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The Resources Agency
Department of Water Resources

South Delta Temporary Barriers Project

2003 South Delta Temporary Barriers
Monitoring Report

FINAL

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Contents

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Chapter 1. Introduction

The Department of Water Resources (DWR) issued the Draft Environmental Impact Report and Environmental Impact Statement for the South Delta Water Management Program in 1990. Objectives of the program are to achieve the following:

1. Increase water levels, circulation patterns and water quality in the southern Delta area for local agricultural diversions.

2. Improve operational flexibility of the State Water Project to help reduce fishery impacts and improve fishery conditions.

Because of concerns related to both agriculture and the fisheries, the Temporary Barriers Project (TBP) was initiated to better determine effects of installing permanent barriers in the southern Delta. A five-year program began in 1991 to test a facsimile of the proposed barriers. In 1996, this test was extended for another five years. In 2001, DWR received an extension from the US Army Corp of Engineers to construct and operate the South Delta Temporary Barrier Project from 2001-2007. Because of varying hydrological conditions, and therefore varying hydrodynamic patterns, as well as concerns for endangered species, the number of barriers installed and the installation schedules have been different each year of the program. The barrier installation and removal dates are based on the US Army Corp of Engineers 404 Permit, the California Department of Fish and Game 1601 Permit and various Temporary Entry Permits required from landowners and local reclamation districts. Table 1-1 shows installation and removal dates for the various years of the Project.

Although the South Delta TBP has been in place since 1991, the Middle River barrier and the fall Head of Old River barrier have been installed in earlier years under different programs. The Grant Line Canal barrier was installed for the first time in 1996, at a site about 4.5 miles east of the originally proposed location. In 1997, the spring Head of Old River barrier was installed with two 48-inch culverts. In 1998, none of the barriers were installed due to high river flows throughout the spring and summer. In 1999, the Head of Old River barrier was not installed in the spring or the fall but the other barriers were installed. In 2000-2003, all the barriers were installed (see table at end of introduction).

Subsequent to the 2001 project extension, a new DWR Monitoring Plan was developed that specifically complies with the requirements of: 1) the April 4, 2001 California Department of Fish and Game (DFG) Incidental Take Permit No. 2081-2001-009-BD, 2) the March 29, 2001 DFG Streambed Alteration Agreement No. BD-2001-0001, 3) the April 5, 2001 National Marine Fisheries Service (now called NOAA Fisheries) Biological Opinion (BO), 4) the March 30, 2001 Fish and Wildlife Service BO for the Department of Water Resources Temporary Barriers Project 2001-2007.

The DWR Monitoring Plan consists of specific elements that are discussed in the following chapters. DWR participates in and /or funds these monitoring efforts. In some cases, funding may be augmented by Interagency Ecological Program (IEP) and /or CALFED funds. The elements of the monitoring plan came from permit conditions required by DFG, NOAA Fisheries, and USFWS. It covers fish species including salmon, steelhead, delta smelt and splittail. Also included are terrestrial species such as Swainson's hawks, pond turtles, and sensitive plants. The following are brief descriptions of each chapter.

Chapter 2. Fish Monitoring and Water Quality Analysis (Prepared by Tobi Rose DFG)

In 2001, a pilot study was developed to provide an experimental approach to determining the behavioral response of fish with the installation of the temporary barriers in the south Delta, however, this project was cancelled due to insufficient data collection and recapture capabilities. A revised program was planned for 2003, however, funding and personnel shortages precluded implementation, therefore the fish monitoring study was not conducted in 2003. Future studies are planned but implementation will be dependent on the availability of necessary staff.

Water quality analysis was conducted and physical water quality parameters were monitored not only for their possible effect on the fisheries but for other pertinent biological information, such as null zones.

Chapter 3. Fish Entrainment Monitoring at the Head of Old River Barrier (Prepared by Andy Rockriver DFG)

Fish entrainment monitoring at the Head of Old River Barrier (HORB) was designed and implemented by the Department of Fish and Game (DFG) to evaluate and quantify fish entrainment with the following specific objectives:

Determine the total number of juvenile Chinook salmon and other fish species entrained through the culverts at the HORB.

- Determine the percentage of coded-wire tagged (CWT) salmon released at Mossdale and Durham Ferry entrained into Old River.

- Determine tidal and diel effects on juvenile Chinook salmon entrainment.

The results are intended to provide information on the design and operation of a future permanent operable barrier at the head of Old River.

Chapter 4. Salmon Smolt Survival Investigations (Prepared by Patricia Brandes USFWS)

This section describes the methods used in conducting the 2003 Vernalis Adaptive Management Plan (VAMP) Chinook salmon smolt survival investigations, and presents results of the calculated survival indices and absolute survival estimates for juvenile Chinook salmon during the VAMP 2003 test period.

Chapter 5. Annual Summary Report of SWP and CVP Salvage (Prepared by Jim Long DWR)

This chapter discusses the effects the TBP has on fish entrainment at the Skinner (State Water Project) and Tracy (Central Valley Project) fish facilities. Daily salvage densities were analyzed and compared to TBP operations, Delta hydrodynamics, and project export flows.

Chapter 6. Swainson's Hawk Monitoring and Mitigation (Prepared by Mike Bradbury DWR)

This section describes Swainson's hawk observations and the effects of the barriers construction activities on nesting pairs within _ mile radius of the sites.

Chapter 7. Water Elevations (Prepared by Mike Abiouli DWR)

Monitoring was conducted to determine the effects of the barriers on water surface elevations and circulations patterns in the southern Delta channels.

Chapter 8. South Delta Water Quality (Prepared by Shaun Philippart DWR)

This monitoring was conducted to evaluate the changes in various water quality parameters due to installation and operation of the barriers. The water quality parameters measured included water temperature, dissolved oxygen, specific electrical conductivity, and turbidity. Water samples were also sent to an analytical laboratory for analysis of dissolved ammonia, dissolved nitrite and nitrate, dissolved organic nitrogen, dissolved orthophosphate, chlorophyll a, and pheophytin a.

Chapter 9. Hydrologic Modeling (Prepared by Bob Suits DWR)

The DWR Delta Simulation Model, DSM2-Hydro, was used to conduct a hydrodynamic simulation of the effects the temporary barriers have on water levels in the south Delta for the year 2003. The DSM2-simulated stages and flows are then compared to historical data in the south Delta.

Table 1 - Schedule of Installation and Removal Dates for South Delta Temporary Barriers from 1987 through 2003

	Middle River							*Old River near Tracy (DMC)*							*Grant Line Canal*						
	Installation			*Notched*	*Removal*			*Installation*			*Notched*	*Removal*			*Installation*			*Flashboards*	*Removal*		
Year	*Started*	*Closed*	*Completed*		*Started*	*Breached*	*Completed*	*Started*	*Closed*	*Completed*		*Started*	*Breached*	*Completed*	*Started*	*Closed*	*Completed*	*Adjusted*	*Started*	*Breached*	*Completed*
1987			15-May		End of Sep		End of Sep														
1988	26-May		28-May		23-Sep		23-Sep														
1989			12-Apr		26-Sep		26-Sep														
1990			16-Apr		29-Sep		29-Sep														
1991	4-Apr		5-Apr		27-Sep		27-Sep	14-Aug		30-Aug		28-Sep		13-Oct. (i)							
1992	8-Apr		10-Apr		28-Sep		29-Sep	15-April boat port on		01-May 09-May boat port on		30-Sep		Oct-09(ii)							
1993	14-Jun		17-Jun		23-Sep		24-Sep	12-May		1-Jun		27-Sep		6-Oct							
1994	23-Apr		25-Apr		29-Sep		5-Oct	22-April boat port on. All culverts tied open (5/18 to 6/1)		24-April 01-May		26-Sep		10-Oct							
1995	8-Aug		11-Aug		10-Oct		10-Oct	3-Aug		8-Aug		27-Sep		6-Oct							
1996	18-May		20-May		29-Sep		29-Sep	12-May		10-Jun (iii)		29-Sep		16-Oct	17-Jun		10-Jul		2-Oct		15-Oct
1997	3-Apr		7-Apr		27-Sep		28-Sep	8-Apr		17-Apr		30-Sep		7-Oct	21-May		4-Jun		26-Sep		15-Oct
1998	(vii)							(vii)							(vii)						
1999	15-May		18-May		29-Sep		2-Oct	15-May		28-May		28-Sep		8-Oct	15-May		3-Jun		23-Sep		5-Oct
2000	4-Apr		6-Apr		1-Oct		7-Oct	4-Apr		16-Apr		1-Oct		7-Oct	19-May		1-Jun		1-Oct		7-Oct
2001	20-Apr		23-Apr		12-Nov	13-Nov	17-Nov	23-Apr		26-Apr		13-Nov	14-Nov	26-Nov	2-May		9-May		11-Nov	12-Nov	18-Nov
2002	10-Apr		15-Apr		20-Nov	20-Nov	23-Nov	1-Apr		18-Apr		16-Nov	16-Nov	29-Nov	1-Apr		12-Jun		14-Nov	16-Nov	25-Nov
2003	12-Apr	15-Apr	23-Apr	17-Sept.	7-Nov	8-Nov	10-Nov	1-Apr	14-Apr	22-Apr	17-Sept.	13-Nov	15-Nov	25-Nov	1-Apr. (Partial) 9-June (Full)	11-Jun	23-Apr. (Partial) 17-June (Full)	16-Sept.	10-Nov	12-Nov	25-Nov

	Spring Head of Old River						*Fall Head of Old River (v)*						
	Installation			*Removal*			*Installation*			*Notched*	*Removal*		
Year	*Started*	*Closed*	*Completed*	*Started*	*Breached*	*Completed*	*Started*	*Closed*	*Completed*		*Started*	*Breached*	*Completed*
1987							9-Sep		11-Sep				28-Nov
1988							22-Sep		28-Sep				2-Dec
1989							27-Sep		28-Sep		27-Nov		30-Nov
1990							10-Sep		11-Sep				27-Nov
1991							9-Sep		13-Sep		22-Nov		27-Nov
1992	15-April boat port on		23-April @ 4ft 26-April@6ft 01-May	2-Jun		8-Jun	8-Sep		11-Sep		30-Nov		4-Dec
1993							8-Nov (vii)		11-Nov		3-Dec		7-Dec
1994	21-April boat port on		23-April@10ft 01-May	18-May		20-May	6-Sep		8-Sep		28-Nov		30-Nov
1995	(vii)						(vii)						
1996	6-May		11-May	16-May		3-Sept (iv)	30-Sep		3-Oct		18-Nov		22-Nov
1997	9-Apr		16-Apr	15-May		19-May (viii)							
1998	(vii)						(vii)						
1999	(vii)						(viii)						
2000	5-Apr		16-Apr	19-May		2-Jun	27-Sep		7-Oct		27-Nov		8-Dec
2001	17-Apr		26-Apr	23-May		30-May	24-Sep		6-Oct		22-Nov	22-Nov	2-Dec
2002	2-Apr		18-Apr	22-May	24-May	7-Jun	24-Sep		4-Oct		11-Nov	12-Nov	21-Nov
2003	1-Apr	15-Apr	21-Apr	16-May	18-May	3-Jun	2-Sept.	15-Sept.	18-Sep	16-Sept.	3-Nov	4-Nov	13-Nov

(i) Barrier notched on Sept. 28, 1991. Construction resumed on Oct. 10 and finished on Oct. 13.
(ii) Barrier notched on Sept. 30, 1992. Construction resumed on Oct. 2 and finished on Oct. 9.
(iii) Construction was delayed on 5/17 and resumed on 6/5 due to high flows.
(iv) Barrier was breached on 5/ 16 on an emergency basis, but complete removal wasn't done until 9/3, after Corps demanded permit compliance of complete removal.
(v) Barrier was installed in previous years.
(vi) Installation delayed due to high flows.
(vii) Not installed due to high San Joaquin River flows.
(viii) Not installed upon DFG's request.

Chapter 2. Fisheries Monitoring and Water Quality Analysis

Introduction

The South Delta Temporary Barriers Project (TBP) began in 1991 and consists of the construction, operation, and monitoring of four temporary rock fill barriers. Three of the barriers, located in three south Delta channels (Grant Line Canal, Old and Middle rivers), are constructed seasonally and operate during the agricultural season, usually April through October. They are designed for two purposes: (1) the improvement of water levels and circulation patterns for agricultural users and (2) the collection of data for the design of permanent barriers. The fourth barrier, located at the head of Old River, is designed as a fish barrier and is installed and removed twice a year; once in the spring and once in the fall. The spring barrier prevents fall-run San Joaquin River Chinook salmon smolts, as well as Central Valley steelhead smolts in the San Joaquin River watershed, from migrating down through Old River towards the Central Valley Project (CVP) and the State Water Project (SWP) export pumping facilities. This barrier is also installed in the fall to increase water quality on the San Joaquin River downstream of the barrier. Of the four barriers, the Middle River barrier (MIDRB) near Victoria Slough has been installed since 1987; the Old River barrier (OLDRB) near Tracy pumping plant has been installed since 1991; the Grant Line Canal barrier (GLCB) near the Tracy Boulevard overpass has been installed since 1996; and the spring head of Old River barrier (HORB) was installed in 1992, 1994, 1996, 1997, and 2000-2003. In 1998, high flows in south Delta channels prevented the installation of all four temporary barriers, however, the monitoring program continued as planned.

Since 1992, a seasonal fish-sampling program has monitored the fishery resources and water quality in the project area. From 1996 through 2000, the fish monitoring program was changed from a year round sampling study, that gathered only descriptive (qualitative) information, to a study conducted March through October concentrated on providing not only qualitative but quantitative measures of potential effects of the barriers on the various fish species inhabiting the channels. In 2001, a pilot study was developed to provide an experimental approach to determining the behavioral response of fish to the installation of the temporary barriers. However, this project was cancelled due to insufficient data collection and recapture capabilities.

In 2002 and 2003, fisheries monitoring was not conducted, however, physical water quality parameters were monitored not only for their possible affects on the fisheries but for other pertinent biological information, such as null zones. A null zone occurs when the upstream flow of water negates the downstream flow of water, creating an area with zero net flow and potentially poorer water quality for fisheries. The objectives of the 2003 study plan were:

1. Determine water quality profiles of the channels affected by the temporary barriers.

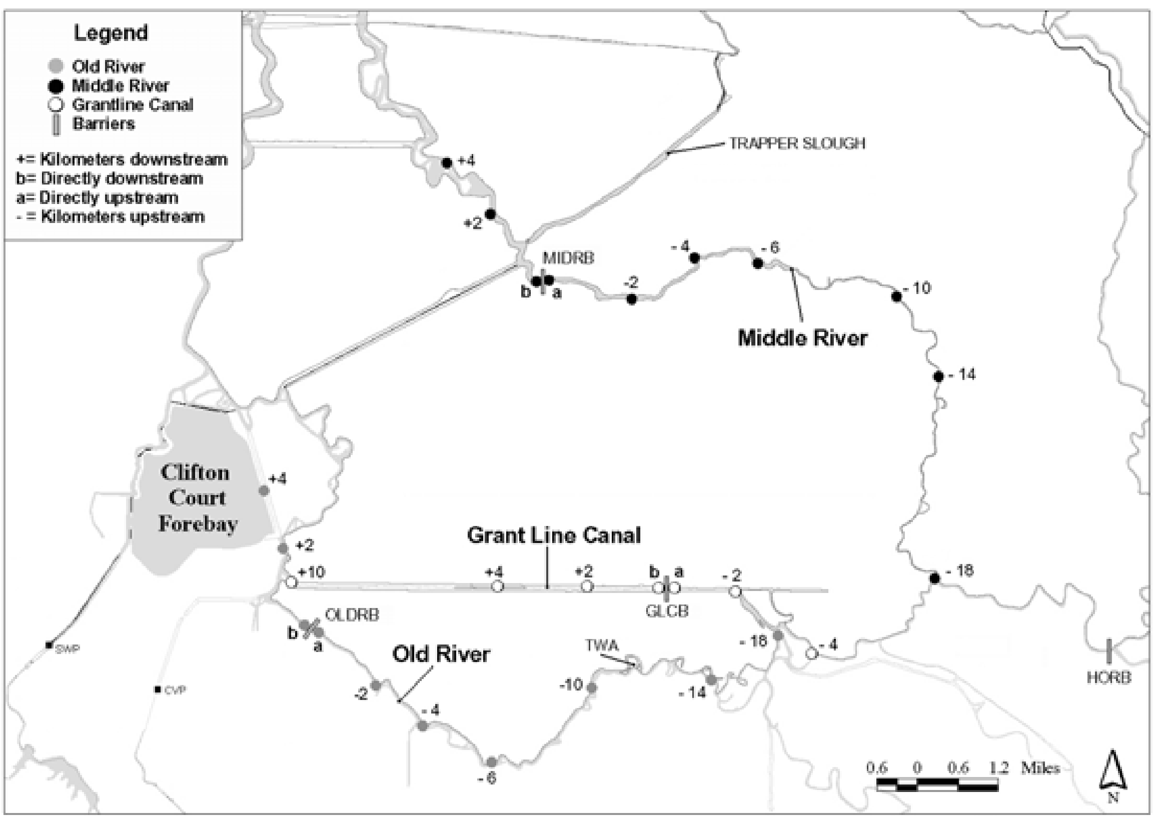
2. Determine any null zones within the south Delta.

Materials and Methods

Twenty-seven permanent water quality sites were sampled on Grant Line Canal, Old and Middle rivers (Figure 2-1). A hydrolab was used to determine water temperature in ºC, dissolved oxygen in mg/L, and specific conductance in _mhos/cm (the water's ability to conduct an electric current and is directly related to the total dissolved salts or ions normalized to 25ºC). Turbidity was measured in NTUs (the degree to which light is scattered by suspended particles) using a portable turbidimeter. Two replicate water samples were collected at each site at depths equal to 40 and 60 percent of the total depth. Water samples were taken from downstream to upstream at the beginning of each tidal stage (ebb and flood tides). Tidal stage, location, and time were recorded at each permanent site. Monthly air temperature was collected from the Tracy Pumping Plant station off of the Western Regional Climate Center Website (www.wrcc.dri.edu).

Each channel's water quality parameters were compared over time (months) and location (sampling sites). Three different water quality profiles were graphed for each channel and parameter: (1) the monthly mean in relation to the barrier (Figures 2-2 through 2-5); (2) the overall mean in relation to the barrier (Figure 2-6); and (3) the monthly mean over time (Figure 2-7). A three-way analysis of variance (ANOVA) was used to compare tide, month, and sampling site. A table was completed that lists these results (Table 2-1). As in 2002, the data used for statistical analysis this year was an average of the four samples taken at each location. Further statistical analysis will include pairwise comparison tests (Bonferroni and Tukey) and correlations between all four variables of each channel. Statistical analysis was not performed on Middle River's data because of insufficient data collection due to various mechanical difficulties of equipment and other project requirements.

Figure 2-1 Map of southern Delta indicating water quality sampling sites.



Results and Discussion

The water quality results from 2003 are similar to the 2001 and 2002 results. All three sets of graphs show similar trends. However, there were some differences and they are addressed in the following sections.

Specific Conductance (Figures 2-2, 2-6A, 2-7A)

As in 2001 and 2002, the specific conductance of 2003 was higher upstream than downstream. Old River had the highest overall specific conductance and Middle River had the lowest. Each channel showed similar patterns of specific conductance for each month. This may indicate a relationship between specific conductance and location. The highpoint in specific conductance was 4 km upstream of the OLDRB and 18 km upstream of the MIDRB. Grant Line Canal's specific conductance had slight fluctuations similar to the past two years, however, the March and April readings were much higher compared to other months and years.

The ANOVAs performed on Old River and Grant Line Canal indicate the mean specific conductance for all sites are significantly different. The same statistical analyses were done for the tides and months with similar results. Also, the pairwise statistical tests indicate that Grant Line Canal's specific conductance measurements were similar for all sites, except for one site 10 km downstream of the barrier.

The results indicate a possible relationship between specific conductance and location. The high points in specific conductance indicate areas of possible null zones in both Middle and Old rivers (Figure 2-9). The ANOVA results indicate that specific conductance varies greatly for both channels within months, sites, and tides. These variances may be caused by farming activities such as: agricultural diversion/return locations, amount of water used and returned, and the time of year it is used. These agricultural effects may also be amplified due to the below normal water year.

Dissolved Oxygen (Figures 2-3, 2-6B, 2-7B)

As in 2001 and 2002, the 2003 dissolved oxygen values were initially elevated during the spring and then decreased throughout the summer months, before improving again in October. All three channels had similar monthly dissolved oxygen patterns that suggest a relationship between dissolved oxygen and the time of year. The most important characteristic for all three channels is that at some point the dissolved oxygen fell below 5.0 mg/L, the minimum water quality objective stated in the California Regional Water Quality Control Board's Basin Plan (4^{th} ed.). The average dissolved oxygen levels per site were similar for all three channels downstream of the barriers however, upstream of the barriers, the values disperse from one another. Sags in dissolved oxygen occurred directly downstream of both OLDRB and GLCB. However, these sags were not as low as they were in 2002. Middle River's dissolved oxygen sag was located approximately 6 km upstream of the MIDRB. The dissolved oxygen spike that appears in May on Middle River is due, in part, to the collection of only one set of data that month instead of the standard four sets per month.

The ANOVAs performed on Old River and Grant Line Canal indicate the mean dissolved oxygen for all sites and months are significantly different. However, the same statistical analysis that was done for both tides indicates no significant difference. Furthermore, the pairwise statistical tests indicate that Grant Line Canal's dissolved oxygen measurements are equal for all sites. The correlation between dissolved oxygen and water temperature is evident for Old River and Grant Line Canal with the Pearson's correlation coefficients being -0.67 and -0.60, respectively.

Results suggest a possible relationship between dissolved oxygen and the time of year. Sags in dissolved oxygen in all three channels could indicate areas where null zones are present (Figure 2-9). The ANOVA results indicate that the tides may not have an effect on dissolved oxygen, but the location and months have an effect. Also, the negative correlation shows that as the water temperature increases, the dissolved oxygen decreases. Variances in dissolved oxygen may be due to water temperature, water agitation, localized (agricultural) nutrient loading, and primary production.

Water Temperature (Figures 2-4, 2-6C, 2-7C)

2003 water temperatures are similar to 2001 and 2002 in that the profile for all three channels began low, then increased over the summer, and dropped off in October. This trend is the exact opposite of the dissolved oxygen profile. All three channels show approximately identical monthly averages in water temperature that suggests a relationship between water temperature and the time of year. Also, the monthly water temperature compared to the average monthly air temperature for the Delta (Figure 2-8) shows that the water temperature of all three channels changes along with the air temperature.

The ANOVA results on the water temperature data were different compared to other parameters. Old River and Grant Line Canal's analysis indicates no significant difference for all sites and tides, however, a significant difference is shown among months. The negative correlation between water temperature and dissolved oxygen was mentioned in the dissolved oxygen section. Unlike last year, there is no correlation between water temperature and turbidity this year.

The results indicate a possible relationship between water temperature and the time of year. This means that the water temperature of all channels varies greatly month to month but varies insignificantly site to site, which is supported by the ANOVA results. Furthermore, the statistical results indicate that the tides do not affect Old River and Grant Line Canal's water temperature. Finally, water temperature seems to follow air temperature based on the graphical data.

Turbidity (Figures 2-5, 2-6D, 2-7D)

Turbidity measurements normally stayed well below 50 NTU's. All three channels had increased turbidity upstream of the barrier in June with spikes located just downstream of the OLDRB and 14 km upstream of the MIDRB. In contrast, Middle River had an apparent decrease in the overall turbidity in May. However, this could be explained by the fact that only one sample was collected that month and most likely biased the data shown in Figure 2-7D.

The ANOVA results for Old River and Grant Line Canal indicate no significant difference for the tides. However, a significant difference is shown among the sites and months. Also, the pairwise statistical tests indicate that Grant Line Canal's turbidity measurements are similar for all sites, except for one site 10 km downstream of the barrier.

Results indicate a possible relationship between turbidity and location. For all three channels, statistical tests show location and time of year had an effect on turbidity and that the tides had no effect. The varying turbidity may be caused by various activities such as agricultural diversion/return locations, suspended solids from agricultural runoff, water recreation (water agitation), bottom feeders, etc.

In summary, there is a possible relationship between the water quality parameters, dissolved oxygen and water temperature, and the time of year (months) and there is a possible relationship between the water quality parameters, specific conductance, water clarity, and turbidity, and the location (sampling sites). Potential null zones are present in Middle River and Old River due to highpoints in specific conductance. Similarly, all three channels have sags in dissolved oxygen indicating other potential null zones. Statistical tests show that the time of year may affect all water quality parameters on Old River and Grant Line Canal. Location appears to have no effect on water temperature for both channels but may have an effect on the other water quality parameters. In Old River and Grant Line Canal, the tides seem to only affect specific conductance. This may be due to Old River / Grant Line Canal's proximity to the SWP and CVP export facilities. These facilities may alter the tidal effects on the water quality due to their water intake during the high tidal cycle. Also, water temperature seems to tracks the ambient air temperature and thus air temperature may have an indirect effect on dissolved oxygen levels. Finally, all the water quality parameters seem to be affected by similar activities such as agricultural diversion/ return locations, amount of water used for agricultural purposes, water agitation, localized nutrient loading, suspended solids from agricultural runoff, primary production, algae blooms, erosion, bottom feeders, low flow, and a below normal water year.

There are two important topics that need to be discussed pertaining to the water quality in the south Delta. First is the aggressive growth of water hyacinth in Old and Middle rivers. This year the growth of hyacinth on Old River was so extreme that by the end of August, the crew was often unable to complete the sampling due to the inability of the boat to traverse the waterway. However, in less severe cases, the sampling was still completed but not in the usual timeframe. This led to inconsistent data collection that in turn may have affected the data analyses.

The second topic is the fish kill that occurred on Old River this year near the Tracy Wildlife Association (TWA). This is the second year in a row a fish kill has occurred in that area. Last year, the crew was on site when this was taking place and determined that extremely low dissolved oxygen was the cause. However, the cause of the low dissolved oxygen was unknown. The area on Old River that had low dissolved oxygen as an indicator for potential null zones was close to the barrier, while the TWA is approximately 12 km upstream of the barrier. This site will be added to the field sampling to better monitor the water quality in upcoming years.

A map of the south Delta's agricultural diversions/returns (Figure 2-10) has been completed for this report. There were an overwhelming number of structures in the area and each will have to be looked at more closely. Due to time constraints this will be completed at a future date.

Recommendations

A similar study is planned for 2004 to further evaluate effects of the temporary barriers on the south Delta water quality. A TWA site will be added to our field study to evaluate any changes in water quality that could potentially affect fish populations. Finally, a map of the south Delta's agricultural diversions/returns has been compiled and further evaluation of the structures, as compared to the water quality sites, should be completed.

Table 2-1 ANOVA results for south Delta water quality. Results indicating no significant difference are denoted by bold type. Noteworthy results from pairwise comparison tests are denoted by an asterisk.

Event	Factor	Grant Line Canal				Old River		
		df	F-ratio	P		df	F-ratio	P
tides	specific conductance	1	15.27	<0.01		1	4.36	0.04
	dissolved oxygen	**1**	**2.85**	**0.10**		**1**	**0.77**	**0.38**
	water temperature	**1**	**0.22**	**0.64**		**1**	**0.55**	**0.46**
	turbidity	**1**	**1.28**	**0.26**		**1**	**3.82**	**0.05**
months	specific conductance	7	39.09	<0.01		7	32.11	<0.01
	dissolved oxygen	7	62.06	<0.01		7	110.61	<0.01
	water temperature	7	120.73	<0.01		7	264.94	<0.01
	turbidity	7	70.73	<0.01		7	57.86	<0.01
sampling sites	specific conductance	6	*6.59	<0.01		9	72.74	<0.01
	dissolved oxygen	6	*2.52	0.03		9	8.44	<0.01
	water temperature	**6**	**0.12**	**0.99**		**9**	**1.57**	**0.13**
	turbidity	6	*3.31	<0.01		9	36.72	<0.01

Figure 2-2 Monthly specific conductance in relation to the barriers.

