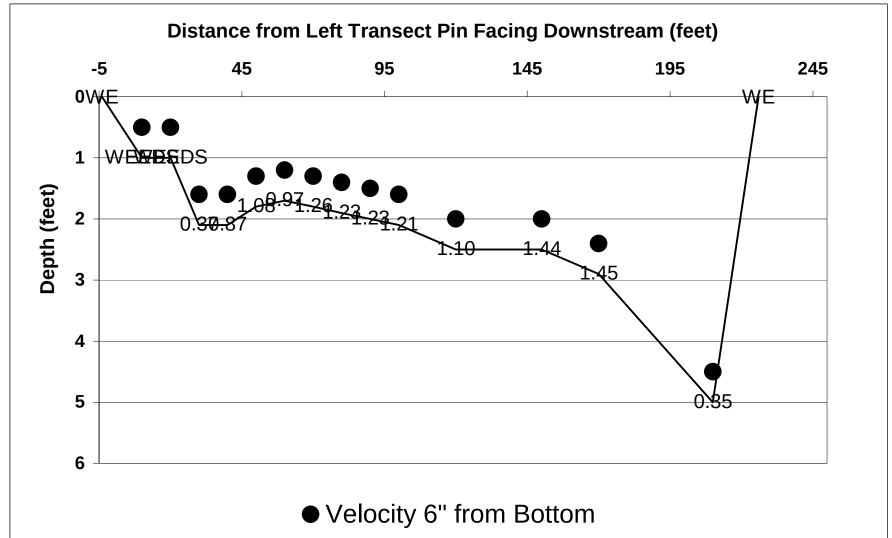
Appendix A. Cross-sectional velocity profiles measured at transects in the Merced River between Crocker-Huffman and Merced Falls dams.



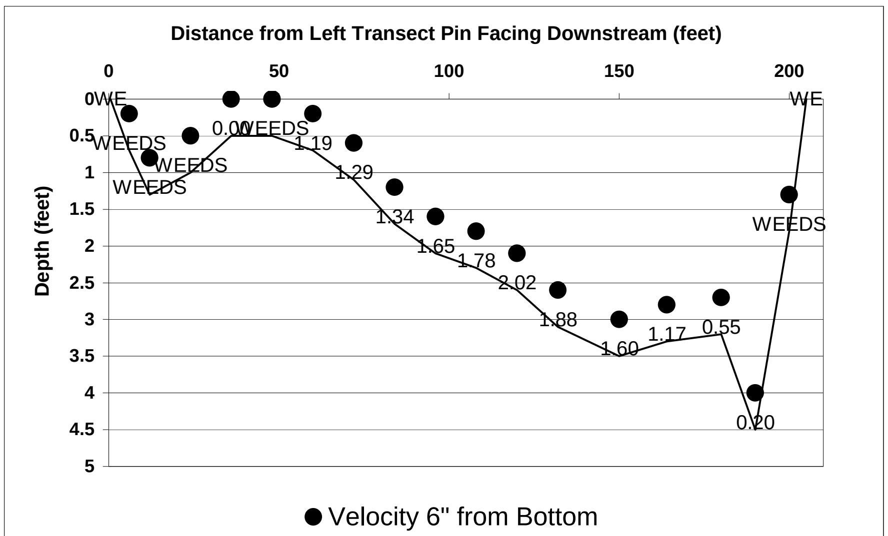
Appendix A. Cross-sectional velocity profiles measured at transects in the Merced River between Crocker-Huffman and Merced Falls dams.



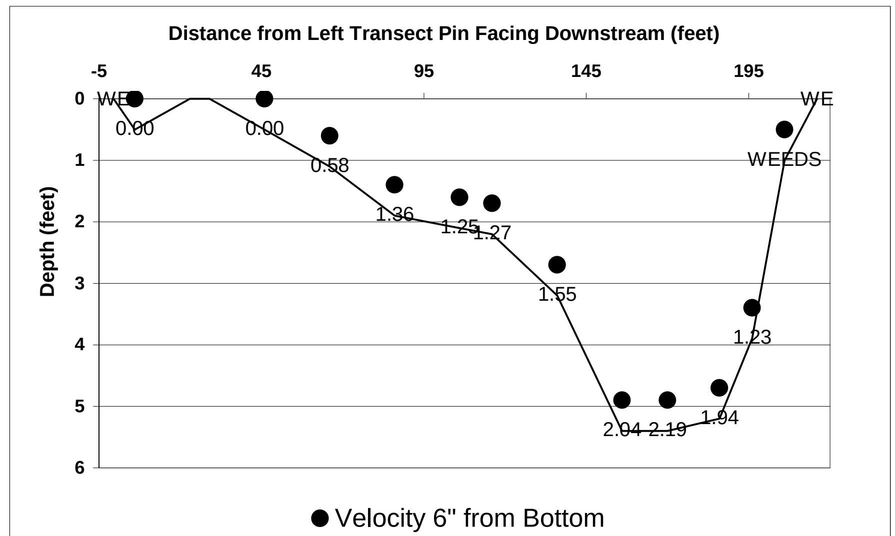
Transect 49 9/22/2004 (Merced Falls Dam Flow = 623 cfs)



Transect 50 9/22/2004 (Merced Falls Dam Flow = 623 cfs)

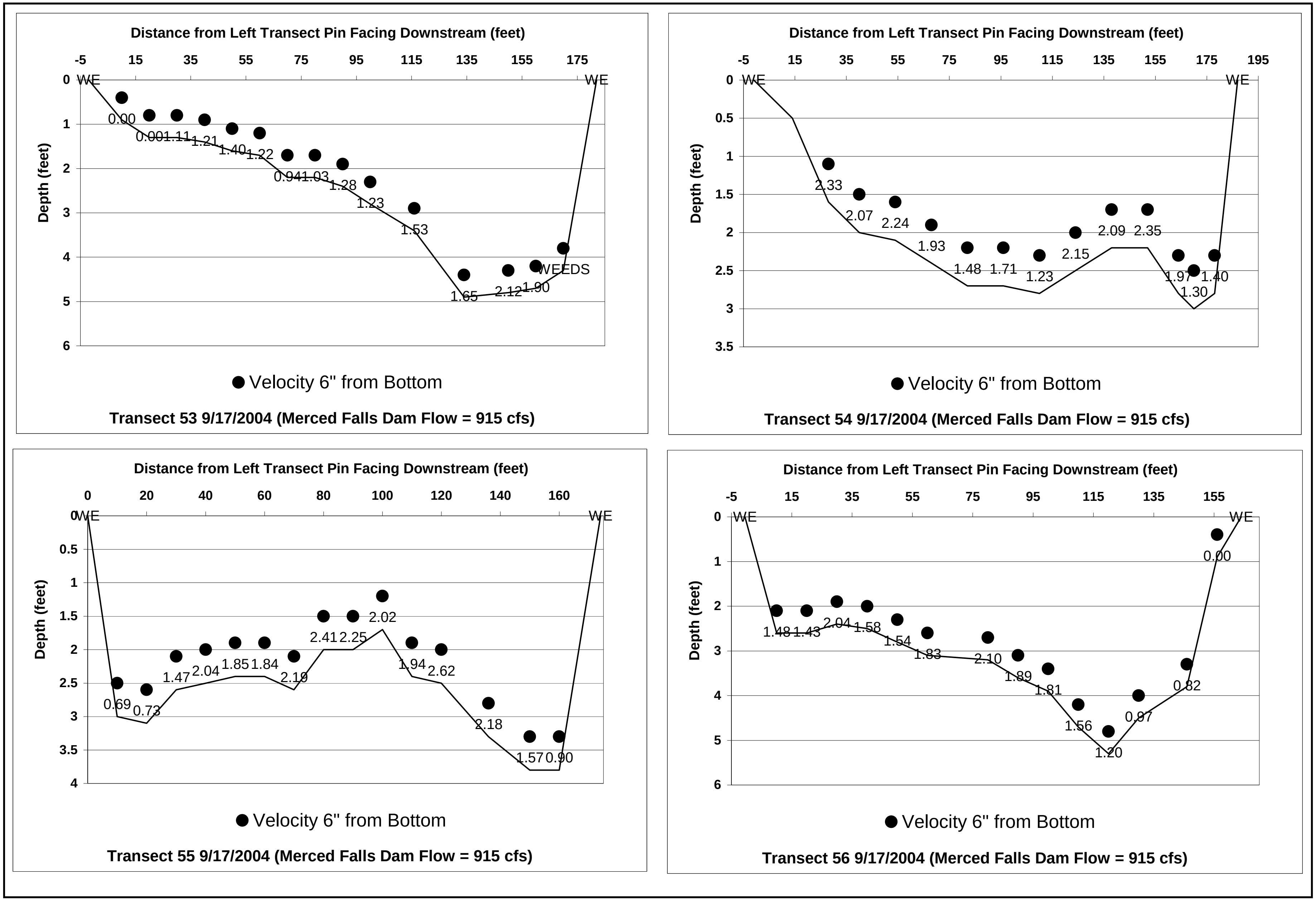


Transect 51 9/22/2004 (Merced Falls Dam Flow = 623 cfs)

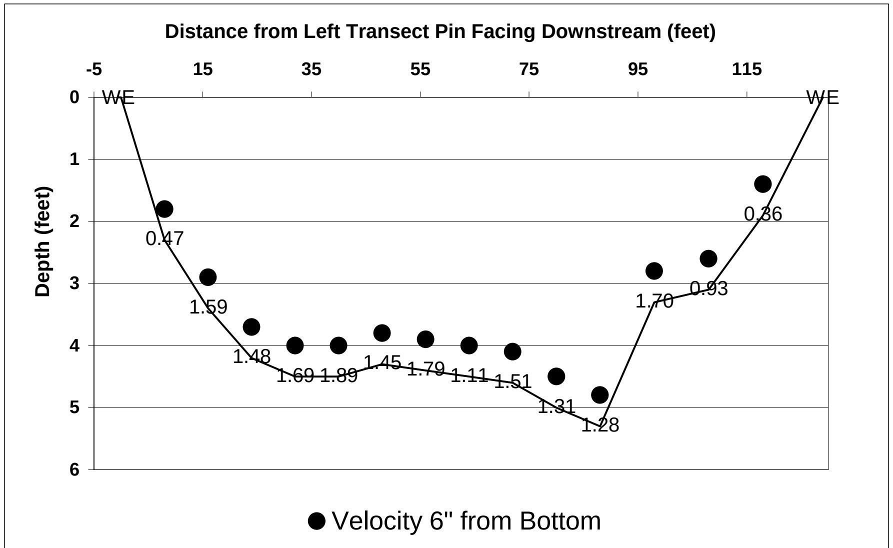


Transect 52 9/17/2004 (Merced Falls Dam Flow = 915 cfs)

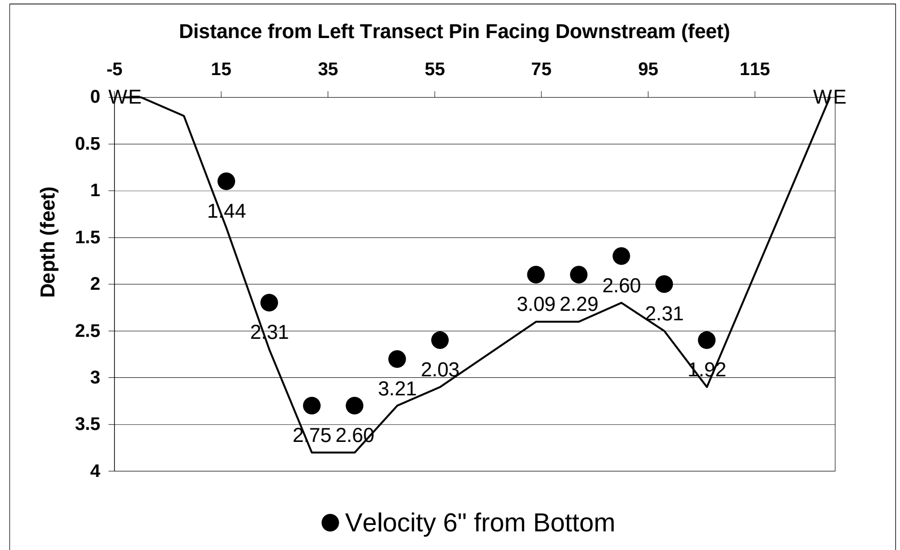
Appendix A. Cross-sectional velocity profiles measured at transects in the Merced River between Crocker-Huffman and Merced Falls dams.



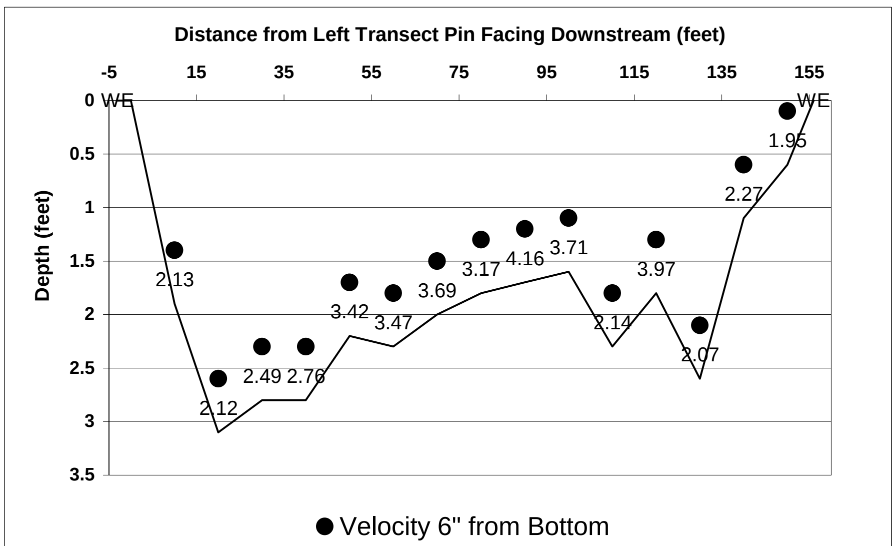
Appendix A. Cross-sectional velocity profiles measured at transects in the Merced River between Crocker-Huffman and Merced Falls dams.



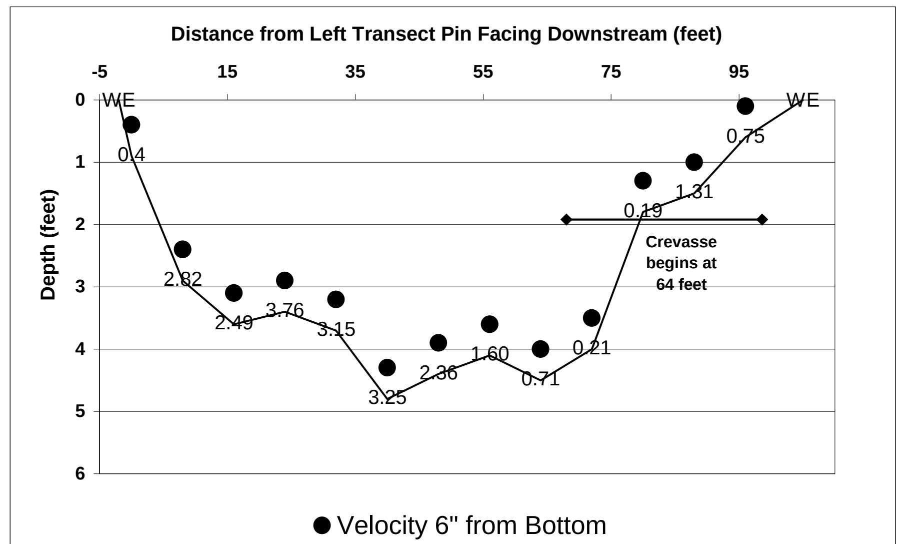
Transect 57 9/15/2004 (Merced Falls Dam Flow = 955 cfs)



Transect 58 9/15/2004 (Merced Falls Dam Flow = 955 cfs)

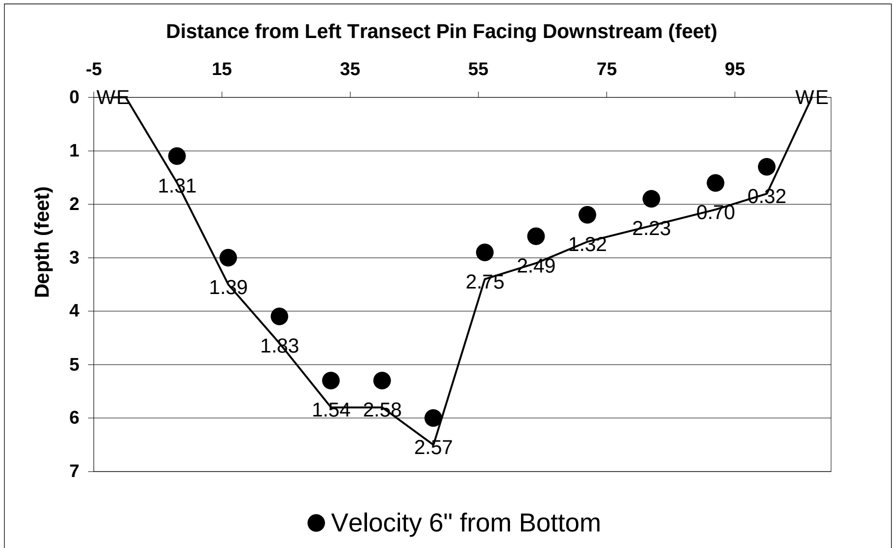


Transect 59 9/14/2004 (Merced Falls Dam Flow = 943 cfs)

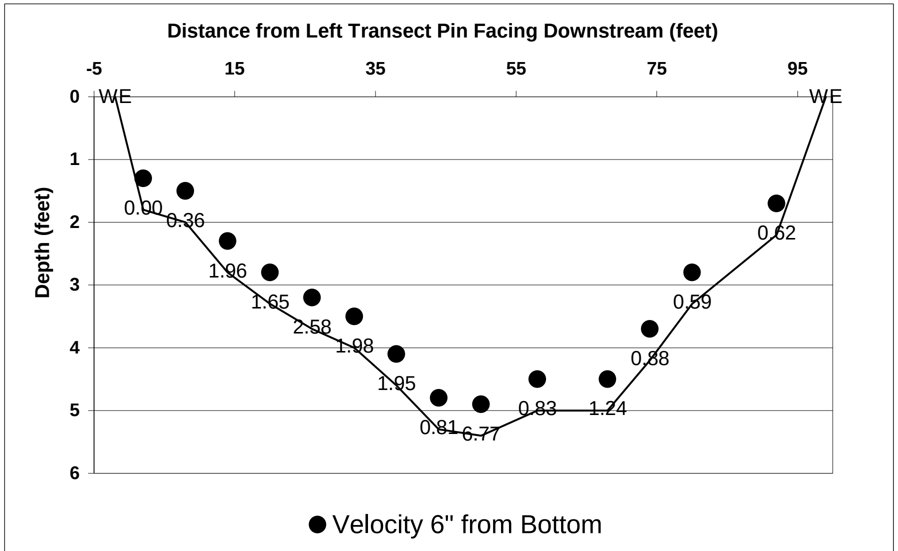


Transect 60 9/14/2004 (Merced Falls Dam Flow = 943 cfs)

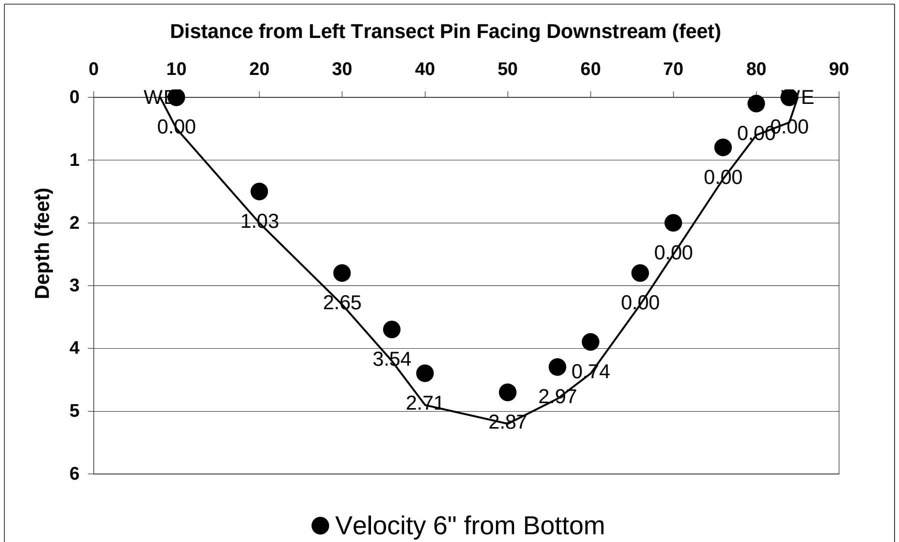
Appendix A. Cross-sectional velocity profiles measured at transects in the Merced River between Crocker-Huffman and Merced Falls dams.



Transect 61 9/7/2004 (Merced Falls Dam Flow = 1051 cfs)

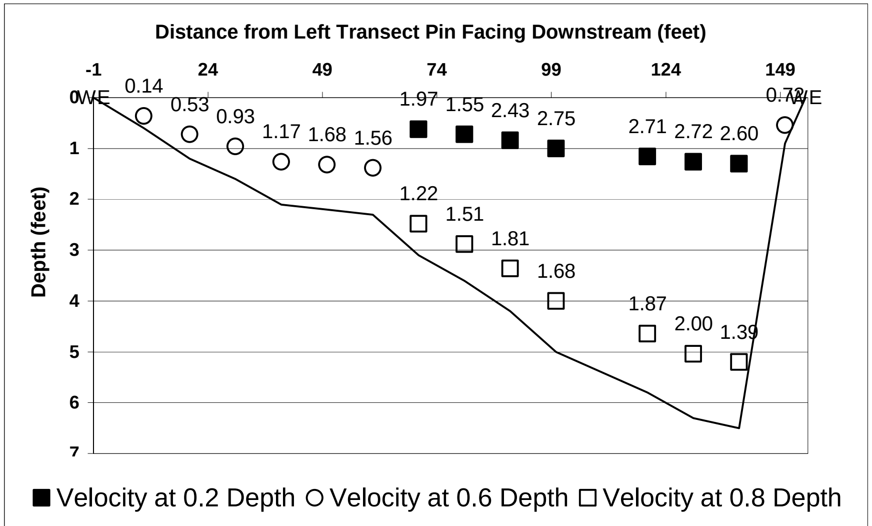


Transect 62 9/2/2004 (Merced Falls Dam Flow = 940 cfs)

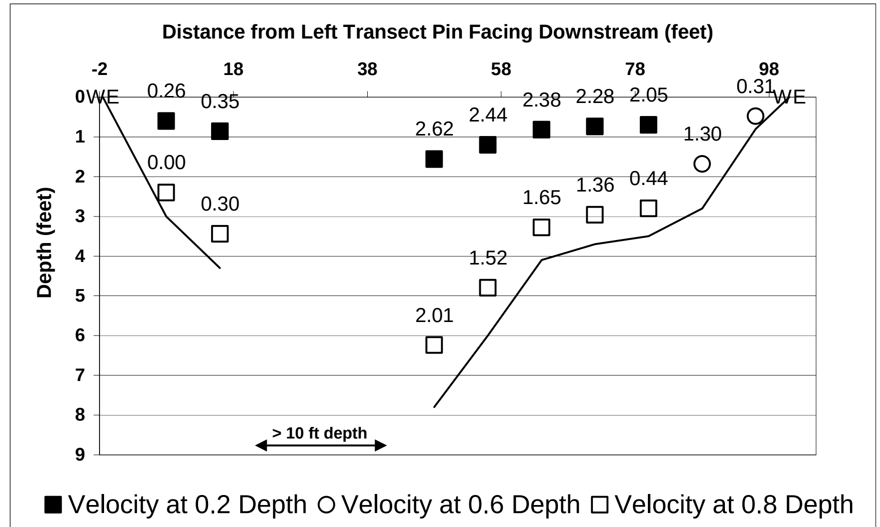


Transect 63 9/27/2004 (Merced Falls Dam Flow = 658 cfs)

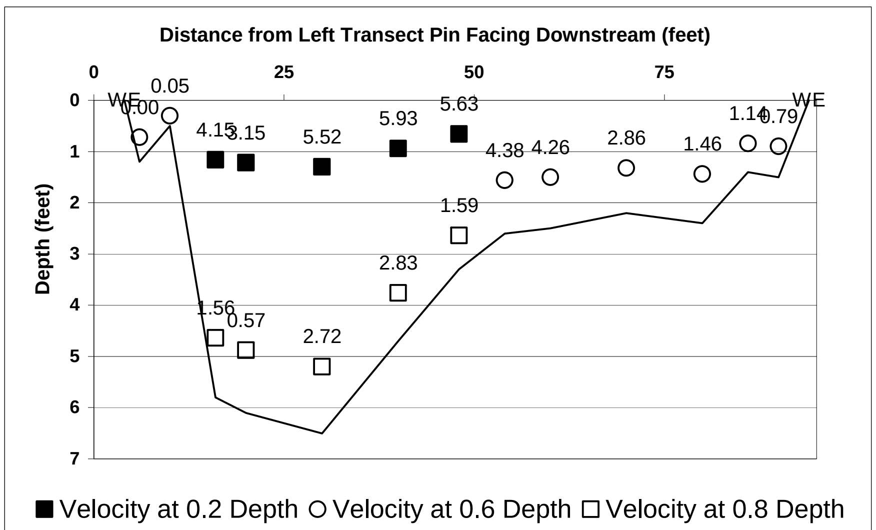
Appendix A. Cross-sectional velocity profiles measured at transects in the Merced River between Crocker-Huffman and Merced Falls dams.



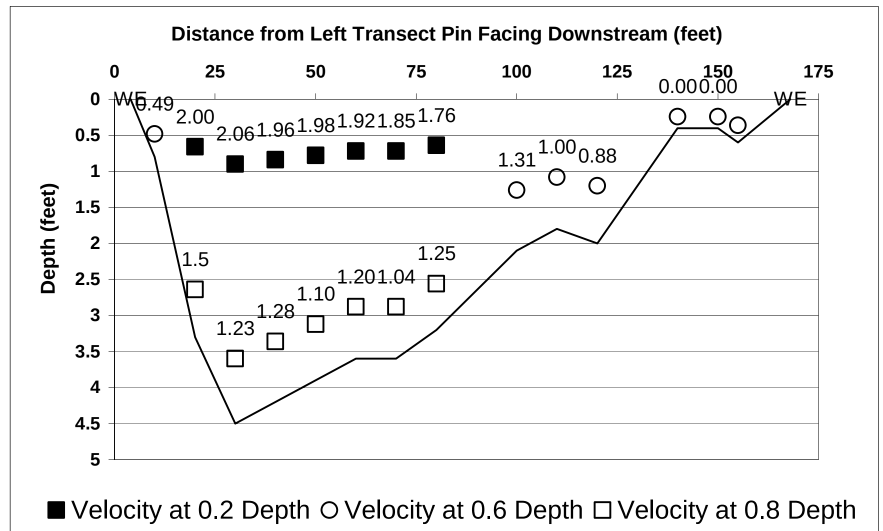
Transect 35 9/30/2004 (Merced Falls Dam Flow = 861 cfs)



Transect 37 9/30/2004 (Merced Falls Dam Flow = 861 cfs)

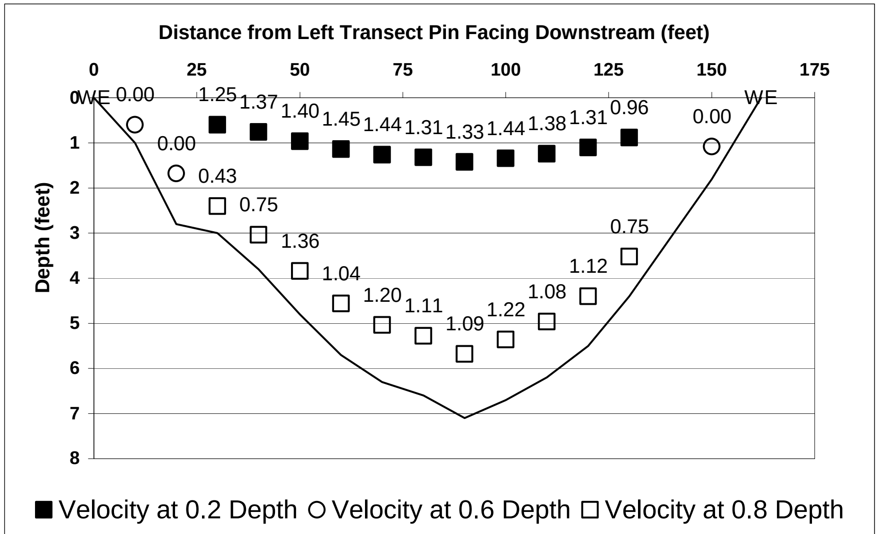


Transect 38 9/30/2004 (Merced Falls Dam Flow = 861 cfs)

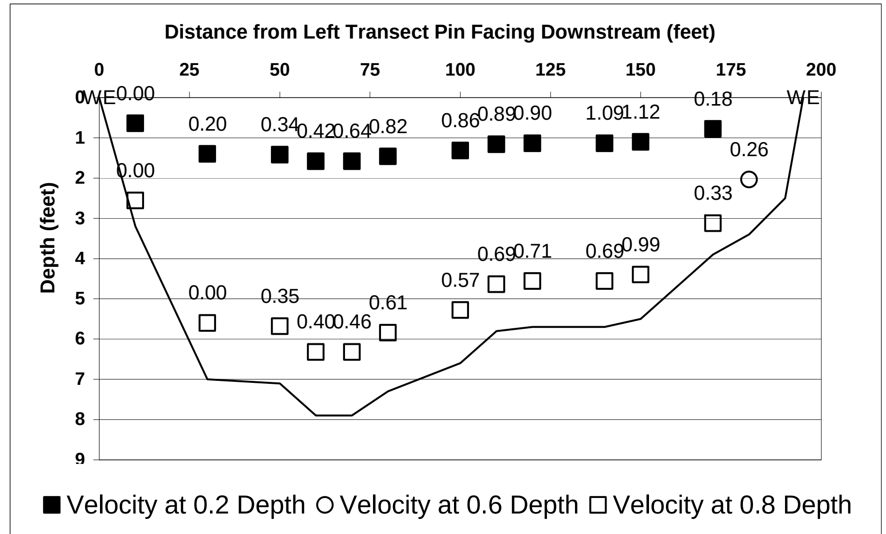


Transect 40 9/24/2004 (Merced Falls Dam Flow = 515 cfs)

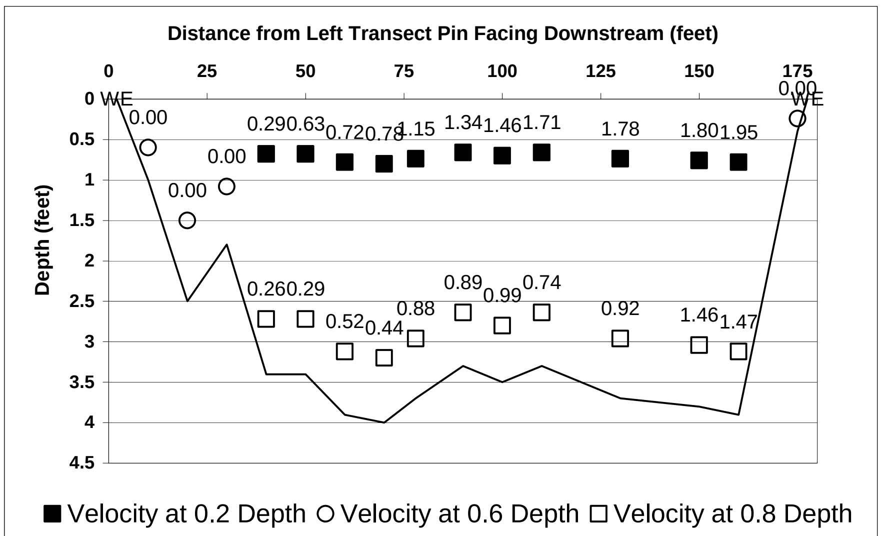
Appendix A. Cross-sectional velocity profiles measured at transects in the Merced River between Crocker-Huffman and Merced Falls dams.



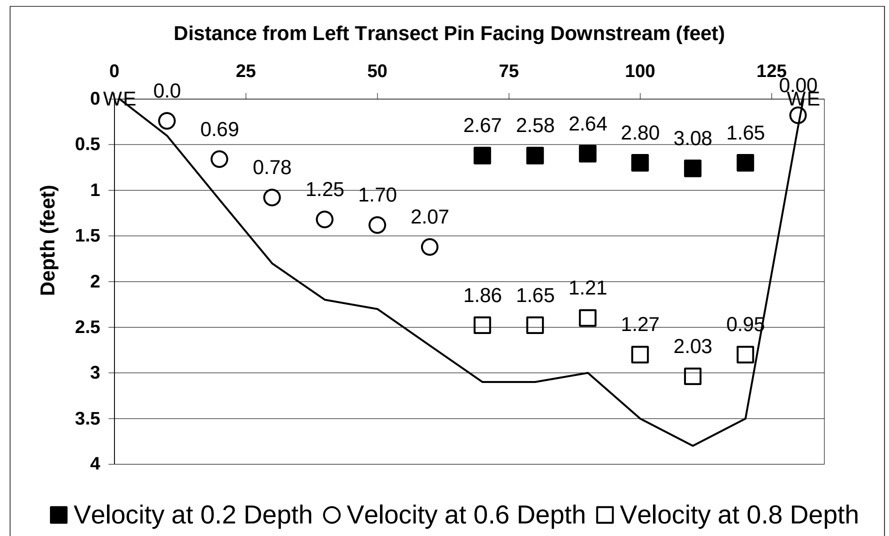
Transect 41 9/27/2004 (Merced Falls Dam Flow = 658 cfs)



Transect 42 9/24/2004 (Merced Falls Dam Flow = 515 cfs)

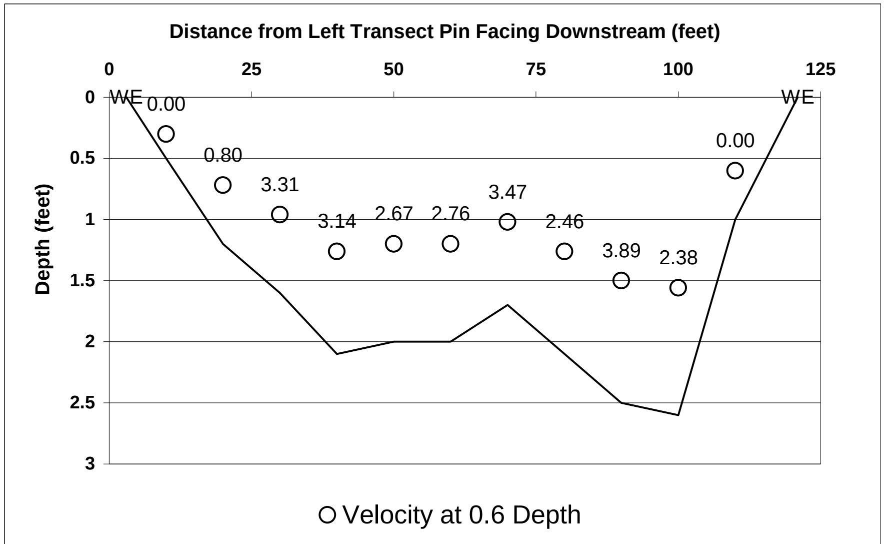


Transect 43 9/24/2004 (Merced Falls Dam Flow = 515 cfs)

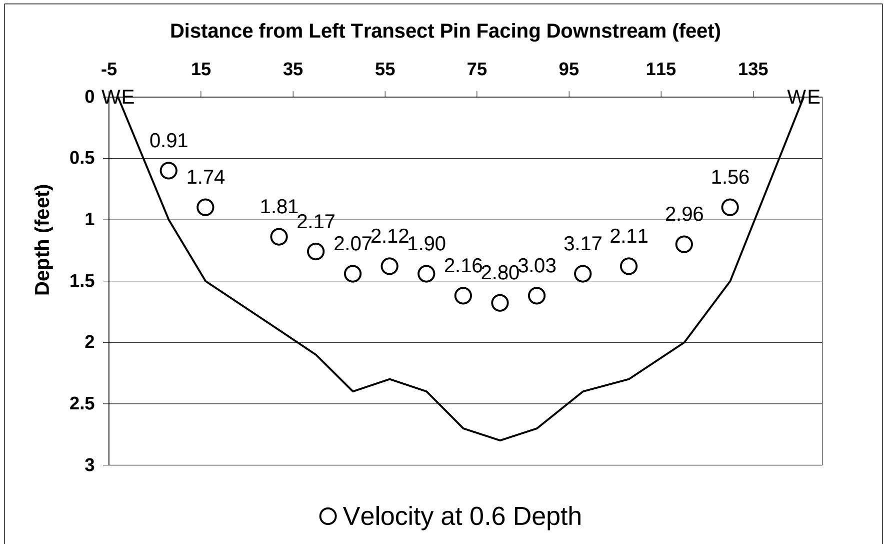


Transect 44 9/24/2004 (Merced Falls Dam Flow = 515 cfs)

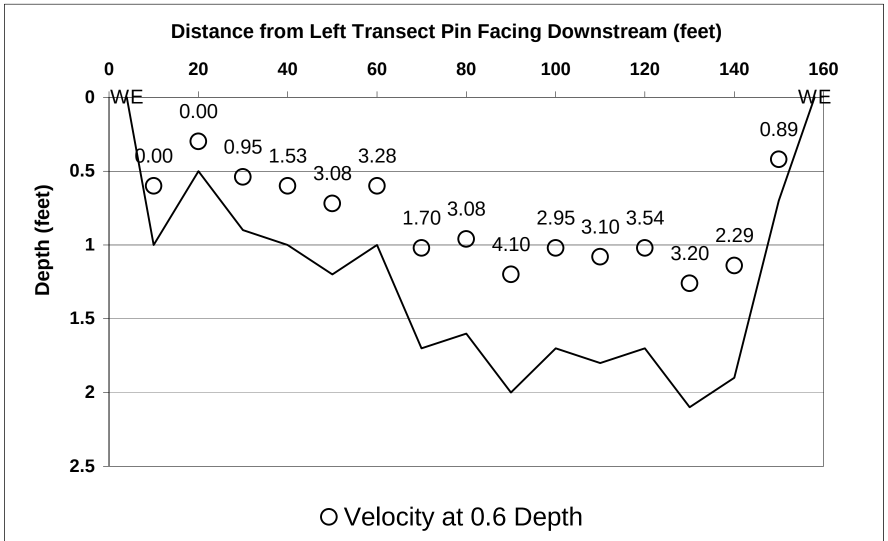
Appendix A. Cross-sectional velocity profiles measured at transects in the Merced River between Crocker-Huffman and Merced Falls dams.



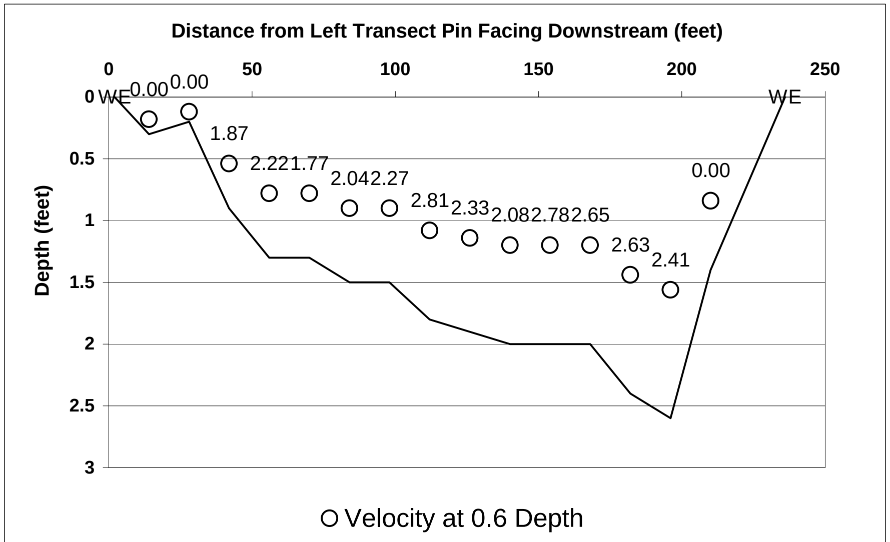
Transect 45 9/23/2004 (Merced Falls Dam Flow = 557 cfs)



Transect 46 9/23/2004 (Merced Falls Dam Flow = 557 cfs)

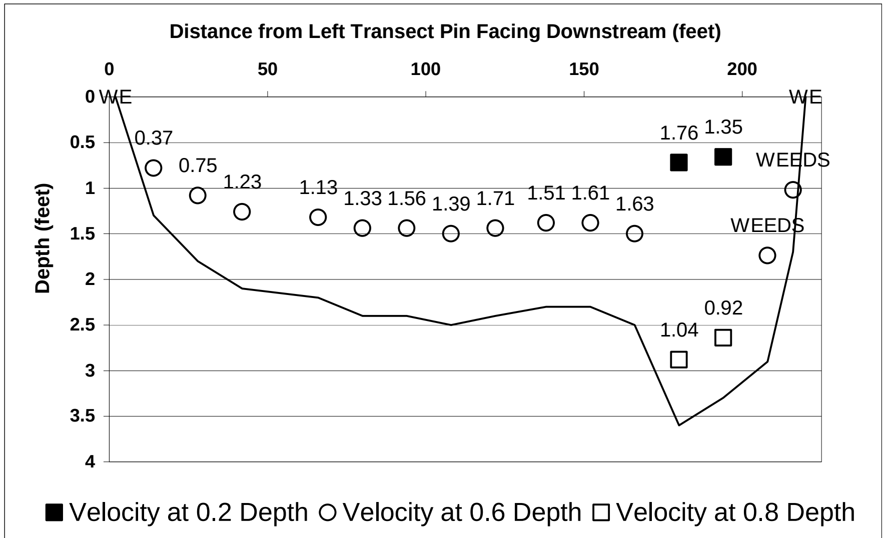


Transect 47 9/23/2004 (Merced Falls Dam Flow = 557 cfs)

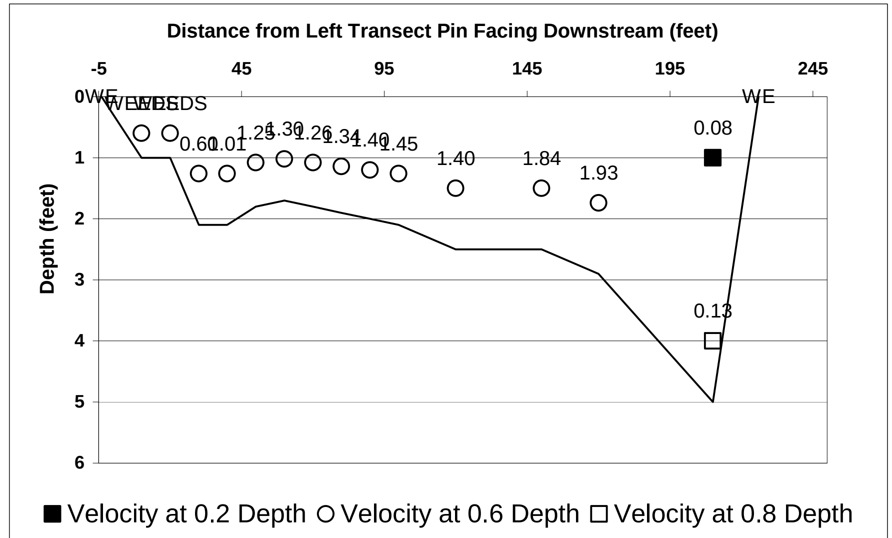


Transect 48 9/22/2004 (Merced Falls Dam Flow = 623 cfs)

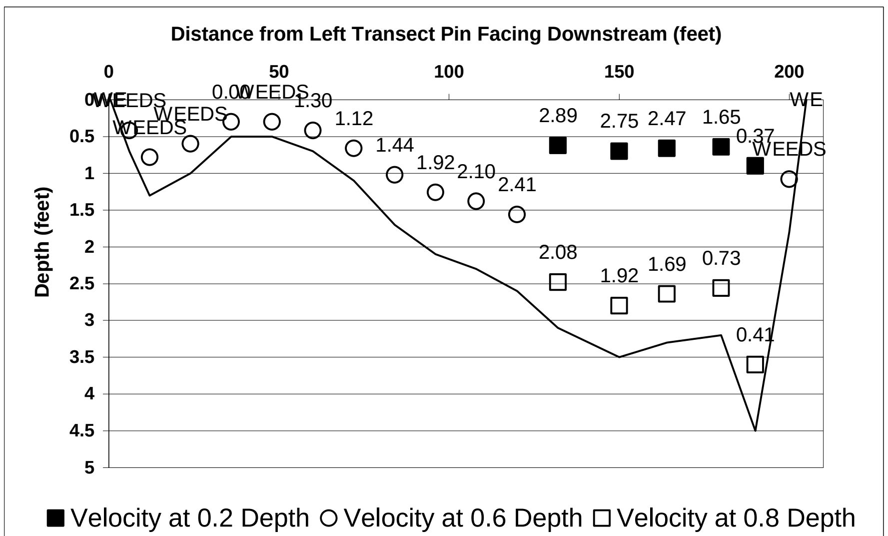
Appendix A. Cross-sectional velocity profiles measured at transects in the Merced River between Crocker-Huffman and Merced Falls dams.



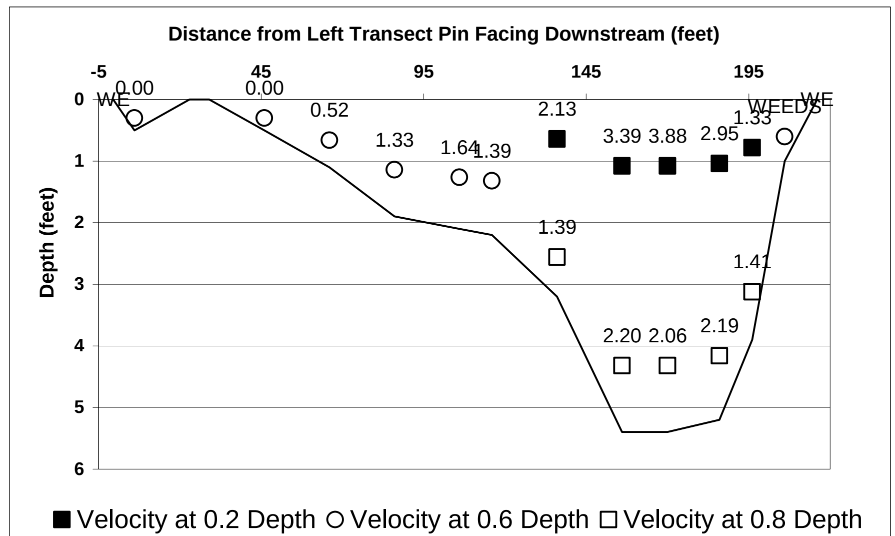
Transect 49 9/22/2004 (Merced Falls Dam Flow = 623 cfs)



Transect 50 9/22/2004 (Merced Falls Dam Flow = 623 cfs)

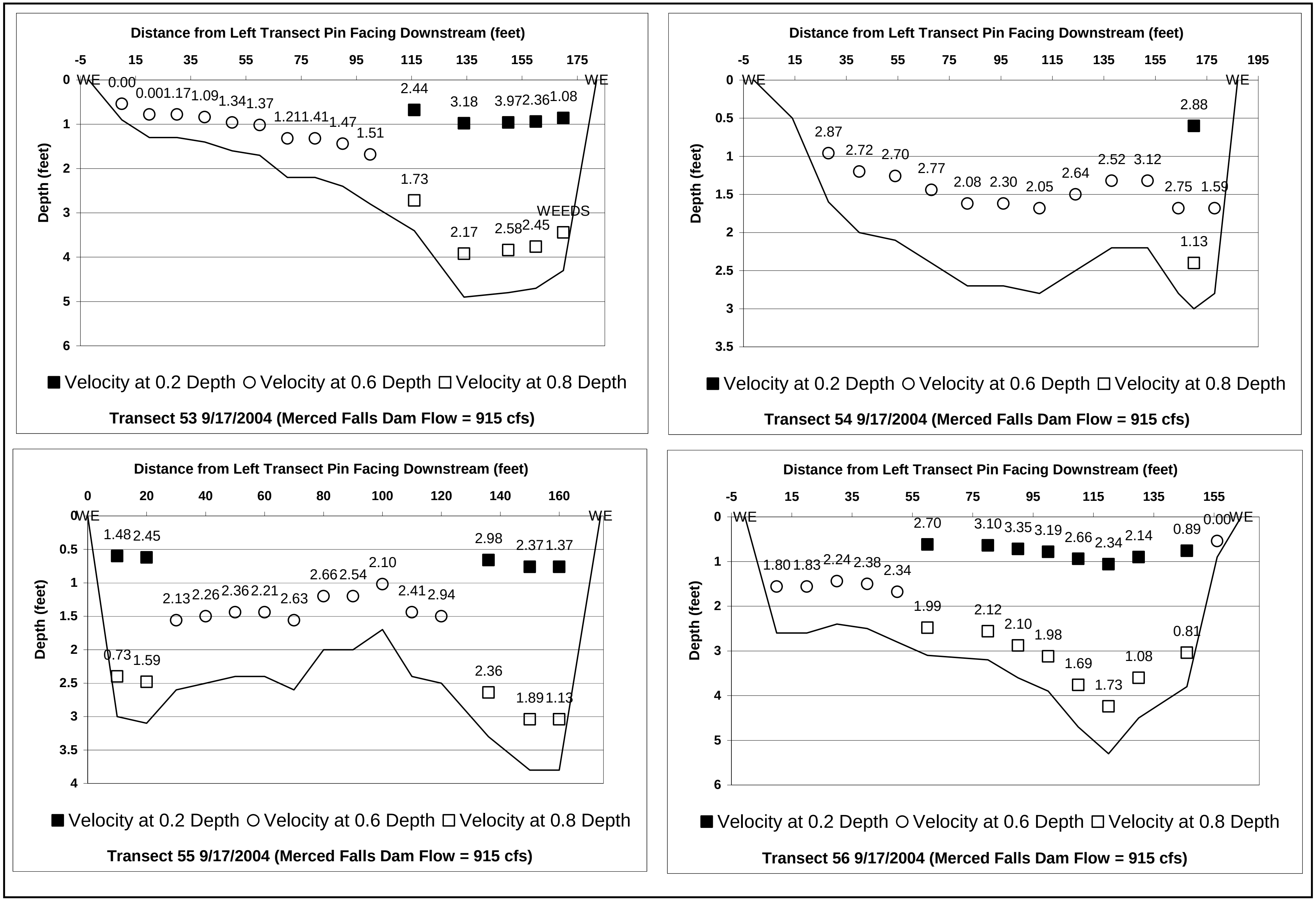


Transect 51 9/22/2004 (Merced Falls Dam Flow = 623 cfs)

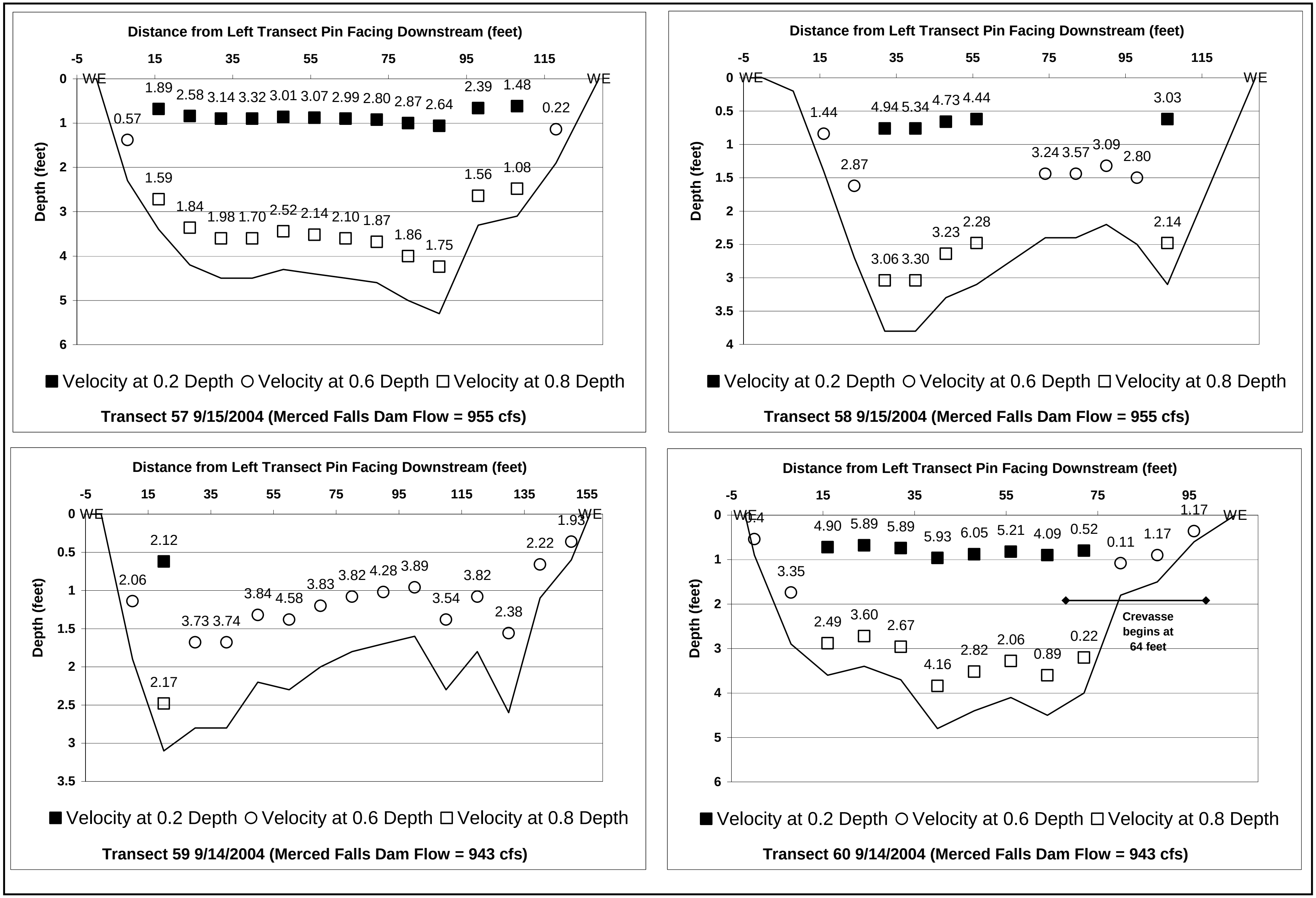


Transect 52 9/17/2004 (Merced Falls Dam Flow = 915cfs)

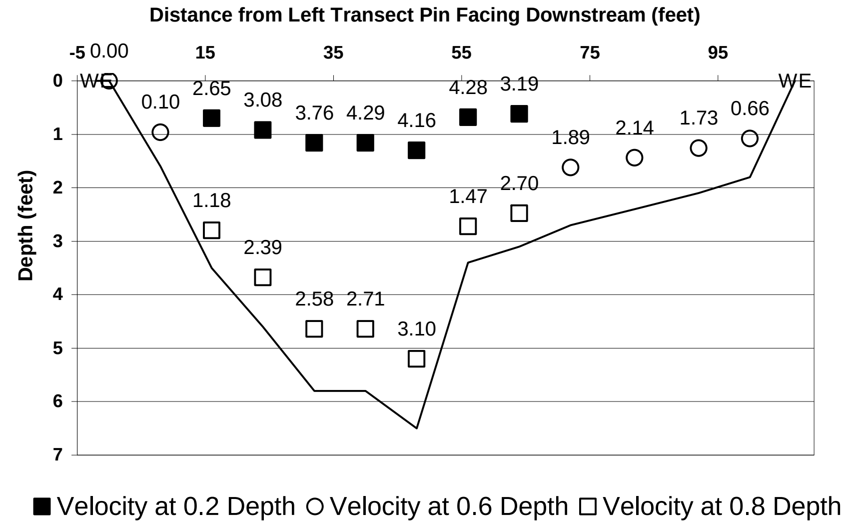
Appendix A. Cross-sectional velocity profiles measured at transects in the Merced River between Crocker-Huffman and Merced Falls dams.



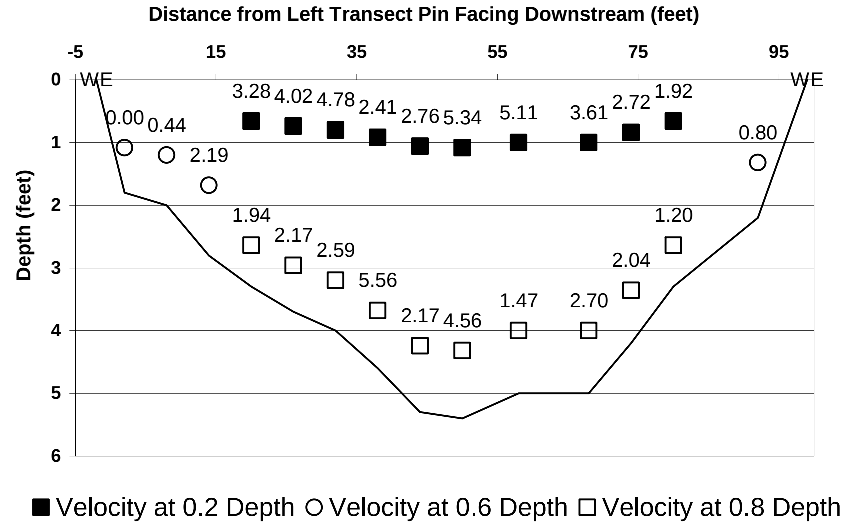
Appendix A. Cross-sectional velocity profiles measured at transects in the Merced River between Crocker-Huffman and Merced Falls dams.



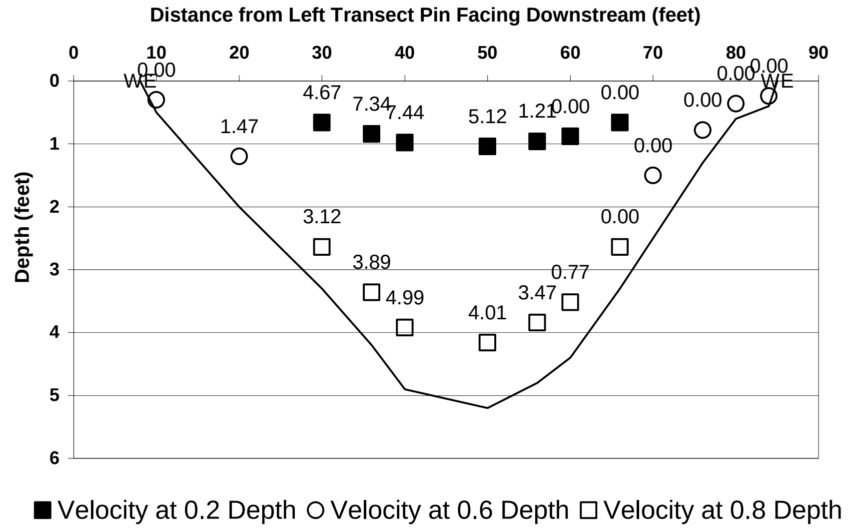
Appendix A. Cross-sectional velocity profiles measured at transects in the Merced River between Crocker-Huffman and Merced Falls dams.