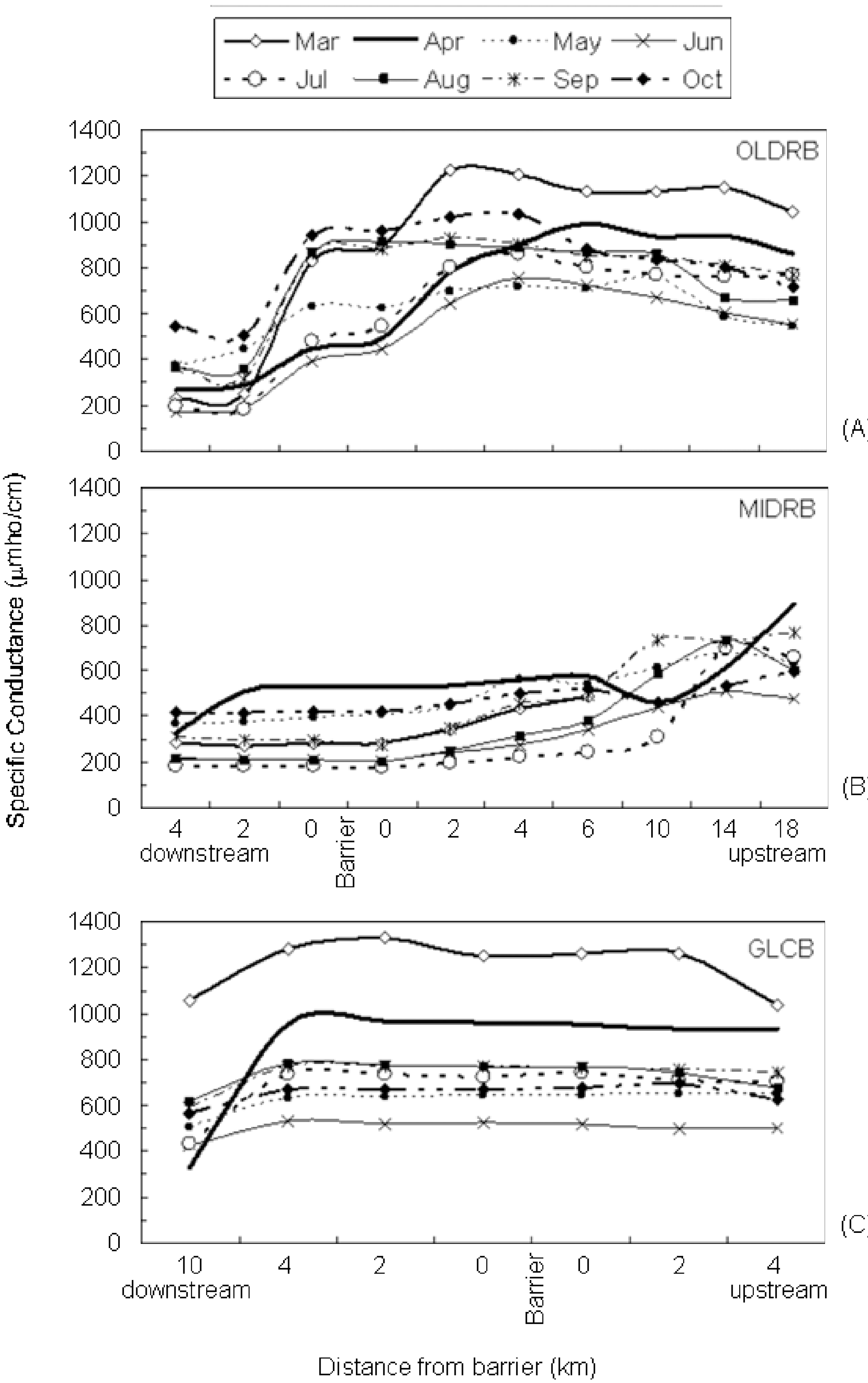


Figure 2-3 Monthly dissolved oxygen in relation to the barriers.

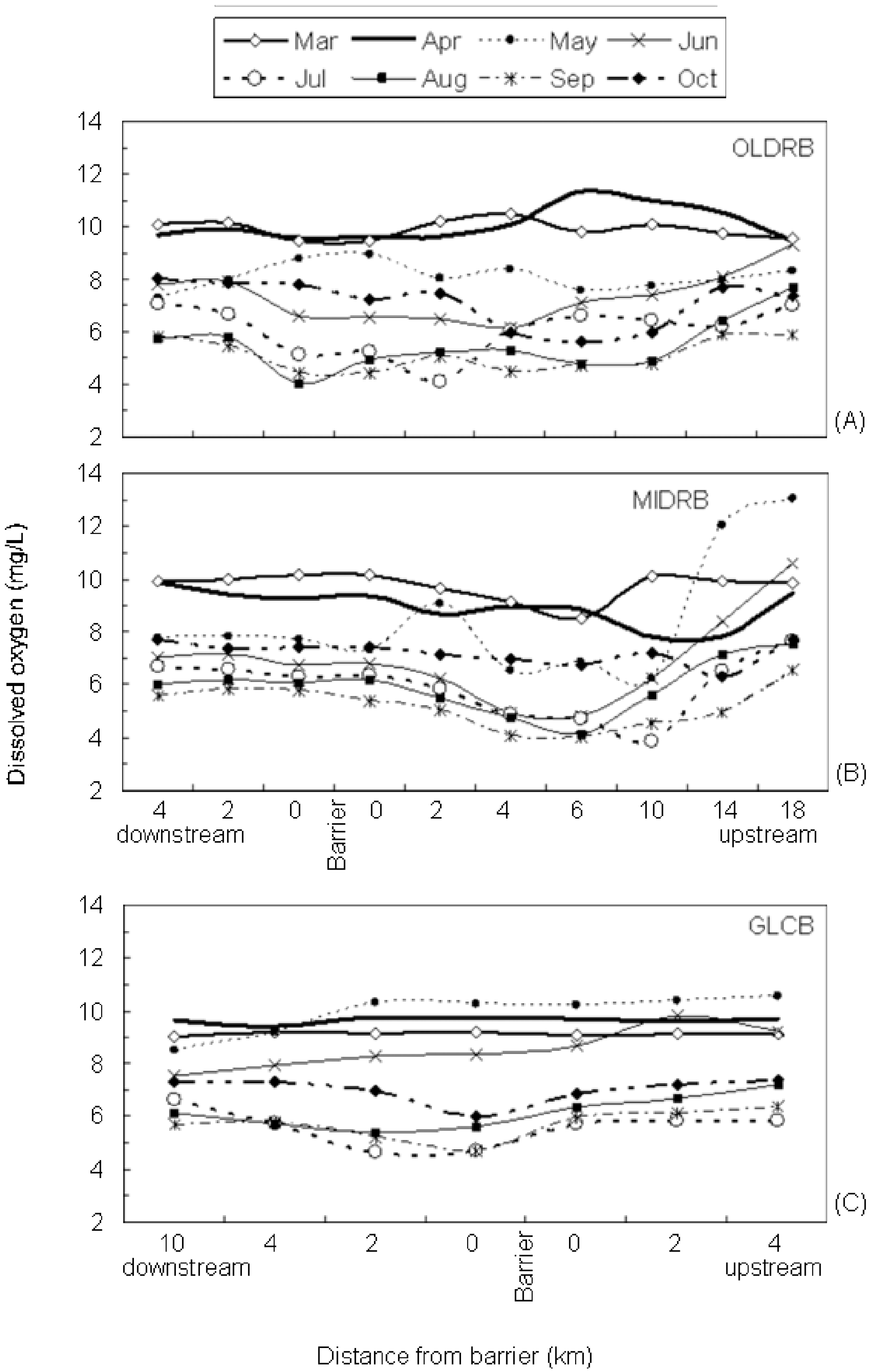


Figure 2-4 Monthly water temperature in relation to the barriers.

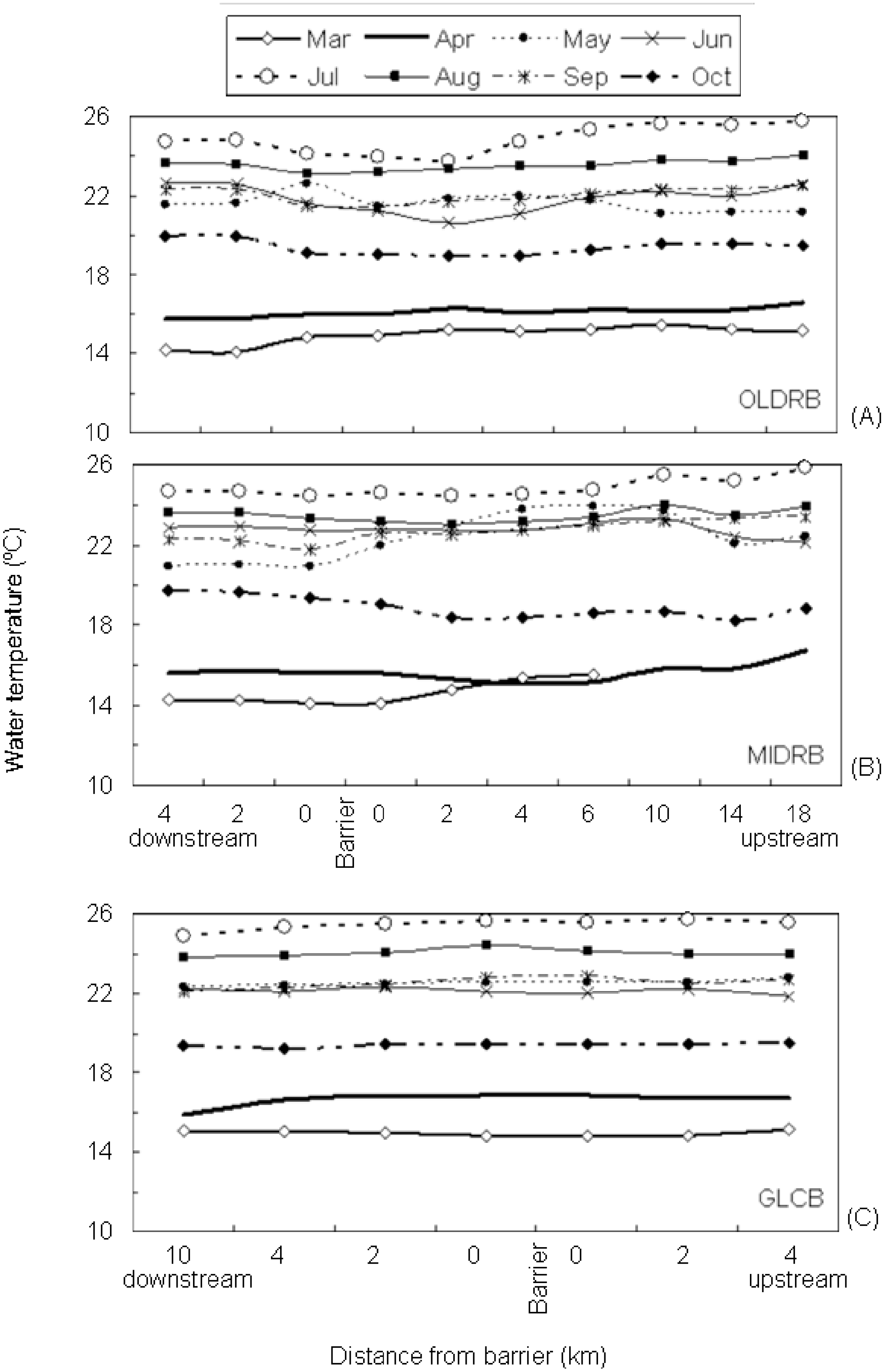


Figure 2-5 Monthly turbidity in relation to the barriers.

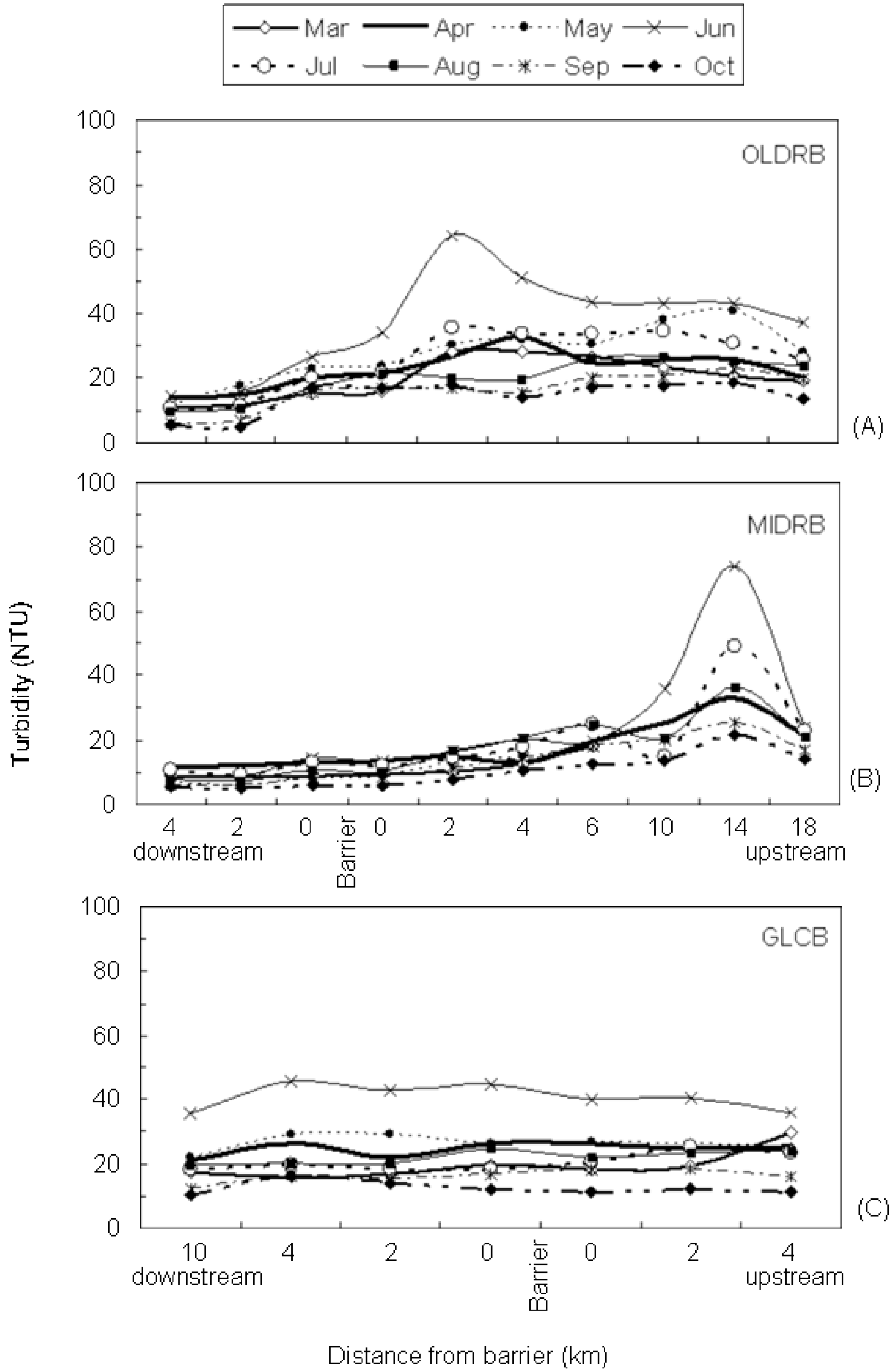


Figure 2-6 Water quality parameters in relation to the barriers. Grant Line Canal was sampled 10km downstream to 4km upstream of the barrier. Old and Middle rivers were sampled 4km downstream to 18km upstream of the barriers.

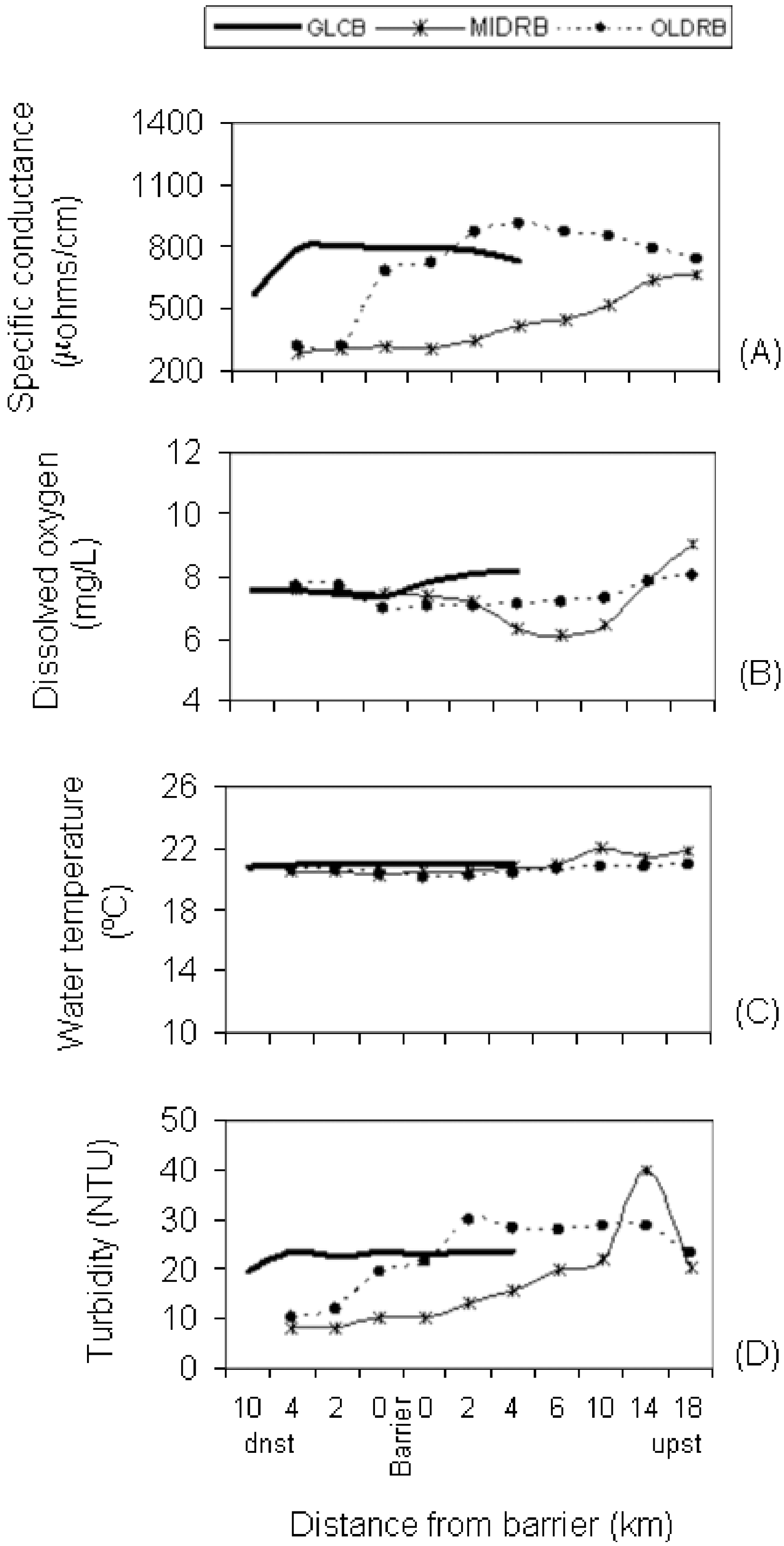


Figure 2-7 Monthly water quality parameters.

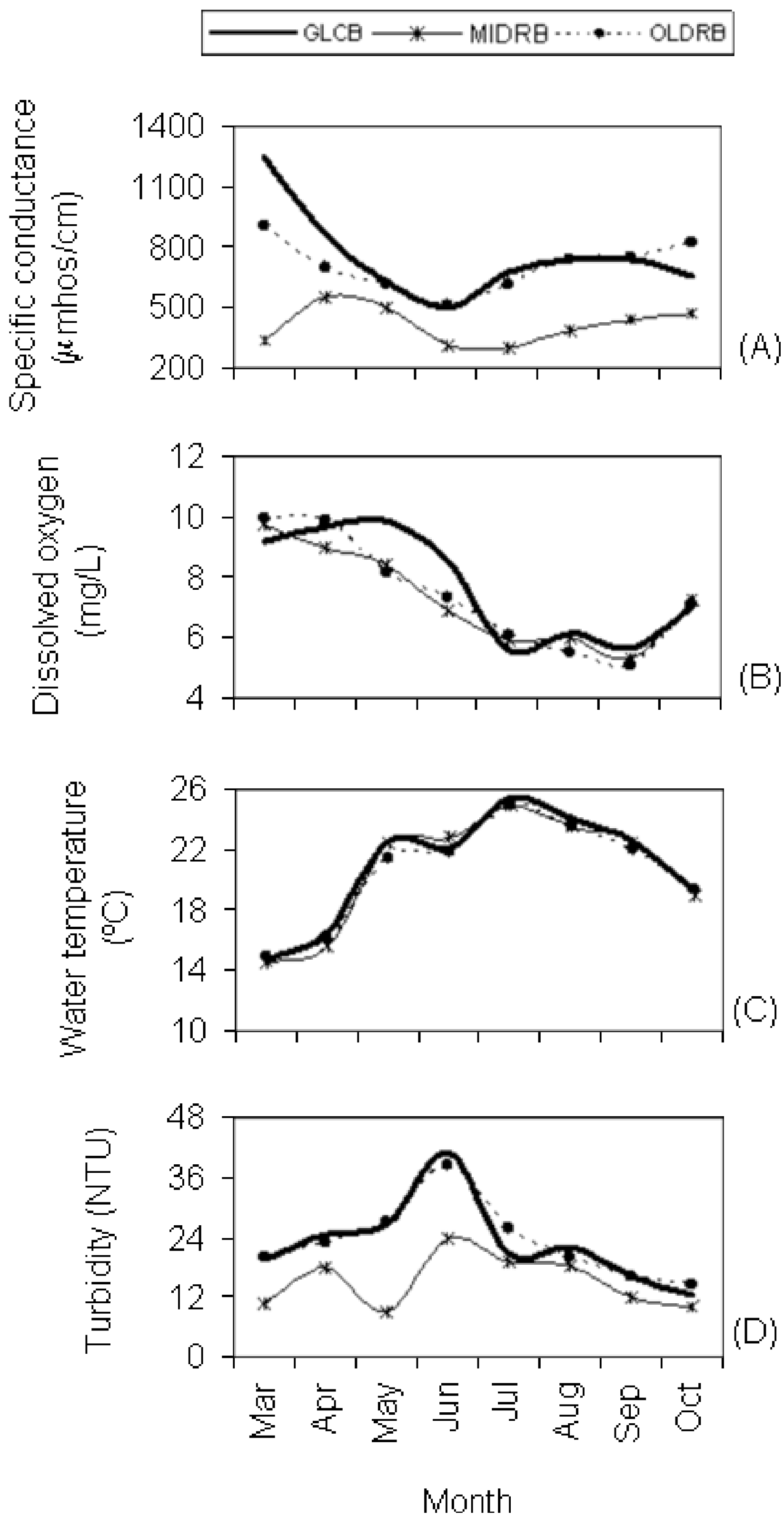


Figure 2-8 Monthly water temperature, air temperature, and dissolved oxygen for the southern Delta.

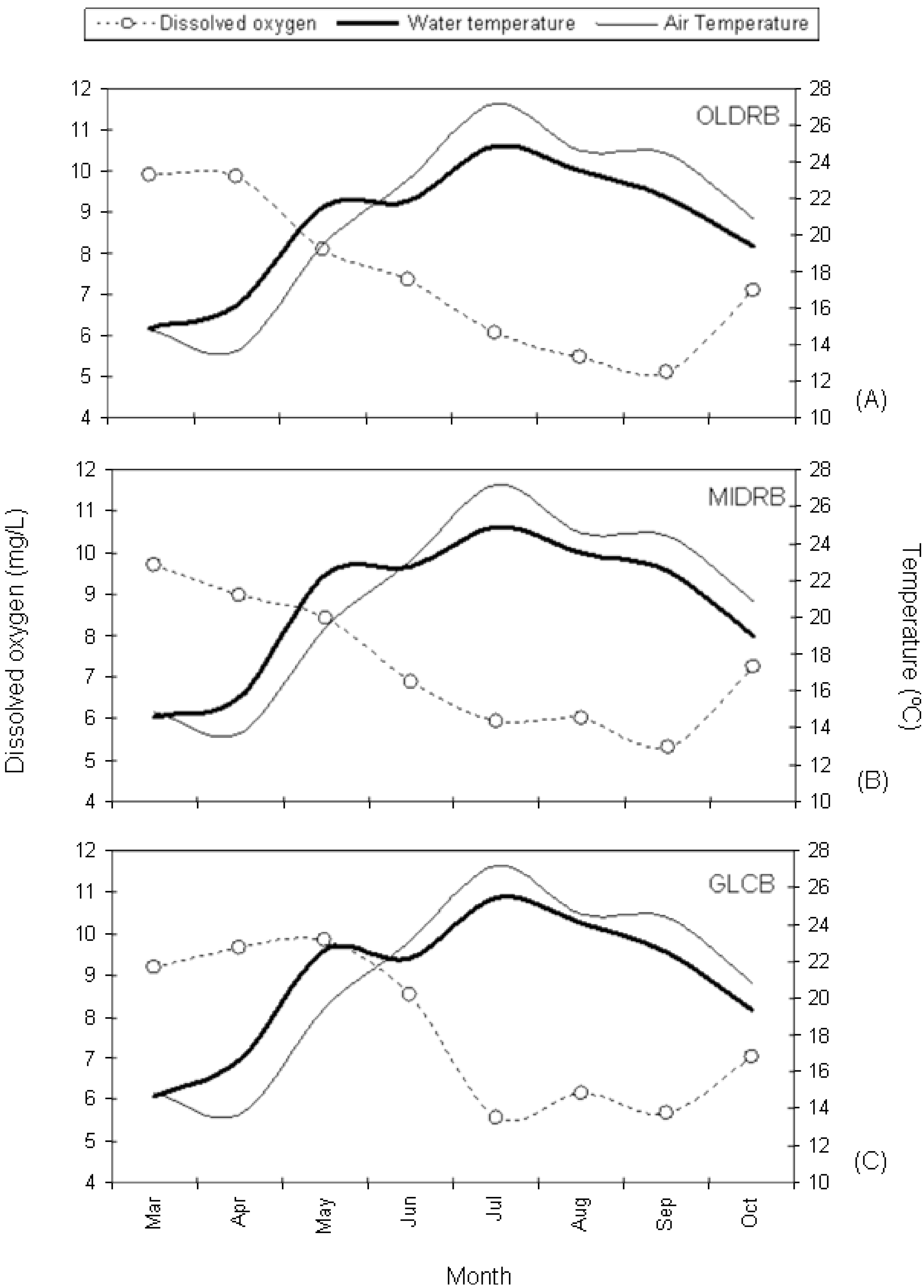


Figure 2-9 Map of possible null zones in southern Delta.