Transect 61 9/7/2004 (Merced Falls Dam Flow = 1051 cfs)

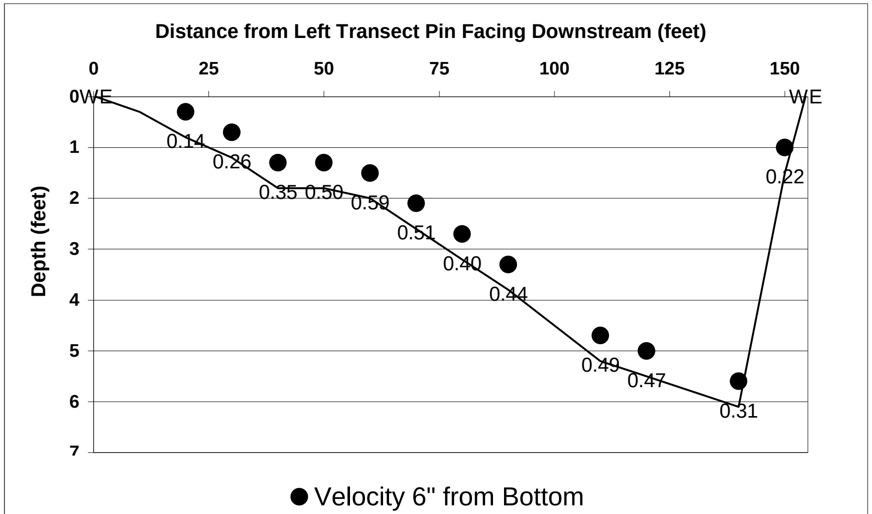


Transect 62 9/2/2004 (Merced Falls Dam Flow = 940 cfs)

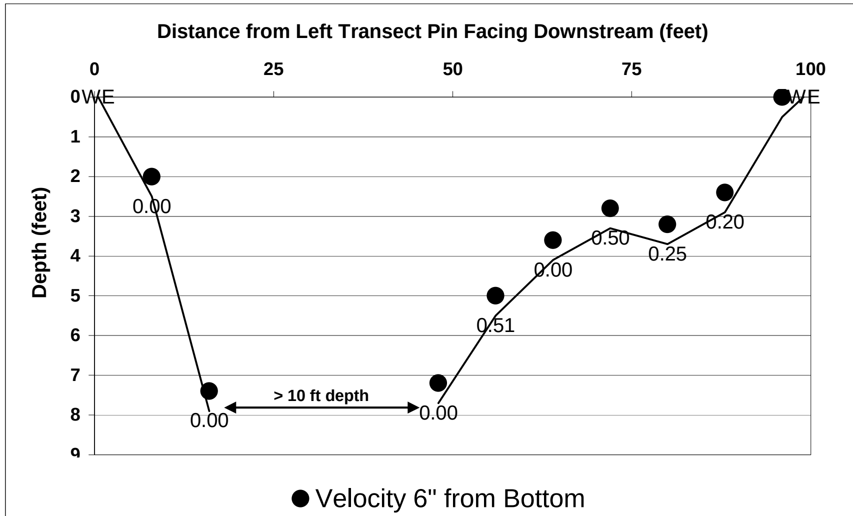


Transect 63 9/27/2004 (Merced Falls Dam Flow = 658 cfs)

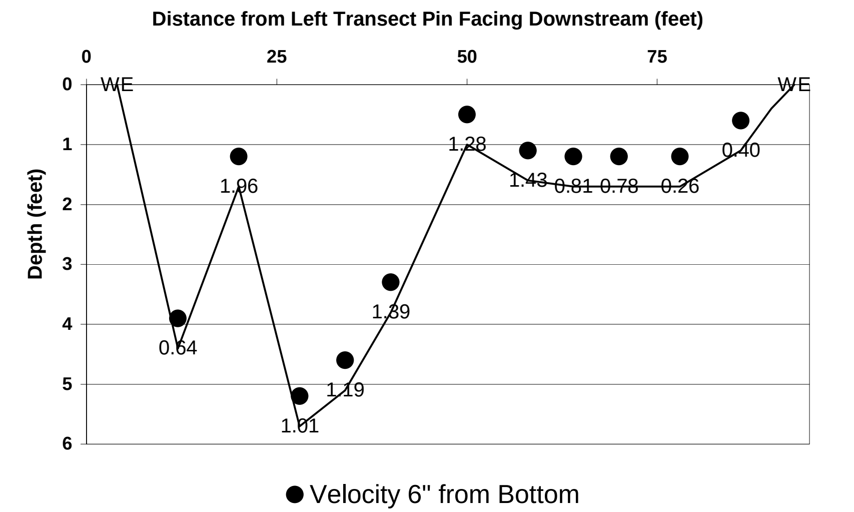
Appendix A. Cross-sectional velocity profiles measured at transects in the Merced River between Crocker-Huffman and Merced Falls dams.



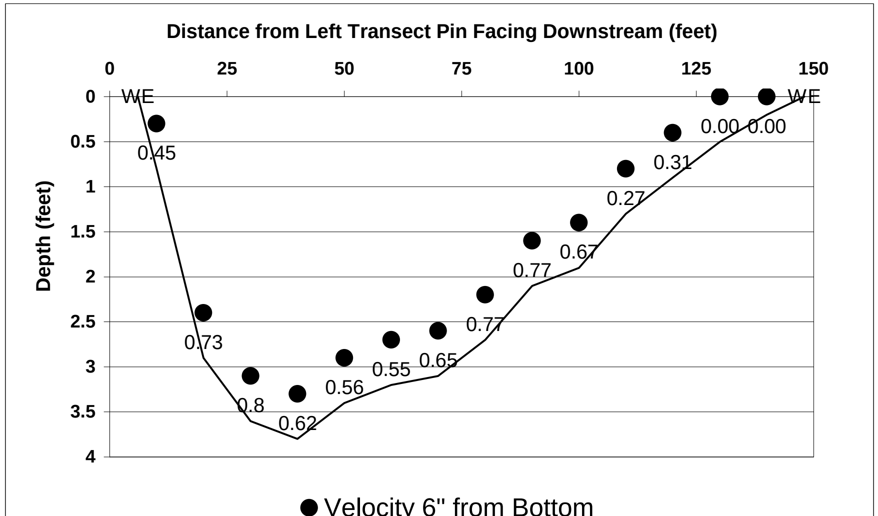
Transect 35 3/6/2005 (Merced Falls Dam Flow = 267 cfs)



Transect 37 3/1/2005 (Merced Falls Dam Flow = 272 cfs)

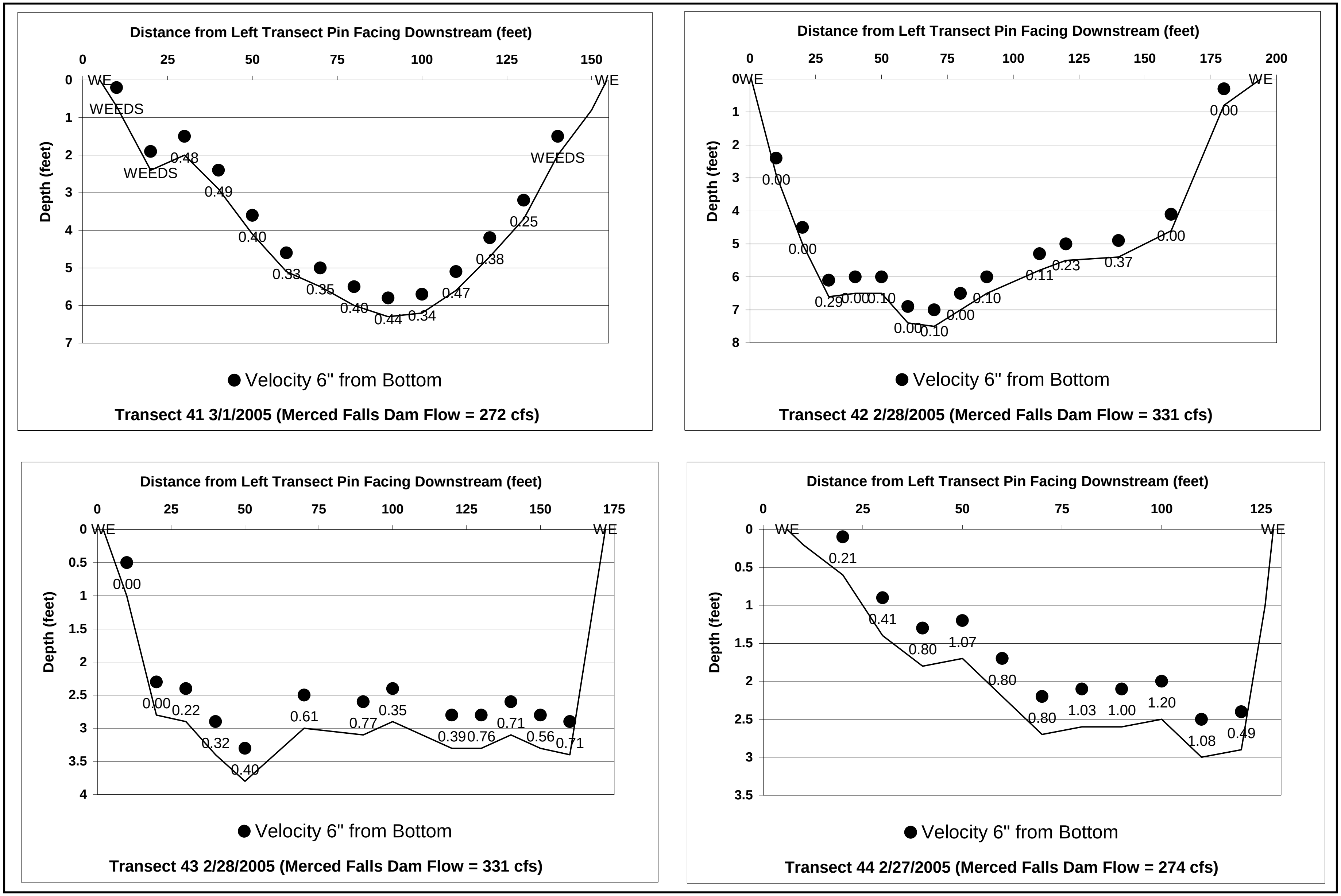


Transect 38 3/1/2005 (Merced Falls Dam Flow = 272 cfs)

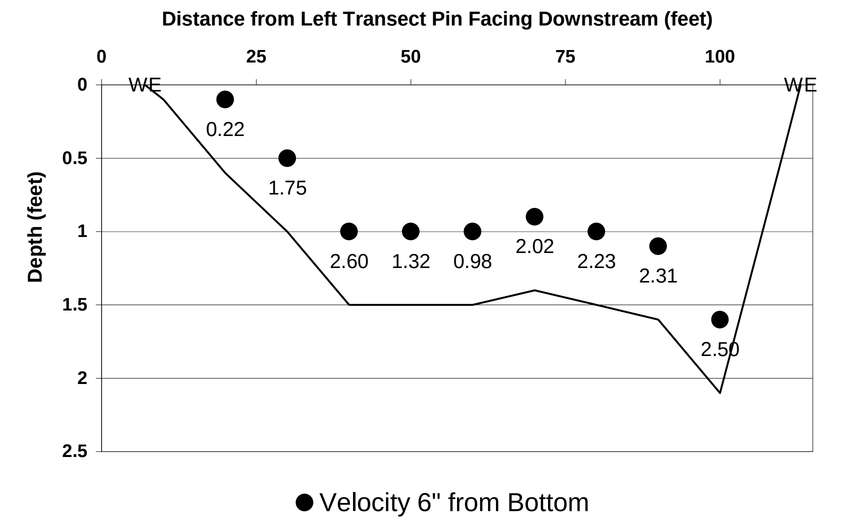


Transect 40 2/27/2005 (Merced Falls Dam Flow = 274 cfs)

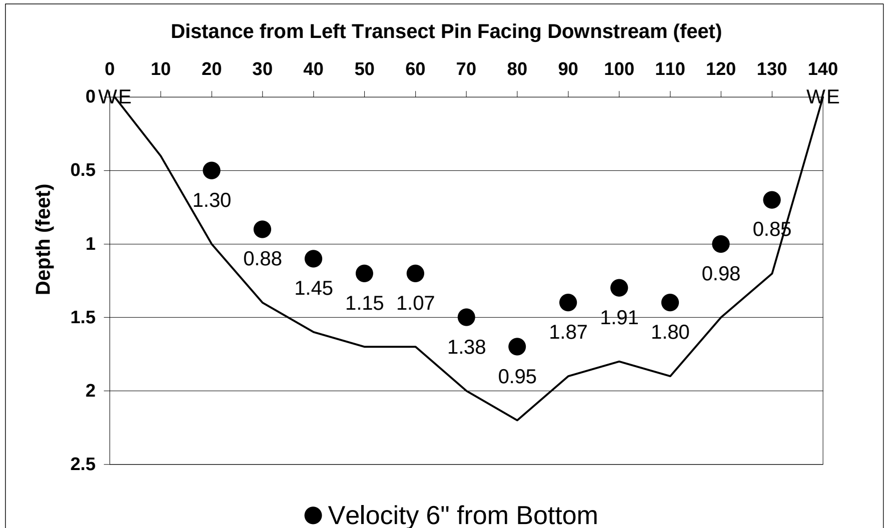
Appendix A. Cross-sectional velocity profiles measured at transects in the Merced River between Crocker-Huffman and Merced Falls dams.



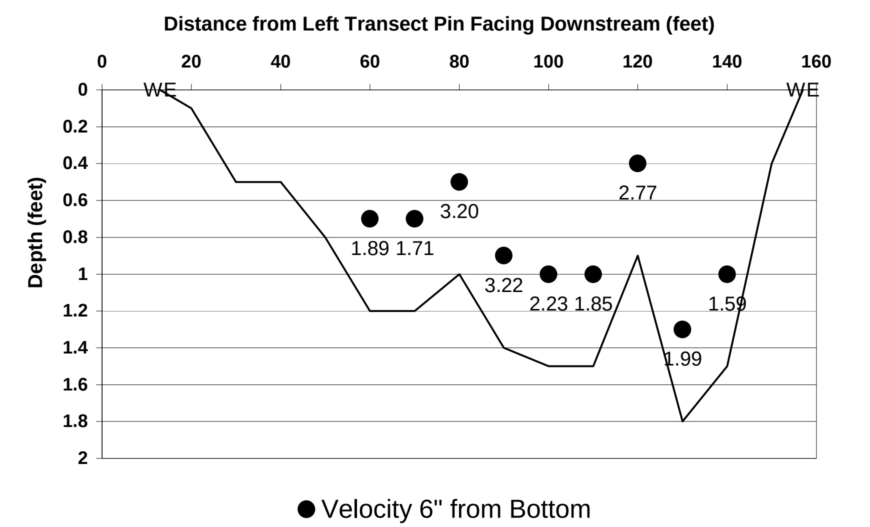
Appendix A. Cross-sectional velocity profiles measured at transects in the Merced River between Crocker-Huffman and Merced Falls dams.



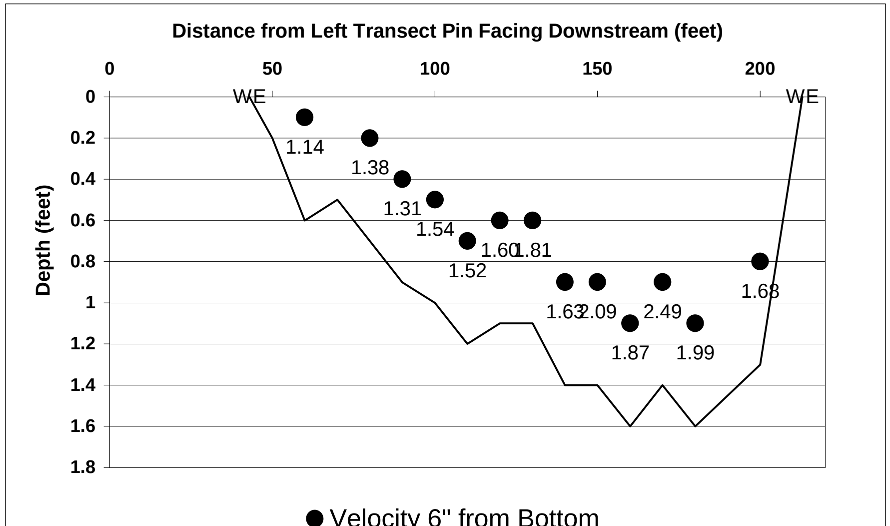
Transect 45 2/24/2005 (Merced Falls Dam Flow = 272 cfs)



Transect 46 2/24/2005 (Merced Falls Dam Flow = 272 cfs)

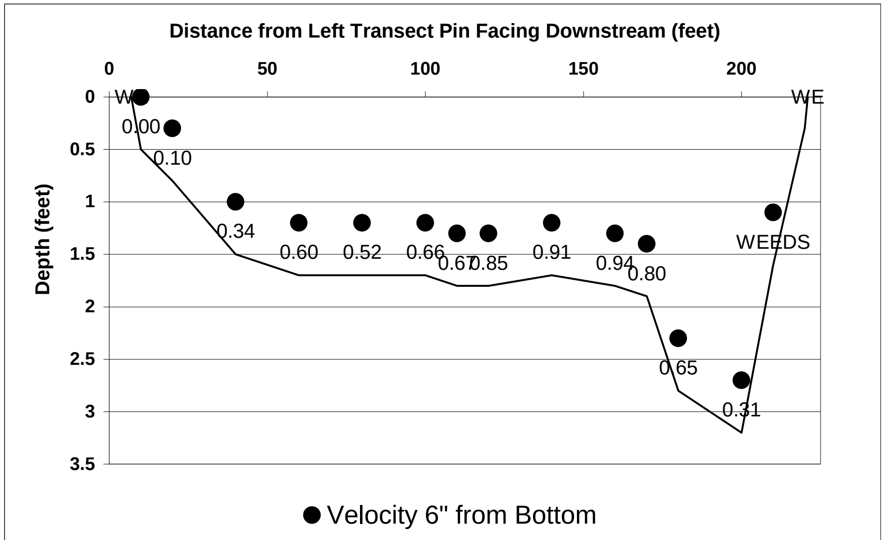


Transect 47 2/23/2005 (Merced Falls Dam Flow = 273 cfs)

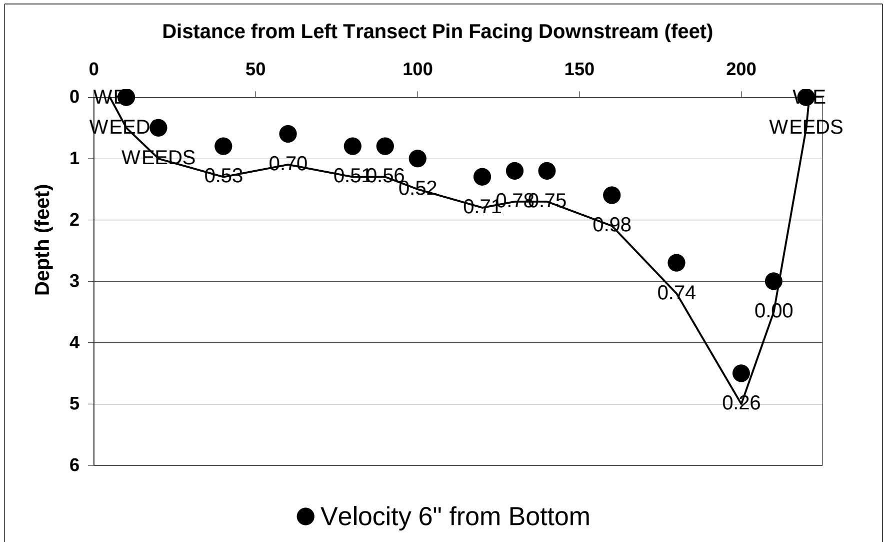


Transect 48 2/21/2005 (Merced Falls Dam Flow = 277 cfs)

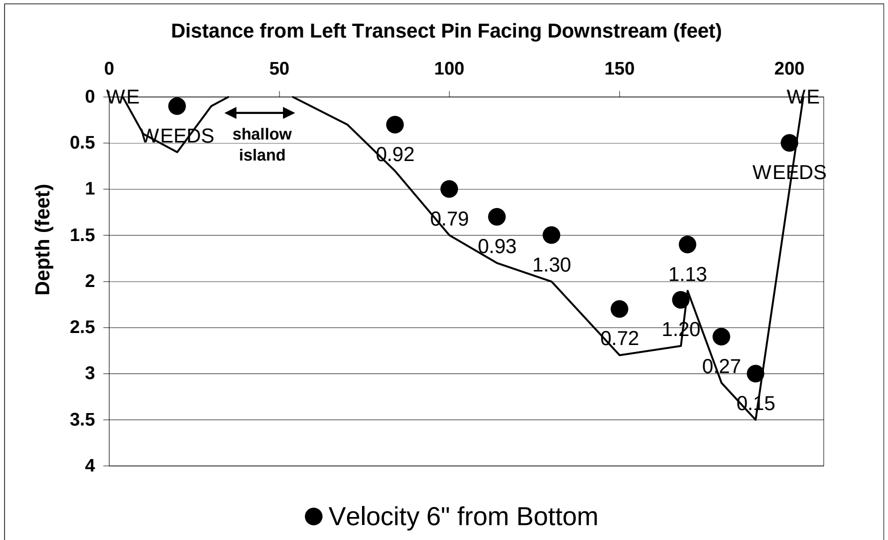
Appendix A. Cross-sectional velocity profiles measured at transects in the Merced River between Crocker-Huffman and Merced Falls dams.



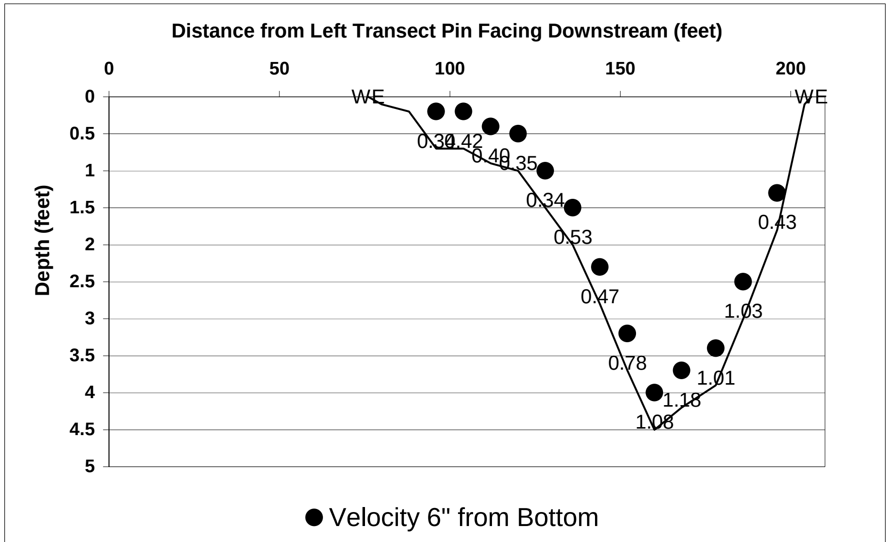
Transect 49 11/30/2004 (Merced Falls Dam Flow = 238 cfs)



Transect 50 11/29/2004 (Merced Falls Dam Flow = 247 cfs)

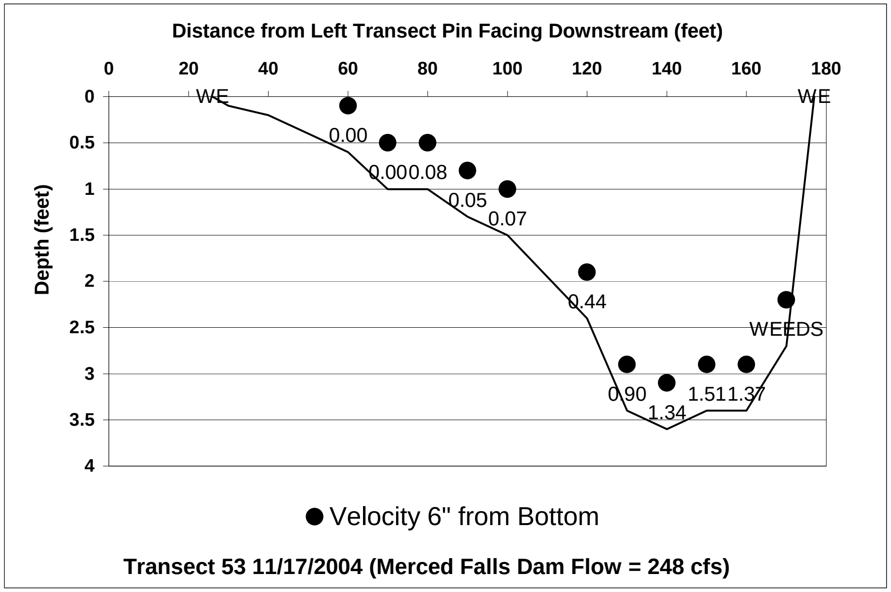


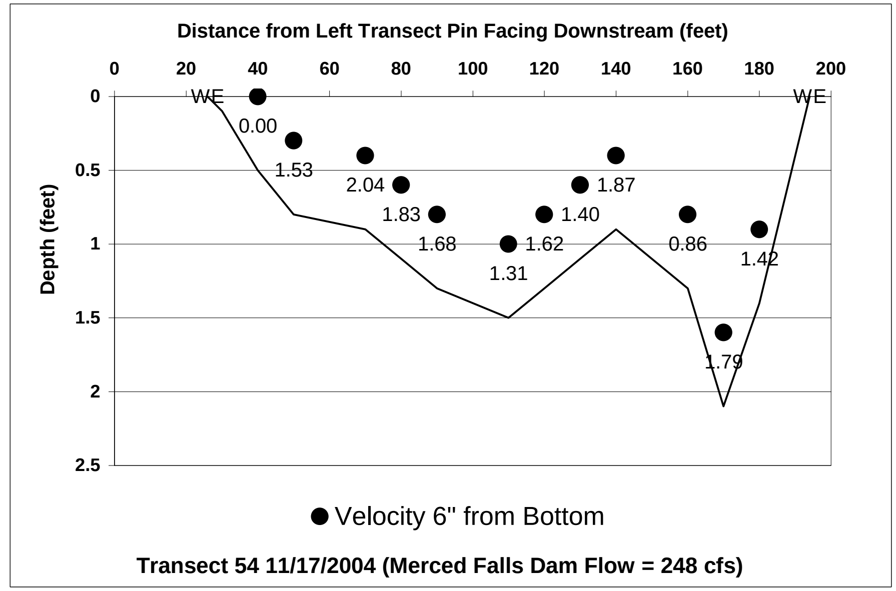
Transect 51 11/29/2004 (Merced Falls Dam Flow = 247 cfs)

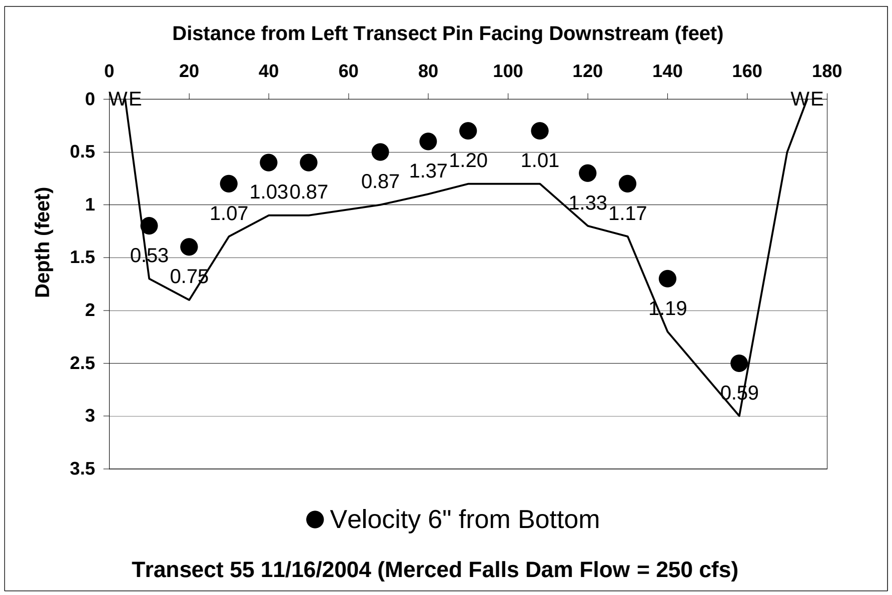


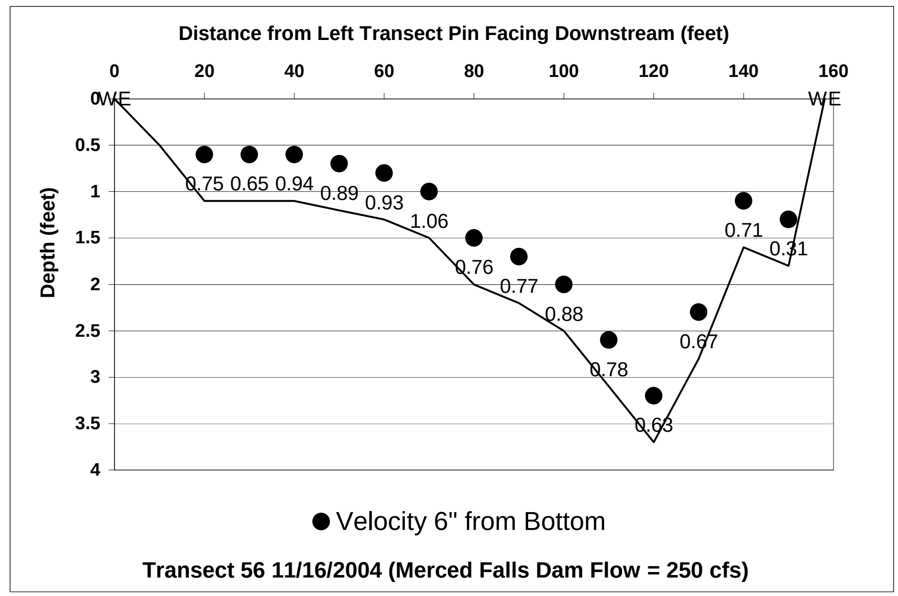
Transect 52 11/29/2004 (Merced Falls Dam Flow = 247 cfs)

Appendix A. Cross-sectional velocity profiles measured at transects in the Merced River between Crocker-Huffman and Merced Falls dams.

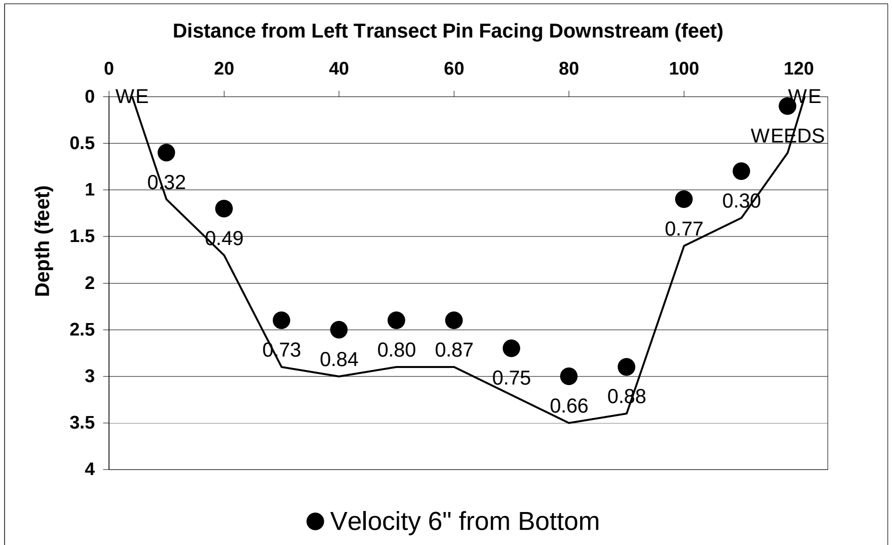




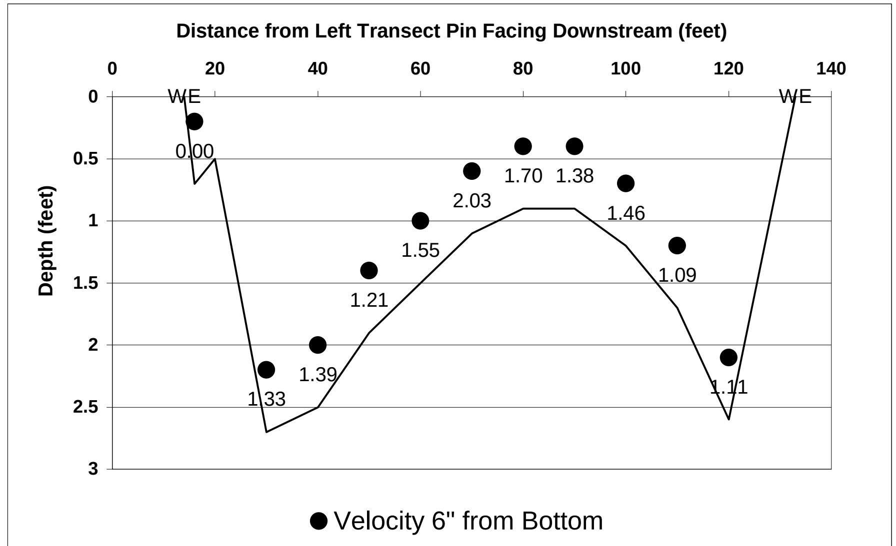




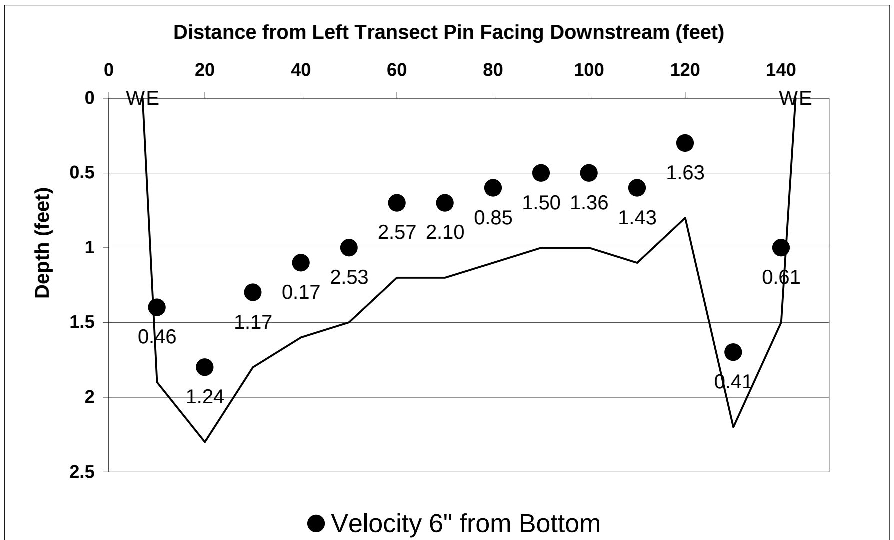
Appendix A. Cross-sectional velocity profiles measured at transects in the Merced River between Crocker-Huffman and Merced Falls dams.



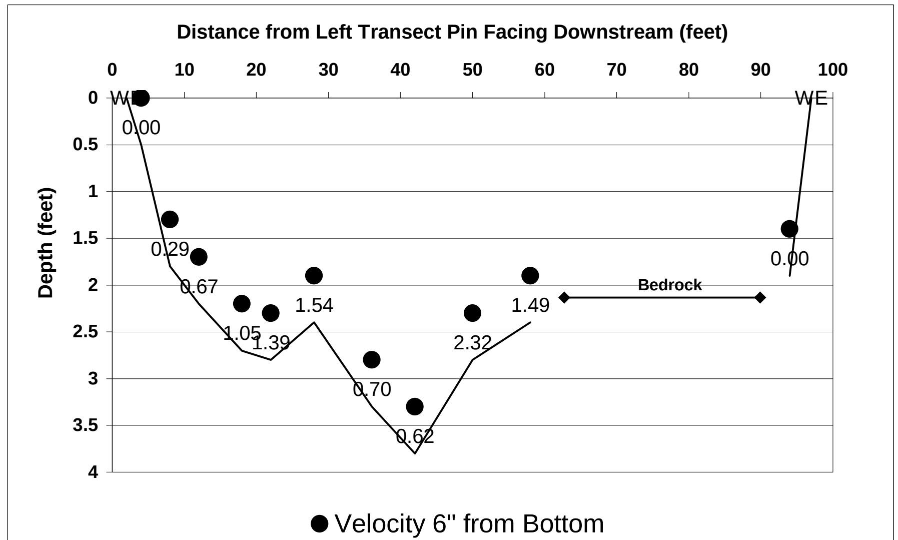
Transect 57 11/16/2004 (Merced Falls Dam Flow = 250 cfs)



Transect 58 11/14/2004 (Merced Falls Dam Flow = 249 cfs)

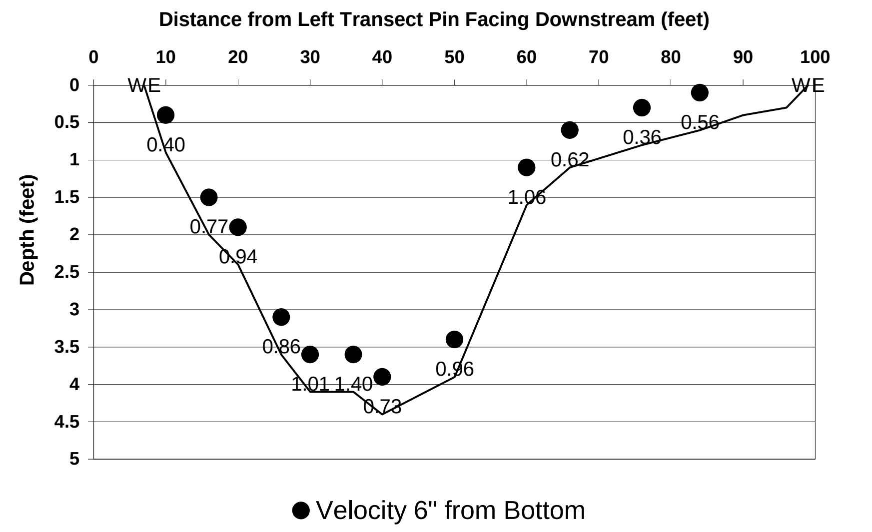


Transect 59 11/12/2004 (Merced Falls Dam Flow = 272 cfs)

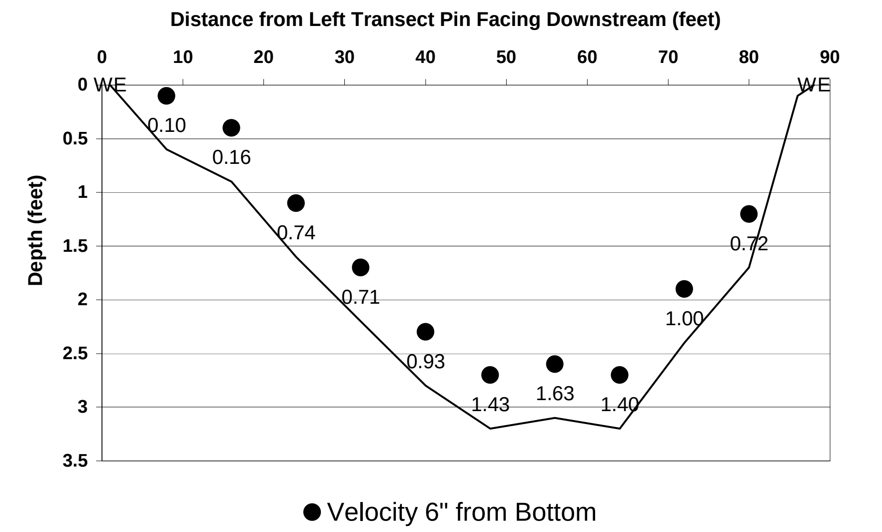


Transect 60 11/16/2004 (Merced Falls Dam Flow = 250 cfs)

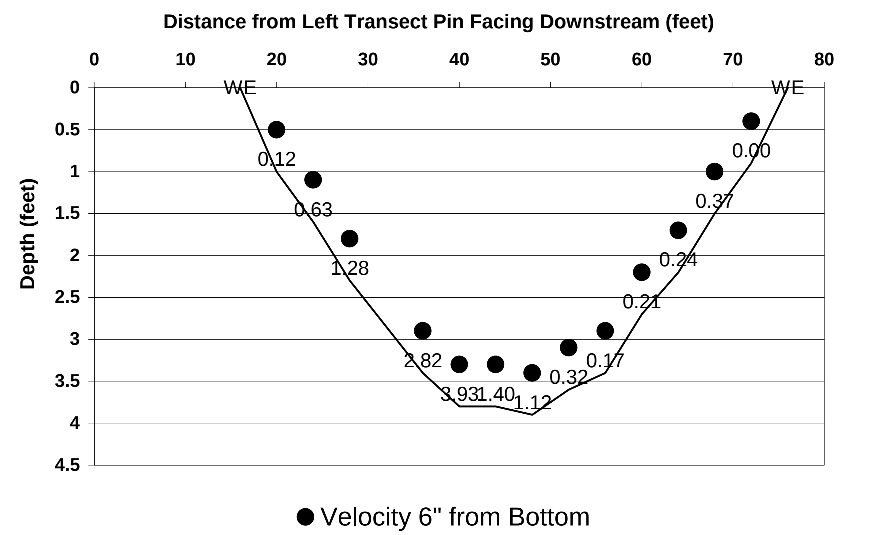
Appendix A. Cross-sectional velocity profiles measured at transects in the Merced River between Crocker-Huffman and Merced Falls dams.



Transect 61 11/8/2004 (Merced Falls Dam Flow = 250 cfs)

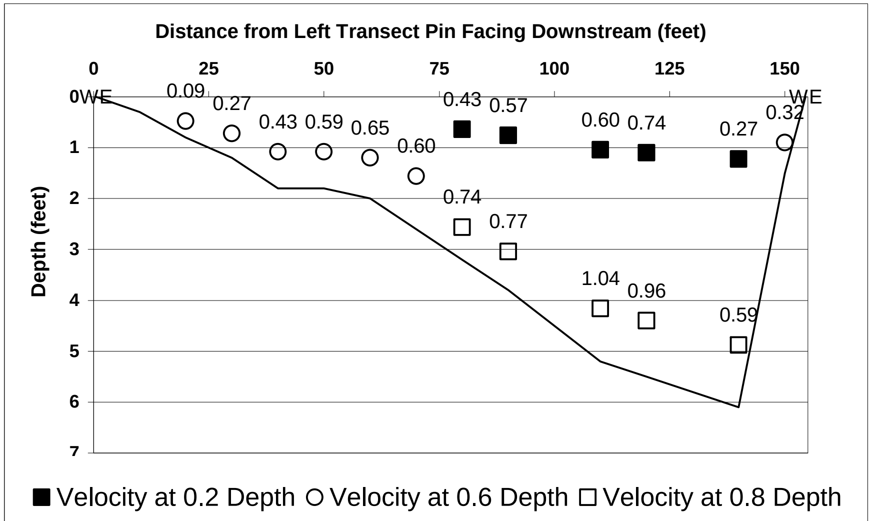


Transect 62 11/8/2004 (Merced Falls Dam Flow = 250 cfs)

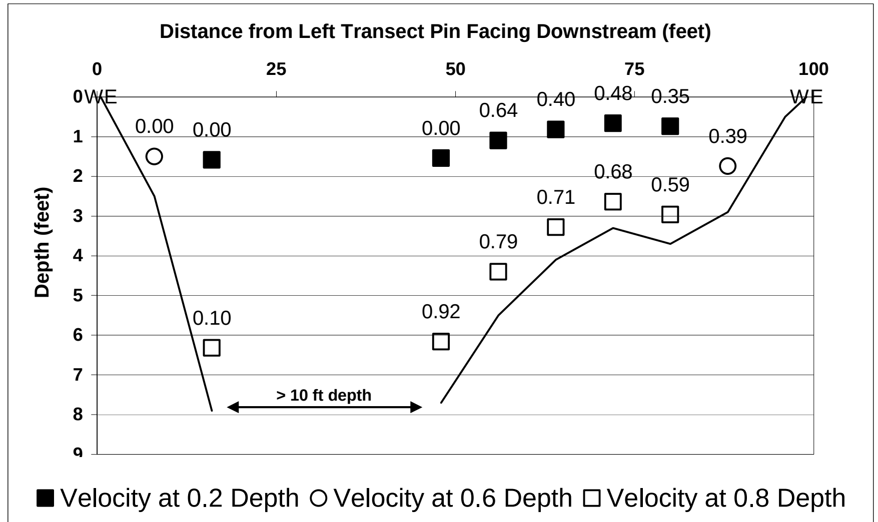


Transect 63 11/8/2004 (Merced Falls Dam Flow = 250 cfs)

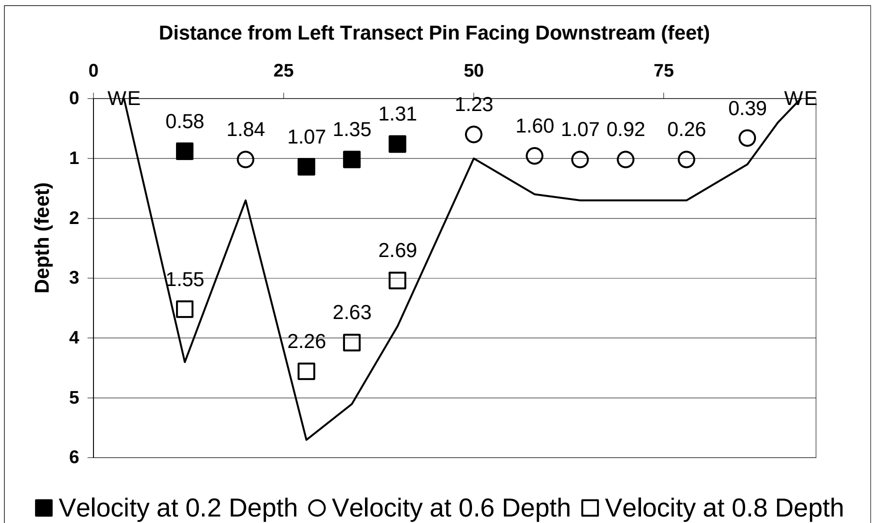
Appendix A. Cross-sectional velocity profiles measured at transects in the Merced River between Crocker-Huffman and Merced Falls dams.



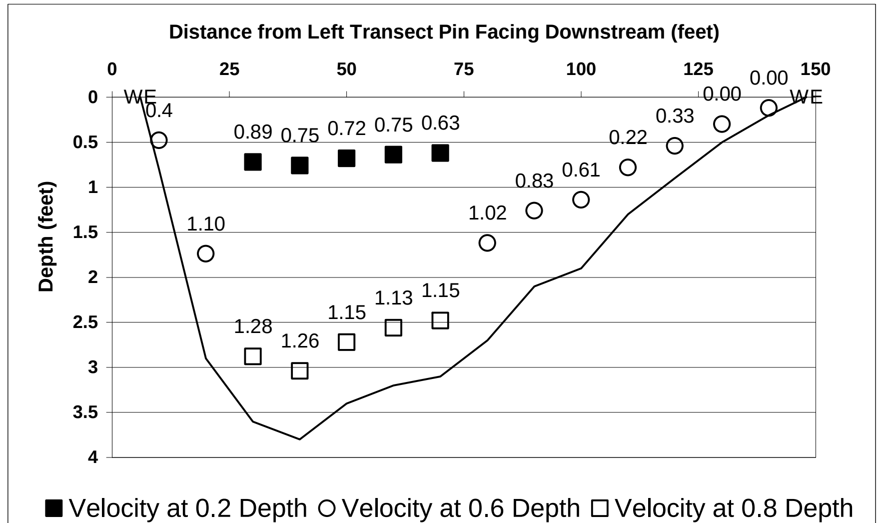
Transect 35 3/6/2005 (Merced Falls Dam Flow = 267 cfs)



Transect 37 3/1/2005 (Merced Falls Dam Flow = 272 cfs)

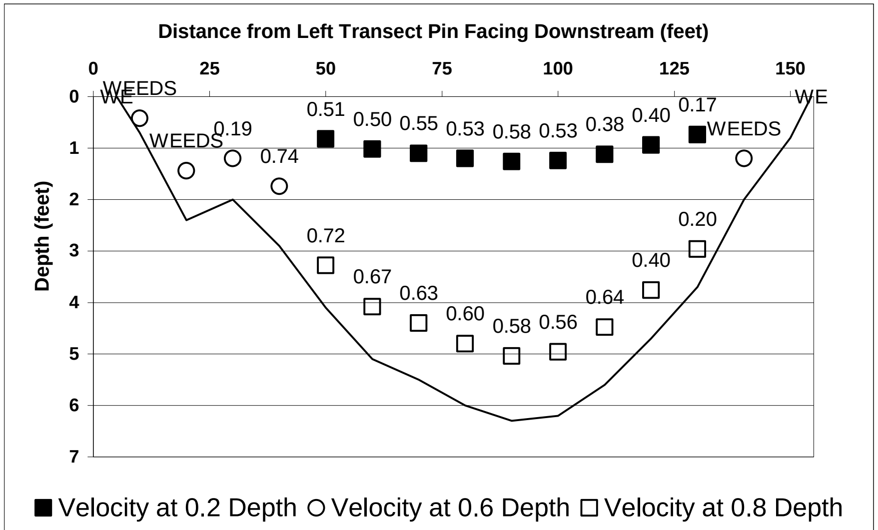


Transect 38 3/1/2005 (Merced Falls Dam Flow = 272 cfs)

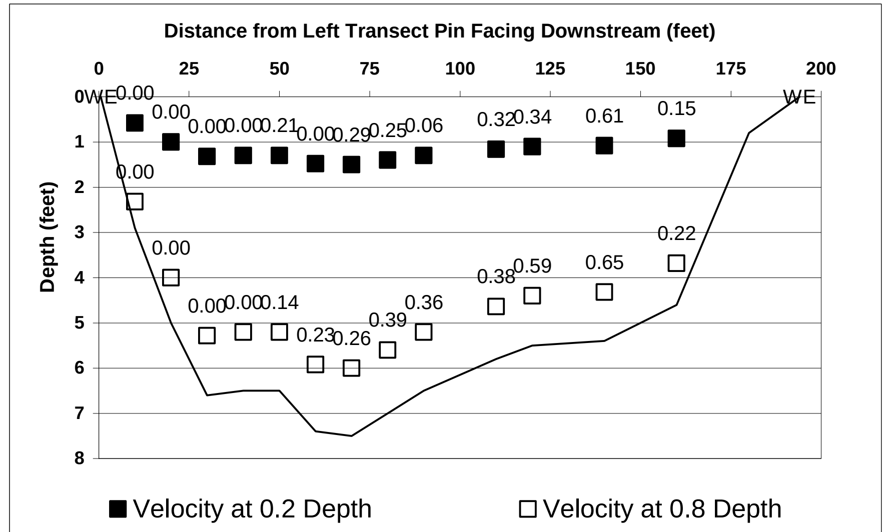


Transect 40 2/27/2005 (Merced Falls Dam Flow = 274 cfs)

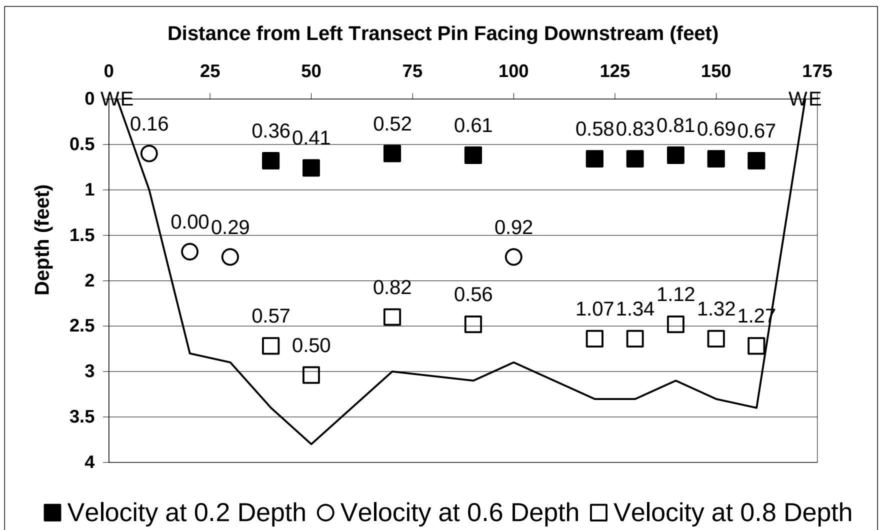
Appendix A. Cross-sectional velocity profiles measured at transects in the Merced River between Crocker-Huffman and Merced Falls dams.



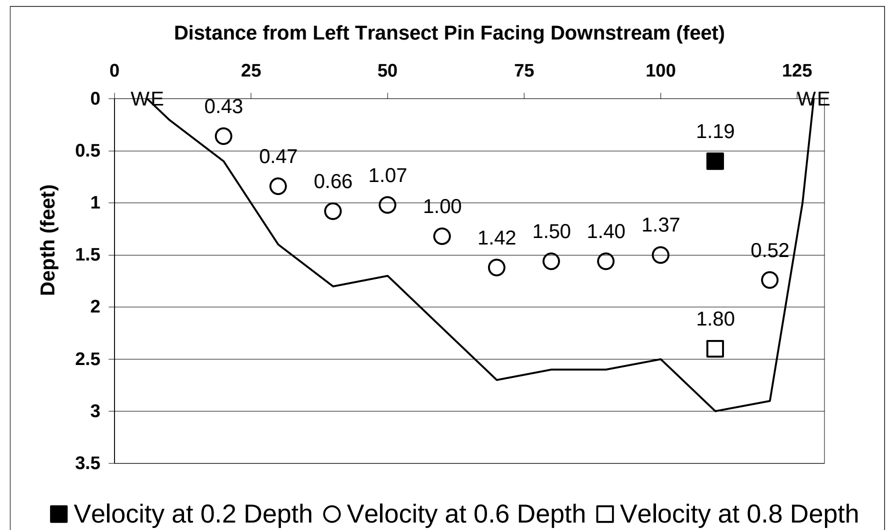
Transect 41 3/1/2005 (Merced Falls Dam Flow = 272 cfs)



Transect 42 2/28/2005 (Merced Falls Dam Flow = 331 cfs)

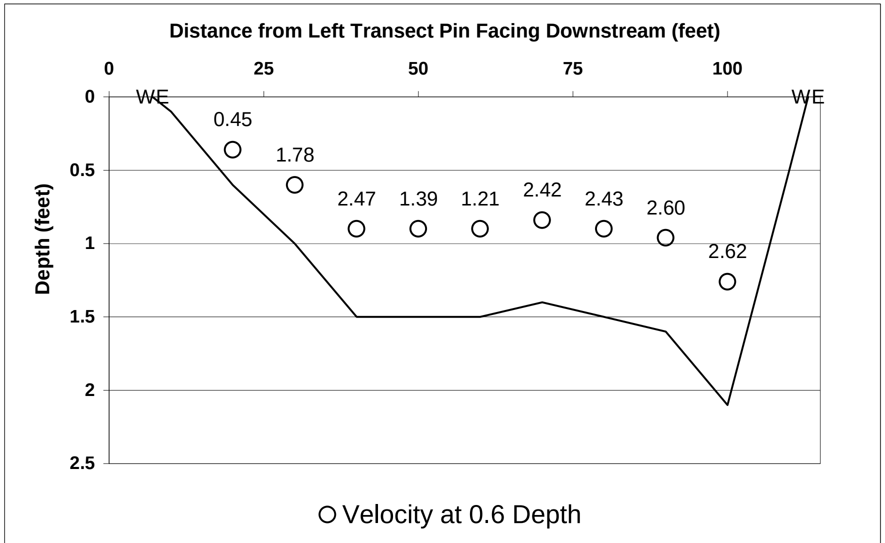


Transect 43 2/28/2005 (Merced Falls Dam Flow = 331 cfs)

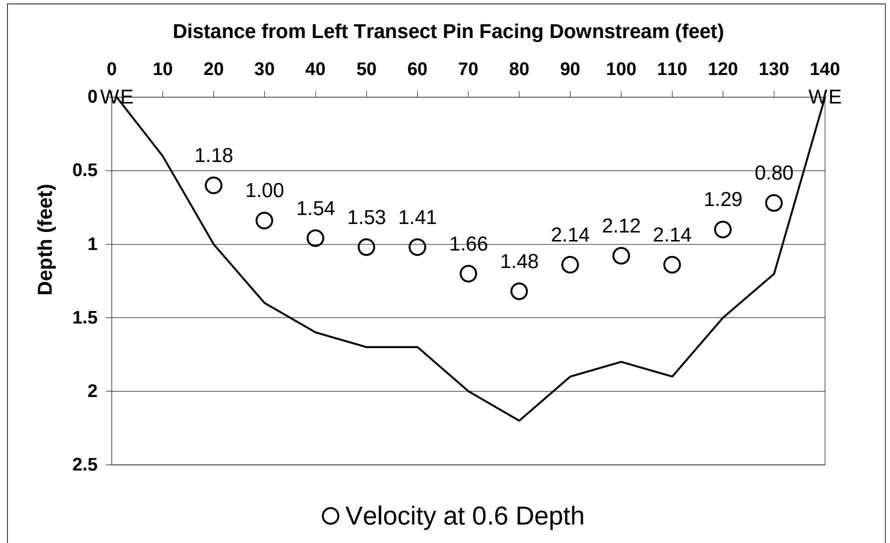


Transect 44 2/27/2005 (Merced Falls Dam Flow = 274 cfs)

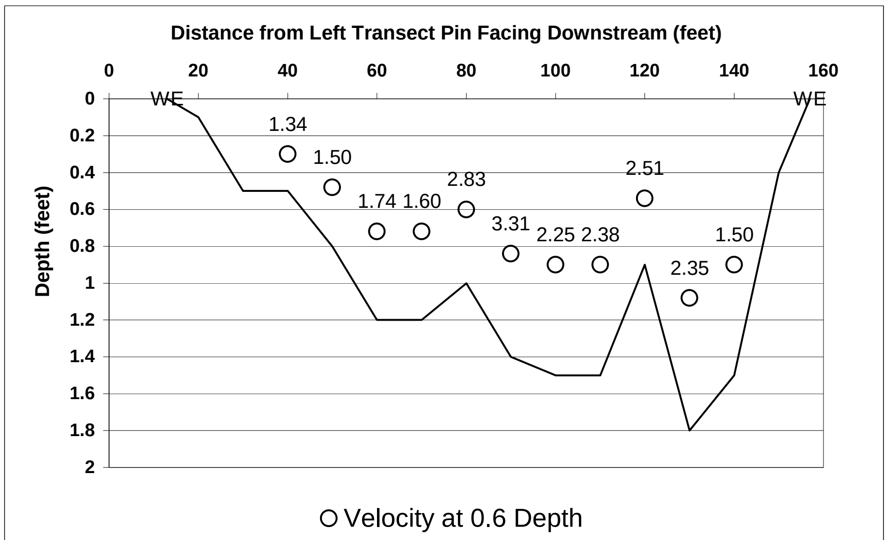
Appendix A. Cross-sectional velocity profiles measured at transects in the Merced River between Crocker-Huffman and Merced Falls dams.



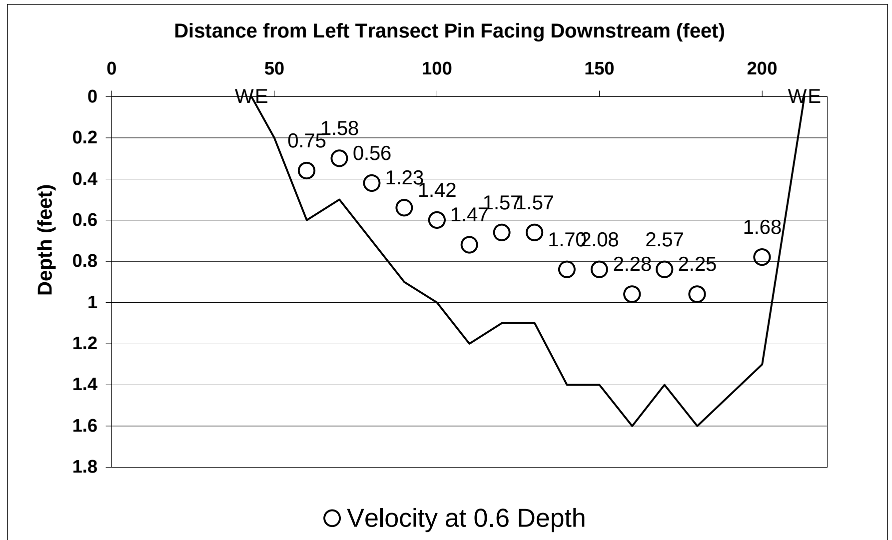
Transect 45 2/24/2005 (Merced Falls Dam Flow = 272 cfs)



Transect 46 2/24/2005 (Merced Falls Dam Flow = 272 cfs)

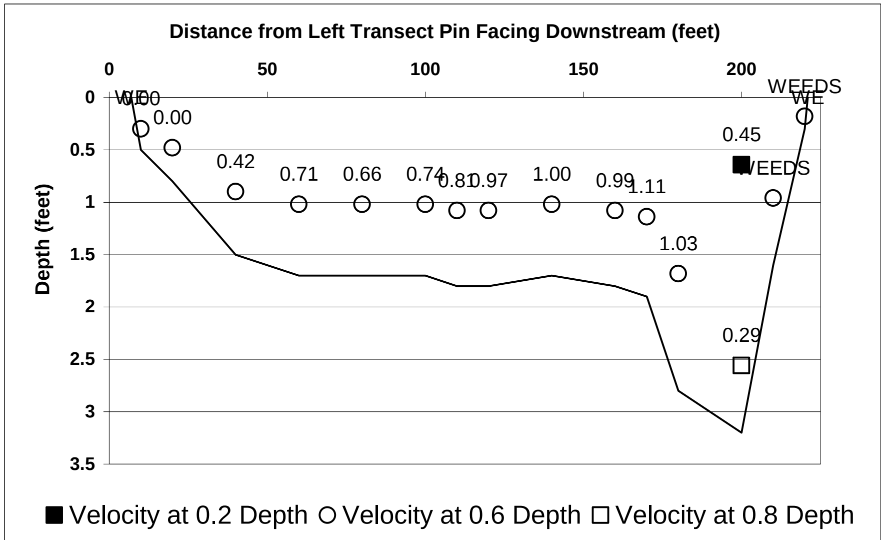


Transect 47 2/23/2005 (Merced Falls Dam Flow = 273 cfs)

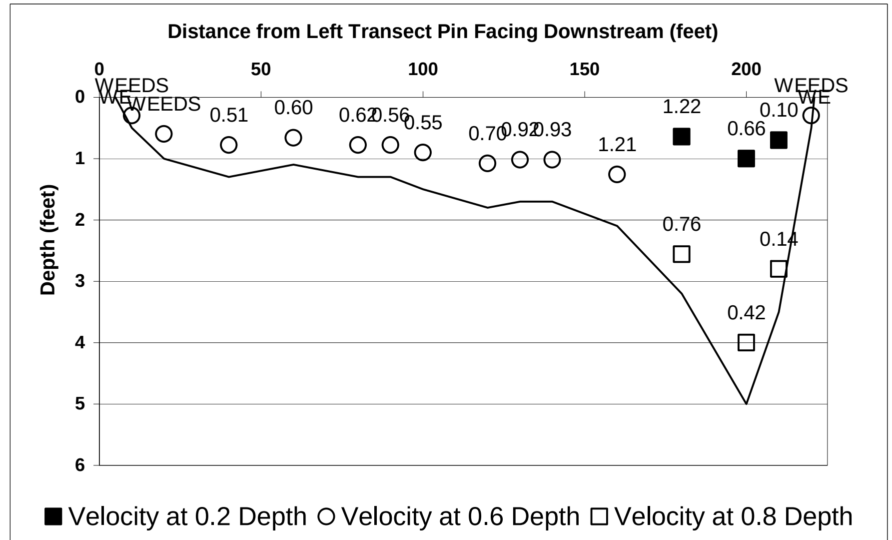


Transect 48 2/21/2005 (Merced Falls Dam Flow = 277 cfs)

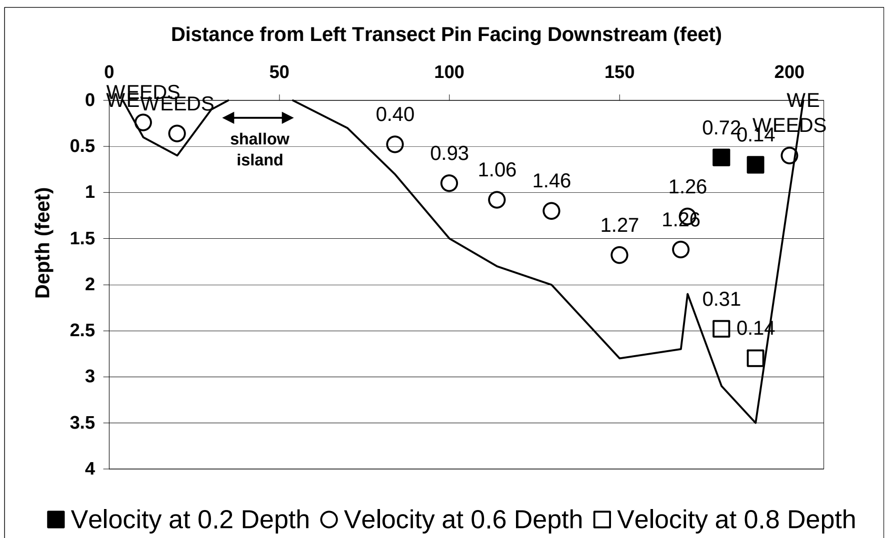
Appendix A. Cross-sectional velocity profiles measured at transects in the Merced River between Crocker-Huffman and Merced Falls dams.



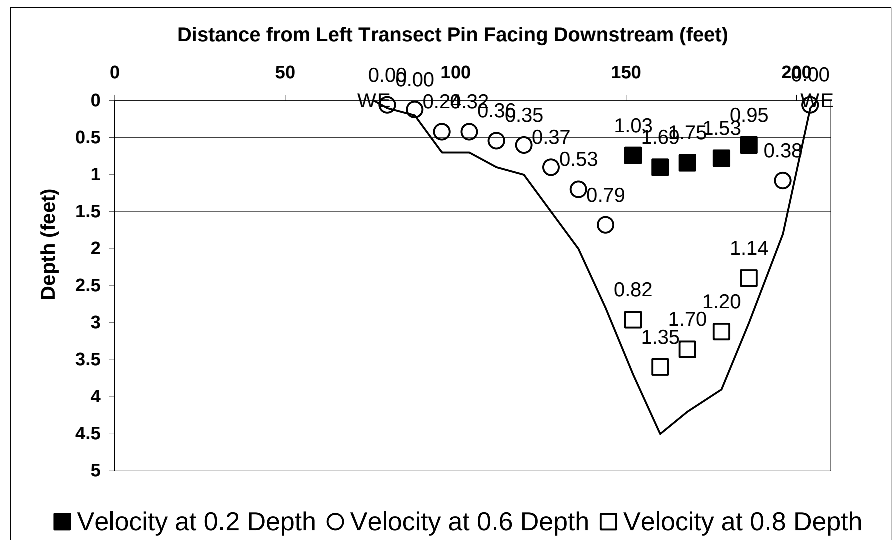
Transect 49 11/30/2004 (Merced Falls Dam Flow = 238 cfs)



Transect 50 11/29/2004 (Merced Falls Dam Flow = 247 cfs)

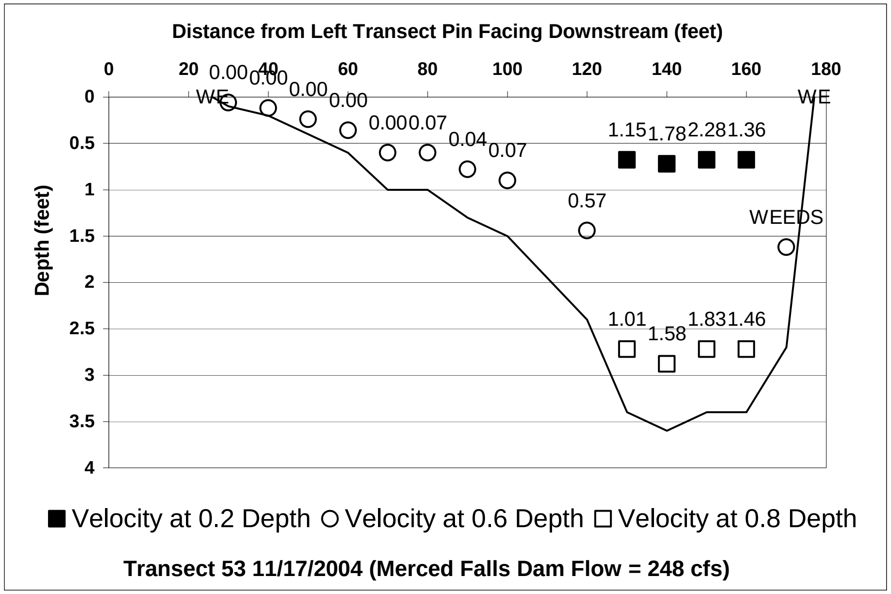


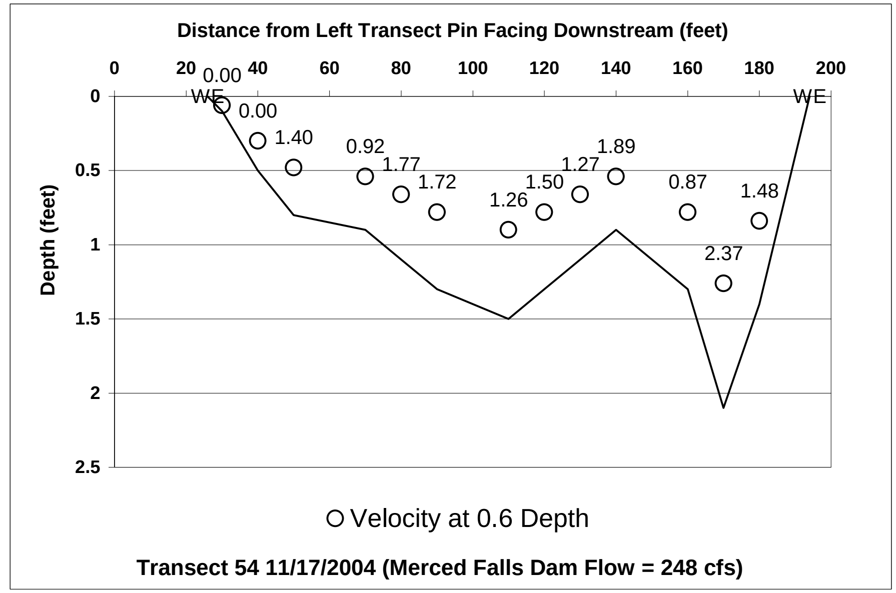
Transect 51 11/29/2004 (Merced Falls Dam Flow = 247 cfs)

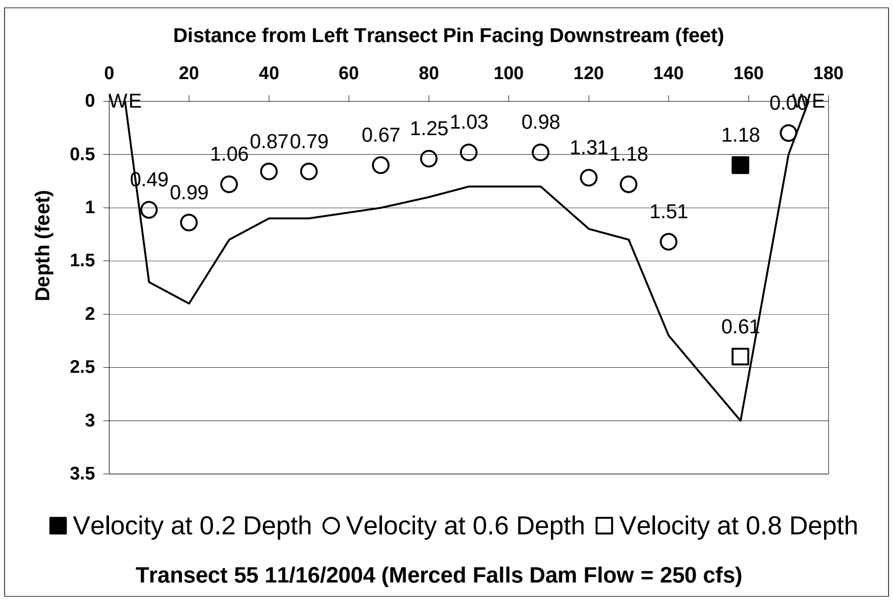


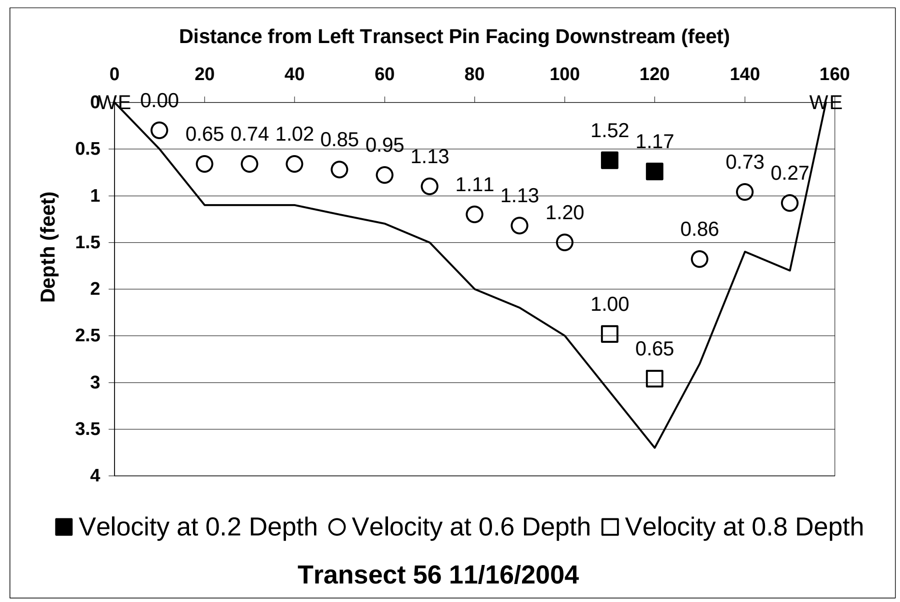
Transect 52 11/29/2004 (Merced Falls Dam Flow = 247 cfs)

Appendix A. Cross-sectional velocity profiles measured at transects in the Merced River between Crocker-Huffman and Merced Falls dams.

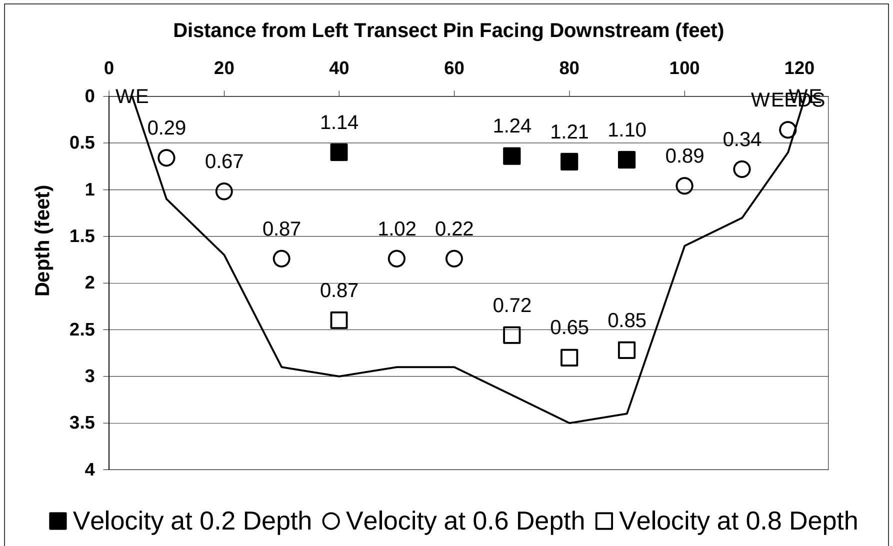




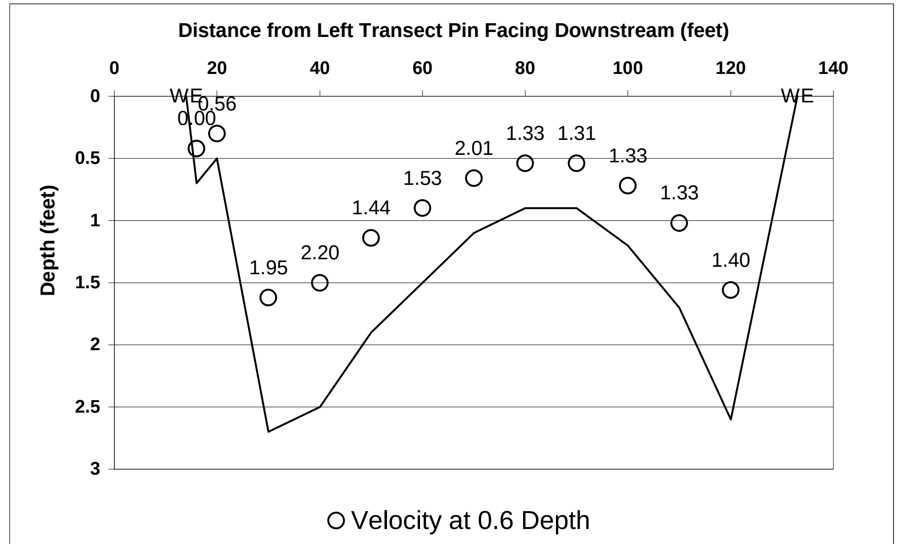




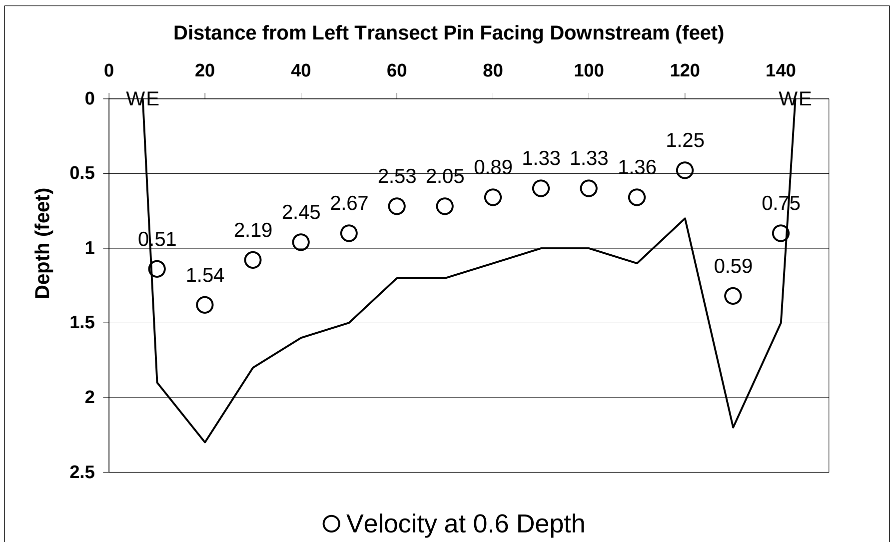
Appendix A. Cross-sectional velocity profiles measured at transects in the Merced River between Crocker-Huffman and Merced Falls dams.



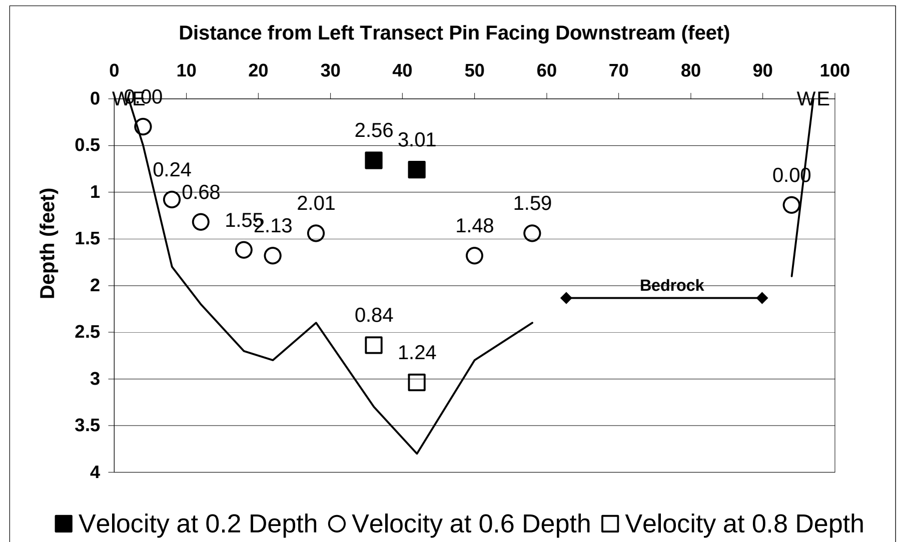
Transect 57 11/16/2004 (Merced Falls Dam Flow = 250 cfs)



Transect 58 11/14/2004 (Merced Falls Dam Flow = 249 cfs)

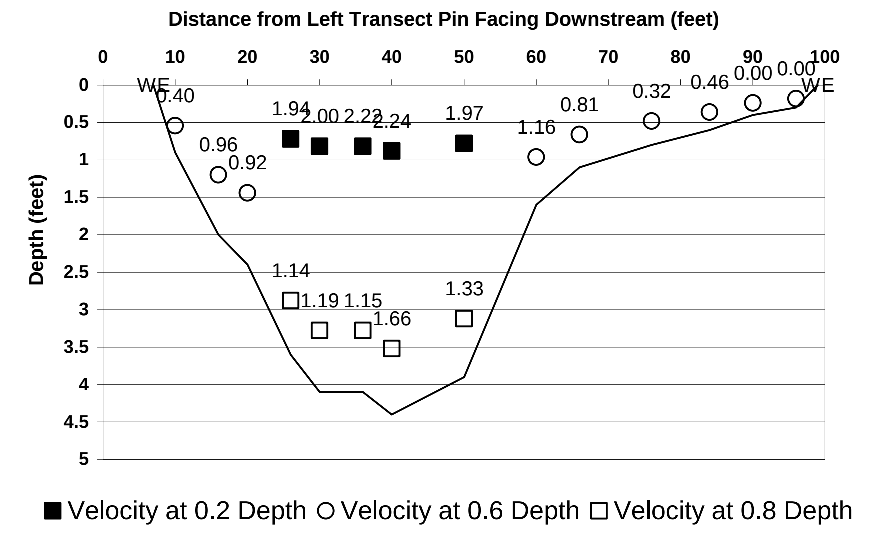


Transect 59 11/12/2004 (Merced Falls Dam Flow = 272 cfs)

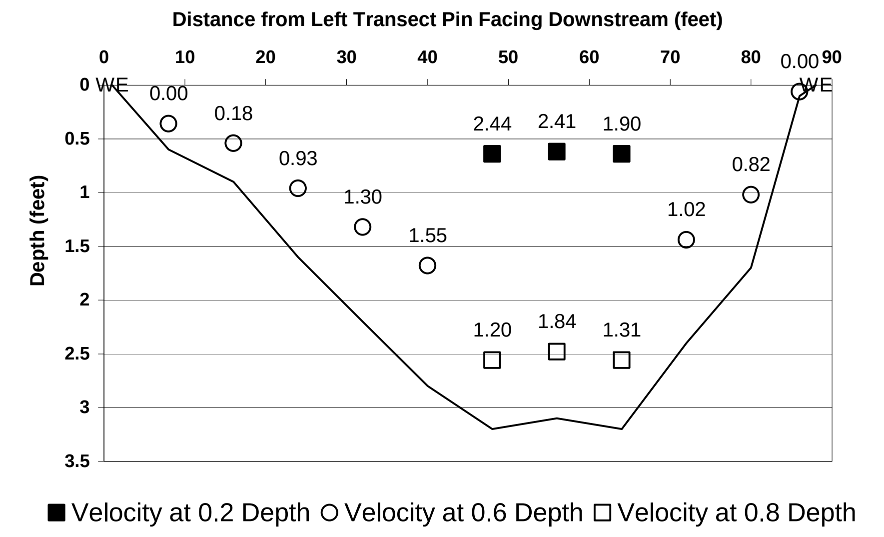


Transect 60 11/16/2004 (Merced Falls Dam Flow = 250 cfs)

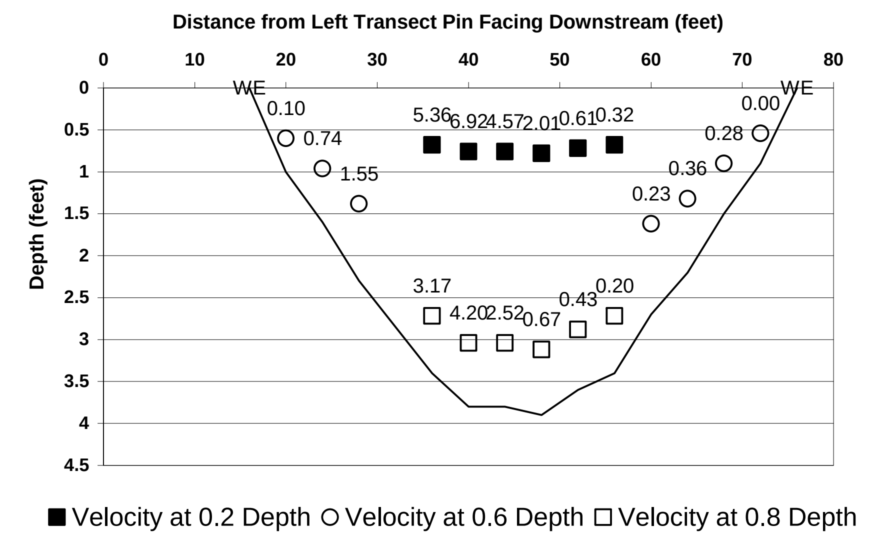
Appendix A. Cross-sectional velocity profiles measured at transects in the Merced River between Crocker-Huffman and Merced Falls dams.



Transect 61 11/8/2004 (Merced Falls Dam Flow = 250 cfs)

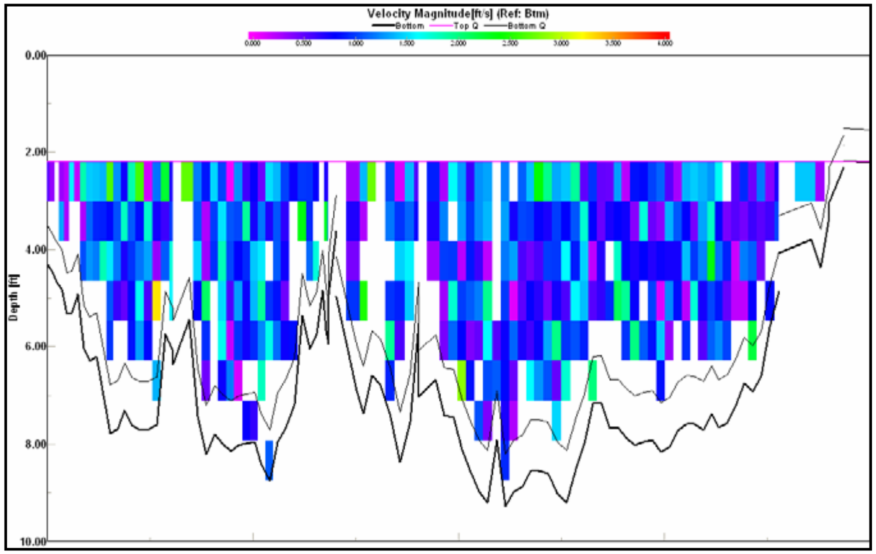


Transect 62 11/8/2004 (Merced Falls Dam Flow = 250 cfs)

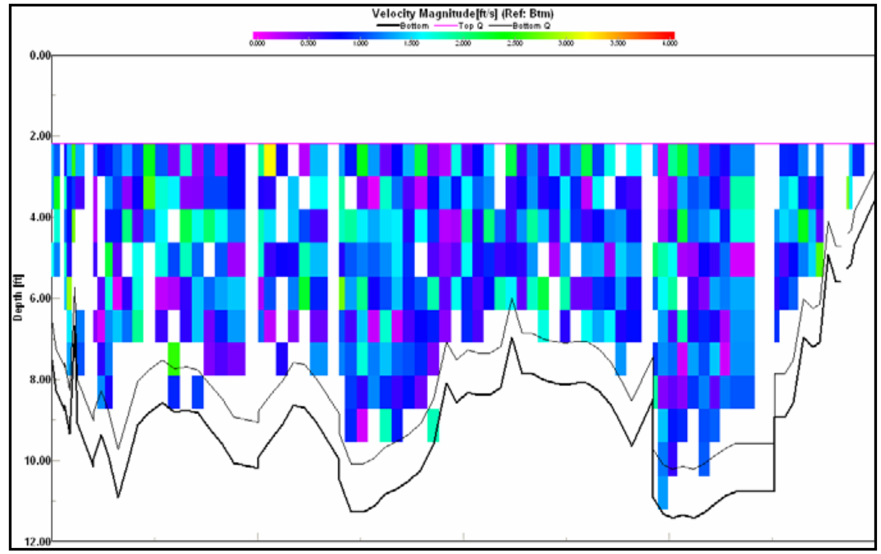


Transect 63 11/8/2004 (Merced Falls Dam Flow = 250 cfs)

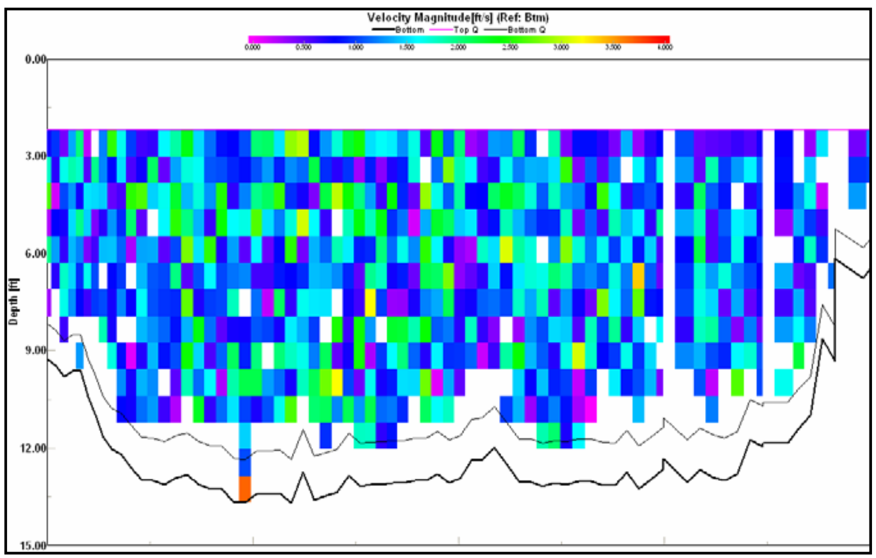
Appendix A. Cross-sectional velocity profiles measured at transects in the Merced River between Crocker-Huffman and Merced Falls dams.



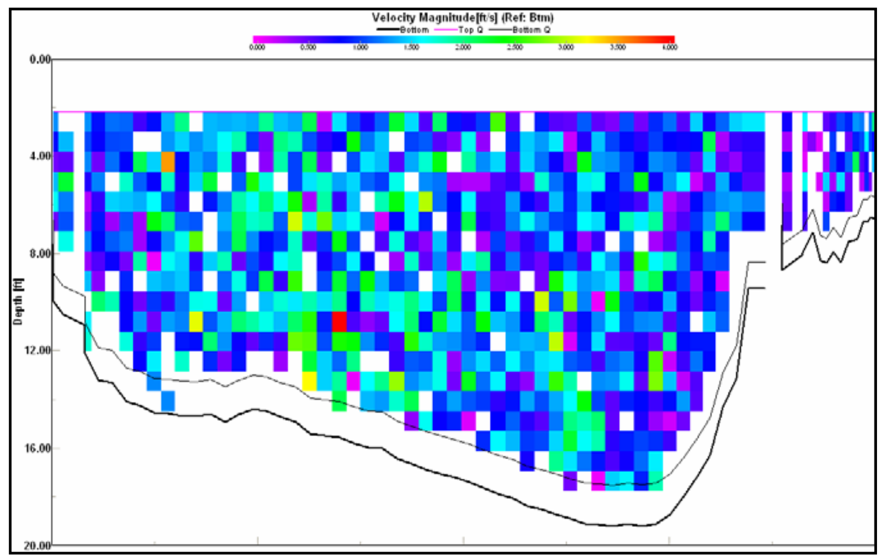
Cross-sectional ADCP velocity profile at transect 4 (facing downstream). Left bank is ~10' from start of transect and right bank is ~20' from end of transect.



Cross-sectional ADCP velocity profile at transect 5 (facing downstream). Right bank is ~8' from start of transect and left bank is ~7' from end of transect.

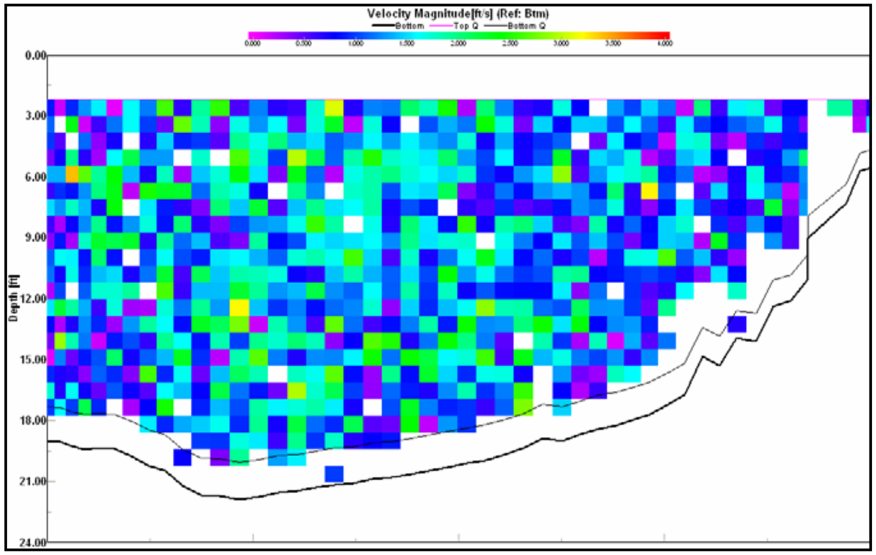


Cross-sectional ADCP velocity profile at transect 6 (facing downstream). Left bank is ~20' from start of transect and right bank is ~20' from end of transect.

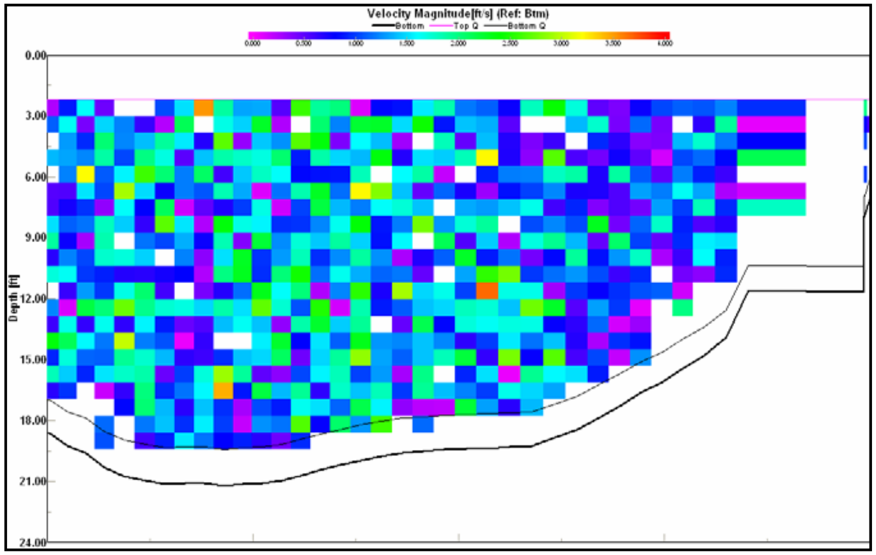


Cross-sectional ADCP velocity profile at transect 7 (facing downstream). Right bank is ~12' from start of transect and left bank is ~8' from end of transect.

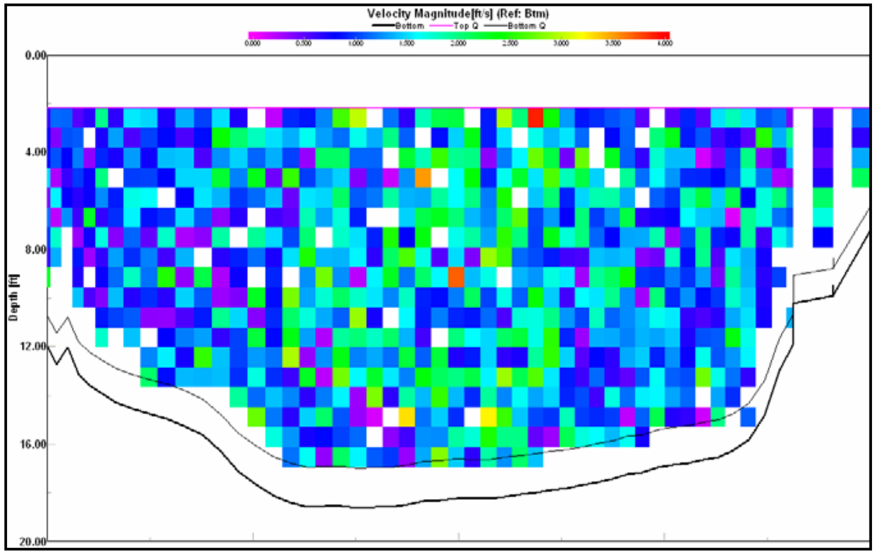
Appendix A. Cross-sectional velocity profiles measured at transects in the Merced River between Crocker-Huffman and Merced Falls dams.



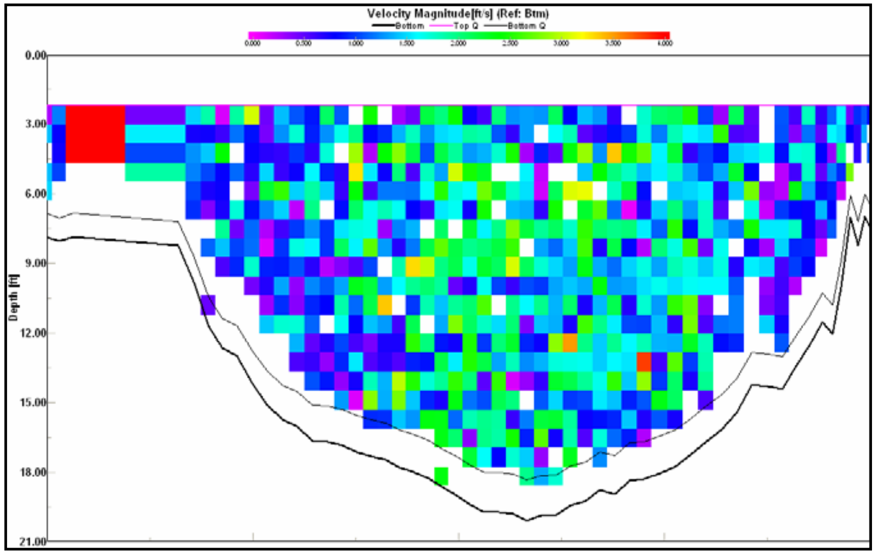
Cross-sectional ADCP velocity profile at transect 8 (facing downstream). Left bank is ~5' from start of transect and right bank is ~9' from end of transect.



Cross-sectional ADCP velocity profile at transect 9 (facing downstream). Right bank is ~10' from start of transect and left bank is ~10' from end of transect.

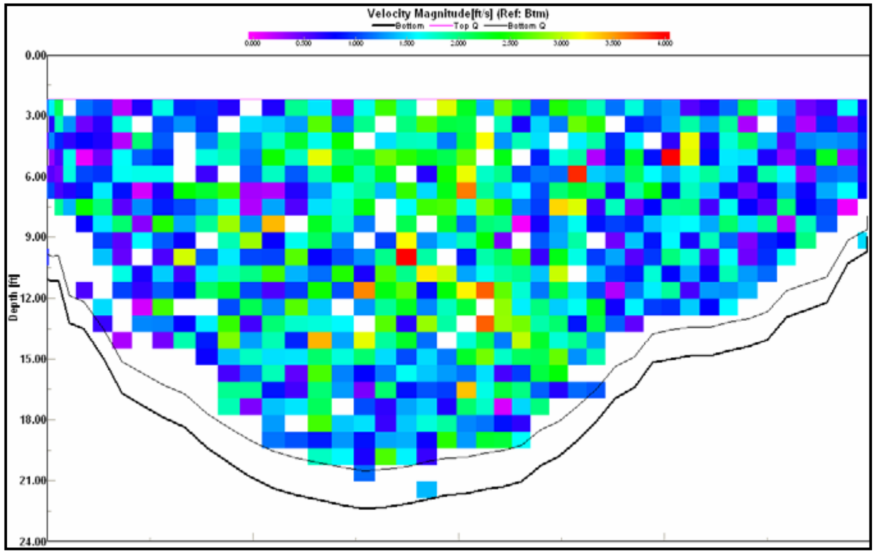


Cross-sectional ADCP velocity profile at transect 10 (facing downstream). Left bank is ~8' from start of transect and right bank is ~12' from end of transect.

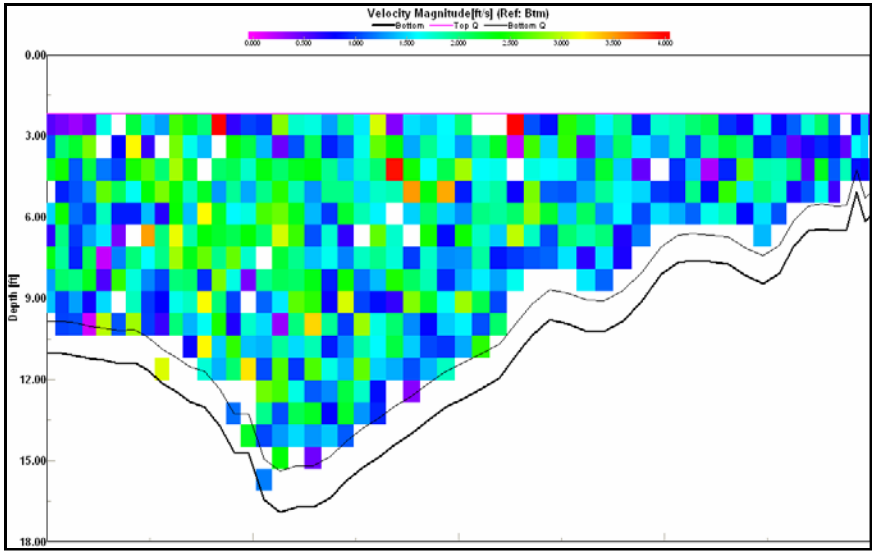


Cross-sectional ADCP velocity profile at transect 11 (facing downstream). Right bank is ~8' from start of transect and left bank is ~8' from end of transect.

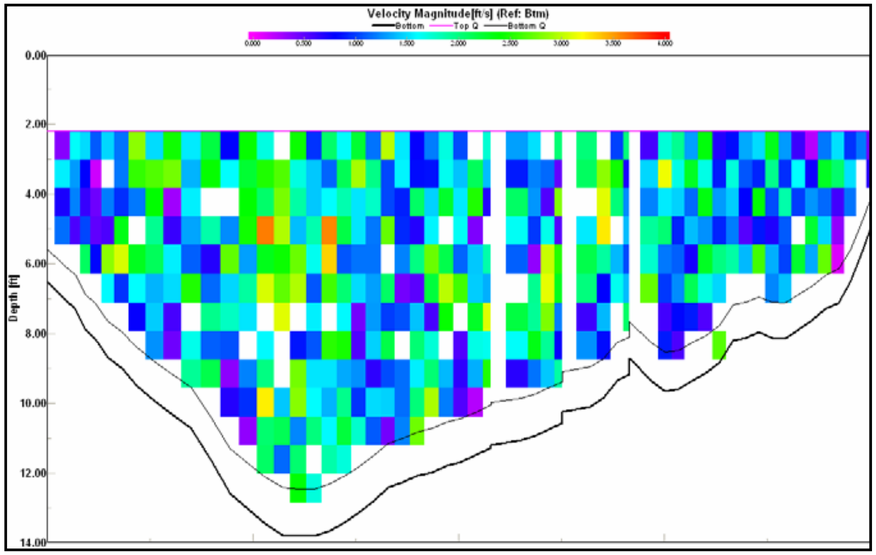
Appendix A. Cross-sectional velocity profiles measured at transects in the Merced River between Crocker-Huffman and Merced Falls dams.



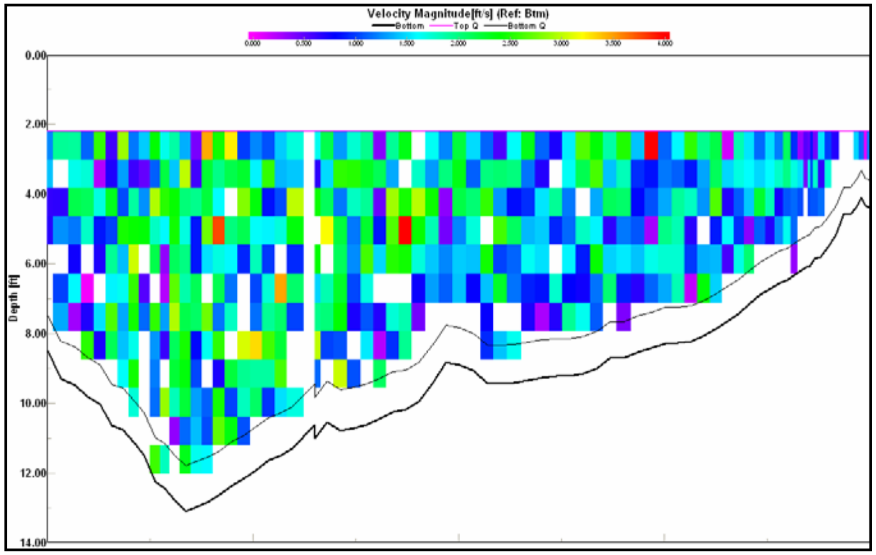
Cross-sectional ADCP velocity profile at transect 12 (facing downstream). Left bank is ~14’ from start of transect and right bank is ~20’ from end of transect.



Cross-sectional ADCP velocity profile at transect 13 (facing downstream). Right bank is ~20’ from start of transect and left bank is ~8’ from end of transect.

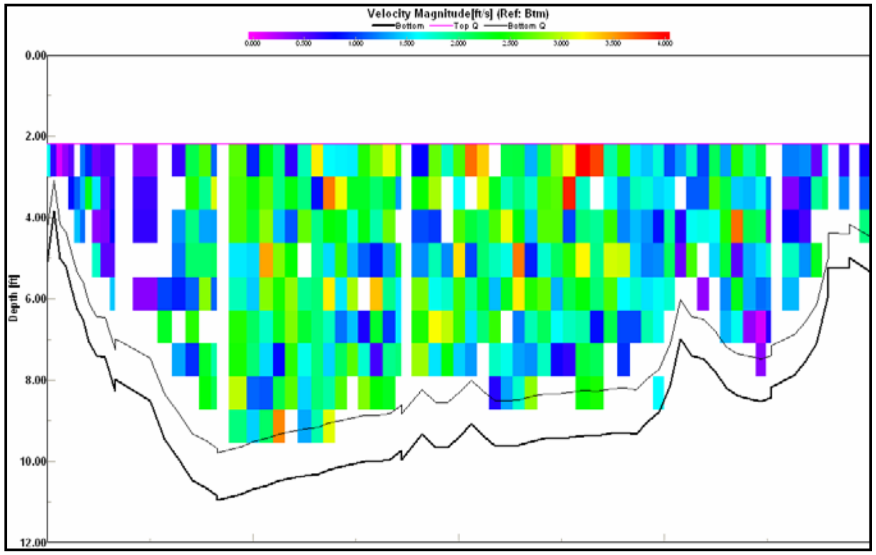


Cross-sectional ADCP velocity profile at transect 14 (facing downstream). Left bank is ~8’ from start of transect and right bank is ~20’ from end of transect.

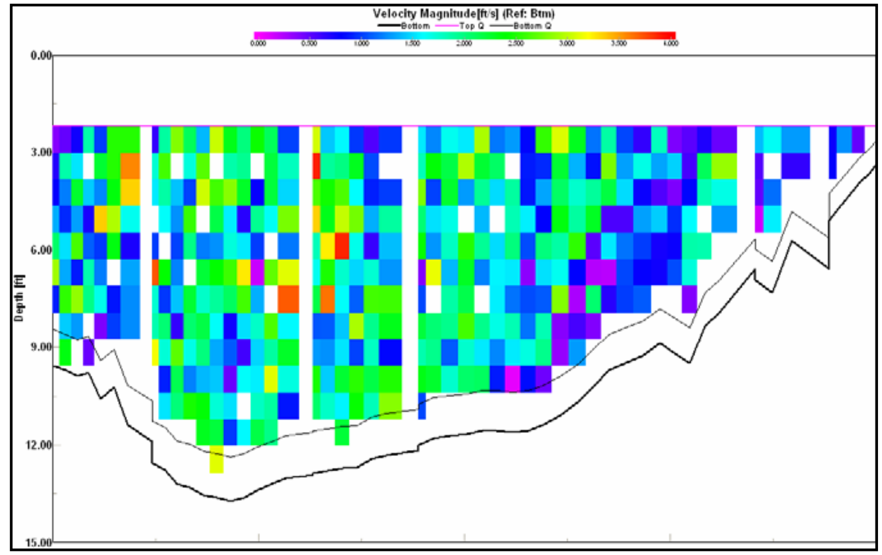


Cross-sectional ADCP velocity profile at transect 15 (facing downstream). Right bank is ~9’ from start of transect and left bank is ~9’ from end of transect.

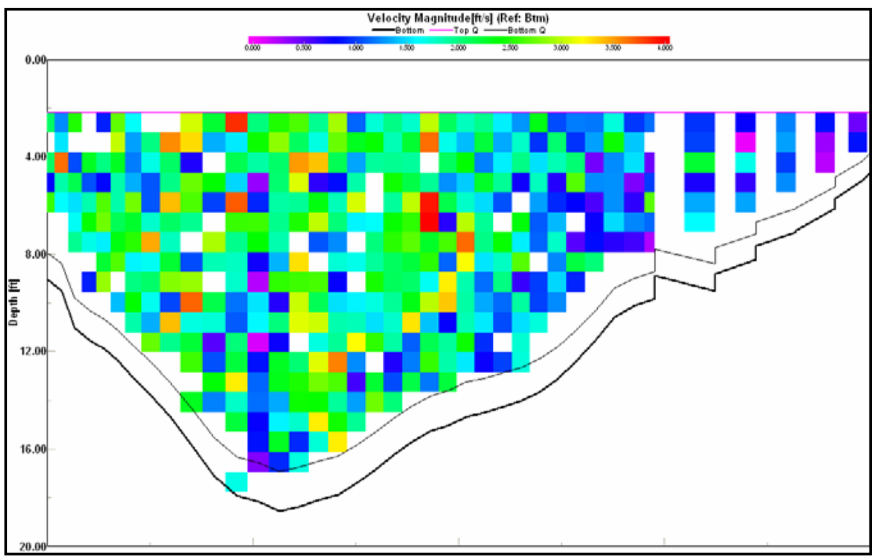
Appendix A. Cross-sectional velocity profiles measured at transects in the Merced River between Crocker-Huffman and Merced Falls dams.



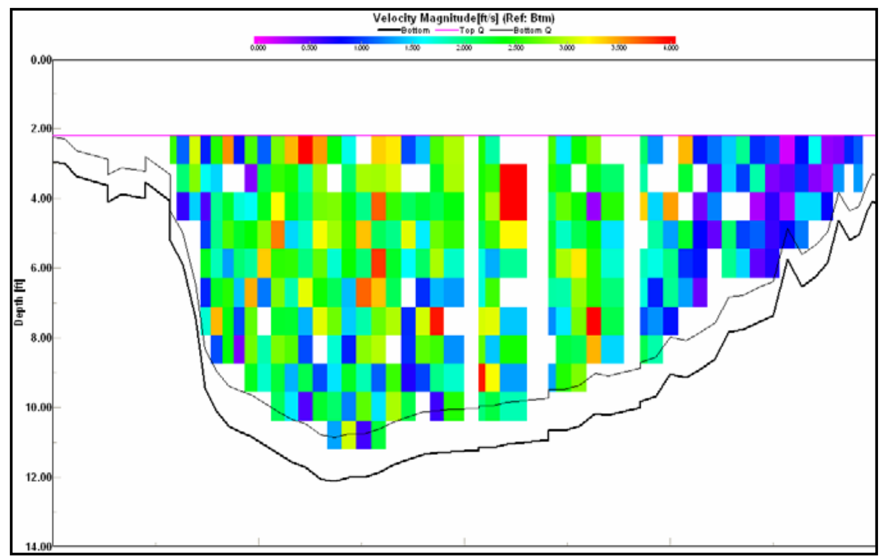
Cross-sectional ADCP velocity profile at transect 16 (facing downstream). Left bank is ~12’ from start of transect and right bank is ~14’ from end of transect.



Cross-sectional ADCP velocity profile at transect 17 (facing downstream). Right bank is ~10’ from start of transect and left bank is ~10’ from end of transect.

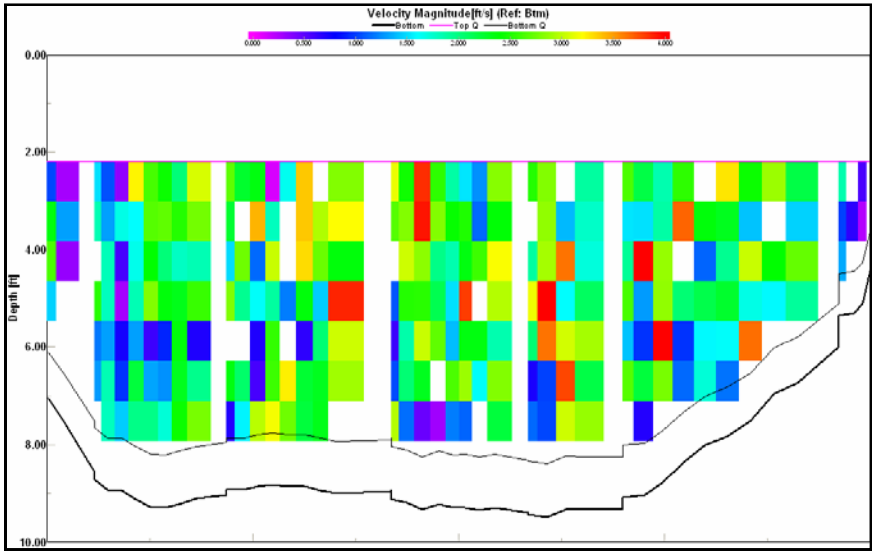


Cross-sectional ADCP velocity profile at transect 18 (facing downstream). Left bank is ~15’ from start of transect and right bank is ~12’ from end of transect.

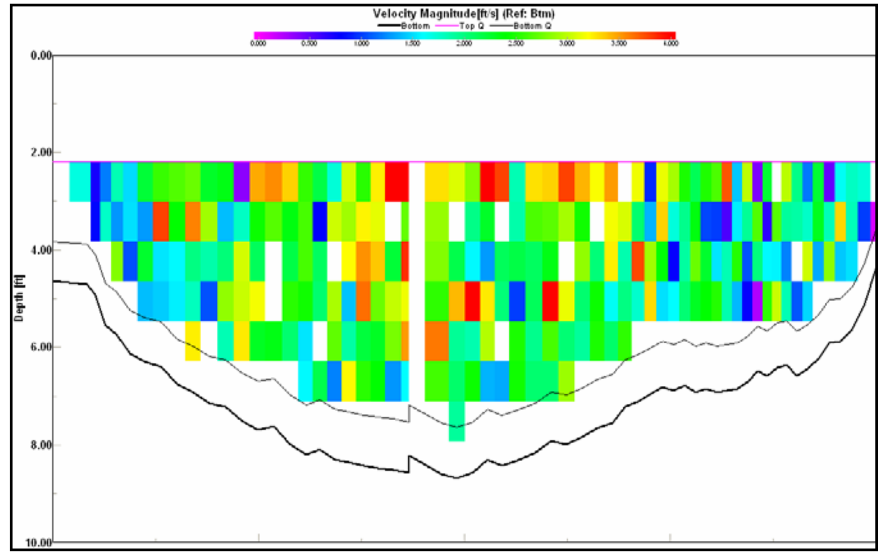


Cross-sectional ADCP velocity profile at transect 19 (facing downstream). Right bank is ~15’ from start of transect and left bank is ~12’ from end of transect.

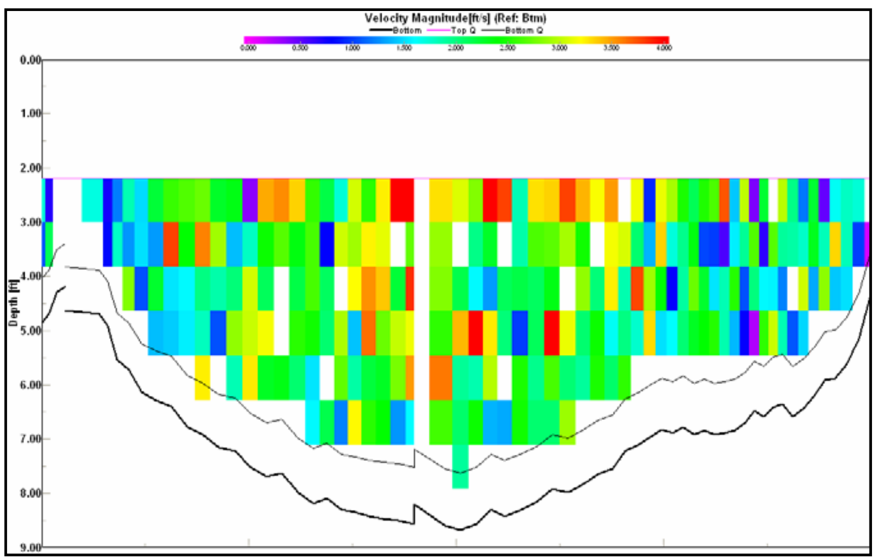
Appendix A. Cross-sectional velocity profiles measured at transects in the Merced River between Crocker-Huffman and Merced Falls dams.