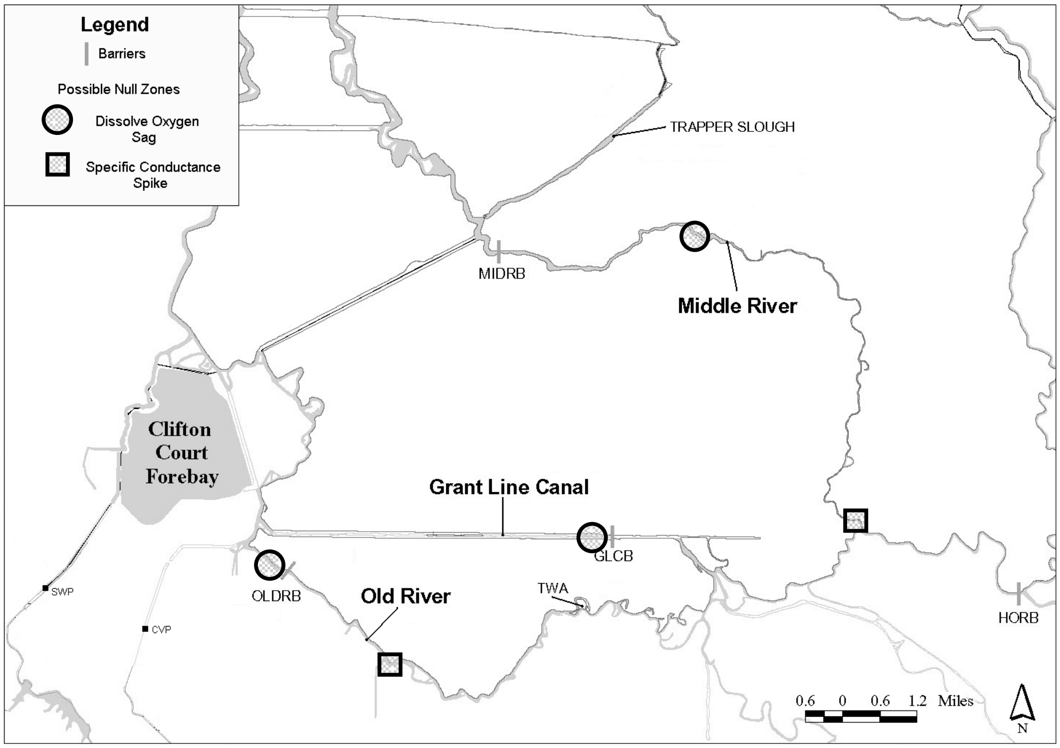
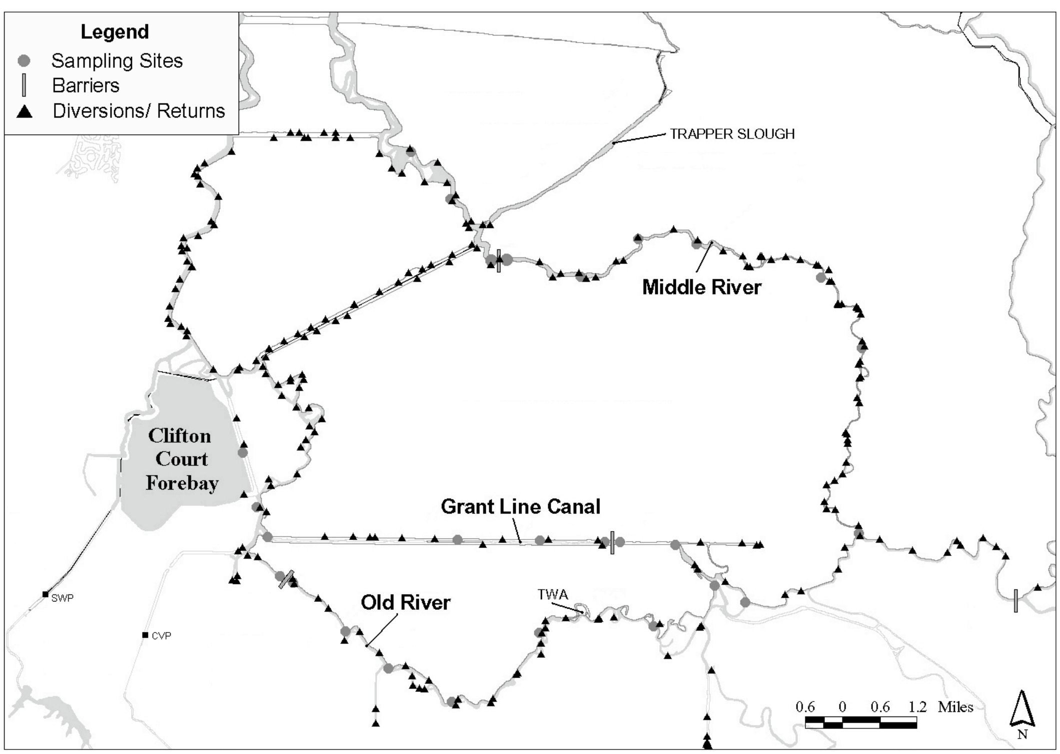


Figure 2-10 Map of southern Delta indicating agricultural diversions/returns in relation to water quality sampling sites.

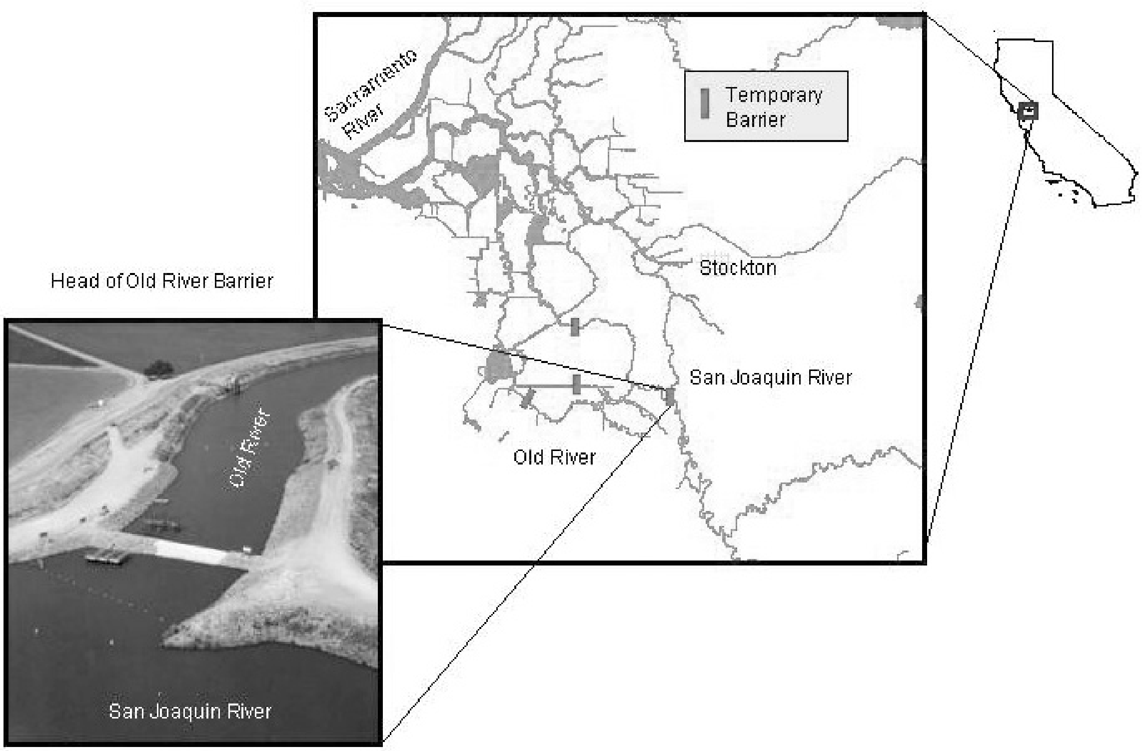


Chapter 3. Fish Entrainment Monitoring at the Head of Old River Barrier

The South Delta Water Management Program was developed in 1990 to achieve two objectives. One was to increase water levels, improve circulation patterns and improve water quality for local agricultural diversions in the south Delta. The other was to improve operational flexibility of the State Water Project (SWP) to help reduce fishery impacts and improve fishery conditions. To meet these objectives, a plan was designed to have four permanent barriers placed at key locations throughout the south Delta. The South Delta Temporary Barriers Project was implemented to study the effectiveness of barriers, using temporary barriers as stand-ins for the permanent barriers.

A temporary rock barrier was designed for the head of Old River to meet the fishery objectives. The barrier is located where Old River diverges from the San Joaquin River, just downstream of Mossdale (Figure 3-1). This barrier is constructed each spring to block the passage of out-migrating San Joaquin River juvenile Chinook salmon (*Oncorhynchus tshawytscha*) into Old River which leads to the SWP and Central Valley Project export facilities.

Figure 3-1 The locations of the south delta temporary barriers with an enlargement of the head of Old River barrier.



In 1997, the South Delta Water Agency (SDWA) expressed concern about water volume and quality in upper Old River due to the installation of the spring head of Old River barrier (HORB). To address this concern, the Department of Water Resources (DWR) requested authorization from the Department of Fish and Game (DFG), through section 1601 of the Fish and Game Code, to modify the existing design of the HORB and install two 48-inch culverts at an average invert elevation of minus four feet (top of the culverts would be at zero foot elevation). DWR indicated that, at flows of 6,500 cfs in the San Joaquin River, the culverts allow approximately 300 cfs to flow through the barrier and down Old River. The DFG, U.S. Fish and Wildlife Service (USFWS), and National Marine Fisheries Service (NMFS) agreed to DWR's modification with the provision that the DFG would monitor the diversion of fish through the newly installed culverts.

In 2000, the DWR again modified the HORB to include six 48-inch gated culverts. The culverts allow approximately 1,000 cfs to flow through the barrier and down Old River. The culvert gates are operated to meet water level objectives of the SDWA. In 2001, the HORB was modified with trash racks to control the amount of debris flowing into the culverts. These racks were small enough to stop most debris from entering the culverts but large enough to allow the passage of Chinook salmon smolts. The design of the HORB has not changed since 2001. As in the previous two years, the 2003 barrier was assembled with six culverts that were gated and operated to address water level concerns of the SDWA.

There is still some uncertainty on how to operate a barrier (permanent or temporary) to both effectively protect out-migrating juvenile salmon on the San Joaquin River and address agricultural water use concerns in Old River. Fish entrainment monitoring at the HORB culverts helps to assess the fishery impacts of the barrier. Specifically, it can help to determine if the modified barrier with culverts is adequate protection for San Joaquin River juvenile Chinook salmon. The 2003 study was designed to increase our understanding of salmon entrainment at the HORB and help develop operational scenarios to minimize the impacts to out-migrating salmon and other species of concern.

During the 2003 Vernalis Adaptive Management Plan (VAMP) test period, all six culverts in the HORB were installed; however, only three of the culverts were open. Since the culverts are not screened, juvenile Chinook salmon and other fish species that pass near the culverts are vulnerable to entrainment. A fish monitoring program was designed and implemented by the DFG to evaluate and quantify fish entrainment at the HORB. The specific objectives of the 2003 fishery investigations were to:

- Determine the total number of juvenile Chinook salmon and other fish species entrained through the culverts at the HORB (Entrainment Monitoring);
- Determine the percentage of coded-wire tagged (CWT) salmon released at Mossdale and Durham Ferry that are entrained into Old River (Entrainment Monitoring); and
- Determine tidal and diel effects on juvenile Chinook salmon entrainment (Entrainment Special Study).

Materials and Methods

As part of the VAMP 2003 studies, approximately 75,000 VAMP CWT juvenile salmon, identifiable by clipped adipose fins, were released at Durham Ferry on April 21 and approximately 50,000 CWT salmon were released at Mossdale on April 22. The Mossdale release was split in half with 25,000 of the fish released around noon and a second group of 25,000 released at 6 pm. The same size releases were repeated on April 28 and 29 at Durham Ferry and Mossdale, respectively, with the Mossdale release again done in two halves. Salmon from the VAMP releases were used in the Entrainment Monitoring studies. For the Entrainment Special Study, eight uniquely color-marked groups of juvenile Chinook salmon (approximately 3,000 fish per group) were marked with photonic fluorescent microspheres at the Merced River

Hatchery. The salmon were transported to the HORB and placed in live cages where they were held at least 10 hours before release. Each color-marked group was released approximately one mile upstream of the HORB, in the middle of the San Joaquin River. The color-marked releases coincided with the two VAMP salmon releases. On the night of April 22, one group of fish was released on the ebb tide and one group on the flood tide. The following day, a group was released on the subsequent ebb and flood tides. The process was repeated on April 29.

Fish entrained into the culverts were caught with fyke nets. The nets have a 48-inch cylindrical mouth tapering down to a 1-foot square cod-end, are made of _ inch braided mesh, and are 60 feet long. A live-box (15.5 x 19.5 x 36 inches), constructed of perforated aluminum sheet metal, was attached to the cod-end of each net. Each live-box has an aluminum baffle designed to reduce water velocities within the live-box and improve survival of captured fish. The fyke nets were attached to the culvert flanges on April 17. The culverts were numbered 1 through 6 with number 1 located next to the shoreline and number 6 located mid-channel (Figure 3-2). The nets were attached to the culverts by closing the culvert slide gates on the upstream side of the barrier, raising the flanges that slide over the culvert outfalls, and then strapping the nets over the flanges. On April 21, flanges for culvert numbers 4, 5, and 6 were lowered down to the culvert outfalls and live-boxes were attached to the cod-end of the nets to commence sampling.

Figure 3-2 Culverts in the HORB were numbered 1-6, with number 1 closest to shore. Culvert numbers 1-3 were closed in 2003.

The fyke nets were checked on every tide change until May 10. From May 10 through May 12, the nets were checked at 04:00, 08:00, 18:00 and 22:00. On May 13, the nets were removed. The nets were checked by closing the culvert slide gate for about 30 minutes which enabled the live-boxes to be pulled onto a boat so that the fish could be removed and placed into buckets. The collected fish were processed once all the nets had been checked and reset. The fish were identified to species and counted. Fork lengths (mm) were recorded for up to 50 salmon per live-box. Salmon were checked for a clipped adipose fin or for the presence of a color mark on the dorsal, anal, or caudal fin. Salmon that had a clipped adipose fin were saved for CWT processing. The color and location of the dyed fin was noted for each color-marked salmon. Culvert number, date, time, water temperature, tidal stage, and diel-period were recorded for each net check. Except for the CWT smolts, all processed fish were released downstream of the fyke nets into Old River.

Loss indices for the CWT salmon released as part of the VAMP survival studies at Durham Ferry and Mossdale were calculated based on data collected from April 21 to May 12. The loss index represents the percentage of CWT salmon entrained into the HORB culverts. The loss index (I) is calculated using the equation I=(TC/TR) where:

TC = Total number of CWT salmon collected in the fyke nets

TR = Total number of CWT released

For the two occasions when all three nets were pulled and the culverts were still open, the number of salmon entrained was estimated by averaging the salmon entrainment the day before and after the time period the nets were pulled. Catch-Per-Unit-Effort (CPUE) for salmon was calculated as the number of fish collected per hour. The percentage of color-marked salmon recovered in the fyke nets compared to the total number released was used as another index of entrainment vulnerability at the HORB.

Results

The HORB was closed on April 15; however, construction on the barrier continued for another week. The DFG monitored the HORB culverts for 22 days and collected 246 samples. The nets sampled 1,421 hours out of a possible 1,581 hours. Approximately 7,000 fish were collected representing at least 26 species (7 native) from 12 families of fish. No delta smelt (*Hypomesus transpacificus*), 2 juvenile steelhead (*Oncorhynchus mykiss*), and 45 adult splittail (*Pogonichthys macrolepidotus*) were collected. The most abundant species was Chinook salmon, followed by white catfish (*Ictalurus catus*) and common carp (*Cyprinus carpio*) (Table 3-1). These 3 fish comprised 90 % of the total entrainment. Of the 4,872 salmon caught; 2,511 had a CWT; 1,937 were unmarked; and 424 had a color mark. Overall, the amount of salmon entrained per hour (3.4) with the 3 culverts was higher than the 6 culverts in 2003 (2.5 salmon/hour) and in 2002 (1.4 salmon/hour).

Table 3-1 The raw abundance and composition of fishes entrained at the HORB in 2003. Chinook salmon catch is divided into CWT salmon (VAMP and nonVAMP), unmarked salmon, and color-marked salmon.

Species	Catch
American shad	1
Western mosquitofish	1
Spotted bass	1
Warmouth bass	1
Yellowfin goby	1
Petromyzontidae spp.	2
Golden shiner	2
Prickly sculpin	2
Steelhead	2
Black crappie	4
Tule perch	4
Largemouth bass	5
Bigscale logperch	6
Striped bass	7
Green sunfish	9
Ameiurus spp.	12
Inland silverside	13
Redear sunfish	13
Bluegill	37
Splittail	45
Goldfish	58
Sacramento sucker	65
Channel catfish	161
Threadfin shad	273
Common carp	383
White catfish	1,170
Total Chinook salmon	4,872
CWT VAMP salmon	1,819
CWT nonVAMP salmon	692
Unmarked salmon	1,937
Color-marked Chinook salmon	308
Total	**7,150**

Salmon smolts were caught throughout the monitoring period (Figure 3-3). Most of the VAMP released salmon were caught within two days of their release. During the first VAMP salmon release, CWT salmon entrainment was the highest on the evening of April 22, especially for the Mossdale evening released fish (Figure 3-4). For the second VAMP release, the highest salmon entrainment occurred during the night of April 29 (Figure 3-5). The loss indices for the first Durham Ferry and Mossdale releases were 0.5 % and 1.6 %, respectively. The loss indices for the second Durham Ferry and Mossdale releases were 0.3 % and 0.8%, respectively. Within the Mossdale releases, the highest loss indices were for the releases that occurred in the evening: 3.1 % for the first release and 1.5 % for the second release. Both of the day releases at Mossdale had a loss index of 0.1 %. The overall loss index for VAMP CWT salmon was 0.7 %. This year’s overall loss index was lower than in 2002 (1.5 %) but similar to 2001 (0.5 %) and 2000 (0.8 %) loss indices.

Figure 3-3 Daily average number of salmon entrained per hour at the HORB in 2003. The total catch is divided into CWT and unmarked salmon.

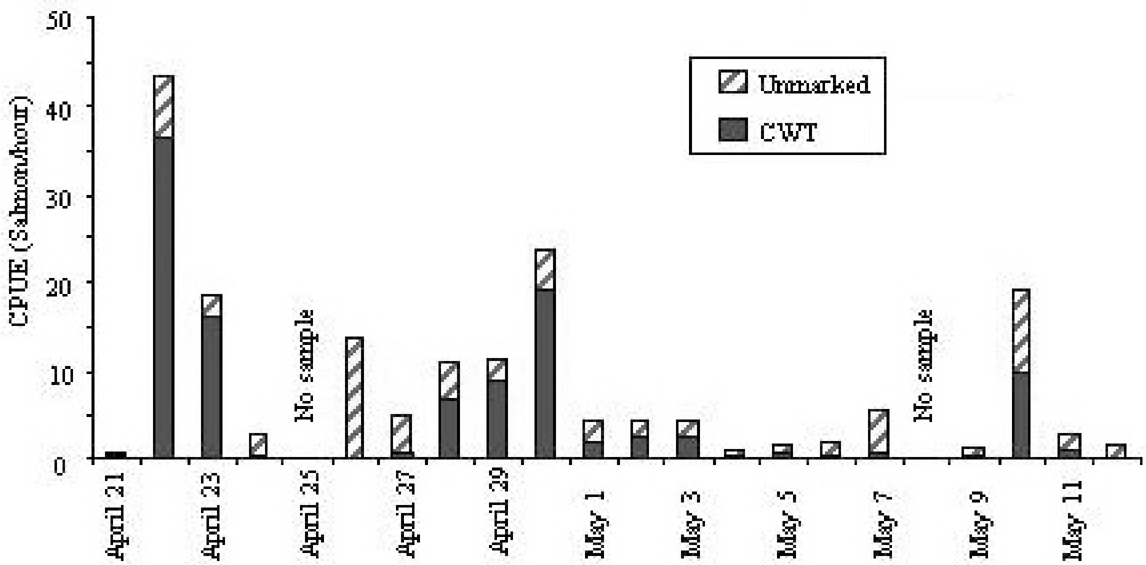


Figure 3-4 Average number of salmon per hour entrained at HORB, by tidal stage, for first VAMP salmon release. Salmon release times are marked by dashed lines. River stage for Old River is indicated by the solid line.

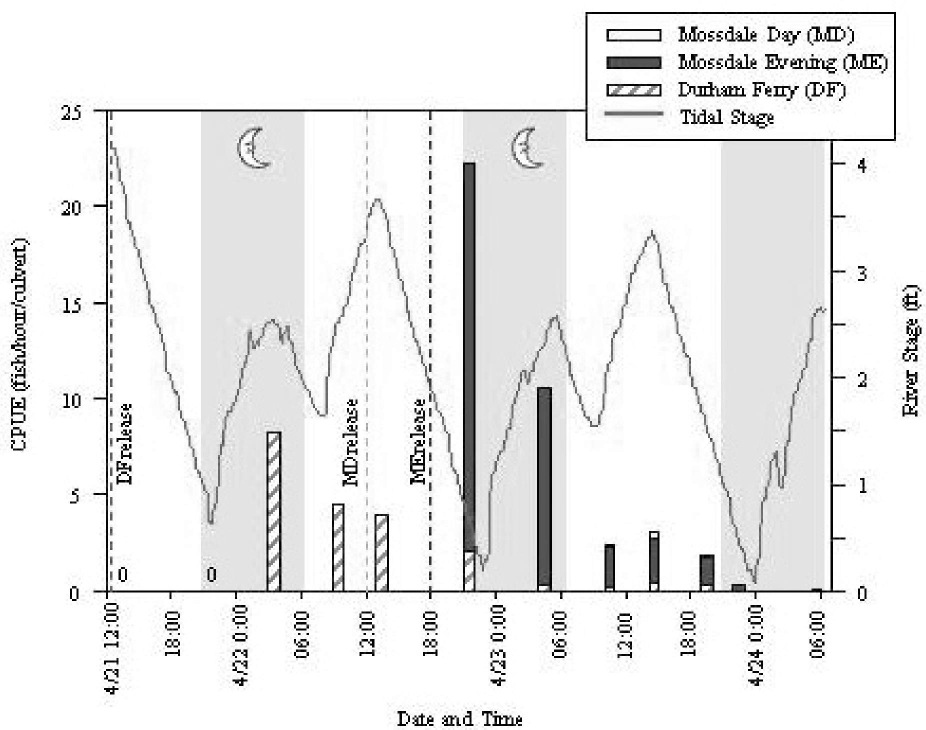
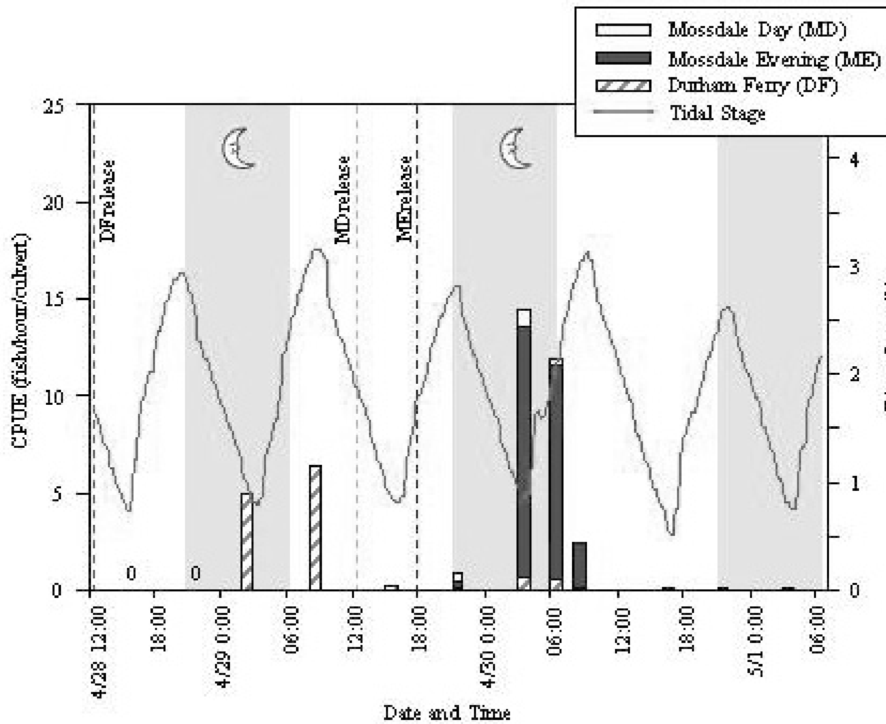


Figure 3-5 Average number of salmon per hour entrained at HORB, by tidal stage, for second VAMP salmon release. Salmon release times are marked by dashed lines. River stage for Old River is indicated by the solid line.



For the entire monitoring duration, the mean CPUE ± SD for VAMP salmon per culvert was 1.1 ± 3.3 fish/hour. The highest CPUEs occurred soon after the VAMP releases, with a maximum CPUE of 25.1 fish/hour on April 22. The mean unmarked smolt CPUE (1.2 ± 2.2) was similar to the VAMP CPUE. The highest unmarked CPUE (12.2) occurred April 27. VAMP mean salmon CPUE was similar between the flood (1.3 ± 4.0) and ebb (1.2 ± 3.0) tides, and slightly higher at night (1.2 ± 3.0) than during the day (0.8 ± 3.2). Unmarked mean CPUE was similar between the flood (1.1 ± 2.2) and ebb (1.3 ± 2.2) tides, and higher at night (2.6 ± 2.8) than during the day (0.5 ± 0.4). Although the mean CPUEs between night and day were close, the actual catch numbers indicate a bigger difference. Almost 11 times more unmarked salmon were entrained in the culverts during the night than during the day. In contrast to the unmarked salmon, only twice as many CWT salmon and 3.5 times as many color-marked salmon were entrained at night (Table 3-3).

To address tidal and diel effects, color-marked smolts were released on various tidal and diel period combinations. The first releases went well; however, like last year, some problems were encountered during the second release when an unknown number of smolts escaped from the holding pens before their intended release. Although some salmon escaped, entrainment rates were higher for the second releases (1.7 %) than the first releases (0.8 %) (Table 3-3). The overall color-marked entrainment rate was 1.3 %. More smolts were caught at night than during the day, and more smolts were entrained during the flood than the ebb tide.

Culvert number 4 entrained about half as many salmon as culvert numbers 5 and 6. (Figure 3-6). This is in contrast to 2002 results in which culvert number 4 entrained the most salmon and culvert number 6 the least. The trend was different for white catfish and threadfin shad in that they had higher entrainment in culvert 6 than culverts 4 and 5 (Table 3-2). Carp had the highest entrainment in culvert 5.

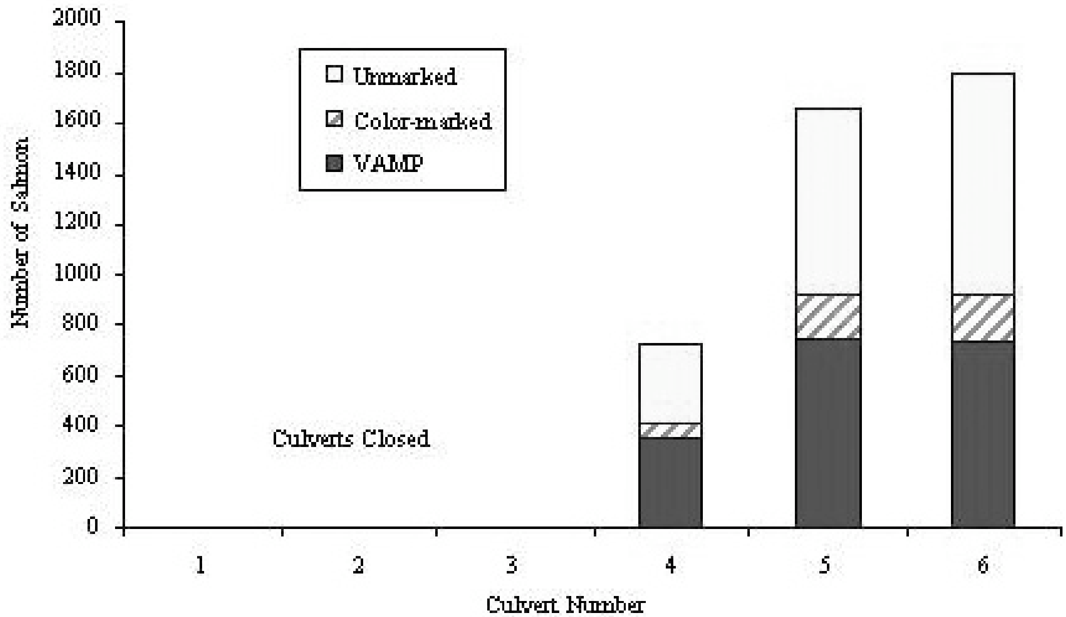
Table 3-2 The number of fish caught per culvert by diel period, excluding crepuscular sampling.

		Culvert Number			
		4	5	6	Total
Salmon					
CWT	Day	141	407	313	861
	Night	356	569	801	1,726
Unmarked	Day	22	59	54	135
	Night	261	603	701	1,565
Color-marked	Day	16	31	20	68
	Night	27	101	112	240
Other Fish					
Common carp	Day	0	336	24	360
	Night	1	6	4	11
Threadfin shad	Day	67	16	26	109
	Night	8	45	97	150
Channel catfish	Day	9	1	4	14
	Night	36	36	53	125
White catfish	Day	50	39	51	140
	Night	127	189	482	798

Table 3-3 The percentage of color-marked salmon entrained for various diel and tidal stages. Due to some salmon escaping from their live-cages, the number of salmon released was estimated for the second releases.

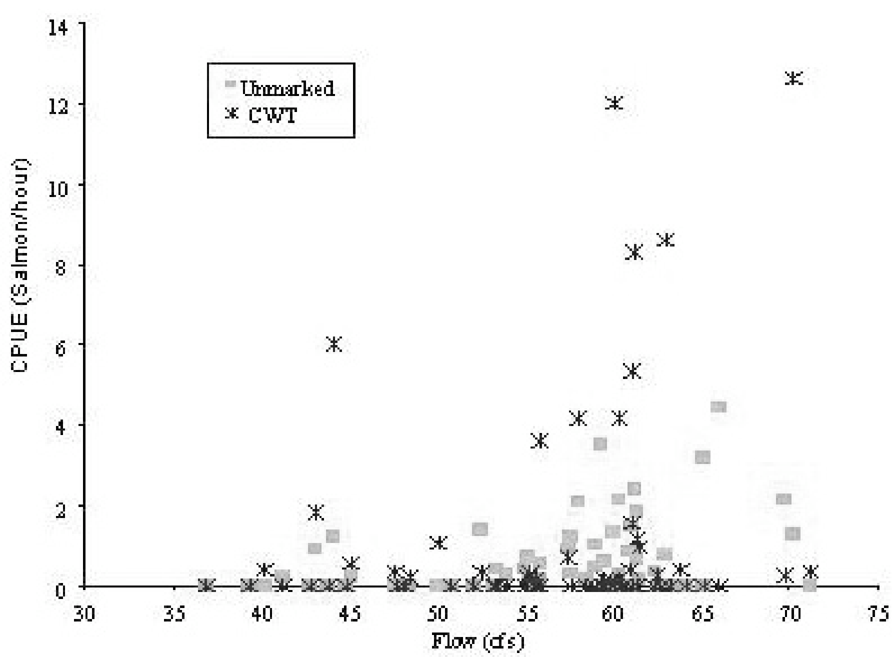
	No. Released	Diel	Tide	Entrained	% Recovered
First Releases (22 & 23 April)					
	3,005	Night	Flood	91	3.0%
	3,008	Night	Ebb	3	0.1%
	2,997	Day	Flood	1	0.0%
	3,014	Day	Ebb	6	0.2%
Total	12,024			101	0.8%
Second Releases (29 & 30 April)					
	3,000	Night	Flood	80	2.7%
	2,990	Night	Ebb	104	3.5%
	3,000	Day	Flood	18	0.6%
	2,980	Day	Ebb	6	0.2%
Total	11,970			208	1.7%

Figure 3-6 The total number of unmarked, color-marked, and VAMP salmon caught by culvert. Culvert numbers 1-3 were closed in 2003.



No current velocity meter was used this year; however, DWR installed a flowmeter in culvert number 4. Flow data for culvert number 4 was recorded throughout the monitoring period. Simple linear regression analysis indicated CWT salmon showed no significant relationship between CPUE and flow (df=65, P=0.11, r^2=0.04) and unmarked salmon showed a weak positive relationship (df=65, P<.01, r^2=0.10) (Figure 3-7).

Figure 3-7 Relationship between salmon entrainment and flow in culvert number 4.



Discussion

Although only half of the culverts were open during the VAMP experiment, some patterns in salmon entrainment were similar to previous years, e.g. higher entrainment at night, and more salmon were entrained from the first releases than the second releases. Interestingly, with fewer open culverts, the overall mean salmon entrainment rate was higher this year than in previous years. The higher entrainment rate was mostly due to the non VAMP salmon. It is possible that the salmon that would normally be entrained in the first three culverts, which were closed, were lingering around the culvert structure and some were subsequently entrained in the three open culverts. Even though the VAMP-released salmon loss index was lower than in 2002, the rate at which the salmon were entrained was similar. If all six culverts were open in 2003, the estimated VAMP salmon loss index of 1.4 % (estimated by multiplying the 3-culvert loss index by 2) would be similar to last year's loss index.

Tidal stage may affect salmon entrainment. Although the mean entrainment rate between the flood and ebb tides was similar, a closer look at when the salmon were released and when they first arrived at the HORB reveals that are some tidal entrainment differences. As in previous years, more salmon were entrained from the first set of VAMP releases than the second set of releases. This difference could be due to the tides, assuming the survival rate to the HORB was the same for each of the releases. The first evening release at Mossdale resulted in the highest entrainment near dusk: 469 of the Mossdale salmon were entrained within 3.5 hours of their release. However, seven days later, only 5 of the evening released Mossdale salmon were entrained within 3 hours of their release. The highest entrainment occurred closer to dawn: 240 salmon. After the first VAMP Mossdale release, a relatively strong ebb tide occurred during the afternoon and evening. Low slack water occurred soon after dark. The low tide caused a relatively large head difference between upstream and downstream water levels as salmon arrived at the HORB. The resulting increase in flow through the culverts, due to the head difference, probably played a role in the high entrainment of Mossdale salmon. In contrast, a week later, high slack water occurred at dusk. Consequently, there was less head difference between upstream and downstream water levels which may have contributed to the lower salmon entrainment. The following morning, when the low tide occurred, salmon entrainment increased considerably. The Mossdale evening results are similar to last year's VAMP results which suggested entrainment is affected by tidal stage near HORB.

The mean salmon entrainment rate between day and night appears closer than it really is due to averaging in zero catches at the end of the monitoring period. A closer look at when the salmon were released and when they first arrived at the HORB reveals that are diel entrainment differences. The results for the Mossdale evening releases were different than the day releases. More salmon were entrained from the two evening releases than for all the other VAMP releases combined. Very few of the Mossdale day-released fish were caught. This is also in contrast to previous years when fish released at Mossdale were typically entrained at a slightly higher rate than they were in 2003. The Mossdale day-released salmon that were entrained followed the same pattern as the evening-released fish. More salmon were entrained during the evening for the first release and more during the early morning for the second release. It is also possible the day and evening-released fish are behaving differently as they move downstream. The day released fish could be migrating down the main channel, or higher in the water column, as they pass the barrier. The evening-released fish could be migrating closer to shore, or lower in the water column, where they are more vulnerable to entrainment. The slightly higher salmon entrainment at night is similar to previous years' results. Typically, more salmon are entrained at night than during the day. The higher nighttime entrainment results of VAMP salmon could be confounded by the daytime release of the salmon, especially for salmon released at Durham Ferry. Due to the timing of VAMP release and the distance of the Durham Ferry release site from the HORB, a majority of the fish may pass by the barrier at night. However, depending on the tide, the fish released at Mossdale may reach HORB before nightfall.

Diel entrainment of unmarked salmon differed from the VAMP salmon. Overall, 59 % of the entrained VAMP salmon were caught at night compared to 92 % of the unmarked salmon. In 2002, about 75 % of both the entrained VAMP and unmarked salmon were caught at night. The proportionately higher entrainment of unmarked salmon at night, when compared to the VAMP salmon, suggests the VAMP-released fish are not behaving the same as the unmarked fish at the HORB. The unmarked salmon and VAMP salmon were similar in size (86 mm ± 6.7 mm and 87 mm ± 5.1 mm, respectively) so size probably was not a factor in the entrainment difference. Without knowing how many unmarked salmon passed the barrier and what percent was entrained, we can only speculate whether this difference is meaningful. In contrast to the diel results, the unmarked salmon tidal results were similar to the overall VAMP salmon tidal results. Entrainment on the flood and ebb tides was similar.

Results from the Entrainment Special Study are similar to those from last year's Entrainment Special Study. More color-marked salmon were entrained on a flood tide than on an ebb tide, and more were entrained at night than during the day. Marked salmon were entrained at the highest rate during a night-flood for the first release. Very few color-marked salmon were entrained on the night-ebb, day-flood and day-ebb. During the second release, slightly more salmon were caught on the night-ebb. The reason for the low entrainment during the first release is unknown. Although only three culverts were open, the overall color-marked salmon entrainment was similar to last year (1.3 % compared to 1.7 %). It is possible attraction to the culvert structure, or localized current patterns caused the salmon to pass near the culverts and be entrained.

The low salmon entrainment in culvert number 4 was surprising in that the culvert entrained roughly half as many salmon as culvert numbers 5 and 6. Debris or something could have been partially obstructing culvert number 4. The measured flows through the culvert were lower than the calculated flows. However, the lower flows in the culvert could be due to net resistance or other factors that affected all three culverts equally. We were unable to measure flows in all three culverts to see if there was a difference among culverts. If entrainment is affected by the amount of flow through the culvert, then higher salmon entrainment should occur at higher flows. In culvert number 4, there was no relationship between CWT salmon entrainment and flow, and only a slight positive relationship between increasing flow and entrainment of unmarked salmon. The reduced catch of salmon in culvert number 4 relative to the other culverts suggest something might be affecting the flow through the culvert and thus affecting the flow-entrainment relationship. However, the relationship between culvert number and entrainment was not the same for other species. Similar numbers of threadfin shad and white catfish were entrained by culverts 4 and 5, while culvert 6 entrained considerably more of those species. In contrast, most of the carp were caught in culvert number 5. The entrainment differences between species are due to differences in life history and use of the water column. The lower salmon catch in culvert number 4 could be due to salmon behavior and the way the currents were created this year with only three culverts open.

In summary, the results from the 2003 Entrainment Monitoring Study and the Entrainment Special Study suggest salmon are more vulnerable to entrainment at night. The tidal effects on entrainment are still unclear. Water velocities through the culverts are greatest on a low tide, near slack water. Salmon entrainment should be highest at this time which was somewhat evident for the Mossdale released fish. However, no significant relationship was found between CWT salmon entrainment and flow through culvert number 4. Only a weak positive relationship was found for unmarked salmon entrainment and flow in culvert number 4. The changing hydraulics surrounding the barrier as the tide changes affects flows near the culverts which may, in turn, affect entrainment. Salmon smolt behavior and relative abundance near the barrier may play an important role in entrainment vulnerability. The same also holds true for other fish species. The differences in life history and use of the water column probably account for most of the entrainment differences between fish species.

It is recommended that VAMP continue delaying the first salmon release by at least 5 days after the closure of the HORB. The delay allows for the completion of the barrier and minimizes the field crew's exposure to heavy equipment operation. The delayed VAMP salmon releases also allows time for any loose material near the culverts to pass through the culverts before the nets are attached. In 2003, no samples were lost to gravel accumulation in the nets. The split CWT salmon releases at Mossdale should also be continued to help elucidate the diel effects on salmon entrainment at the HORB. If feasible, the Mossdale releases should be made at noon and midnight.

Chapter 4. Salmon Smolt Survival Investigations

One of the primary objectives of the VAMP program is to identify how San Joaquin River flows and SWP and CVP export rates, with the HORB in place, affect the survival of juvenile Chinook salmon emigrating from San Joaquin River system. This section describes the methods used to conduct the VAMP 2003 Chinook salmon smolt survival investigations, and presents the calculated survival indices, absolute survival estimates and combined differential recovery rates for coded-wire tagged juvenile Chinook salmon released during the VAMP 2003 test period. We also analyzed how the survival varied with flow, and flow relative to exports, with and without the HORB. Ocean recovery information on past releases and catches of unmarked juvenile salmon at Mossdale and in CVP/SWP salvage are also discussed. Additional data and information related to the salmon survival investigations are presented in Appendix A.

Coded-Wire Tagging

Merced River Fish Facility Chinook salmon smolts, released as part of VAMP 2003, were coded-wire tagged (CWT) between March and early April. After the salmon were tagged, they were held in the hatchery for at least 21 days before being released. Sub-samples of these salmon were measured (for fork length) and checked for retention of tags a day or two prior to release. Sub-samples were comprised of ap proximately 200 salmon collected from the top, middle, and bottom of the release group's raceway. Although tag detection is usually high, all salmon from the sub-samples without a detected tag were sacrificed to verify the accuracy of the CWT detection process. Sacrificed salmon were dissected to determine whether they contained a non-magnetized tag, an undetected tag, or no tag. Each CWT code within a release group was held separately at the hatchery with the exception of the two Durham Ferry releases. Each of these releases was comprised of three CWT codes that were held together at the hatchery.

At release, an additional sub-sample of 25 salmon was sacrificed from each tag group to verify CWT code, except at Durham Ferry. Fifty fish were sampled from each of the Durham Ferry releases because tag codes were combined prior to release.

Coded-wire tag retention rates were typical in 2003, ranging between 93 and 97.5% (Table 4-1). Coded-wire tag retention rates appeared higher than last year, with an overall retention rate of 94.5% for 2003 VAMP groups compared to 90.5% for 2002. Coded-wire tag retention rates were used to estimate the effective release size used in calculating survival indices (Table 4-1). The effective number released (ER) was calculated using the following equation:

ER= (T – M) x TR

Where:

T = estimated number transported,

M = number of mortalities during release and transport
(includes those sacrificed as part of the net pen evaluations), and

TR = CWT retention rate

Coded-Wire Tag Releases

Two sets of CWT salmon releases were made as part of the 2003 VAMP experiment. The first set occurred on April 21 at Durham Ferry, April 22 at Mossdale, and April 25 at Jersey Point. The second set of releases occurred on April 28 at Durham Ferry, April 29 at Mossdale, and May 2 at Jersey Point.

For each set of releases approximately 75,000 salmon, divided among three CWT codes with approximately 25,000 fish, were released at Durham Ferry. Approximately 50,000 fish, divided between two CWT codes, were released at Mossdale. Approximately 25,000 fish with one CWT code were released at Jersey Point (Table 4-1). Prior to VAMP 2000, all CWT groups were trucked from the hatchery and released as a single group. However, since VAMP 2000, a new transport trailer with three tanks has allowed each CWT group to be transported to its release site in a separate tank and released. As mentioned earlier, each Durham Ferry group consisted of three tag codes which were already mixed at the hatchery and were therefore transported in a large, single tank, release truck.

Release strategies were similar to VAMP 2002, except at Mossdale. Both Durham Ferry releases were made from the more desirable location alongside the river, instead of from the top of the levee. The nearby agricultural diversion was turned off from the time of the releases until several hours after each release to allow the tagged salmon time to disperse from the release site. Releases at Jersey Point were made one hour prior to the beginning of the flood tide to increase dispersion of the tagged fish before they passed Antioch and Chipps Island. Water temperatures in the hatchery trucks and at the release sites were measured immediately prior to release (Table 4-2). In all cases, differences between water temperatures in the transport trucks and the release site were less than 5°C (9°F). Releases at Mossdale and Durham Ferry were not made on any specific tidal condition.

Both of the Mossdale releases were divided by CWT code, into afternoon (around 1200) and evening (around 1800) releases (Table 4-2). The two tag groups were released at different times to test day and night differences in entrainment at the HORB. We also planned to test if survival differed between the two release strategies; however, low recoveries prevented evaluation of survival by release time this year. If this release strategy is continued, we may be able to test for differences in survival in the future.

Table 4-1 Coded-wire tag (CWT) retention rates and estimated release numbers for juvenile chinook salmon released for VAMP 2003

Release Site	Release Date	CWT Code	CWT Retention Sample Size	CWT Retention %	Estimated Number Transported	Mortalities After Transport[1]	Estimated Number Released	Effective Number Released
Durham Ferry[2]	4/21/03	06-02-82	199	94.97	25,862	114	25,748	24,453
		06-02-83		94.97	27,414	114	27,300	25,927
		06-27-42		94.97	25,458	114	25,344	24,069
Mossdale	4/22/03	06-27-43	201	94.53	26,955	284	26,671	25,212
		06-27-48	200	93.50	26,464	292	26,172	24,471
Jersey Point	4/25/03	06-27-44	200	93.00	26,504	252	26,252	24,414
Durham Ferry[2]	4/28/03	06-27-45	200	95.00	26,121	137	25,984	24,685
		06-27-46		95.00	26,651	137	26,514	25,189
		06-27-47		95.00	26,061	137	25,924	24,628
Mossdale	4/29/03	06-27-49	189	93.12	26,028	61	25,967	24,180
		06-27-50	201	94.03	26,061	169	25,892	24,346
Jersey Point	5/2/03	06-27-51	200	97.50	26,615	264	26,351	25,692

[1] Mortalities include juvenile Chinook salmon held and later sacrificed for the net pen studies.
[2] Coded-wire tag codes were combined at the hatchery.Therefore,CWT retentions are for all three tag codes combined and mortalities were divided equally among the three tag codes.

Table 4-2 Release time, temperatures, fork length (FL), and effective number released for juvenile Chinook salmon released for VAMP 2003, by coded-wire tag (CWT) code

Release Site	Date	CWT Code	Release Time	Truck Temp (°F)	Release Temp (°F)	Average FL (mm)	Effective Number Released
Durham Ferry	4/21/03	06-02-82	1245	51.8	59.0	86	24,453
		06-02-83		51.8	59.0		25,927
		06-27-42		51.8	59.0		24,069
Total							74,449
Mossdale	4/22/03	06-27-43	1200	51.8	58.6	86	25,212
		06-27-48	1800	55.4	59.9	86	24,471
Total							49,683
Jersey Point	4/25/03	06-27-44	1800	56.0	62.0	88	24,414
Durham Ferry	4/28/03	06-27-45	1215	53.0	62.0	86	24,685
		06-27-46		53.0	62.0		25,189
		06-27-47		53.0	62.0		24,628
Total							74,502
Mossdale	4/29/03	06-27-49	1245	55.0	60.0	87	24,180
		06-27-50	1800	55.0	61.0	88	24,346
Total							48,527
Jersey Point	5/02/03	06-27-51	1145	55.0	59.0	89	25,692

Water Temperature Monitoring

Water temperature was monitored during the VAMP 2003 study using individual computerized temperature recorders (e.g., Onset Stowaway Temperature Monitoring/Data Loggers). Water temperatures were measured at locations along the longitudinal gradient of the San Joaquin River and interior Delta channels between Durham Ferry and Chipps Island—locations along the migratory pathway for the juvenile Chinook salmon released as part of these tests (Appendix A-1). Water temperature was recorded at 24-minute intervals throughout the period of the VAMP 2003 investigations. Water temperatures were also recorded within the hatchery raceways at the Merced River Hatchery coincident with the period when juvenile Chinook salmon were being tagged. These temperature recorders were later transported with the juvenile salmon released at Durham Ferry.

Results of water temperature monitoring within the Merced River Fish Facility showed that juvenile Chinook salmon were reared in, and acclimated to, water temperatures of approximately 10.5°–14°C (51°– 57°F) prior to release into the lower San Joaquin River (Figures 4-1 and 4-2). Results of water temperature monitoring at Durham Ferry and Mossdale following the first and second sets of VAMP 2003 releases are compared in Figures 4-3 and 4-4. No temperature data were available for Jersey Point (the recorder was lost). Results of water temperature monitoring showed that water temperatures at the release locations and throughout the lower San Joaquin River and Delta (Appendix A-2) were higher than those at the hatchery. Water temperatures measured within the lower San Joaquin River and Delta were not expected to result in mortality or adverse effects to emigrating juvenile Chinook salmon released as part of the VAMP 2003 investigations. A comparison of water temperatures measured at Durham Ferry during VAMP 2002 and VAMP 2003 (Figure 4-5a) showed that temperatures were similar during the two years. A comparison of temperatures at downstream locations showed that temperatures were generally higher during VAMP 2002 when compared to the VAMP 2003 test period (Figures 4-5b– 4-5d).

Figure 4-1 Merced River Fish Hatchery - 1

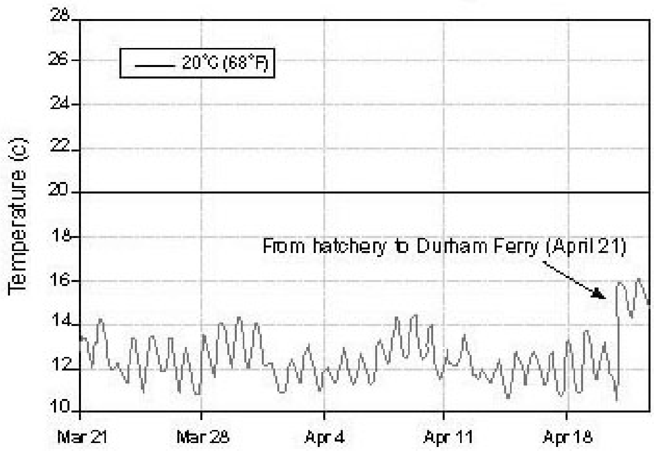


Figure 4-2 Merced River Fish Hatchery - 2.

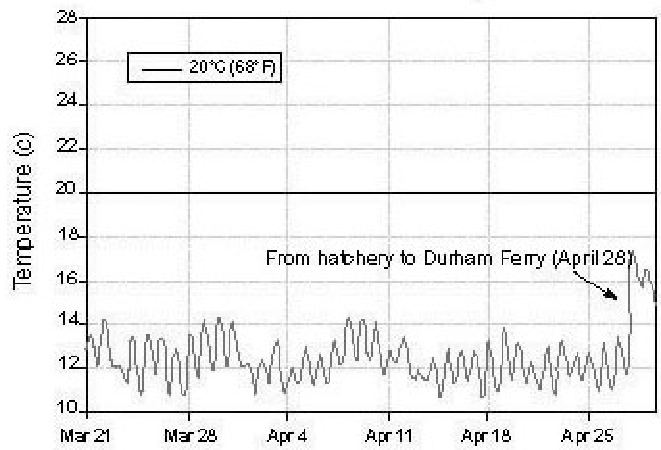


Figure 4-3 Site 1 - Durham Ferry.

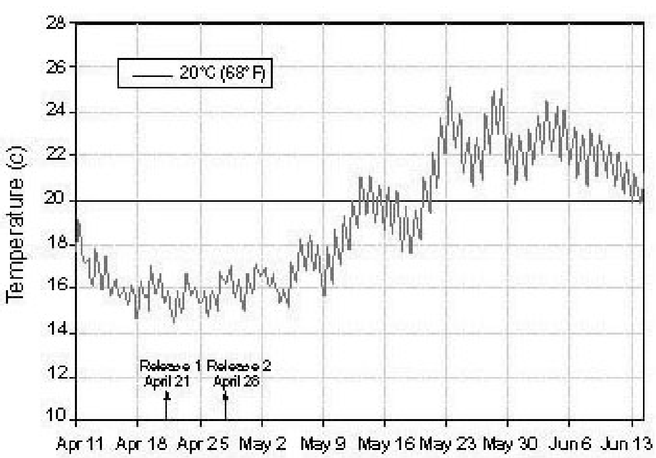


Figure 4-4 Site 10 - Site 2 - Mossdale.

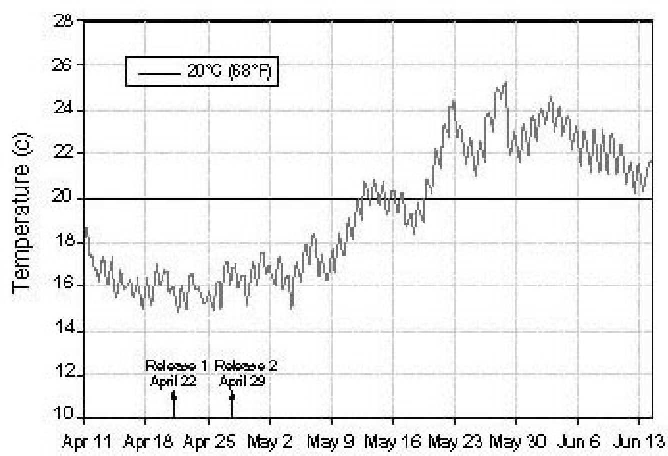


Figure 4-5A Site 1 - Durham Ferry.

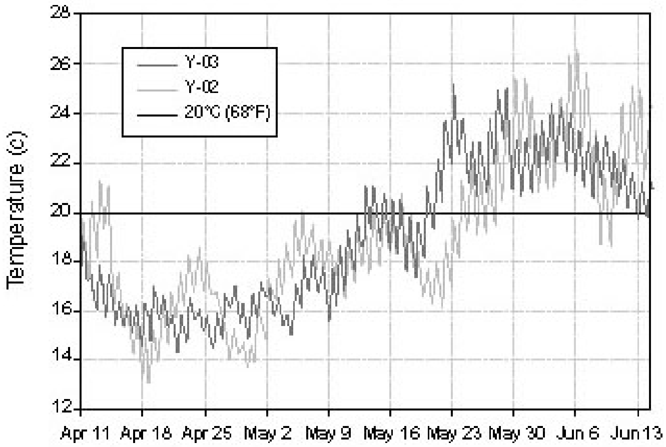


Figure 4-5B Site 4 - DWR Monitoring Station.

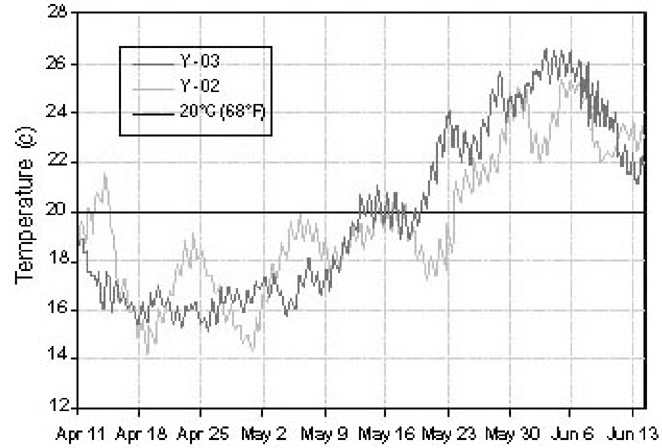


Figure 4-5C Site 7-1/2-mile upstream of Channel Marker 13.

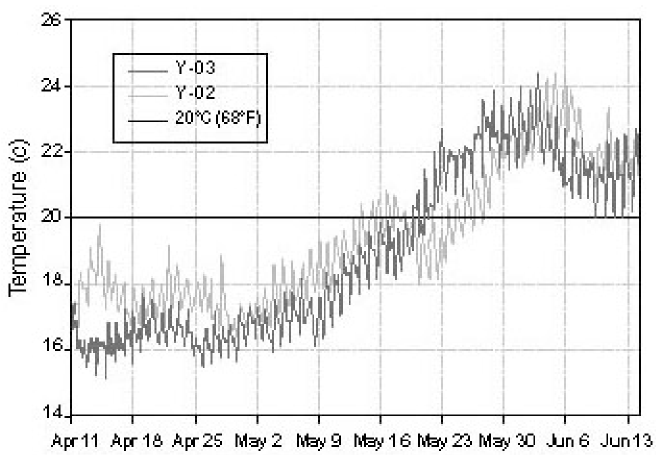
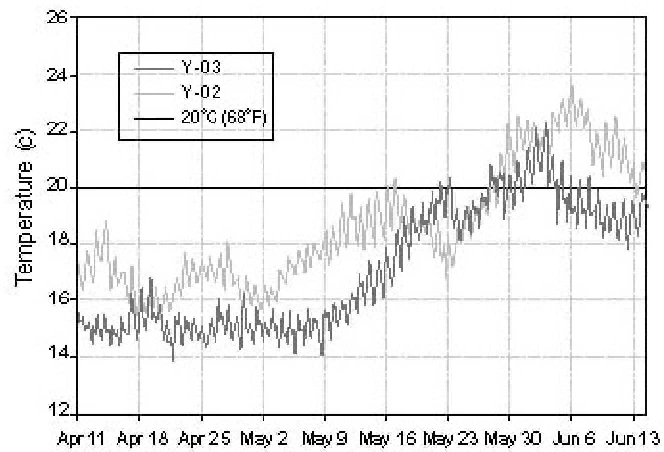


Figure 4-5D Site 10 - Chipps Island.



Post-Release Net Pen Studies

Survival and Condition

Post-release survival and condition of marked salmon were evaluated as part of the VAMP program using sub-samples of marked salmon from each release group. Twenty-five salmon from each CWT group were evaluated for general condition immediately after release. To assess general condition, fork length in millimeters, weight in grams, and six other characteristics were examined (Table 4-3). Other obvious abnormalities or deformities were also noted. To assess short-term effects of handling, transport, and release, an additional sub-sample of approximately 200 salmon from each tag code were held at the respective release sites for 48 hours. Of these, 25 were measured, weighed, and examined for the six general condition characteristics. The remaining fish were measured, weighed, and evaluated for adipose fin clips and short-term mortality. Because CWT codes were held together for the Durham Ferry releases, 50 fish from these release groups (all three CWT codes combined) were evaluated for general condition immediately and 48 hours after release, and two net pens with approximately 200 fish each were held in order to maintain consistency with the other release groups. In all, 499 juvenile Chinook salmon were examined for the six general condition characteristics, and 2,038 (including the 499 examined for general condition) were measured, weighed, and assessed for mortality and presence/absence of an adipose fin clip.

Results of the evaluations of the 499 marked salmon examined for the six general condition characteristics showed few abnormalities (see Appendix A-3). The majority of fish examined had normal coloration (99.2%), no fin hemorrhaging (100%), normal eye characteristics (99.2%), and normal gill color (92.4%). Scale loss ranged from 1% to 35% and averaged 8.6%. Other abnormalities included: fin rot (1%), dorsal fin splitting (0.8%), partial operculum (1%) and ragged dorsal fins (1%). In addition, this year 65 (3%) Chinook salmon had a poor or incomplete adipose fin clip, while 11 (0.5%) had no fin clip. Of the 2,038 juvenile Chinook salmon examined, there were 11 mortalities. In contrast, we observed no mortalities in 2002.