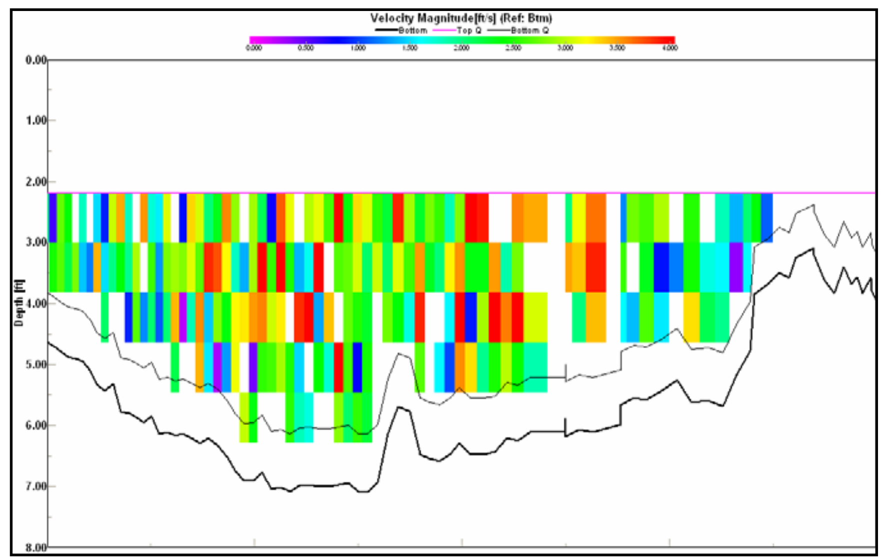
Cross-sectional ADCP velocity profile at transect 20 (facing downstream). Left bank is ~10' from start of transect and right bank is ~20' from end of transect.



Cross-sectional ADCP velocity profile at transect 21 (facing downstream). Right bank is ~8' from start of transect and left bank is ~10' from end of transect.

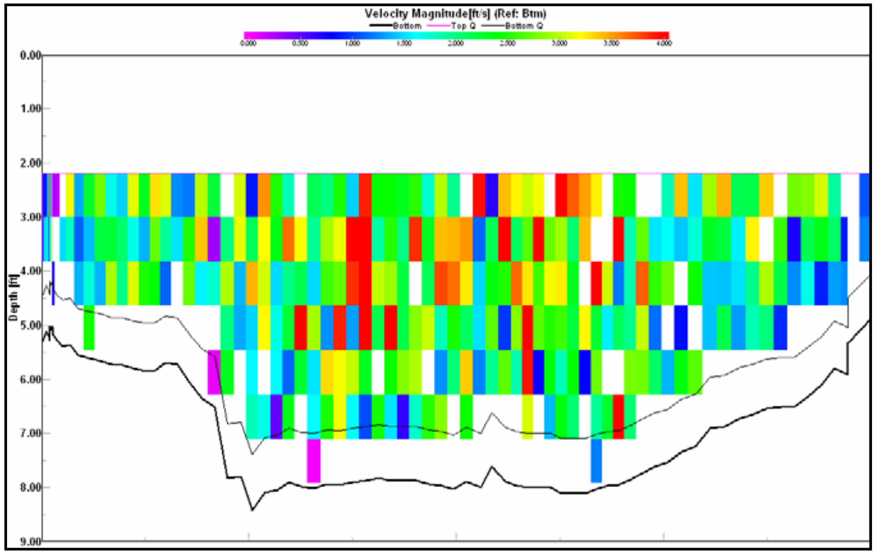


Cross-sectional ADCP velocity profile at transect 22 (facing downstream). Left bank is ~9' from start of transect and right bank is ~15' from end of transect.

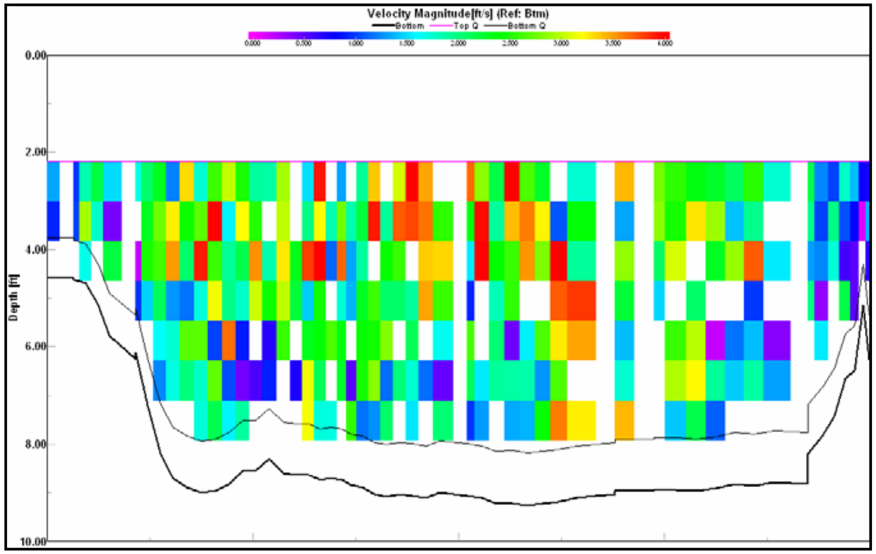


Cross-sectional ADCP velocity profile at transect 23 (facing downstream). Right bank is ~12' from start of transect and left bank is ~5' from end of transect.

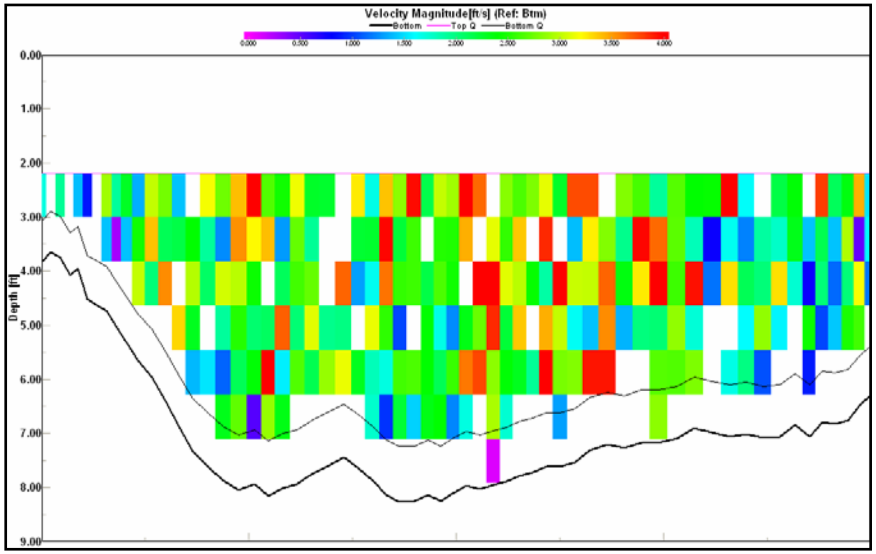
Appendix A. Cross-sectional velocity profiles measured at transects in the Merced River between Crocker-Huffman and Merced Falls dams.



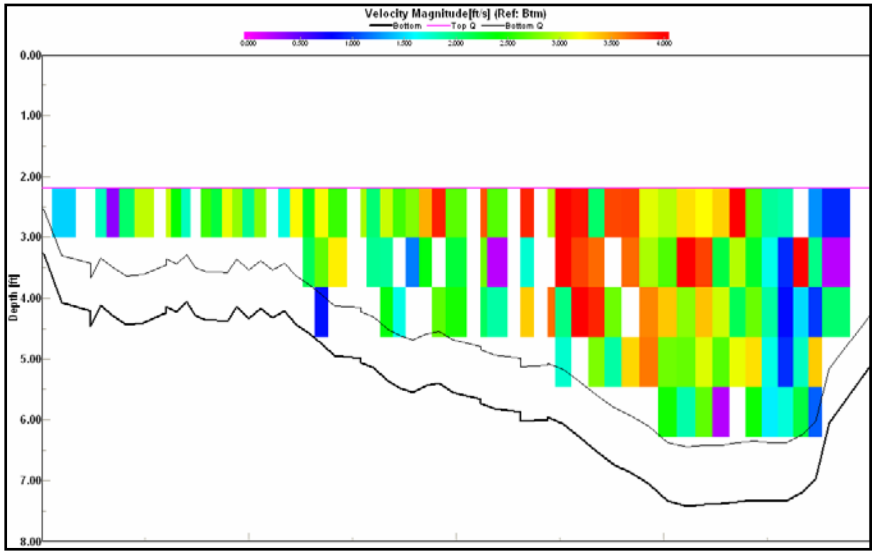
Cross-sectional ADCP velocity profile at transect 24 (facing downstream). Left bank is ~7’ from start of transect and right bank is ~12’ from end of transect.



Cross-sectional ADCP velocity profile at transect 25 (facing downstream). Right bank is ~8’ from start of transect and left bank is ~7’ from end of transect.

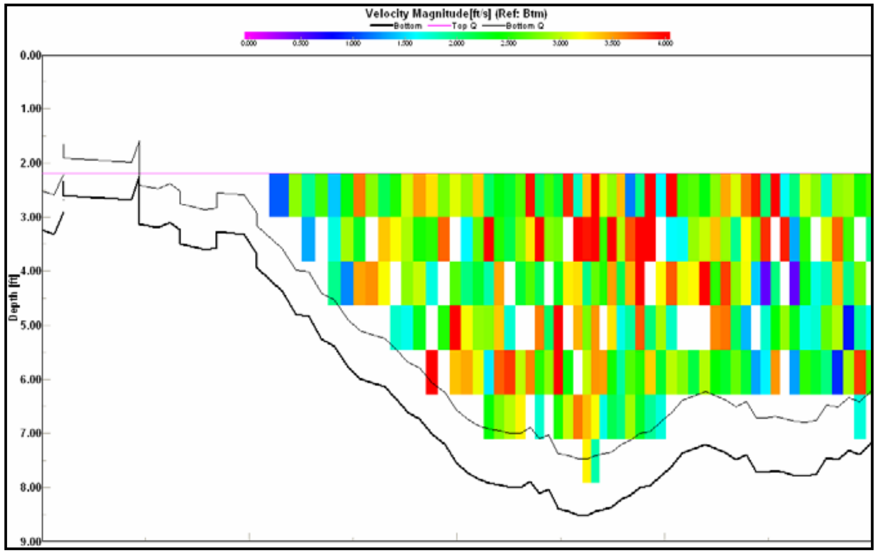


Cross-sectional ADCP velocity profile at transect 26 (facing downstream). Left bank is ~7’ from start of transect and right bank is ~12’ from end of transect.

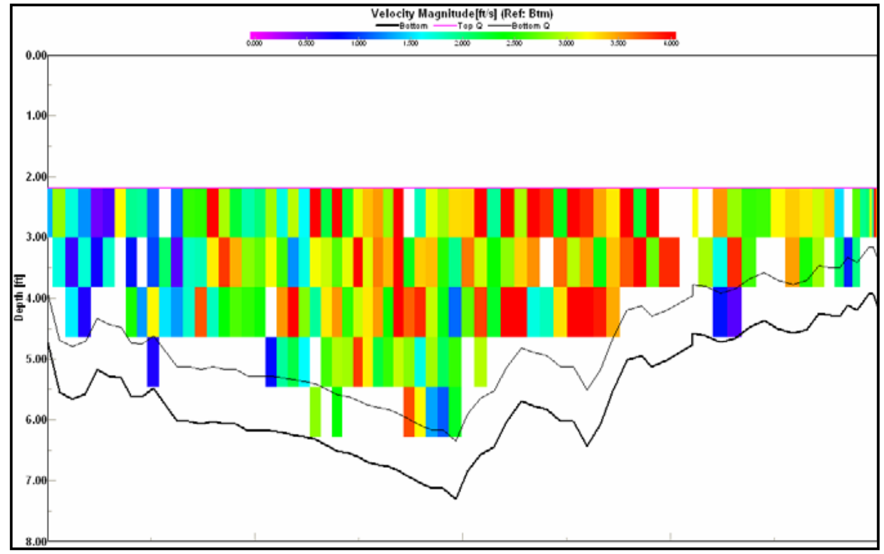


Cross-sectional ADCP velocity profile at transect 27 (facing downstream). Right bank is ~10’ from start of transect and left bank is ~7’ from end of transect.

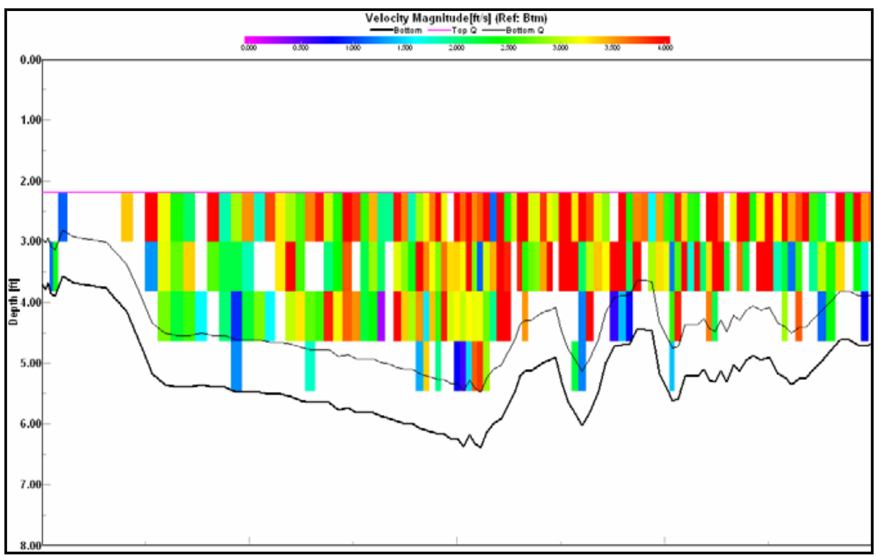
Appendix A. Cross-sectional velocity profiles measured at transects in the Merced River between Crocker-Huffman and Merced Falls dams.



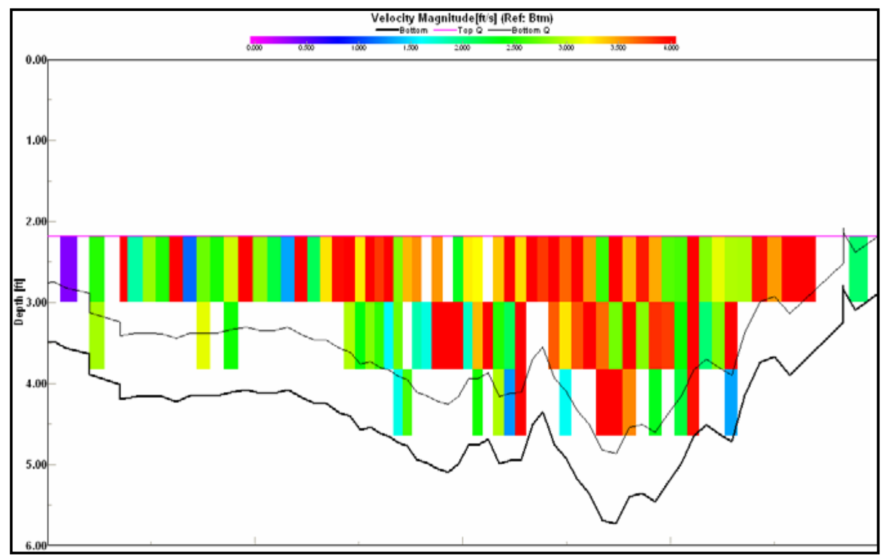
Cross-sectional ADCP velocity profile at transect 28 (facing downstream). Left bank is ~5’ from start of transect and right bank is ~20’ from end of transect.



Cross-sectional ADCP velocity profile at transect 29 (facing downstream). Right bank is ~15’ from start of transect and left bank is ~5’ from end of transect.

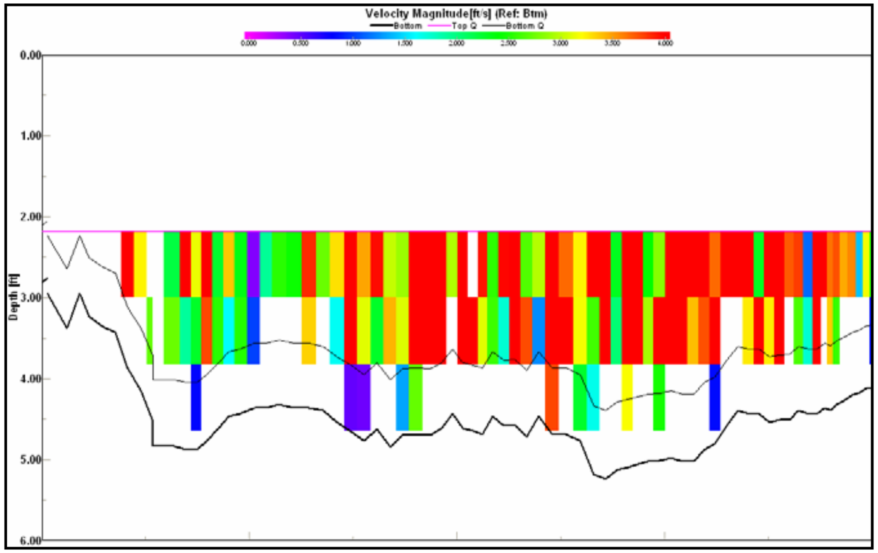


Cross-sectional ADCP velocity profile at transect 30 (facing downstream). Left bank is ~8’ from start of transect and right bank is ~10’ from end of transect.

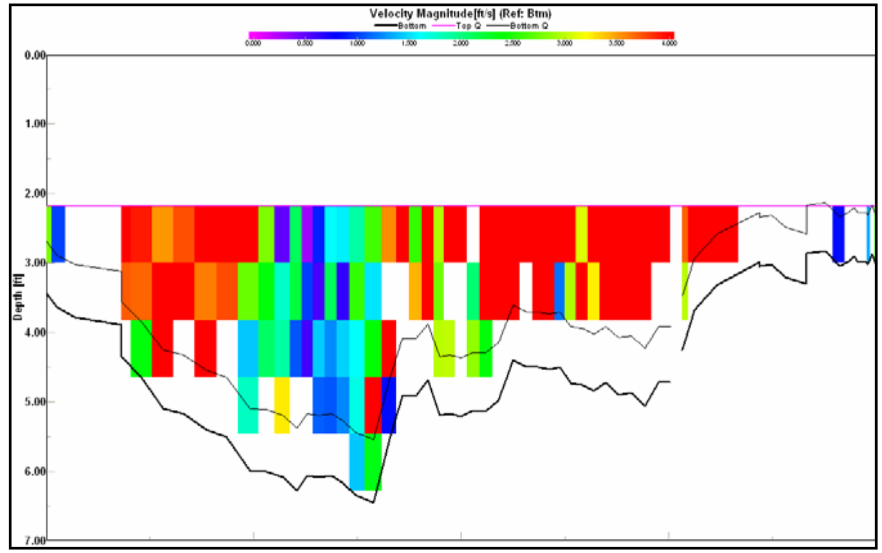


Cross-sectional ADCP velocity profile at transect 31 (facing downstream). Right bank is ~20’ from start of transect and left bank is ~10’ from end of transect.

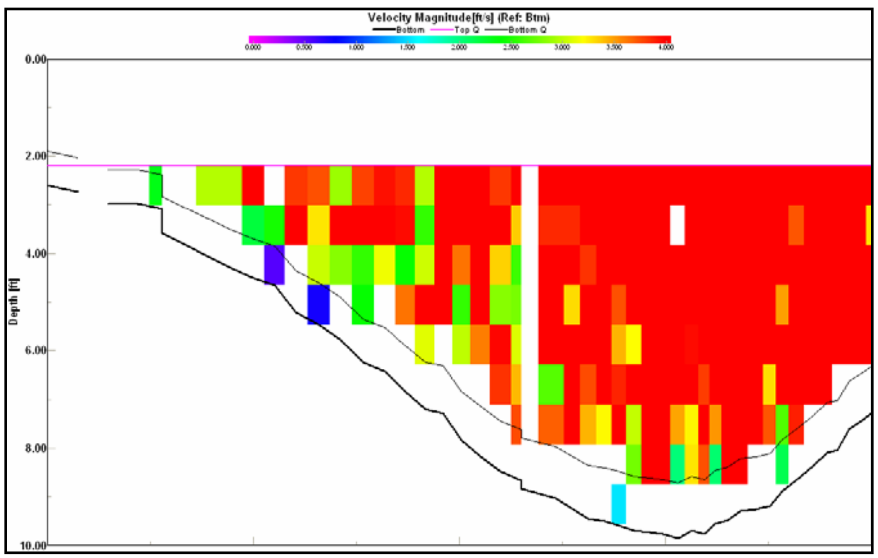
Appendix A. Cross-sectional velocity profiles measured at transects in the Merced River between Crocker-Huffman and Merced Falls dams.



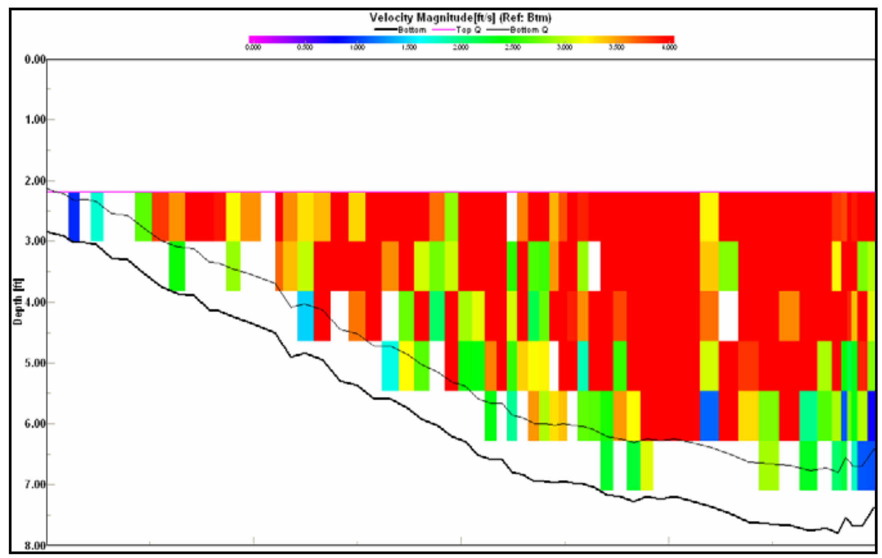
Cross-sectional ADCP velocity profile at transect 32 (facing downstream). Left bank is ~10’ from start of transect and right bank is ~15’ from end of transect.



Cross-sectional ADCP velocity profile at transect 33 (facing downstream). Right bank is ~18’ from start of transect and left bank is ~11’ from end of transect.

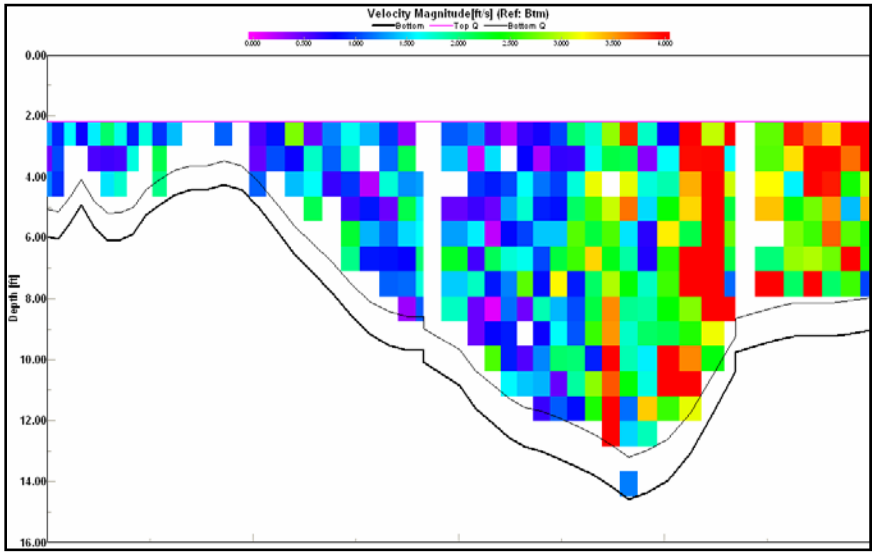


Cross-sectional ADCP velocity profile at transect 34 (facing downstream). Left bank is ~11’ from start of transect and right bank is ~8’ from end of transect.

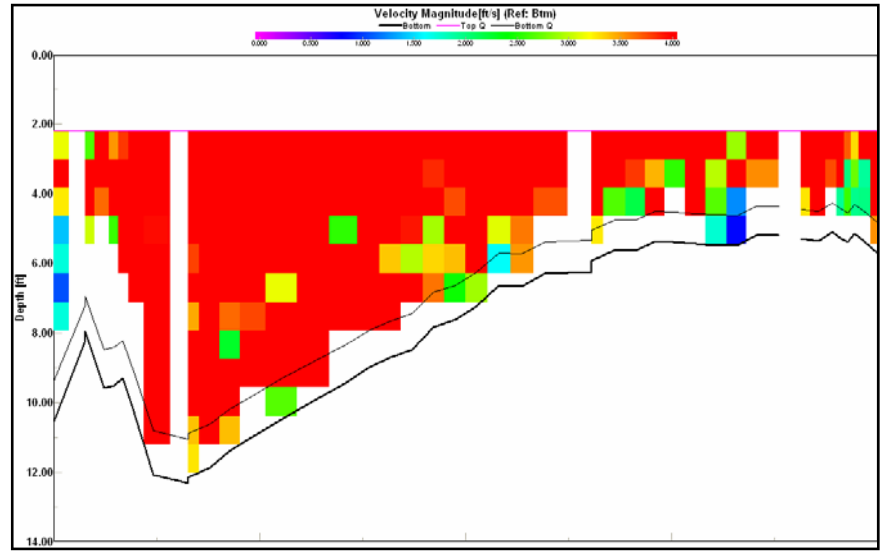


Cross-sectional ADCP velocity profile at transect 35 (facing downstream). Right bank is ~12’ from start of transect and left bank is ~18’ from end of transect.

Appendix A. Cross-sectional velocity profiles measured at transects in the Merced River between Crocker-Huffman and Merced Falls dams.

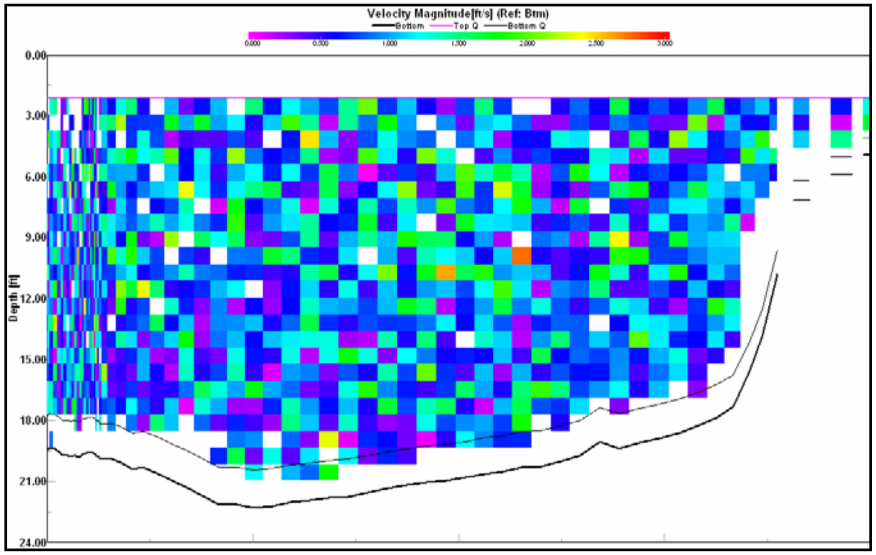


Cross-sectional ADCP velocity profile at transect 36 (facing downstream). Left bank is ~7' from start of transect and right bank is ~20' from end of transect.

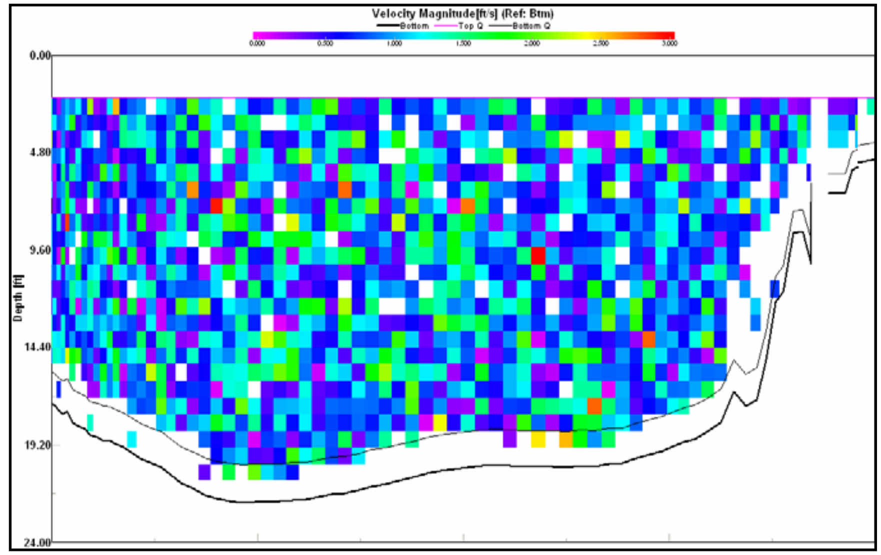


Cross-sectional ADCP velocity profile at transect 37 (facing downstream). Right bank is ~10' from start of transect and left bank is ~10' from end of transect.

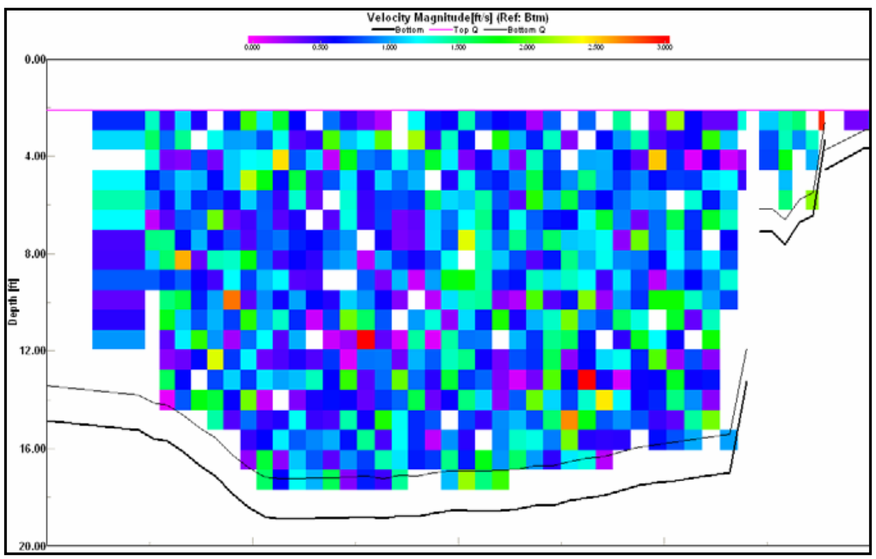
Appendix A. Cross-sectional velocity profiles measured at transects in the Merced River between Crocker-Huffman and Merced Falls dams.



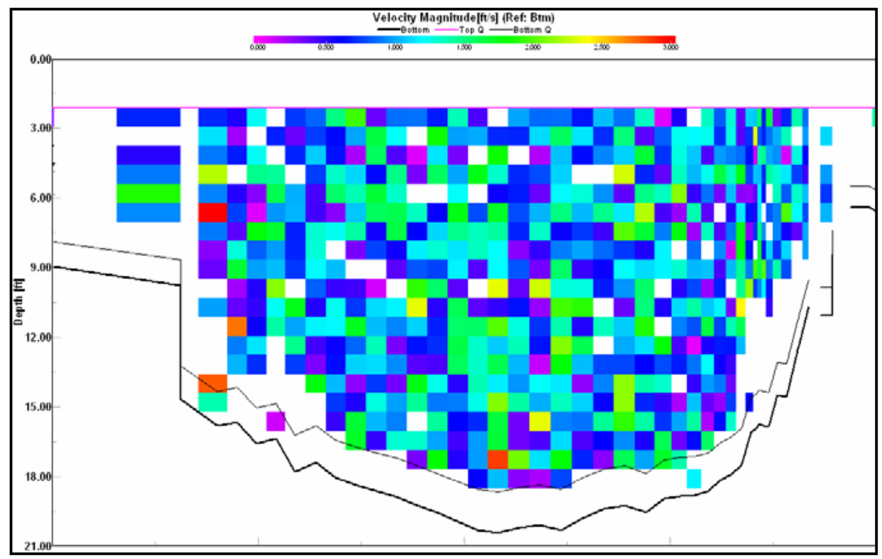
Cross-sectional ADCP velocity profile at transect 8 (facing downstream). Left bank is ~6' from start of transect and right bank is ~15' from end of transect.



Cross-sectional ADCP velocity profile at transect 9 (facing downstream). Left bank is ~6' from start of transect and right bank is ~12' from end of transect.

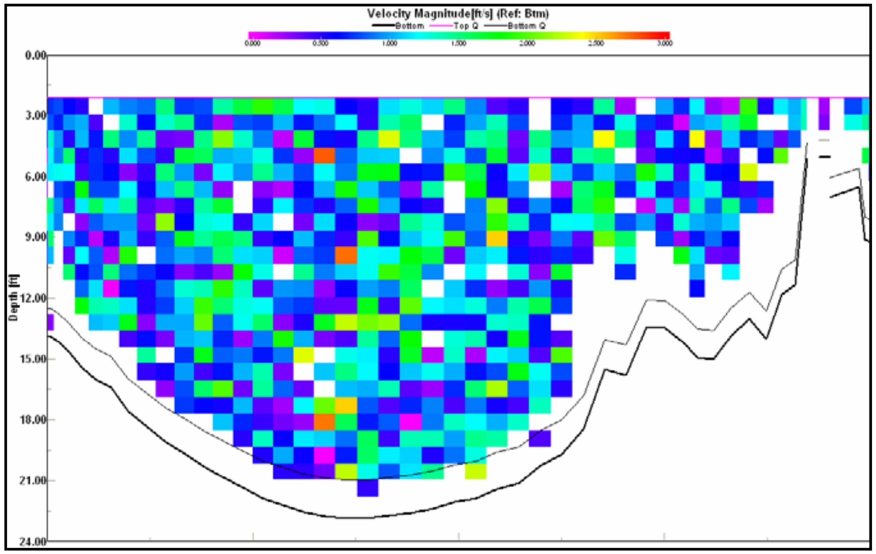


Cross-sectional ADCP velocity profile at transect 10 (facing downstream). Left bank is ~5' from start of transect and right bank is ~20' from end of transect.

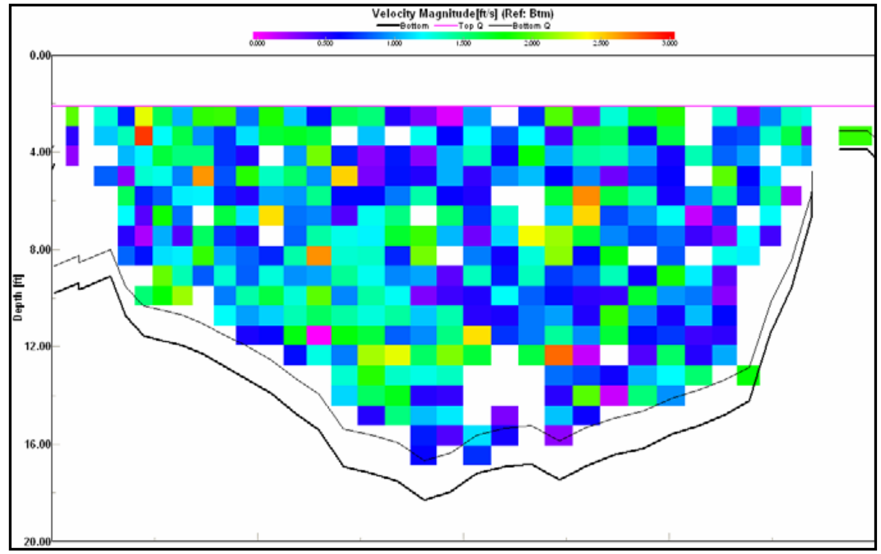


Cross-sectional ADCP velocity profile at transect 11 (facing downstream). Left bank is ~25' from start of transect and right bank is ~10' from end of transect.

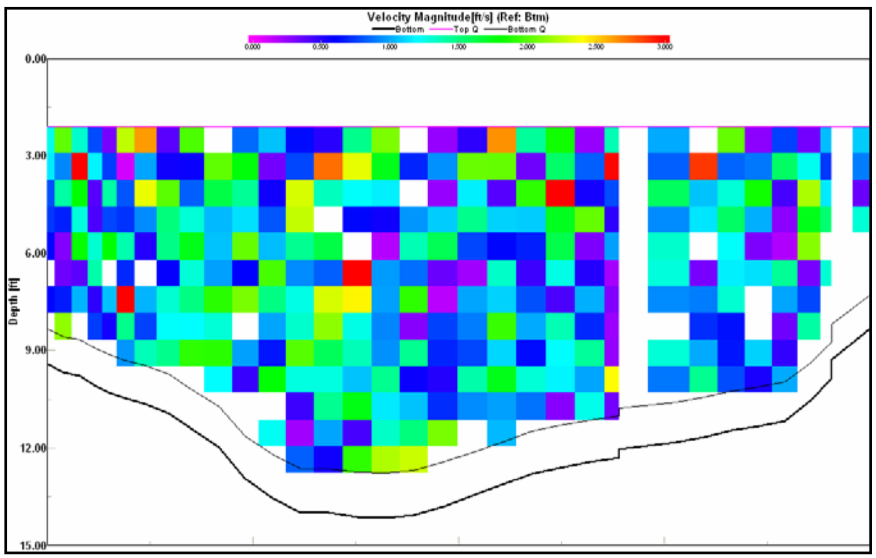
Appendix A. Cross-sectional velocity profiles measured at transects in the Merced River between Crocker-Huffman and Merced Falls dams.



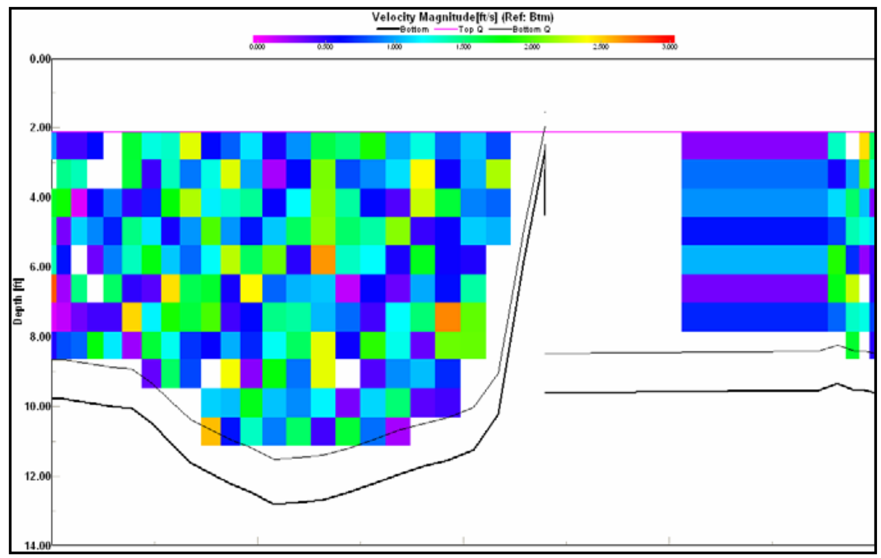
Cross-sectional ADCP velocity profile at transect 12 (facing downstream). Left bank is ~20’ from start of transect and right bank is ~15’ from end of transect.



Cross-sectional ADCP velocity profile at transect 13 (facing downstream). Left bank is ~10’ from start of transect and right bank is ~35’ from end of transect.

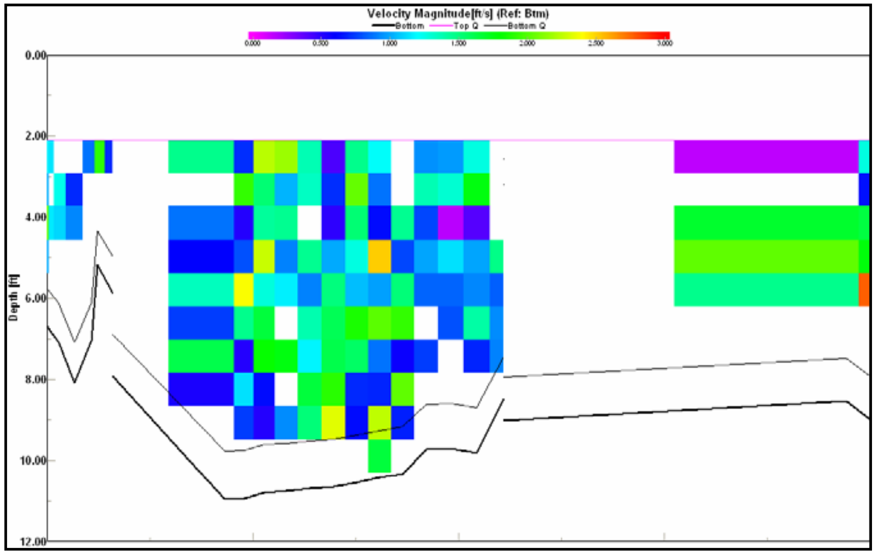


Cross-sectional ADCP velocity profile at transect 14 (facing downstream). Left bank is ~20’ from start of transect and right bank is ~75’ from end of transect.

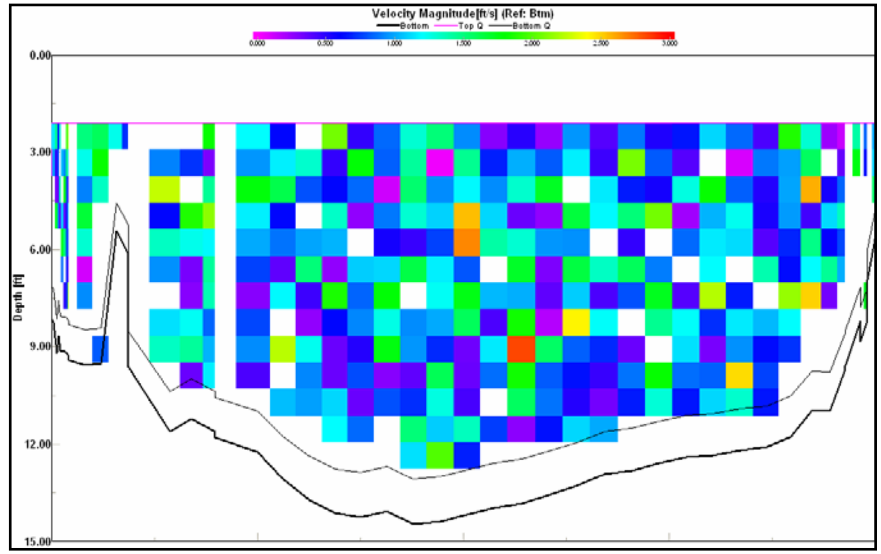


Cross-sectional ADCP velocity profile at transect 15 (facing downstream). Left bank is ~15’ from start of transect and right bank is ~75’ from end of transect.

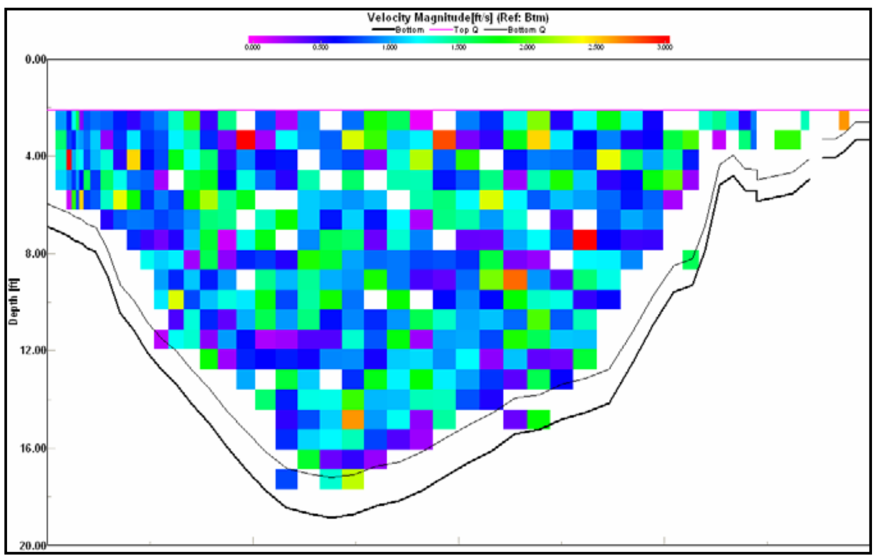
Appendix A. Cross-sectional velocity profiles measured at transects in the Merced River between Crocker-Huffman and Merced Falls dams.



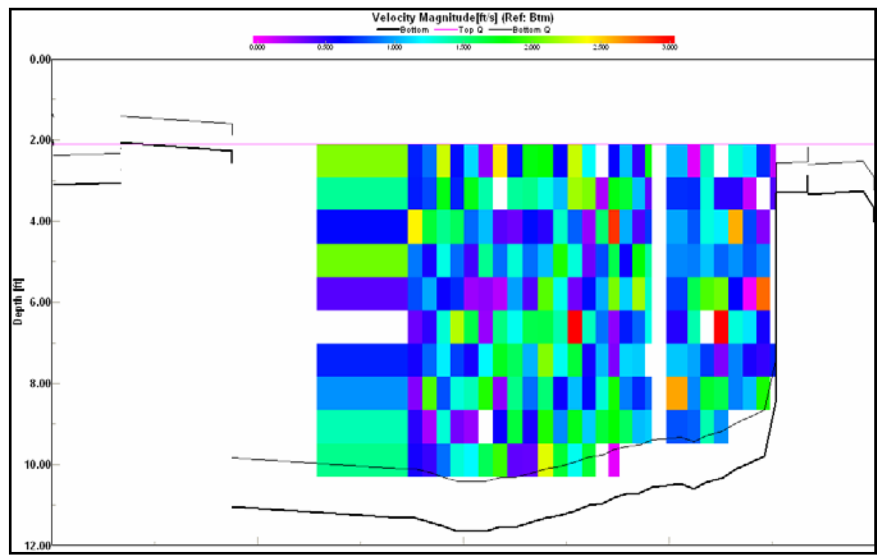
Cross-sectional ADCP velocity profile at transect 16 (facing downstream). Left bank is ~30’ from start of transect and right bank is ~80’ from end of transect.



Cross-sectional ADCP velocity profile at transect 17 (facing downstream). Left bank is ~12’ from start of transect and right bank is ~75’ from end of transect.

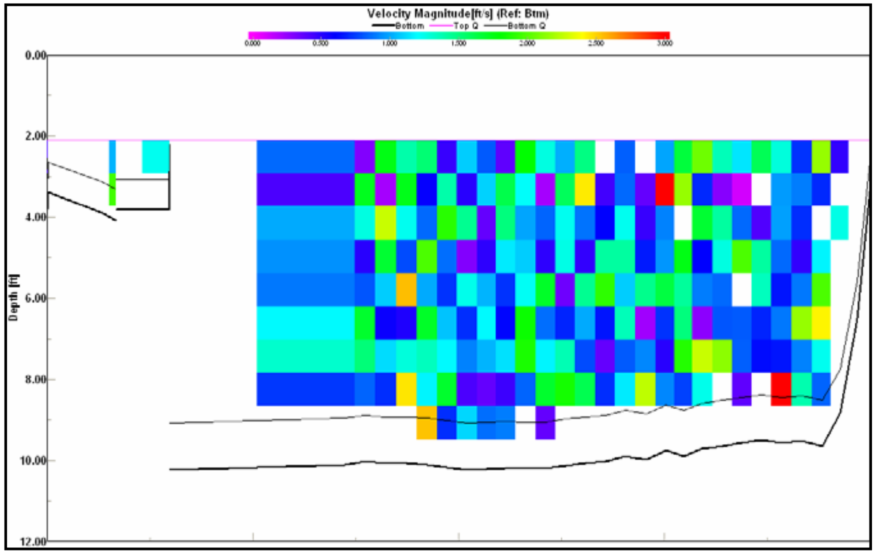


Cross-sectional ADCP velocity profile at transect 18 (facing downstream). Left bank is ~10’ from start of transect and right bank is ~25’ from end of transect.

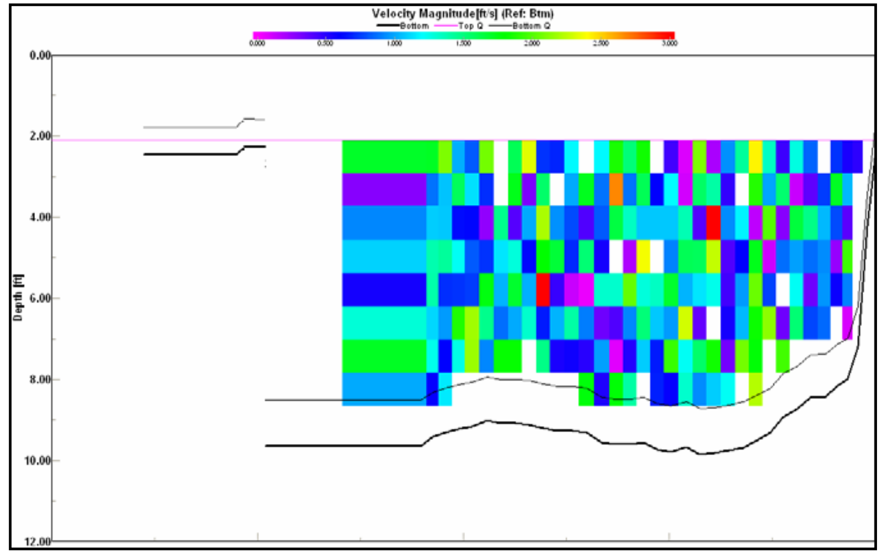


Cross-sectional ADCP velocity profile at transect 19 (facing downstream). Left bank is ~10’ from start of transect and right bank is ~15’ from end of transect.

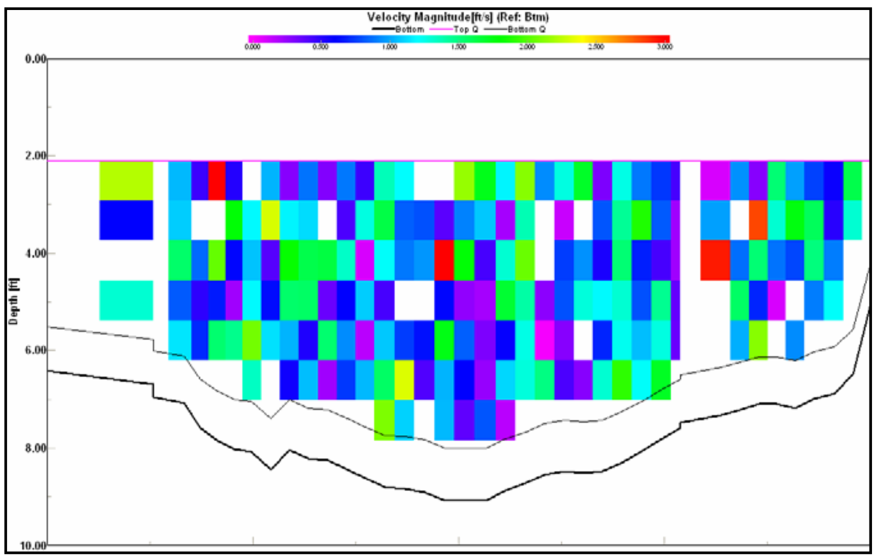
Appendix A. Cross-sectional velocity profiles measured at transects in the Merced River between Crocker-Huffman and Merced Falls dams.



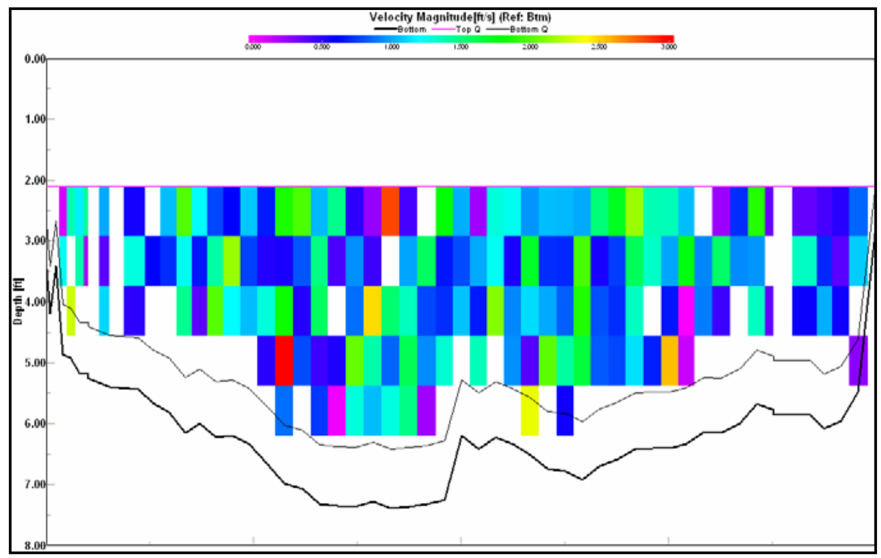
Cross-sectional ADCP velocity profile at transect 20 (facing downstream). Left bank is ~10’ from start of transect and right bank is ~20’ from end of transect.



Cross-sectional ADCP velocity profile at transect 21 (facing downstream). Left bank is ~10’ from start of transect and right bank is ~10’ from end of transect.

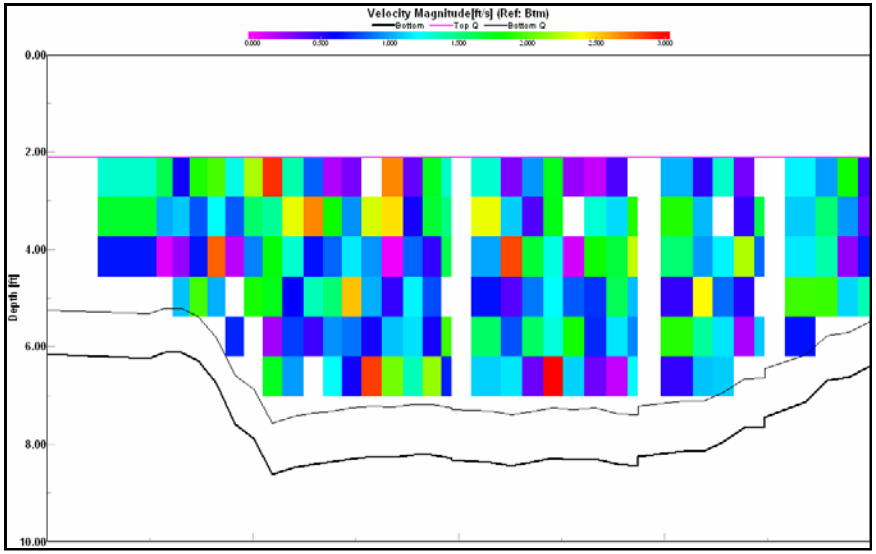


Cross-sectional ADCP velocity profile at transect 22 (facing downstream). Left bank is ~8’ from start of transect and right bank is ~15’ from end of transect.

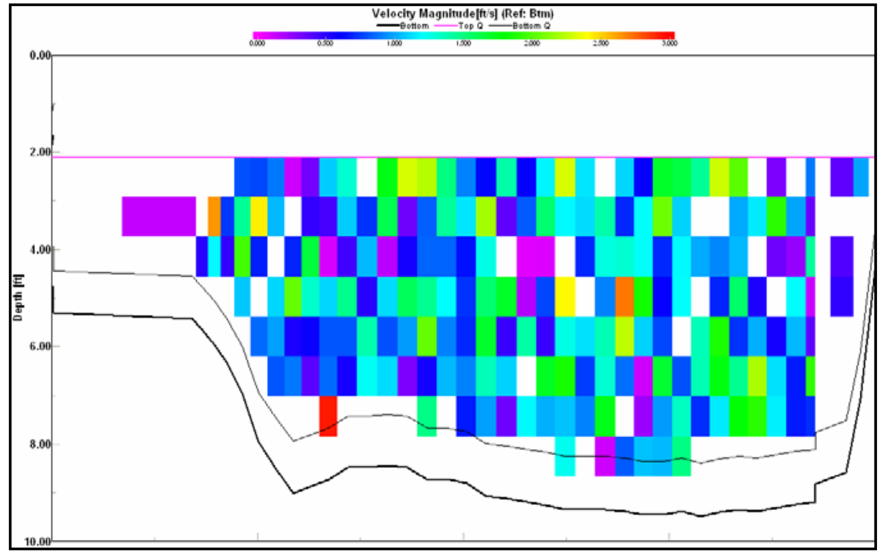


Cross-sectional ADCP velocity profile at transect 23 (facing downstream). Left bank is ~10’ from start of transect and right bank is ~15’ from end of transect.

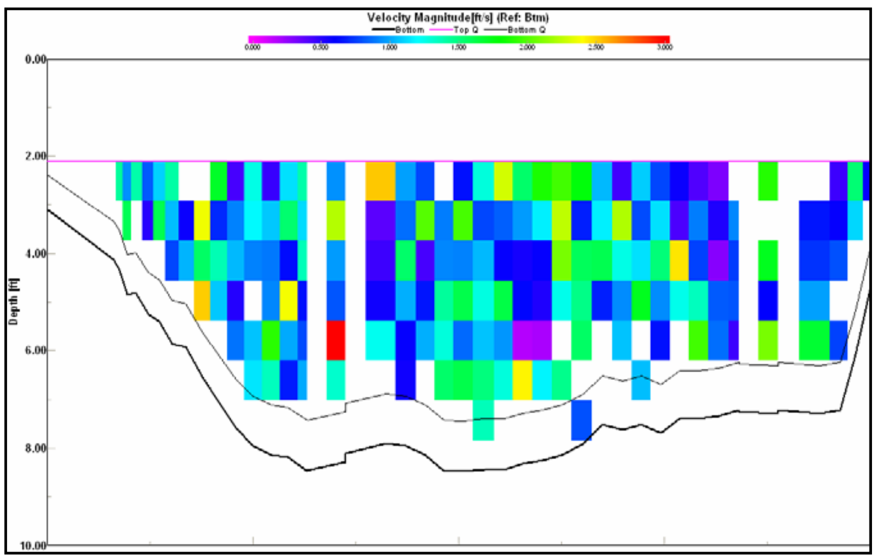
Appendix A. Cross-sectional velocity profiles measured at transects in the Merced River between Crocker-Huffman and Merced Falls dams.



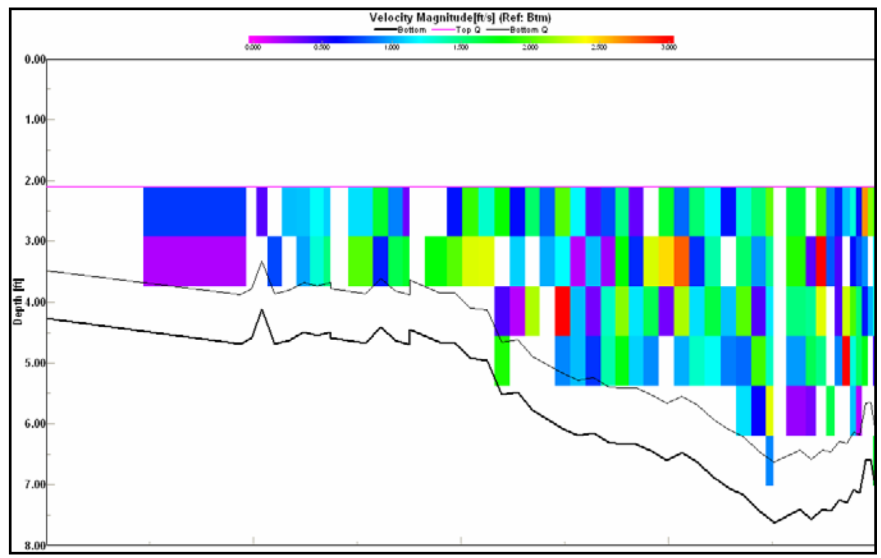
Cross-sectional ADCP velocity profile at transect 24 (facing downstream). Left bank is ~12' from start of transect and right bank is ~20' from end of transect.



Cross-sectional ADCP velocity profile at transect 25 (facing downstream). Left bank is ~12' from start of transect and right bank is ~10' from end of transect.

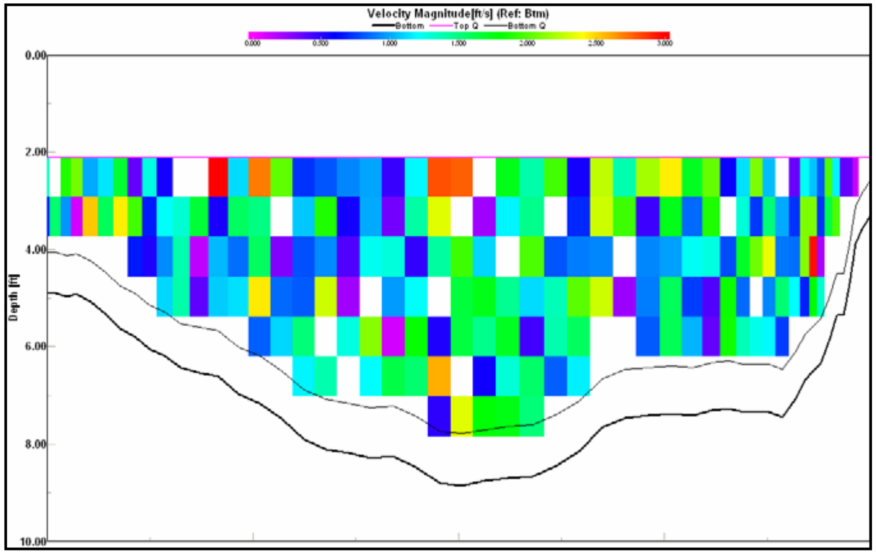


Cross-sectional ADCP velocity profile at transect 26 (facing downstream). Left bank is ~3' from start of transect and right bank is ~20' from end of transect.

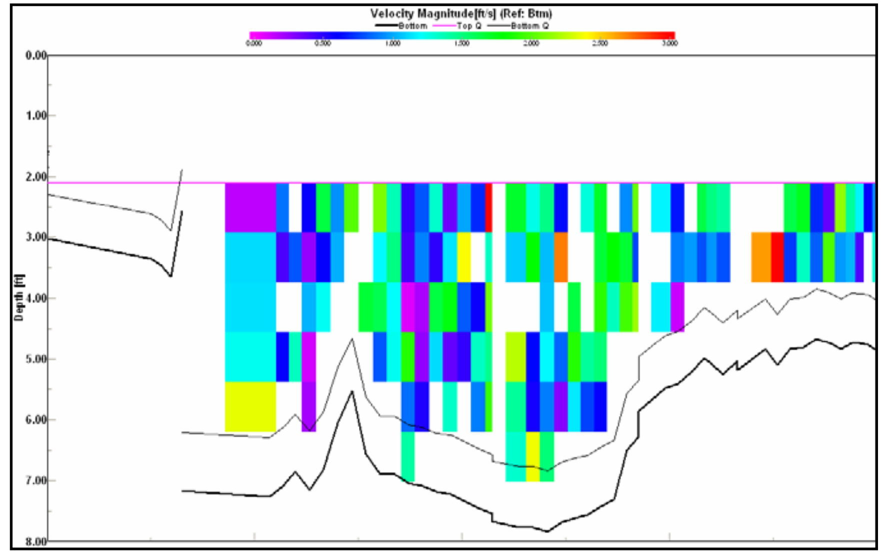


Cross-sectional ADCP velocity profile at transect 27 (facing downstream). Left bank is ~15' from start of transect and right bank is ~15' from end of transect.

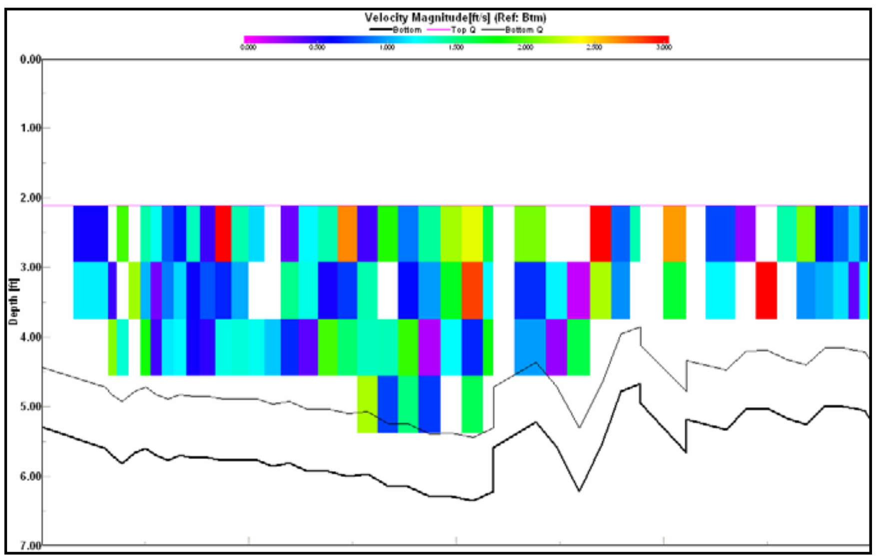
Appendix A. Cross-sectional velocity profiles measured at transects in the Merced River between Crocker-Huffman and Merced Falls dams.



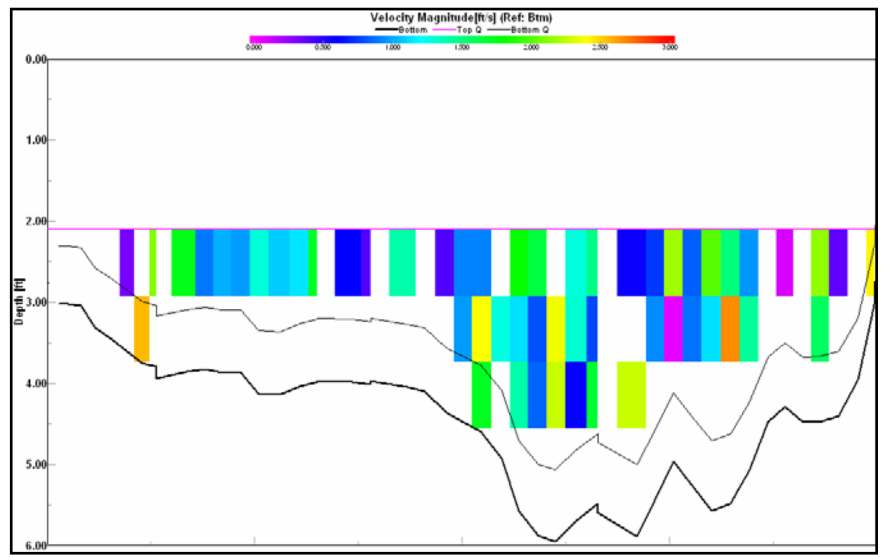
Cross-sectional ADCP velocity profile at transect 28 (facing downstream). Left bank is ~25’ from start of transect and right bank is ~18’ from end of transect.



Cross-sectional ADCP velocity profile at transect 29 (facing downstream). Left bank is ~3’ from start of transect and right bank is ~12’ from end of transect.

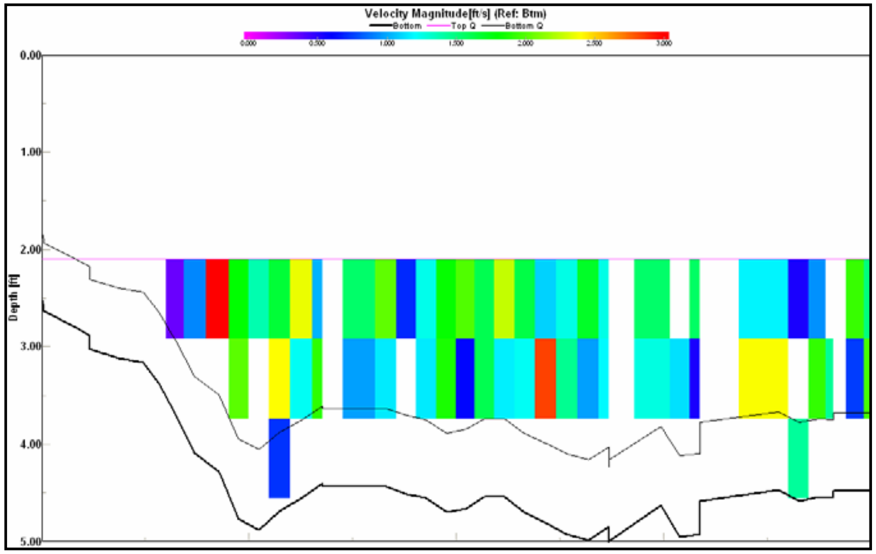


Cross-sectional ADCP velocity profile at transect 30 (facing downstream). Left bank is ~18’ from start of transect and right bank is ~18’ from end of transect.

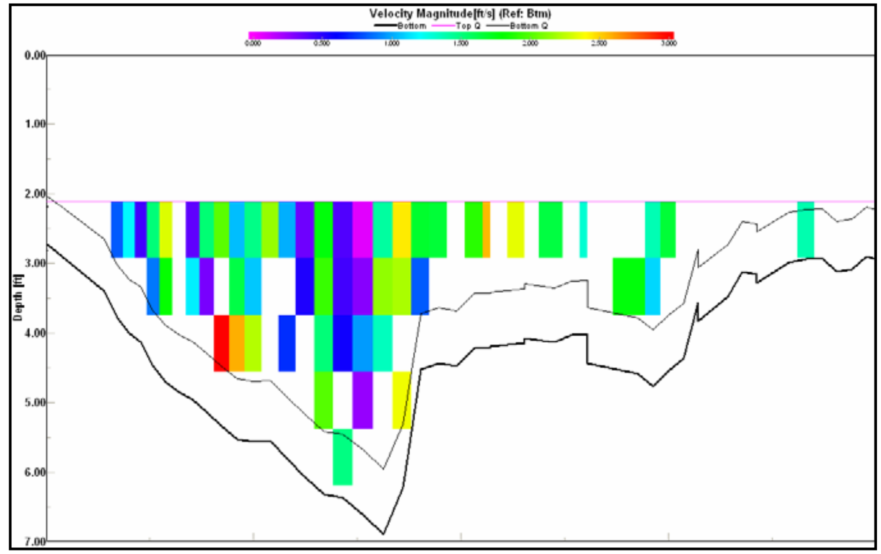


Cross-sectional ADCP velocity profile at transect 31 (facing downstream). Left bank is ~4’ from start of transect and right bank is ~6’ from end of transect.

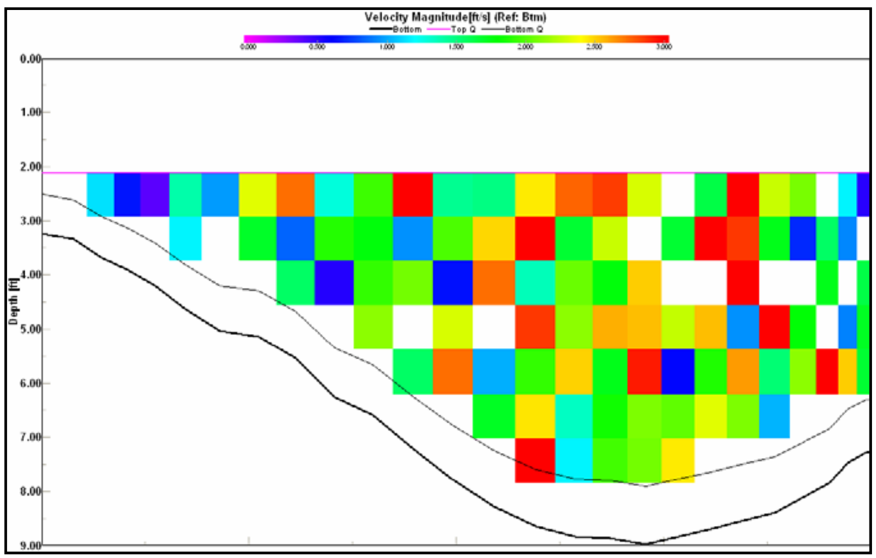
Appendix A. Cross-sectional velocity profiles measured at transects in the Merced River between Crocker-Huffman and Merced Falls dams.



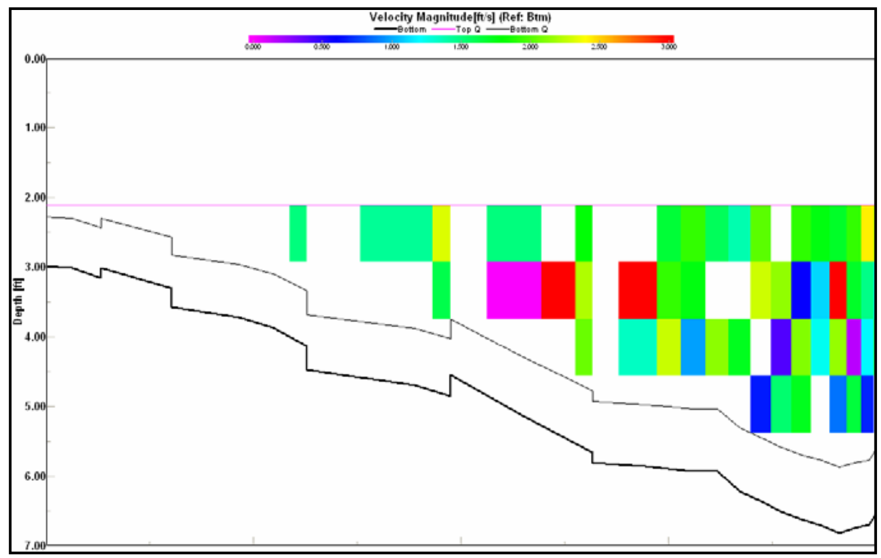
Cross-sectional ADCP velocity profile at transect 32 (facing downstream). Left bank is ~5’ from start of transect and right bank is ~20’ from end of transect.



Cross-sectional ADCP velocity profile at transect 33 (facing downstream). Left bank is ~1-’ from start of transect and right bank is ~12’ from end of transect.

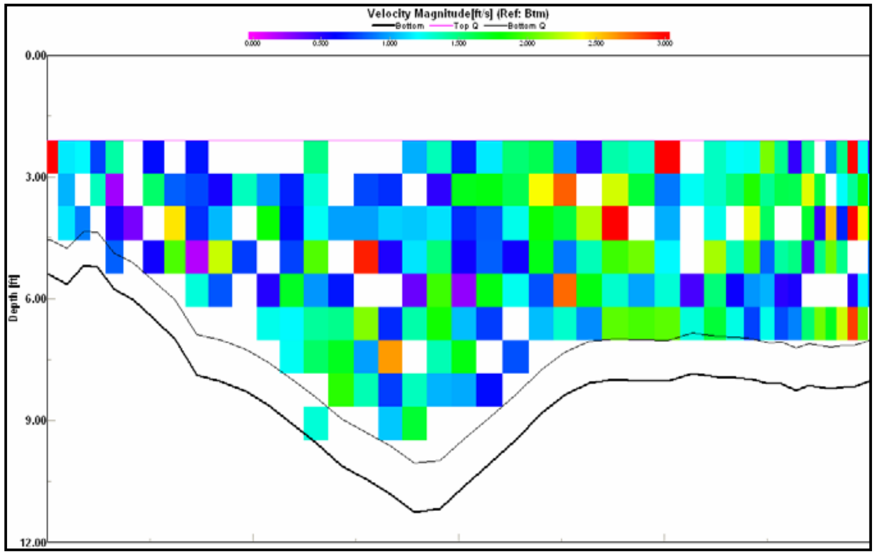


Cross-sectional ADCP velocity profile at transect 34 (facing downstream). Left bank is ~10’ from start of transect and right bank is ~121’ from end of transect.

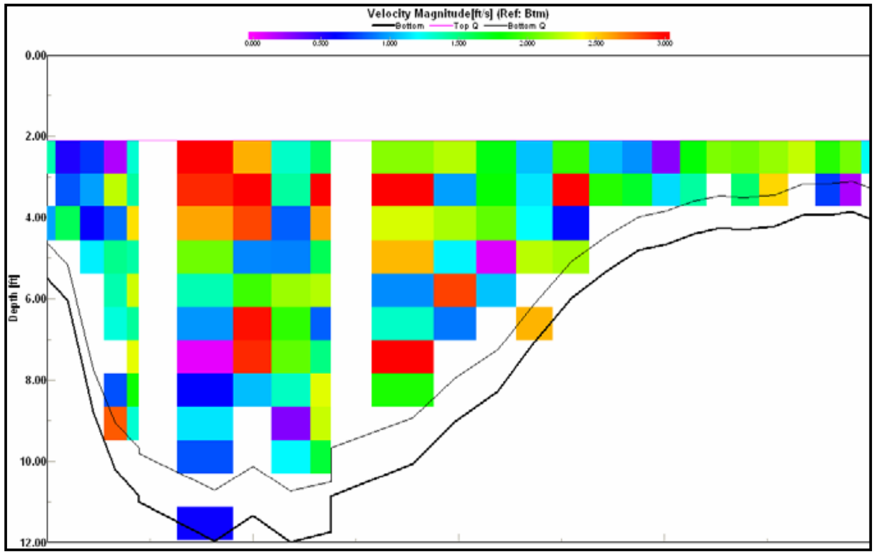


Cross-sectional ADCP velocity profile at transect 35 (facing downstream). Left bank is ~15’ from start of transect and right bank is ~5’ from end of transect.

Appendix A. Cross-sectional velocity profiles measured at transects in the Merced River between Crocker-Huffman and Merced Falls dams.

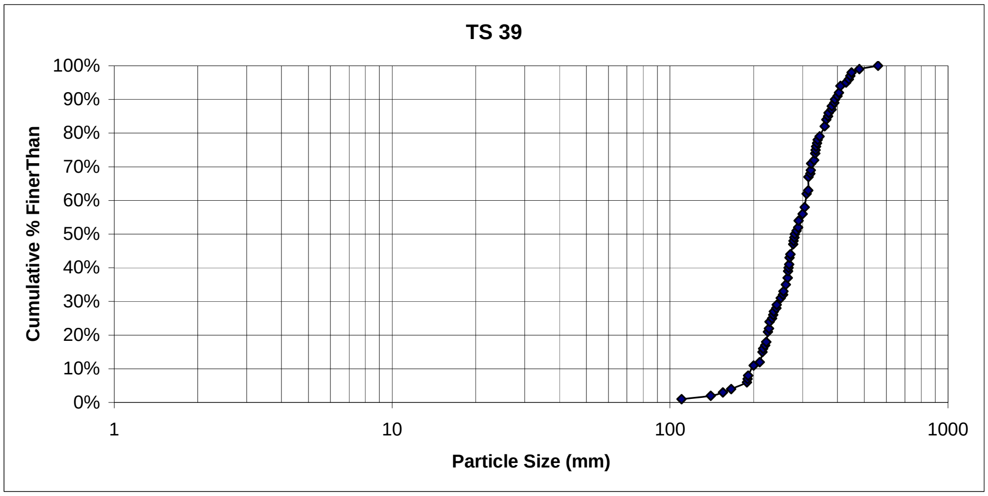


Cross-sectional ADCP velocity profile at transect 36 (facing downstream). Left bank is ~25’ from start of transect and right bank is ~12’ from end of transect.

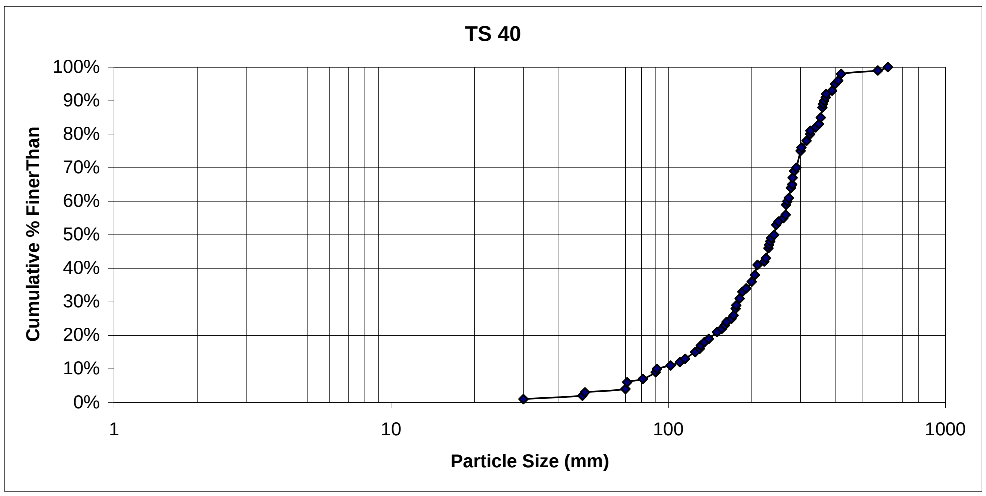


Cross-sectional ADCP velocity profile at transect 37 (facing downstream). Left bank is ~5’ from start of transect and right bank is ~6’ from end of transect.

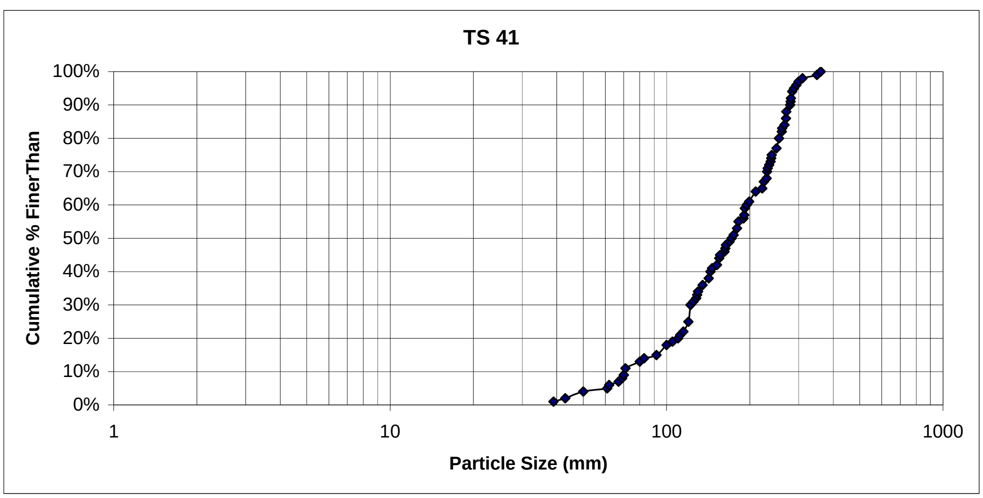
Appendix B. Pebble count data for reaches above and below Crocker-Huffman Dam.



Pebble count at transect No. 39 between Crocker-Huffman and Merced Falls dams.

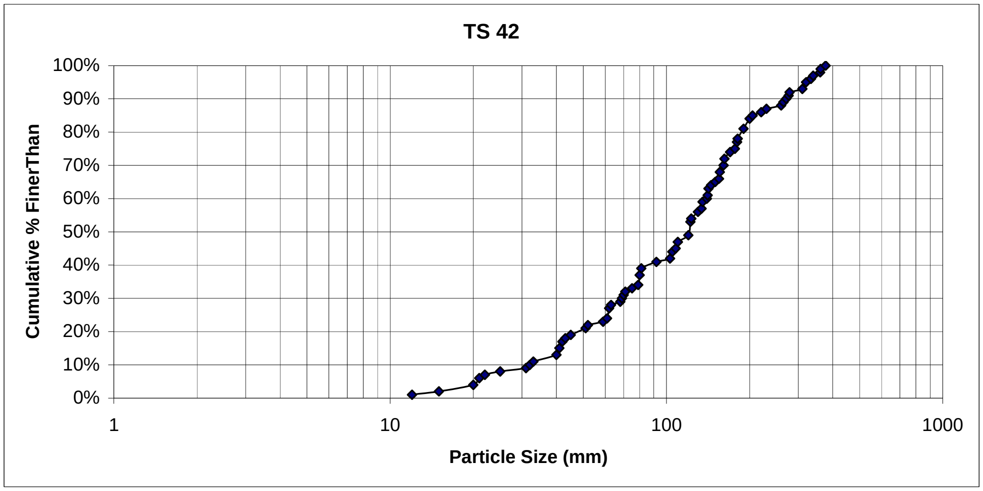


Pebble count at transect No. 40 between Crocker-Huffman and Merced Falls dams.

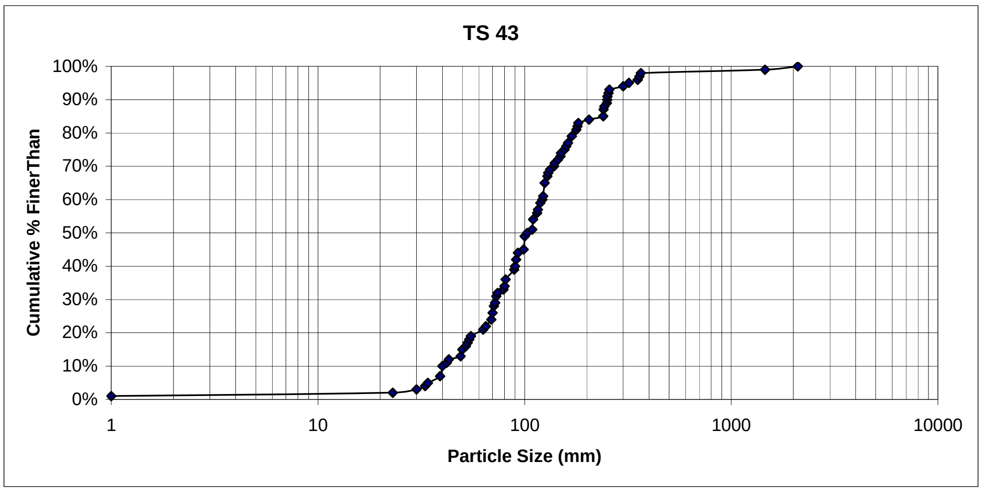


Pebble count at transect No. 41 between Crocker-Huffman and Merced Falls dams.

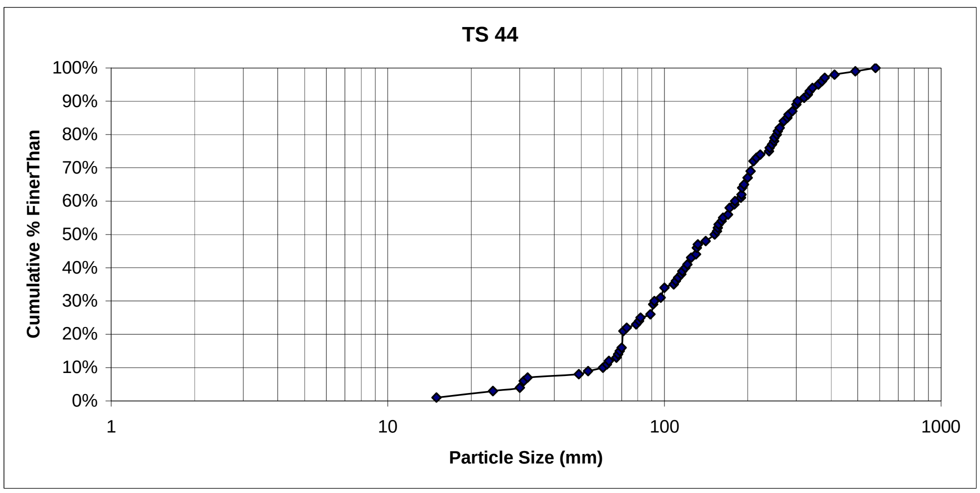
Appendix B. Pebble count data for reaches above and below Crocker-Huffman Dam.



Pebble count at transect No. 42 between Crocker-Huffman and Merced Falls dams.

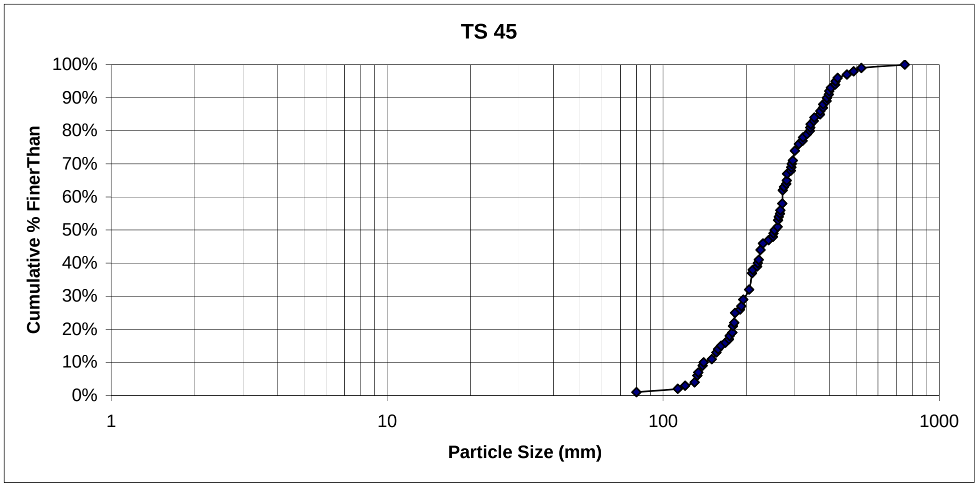


Pebble count at transect No. 43 between Crocker-Huffman and Merced Falls dams.

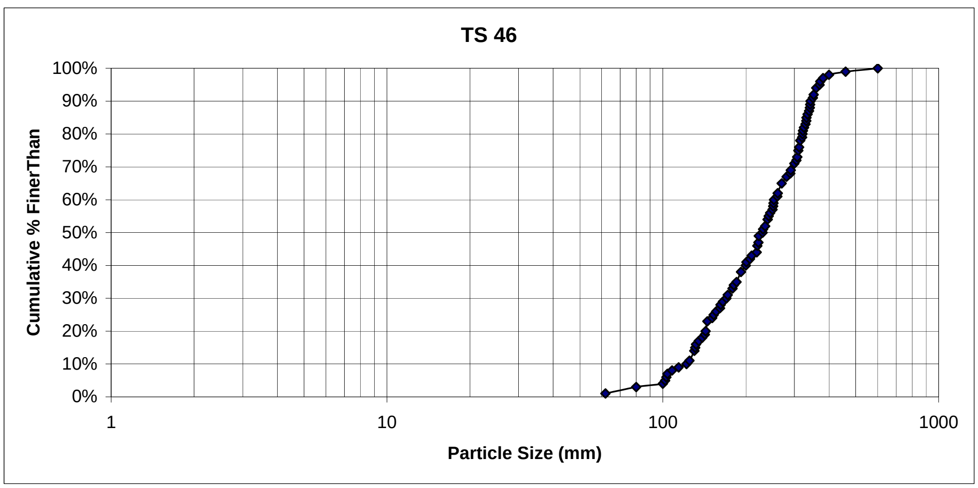


Pebble count at transect No. 44 between Crocker-Huffman and Merced Falls dams.

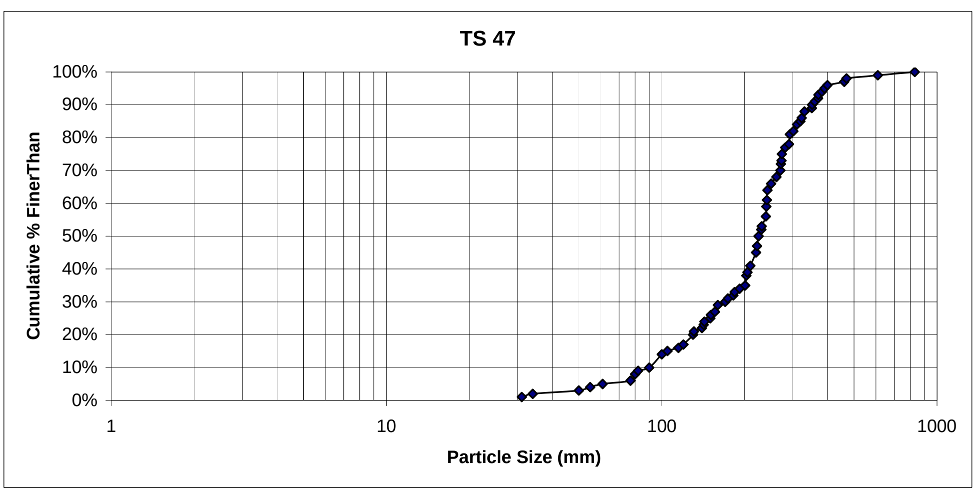
Appendix B. Pebble count data for reaches above and below Crocker-Huffman Dam.



Pebble count at transect No. 45 between Crocker-Huffman and Merced Falls dams.

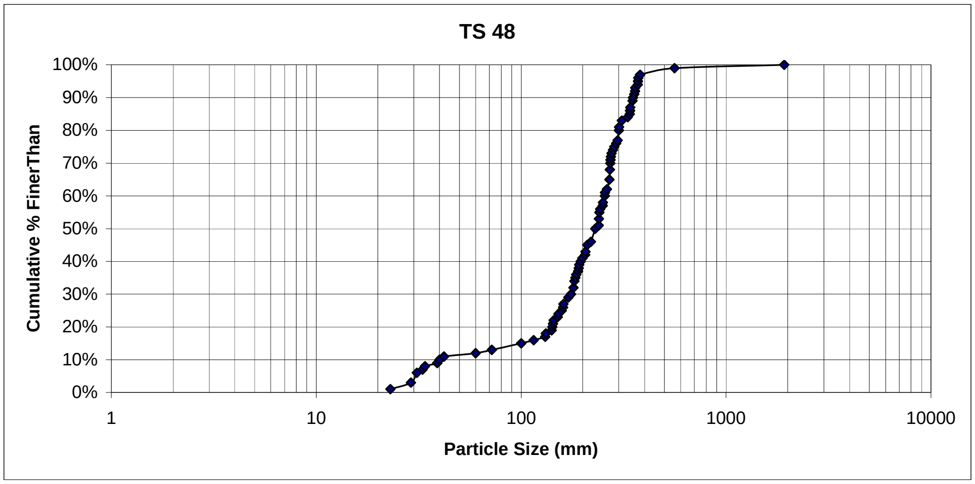


Pebble count at transect No. 46 between Crocker-Huffman and Merced Falls dams.

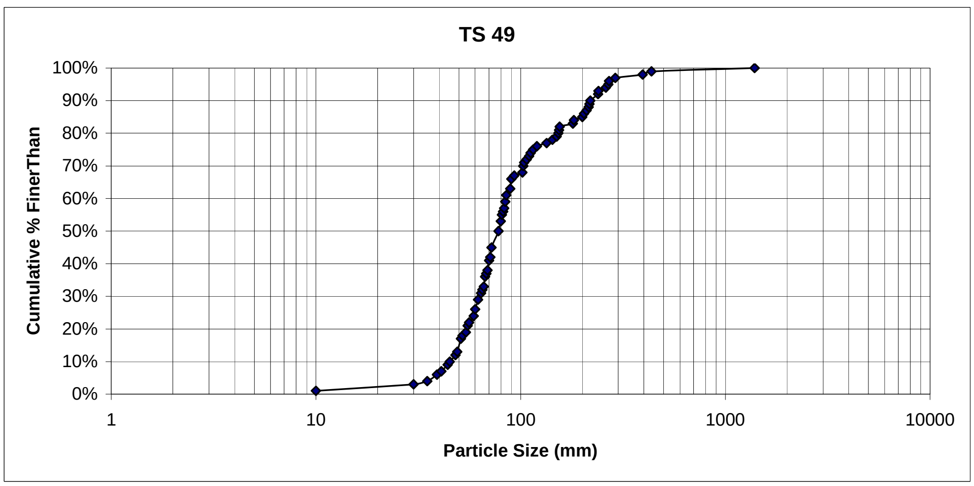


Pebble count at transect No. 47 between Crocker-Huffman and Merced Falls dams.

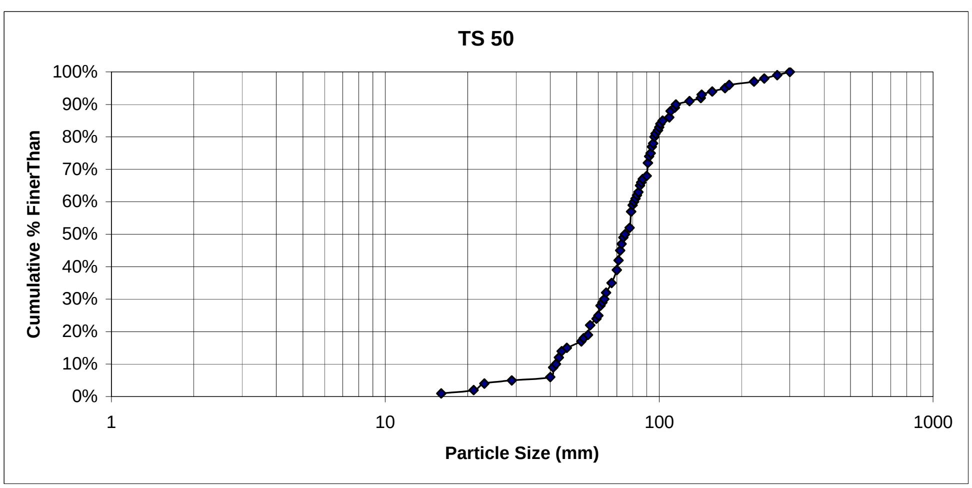
Appendix B. Pebble count data for reaches above and below Crocker-Huffman Dam.



Pebble count at transect No. 48 between Crocker-Huffman and Merced Falls dams.

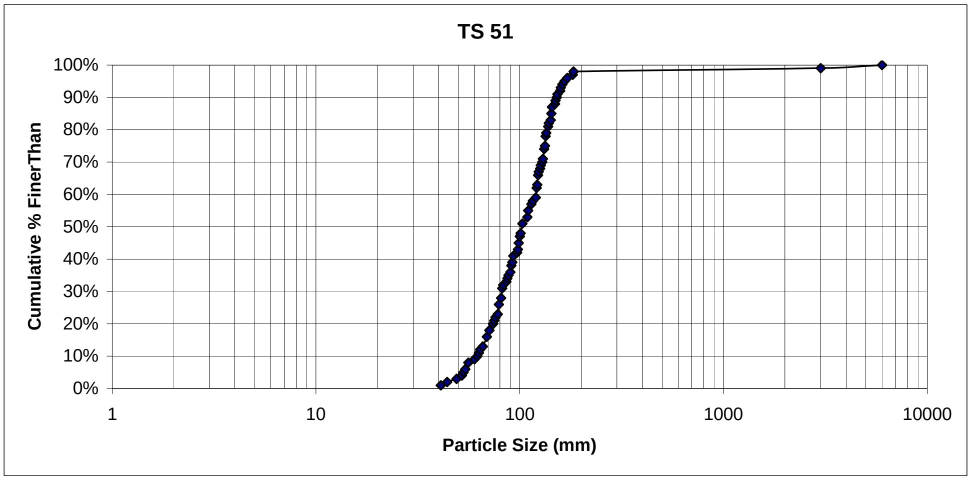


Pebble count at transect No. 49 between Crocker-Huffman and Merced Falls dams.

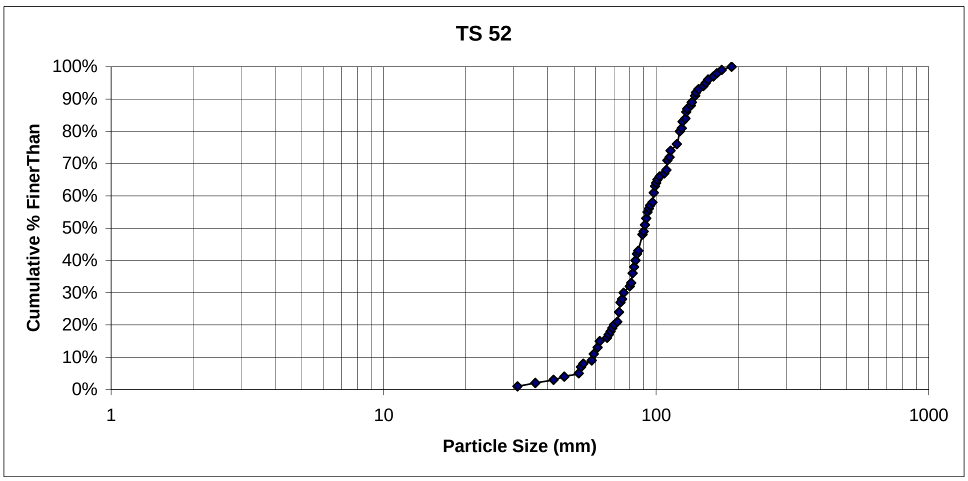


Pebble count at transect No. 50 between Crocker-Huffman and Merced Falls dams.

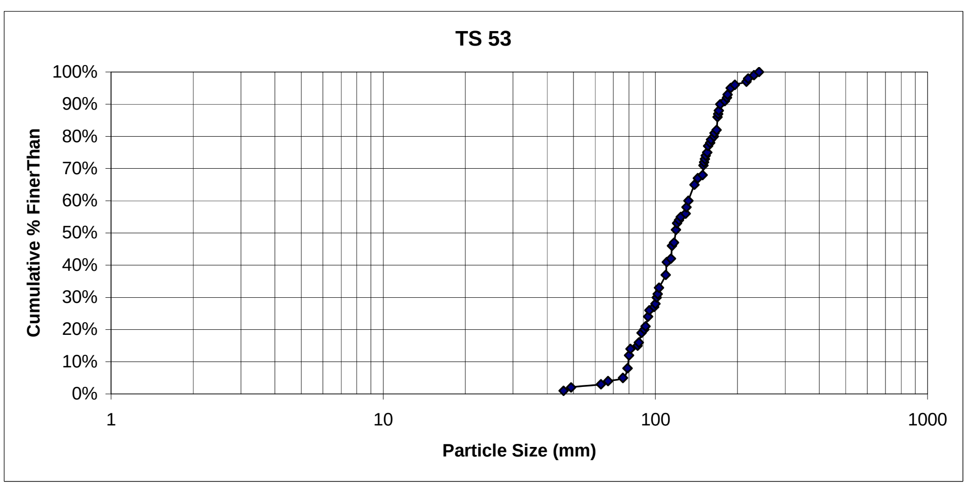
Appendix B. Pebble count data for reaches above and below Crocker-Huffman Dam.



Pebble count at transect No. 51 between Crocker-Huffman and Merced Falls dams.

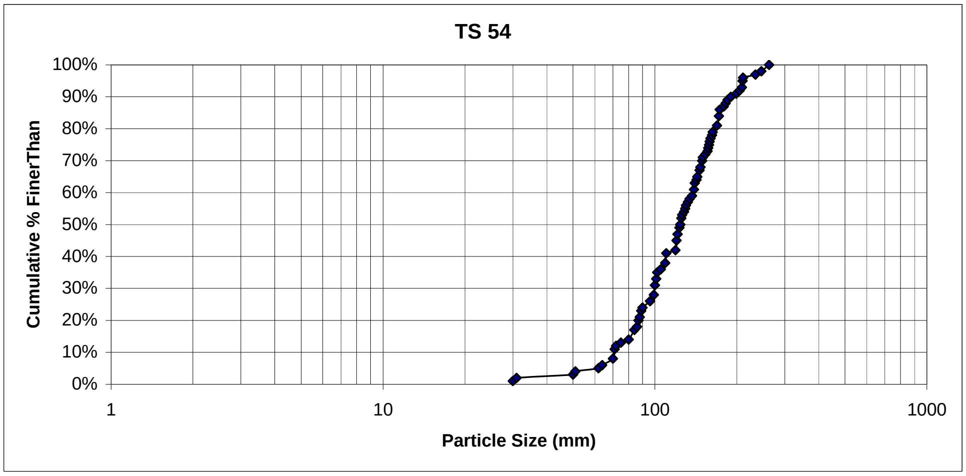


Pebble count at transect No. 52 between Crocker-Huffman and Merced Falls dams.

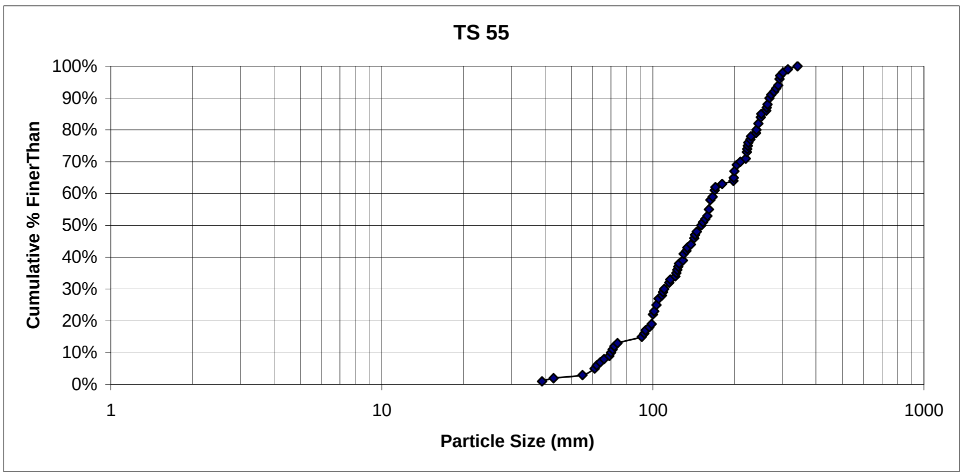


Pebble count at transect No. 53 between Crocker-Huffman and Merced Falls dams.

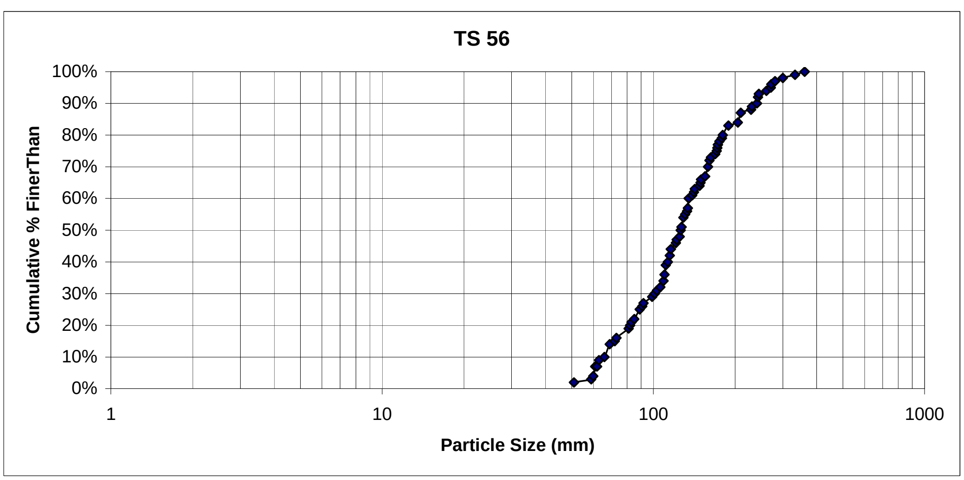
Appendix B. Pebble count data for reaches above and below Crocker-Huffman Dam.



Pebble count at transect No. 54 between Crocker-Huffman and Merced Falls dams.

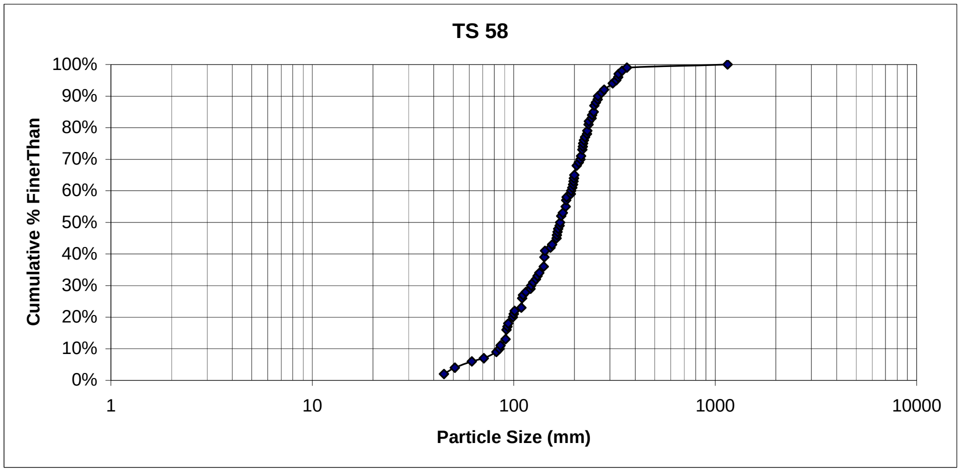


Pebble count at transect No. 55 between Crocker-Huffman and Merced Falls dams.

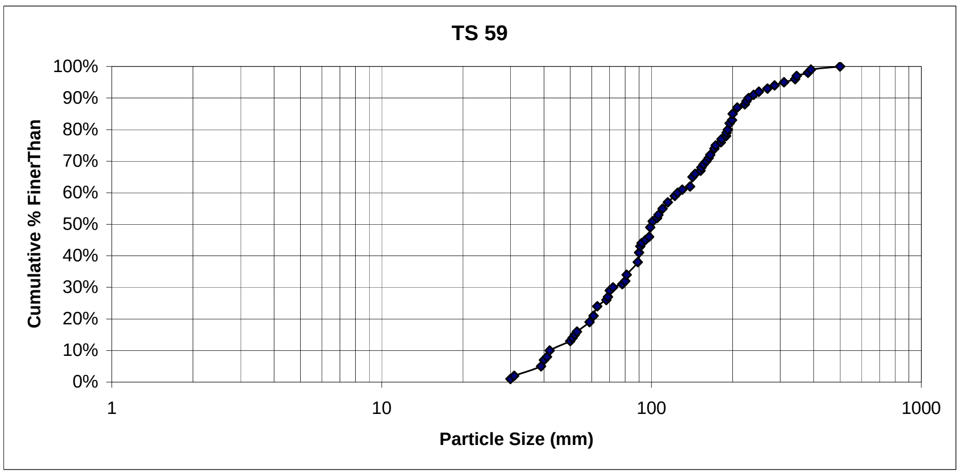


Pebble count at transect No. 56 between Crocker-Huffman and Merced Falls dams.

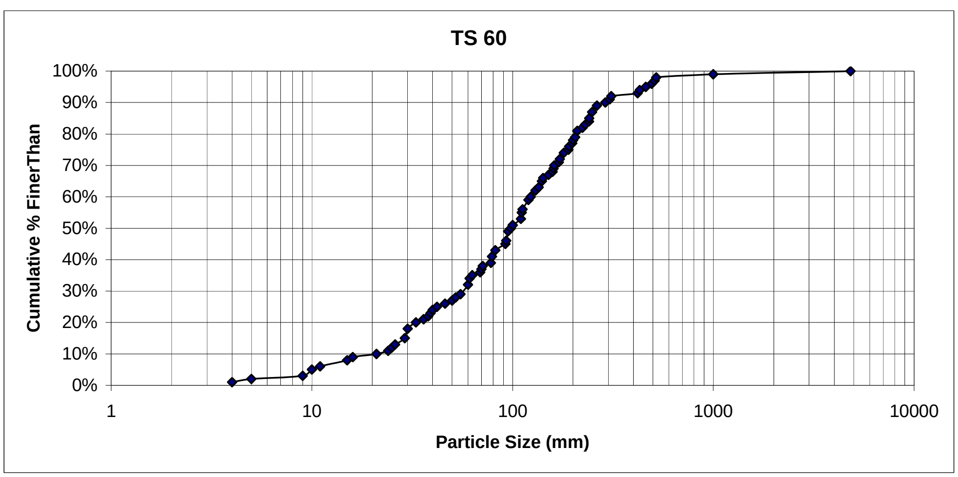
Appendix B. Pebble count data for reaches above and below Crocker-Huffman Dam.



Pebble count at transect No. 58 between Crocker-Huffman and Merced Falls dams.

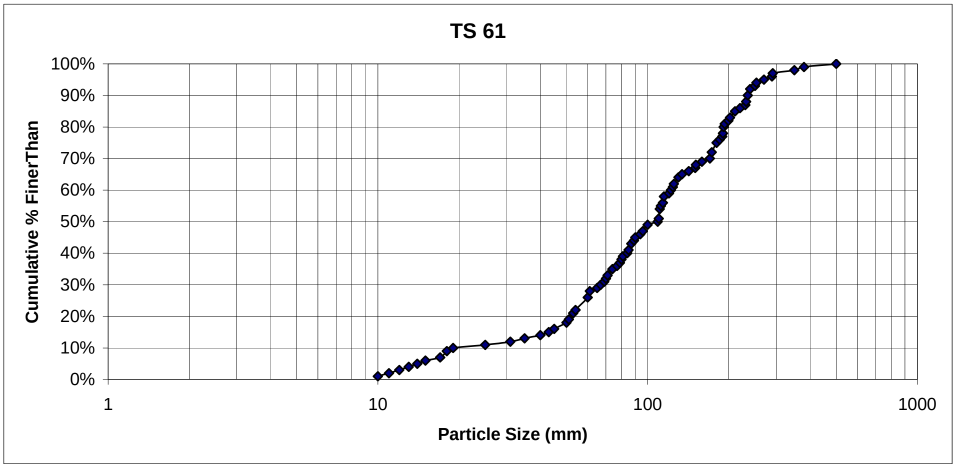


Pebble count at transect No. 59 between Crocker-Huffman and Merced Falls dams.

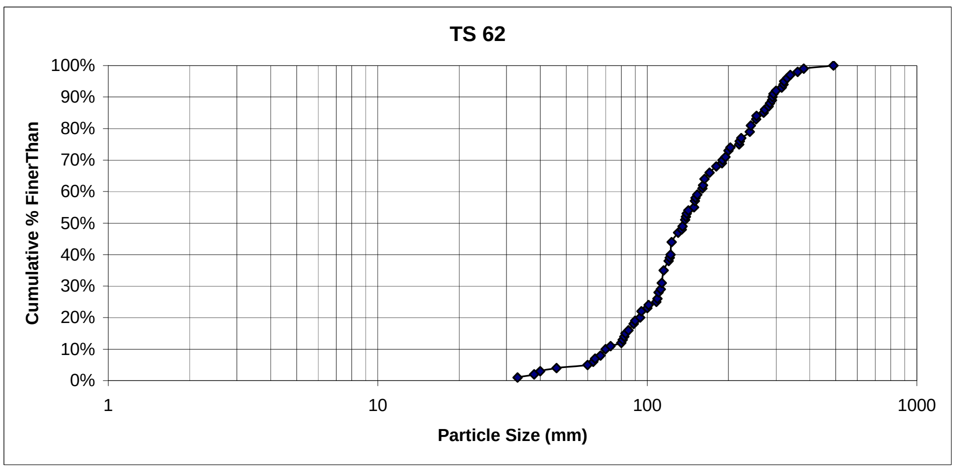


Pebble count at transect No. 60 between Crocker-Huffman and Merced Falls dams.

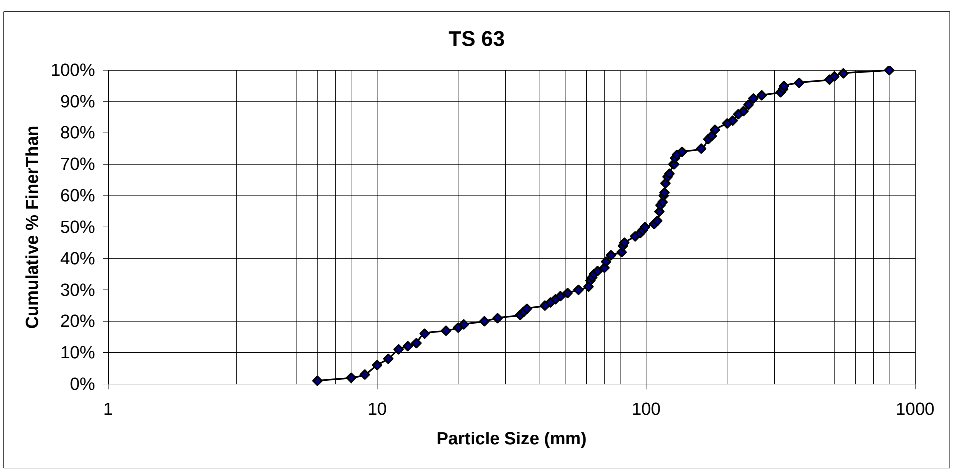
Appendix B. Pebble count data for reaches above and below Crocker-Huffman Dam.



Pebble count at transect No. 61 between Crocker-Huffman and Merced Falls dams.

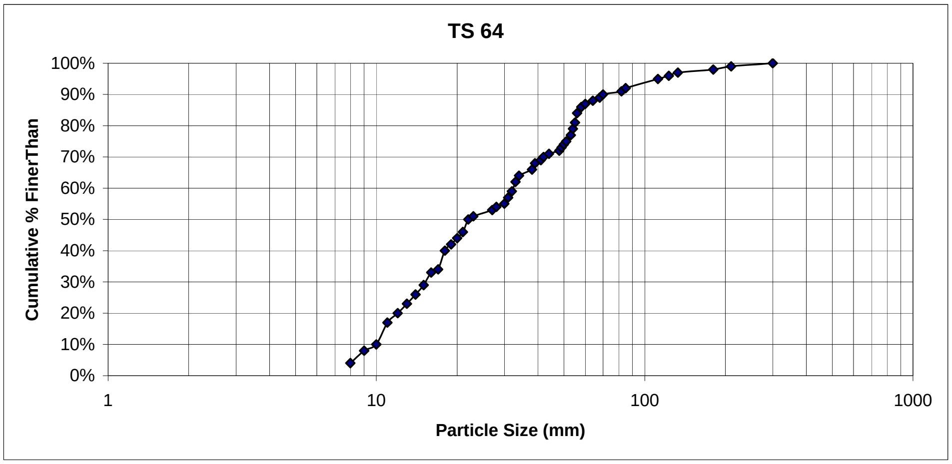


Pebble count at transect No. 62 between Crocker-Huffman and Merced Falls dams.