Tag Quality Control

Though rare, in the past, salmon from different release groups have been unintentionally mixed at some point prior to release. The subset of 25 salmon from each tag group (a total of 25 from each of the Durham Ferry net pens) evaluated for condition as described above were sacrificed to verify purity of tag codes.

Table 4-3 Smolt condition characteristics assessed for post-release net pen studies.

	Normal	Abnormal
Eyes	Normally shaped	Bulging
Color	High contrast dark dorsal surface and light sides	Low contrast dorsal surface and sides, coppery color
Fin Hemorrhaging	No blood or red at base of fins	Blood at base of fins
Percent Scale Loss	Lower relative numbers better based on 0 –100% scale loss	Higher relative numbers worse based on 0 –100% scale loss
Gill Color	Dark beet red to cherry red gill filaments	Light red to gray gill filaments
Vigor	Active swimming (prior to anesthesia)	Lethargic or motionless (prior to anesthesia)

In 2003, there were no errant tags codes associated with the VAMP 2003 net pen study. The remaining fish from each release group that were held in the net pens were archived in a freezer for further evaluation of tag code mixing if deemed necessary.

Health and Physiology

Personnel from the USFWS's California-Nevada Fish Health Center conducted physiological studies on a sub-sample of the juvenile Chinook salmon used in the VAMP study (Nichols and Foott 2003). Results of this work are summarized below.

A total of 284 Merced River Fish Facility fish were examined from the six release groups following transport to release sites at Durham Ferry, Mossdale, and Jersey Point. A general health inspection for viral, *Renibacterium salmoninarum* (Bacterial Kidney Disease agent) and systemic bacterial infection was performed on 60 fish from the first Mossdale release. Additional assays were conducted on the remaining 224 fish including: (1) internal and external abnormalities were recorded for each smolt; (2) smolt development was assessed (gill tissue was analyzed for ATPase activity from 64 fish, spread out over all release groups); and, (3) kidney tissue from 48 fish was examined for presence of *Tetracapsula bryosalmonae*, the parasite responsible for Proliferative Kidney Disease (PKD). To assess stress recovery, blood plasma levels of chloride, sodium, lactate, glucose, total protein, and cortisol were measured. At each release site, blood samples were taken from 7 to 16 fish directly out of the transport truck, and after being held in net pens for two and four hours after release. Because of time and personnel constraints, samples were not taken for fish held two and four hours after release for the second Mossdale release. Additional blood samples were taken and analyzed at 24 hours postrelease for both Durham Ferry releases and for the second Jersey Point release.

No viral pathogens or *R. salmoninarum* were detected in the 60 fish sample. Low levels of bacteria common in the skin and gastrointestinal tract of fish were isolated from 30% of these fish. These isolations were not considered to be significant health risks. *Tetracapsula bryosalmonae* was detected in 63% of the 48 kidneys examined by histology and 21% showed severe inflammation caused by the parasite. Gross clinical signs (swollen kidney or spleen) of PKD were observed in 11% of the 222 smolts examined. Proliferative Kidney Disease infection was more prevalent in the second set of releases (21% for second releases combined) than the first set (3% for first releases combined; $p<0.001$, z-test). Because PKD can reduce performance due to associated kidney dysfunction and anemia, smolts in the first release groups may have had higher survival than cohorts in the second release groups.

All sample groups demonstrated similar levels of smolt development as demonstrated by gill ATPase activity. Observed ATPase levels were consistent with fish undergoing smoltification.

There were few consistent patterns in blood chemistry values among the release groups. It appears that net pen confinement failed to reduce stress on the transported fish as indicators of stress (cortisol, glucose, and lactate) tended to remain altered throughout sampling (up to 24 hours). Plasma chloride was below normal in four of five groups at four hours post-release, but did return to normal in the 24 hour samples. No biologically significant shifts in plasma protein levels were detected in any group. Comparisons of the release groups are complicated by differences in transport time and handling prior to placement in net pens. The variations created by these differences may hide some trends in blood chemistry values that signal survival differences in the release groups. There may also be problems with extrapolating blood chemistry values of smolts held in net pens to those released into the river.

In summary, the incidence of clinical PKD was notably higher in smolts used for the second set of releases compared to smolts from the first set of releases. Consequently, survival of smolts from the second set of releases may be reduced in comparison to cohorts from the first releases. No biologically significant differences in smolt development or stress response were detected among fish from the different release times or sites. Plasma ion balance was disturbed in fish held in net pens for up to four hours post-release but returned to normal by 24 hours.

Coded-Wire Tag Recovery Efforts

Coded-wire tagged salmon were recaptured at Antioch and Chipps Island, at CVP and SWP fish salvage facilities, and during sampling at HORB. Codedwire tagged salmon released upstream of, and at, Mossdale were also recovered in DFG Kodiak trawls at Mossdale but are not discussed in this report. Juvenile Chinook salmon with an adipose fin clip (which identifies CWT salmon) caught at any of these sampling locations were sacrificed, labeled, and frozen for CWT processing. Coded-wire tag processing was done by USFWS (Stockton) for fish recovered at Chipps Island, Antioch, and SWP and CVP salvage facilities. DFG Region IV processed salmon captured in the HORB fyke net sampling.

Coded-wire tags are processed by dissecting each tagged fish to obtain the half (0.5 millimeters) or full (1 millimeter) cylindrical CWT from the snout. Tags are then placed under a dissecting microscope and the numbers are read and recorded in a database. All tags were read twice, and any discrepancies were resolved by a third reader. Tags were archived for future reference. VAMP releases comprise a small portion of the total tagged salmon released in the Sacramento and San Joaquin system. Consequently, many tags recovered at Chipps Island, Antioch, the SWP and CVP salvage facilities, and other locations are from CWT releases not affiliated with VAMP. It is necessary to read all recovered tags to identify CWT recoveries related to VAMP.

SWP and CVP Salvage Recapture Sampling

Sampling at the CVP and SWP fish salvage facilities was conducted approximately every two hours. The number of marked salmon collected (raw salvage) was expanded based on the number of minutes sampled during each two hour time period. The estimated expanded total number of CWT salmon, from each release group, was obtained by adding together the expanded number of each tag group for all time periods. Only CWT salmon recovered in the raw salvage collections were sacrificed for tag processing. Expanded salvage is only a portion of the direct loss experienced by juvenile salmon at the facilities as it does not include losses prior to, and associated with, pre-screen predation, screening, handling and trucking.

Expanded salvage numbers were low at the CVP (n = 84), and only three Chinook salmon were salvaged at the SWP (Table 4-4). These results are consistent with earlier studies showing that the HORB reduces the number of CWT salmon entrained at the fish facilities (Brandes and McLain, 2001). Additional VAMP fish were recovered during special studies at the SWP (n = 13).

Antioch Recapture Sampling

Fish sampling was conducted in the vicinity of Antioch on the lower San Joaquin River (Figure 1-1) using a Kodiak trawl. The Kodiak trawl has a graded stretch mesh, from 2-inch mesh at the mouth to 1/2-inch mesh at the cod-end. Its overall length is 65 feet, and the mouth opening is 6 feet deep and 25 feet wide. The net was towed between two boats, sampling in an upstream direction. Trawls were performed parallel to the left bank, mid-channel, and right bank to sample CWT salmon emigrating from the San Joaquin River. Each tow was approximately 20 minutes in duration.

All captured fish were transferred immediately from the Kodiak trawl to buckets filled with river water, where they were held for processing. Data collected during each trawl included: species identification and fork length for each fish captured, tow start time and duration, and location in the channel. Any fish mortalities or injuries were documented to comply with the Endangered Species Act permit requirements.

Juvenile Chinook salmon with an adipose fin clip were retained for later CWT processing while other fish were released at a location downstream of the sampling site immediately after identification, enumeration, and measurement.

Sampling at Antioch began April 21 and continued through May 20. Each day between 5:00 a.m. and 9:00 p.m., anywhere from 3 to 32 tows were conducted. In all, 800 Kodiak trawl samples were collected, for a total of 15,877 tow minutes. During sampling, 6,971 unmarked juvenile Chinook salmon were captured; 341 salmon with an adipose fin clip (and CWT) were collected, 117 from VAMP releases (Table 4-4) and 214 from other hatchery releases. In addition, 1,328 delta smelt, 16 Sacramento splittail, 29 unmarked steelhead, and 43 adipose fin clipped steelhead were caught during sampling.

Chipps Island Recapture Sampling

As part of VAMP 2003 recovery efforts at Chipps Island, trawling shifts were conducted twice daily between April 21 and May 31. This second shift has been conducted during the spring releases since 1998. The first shift began at sunrise, while the second shift ended at or after sunset, to incorporate the crepuscular periods of the day. Based on analysis of 24-hour sampling at Jersey Point in 1997 (Hanson, Hanson Environmental, unpublished data), greater numbers of juvenile Chinook salmon appear to be caught around sunrise and sunset. Therefore, targeting this crepuscular period and doubling total trawl effort at Chipps Island should increase the number of CWT salmon recaptured and reduce variability in VAMP survival indices. Sampling for other studies occurs once daily between June 1 and June 14, and three days per week after June 16 and prior to April 21.

Midwater trawls were conducted at Chipps Island by towing the trawl net at the surface. The mouth of the net was 10 feet deep by 30 feet wide, and the total length was 82 feet. Aluminum hydrofoils were used on the top bridles and steel depressors, along with a weighted lead line, were used on the bottom bridles to keep the mouth of the net open. The net consisted of graded mesh starting with 4-inch mesh at the mouth and ending with a 1/4-inch cod end mesh.

To sample across the channel, trawling at Chipps Island was conducted in three distinct lanes: the north, south, and middle of the channel. Each lane was generally sampled at least three times per shift, with one lane sampled a fourth time during each shift. The lane sampled four times was chosen at random or selected by the boat operator based on flow conditions.

During the VAMP recovery period, 105 VAMP CWT Chinook salmon were recovered at Chipps Island (Table 4-4). In addition, 11,226 unmarked salmon, 711 CWT salmon from non VAMP experiments, 15 delta smelt, 11 Sacramento splittail, 12 unmarked steelhead, and 17 adipose fin clipped steelhead were collected.

Table 4-4. Survival Indices at Antioch and Chipps Island and expanded salvage at the Central Valley Project (CVP) and State Water Project (SWP) Fish Facilities for the 2003 VAMP Study (drafted: 10/22/03)

Tag Code	Release Site	Date	Effective Number Released[1]	ANTIOCH					CHIPPS ISLAND					Expanded Salvage Numbers[5]	
				Number Recovered	Minutes Fished[2]	Fraction of Time Sampled[3]	Survival Index[4]	Group Index	Number Recovered	Minutes Fished[2]	Fraction of Time Sampled[3]	Survival Index[4]	Group Index	CVP	SWP
San Joaquin															
06-02-82	Durham Ferry		24,453	1	560	0.389	0.008		0	–	–	–		24	0
06-02-83	Durham Ferry		25,927	4	1140	0.396	0.028		2	2394	0.277	0.036		12	0
06-27-42	Durham Ferry		24,069	1	560	0.389	0.008		1	400	0.278	0.019		12	3
Total		4/21/03	74,449	6	2790	0.388		0.015	3	2394	0.277		0.019		
06-27-43	Mossdale		25,212	2	1140	0.396	0.014		3	2379	0.275	0.056		0	0
06-27-48	Mossdale		24,471	2	1690	0.391	0.015		2	1185	0.274	0.039		0	0
Total		4/22/03	49,683	4	3370	0.390		0.015	5	2379	0.275		0.048		
06-27-44	Jersey Point	4/25/03	24,414	71	6828	0.395	0.530		57	4779	0.277	1.097		0	0
06-27-45	Durham Ferry		24,685	0	–	–			0	–	–	–		12	0
06-27-46	Durham Ferry		25,189	0	–	–			0	–	–	–		12	0
06-27-47	Durham Ferry		24,628	0	–	–			0	–	–	–		0	0
Total		4/28/03	74,502	0			–	–	0						
06-27-49	Mossdale		24,180	0	–	–			0	–	–	–		12	0
06-27-50	Mossdale		24,346	0	–	–			1	400	0.278	0.019		0	0
Total		4/29/03	48,526	0			–	–	1	400	0.278		0.010		
06-27-51	Jersey Point	5/02/03	25,692	36	5622	0.390	0.258		39	3460	0.267	0.739		0	0

[1]The Effective Number Released is an estimate of the number of fish released with an adipose fin clip and CWT.

[2]The Minutes Fished is the number of minutes sampled between the first and last day of recovery.

[3]The fraction of time sampled is between the first and last day of recovery.

[4]The survival index is calculated using the formula: # recovered /(# released x fraction of time sampled x fraction of channel sampled).

[5]Expanded salvage numbers are: the number recovered in salvage/(minutes sampled/total minutes between samples).

VAMP Chinook Salmon CWT Survival

Survival Indices

Survival indices were calculated for marked salmon released at Durham Ferry, Mossdale, and Jersey Point and recovered at Antioch and Chipps Island. Survival indices (SI) were calculated using the formula:

SI = (R /(E*T*W))

Where:

R = the number recovered,

E = the effective number released,

T = the fraction of time sampled, and

W = the fraction of channel width sampled

The fraction of the channel width sampled at Chipps Island (0.00769) was calculated by dividing the net width (30 feet) by the estimated channel width (3,900 feet). The fraction of the channel width sampled at Antioch (0.01388) was calculated in the same manner, with the net width being 25 feet and the channel width being 1,800 feet. The fraction of time sampled at both locations was calculated based on the number of minutes sampled between the first and last day of catching each particular tag code or group, divided by the total number of minutes in the time period. The fraction of time sampled for VAMP 2003 release groups at Chipps Island was about 0.28, while at Antioch it was about 0.39 (Table 4-4).

Survival indices were calculated for each tag code to provide a sense of the variability associated with the group survival index. To generate the group survival index, the recovery numbers and release numbers were combined for the tag codes within a release group.

Individual and group survival indices to Antioch and Chipps Island of the CWT salmon released as part of VAMP 2003 are shown in Table 4-4. Survival indices have been reported to three significant digits, but we realize indices were not likely that precise. Survival indices were not corrected for the number of CWT fish recovered at the HORB or in sampling at Mossdale conducted by DFG Region IV.

The first set of VAMP releases appeared to survive at a higher rate than the second set of releases. The first Durham Ferry releases had survival indices to Antioch and Chipps Island of 0.015 and 0.019, respectively. The second Durham Ferry group had an unknown but likely lower survival rate since none were recovered at either location. The first releases at Mossdale had survival indices to Antioch of 0.015 and 0.048 to Chipps Island. No fish were recovered at Antioch from the second Mossdale release and the survival index to Chipps Island was 0.010. Survival indices for the two Jersey Point groups were 0.530 and 0.258 at Antioch and 1.097 and 0.739 at Chipps Island for the first and second releases respectively. Why survival was lower for the second groups relative to the first groups is unknown but may be related to the higher incidence of PKD.

Survival indices for both sets of releases made at Durham Ferry and Mossdale were very low relative to releases made at Jersey Point (Table 4-4).

Chinook Salmon Survival Estimates and Combined Differential Recovery Rates

More important than the differences in survival indices between sets of releases is the comparison of absolute survival estimates and combined differential recovery rates (CDRR). Absolute survival estimates (ASi) are calculated by the formula:

$$\mathbf{ASi = SI_u/SI_d}$$

Where:

SI_u = the survival index of the upstream group (Durham Ferry or Mossdale), to the recovery location,

SI_d = the survival index of the downstream group (Jersey Point) to the recovery location and,

i =recovery location (Antioch or Chipps Island).

Although referred to throughout this document as absolute survival estimates they are more aptly described as standardized or relative survival estimates. The combined recovery rate CRR) is estimated by the formula:

$$\mathbf{CRR = R_{C+A}/ER}$$

Where:

R_{C+A} = the combined recoveries at Antioch and Chipps Island of a CWT group, and

ER = the effective number released.

The combined differential recovery rate (CDRR) is calculated the formula:

$$\mathbf{CDRR = CRR_u/CRR_d}$$

Where:

CRR_u = the combined recovery rate for the upstream group (Durham Ferry or Mossdale), and,

CRR_d = the combined recovery rate for the downstream group (Jersey Point).

The CDRR is another way to estimate survival between the upstream and downstream release locations. It is similar to calculating absolute survival estimates, but does not expand estimates based on the fraction of the time and space sampled. At times the differential recovery rate (DRR) is reported which is similar to the CDRR but only uses recovery numbers from one recovery location—either Chipps Island or the ocean fishery.

The CDRR and the absolute survival estimates should not be very different as (1) the fraction of the time sampled is similar between groups for a recovery location and (2) the fraction of the channel width sampled at each recovery location is a constant. Neither would change the relative differences between groups. However, combining the recovery numbers from Antioch and Chipps Island could result in different survival estimates between the two methods.

Variance and standard errors were calculated for the CDRRs based on the Delta method recommended by Dr. Ken Newman. Plus or minus two standard errors are roughly equivalent to the 95% confidence intervals around the CDRR. Plus or minus one standard error equates to roughly the 68% confidence intervals for normally distributed data (Ken Newman, University of St. Andrews, Scotland, personal communication). In comparing survival between reaches and replicates, the confidence intervals were used to determine if CDRRs were significantly different from each other. If the 95% confidence intervals overlapped CDRRs were not considered statistically different from each other. Differences observed using the lower level of confidence (68%) are noted. It is not clear how variances, standard errors, or confidence intervals could be generated for absolute survival estimates.

Absolute survival estimates and CDRRs should be more robust for comparing survival between groups, recovery locations, and years, since using ratios between upstream and downstream groups theoretically standardizes for differences in catch efficiency between recovery locations and years. Both estimates of absolute survival and CDRRs were calculated for CWT releases as part of VAMP 2003, as in past years. An additional estimate of absolute survival will be possible from recoveries made in the ocean fishery, two to four years following release.

Although the first groups released at Durham Ferry and Mossdale appeared to survive slightly better than the second groups when evaluated using the absolute survival estimates and CDRRs (Table 4-5), the CDRRs of the two Mossdale groups were not statistically different at the 95% confidence level ($p<0.05$ level). They were significantly different using the 68% confidence level (Figure 4-6). No recoveries were made for the second Durham Ferry group at either recovery location, thus the second groups appeared to survive at a lower rate than the first groups. In addition, no recoveries were made at Antioch for the second Mossdale group.

Table 4-5 Group survival indices (SI) and absolute survival estimates (AS) combined differential recovery rates (CDRR) using recoveries at Antioch, Chipps Island or both for coded wire tagged Chinook salmon released as part of VAMP 2003.

Release Site	Date	Antioch Group SI	Antioch Group AS	Chipps Group SI	Chipps Group AS	Combined Differential Recovery Rate
Durham Ferry	4/21/03	0.015	0.028	0.019	0.017	0.023
Mossdale	4/22/03	0.015	0.028	0.048	0.043	0.035
Jersey Point	4/25/03	0.530	-	1.097	-	-
Durham Ferry	4/29/03	-	-	-	-	-
Mossdale	4/28/03	-	-	0.010	0.014	0.007
Jersey Point	5/02/03	0.258	-	0.739	-	-

The first Mossdale group appeared to survive slightly better than the first Durham Ferry group using the absolute survival estimates generated using Chipps Island recoveries and CDRR (Table 4-5). The first Mossdale group appeared to survive about the same as the first Durham Ferry group using the Antioch recoveries (Table 4-5). The CDRR indicated that differences were not significant (Figure 4-6). Fish released at Durham Ferry are thought to incur additional mortality since it is 11 miles farther upstream than Mossdale.

Because there were no significant differences between the CDRRs of the two Mossdale release groups, the groups were pooled and a new CDRR (0.025) and standard error were calculated

(Figure 4-7). The first Durham Ferry group was also combined with the two Mossdale groups (Figure 4-7) since there were no statistical differences in the CDRRs at the 95% level between groups (Figure 4-6). Since no recoveries were made for the second Durham Ferry group, we were uncertain whether it was appropriate to combine Durham Ferry groups and include the second Durham Ferry group in the pooling with the Mossdale groups. To address this, CDRRs were calculated using the two sets of pooled data to determine if they were statistically different. The CDRR for the pooled two Durham Ferry and Mossdale releases was 0.019. Without the second Durham Ferry release included the CDRR was 0.027. CDRRs of the two sets of pooled data were not significantly different. The pooled CDRR for the two Durham Ferry releases was 0.015 (Figure 4-7).

Transit Time

Data on transit times for marked salmon from release to recapture sites during VAMP 2003 is summarized in Table 4-6. The transit time (from release location to Antioch and Chipps Island) for both sets of releases was similar. Recoveries of all groups were made within 13 days after release. It is interesting that the Jersey Point groups were still recovered 10 to 12 days after release, similar to groups released upstream. Daily recovery of each release group by tag code and sampling effort is shown in Appendix A-4.

Transit time for the CWT groups to the CVP and SWP fish facilities varied more than transit times to Antioch and Chipps Island. Coded wire tagged fish released as part of the first Durham Ferry group arrived at the facilities earlier (tag group: 06-02-82), at roughly the same time (tag group: 06-02-83) or much later (tag group: 06-27-42) than they reached Antioch or Chipps Island (Table 4-6). Fish from the second Durham Ferry group and one tag group from the second Mossdale release were observed during salvage operations but were never recovered at Chipps Island or Antioch. Variability in recovery timing could an artifact of low recoveries at all recovery locations.

Figure 4-6 Combined Differential Recovery Rates (CDRR) and (+/- 1 and 2 standard errors) of coded wire tagged (CWT) smolts released in 2003 at Mossdale and Jersey Point (Mossdale) and Durham Ferry and Jersey Point (Durham Ferry for the first (1) and second (2) release groups. CWT smolts were recovered at Antioch and Chipps Island.

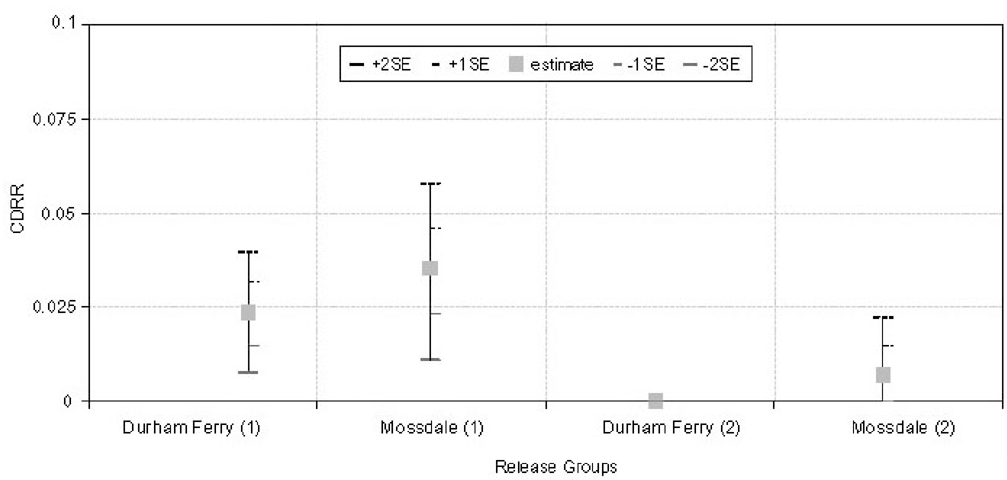


Figure 4-7 Pooled, Combined Differential Recovery Rates (CDRR) and (+/- 1 and 2 standard errors) of CWT smolts released in 2003 at Durham Ferry and Jersey Point (Durham Ferry) and Mossdale and Jersey Point (Mossdale) for the first (1) and second (2) release groups and for the combined Durham Ferry and Mossdale release groups (with and without the second Durham Ferry release group).Recoveries were made at Antioch and Chipps Island.

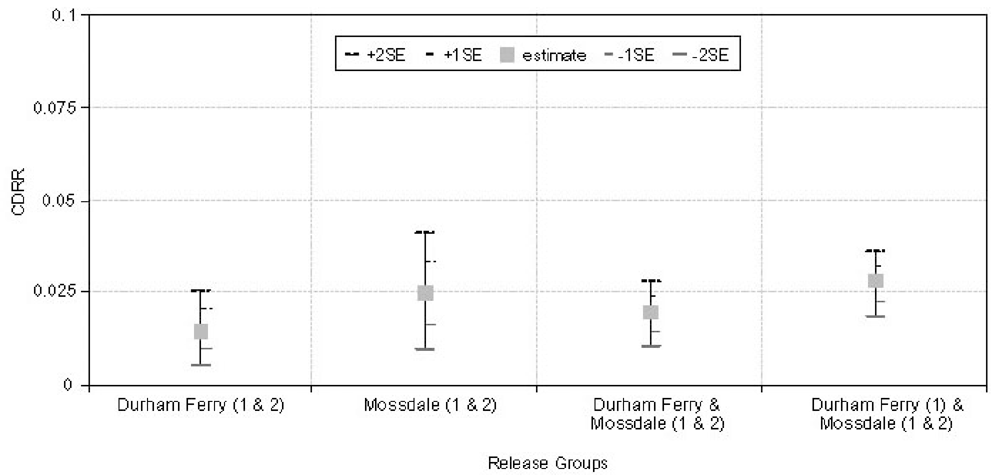


Table 4-6. Recovery timing of juvenile CWT salmon released as part of VAMP 2003

Tag Code	Release Site	Release Date	ANTIOCH					CHIPPS ISLAND					CVP	SWP
			Number Recovered	First Day Recovered	Last Day Recovered	Days to First Rec.	Days at Large	Number Recovered	First Day Recovered	Last Day Recovered	Days to First Rec.	Days at Large	First and Last Day Recovered	First and Last Day Recovered
06-02-82	Durham Ferry		1	5/4	5/4		13	0	–	–			4/29-5/1	
06-02-83	Durham Ferry		4	4/30	5/1		10	2	4/27	5/2		11	5/1	
06-27-42	Durham Ferry		1	4/30	4/30		9	1	4/29	4/29		8	5/7	5/12
Total		4/21/03	6	4/30	5/4	9	13	3	4/27	5/2	6	11		
06-27-43	Mossdale		2	4/30	5/1		9	3	4/30	5/5		13		
06-27-48	Mossdale		2	5/3	5/5		13	2	5/2	5/4		12		
Total		4/22/03	4	4/30	5/5	8	13	5	4/30	5/5	8	13		
06-27-44	Jersey Point	4/25/03	71	4/26	5/7	1	12	57	4/26	5/7	1	12		
06-27-45	Durham Ferry		0	–	–			0	–	–			5/1	
06-27-46	Durham Ferry		0	–	–			0	–	–			5/7	
06-27-47	Durham Ferry		0	–	–			0	–	–				
Total		4/28/03	0					0						
06-27-49	Mossdale		0	–	–			0	–	–			5/7	
06-27-50	Mossdale		0	–	—			1	5/6	5/6		7		
Total		4/29/03	0					1	5/6	5/6	7	7		
06-27-51	Jersey Point	5/02/03	36	5/3	5/12	1	10	39	5/4	5/12	2	10		

Comparison With Past Years

Survival between Durham Ferry and Mossdale appeared high in 2003 as in past years. In 2000 through 2003, CDRRs indicated that survival between Durham Ferry and Jersey Point and Mossdale and Jersey Point was not statistically different ($p<0.05$) (SJRG, 2002 and Figure 4-6), thus we can infer survival between Durham Ferry and Mossdale was generally high in these years. However, low recovery numbers may hinder our ability to detect differences. Continued releases of CWT fish at both sites may allow estimates of mortality between Durham Ferry and Mossdale if it becomes great enough to detect in the future. If survival between locations is shown to be similar (not statistically different) then groups can be combined. When ocean recovery information becomes available it may also provide a means to assess mortality between Durham Ferry and Mossdale.

Survival from Durham Ferry and Mossdale to Jersey Point was much lower in 2003 than in the past. In 2003 the pooled CDRR from Durham Ferry and Mossdale to Jersey Point was 0.019 (or 0.027 including only the first Durham Ferry release). The pooled CDRR in 2003 was the lowest measured to date, and significantly lower than any pooled CDRR estimated since 2000 (Table 4-7). Even prior to VAMP, with only Chipps Island recoveries, the lowest differential recovery rate with the HORB in place was 0.133 in 1994.

The health of the CWT fish in of itself did not appear to account for the low survival observed in 2003. Indices of fish health for VAMP fish used in 2003 were compared with VAMP fish used in earlier years to determine if the incidence and severity of PKD was greater in 2003 than in past years. The severity of PKD infection was determined by examining the kidney tissue. If the parasite was observed the fish was classified as infected. If the parasite had reached a stage where a reaction to the parasite (inflammation) was observed the fish was classified as severely infected.

In 2003, both infection and severe infection were observed in a high percentage of fish used in the VAMP experiments (Table 4-8). However, both the infection and severe infection rates were greater for the VAMP fish released in 2001, when survival through the Delta was estimated to be an order of magnitude higher (0.191 in 2001 versus 0.019 in 2003) (Table 4-8). These data indicate that the PKD infection in and of itself probably did not cause the high mortality of the VAMP fish observed in 2003.

The high level of PKD infection in combination with the lower flows could have increased the mortality of VAMP fish in 2003. PKD in the field likely compromises the fish’s performance in many areas (swimming, salt water entry and disease resistance) and could decrease their survival through the Delta (Nichols and Foott, 2002). Nichols and Foott (2002) speculate that differences in the rate of PKD infection could be due to environmental conditions—namely flow and water temperature and that the small number of infected fish in 2000 may have been caused by the lower concentration of the infectious stage of the parasite because of the dilution effect of higher flows. Thus in contrast the lower flows in 2003 may have concentrated the infectious stage of the parasite.

The transit time (the span of time fish were recovered) at Chipps Island for VAMP groups in 2003 was shorter than in past years and may be a reflection of the lower flows and higher incidence of PKD infection. The mean number of days between the first and last day of recovery at Chipps Island for all VAMP groups was less in 2003 (6) compared to past years (Table 4-9).

The number of days until first recovery to Chipps Island appears to be related to San Joaquin River flow. In 2003 the number of days until first recovery was longer (1 to 8 days) when flows were lower (3298 cfs) than in 2000 and 2001 (1 to 5 days and 6020 and 4211 cfs flow respectively). The number of days until first recovery (1 to 9 days) and flow (3341 cfs) (in 2002) was similar to that observed in 2003 (Table 4-9).

In contrast, the number of days until last recovery was sooner in 2003 (7 to 13 days) than in 2002 (ranged from 15 to 22 days after release) and 2000 (12 to 32 days) when PKD infection rate was lower. The number of days until last recovery in 2003 was similar to that observed in 2001 (Table 4-9). Both 2003 and 2001 had the highest percentage of fish infected with PKD (Table 4-8). Differences in the number of days until last recovery may reflect increased mortality over time. Individuals that took longer than the 7 to 13 days to reach the western Delta had higher mortality due to the higher incidence of PKD in 2003 and 2001. It is possible that the combination of the first fish taking longer to reach Chipps Island due to the lower flows and the increased mortality due to the direct or indirect effects of PKD infection for the later migrants may in part explain why survival was so much lower in 2003 than in past years.

Role of Flow and Exports

San Joaquin River flow and flow relative to exports between April and June is correlated to adult escapement in the San Joaquin basin 2 1/2 years later (SJRG 2003). Both relationships are statistically significant ($p<0.01$) with the ratio of flow to exports accounting for slightly more of the variability in escapement than flow alone (r2 = 0.58 versus r2 = 0.42) (SJRG, 2003). These relationships suggest that adult escapement in the San Joaquin basin is affected by flow in the San Joaquin River and exports from the CVP and SWP during the spring months when juveniles migrate through the river and Delta to the ocean. VAMP was designed to further define the mechanisms behind these relationships by testing how San Joaquin River flows and exports with the HORB affect smolt survival through the Delta.

Survival of juvenile Chinook salmon emigrating from the San Joaquin River system has been evaluated within the framework established by the VAMP experimental design since the spring of 2000. Similar South Delta studies were conducted in 1994 and 1997, prior to the official implementation of VAMP. Fish from the Feather River Hatchery have been used in south Delta studies conducted prior to 1999 (SJRG, 2002).

Table 4-7 Combined Differential Recovery Rate (CDRR) and standard errors for CWT salmon released at Mossdale and Durham Ferry in relation to those released at Jersey Point

Year	CDRR	Standard Error
1994	0.133	0.099
1997	0.186	0.064
2000	0.187	0.019
2001	0.191	0.014
2002	0.151	0.013
2003	0.019*	0.005

*significantly lower than values in other years.

Table 4-8 Severity of PKD infection in VAMP fish between 2000 and 2003. Number positive divided by the sample size is shown in parentheses.

Year	Percent Infected	Percent with Severe Infection
2000	4 (2/45)	0 (0/45)
2001	100 (34/34)	29 (10/34)
2002	46 (92/201)	1 (2/201)
2003	63 (30/48)	21 (10/48)

Table 4-9 Number of days after release of first and last recovery at Chipps Island and the duration of recovery (in days) for VAMP released fish in 2000-2003. Mean duration of recovery period and mean flow in cubic feet per second (cfs) at Vernalis during the two upstream Durham Ferry releases is included.

	Year (San Joaquin Flow Target)			
Release Location	2000	2001	2002	2003
Durham Ferry (1)	5-32 (27)	5-11(6)	8-22(14)	6-11(5)
Mossdale (1)	5-16(11)	4-11(7)	7-17(10)	8-13(5)
Jersey Point (1)	2-12(10)	1-7(6)	2-21(19)	1-12(11)
Durham Ferry (2)	5-23(18)	5-13(8)	7-15(8)	-
Mossdale (2)	N/R	5-10(5)	9-19(10)	7(0)
Jersey Point(2)	1-16(15)	1-11(16)	1-19(18)	2-10(8)
Mean Duration (in days)	16.2	7	13.1	6
Mean Flow (in cfs)	6020	4211	3341	3298

N/R = No second release was made
\- = no fish were recovered

To assess the relationship between San Joaquin River flows and survival, pooled CDRRs from 2000 through 2003 were plotted. The CDRRs of all Durham Ferry and Mossdale releases within a year were pooled as they were not significantly different from each other at the 95% confidence level. These pooled estimates and their 68% and 95% confidence intervals for 2003 (including the second Durham Ferry release) and the past three years of VAMP releases (2000–2002) are shown in relation to the average San Joaquin River flow at Vernalis for the two, ten-day periods after each release in Figure 4-8. Similar data obtained from releases made at Mossdale in 1994 and 1997 are included but have much wider confidence intervals because fewer recoveries were made since tagged fish were recovered at only one location (Chipps Island) in these years. It is obvious that the 2003 CDRR is much lower than would have been predicted based on past data.

The CDRRs with confidence intervals are also shown in comparison to average Vernalis flow relative to combined CVP and SWP exports for the averaged two, ten-day periods after release for each year (Figure 4-9). Prior to 2003, the relationship of CDRRs to San Joaquin River flow was improved by incorporating exports. The CDRR obtained in 2003 is much lower than what would have been predicted from past data and has weakened the benefit of adding exports into the relationship.

In general, the CDRRs do appear to increase as flows and flows relative to exports increase, but the addition of the 2003 data has resulted in these relationships no longer being statistically significant. As mentioned last year, even when the relationships were statistically significant ($p<0.10$), confidence intervals indicated data points were not significantly different from each other (SJRG, 2003).

Figure 4-8 Combined Differential Recovery Rates (CDRR) and (+/- 1 and 2 standard errors) of CWT smolts released at Durham Ferry and Mossdale relative to Jersey Point releases (with HORB in place) versus San Joaquin River flow at Vernalis in cfs, 2000-2003. 1994 and 1997 releases were made at Mossdale and Jersey Point.

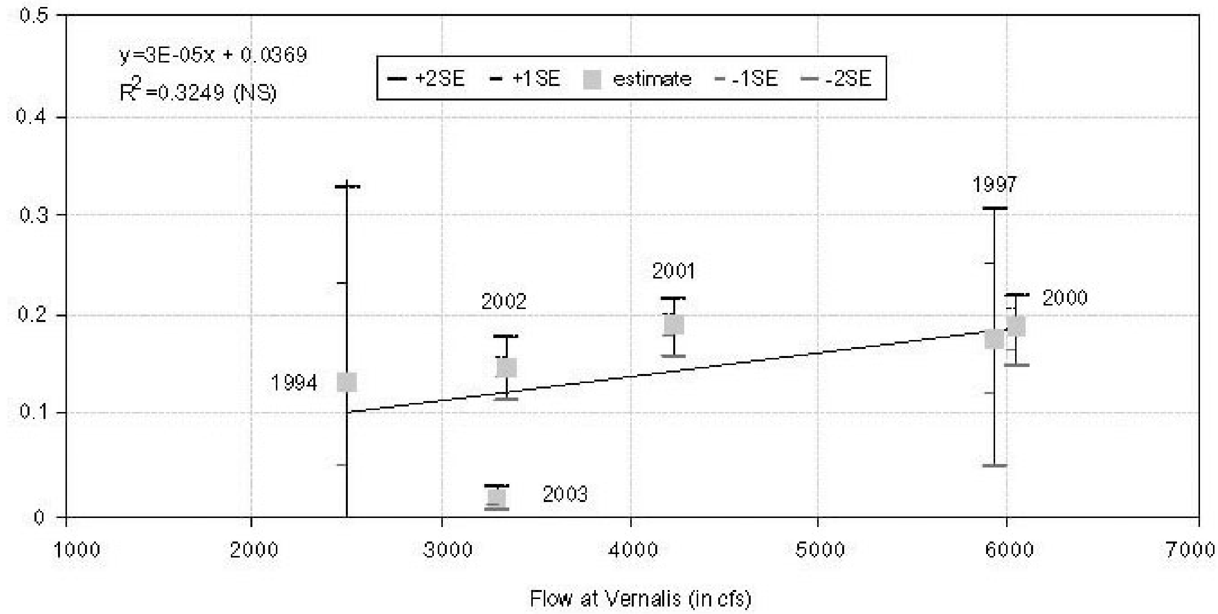
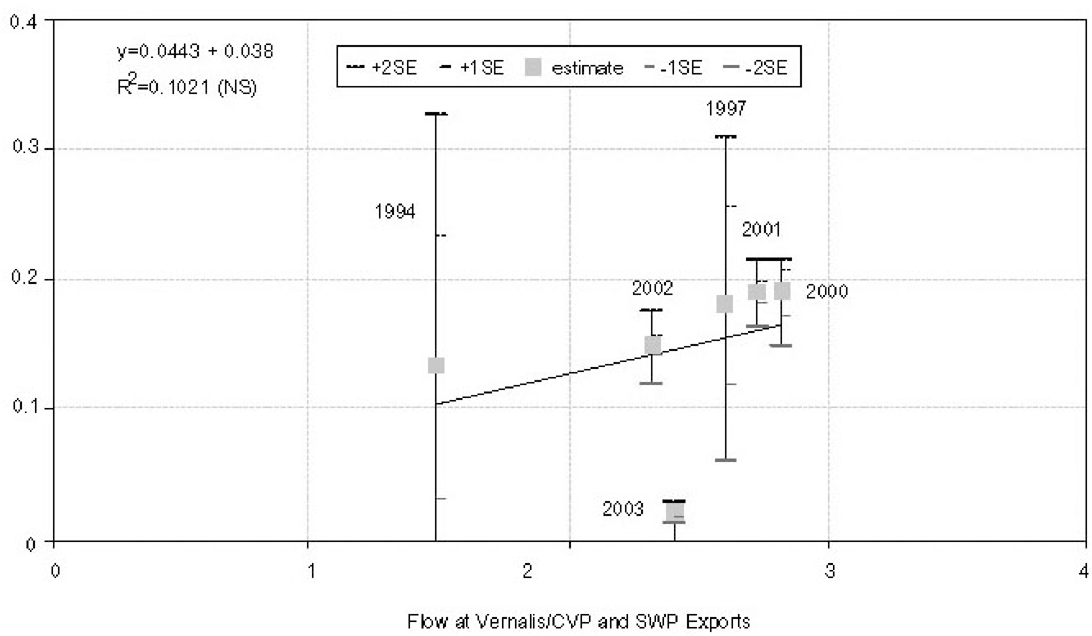


Figure 4-9 Combined Differential Recovery Rates (CDRR) and (+/- 1 and 2 standard errors) of CWT smolts released at Durham Ferry and Mossdale relative to Jersey Point releases (with HORB in place) versus the ratio of inflow at Vernalis and CVP and SWP exports, 2000-2003. 1994 and 1997 releases were made at Mossdale and Jersey Point.



It does not appear that flow and exports in 2003 accounted for the low survival observed. As mentioned earlier, San Joaquin River flows and CVP and SWP exports were similar in 2002, but survival was significantly higher in 2002 as shown using the CDRRs and confidence intervals (Figure 4-10).

The Role of HORB on Survival

In 2003, the HORB was in place with three culverts operating during the VAMP study period. The barrier is assumed to improve survival based on studies conducted in the 1980s and 1990s (Brandes and McLain, 2001). These studies indicated that smolts released downstream of the Head of Old River survived at about twice the rate of those released upstream. And while those data were not statistically significant, placing a temporary barrier at the Head of Old River appeared to be a management action that would improve survival through the Delta for smolts originating from the San Joaquin basin.

The relationships of absolute survival estimates between Mossdale and Jersey Point and the ratio of San Joaquin River flow at Vernalis to exports with and without the HORB are shown in Figure 4-11. Differential recovery rates (using Chipps Island recoveries only) were not reported since they have not been calculated for past releases without the barrier in place. We assume absolute survival estimates would be comparable to the differential recovery rates. Thus, while comparisons can be made between regression lines, variance around each data point has not been estimated. The two regression lines have been developed based on survival data with and without the HORB. The barrier appears to generally increase survival at any one flow to export ratio, although estimated survival in 2003 was lower than would have been predicted from the model and is similar to levels observed without a barrier in place at the lower inflow to export ratios. In addition there hasn't been much variability in the Vernalis flow to export ratios to test with the barrier in place.

Figure 4-10 Combined Differential Recovery Rates (CDRR) and (+/-1 and 2 standard errors) of CWT smolts released at Mossdale and Jersey Point (Mossdale) and Durham Ferry And Jersey Point (Durham Ferry) for the first (1) and second (2) release groups in 2003 (black) and 2002 (red). CDRR were based on the sum of recoveries at Antioch and Chipps Island. Estimates for pooled CDRR's for the two Durham Ferry and Mossdale releases are also provided.

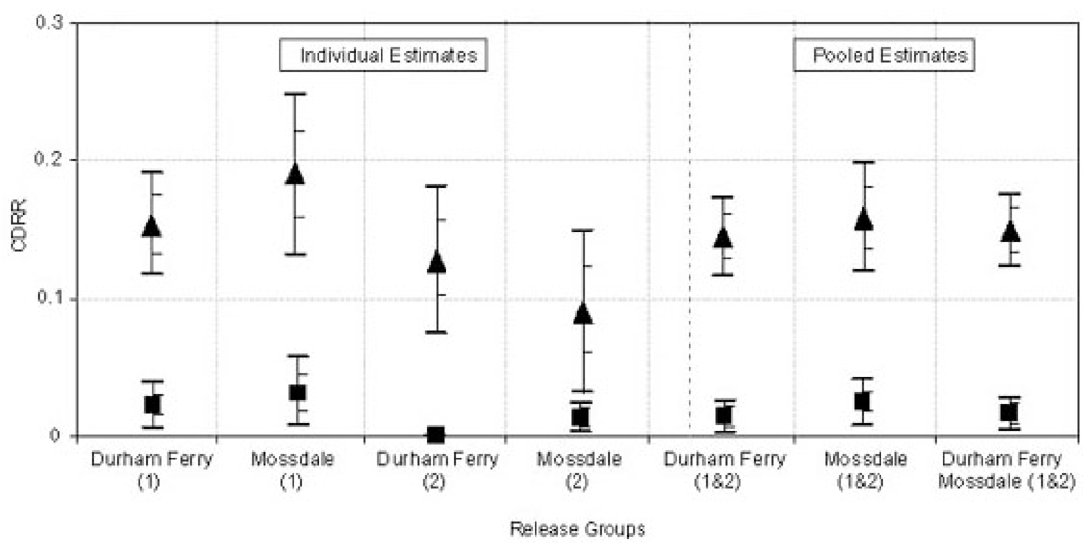
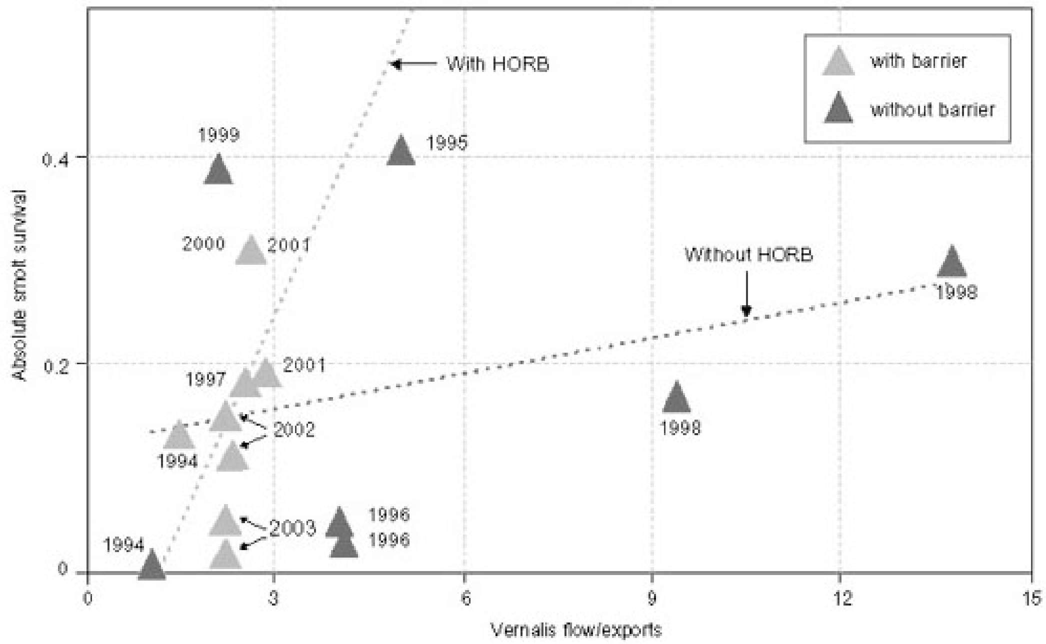


Figure 4-11 Estimates of survival of CWT fish released at Mossdale relative to those released at Jersey Point and recovered at Chipps Island with and without HORB between 1994 and 2003. Similar values were obtained for one 2000 and one 2001 release. HORB can not be installed at Vernalis flow/export levels >4.6



The differences in the target conditions tested in VAMP so far have been small, making it difficult to measure differences in survival due to changes in target conditions. In the six years of measuring survival with the HORB in place, the flow to export ratio has only varied from 1.5 (1994) to 2.9 (2000) (Figures 4-9 and 4-11). The maximum flow to export ratio within the VAMP targets is 4.7, but as of yet has not been tested. The ratios in the relationship between flow to export and adult escapement vary from 0.1 to 1000 (SJRG, 2003); a broader representation of how flows relative to exports, during the spring, have varied since 1951.

Varying designs and changes in the culvert operations of the HORB also make it more difficult to detect significant differences in salmon smolt survival at similar flow to export ratios. During the six years the HORB has been installed (and comparable survival studies conducted) the design and permeability of the HORB have changed. In 1994, the HORB was installed without culverts, while in 1997 the barrier had two open culverts that diverted approximately 300 cfs into upper Old River. In 2000, the HORB had six gated culverts, with two open during the Mossdale and first Durham Ferry releases and four open during the second Durham Ferry release. In 2001 and 2002, six culverts were installed and operated throughout the VAMP test period. It was estimated that approximately 400 cfs from the San Joaquin River moved through the culverts in 2001 and 2002 (Simon Kwan, DWR, personal communication). In 2003, three culverts were open during the studies.

The amount of water flowing through the culverts is based on the head differential between the San Joaquin River and Old River. The amount of water flow moving from the San Joaquin River into Old River would change as flow, stage and the tides change, even if all six culverts remained open for the remaining nine years of the study. These changes in the amount of flow through the culverts and number of culverts operating between years likely affects the entrainment and resulting survival at this point in the river, adding variability in survival from factors other than flow or exports.

The flow through the culverts and the seepage through the rock barrier and would affect the amount of remaining flow left in the San Joaquin River of which the salmon smolts are exposed. Using flow in the San Joaquin River at Vernalis as the estimate of flow the fish are exposed to instead of flow in the San Joaquin River downstream of the HORB adds additional variation to the relationships we are trying to identify and refine. A better estimate of flow to use in these relationships would be the net flow on the San Joaquin River downstream of upper Old River. An estimate of flow in the San Joaquin River downstream of Old River has been made by subtracting the estimated mean daily flow in upper Old River 840 feet downstream of the barrier from the USGS gauged mean daily flow at Vernalis (Chapter 4). In addition in 2003, an Acoustic Doppler Current Profiler (ACDP) was placed in the San Joaquin River downstream of the HORB for the purpose of estimating the flow. This method was deemed the best way to estimate flow at this location. Data from the ACDP are not yet available to use in our analyses. The ACDP data will be compared to that estimated using the mean daily flow in Old River to see how they compare and determine if it is possible to estimate San Joaquin flow downstream of Old River in past years. Future analyses will attempt to use these estimates in comparing smolt survival to San Joaquin River flow.

Comparison with other marked fish released from Merced River Fish Facility

Coded wire tagged salmon from Merced River Fish Facility were released in the San Joaquin River tributaries between April 13 and May 7 as part of independent (complimentary) fishery investigations. Releases were made in the Merced and Stanislaus Rivers at the upper and lower reaches of the rivers below the dams. These studies are reported in more detail in Chapter 6, but are discussed here as they relate to VAMP releases.

Survival indices of the downstream tributary groups to Antioch or Chipps Island would include mortality down the mainstem San Joaquin River as well as through the Delta. While the survival indices of these lower tributary released groups would include some additional river mortality, if main mainstem mortality was low then the indices would be comparable to survival indices of fish released at Durham Ferry and Mossdale as part of VAMP.

Survival indices of the downstream tributary groups were comparable to indices from the upstream VAMP releases. Group survival indices for salmon released in the lower tributaries and recovered at Antioch ranged between 0.002 and 0.032 (Table 4-10). Group survival indices ranged between 0.014 and 0.060 for recoveries made at Chipps Island (Table 4-10). No recoveries were made from the downstream group on the Stanislaus River (Two Rivers) at Chipps Island. Survival indices to Antioch and Chipps Island of VAMP released fish at Mossdale and Durham Ferry ranged from 0.010 to 0.048 (Table 4-4).

These data would indicate that whatever variable affected the survival of upstream released VAMP fish may have affected survival of the lower tributary released fish. It is also likely, that the tributary released fish from Merced River Fish Facility also were infected with PKD.

The survival indices using Antioch and Chipps Island recoveries of releases made in the upper tributaries were also low (Table 4-11) ranging between 0.002 and 0.020. No recoveries were made at Chipps Island for one of the upstream groups released in the Merced River. Again these indices are similar to those obtained for VAMP fish released at Durham Ferry and Mossdale indicating that low survival was not specific to upstream VAMP releases.

Comparison with Sacramento River Delta releases

Average survival indices for three groups of Feather River Hatchery smolts released at Sacramento on April 15, April 30 and May 15, 2003 averaged 0.51. This is within the range and near the average observed in past years (Brandes and McLain, 2001). It appears that whatever factor contributed to the low survival observed for all Durham Ferry and Mossdale CWT fish released from Merced River Fish Facility in 2003 was limited to the San Joaquin basin or Merced River Fish Facility and did not have a similar affect on marked fish released at Sacramento that originated from Feather River Hatchery.

Ocean Recovery Information From Past Years

Ocean recovery data of CWT salmon groups can contribute to a more thorough understanding and evaluation of salmon smolt survival studies. These data can provide another independent estimate of the ratio of recovery rate of a test release group relative to a control release group. Differential recovery rates using ocean recovery information can be compared with absolute survival estimates and the differential or combined differential recovery rates of juvenile salmon recovered at Chipps Island or Chipps Island and Antioch, respectively. The ocean harvest data may be particularly reliable due to the number of CWT recoveries and the extended recovery period.

Adult recovery data are gathered from commercial and sport ocean harvest checked at various ports by DFG. The Pacific States Marine Fisheries Commission database of ocean harvest CWT data was the source of recoveries through 2002. The ocean CWT recovery data accumulate over a one to four year period after the year a study release is made as nearly all given year-classes of salmon have been either harvested or spawned by age five. Consequently, these data are essentially complete for releases made through 1998 and partially available for CWT releases made from 1999 to 2001.

Differential recovery rates based on ocean recoveries, Chipps Island recoveries or combined differential recovery rates using Antioch and Chipps Island recoveries for salmon produced at the Merced River Hatchery are shown in Table 4-12. Absolute survival estimates based on Chipps Island and Antioch survival indices are also included. The earlier releases were made as part of south Delta survival evaluations (1996–1999) with the later releases associated with VAMP (2000–2001). Releases have been made at several locations: Dos Reis (on the San Joaquin River downstream of the upper Old River junction), Mossdale, Durham Ferry, and Jersey Point. The Chipps Island and Antioch survival estimates and combined differential (Antioch and Chipps Island recoveries summed) or differential recovery rates (Chipps Island recoveries only) are graphed in relation to the differential recovery rate using the ocean recovery information in Figure 4-12.

Results of this comparative analysis of survival estimates and differential recovery rates for Chinook salmon produced in the Merced River Hatchery show: (1) to date, there is general, but variable, agreement between survival estimates and differential recovery rates based on juvenile CWT salmon recoveries in Chipps Island and Antioch trawling and adult recoveries from the ocean fishery, (2) absolute survival estimates using Chipps Island or Antioch recoveries were either lower or similar to estimates based on ocean recoveries, with the exception of first releases in 2001, and (3) additional comparisons need to be made, as more data becomes available from VAMP releases for recoveries at Antioch, Chipps Island, and the ocean fishery. Information on survival of juvenile salmon and the contribution to the adult salmon population will be essential to evaluate the biological benefits of changes in flow and export rates under VAMP.

Figure 4-12 Comparison of Antioch and Chipps Island survival estimates and differential or combined differential recovery rates compared to differential ocean recovery rates. The one to one line is also included.

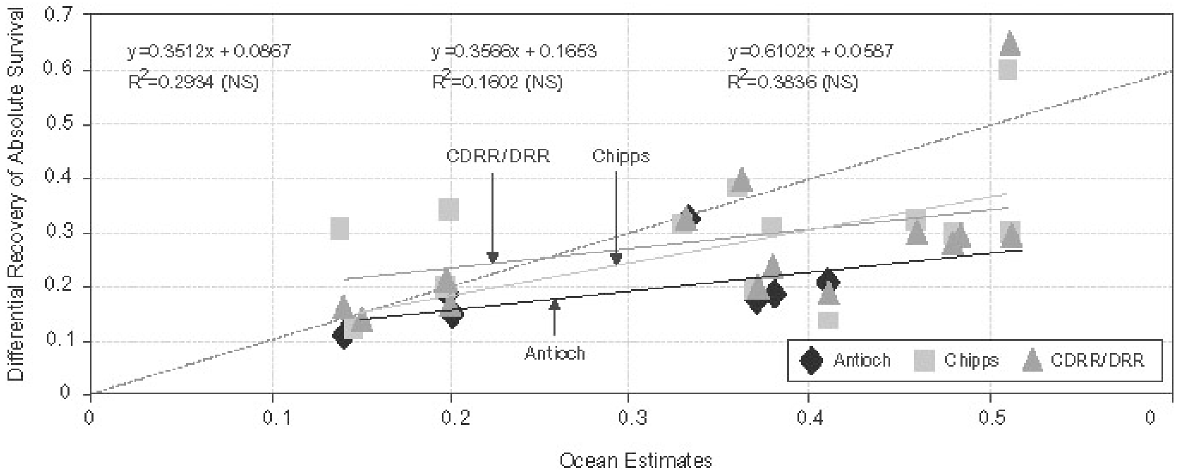


Table 4-10. Survival indices at Antioch and Chipps Island of CWT fish released in the lower Merced and Stanislaus Rivers in 2003. Expanded salvage at the CVP and SWP are also included.