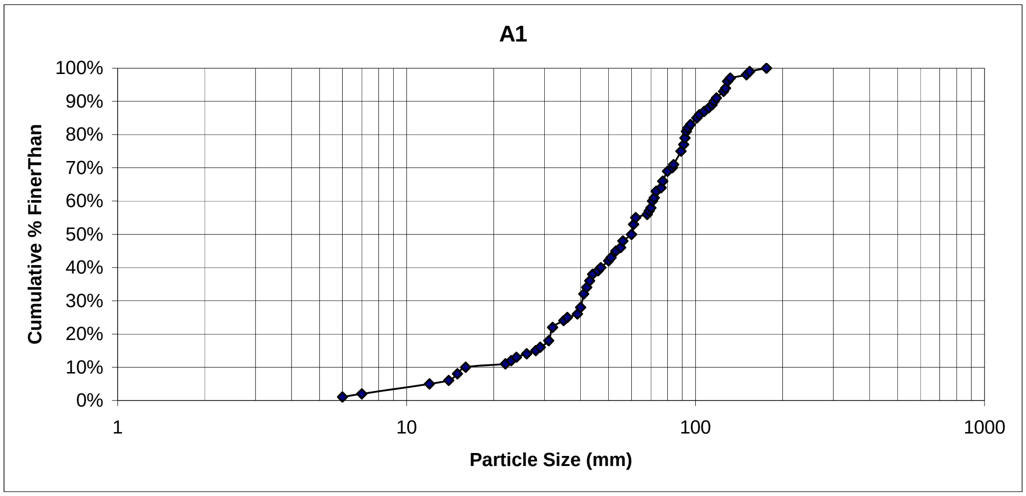
Pebble count at transect No. 63 between Crocker-Huffman and Merced Falls dams.

Appendix B. Pebble count data for reaches above and below Crocker-Huffman Dam.

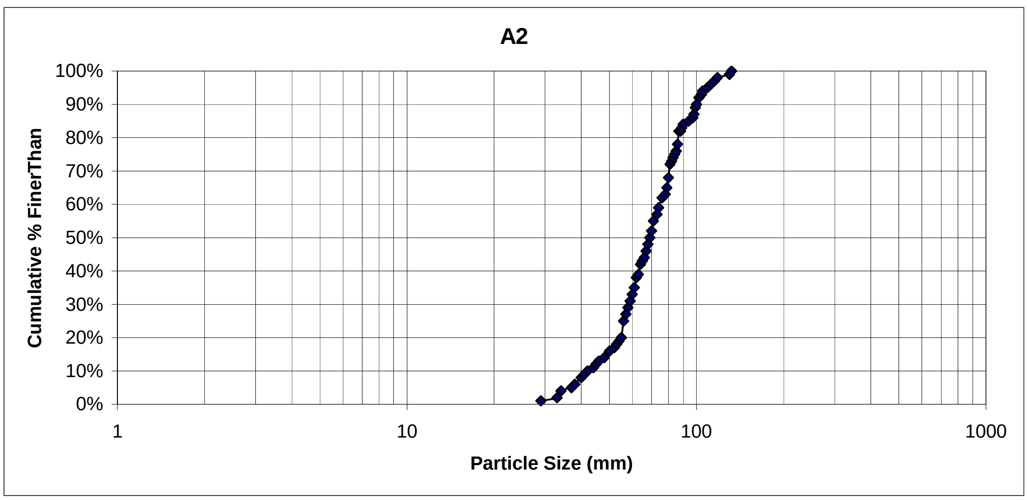


Pebble count at transect No. 64 between Crocker-Huffman and Merced Falls dams.

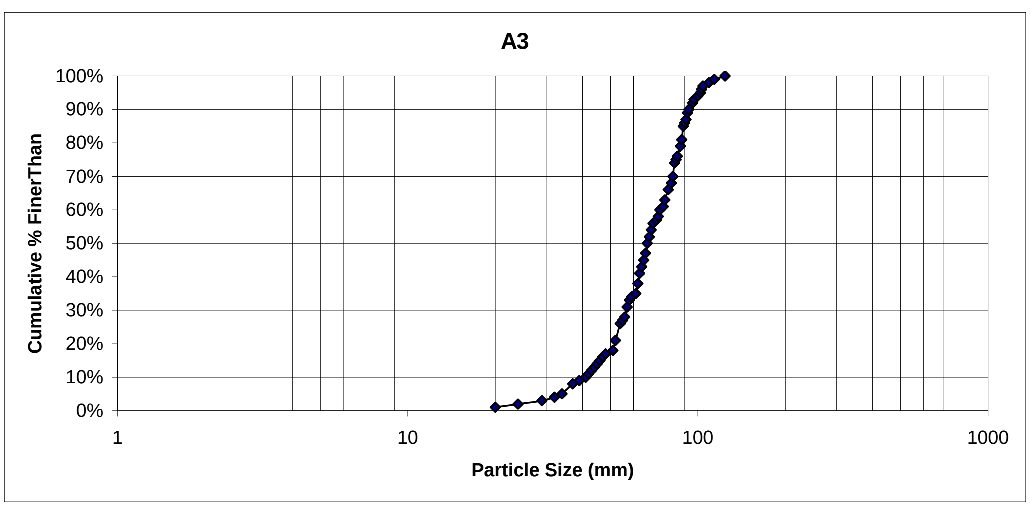
Appendix B. Pebble count data for reaches above and below Crocker-Huffman Dam.



Pebble count at Riffle No. A1 downstream of Crocker-Huffman Dam.

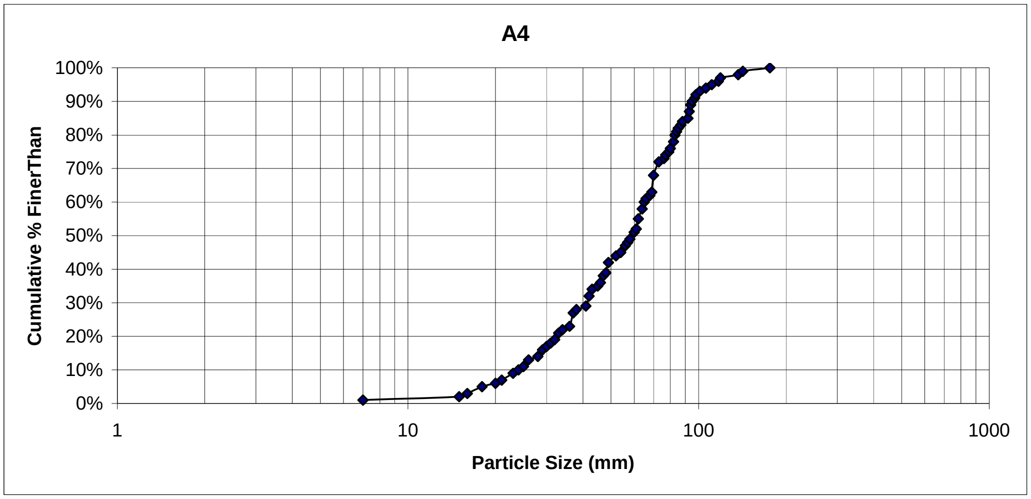


Pebble count at Riffle No. A2 downstream of Crocker-Huffman Dam.

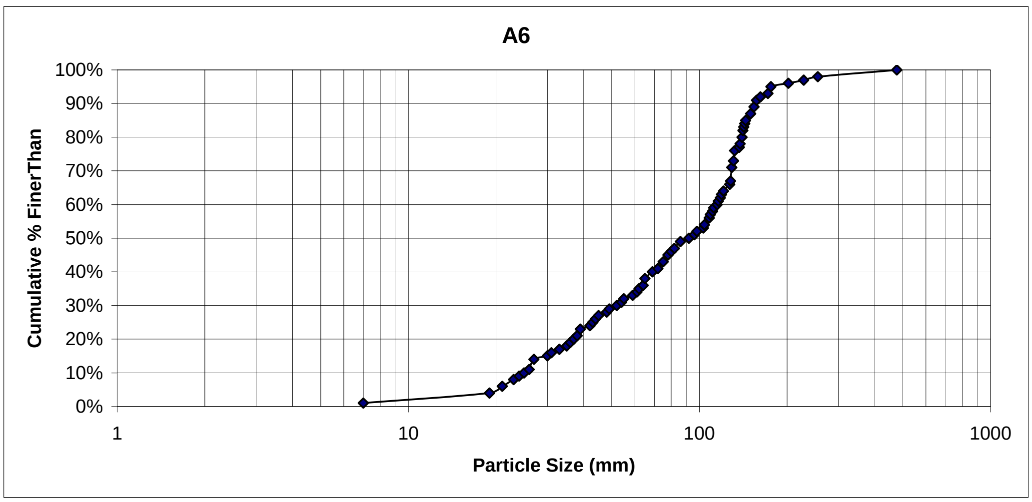


Pebble count at Riffle No. A3 downstream of Crocker-Huffman Dam.

Appendix B. Pebble count data for reaches above and below Crocker-Huffman Dam.



Pebble count at Riffle No. A4 downstream of Crocker-Huffman Dam.



Pebble count at Riffle No. A6 downstream of Crocker-Huffman Dam.

Appendix C. Results of Merced River Substrate Samples (percent retention by sieve size)

Site and Sample #	Date Extracted	Size (g)	12.5mm	4.75mm	2.36mm	0.85mm	<0.85mm
Below Crocker-Huffman Dam							
A1 # 1	7/6/2006	15252.9	79.9	6.0	2.6	4.0	7.6
A1 # 2	7/6/2006	17126.7	89.8	0.1	0.0	0.3	9.7
A1 # 3	7/6/2006	15801.1	96.7	3.1	0.1	0.0	0.0
	Average	**16060.2**	**88.8**	**3.1**	**0.9**	**1.4**	**5.8**
A2 # 1	7/5/2006	12990.6	99.7	0.0	0.0	0.0	0.3
A2 # 2	7/5/2006	15746.6	98.7	0.9	0.0	0.0	0.4
A2 # 3	7/5/2006	15095.6	99.4	0.6	0.0	0.0	0.0
	Average	**14610.9**	**99.2**	**0.5**	**0.0**	**0.0**	**0.2**
A3 # 1	7/5/2006	15367.7	97.1	1.5	0.0	0.0	1.4
A3 # 2	7/5/2006	14843.5	86.7	2.0	0.2	0.4	10.8
A3 # 3	7/5/2006	17002.1	90.3	1.5	0.0	0.4	7.8
	Average	**15737.8**	**91.4**	**1.7**	**0.1**	**0.3**	**6.7**
A4 # 1	7/5/2006	13885.0	78.9	4.5	0.4	0.4	15.8
A4 # 2	7/6/2006	15586.0	78.3	5.3	2.5	3.5	10.3
A4 # 3	7/6/2006	14203.8	71.2	11.5	4.6	5.7	7.0
	Average	**14558.3**	**76.2**	**7.1**	**2.5**	**3.2**	**11.0**
A6 # 1	7/6/2006	19170.9	92.2	5.8	1.2	0.5	0.3
A6 # 2	7/6/2006	10572.5	72.6	15.2	6.4	3.4	2.4
A6 # 3	7/6/2006	12495.5	76.8	4.1	6.0	5.7	7.4
	Average	**14079.6**	**80.5**	**8.4**	**4.5**	**3.2**	**3.4**
Above Crocker-Huffman Dam							
64 # 3	3/6/2005	15828.4	66.5	23.1	1.0	1.8	7.5
64 # 2	3/6/2005	13555.8	80.5	2.5	0.9	2.0	14.0
64 # 1	3/6/2005	16671.2	69.2	16.7	3.4	2.3	8.5
	Average	**15351.8**	**72.1**	**14.1**	**1.8**	**2.0**	**10.0**
63 # 3	3/6/2005	11782.7	86.9	6.5	2.1	1.4	3.2
63 # 2	3/6/2005	13524.6	83.2	8.9	2.9	1.8	3.3
63 # 1	3/6/2005	13580.1	75.7	12.3	4.7	2.7	4.5
	Average	**12962.5**	**81.9**	**9.2**	**3.2**	**1.9**	**3.7**
62 # 3	3/6/2005	14265.9	73.5	8.9	6.5	5.9	5.2
62 # 2	3/6/2005	13335.4	79.5	10.8	4.0	2.7	2.9
62 # 1	3/6/2005	10526.4	89.4	5.7	2.3	1.5	1.2
	Average	**12709.2**	**80.8**	**8.4**	**4.3**	**3.4**	**3.1**
58 # 3	3/7/2005	11613.8	81.5	10.4	4.0	1.4	2.7
58 # 2	3/7/2005	13596.1	78.6	13.6	4.1	1.2	2.6
58 # 1	3/7/2005	12277.5	85.1	9.5	2.4	0.7	2.3
	Average	**12495.8**	**81.7**	**11.2**	**3.5**	**1.1**	**2.5**
56 # 3	3/7/2005	22408.3	55.1	18.8	7.2	7.9	11.0
56 # 2	3/7/2005	15343.0	60.0	19.8	6.1	4.9	9.1
56 # 1	3/7/2005	15901.3	74.0	13.6	4.0	3.3	5.2
	Average	**17884.2**	**63.0**	**17.4**	**5.8**	**5.4**	**8.4**
55 # 3	3/7/2005	16317.0	71.9	16.6	7.5	2.3	1.8

Appendix C. Results of Merced River Substrate Samples (percent retention by sieve size)

55 # 2	3/7/2005	15327.0	67.6	17.0	7.8	4.8	2.7
55 # 1	3/7/2005	11583.0	75.6	12.9	5.6	3.3	2.7
	Average	**14409.0**	**71.7**	**15.5**	**7.0**	**3.5**	**2.4**
54 # 3	3/10/2005	16719.3	81.9	8.1	3.9	3.9	2.2
54 # 2	3/10/2005	16369.2	86.9	7.3	2.5	2.0	1.3
54 # 1	3/10/2005	17257.8	72.6	12.6	6.1	5.3	3.4
	Average	**16782.1**	**80.4**	**9.3**	**4.2**	**3.8**	**2.3**
53 # 3	3/10/2005	12465.0	76.1	10.1	4.8	4.8	4.1
53 # 2	3/10/2005	17980.3	64.6	10.6	10.5	7.0	7.3
53 # 1	3/10/2005	15512.8	73.4	11.7	5.7	5.8	3.3
	Average	**15319.3**	**71.4**	**10.8**	**7.0**	**5.9**	**4.9**
52 # 3	3/10/2005	18108.4	65.2	15.0	8.2	6.7	4.8
52 # 2	3/10/2005	19091.6	65.9	13.8	7.7	7.5	5.2
52 # 1	3/10/2005	19883.7	75.5	10.3	4.4	4.9	5.0
	Average	**19027.9**	**68.9**	**13.0**	**6.7**	**6.4**	**5.0**
51 # 3	3/10/2005	15886.4	56.2	14.6	8.2	10.0	11.0
51 # 2	3/10/2005	16483.2	66.0	14.6	6.0	5.6	7.8
51 # 1	3/10/2005	18971.5	68.0	10.0	6.6	8.7	6.7
	Average	**17113.7**	**63.4**	**13.1**	**6.9**	**8.1**	**8.5**
48 # 3	3/10/2005	18289.6	69.6	15.4	6.1	5.1	3.9
48 # 2	3/10/2005	14433.6	76.5	10.2	4.9	4.0	4.3
48 # 1	3/10/2005	11269.3	72.4	13.8	5.8	5.2	2.8
	Average	**14664.1**	**72.8**	**13.1**	**5.6**	**4.7**	**3.7**
47 # 3	3/14/2005	17505.3	65.9	11.6	6.7	7.1	8.7
47 # 2	3/14/2005	20516.8	74.3	9.9	5.9	5.6	4.3
47 # 1	3/14/2005	13826.0	51.8	20.9	9.4	8.2	9.7
	Average	**17282.7**	**64.0**	**14.2**	**7.3**	**7.0**	**7.6**
46 # 3	3/14/2005	13263.3	82.7	4.8	2.5	4.0	6.1
46 # 2	3/14/2005	21124.0	77.4	7.1	4.0	4.7	6.9
46 # 1	3/14/2005	22151.3	64.2	12.1	6.6	8.7	8.3
	Average	**18846.2**	**74.8**	**8.0**	**4.4**	**5.8**	**7.1**
45 # 3	3/14/2005	22966.5	64.4	15.6	7.9	5.9	6.2
45 # 2	3/14/2005	22804.5	74.9	8.3	5.5	5.6	5.7
45 # 1	3/14/2005	14916.4	64.2	12.9	8.9	6.6	7.4
	Average	**20229.1**	**67.8**	**12.3**	**7.4**	**6.1**	**6.4**
44 # 3	3/14/2005	23397.7	84.9	4.4	2.3	3.0	5.4
44 # 2	3/14/2005	11697.8	71.4	11.6	5.1	7.9	4.0
44 # 1	3/14/2005	19956.8	76.7	6.9	3.4	4.3	8.7
	Average	**18350.8**	**77.7**	**7.6**	**3.6**	**5.1**	**6.0**
40 # 3	3/14/2005	15157.6	68.2	15.0	6.1	4.8	5.8
40 # 2	3/14/2005	16266.6	69.1	11.4	6.4	5.6	7.5
40 # 1	3/14/2005	13659.7	61.2	12.8	8.4	9.0	8.7
	Average	**15028.0**	**66.2**	**13.1**	**7.0**	**6.5**	**7.3**
39 # 3	3/15/05	8330.9	58.1	18.2	9.1	7.0	7.6
39 # 2	3/15/05	13993.7	63.8	17.5	7.3	5.5	5.9
39 # 1	3/15/05	11047.0	54.3	22.9	10.2	7.1	5.5
	Average	**11123.9**	**58.7**	**19.5**	**8.9**	**6.5**	**6.3**

Appendix D. Substrate composition and aquatic vegetation at 64 transects between Crocker-Huffman and Merced Falls dams.

Date	Transect Number	Transect Interval (Left to Right Facing Downstream)	Substrate Type	Estimated % of Substrate	Aquatic Vegetation Type	River Depth (ft)
9/11/2003	1A	0	Silt	100	American Elodea	8”
		10	Silt	100	American Elodea	1’4”
					Coontail	
		20	Silt	100	American Elodea	3’6”
					Filamentous Algae	
		30	Silt	100	American Elodea	5’1”
					Filamentous Algae	
		40	Silt	70	American Elodea	8
			S. Cobble	30	Filamentous Algae	
		50	Silt	100	American Elodea	9
		60	Silt	100	American Elodea	10
		70	Silt	100	American Elodea	10’5”
		80	Silt	100	American Elodea	11’4”
					Filamentous Algae	
		90	Silt	100	American Elodea	8’7”
					Filamentous Algae	
		100	Silt	100	American Elodea	5’4”
					Filamentous Algae	
		110	Silt	100	American Elodea	3’10”
					Filamentous Algae	
		120	Silt	100	American Elodea	3
					Filamentous Algae	
					Eurasian Watermilfoil	
		130	Silt	100	American Elodea	4’10”
					Coontail	
					Eurasian Watermilfoil	
					Filamentous Algae	
		140	Silt	100	American Elodea	5’7”
					Eurasian Watermilfoil	
					Filamentous Algae	
		150	Silt	100	American Elodea	5’1”
		160	Silt	100	American Elodea	3’6”
9/11/2003	1B	0	Silt	100	American Elodea	10”
		10	Silt	100	American Elodea	2’10”
		20	Silt	100	American Elodea	3’4”
					Eurasian Watermilfoil	
		30	Silt	100	American Elodea	3’5”
					Filamentous Algae	

Appendix D. Substrate composition and aquatic vegetation at 64 transects between Crocker-Huffman and Merced Falls dams.

Date	Transect Number	Transect Interval (Left to Right Facing Downstream)	Substrate Type	Estimated % of Substrate	Aquatic Vegetation Type	River Depth (ft)
		40	Silt	100	American Elodea	3’8”
					Eurasian Watermilfoil	
					Filamentous Algae	
		50	Silt	100	American Elodea	3’10”
					Filamentous Algae	
		60	Silt	100	American Elodea	4
					Eurasian Watermilfoil	
					Filamentous Algae	
		70	Silt	100	American Elodea	4’7”
					Eurasian Watermilfoil	
					Filamentous Algae	
		80	Silt	100	American Elodea	5
					Filamentous Algae	
		90	Silt	100	American Elodea	4’11”
					Eurasian Watermilfoil	
					Filamentous Algae	
		100	Silt	100	American Elodea	4’4”
					Eurasian Watermilfoil	
					Filamentous Algae	
		110	Silt	100	American Elodea	5’5”
					Eurasian Watermilfoil	
					Filamentous Algae	
		120	Silt	100	American Elodea	5’6”
					Eurasian Watermilfoil	
					Filamentous Algae	
		130	Silt	100	American Elodea	4’7”
					Filamentous Algae	
		140	Silt	100	American Elodea	5’6”
					Filamentous Algae	
		150	Silt	100	American Elodea	5’6”
					Filamentous Algae	
		160	Silt	100	American Elodea	5’11”
					Filamentous Algae	
		170	Silt	100	American Elodea	6
					Filamentous Algae	
		180	Silt	100	American Elodea	5’11”

Appendix D. Substrate composition and aquatic vegetation at 64 transects between Crocker-Huffman and Merced Falls dams.

Date	Transect Number	Transect Interval (Left to Right Facing Downstream)	Substrate Type	Estimated % of Substrate	Aquatic Vegetation Type	River Depth (ft)
					Filamentous Algae	
		190	Silt	100	American Elodea	5'10"
					Filamentous Algae	
		200	Silt	100	American Elodea	5'11"
					Filamentous Algae	
		210	Silt	100	American Elodea	7'7"
					Filamentous Algae	
		220	Silt	100	American Elodea	6'10"
					Filamentous Algae	
		230	Silt	100	American Elodea	7'7"
					Filamentous Algae	
		240	Silt	100	American Elodea	6'6"
					Filamentous Algae	
		250	Silt	100	American Elodea	6
					Filamentous Algae	
		260	Silt	100	American Elodea	3'2"
					Filamentous Algae	
		270	Silt	100	American Elodea	2'6"
					Filamentous Algae	
		280	Silt	100	American Elodea	2'4"
					Filamentous Algae	
		290	Silt	100	American Elodea	2'7"
					Filamentous Algae	
		300	Silt	100	American Elodea	2'8"
					Filamentous Algae	
		310	Silt	100	Water Primrose	2'4"
					Duckweed	
					Cattail	
		314	Silt	100	Water Primrose	2'1"
					Duckweed	
					Cattail	
9/11/2003	2	0	Gravel	25		8"
			S. Cobble	50		
			L. Cobble	25		
		10	Gravel	25	American Elodea	4'5"
			S. Cobble	50	Coontail	
			L. Cobble	25		
		20	Gravel	25	American Elodea	8'8"
			S. Cobble	50		
			L. Cobble	25		
		30	Gravel	25	American Elodea	10'5"

Appendix D. Substrate composition and aquatic vegetation at 64 transects between Crocker-Huffman and Merced Falls dams.

Date	Transect Number	Transect Interval (Left to Right Facing Downstream)	Substrate Type	Estimated % of Substrate	Aquatic Vegetation Type	River Depth (ft)
			S. Cobble	50		
			L. Cobble	25		
		40	Silt	100	American Elodea	10
					Filamentous Algae	
		50	Silt	100	American Elodea	8’10”
					Eurasian Watermilfoil	
					Filamentous Algae	
		60	Silt	50	American Elodea	7’2”
			S. Cobble	50	Eurasian Watermilfoil	
		70	Silt	50	American Elodea	6
			S. Cobble	50	Filamentous Algae	
		80	Silt	50	American Elodea	6’2”
			S. Cobble	50	Coontail	
					Eurasian Watermilfoil	
		90	Silt	50	American Elodea	5’1”
			S. Cobble	50	Eurasian Watermilfoil	
		100	Silt	100	American Elodea	4’5”
					Eurasian Watermilfoil	
		110	Silt	100	American Elodea	3.7
					Eurasian Watermilfoil	
		120	Silt	50	American Elodea	3’11”
			S. Cobble	50	Eurasian Watermilfoil	
					Filamentous Algae	
		130	Silt	50	American Elodea	3’7”
			S. Cobble	50	Coontail	
					Eurasian Watermilfoil	
		140	Silt	100	American Elodea	3’10”
					Coontail	
					Eurasian Watermilfoil	
		150	Silt	100	American Elodea	3’2”
					Coontail	
					Eurasian Watermilfoil	
		160	Silt	100	Coontail	2’7”
					Filamentous Algae	

Appendix D. Substrate composition and aquatic vegetation at 64 transects between Crocker-Huffman and Merced Falls dams.

Date	Transect Number	Transect Interval (Left to Right Facing Downstream)	Substrate Type	Estimated % of Substrate	Aquatic Vegetation Type	River Depth (ft)
		170	Silt	100	American Elodea	11”
					Eurasian Watermilfoil	
					Water Primrose	
		180	Silt	100	American Elodea	2’2”
					Eurasian Watermilfoil	
					Water Primrose	
		190	Silt	100	American Elodea	2’4”
					Eurasian Watermilfoil	
		200	Silt	100	Eurasian Watermilfoil	2’11”
		210	Silt	100	Eurasian Watermilfoil	3
					Filamentous Algae	
		220	Silt	100	American Elodea	2’10”
					Eurasian Watermilfoil	
					Filamentous Algae	
		230	Silt	100	American Elodea	3’2”
					Coontail	
					Eurasian Watermilfoil	
					Filamentous Algae	
		240	Silt	100	American Elodea	3’8”
					Coontail	
					Eurasian Watermilfoil	
					Filamentous Algae	
		250	Silt	100	Coontail	4’6”
					Eurasian Watermilfoil	
					Filamentous Algae	
		260	Silt	50	American Elodea	4’10”
			S. Cobble	50	Coontail	
					Eurasian Watermilfoil	
					Filamentous Algae	
		270	Silt	50	Coontail	5
			S. Cobble	50	Eurasian Watermilfoil	
					Filamentous Algae	
		280	Silt	50	Coontail	5’2”

Appendix D. Substrate composition and aquatic vegetation at 64 transects between Crocker-Huffman and Merced Falls dams.						
Date	**Transect Number**	**Transect Interval (Left to Right Facing Downstream)**	**Substrate Type**	**Estimated % of Substrate**	**Aquatic Vegetation Type**	**River Depth (ft)**
			S. Cobble	50	Eurasian Watermilfoil	
					Filamentous Algae	
		290	Silt	100	Coontail	5'1"
					Eurasian Watermilfoil	
					Filamentous Algae	
		300	Silt	100	American Elodea	5'5"
					Coontail	
					Eurasian Watermilfoil	
					Filamentous Algae	
		310	Silt	100	American Elodea	5'5"
					Coontail	
					Filamentous Algae	
		320	Silt	100	American Elodea	4'10"
					Coontail	
					Filamentous Algae	
		330	Silt	100	American Elodea	5'8"
					Coontail	
					Filamentous Algae	
		340	Silt	100	American Elodea	5'8"
					Coontail	
					Eurasian Watermilfoil	
					Filamentous Algae	
		350	Silt	100	American Elodea	4'7"
					Filamentous Algae	
		360	Silt	100	American Elodea	5
					Filamentous Algae	
		370	Silt	100	American Elodea	5'5"
					Filamentous Algae	
		380	Silt	100	American Elodea	4'7"
					Filamentous Algae	
		390	Silt	100	American Elodea	4'6"
					Filamentous Algae	
		400	Silt	100	American Elodea	5'1"
					Eurasian Watermilfoil	
					Filamentous Algae	
		410	Silt	100	American Elodea	4'11"
					Eurasian Watermilfoil	

Appendix D. Substrate composition and aquatic vegetation at 64 transects between Crocker-Huffman and Merced Falls dams.

Date	Transect Number	Transect Interval (Left to Right Facing Downstream)	Substrate Type	Estimated % of Substrate	Aquatic Vegetation Type	River Depth (ft)
					Filamentous Algae	
		420	Silt	100	American Elodea	5
					Eurasian Watermilfoil	
					Filamentous Algae	
		430	Silt	100	American Elodea	5'4"
					Filamentous Algae	
		440	Silt	100	American Elodea	5'6"
					Filamentous Algae	
		450	Silt	100	American Elodea	6'2"
					Filamentous Algae	
		460	Silt	100	American Elodea	5'10"
					Filamentous Algae	
		470	Silt	100	American Elodea	5'2"
					Filamentous Algae	
		480	Silt	100	American Elodea	4'5"
					Coontail	
					Filamentous Algae	
		490	Silt	100	American Elodea	4'5"
		500	Silt	100	American Elodea	2'6"
		509	Silt	100	American Elodea	2
					Filamentous Algae	
					Duckweed	
8/20/2003	3	0	Silt	100	Filamentous Algae	1
					Smartweed	
					Knotweed	
		10	Silt	100	American Elodea	1'6"
					Filamentous Algae	
					Water Primrose	
		20	Silt	100	American Elodea	1'6"
					Coontail	
		30	Silt	100	American Elodea	3
					Coontail	
		40	Silt	100	American Elodea	3'11"
					Coontail	
		50	Silt	100	American Elodea	4'10"
		60	Silt	100	American Elodea	4'8"
		70	Silt	100	American Elodea	5'7"
					Eurasian Watermilfoil	
		80	Silt	100	American Elodea	4'4"
					Eurasian	

Appendix D. Substrate composition and aquatic vegetation at 64 transects between Crocker-Huffman and Merced Falls dams.						
Date	**Transect Number**	**Transect Interval (Left to Right Facing Downstream)**	**Substrate Type**	**Estimated % of Substrate**	**Aquatic Vegetation Type**	**River Depth (ft)**
					Watermilfoil	
		90	Silt	100	American Elodea	4
					Eurasian Watermilfoil	
		100	Silt	100	American Elodea	4’2”
					Eurasian Watermilfoil	
		110	Silt	100	American Elodea	4’1”
					Eurasian Watermilfoil	
		120	Silt	100	American Elodea	4’7”
		130	Silt	100	American Elodea	5’5”
		140	Silt	100	American Elodea	3’5”
					Eurasian Watermilfoil	
					Coontail	
		150	Silt	100	Eurasian Watermilfoil	3’5”
		160	Silt	100	American Elodea	3’10”
		170	Silt	100	American Elodea	5’2”
					Water Primrose	
		180	Silt	100	Eurasian Watermilfoil	5’1”
		190	Silt	100	American Elodea	5
					Water Primrose	
		200	Silt	100	American Elodea	4’8”
					Water Primrose	
		210	Silt	100	American Elodea	4’8”
					Water Primrose	
					Coontail	
		220	Silt	100	American Elodea	4’8”
					Water Primrose	
					Coontail	
		230	Silt	100	American Elodea	4’11”
					Water Primrose	
					Coontail	
		240	Silt	100	American Elodea	5’6”
					Eurasian Watermilfoil	
		250	Silt	100	American Elodea	5’6”
		260	Silt	100	American Elodea	4’5”
		270	Silt	100	American Elodea	4’10”
					Eurasian	

Appendix D. Substrate composition and aquatic vegetation at 64 transects between Crocker-Huffman and Merced Falls dams.

Date	Transect Number	Transect Interval (Left to Right Facing Downstream)	Substrate Type	Estimated % of Substrate	Aquatic Vegetation Type	River Depth (ft)
					Watermilfoil	
		280	Silt	80	American Elodea	6'4"
			L. Boulder	20		
		290	Silt	80	American Elodea	6
			L. Boulder	20	Coontail	
		300	Silt	80	American Elodea	5'10"
			L. Boulder	20	Coontail	
		310	Silt	80	American Elodea	5'1"
			L. Boulder	20	Coontail	
		320	Silt	80	Coontail	4'11"
			L. Boulder	20	Eurasian Watermilfoil	
					Water Primrose	
		330	Silt	80	American Elodea	4'5"
			L. Boulder	20		
		340	Silt	80	American Elodea	4'4"
			L. Boulder	20		
		350	Silt	80	Coontail	4
			L. Boulder	20	Water Primrose	
		360	Silt	100	Water Primrose	4
					Coontail	
		370	Silt	100	Water Primrose	4'1"
					Coontail	
		380	Silt	100	Water Primrose	4'4"
					Coontail	
		390	Silt	100	Coontail	4'2"
					American Elodea	
					Water Primrose	
		400	Silt	100	American Elodea	4'6"
					Water Primrose	
		410	Silt	100	American Elodea	4
					Water Primrose	
		420	Silt	100	Eurasian Watermilfoil	4'8"
					Coontail	
		430	Silt	100	Coontail	4'10"
					Eurasian Watermilfoil	
					American Elodea	
		440	Silt	100	Coontail	4'7"
					American Elodea	
		450	Silt	100	American Elodea	4'6"

Appendix D. Substrate composition and aquatic vegetation at 64 transects between Crocker-Huffman and Merced Falls dams.

Date	Transect Number	Transect Interval (Left to Right Facing Downstream)	Substrate Type	Estimated % of Substrate	Aquatic Vegetation Type	River Depth (ft)
		460	Silt	100	American Elodea	5’2”
					Coontail	
		470	Silt	100	American Elodea	5’1”
					Coontail	
		480	Silt	100	American Elodea	5’2”
		490	Silt	100	American Elodea	5’5”
		500	Silt	100	American Elodea	4’2”
		510	Silt	100	American Elodea	2’4”
		520	Silt	100	American Elodea	1’4”
8/20/2003	4	0	Silt	100		1”
		10	Silt	100	American Elodea	2
					Coontail	
		20	Silt	100	American Elodea	4’10”
					Coontail	
		30	Silt	100	American Elodea	6’8”
					Coontail	
		40	Silt	100	American Elodea	7’10”
					Coontail	
		50	Silt	100	Coontail	7’11”
					Water Primrose	
		60	Silt	100	American Elodea	7’2”
					Coontail	
					Water Primrose	
		70	Silt	100	American Elodea	7’7”
					Coontail	
					Water Primrose	
		80	Silt	100	Eurasian Watermilfoil	8’5”
		90	Silt	100		7’2”
		100	Silt	100	Eurasian Watermilfoil	7’4”
					Coontail	
					Water Primrose	
		110	Silt	100	Coontail	9’5”
					Eurasian Watermilfoil	
		120	Silt	100	Water Primrose	8’4”
					Coontail	
		130	Silt	100	Water Primrose	6’2”
					Coontail	
		140	Silt	100	Water Primrose	6’1”

Appendix D. Substrate composition and aquatic vegetation at 64 transects between Crocker-Huffman and Merced Falls dams.						
Date	**Transect Number**	**Transect Interval (Left to Right Facing Downstream)**	**Substrate Type**	**Estimated % of Substrate**	**Aquatic Vegetation Type**	**River Depth (ft)**
					Eurasian Watermilfoil	
		150	Silt	100	Water Primrose	8’4”
					Eurasian Watermilfoil	
		160	Silt	100	Water Primrose	8’7”
					Coontail	
					Eurasian Watermilfoil	
		170	Silt	100	Eurasian Watermilfoil	6’6”
					Coontail	
					Water Primrose	
		180	Silt	100	Eurasian Watermilfoil	7’2”
					Water Primrose	
		190	Silt	100	Eurasian Watermilfoil	7’7”
					Water Primrose	
		200	Silt	100	American Elodea	8’10”
		210	Silt	100	Water Primrose	9
					Coontail	
		220	Silt	100	Water Primrose	8’7”
					Coontail	
		230	Silt	100	Coontail	9’2”
		240	Silt	100	Coontail	8’6”
		250	Silt	100	Coontail	7’11”
					Water Primrose	
		260	Silt	100	Coontail	7’6”
		270	Silt	100	Coontail	7’11”
		280	Silt	100	Coontail	7’8”
					Eurasian Watermilfoil	
					Water Primrose	
		290	Silt	100	Coontail	7’4”
					Eurasian Watermilfoil	
					Water Primrose	
		300	Silt	100	Coontail	7’4”
					Eurasian Watermilfoil	
					Water Primrose	
		310	Silt	100	Coontail	6’8”

Appendix D. Substrate composition and aquatic vegetation at 64 transects between Crocker-Huffman and Merced Falls dams.						
Date	**Transect Number**	**Transect Interval (Left to Right Facing Downstream)**	**Substrate Type**	**Estimated % of Substrate**	**Aquatic Vegetation Type**	**River Depth (ft)**
					Water Primrose	
		320	Silt	100	American Elodea	6'6"
					Water Primrose	
		330	Silt	100	American Elodea	5'8"
					Water Primrose	
		340	Silt	100	American Elodea	4'1"
					Water Primrose	
		350	Silt	100	American Elodea	2'11"
		360	Silt	100	American Elodea	2'7"
		370	Silt	100	American Elodea	2.3
		380	Silt	100	American Elodea	1'10"
		390	Silt	100	American Elodea	1'6"
		400	Silt	100	American Elodea	1'10"
		410	Silt	100	American Elodea	1'1"
					Filamentous Algae	
		415	Silt	100	Filamentous Algae	6"
					Duckweed	
8/21/2003	5	0	S. Boulder	50		0
			L. Cobble	25		
			S. Cobble	25		
		10	S. Boulder	50	American Elodea	5
			L. Cobble	25		
			S. Cobble	25		
		20	S. Cobble	50	American Elodea	8'2"
			L. Cobble	25	Eurasian Watermilfoil	
			S. Cobble	25		
		30	S. Boulder	50	American Elodea	10'1"
			L. Cobble	25	Eurasian Watermilfoil	
			S. Cobble	25		
		40	S. Boulder	50	American Elodea	12
			L. Cobble	25		
			S. Cobble	25		
		50	S. Boulder	50	American Elodea	9'4"
			L. Cobble	25		
			S. Cobble	25		
		60	S. Boulder	50	American Elodea	8
			L. Cobble	25		
			S. Cobble	25		
		70	S. Boulder	50	American Elodea	10'2"
			L. Cobble	25	Coontail	
			S. Cobble	25		

Appendix D. Substrate composition and aquatic vegetation at 64 transects between Crocker-Huffman and Merced Falls dams.

Date	Transect Number	Transect Interval (Left to Right Facing Downstream)	Substrate Type	Estimated % of Substrate	Aquatic Vegetation Type	River Depth (ft)
		80	S. Boulder	50	Coontail	10'1"
			L. Cobble	25	American Elodea	
			S. Cobble	25		
		90	S. Boulder	50	Coontail	10'5"
			L. Cobble	25		
			S. Cobble	25		
		100	S. Boulder	50	Coontail	9'8"
			L. Cobble	25		
			S. Cobble	25		
		110	S. Boulder	50	Coontail	9'7"
			L. Cobble	25		
			S. Cobble	25		
		120	S. Boulder	50	Coontail	11'2"
			L. Cobble	25		
			S. Cobble	25		
		130	S. Boulder	50	Coontail	10'10"
			L. Cobble	25		
			S. Cobble	25		
		140	S. Boulder	50	Coontail	10'1"
			L. Cobble	25		
			S. Cobble	25		
		150	S. Boulder	50	Coontail	9'1"
			L. Cobble	25		
			S. Cobble	25		
		160	S. Boulder	50	Coontail	8'8"
			L. Cobble	25	American Elodea	
			S. Cobble	25		
		170	S. Boulder	50	Coontail	8'10"
			L. Cobble	25	American Elodea	
			S. Cobble	25		
		180	S. Boulder	50	Coontail	8'7"
			L. Cobble	25	American Elodea	
			S. Cobble	25		
		190	S. Boulder	50	Coontail	7'7"
			L. Cobble	25	American Elodea	
			S. Cobble	25		
		200	S. Boulder	50	Coontail	8'4"
			L. Cobble	25	American Elodea	
			S. Cobble	25		
		210	S. Boulder	50	Coontail	10'11"
			L. Cobble	25	American Elodea	

Appendix D. Substrate composition and aquatic vegetation at 64 transects between Crocker-Huffman and Merced Falls dams.

Date	Transect Number	Transect Interval (Left to Right Facing Downstream)	Substrate Type	Estimated % of Substrate	Aquatic Vegetation Type	River Depth (ft)
			S. Cobble	25		
		220	S. Boulder	50	Coontail	11’5”
			L. Cobble	25	American Elodea	
			S. Cobble	25		
		230	S. Boulder	50	Coontail	11’10”
			L. Cobble	25	American Elodea	
			S. Cobble	25		
		240	S. Boulder	50	Coontail	11’4”
			L. Cobble	25	American Elodea	
			S. Cobble	25	Water Primrose	
		250	S. Boulder	50	Coontail	11’4”
			L. Cobble	25	American Elodea	
			S. Cobble	25	Water Primrose	
		260	S. Boulder	50	Coontail	10’6”
			L. Cobble	25	American Elodea	
			S. Cobble	25		
		270	S. Boulder	50	Coontail	9
			L. Cobble	25	American Elodea	
			S. Cobble	25		
		280	S. Boulder	50	American Elodea	5’6”
			L. Cobble	25		
			S. Cobble	25		
		290	Silt	50	American Elodea	2’4”
			S. Boulder	50		
		296	Silt	50	American Elodea	6”
			S. Boulder	50	Coontail	
9/4/2003	6	0	Silt	100	American Elodea	5”
		10	Silt	100	American Elodea	5’2”
					Water Primrose	
					Coontail	
		20	Silt	100	American Elodea	9’4”
					Coontail	
					Water Primrose	
		30	Silt	100	American Elodea	10’8”
					Coontail	
					Water Primrose	
		40	Silt	100	American Elodea	12’1”
					Eurasian Watermilfoil	
		50	Silt	100	American Elodea	12’10”
		60	Silt	100	Eurasian Watermilfoil	13

Appendix D. Substrate composition and aquatic vegetation at 64 transects between Crocker-Huffman and Merced Falls dams.						
Date	**Transect Number**	**Transect Interval (Left to Right Facing Downstream)**	**Substrate Type**	**Estimated % of Substrate**	**Aquatic Vegetation Type**	**River Depth (ft)**
		70	Silt	100	Eurasian Watermilfoil	13'6"
		80	Silt	100	American Elodea	13'6"
					Eurasian Watermilfoil	
		90	Silt	100	Eurasian Watermilfoil	13'6"
		100	Silt	100	Eurasian Watermilfoil	13
		110	Silt	100	Eurasian Watermilfoil	12'11"
		120	Silt	100	Eurasian Watermilfoil	12'8"
		130	Silt	100	Eurasian Watermilfoil	12'7"
		140	Silt	100	Eurasian Watermilfoil	12'8"
		150	Silt	100	Eurasian Watermilfoil	12'11"
		160	Silt	100	Eurasian Watermilfoil	12'10"
		170	Silt	100	Eurasian Watermilfoil	12'10"
		180	Silt	100	American Elodea	13
					Eurasian Watermilfoil	
		190	Silt	100	Eurasian Watermilfoil	13'2"
		200	Silt	100	Eurasian Watermilfoil	13'5"
		210	Silt	100	Eurasian Watermilfoil	13
		220	Silt	100	Eurasian Watermilfoil	12'1"
					Water Primrose	
		230	Silt	100	Eurasian Watermilfoil	10'1"
					Water Primrose	
		240	Silt	100	Eurasian Watermilfoil	9'1"
		250	Silt	100	Eurasian Watermilfoil	7'10"
		260	Silt	100		5'6"
		270	Silt	100	American Elodea	2'8"
		276	Silt	100	American Elodea	8"
8/19/2003	7	0	Silt	100		6"
		10	Silt	100	American Elodea	4

Appendix D. Substrate composition and aquatic vegetation at 64 transects between Crocker-Huffman and Merced Falls dams.

Date	Transect Number	Transect Interval (Left to Right Facing Downstream)	Substrate Type	Estimated % of Substrate	Aquatic Vegetation Type	River Depth (ft)
		20	Silt	100	American Elodea	7’10”
		30	Silt	100	American Elodea	10’4”
					Water Primrose	
		40	Silt	100	American Elodea	12’11”
		50	Silt	100		14
		60	Silt	100	American Elodea	14’5”
		70	Silt	100	American Elodea	14'7”
		80	Silt	100	American Elodea	14'8"
		90	Silt	100	American Elodea	15'4"
		100	Silt	100	American Elodea	15'6"
		110	Silt	100	American Elodea	16
		120	Silt	100		16'6"
		130	Silt	100	American Elodea	17
					Coontail	
		140	Silt	100	American Elodea	17'5"
					Coontail	
		150	Silt	100	American Elodea	18'4"
					Coontail	
		160	Silt	100	American Elodea	19
		170	Silt	100		19'3"
		180	Silt	100	American Elodea	18'7"
		190	Silt	100	Eurasian Watermilfoil	16
		200	Silt	100	American Elodea	13'8"
		210	Silt	100	American Elodea	11'2"
					Coontail	
		220	Silt	100	American Elodea	8'10"
					Coontail	
		230	Silt	100	American Elodea	7
		240	Silt	100	American Elodea	2’5”
					Eurasian Watermilfoil	
		243	Silt	100	American Elodea	1’11”
8/21/2003	8	0	Gravel	100		0
		10	S. Boulder	70		19
			Silt	30		
		20	S. Boulder	70	American Elodea	19'4"
			Silt	30		
		30	S. Boulder	70		21'4"
			Silt	30		
		40	Silt	80		22
			S. Cobble	20		

Appendix D. Substrate composition and aquatic vegetation at 64 transects between Crocker-Huffman and Merced Falls dams.

Date	Transect Number	Transect Interval (Left to Right Facing Downstream)	Substrate Type	Estimated % of Substrate	Aquatic Vegetation Type	River Depth (ft)
		50	Silt	70		21'5"
			S. Cobble	30		
		60	S. Boulder	10		21'3"
			S. Cobble	10		
			Silt	80		
		70	Silt	90		21'6"
			S. Cobble	10		
		80	Silt	100		19'8"
		90	Silt	100	Eurasian Watermilfoil	20'3"
		100	Silt	80		20'3"
			S. Cobble	20		
		110	Silt	100	American Elodea	18'8"
		120	Silt	100	American Elodea	18'5"
		130	Silt	100	American Elodea	16'3"
		140	Silt	100	Eurasian Watermilfoil	14'8"
					Coontail	
		150	Silt	100	American Elodea	13'1"
		160	Silt	100	American Elodea	9'3"
		170	Silt	100	American Elodea	4'5"
		180	Silt	100	American Elodea	1'7"
		184	Silt	100	American Elodea	3"
8/19/2003	9	0	Bedrock	100		1
		10	Silt	100		16'4"
		20	Silt	100	American Elodea	17'9"
		30	Silt	100		21'5"
		40	Silt	95		21'6"
			S. Cobble	5		
		50	Silt	100		22
		60	Silt	95		21
			S. Cobble	5		
		70	Silt	100		20'5"
		80	Silt	100		20
		90	Silt	90		19'10"
			S. Cobble	10		
		100	Silt	100		19'5"
		110	Silt	100		19'5"
		120	Silt	100		18'7"
		130	Silt	100		18'4"
		140	Silt	100	American Elodea	15

Appendix D. Substrate composition and aquatic vegetation at 64 transects between Crocker-Huffman and Merced Falls dams.

Date	Transect Number	Transect Interval (Left to Right Facing Downstream)	Substrate Type	Estimated % of Substrate	Aquatic Vegetation Type	River Depth (ft)
		150	Silt	100	American Elodea	14'4"
		160	Silt	100	American Elodea	11'2"
		170	Silt	100	American Elodea	8'5"
					Eurasian Watermilfoil	
					Water Primrose	
		180	Silt	100	Water Primrose	7'2"
					Eurasian Watermilfoil	
					American Elodea	
8/20/2003	10	0	Bedrock	80	American Elodea	10'7"
			S. Cobble	20		
		10	Silt	100	American Elodea	10'9"
		20	Silt	100	American Elodea	13'10"
		30	Silt	100	American Elodea	14'4"
		40	Silt	100		15'4"
		50	Silt	100		17'8"
		60	Silt	100		18'5"
		70	Silt	100		18'1"
		80	Silt	90	American Elodea	18'2"
			S. Cobble	10		
		90	Silt	80		18'5"
			S. Cobble	20		
		100	Silt	90		17'9"
			S. Cobble	10		
		110	Silt	100		17'7"
		120	L. Cobble	10		17'5"
		130	Silt	90		16'6"
			L. Cobble	10		
			Silt	90		
		140	Silt	100		16'3"
		150	Silt	100	American Elodea	15'8"
					Coontail	
		160	Silt	100	Coontail	13'4"
		170	Silt	100	Coontail	10'8"
		180	Silt	100	American Elodea	8'7"
					Coontail	
		190	Silt	100	American Elodea	6'2"
					Coontail	
		200	Silt	100	American Elodea	2’8”
		203	Silt	100	American Elodea	1’1”
					Water Primrose	

Appendix D. Substrate composition and aquatic vegetation at 64 transects between Crocker-Huffman and Merced Falls dams.						
Date	**Transect Number**	**Transect Interval (Left to Right Facing Downstream)**	**Substrate Type**	**Estimated % of Substrate**	**Aquatic Vegetation Type**	**River Depth (ft)**
8/20/2003	11	0	Silt	100		1
		10	Silt	100	American Elodea	2’10”
		20	Silt	100	American Elodea	6’2”
		30	Silt	100	American Elodea	8’5”
					Coontail	
		40	Silt	100	American Elodea	10'2"
					Coontail	
		50	Silt	100	American Elodea	12'4"
					Coontail	
		60	Silt	100	American Elodea	15'1"
		70	Silt	100	American Elodea	16'6"
		80	Silt	100	Coontail	16'4"
		90	Silt	70		17'5"
			L. Cobble	30		
		100	Silt	70		18'2"
			L. Cobble	30		
		110	Silt	50		19'8"
			S. Cobble	25		
			L. Cobble	25		
		120	Silt	40		19
			S. Boulder	10		
			S. Cobble	25		
			L. Cobble	25		
		130	Silt	100		18'8"
		140	Silt	100		19'1"
		150	Silt	100		18'3"
		160	Silt	100		16'5"
		170	Silt	100	American Elodea	15'3"
					Coontail	
		180	Silt	100	American Elodea	13'6"
					Coontail	
		190	Silt	100	American Elodea	10'2"
					Coontail	
					Water Primrose	
		200	Silt	100	American Elodea	2’6”
					Coontail	
					Water Primrose	
		202	Silt	100	American Elodea	0
					Coontail	
					Water Primrose	
8/20/2003	12	0	Silt	100	American Elodea	2"

Appendix D. Substrate composition and aquatic vegetation at 64 transects between Crocker-Huffman and Merced Falls dams.

Date	Transect Number	Transect Interval (Left to Right Facing Downstream)	Substrate Type	Estimated % of Substrate	Aquatic Vegetation Type	River Depth (ft)
		10	Silt	100	American Elodea	2'7"
					Coontail	
		20	Silt	100	American Elodea	9'6"
		30	Silt	100		16'2"
		40	Silt	100		18'6"
		50	Silt	70		21'2"
			S. Cobble	30		
		60	Silt	70		22
			S. Cobble	30		
		70	Silt	80		22'5"
			S. Cobble	20		
		80	Silt	70		22'5"
			S. Cobble	30		
		90	Silt	70		22
			S. Cobble	30		
		100	Silt	85		21'4"
			S. Cobble	15		
		110	Silt	100	American Elodea	18
		120	Silt	100	American Elodea	15'10"
					Coontail	
		130	L. Boulder	30	American Elodea	13'8"
			Silt	70	Coontail	
		140	Silt	100	Coontail	13'10"
		150	Silt	100	Coontail	10'9"
		160	Silt	100	Coontail	9'3"
		170	Silt	100	Coontail	8'7"
		180	Silt	100	American Elodea	4
		190	Silt	100	Coontail	2"
8/20/2003	13	0	Silt	80	American Elodea	3"
			Gravel	10		
			L. Cobble	10		
		10	Silt	100	American Elodea	3'6"
		20	L. Boulder	80		11'1"
			Silt	20		
		30	Silt	80		11'5"
			S. Cobble	20		
		40	Silt	70	American Elodea	13'5"
			L. Boulder	30		
		50	L. Boulder	20		16'5"
			L. Cobble	40		
			Silt	40		

Appendix D. Substrate composition and aquatic vegetation at 64 transects between Crocker-Huffman and Merced Falls dams.						
Date	**Transect Number**	**Transect Interval (Left to Right Facing Downstream)**	**Substrate Type**	**Estimated % of Substrate**	**Aquatic Vegetation Type**	**River Depth (ft)**
		60	L. Boulder	75		19
			Silt	25		
		70	L. Boulder	30		17'5"
			S. Boulder	30		
			M Boulder	30		
			Silt	10		
		80	Silt	70	American Elodea	17
			L. Cobble	30		
		90	Silt	70		14'4"
			L. Cobble	30		
		100	Silt	80		14'2"
			L. Cobble	20		
		110	Silt	80	American Elodea	12"
			L. Cobble	20		
		120	Silt	80	American Elodea	11
			L. Cobble	20	Coontail	
		130	Silt	80	American Elodea	9'8"
			L. Cobble	20	Coontail	
		140	Silt	80	American Elodea	9'4"
			L. Cobble	20	Coontail	
					Filamentous Algae	
		150	Silt	80	Coontail	9'4"
			L. Cobble	20	Filamentous Algae	
		160	Silt	80	American Elodea	9'3"
			L. Cobble	20	Coontail	
					Filamentous Algae	
		170	Silt	80	Coontail	8'2"
			L. Cobble	20		
		180	Silt	100	Coontail	5'9"
		190	Silt	100	Coontail	3'5"
		200	Silt	100	American Elodea	1'4"
		202	Silt	100	American Elodea	1
					Coontail	
8/21/2003	14	0	Silt	50	American Elodea	2'7"
			L. Boulder	50		
		10	Silt	50	American Elodea	6'4"
			L. Boulder	50		
		20	Silt	100		8'
		30	Silt	100		9'7"
		40	Silt	50		11'
			L. Boulder	50		

Appendix D. Substrate composition and aquatic vegetation at 64 transects between Crocker-Huffman and Merced Falls dams.

Date	Transect Number	Transect Interval (Left to Right Facing Downstream)	Substrate Type	Estimated % of Substrate	Aquatic Vegetation Type	River Depth (ft)
		50	Silt	20		13'4"
			L. Cobble	30		
			L. Boulder	50		
		60	Silt	70		13'10"
			L. Cobble	30		
		70	Silt	70		13'6"
			L. Cobble	30		
		80	Silt	50		13'
			L. Cobble	50		
		90	Silt	80		12'2"
			L. Cobble	20		
		100	L. Cobble	50		11'7"
			S. Cobble	50		
		110	S. Boulder	30		11'9"
			L. Cobble	40		
			Silt	30		
		120	Silt	60	Coontail	10'11”
			L. Cobble	30		
			S. Cobble	10		
		130	Silt	60	Coontail	9'10"
			L. Cobble	30	Eurasian Watermilfoil	
			S. Cobble	10		
		140	Silt	60	Coontail	8'10"
			L. Cobble	30	Filamentous Algae	
			S. Cobble	10		
		150	Silt	60	Coontail	8'6"
			L. Cobble	30	Filamentous Algae	
			S. Cobble	10		
		160	Silt	60	American Elodea	8'6"
			L. Cobble	30	Coontail	
			S. Cobble	10	Eurasian Watermilfoil	
					Filamentous Algae	
		170	Silt	60	American Elodea	7'6"
			L. Cobble	30	Coontail	
			S. Cobble	10	Eurasian Watermilfoil	
					Filamentous Algae	
		180	Silt	60	American Elodea	6'2"
			L. Cobble	30	Filamentous Algae	
			S. Cobble	10		
		190	Silt	100	American Elodea	5'3"

Appendix D. Substrate composition and aquatic vegetation at 64 transects between Crocker-Huffman and Merced Falls dams.

Date	Transect Number	Transect Interval (Left to Right Facing Downstream)	Substrate Type	Estimated % of Substrate	Aquatic Vegetation Type	River Depth (ft)
					Coontail	
		200	Silt	100	American Elodea	3'4"
					Coontail	
		210	Silt	100	American Elodea	2'2"
					Coontail	
		220	Silt	100	American Elodea	1'2"
		228	Silt	100	American Elodea	2"
8/21/2003	15	0	Silt	100	American Elodea	3’1”
		10	Silt	100	American Elodea	7’2”
		20	Silt	100	American Elodea	9
		30	Silt	100		9'4"
		40	Silt	100		10'11'
		50	Silt	50		13
			L. Cobble	50		
		60	Silt	50		12'3"
			L. Cobble	50		
		70	L. Cobble	70		11'5"
			Silt	30		
		80	Silt	50		11'4"
			L. Cobble	50		
		90	L. Cobble	80	American Elodea	10
			Silt	20		
		100	L. Cobble	80	American Elodea	10
			Silt	20		
		110	L. Cobble	80	American Elodea	9’10”
			Silt	20		
		120	Silt	20	American Elodea	9’2”
			L. Cobble	40		
			S. Cobble	40		
		130	Silt	20	American Elodea	9’2”
			L. Cobble	40		
			S. Cobble	40		
		140	L. Cobble	40	American Elodea	9’1”
			S. Cobble	40		
			Silt	20		
		150	L. Cobble	40		9’1”
			S. Cobble	20		
			Silt	40		
		160	L. Cobble	40	American Elodea	8’11”
			S. Cobble	20	Coontail	
			Silt	40	Eurasian	

Appendix D. Substrate composition and aquatic vegetation at 64 transects between Crocker-Huffman and Merced Falls dams.

Date	Transect Number	Transect Interval (Left to Right Facing Downstream)	Substrate Type	Estimated % of Substrate	Aquatic Vegetation Type	River Depth (ft)
					Watermilfoil	
					Filamentous Algae	
		170	L. Cobble	40	American Elodea	8'10"
			S. Cobble	20	Coontail	
			Silt	40	Eurasian Watermilfoil	
					Filamentous Algae	
		180	L. Cobble	40	American Elodea	8'6"
			S. Cobble	20	Coontail	
			Silt	40	Eurasian Watermilfoil	
					Filamentous Algae	
		190	L. Cobble	40	American Elodea	8'2"
			S. Cobble	20	Coontail	
			Silt	40	Eurasian Watermilfoil	
					Filamentous Algae	
		200	L. Cobble	40	American Elodea	7'1"
			S. Cobble	20	Coontail	
			Silt	40	Eurasian Watermilfoil	
					Filamentous Algae	
		210	Silt	100	American Elodea	6'6"
					Coontail	
					Eurasian Watermilfoil	
					Filamentous Algae	
		220	Silt	100	American Elodea	3'2"
					Eurasian Watermilfoil	
		230	Silt	100	American Elodea	8"
					Coontail	
		231	Silt	100	American Elodea	2"
					Coontail	
8/21/2003	16	0	Silt	80		1"
			S. Cobble	20		
		10	Silt	80	American Elodea	4'5"
			S. Cobble	20		
		20	Silt	80	American Elodea	7'5"
			S. Cobble	20		
		30	Silt	80	American Elodea	9'2"
			S. Cobble	20		
		40	L. Cobble	50	American Elodea	10'4"

Appendix D. Substrate composition and aquatic vegetation at 64 transects between Crocker-Huffman and Merced Falls dams.