				ANTIOCH					CHIPPS ISLAND					Expanded Salvage Numbers	
Tag Code	Release Site	Date	Number Released	Number Recovered	Minutes Fished	Percent Sampled	Survival Index	Group Index	Number Recovered	Minutes Fished	Percent Sampled	Survival Index	Group Index	CVP	SWP
Merced River															
06-44-93	Hatfield State Park (lower Merced)		23274	6	2185	0.379	0.049		4	1200	0.278	0.080		12	18
06-44-94	Hatfield State Park (lower Merced)		23872	2	5083	0.392	0.015		1	400	0.278	0.020		12	9
06-44-95	Hatfield State Park (lower Merced)		23833	4	2145	0.372	0.032		4	4379	0.276	0.079		12	0
Total		4/16/03	70979	12	6103	0.385		0.032	9	4779	0.277		0.060		
06-45-64	Hatfield State Park (lower Merced)		24545	0	–	–	–		0	–	–	–		0	0
06-45-65	Hatfield State Park (lower Merced)		24483	0	–	–	–		2	1460	0.253	0.042		0	0
06-45-66	Hatfield State Park (lower Merced)		24358	1	590	0.410	0.007		0	–	–	–		0	6
Total		4/29/03	73386	1	590	0.410		0.002	2	1460	0.253		0.014		
06-45-46	Hatfield State Park (lower Merced)		22603	0	–	–	–		1	400	0.278	0.021		0	0
06-45-47	Hatfield State Park (lower Merced)		22714	2	1780	0.412	0.015		0	–	–	–		0	0
06-45-72	Hatfield State Park (lower Merced)		22649	0	–	–	–		2	400	0.278	0.041		0	0
Total		5/7/03	67966	2	1780	0.412		0.005	3	1200	0.278		0.021		
Stanislaus River															
06-45-70	Two Rivers		26101	1	580	0.403	0.007		0	–	–	–		0	0
06-45-71	Two Rivers		26632	3	3392	0.393	0.021		0	–	–	–		0	0
Total		4/27- 4/28/03	52733	4	4512	0.392		0.014	0		–				

Table 4-11. Survival indices at Antioch and Chipps Island for coded wire tag releases made in the upper Merced and Stanislaus Rivers in 2003. Expanded salvage at the CVP and SWP are also included.

				ANTIOCH					CHIPPS ISLAND					Expanded Salvage Numbers	
Tag Code	Release Site	Date	Number Released	Number Recovered	Minutes Fished	Percent Sampled	Survival Index	Group Index	Number Recovered	Minutes Fished	Percent Sampled	Survival Index	Group Index	CVP	SWP
Merced River															
06-44-89	Merced River Fish Facility		22677	3	2185	0.379	0.025		1	400	0.278	0.021		24	6
06-44-90	Merced River Fish Facility		22816	1	590	0.410	0.008		1	400	0.278	0.021		0	0
06-44-91	Merced River Fish Facility		22946	2	5108	0.394	0.016		0	–	–	–		0	6
06-44-92	Merced River Fish Facility		21725	0	–	–	–		1	400	0.278	0.022		0	6
Total		4/13/03	90164	6	6123	0.387		0.012	3	2800	0.278		0.016		
06-44-96	Merced River Fish Facility		24232	0	–	–	–		0	–	–	–		0	0
06-44-97	Merced River Fish Facility		23869	0	–	–	–		0	–	–	–		0	0
06-44-98	Merced River Fish Facility		23757	1	572	0.397	0.008		0	–	–	–		0	0
06-44-99	Merced River Fish Facility		23950	0	–	–	–		0	–	–	–		12	0
		4/25/03	95808	1	572	0.397		0.002	0						
06-27-77	Merced River Fish Facility		23590	0	–	–	–		1	400	0.278	0.020		0	0
06-27-78	Merced River Fish Facility		23862	0	–	–	–		0	–	–	–		12	0
06-44-49	Merced River Fish Facility		23512	1	487	0.338	0.009		1	400	0.278	0.020		12	0
06-44-50	Merced River Fish Facility		24330	0	–	–	–		2	1600	0.278	0.038		0	6
Total		5/4/03	95294	1	487	0.338		0.002	4	2387	0.276		0.020		
Stanislaus River															
06-45-67	Knight's Ferry		25599	1	600	0.417	0.007		0	–	–	–		0	0
06-45-68	Knight's Ferry		26226	0	–	–	–		1	400	0.278	0.018		0	0
06-45-69	Knight's Ferry		26136	1	560	0.389	0.007		0	–	–	–		0	0
Total		4/25/03	77961	2	7967	0.395		0.005	1	400	0.278		0.006		

Table 4-12 Survival indices based on Chipps Island, Antioch, and ocean recoveries of Merced River Fish Facility salmon released as part of South Delta studies between 1996 and 2001.

Release Year	San Joaquin River (Merced River origin) Tag No.	Release Number	Release Site	Release Date	Chipps Island Recovs.	Antioch Recovs.	Expanded Adult Ocean Recovs. (age 1+ to 4+) Total	Chipps Island	Antioch	DRR or CDRR	Ocean Catch
		Juvenile Salmon CWT Releases						Absolute Survival Estimates		Differential Recovery Rates	
1996	H61110412	25,633	Dos Reis	1 May 96	2		3				
	H61110413	28,192	Dos Reis	1 May 96	3		37				
	H61110414	18,533	Dos Reis	1 May 96	1		8				
	H61110415	36,037	Dos Reis	1 May 96	5		10				
	H61110501	53,337	Jersey Pt	3 May 96	39		187				
	Effective Release	107,961	Dos Reis		11		58	0.12		0.14	0.15
	Effective Release	51,737	Jersey Pt		39		187				
1997	H62545	50,695	Dos Reis	29 Apr 97	9		183				
	H62546	55,315	Dos Reis	29 Apr 97	7		167				
	H62547	51,588	Jersey Pt	2 May 97	27		355				
	Effective Release	106,010	Dos Reis		16		350	0.29		0.29	0.48
	Effective Release	51,588	Jersey Pt		27		355				
	H62548	46,728	Dos Reis	8 May 97	5		91	0.30		0.28	0.48
	H62549	47,254	Jersey Pt	12 May 97	18		192				
1998	61110809	26,465	Mossdale	16 Apr 98	25		61				
	61110810	25,264	Mossdale	16 Apr 98	31		40				
	61110811	25,926	Mossdale	16 Apr 98	32		58				
	61110806	26,215	Dos Reis	17 Apr 98	33		47				
	61110807	26,366	Dos Reis	17 Apr 98	23		35				
	61110808	24,792	Dos Reis	17 Apr 98	34		61				
	61110812	24,598	Jersey Pt	20 Apr 98	87		110				
	61110813	25,673	Jersey Pt	20 Apr 98	100		91				
	Effective Release	77,655	Mossdale		88		159	0.30		0.30	0.51
	Effective Release	77,373	Dos Reis		90		143	0.32		0.31	0.46
	Effective Release	50,271	Jersey Pt		187		201				
1999	062642	24,715	Mossdale	19 Apr 99	8		128				
	062643	24,725	Mossdale	19 Apr 99	15		134				
	062644	25,433	Mossdale	19 Apr 99	13		130				
	062645	25,014	Dos Reis	19 Apr 99	20		151				
	062646	24,841	Dos Reis	19 Apr 99	19		218				
	0601110815	24,927	Jersey Pt	21 Apr 99	34		333				
	062647	24,193	Jersey Pt	21 Apr 99	25		379				
	Effective Release	74,873	Mossdale		36		392	0.38		0.40	0.36
	Effective Release	49,855	Dos Reis		39		369	0.60		0.65	0.51
	Effective Release	49,120	Jersey Pt		59		712				

Table 4-12 Survival indices based on Chipps Island, Antioch, and ocean recoveries of Merced River Fish Facility salmon released as part of South Delta studies between 1996 and 2001. (continued)

Release Year	San Joaquin River (Merced River origin) Tag No.	Release Number	Release Site	Release Date	Chipps Island Recovs.	Antioch Recovs.	Expanded Adult Ocean Recovs. (age 1+ to 4+) Total	Chipps Island	Antioch	DRR or CDRR	Ocean Catch
		Juvenile Salmon CWT Releases						Absolute Survival Estimates		Differential Recovery Rates	
2000	06-45-63	24,457	Durham Ferry	17 Apr 00	11	11	235				
	06-04-01	23,529	Durham Ferry	17 Apr 00	7	6	190				
	06-04-02	24,177	Durham Ferry	17 Apr 00	10	10	225				
	06-44-01	23,465	Mossdale	18 Apr 00	9	14	198				
	06-44-02	22,784	Mossdale	18 Apr 00	9	16	159				
	06-44-03	25,527	Jersey Pt	20 Apr 00	24	50	592				
	06-44-04	25,824	Jersey Pt	20 Apr 00	41	47	617				
	Effective Release	72,163	Durham Ferry		28	27	650	0.31	0.19	0.24	0.38
	Effective Release	46,249	Mossdale		18	30	357	0.31	0.33	0.33	0.33
	Effective Release	51,351	Jersey Pt		65	97	1209				
	601060914	23,698	Durham Ferry	28 Apr 00	7	8	43				
	601060915	26,805	Durham Ferry	28 Apr 00	5	15	36				
	0601110814	23,889	Durham Ferry	28 Apr 00	10	8	70				
	0601061001	25,572	Jersey Pt	1 May 00	48	76	300				
	0601061002	24,661	Jersey Pt	1 May 00	30	76	215				
	Effective Release	74,392	Durham Ferry		22	31	149	0.19	0.14	0.16	0.20
	Effective Release	50,233	Jersey Pt		78	152	515				
2001	06-44-29	23,354	Durham Ferry	30 Apr 01	14	28	4				
	06-44-30	22,837	Durham Ferry	30 Apr 01	22	30	26				
	06-44-31	22,491	Durham Ferry	30 Apr 01	17	18	4				
	06-44-32	23,000	Mossdale	1 May 01	17	18	16				
	06-44-33	22,177	Mossdale	1 May 01	14	15	0				
	06-44-34	24,443	Jersey Pt	4 May 01	50	156	50				
	06-44-35	24,992	Jersey Pt	4 May 01	61	173	72				
	Effective Release	68,682	Durham Ferry		53	76	34	0.34	0.17	0.21	0.20
	Effective Release	45,177	Mossdale		31	33	16	0.31	0.11	0.16	0.14
	Effective Release	49,435	Jersey Pt		111	329	122				
	06-44-36	24,025	Durham Ferry	7 May 01	2	8	5				
	06-44-37	24,029	Durham Ferry	7 May 01	5	11	9				
	06-44-38	24,177	Durham Ferry	7 May 01	2	10	4				
	06-44-39	23,878	Mossdale	8 May 01	4	8	11				
	06-44-40	25,308	Mossdale	8 May 01	4	11	0				
	06-44-41	25,909	Jersey Pt	11 May 01	17	43	18				
	06-44-42	25,465	Jersey Pt	11 May 01	27	53	13				
	Effective Release	72,231	Durham Ferry		9	29	18	0.13	0.20	0.19	0.41
	Effective Release	49,186	Mossdale		8	19	11	0.19	0.18	0.20	0.37
	Effective Release	51,374	Jersey Pt		44	96	31				

Note: Ocean recoveries are based on data through 2002

San Joaquin River Salmon Protection

One of the VAMP objectives is to provide improved conditions to increase the survival of juvenile Chinook salmon smolts produced in the San Joaquin River tributaries during their downstream migration through the lower river and Delta. It is assumed that these actions to improve conditions for the juveniles will translate into greater adult abundance and escapement in future years, especially during low flows, when corresponding adult escapement (2 1/2 years later) has been extremely low (SJRG, 2003).

To determine if VAMP in 2003 was successful in targeting the migration period of naturally produced juvenile salmon, catches of unmarked salmon at Mossdale and in salvage at the CVP and SWP facilities were compared prior to and during the VAMP period.

Unmarked Salmon Recovered at Mossdale

The time period for VAMP (April 15 to May 15) was chosen based on historical data that indicated a high percentage of the juvenile salmon emigrating from the San Joaquin tributaries passed into the Delta at Mossdale during that time. The average catch per minute per day of unmarked juvenile salmon caught in kodiak trawling at Mossdale between March 15 and June 30, 2003 is shown in Figure 4-13. Unmarked salmon do not have an adipose clip and could be unmarked fish from the Merced River Fish Facility or juveniles from natural spawning. Approximately 80% of the unmarked catch that passed Mossdale between March 15 and June 30 passed during the VAMP period: April 15 to May 15. The size of the juvenile salmon migrating past Mossdale between March 15 and June 30, 2003 is shown in Figure 4-14.

The pattern of unmarked juvenile salmon caught at Mossdale in 2003 was different than that observed in 2002, and did not obviously show that the number of fish passing Mossdale was less in 2003 than it was in 2002 (Figure 4-15). The peak in early May of 2002 was greater than any peak observed in 2003, but catches in 2003 were greater than 2002 during other times.

Salmon Salvage and Losses at Delta Export Pumps

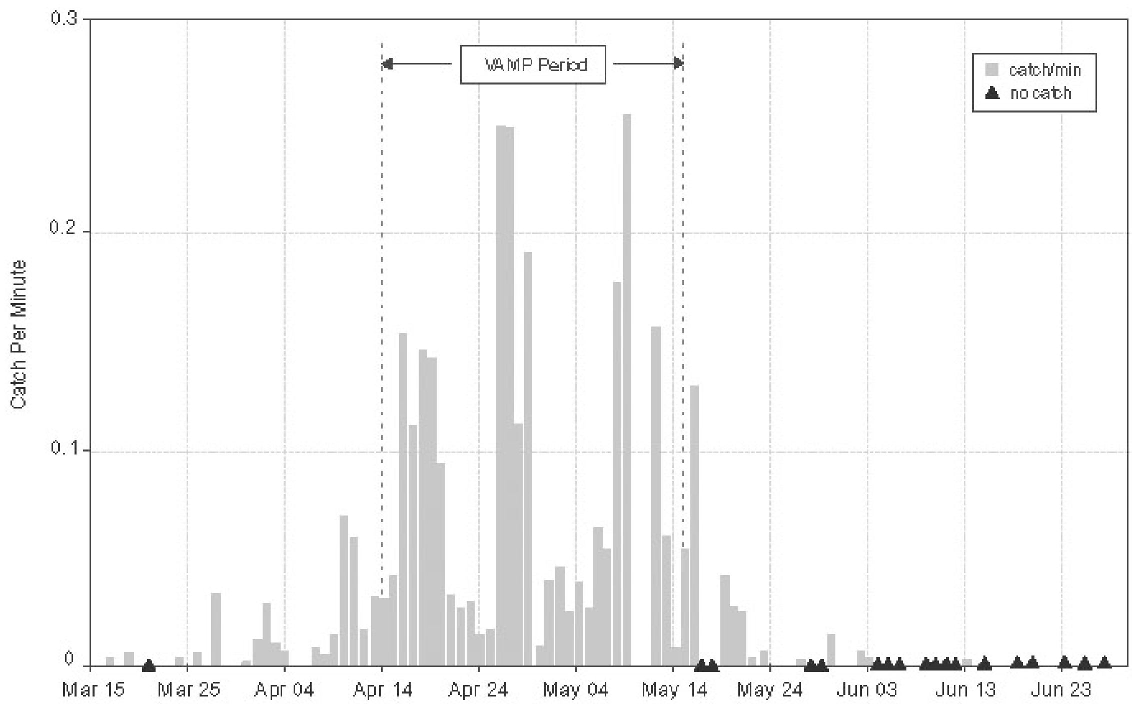
Fish salvage operations at the CVP and SWP export facilities capture unmarked salmon for transport by tanker truck and release them downstream in the western Sacramento–San Joaquin Delta. The untagged salmon are either naturally produced or untagged hatchery salmon, potentially from any source in the Central Valley. It is not certain which unmarked salmon recovered are of San Joaquin basin origin, although the timing of salvage and fish size can be compared with Mossdale trawl data and CWT recovery data for Merced River Fish Facility smolts at the facilities to provide some general indications.

The salvage at the facilities is based on expansions from sub-samples taken throughout the day. Four to five salmon are estimated to be lost per salvaged salmon in the SWP Clifton Court Forebay based on high predation rates. The CVP pumps divert directly from the Old River channel and the loss estimates range from about 50 to 80% of the number salvaged, or about six to eight times less per salvaged salmon than for the SWP. The loss estimates do not include any indirect mortality in the Delta due to water export operations, additional mortality associated with trucking and handling, or post-release predation. Salvage density of salmon is the number of salvaged salmon per acre-foot of water pumped. The California Department of Water Resources maintains a database of daily, weekly, and monthly salvage data.

The number and density of juvenile salmon that migrated through the system, the placement of the HORB, and the amount of water pumped by each facility are some of the factors that influence the number of juvenile salmon salvaged and lost. Density is the best indicator of when concentrations of juvenile salmon are most susceptible to the export facilities and salvage system.

The weekly data covering the period of April 13 to May 17 encompassed the 2003 VAMP period. A review of weekly data for March through May indicates that the highest salvage and losses occurred during the three weeks prior to VAMP (period of March 23 to April 12), with the exception of the highest CVP losses being recorded in the second VAMP week, April 20 to 26 (Figures 4-16 and 4-17). Combined CVP and SWP weekly export rates during those three weeks proceeding VAMP averaged 7,500–10,900 cfs (Figure 4-18). Salmon density was highest in the second week of the VAMP period at both the CVP and SWP facilities, and continued to be relatively high during the VAMP period (Figure 4-19), indicating the VAMP export reductions were in place when the density of salmon was the highest. Based on comparisons with Mossdale data in Figure 4-13, it appears that most of the salmon salvaged in early April may not have been of San Joaquin basin origin. Reducing exports earlier in April may provide better conditions for juvenile spring-, winter-, and fall- run Chinook salmon migrating through the Delta from the Sacramento River basin.

Figure 4-13 Standardized catch per cubic meter of all unmarked juvenile Chinook salmon in the Mossdale Kodiak trawl, March 15, 2003 through June 30, 2003.



The size distribution of unmarked salmon during April and May in the Mossdale trawl (Figure 4-14) is a subset of the size distribution of those salvaged at the fish facilities (Figure 4-20: Source E. Chappell, DWR). In 2003, the fish facilities salvaged some juvenile salmon between March 15 and early May that were larger (winter run sized) than any observed at Mossdale.

Results of these analyses showed that the 2003 VAMP test period coincided with much of the peak period of San Joaquin River salmon smolt emigration. Reductions in SWP and CVP exports and increased San Joaquin River flow likely provided improved conditions for salmon survival, although starting the VAMP period two to three weeks earlier may have had substantial benefits for other salmon races and stocks.

Figure 4-14 Individual fork lengths (mm) of all unmarked juvenile Chinook salmon in the Mossdale Kodiak trawl, March 15, 2003 through June 30, 2003.

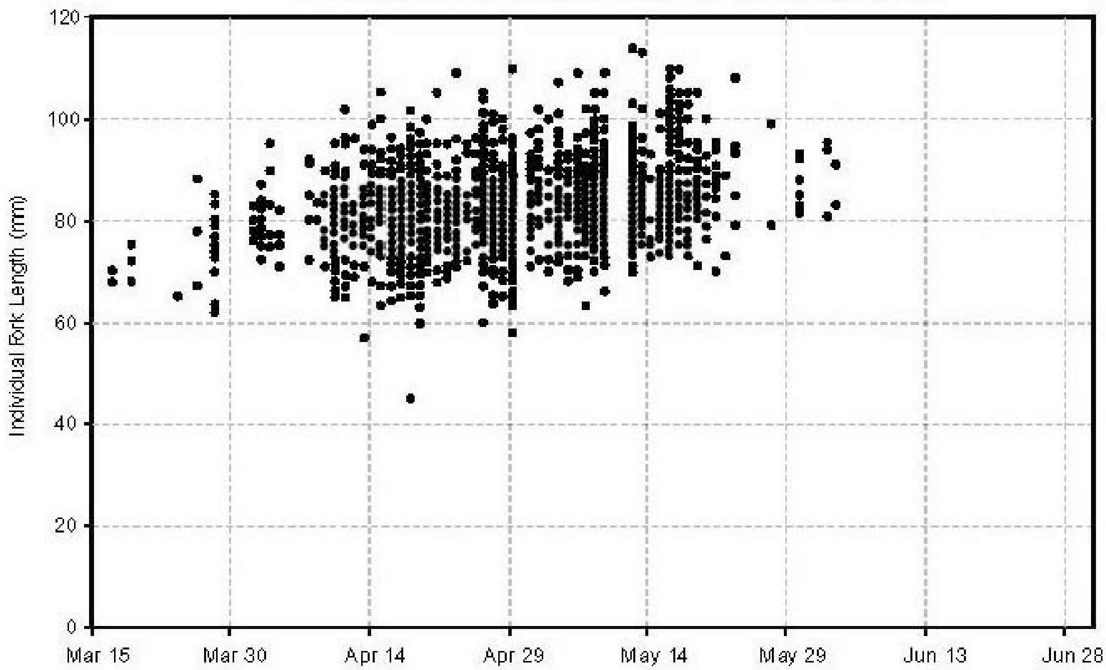


Figure 4-15 Standardized catch per minute of all unmarked juvenile Chinook salmon in the Mossdale Kodiak trawl, March 15 through June 30, 2002 and 2003.

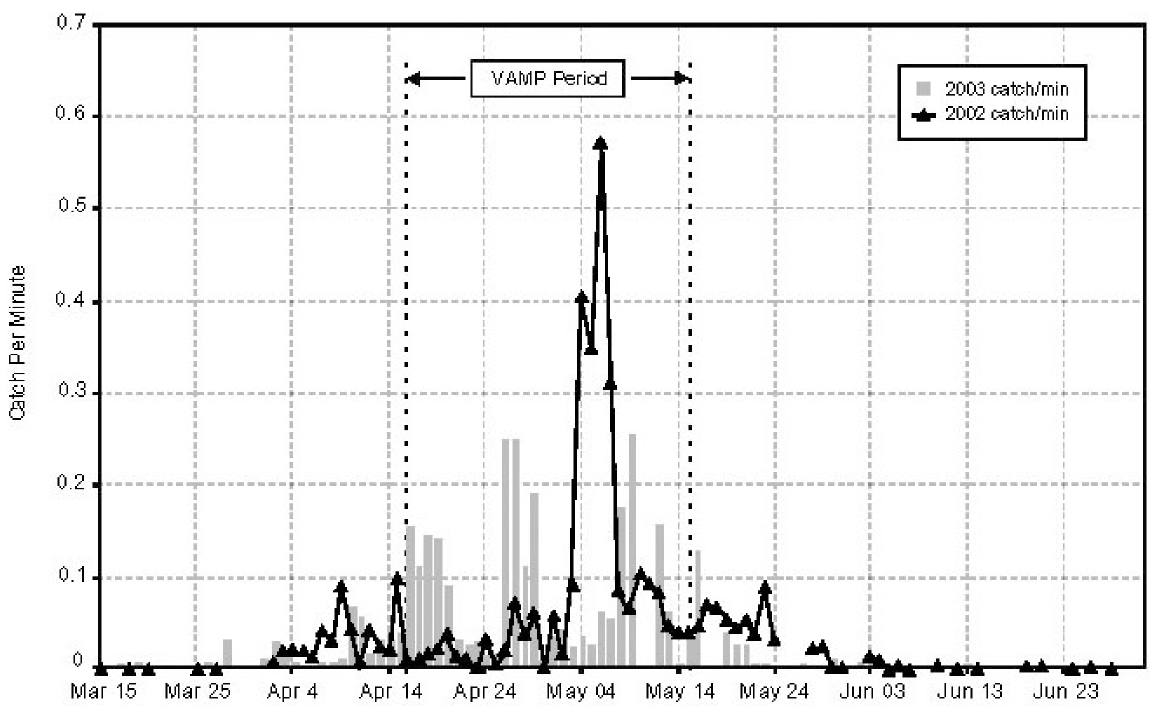


Figure 4-16 2003 SWP salmon salvage and loss.

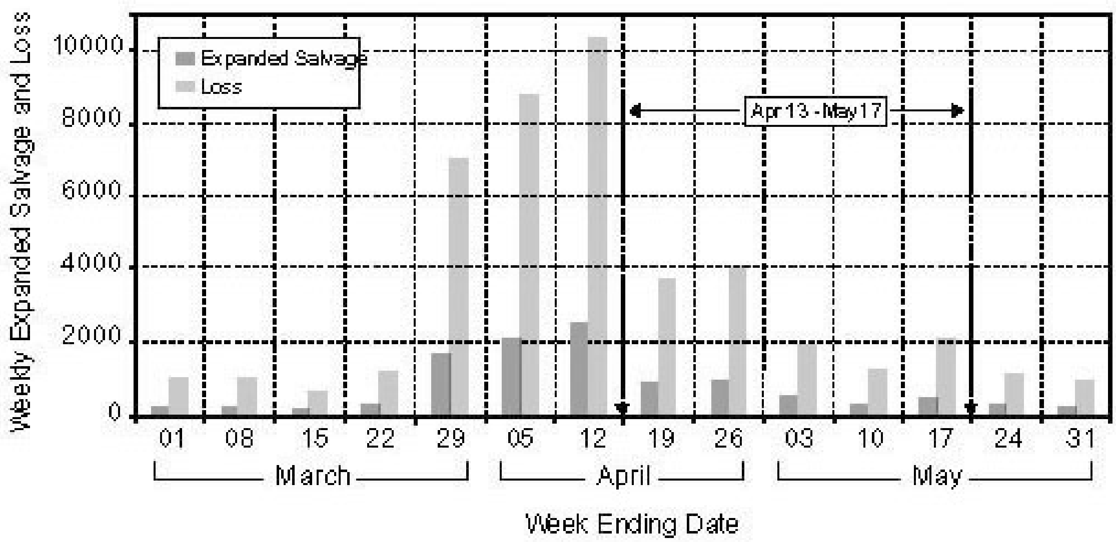


Figure 4-17 2003 CVP salmon salvage and loss.