Date	Transect Number	Transect Interval (Left to Right Facing Downstream)	Substrate Type	Estimated % of Substrate	Aquatic Vegetation Type	River Depth (ft)
			S. Cobble	20		
			Silt	30		
		50	L. Cobble	50		13'2"
			S. Cobble	20		
			Silt	30		
		60	L. Cobble	50		11'1"
			S. Cobble	20		
			Silt	30		
		70	S. Cobble	50		10’1”
			L. Cobble	20		
			Silt	30		
		80	L. Cobble	50		10'5"
			S. Cobble	20		
			Silt	30		
		90	L. Cobble	50		10'3"
			S. Cobble	20		
			Silt	30		
		100	L. Cobble	50	American Elodea	9'5"
			S. Cobble	20		
			Silt	30		
		110	L. Cobble	50	American Elodea	9’2”
			S. Cobble	20		
			Silt	30		
		120	S. Cobble	50	American Elodea	9’6”
			L. Cobble	30		
			Silt	20		
		130	Silt	70		9’6”
			S. Cobble	30		
		140	Silt	50		9’2”
			S. Cobble	20		
			L. Cobble	30		
		150	Silt	50	American Elodea	9'4"
			S. Cobble	20		
			L. Cobble	30		
		160	Silt	50	Eurasian Watermilfoil	9
			S. Cobble	20		
			L. Cobble	30		
		170	Silt	50	Eurasian Watermilfoil	8’5”
			S. Cobble	20	Filamentous Algae	
			L. Cobble	30		

Appendix D. Substrate composition and aquatic vegetation at 64 transects between Crocker-Huffman and Merced Falls dams.						
Date	**Transect Number**	**Transect Interval (Left to Right Facing Downstream)**	**Substrate Type**	**Estimated % of Substrate**	**Aquatic Vegetation Type**	**River Depth (ft)**
		180	Silt	50	Eurasian Watermilfoil	7’4”
			S. Cobble	20	Filamentous Algae	
			L. Cobble	30		
		190	Silt	50	Eurasian Watermilfoil	7’4”
			S. Cobble	20	Coontail	
			L. Cobble	30		
		200	Silt	50	Eurasian Watermilfoil	8’2”
			S. Cobble	20	Coontail	
			L. Cobble	30	Filamentous Algae	
		210	Silt	50	Eurasian Watermilfoil	7’1”
			S. Cobble	20	Coontail	
			L. Cobble	30	Filamentous Algae	
		220	Silt	50	American Elodea	6
			S. Cobble	20	Coontail	
			L. Cobble	30	Eurasian Watermilfoil	
					Filamentous Algae	
		230	Silt	50	American Elodea	5’6”
			S. Cobble	20	Coontail	
			L. Cobble	30	Eurasian Watermilfoil	
					Filamentous Algae	
		240	Silt	100	American Elodea	4
					Filamentous Algae	
		250	Silt	100	American Elodea	1
		254	Silt	100	American Elodea	2”
8/22/2003	17	0	Silt	100		1'3"
		10	Silt	100	American Elodea	6'3"
					Eurasian Watermilfoil	
		20	Silt	100	American Elodea	7'5"
		30	Silt	100	American Elodea	8'4"
		40	L. Cobble	50		10'10"
			S. Cobble	20		
			Silt	30		
		50	L. Cobble	50		12'7"
			S. Cobble	20		
			Silt	30		
		60	S. Boulder	30		14'4"

Appendix D. Substrate composition and aquatic vegetation at 64 transects between Crocker-Huffman and Merced Falls dams.						
Date	**Transect Number**	**Transect Interval (Left to Right Facing Downstream)**	**Substrate Type**	**Estimated % of Substrate**	**Aquatic Vegetation Type**	**River Depth (ft)**
			L. Cobble	50		
			Silt	30		
		70	S. Boulder	30		14'10"
			L. Cobble	40		
			S. Cobble	20		
			Silt	10		
		80	S. Boulder	30		14'9"
			L. Cobble	40		
			S. Cobble	20		
			Silt	10		
		90	S. Boulder	20		14'2"
			L. Cobble	50		
			S. Cobble	10		
			Silt	10		
		100	S. Cobble	50		13'10"
			Silt	50		
		110	Silt	70		13
			S. Cobble	30		
		120	Silt	80		13
			S. Cobble	20		
		130	Silt	70	American Elodea	12'1"
			S. Cobble	30		
		140	Silt	70	Eurasian Watermilfoil	10'2"
			S. Cobble	30		
		150	Silt	70	Eurasian Watermilfoil	9'5"
			S. Cobble	30		
		160	Silt	70	Eurasian Watermilfoil	8'10"
			S. Cobble	30		
		170	Silt	70	Eurasian Watermilfoil	7'8"
			S. Cobble	30		
		180	Silt	70	Eurasian Watermilfoil	4'5"
			S. Cobble	30	American Elodea	
		190	Silt	70	American Elodea	6'10"
			S. Cobble	30	Filamentous Algae	
		200	Silt	100	American Elodea	2’1’
					Filamentous Algae	
8/27/2003	18	0	Silt	100		2’6”
		10	Silt	100		7'8"
		20	Silt	100		11
		30	Silt	100		13'8"

Appendix D. Substrate composition and aquatic vegetation at 64 transects between Crocker-Huffman and Merced Falls dams.						
Date	**Transect Number**	**Transect Interval (Left to Right Facing Downstream)**	**Substrate Type**	**Estimated % of Substrate**	**Aquatic Vegetation Type**	**River Depth (ft)**
		40	Silt	100		17'1"
		50	Silt	90		17'7"
			S. Cobble	10		
		60	Silt	80		17'5"
			S. Cobble	10		
			L. Cobble	10		
		70	Silt	50		16'4"
			L. Cobble	25		
			S. Cobble	25		
		80	Silt	25		15
			S. Cobble	40		
			L. Cobble	35		
		90	Silt	30		14'7"
			S. Cobble	50		
			L. Cobble	20		
		100	Silt	30	American Elodea	11'3"
			S. Cobble	50		
			L. Cobble	20		
		110	Silt	30	American Elodea	10'4"
			S. Cobble	50	Coontail	
			L. Cobble	20		
		120	Silt	30	Coontail	9'10"
			S. Cobble	50		
			L. Cobble	20		
		130	Silt	30	Coontail	9'3"
			S. Cobble	50	American Elodea	
			L. Cobble	20		
		140	Silt	30	American Elodea	7'8"
			S. Cobble	50		
			L. Cobble	20		
		150	Silt	100	American Elodea	6'1"
		160	Silt	100	American Elodea	4'1"
		170	Silt	100	American Elodea	2'2"
		177	Silt	100		3"
8/27/2003	19	0	Silt	100	American Elodea	5"
		10	Silt	100	American Elodea	3'4"
					Eurasian Watermilfoil	
		20	Silt	100	American Elodea	4'1"
					Water Primrose	
		30	Silt	100	American Elodea	4'6"

Appendix D. Substrate composition and aquatic vegetation at 64 transects between Crocker-Huffman and Merced Falls dams.

Date	Transect Number	Transect Interval (Left to Right Facing Downstream)	Substrate Type	Estimated % of Substrate	Aquatic Vegetation Type	River Depth (ft)
					Water Primrose	
		40	Silt	100	Water Primrose	4'9"
					American Elodea	
		50	Silt	100	American Elodea	5'4"
		60	Silt	100	American Elodea	9'8"
		70	Silt	30		11
			L. Cobble	40		
			S. Boulder	30		
		80	S. Boulder	10		11'3"
			L. Cobble	50		
			S. Cobble	40		
		90	Silt	15		11'6"
			S. Cobble	25		
			L. Cobble	50		
			S. Boulder	10		
		100	Silt	15		11'5"
			L. Cobble	35		
			S. Cobble	50		
		110	L. Cobble	10		11
			S. Cobble	50		
			Silt	40		
		120	L. Cobble	70		10'11"
			S. Cobble	10		
			Silt	20		
		130	Silt	10		10'7"
			S. Cobble	50		
			L. Cobble	40		
		140	S. Boulder	10		10'5"
			L. Cobble	50		
			S. Cobble	30		
			Silt	10		
		150	S. Boulder	10		9'9"
			L. Cobble	50		
			S. Cobble	30		
			Silt	10		
		160	S. Boulder	10		9'4"
			L. Cobble	50		
			S. Cobble	30		
			Silt	10		
		170	S. Boulder	10	American Elodea	8'6"
			L. Cobble	50		

Appendix D. Substrate composition and aquatic vegetation at 64 transects between Crocker-Huffman and Merced Falls dams.

Date	Transect Number	Transect Interval (Left to Right Facing Downstream)	Substrate Type	Estimated % of Substrate	Aquatic Vegetation Type	River Depth (ft)
			S. Cobble	30		
			Silt	10		
		180	S. Boulder	10	American Elodea	6'11"
			L. Cobble	50	Water Primrose	
			S. Cobble	30		
			Silt	10		
		190	S. Boulder	10	American Elodea	7'3"
			L. Cobble	50	Water Primrose	
			S. Cobble	30		
			Silt	10		
		200	S. Boulder	10	American Elodea	6'7"
			L. Cobble	50	Water Primrose	
			S. Cobble	30		
			Silt	10		
		210	Silt	100	American Elodea	5
		220	Silt	100	American Elodea	3
		228	Silt	100	American Elodea	1'2"
					Water Primrose	
					Duckweed	
8/27/2003	20	0	Silt	100		2"
		10	Silt	100	American Elodea	3'4"
		20	Silt	100	American Elodea	5'9"
					Water Primrose	
		30	Silt	100	American Elodea	8'9"
		40	Silt	20		9'10"
			S. Cobble	20		
			L. Cobble	60		
		50	Silt	30		10'
			L. Cobble	50		
			S. Cobble	20		
		60	Silt	30		9'6"
			L. Cobble	50		
			S. Cobble	20		
		70	Silt	30		9'8"
			L. Cobble	50		
			S. Cobble	20		
		80	Silt	30		9'7"
			L. Cobble	50		
			S. Cobble	20		
		90	Silt	20		9'8"
			S. Cobble	60		

Appendix D. Substrate composition and aquatic vegetation at 64 transects between Crocker-Huffman and Merced Falls dams.						
Date	**Transect Number**	**Transect Interval (Left to Right Facing Downstream)**	**Substrate Type**	**Estimated % of Substrate**	**Aquatic Vegetation Type**	**River Depth (ft)**
			L. Cobble	20		
		100	Silt	20		10
			S. Cobble	60		
			L. Cobble	20		
		110	Silt	20		9'7"
			L. Cobble	40		
			S. Cobble	40		
		120	Silt	20		9'4"
			L. Cobble	40		
			S. Cobble	40		
		130	Silt	20		9
			L. Cobble	40		
			S. Cobble	40		
		140	S. Boulder	10		9'2"
			Silt	20		
			S. Cobble	40		
			L. Cobble	30		
		150	S. Boulder	20		9'3"
			Silt	10		
			S. Cobble	40		
			L. Cobble	30		
		160	S. Boulder	20	American Elodea	8'6"
			Silt	10		
			S. Cobble	40		
			L. Cobble	30		
		170	S. Boulder	20	American Elodea	7'5"
			Silt	10	Water Primrose	
			S. Cobble	40		
			L. Cobble	30		
		180	Silt	100	American Elodea	4'5"
		190	Silt	100	American Elodea	1
		196	Silt	100		5"
8/27/2003	21	0	Silt	100	American Elodea	5"
		10	Silt	100	American Elodea	3'6"
		20	Silt	100	American Elodea	7
		30	Silt	100	American Elodea	8'7"
		40	Silt	40		9'1"
			S. Boulder	20		
			L. Cobble	40		
		50	Silt	70		8'7"
			S. Cobble	30		

Appendix D. Substrate composition and aquatic vegetation at 64 transects between Crocker-Huffman and Merced Falls dams.

Date	Transect Number	Transect Interval (Left to Right Facing Downstream)	Substrate Type	Estimated % of Substrate	Aquatic Vegetation Type	River Depth (ft)
		60	S. Boulder	20		9'3"
			L. Cobble	40		
			S. Cobble	40		
		70	S. Boulder	20		8'8”
			L. Cobble	40		
			S. Cobble	40		
		80	S. Boulder	10		8'9"
			L. Cobble	50		
			S. Cobble	30		
			Silt	10		
		90	S. Boulder	10		9'1"
			L. Cobble	50		
			S. Cobble	30		
			Silt	10		
		100	S. Boulder	10		9'1"
			L. Cobble	50		
			S. Cobble	40		
		110	S. Boulder	10		9'5"
			L. Cobble	50		
			S. Cobble	40		
		120	S. Boulder	10		9'1"
			L. Cobble	50		
			S. Cobble	40		
		130	S. Boulder	20		9'3"
			L. Cobble	50		
			S. Cobble	30		
		140	S. Boulder	15		8'5"
			L. Cobble	60		
			S. Cobble	25		
		150	S. Boulder	30		7'8"
			L. Cobble	70		
		160	S. Boulder	40		6'11"
			L. Cobble	60		
		170	S. Boulder	40	American Elodea	4'11"
			L. Cobble	60	Water Primrose	
		180	Silt	100	American Elodea	3'5"
		186	Silt	100	American Elodea	1'1"
8/27/2003	22	0	Silt	100	American Elodea	1"
					Water Primrose	
		10	Silt	30	American Elodea	3'3"
			L. Cobble	70	Water Primrose	

Appendix D. Substrate composition and aquatic vegetation at 64 transects between Crocker-Huffman and Merced Falls dams.

Date	Transect Number	Transect Interval (Left to Right Facing Downstream)	Substrate Type	Estimated % of Substrate	Aquatic Vegetation Type	River Depth (ft)
		20	S. Boulder	70		6'2"
			L. Cobble	30		
		30	S. Boulder	60		6'6"
			L. Cobble	30		
			Silt	10		
		40	Silt	10		7'8"
			L. Cobble	20		
			S. Boulder	70		
		50	S. Boulder	60		7'8"
			M Boulder	10		
			L. Cobble	20		
			Silt	10		
		60	S. Boulder	60		8
			M Boulder	10		
			L. Cobble	20		
			Silt	10		
		70	S. Boulder	60		8'8"
			M Boulder	10		
			L. Cobble	20		
			Silt	10		
		80	S. Boulder	60		8'4"
			M Boulder	10		
			L. Cobble	20		
			Silt	10		
		90	S. Boulder	50		8'4"
			M Boulder	10		
			L. Cobble	20		
			S. Cobble	10		
			Silt	10		
		100	M Boulder	10		7'7"
			S. Boulder	60		
			L. Cobble	10		
			S. Cobble	10		
			Silt	10		
		110	M Boulder	10		7'6"
			S. Boulder	60		
			L. Cobble	10		
			S. Cobble	10		
			Silt	10		
		120	M Boulder	10		7'2"
			S. Boulder	60		

Appendix D. Substrate composition and aquatic vegetation at 64 transects between Crocker-Huffman and Merced Falls dams.						
Date	Transect Number	Transect Interval (Left to Right Facing Downstream)	Substrate Type	Estimated % of Substrate	Aquatic Vegetation Type	River Depth (ft)
			L. Cobble	10		
			S. Cobble	10		
			Silt	10		
		130	M Boulder	10		6'9"
			S. Boulder	40		
			L. Cobble	30		
			S. Cobble	10		
			Silt	10		
		140	S. Boulder	60		6
			L. Cobble	30		
			Silt	10		
		150	S. Boulder	60		6'2"
			L. Cobble	30		
			Silt	10		
		160	S. Boulder	60	American Elodea	5’10”
			L. Cobble	30		
			Silt	10		
		170	S. Boulder	60	American Elodea	5’6”
			L. Cobble	30	Water Primrose	
			Silt	10		
		180	Silt	100	American Elodea	5’4”
		190	Silt	100	American Elodea	4’1”
		200	Silt	100	American Elodea	2’2”
		208	Silt	100	American Elodea	6”
8/27/03	23	0	Silt	100	Cattail	6”
		10	Silt	100	American Elodea	3’6”
		20	S. Boulder	70		4'3"
			L. Cobble	30		
		30	L. Boulder	10		5'2"
			S. Boulder	50		
			L. Cobble	30		
			S. Cobble	10		
		40	L. Boulder	10		5'7"
			S. Boulder	60		
			L. Cobble	30		
		50	S. Boulder	70		5'7"
			L. Cobble	30		
		60	S. Boulder	70		6'3"
			L. Cobble	30		
		70	S. Boulder	70		6'5"
			L. Cobble	30		

Appendix D. Substrate composition and aquatic vegetation at 64 transects between Crocker-Huffman and Merced Falls dams.

Date	Transect Number	Transect Interval (Left to Right Facing Downstream)	Substrate Type	Estimated % of Substrate	Aquatic Vegetation Type	River Depth (ft)
		80	S. Boulder	70		6'7"
			L. Cobble	30		
		90	S. Boulder	70		6’9”
			L. Cobble	30		
		100	L. Boulder	10		6'10"
			S. Boulder	50		
			L. Cobble	30		
			S. Cobble	10		
		110	L. Boulder	10		6'3"
			S. Boulder	50		
			L. Cobble	30		
			S. Cobble	10		
		120	S. Boulder	60		6'4"
			L. Cobble	30		
			Silt	10		
		130	S. Boulder	60		5'10"
			L. Cobble	30		
			Silt	10		
		140	S. Boulder	60		5'7"
			L. Cobble	30		
			Silt	10		
		150	S. Boulder	50		5'8"
			L. Cobble	40		
			Silt	10		
		160	L. Boulder	20		5'3"
			S. Boulder	50		
			L. Cobble	30		
		170	L. Boulder	20		5'6"
			S. Boulder	50		
			L. Cobble	20		
			S. Cobble	10		
		180	Silt	100	American Elodea	3'1"
					Water Primrose	
		190	Silt	100	American Elodea	4'1"
					Water Primrose	
		200	Silt	100	American Elodea	3'11"
					Water Primrose	
		210	Silt	100	American Elodea	2'8"
					Water Primrose	
		220	Silt	100	American Elodea	2'2"
					Water Primrose	

Appendix D. Substrate composition and aquatic vegetation at 64 transects between Crocker-Huffman and Merced Falls dams.						
Date	**Transect Number**	**Transect Interval (Left to Right Facing Downstream)**	**Substrate Type**	**Estimated % of Substrate**	**Aquatic Vegetation Type**	**River Depth (ft)**
		230	Silt	100	American Elodea	10"
		233	Silt	100		2"
8/28/2003	24	0	Silt	100		0.1
		10	Bedrock	100	American Elodea	3.4
		20	Bedrock	100		4'10"
		30	Bedrock	100		5'6"
		40	Bedrock	100		5'5"
		50	S. Boulder	70		7'6"
			L. Cobble	30		
		60	S. Boulder	60		7'8"
			L. Cobble	30		
			S. Cobble	10		
		70	S. Boulder	60		7'6"
			L. Cobble	30		
			S. Cobble	10		
		80	S. Boulder	60		7'8"
			L. Cobble	30		
			S. Cobble	10		
		90	S. Boulder	60		7'8"
			L. Cobble	30		
			S. Cobble	10		
		100	S. Boulder	50		7'8"
			L. Cobble	30		
			S. Cobble	20		
		110	S. Boulder	50		8
			L. Cobble	30		
			S. Cobble	20		
		120	S. Boulder	50		7'4"
			L. Cobble	30		
			S. Cobble	20		
		130	S. Boulder	50		7'
			L. Cobble	30		
			S. Cobble	20		
		140	S. Boulder	50		6'10"
			L. Cobble	30		
			S. Cobble	20		
		150	S. Boulder	60		6'2"
			L. Cobble	30		
			Silt	10		
		160	S. Boulder	60		6
			L. Cobble	30		

Appendix D. Substrate composition and aquatic vegetation at 64 transects between Crocker-Huffman and Merced Falls dams.

Date	Transect Number	Transect Interval (Left to Right Facing Downstream)	Substrate Type	Estimated % of Substrate	Aquatic Vegetation Type	River Depth (ft)
			Silt	10		
		170	S. Boulder	60	American Elodea	5'3"
			L. Cobble	30		
			Silt	10		
		180	S. Boulder	60	American Elodea	4'1"
			L. Cobble	30		
			Silt	10		
		190	Silt	100	American Elodea	4
		200	Silt	100	American Elodea	1’1”
					Water Primrose	
		203	Silt	100		1”
8/28/2003	25	0	Silt	100		5”
		10	Silt	100	American Elodea	2’10”
					Water Primrose	
		20	Bedrock	100	American Elodea	4
					Water Primrose	
		30	Bedrock	100		5'3"
		40	L. Boulder	100		7'8"
		50	S. Boulder	70		8'2"
			L. Cobble	30		
		60	S. Boulder	70		8'7"
			L. Cobble	30		
		70	S. Boulder	60		8'7"
			L. Cobble	30		
			L. Cobble	10		
		80	S. Boulder	60		8'6"
			L. Cobble	30		
			L. Cobble	10		
		90	S. Boulder	50		8'8"
			L. Cobble	40		
			S. Cobble	10		
		100	S. Boulder	50		8'9"
			L. Cobble	40		
			S. Cobble	10		
		110	S. Boulder	20		9'2"
			L. Cobble	60		
			S. Cobble	20		
		120	S. Boulder	20		8'10"
			L. Cobble	60		
			S. Cobble	20		
		130	S. Boulder	10		8'6"

Appendix D. Substrate composition and aquatic vegetation at 64 transects between Crocker-Huffman and Merced Falls dams.

Date	Transect Number	Transect Interval (Left to Right Facing Downstream)	Substrate Type	Estimated % of Substrate	Aquatic Vegetation Type	River Depth (ft)
			L. Cobble	60		
			S. Cobble	20		
			Silt	10		
		140	S. Boulder	10		8'11"
			L. Cobble	60		
			S. Cobble	20		
			Silt	10		
		150	S. Boulder	10	American Elodea	8'9"
			L. Cobble	60		
			S. Cobble	20		
			Silt	10		
		160	S. Boulder	10	American Elodea	7
			L. Cobble	60		
			S. Cobble	20		
			Silt	10		
		170	S. Boulder	10		6'7"
			L. Cobble	60		
			S. Cobble	20		
			Silt	10		
		180	Silt	100	American Elodea	4’8”
		190	Silt	100		2’7”
		195	Silt	100	American Elodea	4”
8/28/2003	26	0	Silt	100	American Elodea	1’2”
					Water Primrose	
		10	M Boulder	5		3'3"
			S. Cobble	5		
			S. Boulder	50		
			L. Cobble	40		
		20	M Boulder	5		4'11"
			S. Cobble	5		
			S. Boulder	50		
			L. Cobble	40		
		30	S. Boulder	40		6'5"
			L. Cobble	40		
			S. Cobble	10		
			Silt	10		
		40	S. Boulder	40		7'11"
			L. Cobble	40		
			S. Cobble	10		
			Silt	10		
		50	S. Boulder	40		7'11"

Appendix D. Substrate composition and aquatic vegetation at 64 transects between Crocker-Huffman and Merced Falls dams.

Date	Transect Number	Transect Interval (Left to Right Facing Downstream)	Substrate Type	Estimated % of Substrate	Aquatic Vegetation Type	River Depth (ft)
			L. Cobble	40		
			S. Cobble	10		
			Silt	10		
		60	M Boulder	30		7'7"
			S. Boulder	30		
			L. Cobble	40		
		70	M Boulder	10		7'8"
			S. Boulder	40		
			L. Cobble	40		
			S. Cobble	10		
		80	M Boulder	10		7'8"
			S. Boulder	40		
			L. Cobble	40		
			S. Cobble	10		
		90	S. Boulder	60		7'7"
			L. Cobble	30		
			S. Cobble	10		
		100	S. Boulder	60		7'4"
			L. Cobble	30		
			S. Cobble	10		
		110	S. Boulder	60		7'5"
			L. Cobble	30		
			S. Cobble	10		
		120	S. Boulder	60		7'4"
			L. Cobble	30		
			S. Cobble	10		
		130	S. Boulder	60		6'9"
			L. Cobble	30		
			S. Cobble	10		
		140	S. Boulder	60		6'6"
			L. Cobble	30		
			S. Cobble	10		
		150	Silt	100	American Elodea	5'11"
		160	Silt	100	American Elodea	5’6”
					Eurasian Watermilfoil	
		170	Silt	100	American Elodea	5’5”
		180	Silt	100		4
		187	Silt	100	American Elodea	5”
8/28/2003	27	0	Silt	100	American Elodea	5"
					Water Primrose	

Appendix D. Substrate composition and aquatic vegetation at 64 transects between Crocker-Huffman and Merced Falls dams.						
Date	Transect Number	Transect Interval (Left to Right Facing Downstream)	Substrate Type	Estimated % of Substrate	Aquatic Vegetation Type	River Depth (ft)
		10	Silt	100	American Elodea	2'4"
					Water Primrose	
		20	L. Cobble	50	American Elodea	3'1"
			S. Boulder	50	Water Primrose	
		30	L. Cobble	40		3'11"
			S. Boulder	40		
			S. Cobble	20		
		40	L. Cobble	40		4
			S. Boulder	30		
			S. Cobble	20		
			Silt	10		
		50	L. Cobble	40		4
			S. Boulder	30		
			S. Cobble	20		
			Silt	10		
		60	L. Cobble	40		4'1"
			S. Boulder	30		
			S. Cobble	20		
			Silt	10		
		70	S. Boulder	60		4
			L. Cobble	30		
			S. Cobble	10		
		80	S. Boulder	60		3’11”
			L. Cobble	30		
			S. Cobble	10		
		90	S. Boulder	60		4’4”
			L. Cobble	30		
			S. Cobble	10		
		100	S. Boulder	60		4’8”
			L. Cobble	30		
			S. Cobble	10		
		110	S. Boulder	60		4’4”
			L. Cobble	30		
			S. Cobble	10		
		120	S. Boulder	70		5’4”
			L. Cobble	30		
		130	S. Boulder	70		5’4”
			L. Cobble	30		
		140	S. Boulder	70		6
			L. Cobble	30		
		150	S. Boulder	70		6’2”

Appendix D. Substrate composition and aquatic vegetation at 64 transects between Crocker-Huffman and Merced Falls dams.

Date	Transect Number	Transect Interval (Left to Right Facing Downstream)	Substrate Type	Estimated % of Substrate	Aquatic Vegetation Type	River Depth (ft)
			L. Cobble	30		
		160	S. Boulder	70		6’7”
			L. Cobble	30		
		170	S. Boulder	70		6’10”
			L. Cobble	30		
		180	S. Boulder	70		6’11”
			L. Cobble	30		
		190	S. Boulder	60		6’5”
			L. Cobble	30		
			S. Cobble	10		
		200	S. Boulder	60	American Elodea	6
			L. Cobble	30		
			S. Cobble	10		
		210	Silt	100	American Elodea	3’4”
		212	Silt	100	American Elodea	11”
					Coontail	
8/29/2003	28	0	L. Cobble	50	American Elodea	11”
			S. Cobble	50	Water Primrose	
		10	L. Cobble	50	American Elodea	2’2”
			S. Cobble	50	Water Primrose	
		20	L. Cobble	50	American Elodea	2’10”
			S. Cobble	50	Water Primrose	
		30	L. Cobble	50	American Elodea	3’1”
			S. Cobble	50	Water Primrose	
		40	L. Cobble	50	American Elodea	3’10”
			S. Cobble	50	Water Primrose	
		50	S. Boulder	20		4’7”
			L. Cobble	50		
			S. Cobble	20		
			Silt	10		
		60	S. Boulder	20		5
			L. Cobble	50		
			S. Cobble	20		
			Silt	10		
		70	S. Boulder	30		6’2”
			L. Cobble	40		
			S. Cobble	20		
			Silt	10		
		80	S. Boulder	30		7’8”
			L. Cobble	40		
			S. Cobble	20		

Appendix D. Substrate composition and aquatic vegetation at 64 transects between Crocker-Huffman and Merced Falls dams.

Date	Transect Number	Transect Interval (Left to Right Facing Downstream)	Substrate Type	Estimated % of Substrate	Aquatic Vegetation Type	River Depth (ft)
			Silt	10		
		90	S. Boulder	30		8'4"
			L. Cobble	40		
			S. Cobble	20		
			Silt	10		
		100	S. Boulder	30		8'6"
			L. Cobble	40		
			S. Cobble	20		
			Silt	10		
		110	M Boulder	5		8'6"
			S. Boulder	30		
			L. Cobble	40		
			S. Cobble	15		
			Silt	10		
		120	S. Boulder	30		8'8"
			L. Cobble	40		
			S. Cobble	20		
			Silt	10		
		130	M Boulder	5		8'6"
			S. Boulder	30		
			L. Cobble	40		
			S. Cobble	15		
			Silt	10		
		140	S. Boulder	50		6'11"
			L. Cobble	30		
			S. Cobble	20		
		150	S. Boulder	50		6'2"
			L. Cobble	30		
			S. Cobble	20		
		160	S. Boulder	50		5'11"
			L. Cobble	30		
			S. Cobble	10		
			Silt	10		
		170	L. Boulder	100		4'7"
		180	S. Boulder	50	American Elodea	3'11"
			L. Cobble	30		
			S. Cobble	10		
			Silt	10		
		188	Silt	100	American Elodea	1'8"
					Water Primrose	
8/29/2003	29	0	Silt	50	Water Primrose	1

Appendix D. Substrate composition and aquatic vegetation at 64 transects between Crocker-Huffman and Merced Falls dams.						
Date	**Transect Number**	**Transect Interval (Left to Right Facing Downstream)**	**Substrate Type**	**Estimated % of Substrate**	**Aquatic Vegetation Type**	**River Depth (ft)**
			L. Cobble	50		
		10	Silt	100	American Elodea	2'11"
		20	Silt	70	American Elodea	4'5"
			L. Cobble	30		
		30	Silt	70	American Elodea	5'8"
			L. Cobble	30	Water Primrose	
		40	Silt	70	American Elodea	6'6"
			L. Cobble	30		
		50	Silt	70		6'4"
			L. Cobble	30		
		60	Silt	50		5'11"
			L. Cobble	25		
			S. Cobble	25		
		70	Silt	50		5'11"
			L. Cobble	25		
			S. Cobble	25		
		80	Silt	50		5'11"
			L. Cobble	25		
			S. Cobble	25		
		90	Silt	25		6'2"
			L. Cobble	45		
			S. Cobble	30		
		100	Silt	25		6'5"
			L. Cobble	45		
			S. Cobble	30		
		110	Silt	25		7
			L. Cobble	45		
			S. Cobble	30		
		120	L. Boulder	10		6'7"
			L. Cobble	50		
			S. Cobble	40		
		130	L. Boulder	40		5'10"
			S. Boulder	30		
			L. Cobble	30		
		140	L. Boulder	60		5'6"
			S. Boulder	30		
			L. Cobble	10		
		150	L. Boulder	100		4'1"
		160	L. Boulder	100		4
		170	L. Boulder	80		4'1"
			L. Cobble	20		

Appendix D. Substrate composition and aquatic vegetation at 64 transects between Crocker-Huffman and Merced Falls dams.

Date	Transect Number	Transect Interval (Left to Right Facing Downstream)	Substrate Type	Estimated % of Substrate	Aquatic Vegetation Type	River Depth (ft)
		180	L. Boulder	70		3’7”
			S. Boulder	20		
			L. Cobble	10		
		190	L. Boulder	90		3’8”
			S. Boulder	10		
		200	Bedrock	100		3’4”
		210	Bedrock	100	American Elodea	3
		220	Silt	100	American Elodea	2’1”
		225	Silt	100		1’1”
8/29/2003	30	0	Silt	100	Cattail	0
		10	Bedrock	100	American Elodea	1’6”
		20	Bedrock	100	American Elodea	3’1”
		30	Bedrock	100	American Elodea	4’1”
		40	Silt	60		4’10”
			L. Cobble	10		
			S. Cobble	30		
		50	Silt	40		4’11”
			S. Cobble	40		
			L. Cobble	20		
		60	Silt	40		5
			S. Cobble	40		
			L. Cobble	20		
		70	Silt	20		5’2”
			L. Cobble	20		
			S. Cobble	60		
		80	S. Cobble	80		5’1”
			Silt	20		
		90	S. Cobble	80		4’4”
			Silt	20		
		100	S. Boulder	25		5’1”
			L. Cobble	25		
			S. Cobble	50		
		110	L. Boulder	70		4
			S. Boulder	15		
			L. Cobble	15		
		120	L. Boulder	100		5
		130	L. Boulder	100		3’8”
		140	L. Boulder	50		4’2”
			S. Boulder	50		
		150	L. Boulder	100		4
		160	L. Boulder	100		4

Appendix D. Substrate composition and aquatic vegetation at 64 transects between Crocker-Huffman and Merced Falls dams.						
Date	**Transect Number**	**Transect Interval (Left to Right Facing Downstream)**	**Substrate Type**	**Estimated % of Substrate**	**Aquatic Vegetation Type**	**River Depth (ft)**
		170	L. Boulder	100		3'4"
		180	L. Boulder	30		4'1"
			S. Boulder	70		
		190	Bedrock	100		3'8"
		197	Bedrock	100	American Elodea	1'10"
8/29/2003	31	0	L. Cobble	100	American Elodea	1'2"
					Water Primrose	
		10	L. Cobble	70		2'5"
			S. Cobble	20		
			Silt	10		
		20	S. Boulder	10		2'11"
			L. Cobble	60		
			S. Cobble	20		
			Silt	10		
		30	S. Boulder	10		3'4"
			L. Cobble	60		
			S. Cobble	20		
			Silt	10		
		40	S. Boulder	10		3'2"
			L. Cobble	60		
			S. Cobble	20		
			Silt	10		
		50	L. Cobble	60		3'4"
			S. Cobble	40		
		60	L. Cobble	60		3'4"
			S. Cobble	40		
		70	L. Cobble	60		3'6"
			S. Cobble	40		
		80	L. Cobble	70		4
			S. Cobble	30		
		90	L. Cobble	70		4'7"
			S. Cobble	30		
		100	L. Boulder	80		4'2"
			L. Cobble	20		
		110	L. Boulder	80		4'11"
			S. Boulder	20		
		120	L. Boulder	80		4'6"
			S. Boulder	20		
		130	L. Boulder	50		5'2"
			M Boulder	25		
			S. Boulder	25		

Appendix D. Substrate composition and aquatic vegetation at 64 transects between Crocker-Huffman and Merced Falls dams.						
Date	**Transect Number**	**Transect Interval (Left to Right Facing Downstream)**	**Substrate Type**	**Estimated % of Substrate**	**Aquatic Vegetation Type**	**River Depth (ft)**
		140	L. Boulder	100		4
		150	L. Boulder	90		3’5”
			S. Boulder	10		
		160	L. Boulder	100		2’5”
		170	L. Boulder	90		2’5”
			L. Cobble	10		
		180	L. Boulder	80		2’1”
			L. Cobble	20		
		190	L. Boulder	100		11”
		195	L. Cobble	30		6”
			Silt	70		
9/3/2003	32	0	S. Boulder	10		5”
			L. Cobble	70		
			S. Cobble	20		
		10	S. Boulder	40		1’2”
			L. Cobble	50		
			S. Cobble	10		
		20	L. Cobble	50		2
			S. Cobble	50		
		30	S. Boulder	30		2’8”
			L. Cobble	50		
			S. Cobble	20		
		40	S. Boulder	10		3’4”
			L. Cobble	70		
			S. Cobble	20		
		50	L. Cobble	20		4
			S. Cobble	80		
		60	S. Cobble	80		3’10”
			Silt	20		
		70	S. Cobble	80		3’10”
			L. Cobble	10		
			Silt	10		
		80	S. Cobble	80		3’11”
			L. Cobble	10		
			Silt	10		
		90	S. Boulder	10		4
			L. Cobble	30		
			S. Cobble	40		
			Silt	20		
		100	S. Boulder	10		4
			L. Cobble	40		

Appendix D. Substrate composition and aquatic vegetation at 64 transects between Crocker-Huffman and Merced Falls dams.						
Date	**Transect Number**	**Transect Interval (Left to Right Facing Downstream)**	**Substrate Type**	**Estimated % of Substrate**	**Aquatic Vegetation Type**	**River Depth (ft)**
			S. Cobble	40		
			Silt	10		
		110	L. Cobble	60		4’4”
			S. Cobble	40		
		120	S. Boulder	10		4’4”
			L. Cobble	50		
			S. Cobble	40		
		130	L. Boulder	50		4’6”
			S. Boulder	25		
			L. Cobble	25		
		140	L. Boulder	100		3’10”
		150	L. Boulder	100		3’6”
		160	L. Boulder	100		3’5”
		170	L. Boulder	100		2’5”
		180	L. Boulder	100		4’8”
		190	L. Boulder	30		3’6”
			S. Boulder	20		
			L. Cobble	50		
		200	L. Boulder	30		10”
			S. Boulder	20		
			L. Cobble	50		
9/3/2003	33	0	S. Boulder	80	American Elodea	6”
			L. Cobble	20	Cattail	
		10	S. Boulder	80	American Elodea	1’4”
			L. Cobble	20		
		20	S. Boulder	80	American Elodea	1’11”
			L. Cobble	20	Water Primrose	
		30	L. Cobble	50	American Elodea	2’4”
			S. Cobble	50	Water Primrose	
		40	L. Cobble	50		3’4”
			S. Cobble	50		
		50	L. Cobble	50		4’1”
			S. Cobble	50		
		60	L. Cobble	50		5’1”
			S. Cobble	50		
		70	S. Boulder	20		5’6”
			L. Cobble	40		
			S. Cobble	40		
		80	S. Boulder	30		6’2”
			L. Cobble	40		
			S. Cobble	10		

Appendix D. Substrate composition and aquatic vegetation at 64 transects between Crocker-Huffman and Merced Falls dams.						
Date	**Transect Number**	**Transect Interval (Left to Right Facing Downstream)**	**Substrate Type**	**Estimated % of Substrate**	**Aquatic Vegetation Type**	**River Depth (ft)**
			L. Boulder	20		
		90	S. Boulder	30		3’7”
			L. Cobble	40		
			S. Cobble	10		
			L. Boulder	20		
		100	S. Boulder	30		4’1”
			L. Cobble	40		
			S. Cobble	10		
			L. Boulder	20		
		110	S. Boulder	20		3’5”
			L. Cobble	40		
			S. Cobble	40		
		120	S. Boulder	20		
			L. Cobble	40		
			S. Cobble	40		
		130	S. Boulder	10		3’10”
			L. Cobble	60		
			S. Cobble	30		
		140	L. Boulder	20		3’6”
			M Boulder	20		
			S. Boulder	20		
			L. Cobble	40		
		150	L. Boulder	50		2’2”
			S. Boulder	30		
			L. Cobble	20		
		160	L. Boulder	50		2’7”
			S. Boulder	30		
			L. Cobble	20		
		170	L. Boulder	50		1’10”
			S. Boulder	30		
			L. Cobble	20		
		180	L. Boulder	50		2’6”
			S. Boulder	30		
			L. Cobble	20		
		190	S. Boulder	50	American Elodea	1’10”
			L. Cobble	25		
			S. Cobble	25		
		197	Silt	30	American Elodea	2”
			S. Cobble	30		
			L. Cobble	40		
9/3/2003	34	0	Silt	30		3"

Appendix D. Substrate composition and aquatic vegetation at 64 transects between Crocker-Huffman and Merced Falls dams.						
Date	**Transect Number**	**Transect Interval (Left to Right Facing Downstream)**	**Substrate Type**	**Estimated % of Substrate**	**Aquatic Vegetation Type**	**River Depth (ft)**
			L. Cobble	70		
		10	S. Boulder	50		1'3"
			L. Cobble	25		
			S. Cobble	25		
		20	S. Boulder	50		1'8"
			L. Cobble	25		
			S. Cobble	25		
		30	S. Boulder	50		2'6"
			L. Cobble	25		
			S. Cobble	25		
		40	S. Boulder	50		4'3"
			L. Cobble	25		
			S. Cobble	25		
		50	S. Boulder	50		5'9"
			L. Cobble	25		
			S. Cobble	25		
		60	S. Boulder	60		8'2"
			L. Cobble	20		
			S. Cobble	20		
		70	S. Boulder	60		8'8"
			L. Cobble	20		
			S. Cobble	20		
		80	S. Boulder	60		8'8"
			L. Cobble	20		
			S. Cobble	20		
		90	Bedrock	70		7'5"
			S. Boulder	30		
		100	Bedrock	50		6'1"
			M Boulder	30		
			Silt	20		
		110	S. Boulder	10		3'9"
			L. Cobble	30		
			S. Cobble	40		
			Silt	20		
		114	S. Boulder	30		1'10"
			M Boulder	30		
			L. Cobble	30		
			Silt	10		
9/3/2003	35	0	S. Boulder	30		2"
			L. Cobble	40		
			S. Cobble	30		

Appendix D. Substrate composition and aquatic vegetation at 64 transects between Crocker-Huffman and Merced Falls dams.						
Date	**Transect Number**	**Transect Interval (Left to Right Facing Downstream)**	**Substrate Type**	**Estimated % of Substrate**	**Aquatic Vegetation Type**	**River Depth (ft)**
		10	S. Boulder	10		9"
			L. Cobble	40		
			S. Cobble	50		
		20	S. Boulder	10		1
			L. Cobble	40		
			S. Cobble	50		
		30	L. Cobble	70		1'10"
			S. Cobble	30		
		40	S. Boulder	20		2
			L. Cobble	30		
			S. Cobble	50		
		50	S. Boulder	20		2'2"
			L. Cobble	30		
			S. Cobble	50		
		60	S. Boulder	20		2'4"
			L. Cobble	30		
			S. Cobble	50		
		70	S. Boulder	10		2'11"
			L. Cobble	40		
			S. Cobble	50		
		80	S. Boulder	10		3'7"
			L. Cobble	40		
			S. Cobble	50		
		90	S. Boulder	20		4'5"
			L. Cobble	40		
			S. Cobble	40		
		100	S. Boulder	20		5'1"
			L. Cobble	40		
			S. Cobble	40		
		110	S. Boulder	20		5'9"
			L. Cobble	50		
			S. Cobble	30		
		120	S. Boulder	20		6'5"
			L. Cobble	50		
			S. Cobble	30		
		130	S. Boulder	20		6'6"
			L. Cobble	50		
			S. Cobble	30		
		140	S. Boulder	30		6'8"
			L. Cobble	40		
			S. Cobble	30		

Appendix D. Substrate composition and aquatic vegetation at 64 transects between Crocker-Huffman and Merced Falls dams.

Date	Transect Number	Transect Interval (Left to Right Facing Downstream)	Substrate Type	Estimated % of Substrate	Aquatic Vegetation Type	River Depth (ft)
		150	M Boulder	10	American Elodea	2
			S. Boulder	20		
			L. Cobble	50		
			S. Cobble	20		
		154	L. Cobble	50	American Elodea	9"
			S. Cobble	40		
			Silt	10		
9/4/2003	36	0	Bedrock	100		0
		10	Silt	100	American Elodea	5’4”
		20	Silt	100	American Elodea	3’7”
		30	Bedrock	100	American Elodea	1.1
					Water Primrose	
		40	Bedrock	100	American Elodea	2
		50	Silt	100	American Elodea	5
		60	Silt	100	American Elodea	5’4”
		70	Silt	70		5’1”
			L. Cobble	15		
			S. Cobble	15		
		80	Bedrock	100		6’7”
		90	L. Cobble	25		7’8”
			S. Cobble	50		
			Silt	25		
		100	L. Cobble	40		8’5”
			S. Cobble	50		
			Silt	10		
		110	L. Cobble	40		8’7”
			S. Cobble	50		
			Silt	10		
		120	L. Cobble	40		7’1”
			S. Cobble	50		
			Silt	10		
		130	L. Cobble	60		6’6”
			S. Cobble	40		
		140	L. Cobble	50		6’8”
			S. Cobble	50		
		150	L. Cobble	50		7’4”
			S. Cobble	50		
		160	S. Boulder	10		7’5”
			L. Cobble	50		
			S. Cobble	40		
		170	S. Boulder	10		7’1”

Appendix D. Substrate composition and aquatic vegetation at 64 transects between Crocker-Huffman and Merced Falls dams.						
Date	**Transect Number**	**Transect Interval (Left to Right Facing Downstream)**	**Substrate Type**	**Estimated % of Substrate**	**Aquatic Vegetation Type**	**River Depth (ft)**
			L. Cobble	50		
			S. Cobble	40		
		180	S. Boulder	10		5’2”
			L. Cobble	50		
			S. Cobble	40		
		189	S. Boulder	10		7”
			L. Cobble	50		
			S. Cobble	40		
9/4/2003	37	0	Bedrock	60		5”
			L. Cobble	15		
			S. Cobble	15		
			Silt	10		
		10	Bedrock	90		3’1”
			Gravel	10		
		20	L. Boulder	70		10’5”
			Bedrock	30		
		30	L. Boulder	70		11’1”
			Bedrock	30		
		40	L. Boulder	70		10’1”
			Bedrock	30		
		50	L. Cobble	50		7’8”
			S. Cobble	50		
		60	S. Boulder	10		5’2”
			L. Cobble	50		
			S. Cobble	40		
		70	S. Boulder	30		3’11”
			L. Cobble	50		
			S. Cobble	20		
		80	S. Boulder	10		3’8”
			L. Cobble	40		
			S. Cobble	50		
		90	S. Boulder	10		2’4”
			L. Cobble	40		
			S. Cobble	50		
		100	Gravel	20		5”
			S. Boulder	20		
			L. Cobble	30		
			S. Cobble	30		
9/4/2003	38	0	Bedrock	50		0
			L. Boulder	50		
		10	S. Boulder	25		4’8”

Appendix D. Substrate composition and aquatic vegetation at 64 transects between Crocker-Huffman and Merced Falls dams.						
Date	**Transect Number**	**Transect Interval (Left to Right Facing Downstream)**	**Substrate Type**	**Estimated % of Substrate**	**Aquatic Vegetation Type**	**River Depth (ft)**
			L. Boulder	25		
			Bedrock	50		
		20	S. Boulder	25		6’6”
			L. Boulder	25		
			Bedrock	50		
		30	S. Boulder	25		5’8”
			L. Boulder	25		
			Bedrock	50		
		40	M Boulder	25		4’1”
			S. Boulder	25		
			L. Cobble	25		
			S. Cobble	25		
		50	L. Boulder	25		2’5”
			S. Boulder	25		
			L. Cobble	25		
			S. Cobble	25		
		60	S. Boulder	50		2’7”
			L. Cobble	25		
			S. Cobble	25		
		70	L. Boulder	25		4’2”
			S. Boulder	25		
			L. Cobble	25		
			S. Cobble	25		
		80	L. Boulder	25		4’6”
			S. Boulder	25		
			L. Cobble	25		
			S. Cobble	25		
		90	S. Boulder	25		4’7”
			L. Cobble	25		
			S. Cobble	25		
			Gravel	25		
		100	S. Boulder	25		2’4”
			L. Cobble	25		
			S. Cobble	25		
			Gravel	25		
		105	S. Boulder	25		11”
			L. Cobble	25		
			S. Cobble	25		
			Gravel	25		
9/4/2003	39	0	S. Boulder	50		0
			L. Cobble	20		

Appendix D. Substrate composition and aquatic vegetation at 64 transects between Crocker-Huffman and Merced Falls dams.						
Date	**Transect Number**	**Transect Interval (Left to Right Facing Downstream)**	**Substrate Type**	**Estimated % of Substrate**	**Aquatic Vegetation Type**	**River Depth (ft)**
			S. Cobble	20		
			Silt	10		
		10	S. Boulder	50		11”
			L. Cobble	20		
			S. Cobble	20		
			Silt	10		
		20	S. Boulder	50		2
			L. Cobble	20		
			S. Cobble	20		
			Silt	10		
		30	S. Boulder	50		2’11”
			L. Cobble	20		
			S. Cobble	20		
			Silt	10		
		40	S. Boulder	50		2’5”
			L. Cobble	20		
			S. Cobble	20		
			Gravel	10		
		50	S. Boulder	50		2’1”
			L. Cobble	20		
			S. Cobble	20		
			Gravel	10		
		60	S. Boulder	50		2’7”
			L. Cobble	20		
			S. Cobble	20		
			Gravel	10		
		70	S. Boulder	50		2’4”
			L. Cobble	20		
			S. Cobble	20		
			Gravel	10		
		80	S. Boulder	50		1’9”
			L. Cobble	25		
			S. Cobble	25		
		90	S. Boulder	50		1’7”
			L. Cobble	25		
			S. Cobble	25		
		100	S. Boulder	40		2
			L. Cobble	25		
			S. Cobble	25		
			Silt	10		
		110	S. Boulder	50		1’7”

Appendix D. Substrate composition and aquatic vegetation at 64 transects between Crocker-Huffman and Merced Falls dams.						
Date	**Transect Number**	**Transect Interval (Left to Right Facing Downstream)**	**Substrate Type**	**Estimated % of Substrate**	**Aquatic Vegetation Type**	**River Depth (ft)**
			L. Cobble	25		
			S. Cobble	25		
		120	S. Boulder	50		1’1”
			L. Cobble	25		
			S. Cobble	25		
		130	S. Boulder	50		11”
			L. Cobble	25		
			S. Cobble	25		
		140	S. Boulder	50		8”
			L. Cobble	25		
			S. Cobble	25		
		150	S. Boulder	50		6”
			L. Cobble	25		
			S. Cobble	25		
		160	M Boulder	10		5”
			S. Boulder	40		
			L. Cobble	25		
			S. Cobble	25		
		170	M Boulder	10		6”
			S. Boulder	40		
			L. Cobble	25		
			S. Cobble	25		
		180	M Boulder	10		8”
			S. Boulder	40		
			L. Cobble	25		
			S. Cobble	25		
		190	M Boulder	10		6”
			S. Boulder	40		
			L. Cobble	25		
			S. Cobble	25		
		200	S. Boulder	40		6”
			L. Cobble	20		
			S. Cobble	20		
			Silt	20		
		210	S. Boulder	40	Filamentous Algae	2”
			L. Cobble	10		
			S. Cobble	10		
			Silt	40		
		220	S. Boulder	40	Filamentous Algae	4”
			L. Cobble	10		
			S. Cobble	10		

Appendix D. Substrate composition and aquatic vegetation at 64 transects between Crocker-Huffman and Merced Falls dams.						
Date	**Transect Number**	**Transect Interval (Left to Right Facing Downstream)**	**Substrate Type**	**Estimated % of Substrate**	**Aquatic Vegetation Type**	**River Depth (ft)**
			Silt	40		
		228	S. Boulder	40		1”
			L. Cobble	10		
			S. Cobble	10		
			Silt	40		
10/1/2003	40	0	S. Boulder	50		0
			L. Cobble	25		
			S. Cobble	25		
		10	S. Boulder	75		1’11”
			L. Cobble	25		
		20	S. Boulder	50		4
			L. Cobble	25		
			S. Cobble	25		
		30	S. Boulder	50		4’7”
			L. Cobble	25		
			S. Cobble	25		
		40	S. Boulder	50		4’6”
			L. Cobble	25		
			S. Cobble	25		
		50	S. Boulder	50		4’1”
			L. Cobble	25		
			S. Cobble	25		
		60	S. Boulder	50		4’1”
			L. Cobble	25		
			S. Cobble	25		
		70	S. Boulder	50		3’8”
			L. Cobble	25		
			S. Cobble	25		
		80	S. Boulder	50		3’7”
			L. Cobble	25		
			S. Cobble	25		
		90	S. Boulder	50		3’1”
			L. Cobble	25		
			S. Cobble	25		
		100	S. Boulder	20		2’8”
			L. Cobble	40		
			S. Cobble	40		
		110	S. Boulder	20		2
			L. Cobble	40		
			S. Cobble	40		
		120	S. Boulder	20		1’8”

Appendix D. Substrate composition and aquatic vegetation at 64 transects between Crocker-Huffman and Merced Falls dams.

Date	Transect Number	Transect Interval (Left to Right Facing Downstream)	Substrate Type	Estimated % of Substrate	Aquatic Vegetation Type	River Depth (ft)
			L. Cobble	40		
			S. Cobble	40		
		130	S. Boulder	20		1’5”
			L. Cobble	30		
			S. Cobble	30		
			Gravel	20		
		140	S. Boulder	20		7”
			L. Cobble	30		
			S. Cobble	30		
			Gravel	20		
		150	S. Boulder	20		6”
			L. Cobble	30		
			S. Cobble	30		
			Gravel	20		
		160	S. Boulder	20		8”
			L. Cobble	20		
			Gravel	20		
			Silt	40		
		166	S. Boulder	50		6”
			Silt	50		
10/1/2003	41	0	S. Boulder	50	American Elodea	0
			L. Cobble	25	Coontail	
			S. Cobble	25		
		10	M Boulder	10	American Elodea	1’6”
			S. Boulder	50	Coontail	
			L. Cobble	40	Filamentous Algae	
		20	M Boulder	10	American Elodea	3’2”
			S. Boulder	50	Coontail	
			L. Cobble	40	Filamentous Algae	
		30	S. Boulder	50		3
			L. Cobble	25		
			S. Cobble	25		
		40	S. Boulder	50		3’10”
			L. Cobble	25		
			S. Cobble	25		
		50	S. Boulder	50		4’11”
			L. Cobble	25		
			S. Cobble	25		
		60	S. Boulder	50		5’11”
			L. Cobble	25		
			S. Cobble	25		

Appendix D. Substrate composition and aquatic vegetation at 64 transects between Crocker-Huffman and Merced Falls dams.						
Date	**Transect Number**	**Transect Interval (Left to Right Facing Downstream)**	**Substrate Type**	**Estimated % of Substrate**	**Aquatic Vegetation Type**	**River Depth (ft)**
		70	S. Boulder	50		6’5”
			L. Cobble	25		
			S. Cobble	25		
		80	S. Boulder	50		6’11”
			L. Cobble	25		
			S. Cobble	25		
		90	S. Boulder	50		7’2”
			L. Cobble	25		
			S. Cobble	25		
		100	S. Boulder	50		7
			L. Cobble	25		
			S. Cobble	25		
		110	S. Boulder	50		6’4”
			L. Cobble	25		
			S. Cobble	25		
		120	S. Boulder	50		5’7”
			L. Cobble	25		
			S. Cobble	25		
		130	S. Boulder	40		4’7”
			L. Cobble	20		
			S. Cobble	20		
			Gravel	10		
			Sand	10		
		140	S. Boulder	40		3’3”
			L. Cobble	20		
			S. Cobble	20		
			Gravel	10		
			Sand	10		
		150	Silt	100	American Elodea	1’10”
					Coontail	
		156	Silt	100	American Elodea	1
					Coontail	
10/1/2003	42	0	S. Boulder	10		6”
			L. Cobble	30		
			S. Cobble	30		
			Gravel	15		
			Sand	15		
		10	S. Boulder	50		4’5”
			L. Cobble	25		
			S. Cobble	25		
		20	Silt	100		7’2”

Appendix D. Substrate composition and aquatic vegetation at 64 transects between Crocker-Huffman and Merced Falls dams.						
Date	**Transect Number**	**Transect Interval (Left to Right Facing Downstream)**	**Substrate Type**	**Estimated % of Substrate**	**Aquatic Vegetation Type**	**River Depth (ft)**
		30	S. Boulder	50		7’1”
			L. Cobble	25		
			S. Cobble	25		
		40	S. Boulder	50		7’4”
			L. Cobble	25		
			S. Cobble	25		
		50	S. Boulder	50		7’8”
			L. Cobble	25		
			S. Cobble	25		
		60	S. Boulder	50		8’3”
			L. Cobble	20		
			S. Cobble	20		
			Sand	10		
		70	S. Boulder	50		8’2”
			L. Cobble	25		
			S. Cobble	25		
		80	S. Boulder	50		7’10”
			L. Cobble	25		
			S. Cobble	25		
		90	S. Boulder	50		7’2”
			L. Cobble	25		
			S. Cobble	25		
		100	S. Boulder	50		7
			L. Cobble	25		
			S. Cobble	25		
		110	S. Boulder	50		6’5”
			L. Cobble	25		
			S. Cobble	25		
		120	S. Boulder	50		6’2”
			L. Cobble	25		
			S. Cobble	25		
		130	S. Boulder	50		6’2”
			L. Cobble	25		
			S. Cobble	25		
		140	L. Cobble	25		6
			S. Cobble	25		
			Gravel	50		
		150	S. Boulder	10		5’11”
			L. Cobble	25		
			S. Cobble	25		
			Gravel	40		

Appendix D. Substrate composition and aquatic vegetation at 64 transects between Crocker-Huffman and Merced Falls dams.

Date	Transect Number	Transect Interval (Left to Right Facing Downstream)	Substrate Type	Estimated % of Substrate	Aquatic Vegetation Type	River Depth (ft)
		160	L. Boulder	10		5’6”
			S. Boulder	40		
			L. Cobble	25		
			S. Cobble	25		
		170	Silt	100	American Elodea	4
					Coontail	
					Filamentous Algae	
		180	Silt	100	American Elodea	1’11”
					Filamentous Algae	
		186	Silt	100		0
10/1/2003	43	0	Silt	100	Eurasian Watermilfoil	0
		10	Silt	90	Eurasian Watermilfoil	1’7”
			L. Cobble	10		
		20	Silt	90	American Elodea	3
			L. Cobble	10	Eurasian Watermilfoil	
		30	L. Boulder	50	American Elodea	3’6”
			S. Boulder	50	Eurasian Watermilfoil	
		40	S. Boulder	50		3’10”
			L. Cobble	20		
			S. Cobble	20		
			Sand	10		
		50	S. Boulder	50		4’2”
			L. Cobble	20		
			S. Cobble	20		
			Sand	10		
		60	S. Boulder	50		4’4”
			L. Cobble	20		
			S. Cobble	20		
			Sand	10		
		70	S. Boulder	50		4’4”
			L. Cobble	20		
			S. Cobble	20		
			Sand	10		
		80	S. Boulder	50		4
			L. Cobble	25		
			S. Cobble	25		
		90	S. Boulder	50		3’8”
			L. Cobble	25		
			S. Cobble	25		

Appendix D. Substrate composition and aquatic vegetation at 64 transects between Crocker-Huffman and Merced Falls dams.						
Date	**Transect Number**	**Transect Interval (Left to Right Facing Downstream)**	**Substrate Type**	**Estimated % of Substrate**	**Aquatic Vegetation Type**	**River Depth (ft)**
		100	S. Boulder	50		3’8”
			L. Cobble	25		
			S. Cobble	25		
		110	S. Boulder	50		3’8”
			L. Cobble	25		
			S. Cobble	25		
		120	S. Boulder	50		4’2”
			L. Cobble	25		
			S. Cobble	25		
		130	S. Boulder	50		4’2”
			L. Cobble	25		
			S. Cobble	25		
		140	S. Boulder	50		4’4”
			L. Cobble	25		
			S. Cobble	25		
		150	S. Boulder	50		4’2”
			L. Cobble	25		
			S. Cobble	25		
		160	S. Boulder	50		4’2”
			L. Cobble	25		
			S. Cobble	25		
		170	S. Boulder	50		3
			L. Cobble	25		
			S. Cobble	25		
		177	S. Boulder	30		3
			L. Cobble	20		
			S. Cobble	20		
			Gravel	20		
			Silt	10		
10/1/2003	44	0	S. Boulder	50		6”
			L. Cobble	25		
			S. Cobble	25		
		10	S. Boulder	50		1’1”
			L. Cobble	25		
			S. Cobble	25		
		20	S. Boulder	50		1’5”
			L. Cobble	25		
			S. Cobble	25		
		30	S. Boulder	70		2’2”
			L. Cobble	30		
		40	S. Boulder	70		2’8”

Appendix D. Substrate composition and aquatic vegetation at 64 transects between Crocker-Huffman and Merced Falls dams.						
Date	**Transect Number**	**Transect Interval (Left to Right Facing Downstream)**	**Substrate Type**	**Estimated % of Substrate**	**Aquatic Vegetation Type**	**River Depth (ft)**
			L. Cobble	30		
		50	S. Boulder	70		2'10"
			L. Cobble	30		
		60	S. Boulder	70		3'6"
			L. Cobble	30		
		70	S. Boulder	70		3'4"
			L. Cobble	30		
		80	S. Boulder	70		3'6"
			L. Cobble	30		
		90	S. Boulder	70		3'8"
			L. Cobble	30		
		100	S. Boulder	100		4'1"
		110	S. Boulder	100		4'1"
		120	S. Boulder	100		3'10"
		130	S. Boulder	50		8"
			L. Cobble	25		
			S. Cobble	25		
10/1/2003	45	0	Silt	50	American Elodea	5"
			S. Boulder	50	Filamentous Algae	
		10	S. Boulder	50		1'2"
			L. Cobble	25		
			S. Cobble	25		
		20	S. Boulder	50		1'6"
			L. Cobble	25		
			S. Cobble	25		
		30	S. Boulder	50		2'2"
			L. Cobble	50		
		40	S. Boulder	50		2'11"
			L. Cobble	50		
		50	S. Boulder	50		2'5"
			L. Cobble	50		
		60	S. Boulder	50		3
			L. Cobble	50		
		70	S. Boulder	50		3
			L. Cobble	50		
		80	S. Boulder	50		2'8"
			L. Cobble	50		
		90	S. Boulder	50		3
			L. Cobble	50		
		100	S. Boulder	50		3
			L. Cobble	50		

Appendix D. Substrate composition and aquatic vegetation at 64 transects between Crocker-Huffman and Merced Falls dams.						
Date	**Transect Number**	**Transect Interval (Left to Right Facing Downstream)**	**Substrate Type**	**Estimated % of Substrate**	**Aquatic Vegetation Type**	**River Depth (ft)**
		110	Silt	100		1’2”
		120	Silt	20		1”
			S. Boulder	50		
			L. Cobble	30		
10/1/2003	46	0	S. Boulder	80		6”
			Sand	20		
		10	S. Boulder	50		1’1”
			L. Cobble	25		
			S. Cobble	25		
		20	S. Boulder	50		1’8”
			L. Cobble	25		
			S. Cobble	25		
		30	S. Boulder	50		2’4”
			L. Cobble	25		
			S. Cobble	25		
		40	S. Boulder	50		2’4”
			L. Cobble	25		
			S. Cobble	25		
		50	S. Boulder	50		2’7”
			L. Cobble	25		
			S. Cobble	25		
		60	S. Boulder	50		2’6”
			L. Cobble	25		
			S. Cobble	25		
		70	S. Boulder	50		2’8”
			L. Cobble	25		
			S. Cobble	25		
		80	S. Boulder	80		3’3”
			L. Cobble	10		
			S. Cobble	10		
		90	S. Boulder	80		3’2”
			L. Cobble	10		
			S. Cobble	10		
		100	S. Boulder	50		2’7”
			L. Cobble	25		
			S. Cobble	25		
		110	S. Boulder	50		2’7”
			L. Cobble	25		
			S. Cobble	25		
		120	S. Boulder	50		2’4”
			L. Cobble	25		

Appendix D. Substrate composition and aquatic vegetation at 64 transects between Crocker-Huffman and Merced Falls dams.

Date	Transect Number	Transect Interval (Left to Right Facing Downstream)	Substrate Type	Estimated % of Substrate	Aquatic Vegetation Type	River Depth (ft)
			S. Cobble	25		
		130	S. Boulder	50		2
			L. Cobble	25		
			S. Cobble	25		
		140	Silt	100		1’1”
		142	Silt	100		1”
10/1/2003	47	0	S. Boulder	80	Water Primrose	2”
			Sand	20		
		10	S. Boulder	80		7”
			Gravel	20		
		20	S. Boulder	80		10”
			S. Cobble	20		
		30	S. Boulder	70		1’2”
			L. Cobble	15		
			S. Cobble	15		
		40	S. Boulder	50		1’5”
			L. Cobble	20		
			S. Cobble	20		
			Gravel	10		
		50	S. Boulder	50		1’10”
			L. Cobble	20		
			S. Cobble	20		
			Gravel	10		
		60	S. Boulder	50		2
			L. Cobble	20		
			S. Cobble	20		
			Gravel	10		
		70	S. Boulder	50		2’2”
			L. Cobble	20		
			S. Cobble	20		
			Gravel	10		
		80	S. Boulder	50		2’5”
			L. Cobble	20		
			S. Cobble	20		
			Gravel	10		
		90	S. Boulder	50		2’6”
			L. Cobble	20		
			S. Cobble	20		
			Gravel	10		
		100	S. Boulder	100		2’4”
		110	S. Boulder	50		2’2”

Appendix D. Substrate composition and aquatic vegetation at 64 transects between Crocker-Huffman and Merced Falls dams.						
Date	**Transect Number**	**Transect Interval (Left to Right Facing Downstream)**	**Substrate Type**	**Estimated % of Substrate**	**Aquatic Vegetation Type**	**River Depth (ft)**
			L. Cobble	25		
			S. Cobble	25		
		120	S. Boulder	50		2’5”
			L. Cobble	25		
			S. Cobble	25		
		130	S. Boulder	50		2’7”
			L. Cobble	25		
			S. Cobble	25		
		140	S. Boulder	50		2’5”
			L. Cobble	25		
			S. Cobble	25		
		150	S. Boulder	50		1’1”
			L. Cobble	25		
			S. Cobble	25		
		153	S. Boulder	50		1
			L. Cobble	25		
			S. Cobble	25		
9/29/2003	48	0	Silt	100		0
		10	S. Boulder	50		10”
			L. Cobble	25		
			S. Cobble	25		
		20	S. Boulder	50		6”
			L. Cobble	25		
			S. Cobble	25		
		30	S. Boulder	50		5”
			L. Cobble	25		
			S. Cobble	25		
		40	S. Boulder	70		5”
			L. Cobble	15		
			S. Cobble	15		
		50	S. Boulder	30		11”
			L. Cobble	30		
			S. Cobble	30		
			Gravel	10		
		60	S. Boulder	30		1’4”
			L. Cobble	30		
			S. Cobble	30		
			Gravel	10		
		70	S. Boulder	60		1’4”
			L. Cobble	20		
			S. Cobble	20		

Appendix D. Substrate composition and aquatic vegetation at 64 transects between Crocker-Huffman and Merced Falls dams.

Date	Transect Number	Transect Interval (Left to Right Facing Downstream)	Substrate Type	Estimated % of Substrate	Aquatic Vegetation Type	River Depth (ft)
		80	S. Boulder	60		1'7"
			L. Cobble	20		
			S. Cobble	20		
		90	S. Boulder	60		1'10"
			L. Cobble	20		
			S. Cobble	20		
		100	S. Boulder	60		1'8"
			L. Cobble	20		
			S. Cobble	20		
		110	S. Boulder	60		1'7"
			L. Cobble	20		
			S. Cobble	20		
		120	S. Boulder	60		1'6"
			L. Cobble	20		
			S. Cobble	20		
		130	S. Boulder	60		2
			L. Cobble	20		
			S. Cobble	20		
		140	S. Boulder	60		2'1"
			L. Cobble	20		
			S. Cobble	20		
		150	S. Boulder	60		2'4"
			L. Cobble	20		
			S. Cobble	20		
		160	S. Boulder	50		2'5"
			S. Cobble	50		
		170	S. Boulder	50		2'2"
			S. Cobble	50		
		180	S. Boulder	50		2'4"
			L. Cobble	25		
			S. Cobble	25		
		190	S. Boulder	70		1'11"
			L. Cobble	30		
		200	S. Boulder	70		2
			L. Cobble	30		
		210	Silt	100		5"
		215	Silt	100		4"
9/29/2003	49	0	Silt	100		0
		10	Silt	100	American Elodea	1'2"
		20	Bedrock	100		1'7"
		30	S. Boulder	50		2'2"

Appendix D. Substrate composition and aquatic vegetation at 64 transects between Crocker-Huffman and Merced Falls dams.

Date	Transect Number	Transect Interval (Left to Right Facing Downstream)	Substrate Type	Estimated % of Substrate	Aquatic Vegetation Type	River Depth (ft)
			L. Cobble	30		
			S. Cobble	20		
		40	L. Cobble	50		2'5"
			S. Cobble	50		
		50	L. Cobble	40		2'5"
			S. Cobble	50		
			Sand	10		
		60	L. Cobble	40		2'6"
			S. Cobble	50		
			Sand	10		
		70	L. Cobble	40		2'6"
			S. Cobble	50		
			Sand	10		
		80	L. Cobble	40		2'6"
			S. Cobble	50		
			Sand	10		
		90	L. Cobble	40		2'7"
			S. Cobble	50		
			Sand	10		
		100	L. Cobble	40		2'7"
			S. Cobble	50		
			Sand	10		
		110	L. Cobble	40		2'6"
			S. Cobble	50		
			Sand	10		
		120	S. Cobble	100		2'6"
		130	S. Boulder	10		2'5"
			L. Cobble	20		
			S. Cobble	50		
			Gravel	20		
		140	S. Boulder	10		2'6"
			L. Cobble	20		
			S. Cobble	50		
			Gravel	20		
		150	S. Boulder	10		2'7"
			L. Cobble	30		
			S. Cobble	60		
		160	S. Boulder	20		2'6"
			L. Cobble	40		
			S. Cobble	40		
		170	S. Boulder	20		2'10"

Appendix D. Substrate composition and aquatic vegetation at 64 transects between Crocker-Huffman and Merced Falls dams.

Date	Transect Number	Transect Interval (Left to Right Facing Downstream)	Substrate Type	Estimated % of Substrate	Aquatic Vegetation Type	River Depth (ft)
			L. Cobble	40		
			S. Cobble	40		
		180	S. Boulder	30		3’8”
			M Boulder	10		
			L. Cobble	30		
			S. Cobble	30		
		190	S. Boulder	30		3’8”
			M Boulder	10		
			L. Cobble	30		
			S. Cobble	30		
		200	Bedrock	100		4
		210	Silt	100	American Elodea	2’5”
					Coontail	
		220	Silt	100	American Elodea	1
					Coontail	
		224	Silt	100		1”
9/29/2003	50	0	Silt	100		0
		10	Silt	100	American Elodea	1’8”
		20	Silt	100	American Elodea	1’11”
					Filamentous Algae	
		30	S. Cobble	50		2’4”
			Sand	25		
			Sand	25		
		40	S. Boulder	10		2’4”
			L. Cobble	30		
			S. Cobble	50		
			Sand	10		
		50	L. Cobble	40		2’1”
			S. Cobble	50		
			Sand	10		
		60	L. Cobble	40		2
			S. Cobble	50		
			Sand	10		
		70	L. Cobble	40		2’2”
			S. Cobble	50		
			Sand	10		
		80	L. Cobble	30		2’2”
			S. Cobble	60		
			Sand	10		
		90	L. Cobble	20		2’4”
			S. Cobble	60		

Appendix D. Substrate composition and aquatic vegetation at 64 transects between Crocker-Huffman and Merced Falls dams.

Date	Transect Number	Transect Interval (Left to Right Facing Downstream)	Substrate Type	Estimated % of Substrate	Aquatic Vegetation Type	River Depth (ft)
			Gravel	10		
			Sand	10		
		100	L. Cobble	20		2’5”
			S. Cobble	60		
			Gravel	10		
			Sand	10		
		110	L. Cobble	20		2’7”
			S. Cobble	50		
			Gravel	20		
			Sand	10		
		120	L. Cobble	20		2’8”
			S. Cobble	50		
			Gravel	20		
			Sand	10		
		130	S. Cobble	60		2’8”
			L. Cobble	20		
			Gravel	20		
		140	S. Boulder	10		2’6”
			L. Cobble	20		
			S. Cobble	50		
			Gravel	20		
		150	S. Boulder	10		2’8”
			L. Cobble	20		
			S. Cobble	50		
			Gravel	20		
		160	S. Cobble	60		3
			Gravel	30		
			Sand	10		
		170	S. Cobble	50		3’3”
			L. Cobble	20		
			Gravel	30		
		180	L. Cobble	20		3’8”
			S. Cobble	40		
			Gravel	40		
		190	L. Cobble	20		4’7”
			S. Cobble	40		
			Gravel	40		
		200	S. Boulder	100		6’2
		210	S. Boulder	50	American Elodea	5’8”
			L. Cobble	25	Coontail	
			S. Cobble	25		

Appendix D. Substrate composition and aquatic vegetation at 64 transects between Crocker-Huffman and Merced Falls dams.						
Date	**Transect Number**	**Transect Interval (Left to Right Facing Downstream)**	**Substrate Type**	**Estimated % of Substrate**	**Aquatic Vegetation Type**	**River Depth (ft)**
		220	Silt	100	American Elodea	2'5"
		224	Silt	100	American Elodea	1
9/29/2003	51	0	Silt	100		4"
		10	Silt	100	American Elodea	1'5"
					Coontail	
		20	L. Cobble	50	American Elodea	1'5"
			S. Cobble	50	Coontail	
		30	L. Cobble	50	American Elodea	1
			S. Cobble	50	Filamentous Algae	
		40	L. Cobble	25	American Elodea	10"
			S. Cobble	25	Coontail	
			Gravel	25	Filamentous Algae	
			Sand	25		
		50	L. Cobble	25	American Elodea	8"
			S. Cobble	25	Coontail	
			Gravel	25	Filamentous Algae	
			Sand	25		
		60	L. Cobble	50		1
			S. Cobble	50		
		70	L. Cobble	50		1'3"
			S. Cobble	50		
		80	L. Cobble	50		1'8"
			S. Cobble	50		
		90	L. Cobble	50		2'1"
			S. Cobble	50		
		100	L. Cobble	50		2'4"
			S. Cobble	50		
		110	L. Cobble	50		2'6"
			S. Cobble	50		
		120	L. Cobble	50		2'10"
			S. Cobble	50		
		130	L. Cobble	50		3'2"
			S. Cobble	50		
		140	S. Boulder	30		3'8"
			L. Cobble	35		
			S. Cobble	35		
		150	S. Boulder	30		3'7"
			L. Cobble	35		
			S. Cobble	35		
		160	L. Cobble	50		3'8"
			S. Cobble	50		

Appendix D. Substrate composition and aquatic vegetation at 64 transects between Crocker-Huffman and Merced Falls dams.						
Date	**Transect Number**	**Transect Interval (Left to Right Facing Downstream)**	**Substrate Type**	**Estimated % of Substrate**	**Aquatic Vegetation Type**	**River Depth (ft)**
		170	Bedrock	100		2’8”
		180	Bedrock	70		3’7”
			S. Boulder	30		
		190	Silt	100		4’8”
		200	Silt	100	American Elodea	1’7”
					Filamentous Algae	
		209	Silt	100		0
9/29/2003	52	0	Silt	100		0
		10	Silt	100	American Elodea	5”
		20	Silt	50		Dry land
			S. Cobble	50		
		30	Silt	50		Dry land
			S. Cobble	50		
		40	Silt	50	Filamentous Algae	4”
			L. Cobble	25	Water Primrose	
			S. Cobble	25		
		50	Silt	50	Filamentous Algae	5”
			L. Cobble	25	Water Primrose	
			S. Cobble	25		
		60	Silt	50	Filamentous Algae	5”
			L. Cobble	25	Water Primrose	
			S. Cobble	25		
		70	L. Cobble	40	Filamentous Algae	7”
			S. Cobble	40	Water Primrose	
			Gravel	20		
		80	L. Cobble	40		1
			S. Cobble	40		
			Gravel	20		
		90	L. Cobble	40		1’6”
			S. Cobble	40		
			Gravel	20		
		100	L. Cobble	40		1’7”
			S. Cobble	40		
			Gravel	20		
		110	L. Cobble	40		1’10”
			S. Cobble	40		
			Gravel	20		
		120	L. Cobble	40		2
			S. Cobble	40		
			Gravel	20		
		130	L. Cobble	40		2’6”

Appendix D. Substrate composition and aquatic vegetation at 64 transects between Crocker-Huffman and Merced Falls dams.						
Date	**Transect Number**	**Transect Interval (Left to Right Facing Downstream)**	**Substrate Type**	**Estimated % of Substrate**	**Aquatic Vegetation Type**	**River Depth (ft)**
			S. Cobble	40		
			Gravel	20		
		140	L. Cobble	50		3’6”
			S. Cobble	50		
		150	L. Cobble	50		5
			S. Cobble	50		
		160	L. Cobble	50		5’6”
			S. Cobble	50		
		170	L. Cobble	50		5
			S. Cobble	50		
		180	L. Cobble	50		5
			S. Cobble	50		
		190	L. Cobble	40		4
			S. Cobble	40		
			Gravel	20		
		200	Silt	100	American Elodea	1’11”
		206	Silt	100	American Elodea	11”
					Filamentous Algae	
					Water Primrose	
9/29/2003	53	0	Silt	100		0
		10	Silt	100	American Elodea	11”
		20	Silt	100	American Elodea	1’2”
					Eurasian Watermilfoil	
		30	S. Cobble	50		1’1”
			L. Cobble	50		
		40	S. Cobble	50		1’1”
			L. Cobble	40		
			Sand	10		
		50	S. Cobble	50		1’4”
			L. Cobble	40		
			Sand	10		
		60	S. Cobble	50		1’7”
			L. Cobble	40		
			Sand	10		
		70	S. Cobble	50		1’11”
			L. Cobble	40		
			Sand	10		
		80	S. Cobble	50		2’1”
			L. Cobble	40		
			Sand	10		

Appendix D. Substrate composition and aquatic vegetation at 64 transects between Crocker-Huffman and Merced Falls dams.						
Date	**Transect Number**	**Transect Interval (Left to Right Facing Downstream)**	**Substrate Type**	**Estimated % of Substrate**	**Aquatic Vegetation Type**	**River Depth (ft)**
		90	S. Cobble	50		2’5”
			L. Cobble	40		
			Sand	10		
		100	S. Cobble	50		3
			L. Cobble	40		
			Sand	10		
		110	S. Cobble	50		3’2”
			L. Cobble	40		
			Sand	10		
		120	S. Cobble	50		3’6”
			L. Cobble	40		
			Sand	10		
		130	S. Cobble	50		4’4”
			L. Cobble	40		
			Sand	10		
		140	S. Cobble	50		4’7”
			L. Cobble	40		
			Sand	10		
		150	L. Boulder	50		4’7”
			S. Cobble	25		
			L. Cobble	25		
		160	L. Boulder	50		4’6”
			S. Cobble	25		
			L. Cobble	25		
		170	L. Boulder	50		4’4”
			S. Cobble	25		
			L. Cobble	25		
		180	Silt	100		8”
		183	Silt	100		0
9/29/2003	54	0	Silt	100		0
		10	Silt	50		4”
			Sand	50		
		20	L. Cobble	25		1
			S. Cobble	50		
			Gravel	25		
		30	L. Cobble	25		1
			S. Cobble	50		
			Gravel	25		
		40	L. Cobble	25		1’6”
			S. Cobble	50		
			Gravel	25		

Appendix D. Substrate composition and aquatic vegetation at 64 transects between Crocker-Huffman and Merced Falls dams.						
Date	**Transect Number**	**Transect Interval (Left to Right Facing Downstream)**	**Substrate Type**	**Estimated % of Substrate**	**Aquatic Vegetation Type**	**River Depth (ft)**
		50	L. Cobble	25		1’4”
			S. Cobble	50		
			Gravel	25		
		60	L. Cobble	40		1’8”
			S. Cobble	40		
			Gravel	20		
		70	L. Cobble	40		1’8”
			S. Cobble	40		
			Gravel	20		
		80	L. Cobble	50		2’2”
			S. Cobble	50		
		90	L. Cobble	50		2’4”
			S. Cobble	50		
		100	L. Cobble	50		2’5”
			S. Cobble	50		
		110	L. Cobble	50		2’6”
			S. Cobble	50		
		120	L. Cobble	50		2’6”
			S. Cobble	50		
		130	L. Cobble	50		2’4”
			S. Cobble	50		
		140	L. Cobble	50		2’5”
			S. Cobble	50		
		150	L. Cobble	50		2’6”
			S. Cobble	50		
		160	L. Cobble	40		3’1”
			S. Cobble	40		
			S. Boulder	20		
		170	L. Cobble	40		3’8”
			S. Cobble	40		
			S. Boulder	20		
9/25/2003	55	0	Silt	100		0
		10	Silt	50	American Elodea	3
			S. Boulder	50		
		20	L. Cobble	50		2’11”
			S. Cobble	50		
		30	L. Cobble	50		2’7”
			S. Cobble	50		
		40	L. Cobble	50		2’4”
			S. Cobble	50		
		50	L. Cobble	50		2’2”

Appendix D. Substrate composition and aquatic vegetation at 64 transects between Crocker-Huffman and Merced Falls dams.

Date	Transect Number	Transect Interval (Left to Right Facing Downstream)	Substrate Type	Estimated % of Substrate	Aquatic Vegetation Type	River Depth (ft)
			S. Cobble	50		
		60	S. Boulder	10		2'1"
			L. Cobble	45		
			S. Cobble	45		
		70	S. Boulder	10		2
			L. Cobble	45		
			S. Cobble	45		
		80	S. Boulder	10		2
			L. Cobble	45		
			S. Cobble	45		
		90	S. Boulder	20		2
			L. Cobble	40		
			S. Cobble	40		
		100	L. Cobble	50		2'2"
			S. Cobble	50		
		110	L. Cobble	50		2'5"
			S. Cobble	50		
		120	S. Boulder	20		3
			L. Cobble	40		
			S. Cobble	40		
		130	S. Boulder	20		3'8"
			L. Cobble	40		
			S. Cobble	40		
		140	S. Boulder	20		3'6"
			L. Cobble	40		
			S. Cobble	40		
		150	S. Boulder	50		3'8"
			L. Cobble	25		
			S. Cobble	25		
		160	Bedrock	100		1'4"
		175	Bedrock	100		5"
9/25/2003	56	0	Silt	100		0
		10	S. Boulder	50		2
			L. Cobble	25		
			S. Cobble	25		
		20	L. Cobble	50		2'4"
			S. Cobble	50		
		30	L. Cobble	50		2'4"
			S. Cobble	50		
		40	S. Boulder	20		2'5"
			L. Cobble	40		

Appendix D. Substrate composition and aquatic vegetation at 64 transects between Crocker-Huffman and Merced Falls dams.

Date	Transect Number	Transect Interval (Left to Right Facing Downstream)	Substrate Type	Estimated % of Substrate	Aquatic Vegetation Type	River Depth (ft)
			S. Cobble	40		
		50	S. Boulder	50		2’5”
			L. Cobble	25		
			S. Cobble	25		
		60	S. Boulder	20		2’8’
			L. Cobble	40		
			S. Cobble	40		
		70	S. Boulder	20		3’8”
			L. Cobble	40		
			S. Cobble	40		
		80	S. Boulder	50		3’3”
			L. Cobble	25		
			S. Cobble	25		
		90	S. Boulder	50		3’5”
			L. Cobble	25		
			S. Cobble	25		
		100	S. Boulder	50		3’8”
			L. Cobble	25		
			S. Cobble	25		
		110	S. Boulder	50		4’6”
			L. Cobble	25		
			S. Cobble	25		
		120	L. Boulder	30		5
			S. Boulder	70		
		130	L. Boulder	100		5’7”
		140	L. Boulder	100		3
		150	L. Boulder	100	American Elodea	3’4”
					Coontail	
		160	Silt	100		8”
9/25/2003	57	0	Sand	100		0
		10	Bedrock	100		2’8”
		20	S. Boulder	50		3’8”
			L. Cobble	50		
		30	S. Boulder	50		4’2”
			L. Cobble	50		
		40	S. Boulder	50		4’4”
			L. Cobble	50		
		50	S. Boulder	50		4’4”
			L. Cobble	50		
		60	S. Boulder	50		4’4”
			L. Cobble	50		

Appendix D. Substrate composition and aquatic vegetation at 64 transects between Crocker-Huffman and Merced Falls dams.

Date	Transect Number	Transect Interval (Left to Right Facing Downstream)	Substrate Type	Estimated % of Substrate	Aquatic Vegetation Type	River Depth (ft)
		70	S. Boulder	50		4’6”
			L. Cobble	50		
		80	S. Boulder	50		4’8”
			L. Cobble	50		
		90	L. Boulder	20		4’8”
			S. Boulder	50		
			S. Cobble	30		
		100	L. Boulder	70		2’8”
			S. Boulder	30		
		110	Bedrock	100		2’10”
		120	Silt	100	American Elodea	1’5”
		124	Silt	100		1
9/25/2003	58	0	Bedrock	50		1”
			Gravel	25		
			Sand	25		
		10	Bedrock	50		1’7”
			L. Cobble	50		
		20	Bedrock	50		4
			L. Cobble	50		
		30	S. Boulder	50		3’11”
			L. Cobble	50		
		40	S. Boulder	50		3’10”
			L. Cobble	50		
		50	S. Boulder	50		2’8”
			L. Cobble	25		
			S. Cobble	25		
		60	S. Boulder	50		2’7”
			L. Cobble	25		
			S. Cobble	25		
		70	S. Boulder	50		2’2”
			L. Cobble	25		
			S. Cobble	25		
		80	S. Boulder	50		2’4”
			L. Cobble	25		
			S. Cobble	25		
		90	S. Boulder	50		2’4”
			L. Cobble	25		
			S. Cobble	25		
		100	S. Boulder	50		2’7”
			L. Cobble	25		
			S. Cobble	25		

Appendix D. Substrate composition and aquatic vegetation at 64 transects between Crocker-Huffman and Merced Falls dams.						
Date	**Transect Number**	**Transect Interval (Left to Right Facing Downstream)**	**Substrate Type**	**Estimated % of Substrate**	**Aquatic Vegetation Type**	**River Depth (ft)**
		110	S. Boulder	50		4
			L. Cobble	25		
			S. Cobble	25		
		120	Bedrock	100		3’1”
		123	Silt	100		2’7”
9/25/2003	59	0	Bedrock	100		0
		10	Bedrock	100		3’1”
		20	S. Boulder	50		3’4”
			L. Cobble	50		
		30	S. Boulder	50		2’8”
			L. Cobble	50		
		40	S. Boulder	40		2’8”
			L. Cobble	50		
			S. Cobble	10		
		50	S. Boulder	40		2’6”
			L. Cobble	50		
			S. Cobble	10		
		60	S. Boulder	50		2’4”
			L. Cobble	25		
			S. Cobble	25		
		70	S. Boulder	30		2’1”
			L. Cobble	35		
			S. Cobble	35		
		80	S. Boulder	50		2’4”
			L. Cobble	25		
			S. Cobble	25		
		90	S. Boulder	50		2’4”
			L. Cobble	25		
			S. Cobble	25		
		100	S. Boulder	50		2’2”
			L. Cobble	25		
			S. Cobble	25		
		110	S. Boulder	50		2’2”
			L. Cobble	25		
			S. Cobble	25		
		120	S. Boulder	50		2’4”
			L. Cobble	50		
		130	L. Boulder	25		1’6”
			S. Boulder	25		
			L. Cobble	50		
		140	L. Boulder	100		6”

Appendix D. Substrate composition and aquatic vegetation at 64 transects between Crocker-Huffman and Merced Falls dams.

Date	Transect Number	Transect Interval (Left to Right Facing Downstream)	Substrate Type	Estimated % of Substrate	Aquatic Vegetation Type	River Depth (ft)
		150	L. Boulder	100		11”
9/25/2003	60	0	Silt	20		0
			L. Cobble	40		
			S. Boulder	40		
		10	S. Boulder	50		3
			L. Cobble	50		
		20	S. Boulder	50		3’7”
			L. Cobble	50		
		30	S. Boulder	50		3’10”
			L. Cobble	50		
		40	S. Boulder	50		4’2”
			L. Cobble	50		
		50	S. Boulder	50		4
			L. Cobble	50		
		60	L. Boulder	50		3’11”
			S. Boulder	25		
			L. Cobble	25		
		70	L. Boulder	100		10”
		80	L. Boulder	100	Filamentous Algae	1”
		90	L. Boulder	100		2’1”
		100	L. Boulder	50		10”
			S. Boulder	50		
		102	L. Boulder	50		1”
			S. Boulder	50		
9/25/2003	61	0	S. Boulder	100		0
		10	S. Boulder	80		2’1”
			L. Cobble	20		
		20	S. Boulder	70		4’4”
			M Boulder	20		
			L. Cobble	10		
		30	S. Boulder	70		5’6”
			M Boulder	20		
			L. Cobble	10		
		40	S. Boulder	70		5’7”
			M Boulder	20		
			L. Cobble	10		
		50	S. Boulder	100		5’8”
		60	L. Boulder	30		4’5”
			S. Boulder	70		
		70	L. Boulder	30		2’8”
			S. Boulder	30		

Appendix D. Substrate composition and aquatic vegetation at 64 transects between Crocker-Huffman and Merced Falls dams.

Date	Transect Number	Transect Interval (Left to Right Facing Downstream)	Substrate Type	Estimated % of Substrate	Aquatic Vegetation Type	River Depth (ft)
			L. Cobble	40		
		80	S. Boulder	20		2'4"
			L. Cobble	50		
			S. Cobble	30		
		90	S. Boulder	50		2'4"
			L. Cobble	50		
		100	L. Cobble	100		1'1"
		105	L. Cobble	50		1"
			S. Cobble	50		
9/25/2003	62	0	Silt	100		0
		10	S. Boulder	50		1'8"
			L. Cobble	50		
		20	S. Boulder	50		2'6"
			L. Cobble	50		
		30	S. Boulder	50		3'7"
			L. Cobble	50		
		40	S. Boulder	100		4'8"
		50	S. Boulder	100		5
		60	S. Boulder	50		4'10"
			L. Cobble	50		
		70	S. Boulder	50		4'2"
			L. Cobble	50		
		80	S. Boulder	50		2'8"
			L. Cobble	25		
			S. Cobble	25		
		90	S. Boulder	50		1'4"
			L. Cobble	25		
			S. Cobble	25		
		95	S. Boulder	50		0
			L. Cobble	25		
			S. Cobble	25		
9/29/2003	63	0	S. Boulder	50		0
			L. Cobble	50		
		10	S. Boulder	50		1'10"
			L. Cobble	50		
		20	S. Boulder	50		4
			L. Cobble	50		
		30	S. Boulder	50		4'4"
			L. Cobble	50		
		40	S. Boulder	50		5'6"
			L. Cobble	50		

Appendix D. Substrate composition and aquatic vegetation at 64 transects between Crocker-Huffman and Merced Falls dams.						
Date	**Transect Number**	**Transect Interval (Left to Right Facing Downstream)**	**Substrate Type**	**Estimated % of Substrate**	**Aquatic Vegetation Type**	**River Depth (ft)**
		50	S. Boulder	50		4’7”
			L. Cobble	50		
		60	S. Boulder	50		2’10”
			L. Cobble	50		
		70	M Boulder	10		1’6”
			S. Boulder	40		
			L. Cobble	50		
		80	S. Boulder	50		4”
			L. Cobble	25		
			S. Cobble	25		
		87	S. Boulder	50		0
			L. Cobble	25		
			S. Cobble	25		
9/24/2003	64	0	S. Boulder	30		7”
			L. Cobble	35		
			S. Cobble	35		
		10	S. Boulder	30		1’8”
			L. Cobble	35		
			S. Cobble	35		
		20	L. Boulder	10		3’5”
			S. Boulder	30		
			L. Cobble	30		
			S. Cobble	30		
		30	L. Boulder	10		4’7”
			S. Boulder	30		
			L. Cobble	30		
			S. Cobble	30		
		40	L. Boulder	10		5’7”
			S. Boulder	30		
			L. Cobble	30		
			S. Cobble	30		
		50	S. Boulder	20		6’5”
			L. Cobble	40		
			S. Cobble	40		
		60	S. Boulder	30		7
			L. Cobble	35		
			S. Cobble	35		
		70	S. Boulder	30		7
			L. Cobble	35		
			S. Cobble	35		
		80	S. Boulder	30		7’6”

Appendix D. Substrate composition and aquatic vegetation at 64 transects between Crocker-Huffman and Merced Falls dams.

Date	Transect Number	Transect Interval (Left to Right Facing Downstream)	Substrate Type	Estimated % of Substrate	Aquatic Vegetation Type	River Depth (ft)
			L. Cobble	35		
			S. Cobble	35		
		90	L. Boulder	30		7
			S. Boulder	10		
			L. Cobble	30		
			S. Cobble	30		
		100	L. Boulder	30		6’10”
			S. Boulder	10		
			L. Cobble	30		
			S. Cobble	30		
		110	L. Boulder	30		6’8”
			S. Boulder	10		
			L. Cobble	30		
			S. Cobble	30		
		120	L. Boulder	30		6’6”
			S. Boulder	10		
			L. Cobble	30		
			S. Cobble	30		
		130	L. Boulder	40		7
			S. Cobble	60		
		140	L. Boulder	100		2’5”
		150	L. Boulder	100		2’7”
		160	L. Boulder	100		0
		170	L. Boulder	100		0
		180	L. Boulder	100		1’5”
		190	L. Boulder	100		4’7”
		200	L. Boulder	100		4’7”
		210	L. Boulder	100		4
		220	L. Boulder	70		2’8”
			L. Cobble	30		
		230	L. Boulder	100		1’6”
		240	L. Boulder	100		2’11”

Substrate Size Key

Silt based on observer’s judgment; Sand = <.08"; Gravel = 0.08"-2.5"; Small (S) Cobble = 2.5"-5"; Large (L) Cobble = 5"-10"; Small (S) Boulder = 10"-20"; Medium (M) Boulder = 20"-40"; Large (L) Boulder = >40"; Bedrock based on observer’s judgment

Appendix E. Bank Riparian Habitat Data

Transect (TS)	Bank	Canopy	Density of Coverage	% TS with Vegetation Overhang >5 ft	Vegetation Sighted
0	Right	Upper	High	50	Valley Oak, Alder, Willow, Button Bush
0	Right	Lower	High	20	Concord Grape, Grasses, Cattails
0	Missing Left Bank Data				
1	Missing Left Bank Data				
1	Right	Upper	High	100	Willow, Button Bush, Alder
1	Right	Lower	High	100	Grasses, Cattails
2	Left	Upper	Med	50	Valley Oak, Alder, Willow, Button Bush
2	Left	Lower	Med	20	Concord Grape, Grasses, Blackberry
2	Right	Upper	High	50	Alder, Willow
2	Right	Lower	High	75	Grasses
3	Left	Upper	Low	10	Valley Oak
3	Left	Lower	Low	10	Grasses, Blackberry
3	Right	Upper	High	100	Alder, Willow
3	Right	Lower	High	20	Willow, Grasses
4	Left	Upper	Low	10	Alder
4	Left	Lower	High	75	Concord Grape, Grasses, Blackberry
4	Right	Upper	High	100	Alder, Button Bush
4	Right	Upper	Med	100	Willow
4	Right	Lower	High	100	Grasses, Cattails, Blackberry, Rose
5	Left	Upper	Low	10	Valley Oak, Alder, Button Bush, California Buckeye
5	Left	Lower	Med	5	Grasses, Blackberry
5	Right	Upper	High	50	Valley Oak, Alder, Willow
5	Right	Lower	Med	30	Concord Grape, Grasses, Blackberry
6	Left	Upper	Low	20	Alder, Button Bush
6	Left	Lower	Low	0	Grasses
6	Right	Upper	High	50	Valley Oak, Alder, Willow
6	Right	Lower	Med	30	Concord Grape, Grasses, Blackberry
7	Left	Upper	Low	5	Alder, Button Bush, Grasses, California Buckeye
7	Left	Lower	Low	5	Grasses, Blackberry
7	Right	Upper	High	100	Valley Oak, Alder, Willow, Button Bush, Boxwood Alder

Appendix E. Bank Riparian Habitat Data

Transect (TS)	Bank	Canopy	Density of Coverage	% TS with Vegetation Overhang >5 ft	Vegetation Sighted
7	Right	Lower	High	100	Concord Grape, Grasses, Cattails
8	Left	Upper	Med	80	Valley Oak, Alder, Fig, California Buckeye, Tree of Heaven
8	Left	Lower	High	20	Concord Grape, Blackberry
8	Right	Upper	High	50	Alder, Willow, Button Bush, Boxwood Alder
8	Right	Lower	High	100	Concord Grape, Grasses
9	Left	Upper	Low	20	Valley Oak, Alder, Button Bush
9	Left	Lower	Low	5	Grasses, Blackberry
9	Right	Upper	Med	30	Valley Oak, Alder, Willow, Button Bush
9	Right	Lower	Med	20	Concord Grape, Grasses, Blackberry
10	Left	Upper	Med	20	Valley Oak, Alder, Willow
10	Left	Lower	Med	20	Grasses, Blackberry
10	Right	Upper	High	70	Valley Oak, Alder, Willow, Boxwood Alder
10	Right	Lower	High	70	Concord Grape, Grasses, Blackberry, Rose
11	Left	Upper	Med	50	Alder, Button Bush, Concord Grape, Grasses, Fig, California Buckeye, Tree of Heaven
11	Left	Lower	Med	50	Blackberry
11	Right	Upper	Med	30	Valley Oak, Alder, Willow, Boxwood Alder
11	Right	Lower	High	30	Concord Grape, Grasses, Blackberry, Rose
12	Left	Upper	Med	50	Alder, California Buckeye
12	Left	Lower	Med	50	Concord Grape, Grasses, Blackberry, Poison Oak
12	Right	Upper	Med	60	Valley Oak, Alder, Willow, Boxwood Alder, Fig
12	Right	Lower	Med	0	Blackberry
13	Left	Upper	Low	40	Alder, Button Bush, Ash
13	Left	Lower	Low	40	Grasses, Blackberry, Poison Oak
13	Right	Upper	Med	50	Alder, Willow, Boxwood Alder
13	Right	Lower	Med	0	Concord Grape, Blackberry
14	Left	Upper	Med	50	Valley Oak, Alder, California Buckeye, Ash
14	Left	Lower	Low	5	Grasses, Blackberry
14	Right	Upper	Med	50	Valley Oak, Alder, Willow, Button Bush, Fig
14	Right	Lower	Med	50	Blackberry

Appendix E. Bank Riparian Habitat Data

Transect (TS)	Bank	Canopy	Density of Coverage	% TS with Vegetation Overhang >5 ft	Vegetation Sighted
14	Right	Lower	Med	0	Concord Grape, Grasses, Rose
15	Left	Upper	Low	30	Valley Oak, Alder, Ash
15	Left	Lower	Low	20	Grasses, Blackberry, Rose
15	Right	Upper	Med	30	Valley Oak, Alder, Willow, Boxwood Alder
15	Right	Lower	Med	20	Concord Grape, Blackberry
16	Left	Upper	Low	20	Valley Oak, Alder, California Buckeye
16	Left	Lower	Low	5	Grasses, Blackberry, Fig
16	Right	Upper	Low	10	Alder, Button Bush, Boxwood Alder
16	Right	Lower	Low	0	Grasses
17	Left	Upper	Low	20	Valley Oak, Alder, California Buckeye
17	Left	Lower	Low	10	Grasses, Blackberry
17	Right	Upper	Low	0	Willow
17	Right	Lower	Low	0	Button Bush, Grasses
18	Left	Upper	Med	20	Valley Oak, Alder, Button Bush, Fig, California Buckeye, Ash
18	Left	Lower	Med	10	Button Bush, Concord Grape, Grasses, Blackberry, Poison Oak, Fern
18	Right	Upper	Low	0	Willow
18	Right	Lower	Low	0	Button Bush, Grasses
19	Left	Upper	Low	10	Alder, Button Bush, Fig
19	Left	Lower	High	20	Grasses, Blackberry
19	Right	Upper	Med	40	Valley Oak, Alder, Willow, Fig
19	Right	Lower	Med	10	Concord Grape, Grasses, Blackberry, Fern
20	Left	Upper	Low	10	Valley Oak, California Buckeye
20	Left	Lower	Low	20	Concord Grape, Blackberry
20	Right	Upper	High	50	Valley Oak, Alder, Willow, Button Bush, Boxwood Alder
20	Right	Lower	High	0	Grasses, Blackberry
21	Left	Upper	High	50	Valley Oak, Alder, Fig
21	Left	Lower	High	50	Grasses, Blackberry
21	Right	Upper	High	50	Alder, Willow, Button Bush, Fig
21	Right	Lower	High	20	Concord Grape, Grasses
22	Left	Upper	Low	10	Valley Oak, Willow

Appendix E. Bank Riparian Habitat Data					
Transect (TS)	Bank	Canopy	Density of Coverage	% TS with Vegetation Overhang >5 ft	Vegetation Sighted
22	Left	Lower	Low	10	Grasses, Blackberry, Rose
22	Right	Upper	High	60	Alder, Willow, Button Bush, Boxwood Alder
22	Right	Lower	High	0	Concord Grape, Grasses, Blackberry
23	Left	Upper	Med	30	Alder, Willow, Fig
23	Left	Lower	Med	30	Grasses, Blackberry
23	Right	Upper	High	75	Alder, Willow, Button Bush, Boxwood Alder, Fig
23	Right	Lower	High	20	Concord Grape, Grasses
24	Left	Upper	Low	15	Alder, Willow
24	Left	Lower	Med	100	Grasses, Blackberry
24	Right	Upper	High	70	Alder, Willow, Boxwood Alder
24	Right	Lower	Low	30	Concord Grape
25	Left	Upper	Med	50	Alder
25	Left	Lower	High	0	Grasses, Blackberry
25	Right	Upper	Med	50	Valley Oak, Alder, Willow, Boxwood Alder
25	Right	Lower	Low	0	Rose
26	Left	Upper	Med	50	Alder, Willow
26	Left	Lower	High	0	Grasses, Blackberry
26	Right	Upper	High	50	Valley Oak, Alder, Willow, Boxwood Alder
26	Right	Lower	Low	20	Concord Grape
27	Left	Upper	Low	0	0
27	Left	Lower	High	0	Grasses, Blackberry
27	Right	Upper	Low	10	Valley Oak, Alder, Willow
27	Right	Lower	Low	0	Concord Grape, Grasses, Blackberry
28	Left	Upper	Low	10	Alder, Willow
28	Left	Lower	High	0	Grasses, Blackberry
28	Right	Upper	Low	5	Valley Oak, Button Bush
28	Right	Lower	Low	0	Grasses
29	Left	Upper	Low	15	Alder, Button Bush
29	Left	Lower	High	25	Grasses
29	Right	Upper	Med	50	Valley Oak, Alder, Willow, Button Bush

Appendix E. Bank Riparian Habitat Data					
Transect (TS)	**Bank**	**Canopy**	**Density of Coverage**	**% TS with Vegetation Overhang >5 ft**	**Vegetation Sighted**
29	Right	Lower	Med	50	Willow, Concord Grape, Grasses
30	Left	Upper	Low	0	0
30	Left	Lower	High	0	Grasses
30	Right	Upper	High	70	Valley Oak, Alder, Willow, Boxwood Alder
30	Right	Lower	Low	0	Grasses, Blackberry
31	Left	Upper	Low	0	0
31	Left	Lower	High	0	Grasses
31	Right	Upper	High	70	Alder, Willow
31	Right	Lower	Low	0	Button Bush, Blackberry
32	Left	Upper	Low	0	0
32	Left	Lower	High	0	Button Bush, Grasses, Blackberry
32	Right	Upper	Med	50	Valley Oak, Alder, Willow, Button Bush, Boxwood Alder, Fig
32	Right	Lower	Low	0	Concord Grape, Grasses
33	Left	Upper	Low	10	Alder, Willow
33	Left	Lower	High	0	Willow, Grasses, Blackberry
33	Right	Upper	Low	30	Valley Oak, Alder, Willow, Boxwood Alder, Maple
33	Right	Lower	Low	0	Concord Grape
34	Left	Upper	Low	0	Alder, Button Bush
34	Left	Lower	High	0	Willow, Grasses
34	Right	Upper	Low	20	Valley Oak, Alder, Willow, Button Bush
34	Right	Lower	Low	0	0
35	Left	Upper	Med	30	Valley Oak, Alder, Concord Grape
35	Left	Lower	High	10	Willow, Blackberry
35	Right	Upper	Low	40	Alder, Willow
35	Right	Lower	High	0	Grasses
36	Left	Upper	Med	50	Alder, Willow
36	Left	Lower	Med	10	Grasses
36	Right	Upper	Med	40	Valley Oak, Alder, Button Bush
36	Right	Lower	Low	0	Concord Grape, Blackberry
37	Missing Left Bank Data				

Appendix E. Bank Riparian Habitat Data

Transect (TS)	Bank	Canopy	Density of Coverage	% TS with Vegetation Overhang >5 ft	Vegetation Sighted
37	Right	Upper	Med	50	Valley Oak, Willow, Button Bush, Boxwood Alder
37	Right	Lower	Low	0	Concord Grape, Blackberry
38	Left	Upper	Low	0	0
38	Left	Lower	Low	0	0
38	Right	Upper	High	50	Valley Oak, Willow
38	Right	Lower	High	50	Blackberry
39	Left	Upper	Low	20	Willow, Rose, Cottonwood
39	Left	Lower	Low	70	Blackberry
39	Right	Upper	High	0	Valley Oak, Willow
39	Right	Lower	High	0	Grasses, Blackberry
40	Left	Upper	Low	0	0
40	Left	Lower	Low	0	0
40	Right	Upper	High	50	Willow
40	Right	Lower	High	50	Willow
41	Left	Upper	Med	80	Willow, Button Bush
41	Left	Lower	Med	80	Grasses, Blackberry
41	Right	Upper	Med	40	Alder, Willow, Button Bush
41	Right	Lower	High	30	Grasses, Blackberry
42	Left	Upper	Low	20	Willow
42	Left	Lower	Low	40	Willow, Grasses
42	Right	Upper	Low	0	Alder, Willow
42	Right	Lower	Med	0	Grasses, Blackberry
43	Left	Upper	Med	20	Willow, Concord Grape
43	Left	Lower	Low	20	Button Bush, Grasses
43	Right	Upper	Low	10	Valley Oak, Alder, Boxwood Alder
43	Right	Lower	Low	20	Grasses
44	Left	Upper	Med	30	Willow
44	Left	Lower	Low	30	Grasses
44	Right	Upper	High	80	Willow, Button Bush
44	Right	Lower	High	80	Valley Oak, Concord Grape

Appendix E. Bank Riparian Habitat Data

Transect (TS)	Bank	Canopy	Density of Coverage	% TS with Vegetation Overhang >5 ft	Vegetation Sighted
45	Left	Upper	High	70	Alder, Willow, Boxwood Alder
45	Left	Lower	High	70	Blackberry, Rose
45	Right	Upper	High	80	Willow, Concord Grape
45	Right	Lower	High	80	Alder, Button Bush, Blackberry
46	Left	Upper	Med	50	Willow
46	Left	Lower	Med	50	Button Bush, Concord Grape
46	Right	Upper	Med	70	Willow
46	Right	Lower	Low	70	Concord Grape
47	Left	Upper	Med	20	Alder, Willow
47	Left	Lower	Med	20	Fig
47	Right	Upper	Med	80	Willow, Concord Grape
47	Right	Lower	Med	80	Blackberry
48	Left	Upper	Med	30	Valley Oak, Willow
48	Left	Lower	High	20	Concord Grape, Blackberry
48	Right	Upper	High	70	Willow, Concord Grape
48	Right	Lower	High	70	Willow, Button Bush, Concord Grape
49	Left	Upper	High	40	Valley Oak, Willow, Concord Grape, Fig
49	Left	Lower	High	70	Willow, Concord Grape, Grasses, Blackberry, Fig
49	Right	Upper	High	80	Valley Oak, Willow, Concord Grape
49	Right	Lower	High	80	Button Bush, Concord Grape, Blackberry
50	Left	Upper	High	70	Alder, Willow, Concord Grape
50	Left	Lower	High	50	Willow, Concord Grape
50	Right	Upper	High	50	Willow, Concord Grape, Fig
50	Right	Lower	High	50	Willow, Concord Grape, Blackberry, Fig
51	Left	Upper	High	50	Alder, Willow, Concord Grape
51	Left	Lower	High	50	Willow, Concord Grape, Blackberry, Fig
51	Right	Upper	High	70	Willow, Button Bush, Concord Grape
51	Right	Lower	High	70	Blackberry, Fig
52	Left	Upper	Med	20	Valley Oak, Alder, Willow, Fig
52	Left	Lower	Med	0	Concord Grape, Grasses, Blackberry, Rose

Appendix E. Bank Riparian Habitat Data

Transect (TS)	Bank	Canopy	Density of Coverage	% TS with Vegetation Overhang >5 ft	Vegetation Sighted
52	Right	Upper	Med	50	Willow, Concord Grape, Fig
52	Right	Lower	Med	50	Willow, Concord Grape, Fig
53	Left	Upper	Med	30	Alder, Willow
53	Left	Lower	Med	0	Willow, Grasses, Blackberry
53	Right	Upper	High	70	Willow
53	Right	Lower	High	50	Concord Grape, Honeysuckle
54	Left	Upper	High	50	Alder, Willow, Boxwood Alder
54	Left	Lower	High	10	Button Bush, Blackberry
54	Right	Upper	High	90	Valley Oak, Alder, Willow, Boxwood Alder, Concord Grape, Honeysuckle
54	Right	Lower	High	70	Willow, Boxwood Alder, Concord Grape, Honeysuckle
55	Left	Upper	High	50	Alder, Willow, Button Bush, Boxwood Alder, Concord Grape, Fig
55	Left	Lower	High	50	Willow, Button Bush, Boxwood Alder, Concord Grape, Blackberry
55	Missing Right Bank Data				
56	Left	Upper	Med	50	Alder, Willow, Boxwood Alder, Fig
56	Left	Lower	Med	50	Blackberry
56	Right	Upper	High	50	Alder, Willow, Boxwood Alder, Concord Grape
56	Right	Lower	High	50	Willow, Button Bush, Concord Grape, Blackberry
57	Left	Upper	Med	20	Alder, Willow, Concord Grape
57	Left	Lower	Med	20	Willow, Concord Grape
57	Right	Upper	High	50	Alder, Willow, Concord Grape
57	Right	Lower	High	50	Willow, Button Bush, Concord Grape, Blackberry
58	Left	Upper	High	20	Valley Oak, Alder, Fig
58	Left	Lower	Med	0	Grasses
58	Right	Upper	High	20	Alder, Willow, Boxwood Alder, Concord Grape
58	Right	Lower	High	0	Willow, Button Bush, Concord Grape, Blackberry
59	Left	Upper	Med	10	Alder, Willow, Concord Grape
59	Left	Lower	Low	0	Willow, Boxwood Alder, Concord Grape, Blackberry
59	Right	Upper	Med	20	Alder, Willow, Concord Grape
59	Right	Lower	High	10	Willow, Concord Grape, Grasses, Blackberry
60	Left	Upper	Med	30	Alder, Willow, Concord Grape, Fig

Appendix E. Bank Riparian Habitat Data					
Transect (TS)	**Bank**	**Canopy**	**Density of Coverage**	**% TS with Vegetation Overhang >5 ft**	**Vegetation Sighted**
60	Left	Lower	Low	10	Willow, Concord Grape, Blackberry
60	Right	Upper	High	50	Alder, Willow, Concord Grape
60	Right	Lower	High	50	Willow, Button Bush, Grasses, Blackberry
61	Missing Right and Left Bank Data				
62	Left	Upper	Med	10	Alder, Willow, Boxwood Alder
62	Left	Lower	Low	10	Willow, Grasses, Boxwood Alder
62	Right	Upper	Med	40	Alder, Willow, Concord Grape, Fig
62	Right	Lower	Low	0	Willow, Button Bush, Concord Grape, Grasses, Blackberry
63	Left	Upper	Med	0	Alder, Fig
63	Left	Lower	Med	0	Grasses
63	Right	Upper	Med	40	Alder, Concord Grape
63	Right	Lower	Low	0	Concord Grape, Grasses, Blackberry

Appendix F. Submerged Riparian Habitat Data

Transect (TS)	Bank	Density of Coverage	% TS with Vegetation Overhang >5 ft	Vegetation Sighted
0	Right	Med	50	Willow
0	Missing Left Bank Data			
1	Right	High	60	Willow, Dead Branches
1	Missing Left Bank Data			
2	Left	Med	50	Dead Branches, Dead Fallen Tree, Live Fallen Tree
2	Right	High	100	Willow, Dead Branches
3	Left	Low	10	Dead Branches, Dead Fallen Tree
3	Right	High	100	Willow, Dead Branches
4	Left	Med	50	Dead Branches, Dead Fallen Tree, Live Fallen Tree
4	Right	Med	70	Dead Branches, Live Fallen Tree
5	Left	High	70	Dead Branches, Dead Fallen Tree, Live Fallen Tree
5	Right	Low	0	No Submerged Habitat
6	Left	Low	10	Dead Branches
6	Right	Med	50	Dead Branches, Dead Fallen Tree
7	Left	Low	20	Dead Branches, Dead Fallen Tree, Live Fallen Tree
7	Right	High	100	Dead Branches, Dead Fallen Tree
8	Left	Med	50	Dead Branches, Dead Fallen Tree
8	Right	Med	70	Dead Fallen Tree
9	Left	Low	10	Dead Fallen Tree
9	Right	Med	50	Dead Fallen Tree
10	Left	Med	50	Blackberry, Dead Branches, Dead Fallen Tree, Live Fallen Tree
10	Right	Med	70	Dead Branches, Dead Fallen Tree
11	Left	Med	50	Blackberry, Dead Branches, Dead Fallen Tree
11	Right	Med	50	Dead Branches
12	Left	Med	50	Blackberry, Dead Branches, Dead Fallen Tree
12	Right	Med	40	Dead Branches, Dead Fallen Tree
13	Missing Left Bank Data			

Appendix F. Submerged Riparian Habitat Data

Transect (TS)	Bank	Density of Coverage	% TS with Vegetation Overhang >5 ft	Vegetation Sighted
13	Right	Med	50	Dead Branches, Dead Fallen Tree
14	Left	Med	50	Dead Branches, Dead Fallen Tree, Live Fallen Tree
14	Right	Med	50	Dead Branches, Dead Fallen Tree
15	Left	Low	20	Dead Branches
15	Right	High	100	Dead Branches, Dead Fallen Tree
16	Left	Med	50	Blackberry, Dead Branches, Dead Fallen Tree
16	Right	Low	30	Dead Fallen Tree
17	Left	Med	20	Blackberry
17	Left	Med	50	Dead Branches
17	Right	Low	0	No Submerged Habitat
18	Left	Med	30	Blackberry, Dead Branches, Dead Fallen Tree
18	Right	Med	50	Willow, Dead Branches, Live Fallen Tree
19	Left	Med	50	Blackberry, Dead Branches, Dead Fallen Tree
19	Right	Med	80	Dead Branches, Dead Fallen Tree
20	Left	Med	30	Blackberry, Dead Branches, Dead Fallen Tree
20	Right	Low	40	Dead Branches, Dead Fallen Tree
21	Left	Low	30	Dead Branches, Dead Fallen Tree
21	Right	Low	40	Dead Branches, Dead Fallen Tree
22	Left	Low	30	Dead Branches
22	Right	High	80	Dead Branches, Dead Fallen Tree
23	Left	Med	50	Willow, Dead Branches, Dead Fallen Tree, Live Fallen Tree
23	Right	High	100	Dead Branches, Dead Fallen Tree
24	Left	Low	10	Dead Branches
24	Right	Med	70	Dead Branches, Live Fallen Tree
25	Left	Med	15	Dead Branches, Dead Fallen Tree
25	Right	Low	30	Dead Branches, Dead Fallen Tree
26	Left	Low	5	Dead Branches, Dead Fallen Tree
26	Right	Low	30	Dead Branches, Live Fallen Tree

Appendix F. Submerged Riparian Habitat Data

Transect (TS)	Bank	Density of Coverage	% TS with Vegetation Overhang >5 ft	Vegetation Sighted
27	Left	Low	0	No Submerged Habitat
27	Right	Low	20	Dead Branches
28	Left	Low	0	Dead Branches
28	Right	Low	0	No Submerged Habitat
29	Left	Low	5	Live Fallen Tree
29	Right	Low	20	Dead Branches
30	Left	Low	0	No Submerged Habitat
30	Right	Low	30	Dead Branches
31	Left	Low	0	No Submerged Habitat
31	Right	Med	50	Dead Branches
32	Left	Low	5	Dead Branches
32	Right	Low	40	Dead Branches, Dead Fallen Tree
33	Left	Low	15	Dead Branches
33	Right	Low	10	Dead Branches
34	Left	Low	0	No Submerged Habitat
34	Right	Low	30	Willow, Dead Branches
35	Left	Low	30	Blackberry, Dead Branches, Dead Fallen Tree
35	Right	Low	30	Dead Branches, Dead Fallen Tree
36	Left	Low	30	Dead Branches, Live Fallen Tree
36	Right	Low	20	Dead Branches
37	Missing Left Bank Data			
37	Right	Low	10	Dead Branches
38	Left	Low	0	No Submerged Habitat
38	Right	Low	0	No Submerged Habitat
39	Left	Low	0	No Submerged Habitat
39	Right	Low	0	No Submerged Habitat
40	Left	Low	30	Dead Branches
40	Right	Low	10	Willow

Appendix F. Submerged Riparian Habitat Data

Transect (TS)	Bank	Density of Coverage	% TS with Vegetation Overhang >5 ft	Vegetation Sighted
41	Left	Med	50	Willow
41	Right	Low	0	No Submerged Habitat
42	Left	Med	70	Dead Branches
42	Right	Low	10	Dead Branches
43	Left	Low	0	No Submerged Habitat
43	Right	Med	50	Dead Branches, Dead Fallen Tree
44	Left	Med	50	Dead Branches
44	Right	High	100	Dead Branches, Dead Fallen Tree
45	Left	High	100	Dead Branches, Dead Fallen Tree
45	Right	High	100	Dead Fallen Tree
46	Left	Med	70	Dead Branches
46	Right	Med	70	Dead Branches
47	Left	Low	0	No Submerged Habitat
47	Right	High	80	Willow, Dead Branches
48	Left	Med	70	Dead Branches
48	Right	High	100	Willow, Dead Branches
49	Left	Med	50	Willow, Dead Branches
49	Right	High	80	Willow, Dead Branches
50	Left	High	80	Willow, Dead Branches
50	Right	High	50	Willow, Dead Branches
51	Left	Med	50	Willow, Dead Branches
51	Right	Med	60	Dead Branches
52	Left	Low	0	No Submerged Habitat
52	Right	Low	40	Dead Branches
53	Left	Low	30	Willow
53	Right	Low	30	Dead Branches
54	Left	Low	20	Willow
54	Right	Med	50	Willow

Appendix F. Submerged Riparian Habitat Data				
Transect (TS)	**Bank**	**Density of Coverage**	**% TS with Vegetation Overhang >5 ft**	**Vegetation Sighted**
55	Left	Low	20	Willow
55	Missing Right Bank Data			
56	Left	Low	20	Willow, Dead Branches
56	Right	High	70	Willow
57	Left	Low	40	Dead Branches
57	Right	Med	70	Dead Branches
58	Left	Low	0	No Submerged Habitat
58	Right	Low	20	Willow
59	Left	Low	20	Dead Branches
59	Right	Low	10	Willow, Dead Fallen Tree
60	Left	Low	10	Dead Branches
60	Right	Low	0	No Submerged Habitat
61	Missing Right and Left Bank Data			
62	Left	Low	10	Dead Branches
62	Right	Low	0	No Submerged Habitat
63	Left	Low	0	No Submerged Habitat
63	Missing Right Bank Data			