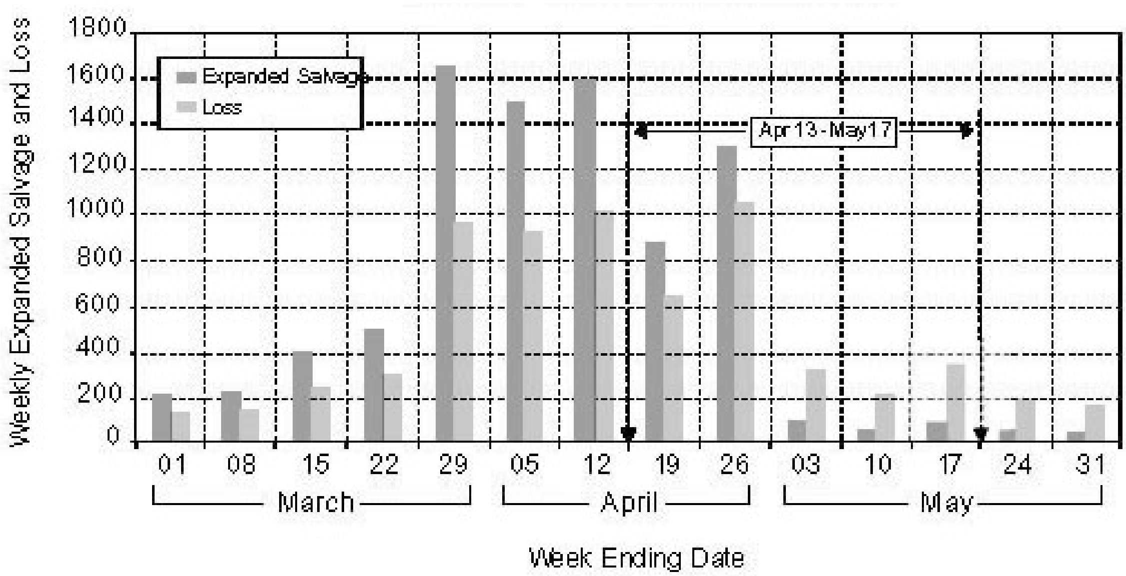


Figure 4-18 2003 weekly SWP/CVP export rates and Vernalis flow

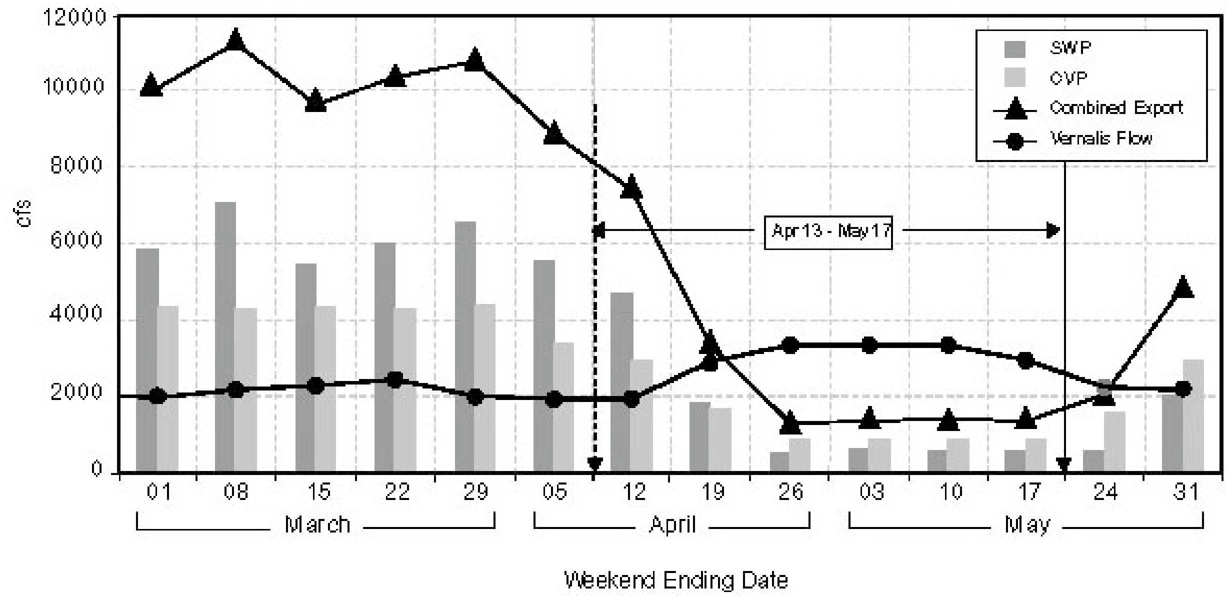


Figure 4-19 2003 SWP/CVP expanded salmon salvage density

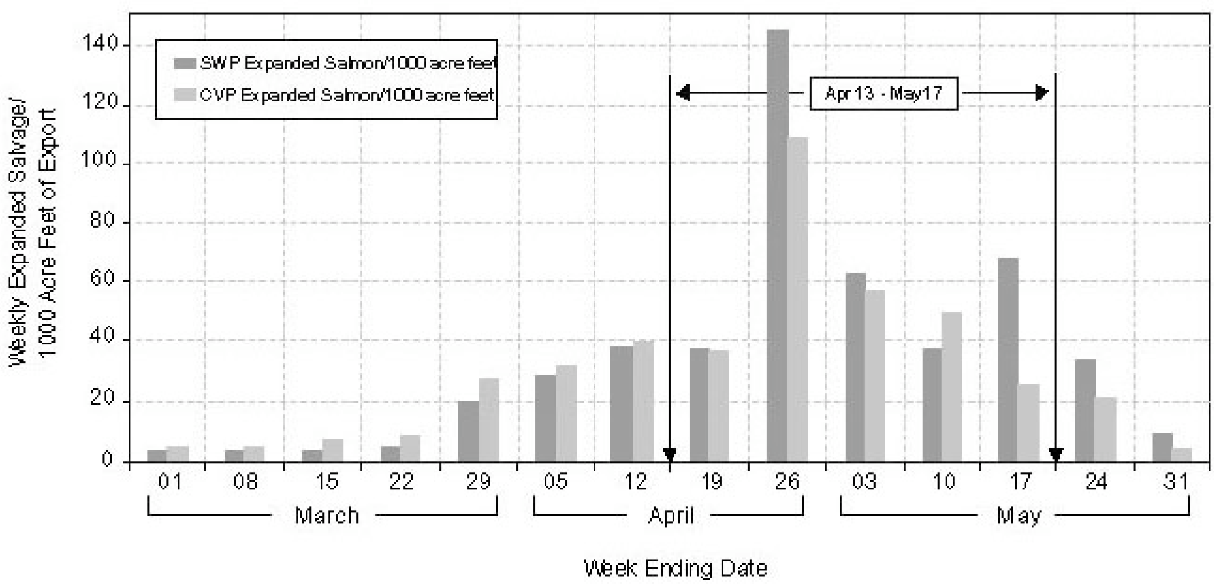
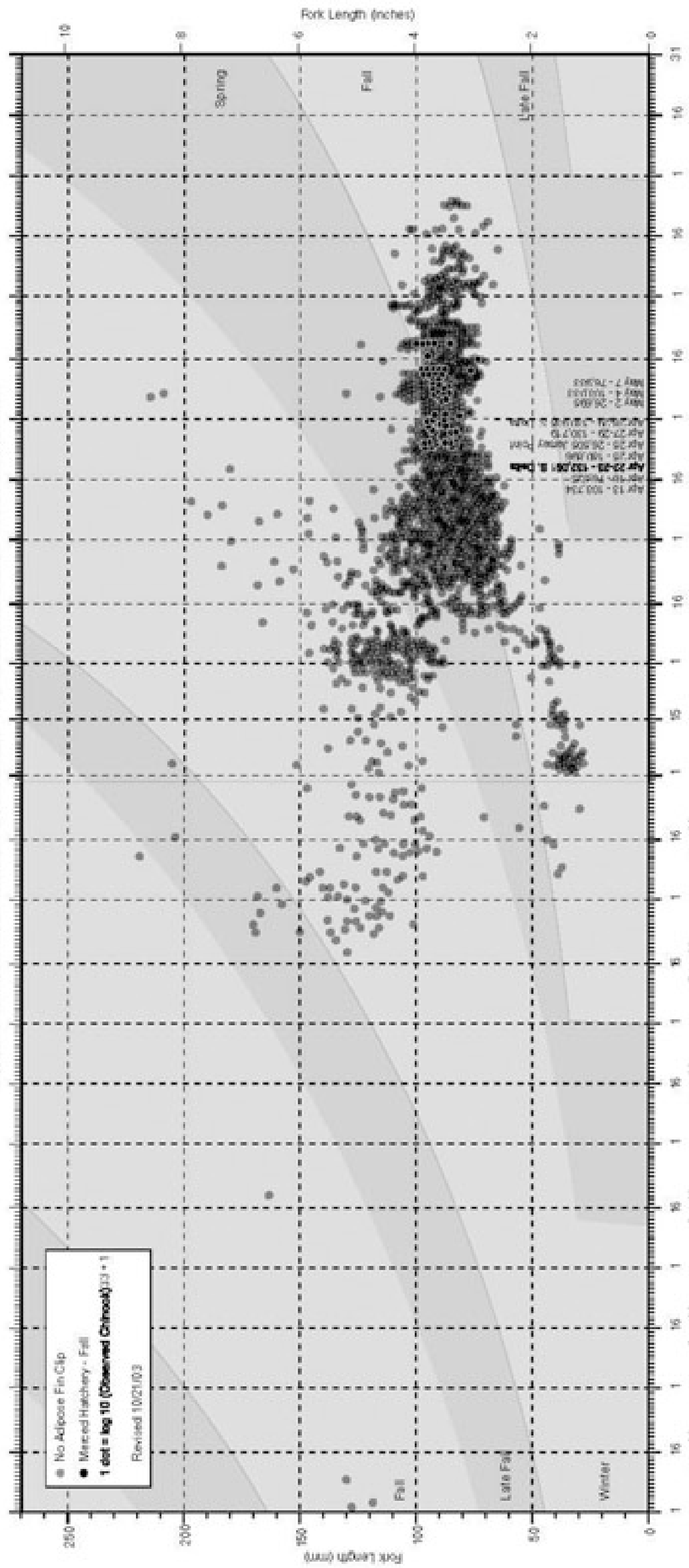


Figure 4-20. Observed Chinook Salvage at the SWP &CVP Delta Fish Facilities 8/1/02 through 7/31/03



Summary and Recommendations

The survival estimates and CDRRs measured in 2003 were low compared to past years. It is unclear why survival in 2003 was so low but it does not seem to be directly related to San Joaquin River flow, CVP and SWP exports or water temperature. The hatchery fish were infected with the parasite that causes PKD. Fish have been infected in past VAMP study years and it does not appear that the incidence of PKD was actually higher in 2003. However, the combination of the lower flows and PKD infection may have affected the mortality of the VAMP fish in 2003 resulting in shorter transit duration and higher mortality relative to past VAMP releases.

Some rain occurred during the studies, which was somewhat unusual, and possibly agricultural and/or urban run-off from the storm caused mortality, but a toxic event due to stormwater run-off should be episodic and not be a long-term event affecting all the releases made at Merced River Fish Facility over a three week period. The high and similar mortality of the tributary CWT groups released from Merced River Fish Facility indicates that whatever increased the mortality of the VAMP fish was some condition that was common to the Merced River Fish Facility (with the exception of the Jersey Point releases) and lasted for several weeks. This condition also appeared to be restricted to the Delta or differences in the survival indices for the upstream and downstream tributary releases would have been greater. While the causes are unclear, it would appear the VAMP data in 2003 are outliers and repeating the study in future years will determine if this anomaly is limited to 2003 or is a change in overall conditions.

Even without the 2003 data, there have been several impediments to defining and refining the relationships between smolt survival and San Joaquin River flow and CVP and SWP exports. These impediments have been discussed in this and previous VAMP reports. The different permeability of the HORB and not having estimates of flow in the San Joaquin River downstream of the barrier add noise to our estimates of flow. In addition, using diseased hatchery fish in VAMP experiments adds a potential bias to our estimates of survival, even though PKD is also present in wild stocks (Ken Nichols, USFWS internal memo, 12/6/02). Measuring survival within the narrowly defined flow and export VAMP targets further exacerbates the problem of noise in the variables of interest. The level of precision of our survival estimates and the noise in flow measurements limits our ability to precisely define the relationship of survival to flow and exports. Yearly, pooled estimates are now based on releases of 300,000 to 400,000 fish with two recovery locations, sampling roughly seven to ten hours per day, yet recoveries have not been great enough to statistically differentiate between survival estimates measured at VAMP target flow and exports levels obtained to date. Differences in survival may be occurring but our ability to detect them is limited.

To address this dilemma, future studies should prioritize measuring survival at the highest VAMP target flow and lowest export levels. Flows of 7000 cfs and exports of 1500 cfs would achieve the highest inflow to export ratio (4.7) within the VAMP design and provide a new target to test. Based on information to date, the higher flow would be probably increase survival and may lessen any effects or infection rate of PKD. The higher survival should increase recovery numbers such that CDRRs and confidence intervals may show statistical differences when compared to previously obtained CDRRs. It is uncertain how such a condition can be prescribed, independent of the hydrology, within the existing San Joaquin River Agreement, but the idea should be explored by the VAMP Management Team.

Further confidence in defining and refining the relationship of smolt survival to flow and exports could be obtained by increasing the length of the study. The fourth year of VAMP was completed in 2003 with eight years remaining in the study. Additional replication can resolve uncertainty when variation is high.

Continued assessment of past data is also recommended such that other methodologies or criteria for determining statistical differences between groups may be developed.

Chapter 5. Annual Summary Report of SWP and CVP Salvage

In preparation of future evaluations on the effect of the Temporary Barriers Project (TBP) on fish entrainment at the Skinner (State Water Project) and Tracy (Central Valley Project) fish facilities, a comparison of barrier operations, Delta hydrodynamics, project exports and salvage densities was updated for 2003. Graphic representations of weekly averaged data were created as a tool for the visual comparison of changes in each variable. Each species chart was studied in order to determine a plausible method for future retroactive analyses of temporary barrier operations and fish salvage in the south Delta. Insight gained could be utilized later to better manage temporary barrier and subsequent permanent barrier operations to reduce Project entrainment impacts on special concern fishes in the Delta.

Data Collection

The USGS provided hydrodynamics data in the form of tidally averaged daily net flow for Middle and Old Rivers (at Bacon Island) for 2003. These will be referred to as "central Delta flows". Delta fish facility salvage and associated water volumes were downloaded from the DFG Bay-Delta Office ftp Web site (ftp://ftp.delta.dfg.ca.gov). SWP and the CVP water exports were queried from the IEP online "Data Vaults" (http://www.iep.ca.gov/data.html). Barrier operations were obtained from the Temporary Barriers Project "Weekly Updates" and "Schedule of Operations", which are posted on the DWR's South Delta section website (http://sdelta.water.ca.gov), and from Michael Burns (verbal communication). In some cases, the specific time of barrier closure and/or breech was estimated based on this information.

Methods

The TBP barriers include the Head of Old River barrier (HORB) and the three agricultural barriers: Old River barrier near the Delta Mendota Canal (OR barrier); Middle River barrier (MR barrier); and the Grant Line Canal barrier (GLC barrier). Barrier operations were graphically represented by vertical lines that identify relative points in time when specific barriers had been put into full operation (closed) and when each had been sufficiently removed (breeched), returning flow to near-normal (pre-barrier) conditions. The figures only take complete barrier installations into consideration. Barrier-specific operational adjustments, or minor changes such as manual culvert operations and addition of salmonid passage notches are listed here, but were not included in the figures. Incomplete structures and adjustments in configuration were not included. Despite this simplification of TBP operations, several uncharted adjustments in barrier structure and operation altered flow to an unknown degree. These adjustments were assumed to have an insignificant effect on fish salvage densities at the south Delta fish facilities. The most notable of these adjustments made in 2003 are listed below.

- The GLC barrier installation began April 2, but its center portion was left open due to sufficient upstream water levels. The barrier was closed on June 11 in anticipation of significantly increased exports that would otherwise lower upstream water levels.

- The tidal flap gates on the OR and MR barriers were tied open from the week of May 14 (specifically-May 16) through the week of May 31 (June 2) in anticipation of significantly increased exports.

- The OR and MR barriers were notched during the week of September 15 to allow passage of migrating adult salmon over the top of the weir. Flashboards on the GLC barrier were adjusted accordingly for the same purpose.

- Three of six culverts (# 4-6) on the H.O.R.B. were left open throughout the spring operating period in order to protect downstream water levels. Beginning September 22 after completion of installation, all six culverts were closed throughout the fall operating period.

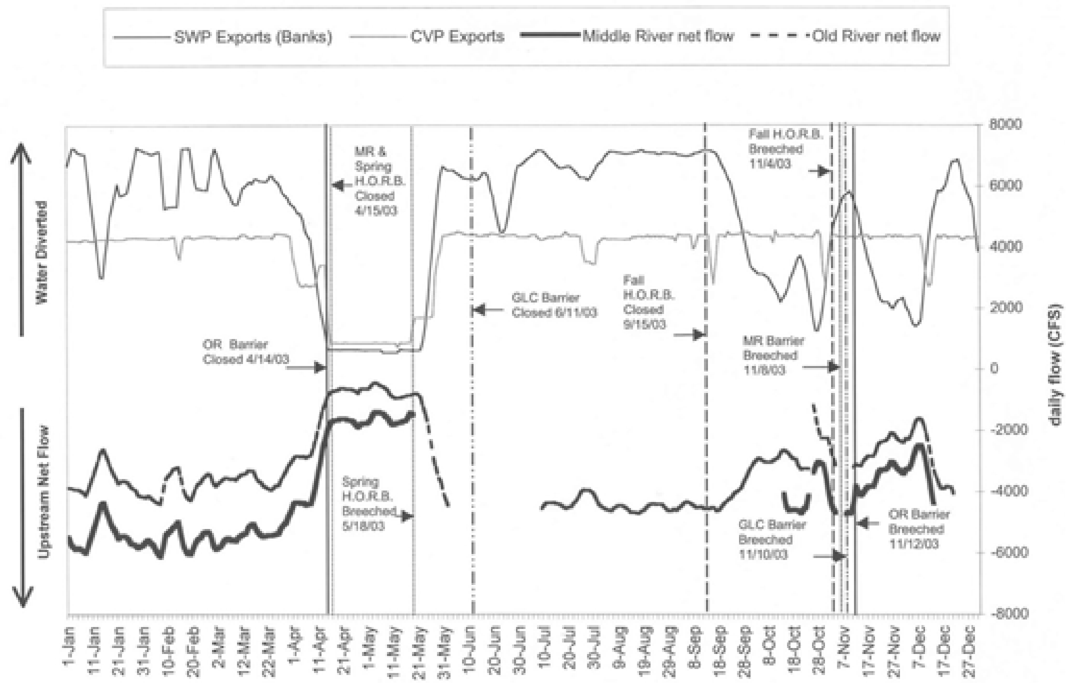
- During the removal process, partial breaches of the GLC and OR barriers were performed on November 10 and 12, respectively, prior to complete breaching on November 13 and 15.

Project exports and central Delta flows were plotted as cubic feet per second (cfs) (Figure 5-1). It is important to note that their respective curves respond differently to increased upstream flow rates. Exports represent water being pumped upstream out of the Delta through the Skinner and Tracy fish salvage facilities by the Banks (SWP) and Tracy (CVP) pumping plants. Their rates are greater than or equal to zero since water transport from the south Delta occurs in only one direction. Central Delta net flows can be bi-directional with positive downstream flows and negative upstream flows. Beginning this year, SWP export is recorded as Clifton Court Forebay gate flow rather than Banks pumping to better characterize SWP impact on central Delta water transport.

In 2003, central Delta flows were always negative, exhibiting only upstream daily net flow. An increase in the intensity of central Delta flows in this direction was plotted as a lower value, and thus a lower position graphically. Practically speaking, export curves and central Delta net flow curves respond inversely when upstream flow occurs for each variable. Problems with each of the USGS flow loggers left large gaps in the data. Unfortunately, the splittail and delta smelt salvage plots were most affected by the lack of flow data, since salvage densities were quite high during such periods. On Middle River, the logger was eventually replaced with a new unit.

The Vernalis Adaptive Management Plan (VAMP) was implemented during the spring of 2003 to protect juvenile Chinook salmon and evaluate the relationship between San Joaquin River flow and SWP and CVP exports on survival of juvenile Chinook salmon migrating through the Sacramento- San Joaquin Delta (VAMP, 2003 Annual Technical Report). VAMP maintained moderate central Delta flows from April 15 through May 15.

Figure 5-1 Seven-day running averages of daily SWP (Clifton Court Forebay gates flow) and CVP exports, central Delta flows and Temporary Barriers Project operations in 2003.



Salvage densities for each species were plotted as the number of fish per acre feet of water (#fish/AF) pumped through the project facility. One species chart was created for each of several special concern fishes including delta smelt (Hypomesus transpacificus), Chinook salmon (Oncorhynchus tshawytscha), splittail (Pogonichthys macrolepidotus), steelhead (Oncorhyncus mykiss) and longfin smelt (Spirinchus thaleichthys). Each chart focuses on the salvage season, or the time of the year when salvage of the particular species occurred. Dates when salvage occurred outside of the TBP operating season may not have been plotted since the data was not important to this report. For instance, steelhead salvage densities reached relatively low to moderate levels during the last two weeks of December. Only three green sturgeon (Acipenser medirostris) were salvaged (1/11/03, 2/2/03 and 7/13/03) at the Skinner Fish Facility, and were not included further in this report.

Data used in species charts were averaged weekly in order to enhance the visual characterization of potentially significant changes. This modification helped to weaken timing discrepancies (see next section) from barrier operations and facility salvage data. It also afforded some continuity to the central Delta flow curves where a few daily data points were missing.

Fish Salvage Concerns

An examination of fish salvage was complicated by the fact that different fishes and age groups behave differently to environmental conditions. The Skinner and Tracy fish salvage facilities are not geared to effectively sample all fish equally. Salvage efficiency can be related to the size and swimming ability of specific fishes or age groups. Significantly large proportions of populations may be entrained in certain years because of their inability to escape the pumps' zone of influence. Larval fishes are especially susceptible to entrainment. Nobriga and others (2000) explained that salvage of young delta smelt at the Delta fish facilities begins to be quantified each spring when the smelt reach a length of about 25 mm. Although smaller fish were salvaged, their numbers would not offer a reasonable estimate of the population entrained since an unknown quantity simply pass through the screens undetected.

Differences in SWP and CVP fish collection configurations further complicate a comparison of project salvage data. For example, the Clifton Court Forebay (CCF) may delay salvage of fishes entrained by the SWP for up to several days relative to the CVP, which does not have a similar holding basin. In addition, pre-screening loss of fishes in the CCF is unknown. Because of these differences, project-specific salvage data are better suited to characterize entrainment vulnerabilities of local populations of fishes than is their combined total salvage.

Since all four races of Chinook salmon are listed as species of special concern, they were not separated by race in this comparison. Winter-run length salmon were salvaged from mid-December 2002 through early May 2003 (SJRGA, 2003). Chinook salmon data may be separated by race in future analyses.

Salvage Observation and Evaluation

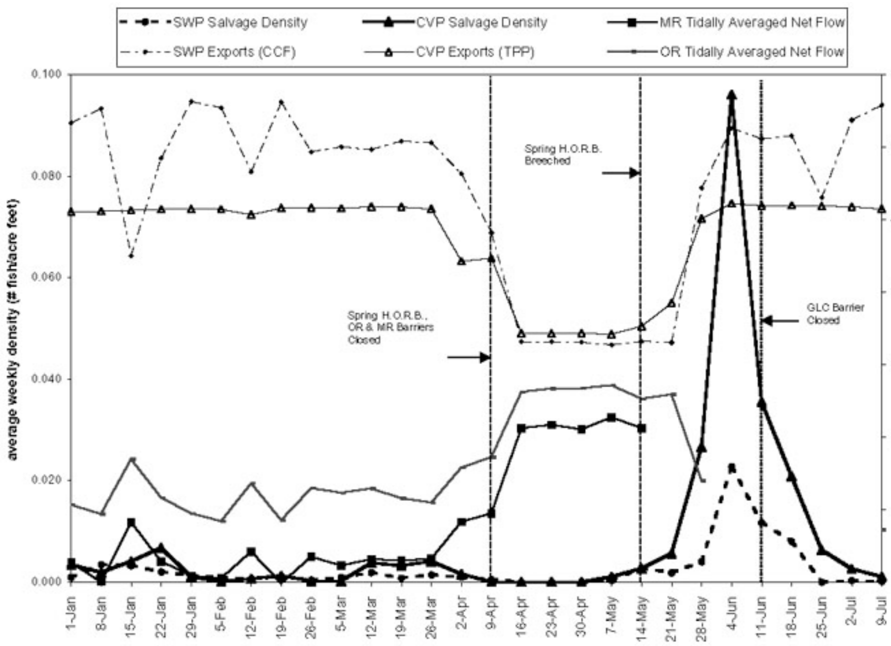
Total species salvage at the South Delta fish collection facilities in 2003 often varied greatly from salvage in 2002 (Table 5-1). Despite such variation, salvage of each special concern species appeared to occur in a single wave for most species examined. This was indicative of a population’s movement through the south Delta projects’ zone of influence.

Table 5-1 Sum of CVP and SWP species’ salvage for 2002 and 2003.

Species	Splittail		Delta smelt		Chinook salmon		Steelhead		Longfin smelt	
Year	SWP salvage	CVP salvage	SWP salvage	CVP salvage	SWP salvage	CVP salvage	SWP salvage	CVP salvage	SWP salvage	CVP salvage
2002	5768	3269	49823	18396	6348	15573	2181	1656	54582	43188
2003	6066	13666	21248	16662	17492	16497	5766	6871	706	4562

Splittail proved to be the exception for the second year in a row (DWR 2002), showing up in weekly salvage for three pulses; in January, March and June (Figure 5-2). Peak weekly averaged salvage densities for each of the first two pulses were similar to peak levels in 2002, but occurred prior to the start of the temporary barriers operating season. Elevated splittail salvage densities corresponding with the second two peaks appear to bracket the moderate central Delta flows of the VAMP, although no splittail were salvaged on most days during the this period. The post-VAMP salvage peak was significantly larger than earlier pulses in 2003. The aforementioned third and final pulse of salvage appeared in June, when the peak average weekly salvage density at both facilities exhibited nearly a ten-fold increase over 2002 levels. This rise in salvage densities occurred in lock step with an increase in project exports following the end of the VAMP period (April 15-May 15). It further indicates that a sizable number of juvenile splittail were present within the projects’ zone of influence when exports were stepped higher beginning May 19 and May 29, respectively, for the CVP and SWP. Although the change in salvage at each facility mirrored the other, the peak density of splittail salvaged by the CVP was over four times greater than peak SWP salvage. The final pulse of splittail salvage dropped with the closing of the GLC barrier and a moderate reduction in SWP exports. This decline occurred, as exports remained relatively constant, suggesting that the barrier closure may have had some influence in lowering salvage densities. Likely, this change was due to the movement of susceptible splittail from the projects' zone of influence. Together, these observations of splittail salvage are suggestive of several potentially significant relationships within the data. A further examination is warranted.

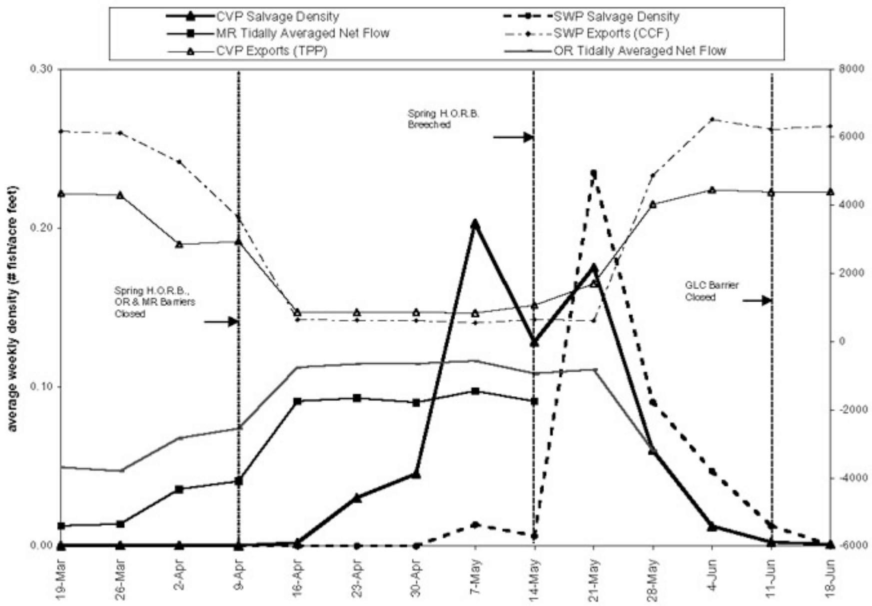
Figure 5-2 Weekly averaged splittail salvage densities, SWP and CVP exports, central Delta flows and Temporary Barriers Project operations for the weeks beginning 3/12 – 6/25/03.



Adult delta smelt predominantly move upstream into fresh water areas from January through March to spawn (DWR and USBR, 2003). Adults were salvaged in relatively low densities in January and early February, prior to the temporary barriers operating season. Typically, young smelt are entrained as they hatch and disperse from March through June. These made up the bulk of salvaged delta smelt, which began to show up in mid-April as the population entered the projects' zone of influence, and reached some minimum length necessary to be screened by the facilities (Figure 5-3). Sparse salvage densities throughout February and March edged upward in mid-April before showing a moderate gain during the weeks of April 23 and April 30. CVP salvage density jumped to a peak of 0.203 fish/AF during the week of May 7. This increase in salvage is likely due to the location and average size of the juvenile smelt population, since no changes to barrier operations and export rates had recently occurred. During the week of May 14, the spring H.O.R.B. was breeched (May 18) and CVP weekly averaged salvage density decreased to 0.128 fish/AF. The following week showed a moderate increase in salvage, coinciding with a slight increase in federal exports, before returning to pre-peak levels. SWP salvage followed roughly the trend set by the federal facility. The weekly averaged salvage density at Skinner started off relatively low throughout the VAMP period, dropped slightly for the week of the spring H.O.R.B. breech, then increased steeply the following week to a peak of 0.235 fish/AF before dropping to pre-peak levels over the next three weeks. It appears that the breeching of the spring H.O.R.B. may have temporarily lowered salvage densities of delta smelt at the two facilities. Salvage densities were near pre-peak levels by the time the GLC Barrier was closed on June 11, 2003. This drop in salvage, despite increasingly greater exports likely indicates that the population moved out of the south Delta and the projects' zone of influence.

These observations present clear indications that significant relationships may exist among the charted variables.

Figure 5-3 Weekly averaged delta smelt salvage densities, SWP and CVP exports, central Delta flows and Temporary Barriers Project operations for the weeks beginning 3/19 – 6/18/03.



Observations of the remaining species plots were not made here, but will be utilized for future analyses of TBP operations (Figures 5-4 through 5-6).

Figure 5-4 Weekly averaged Chinook salmon salvage densities, SWP and CVP exports, central Delta flows and Temporary Barriers Project operations for the weeks beginning 2/19 – 6/18/03.

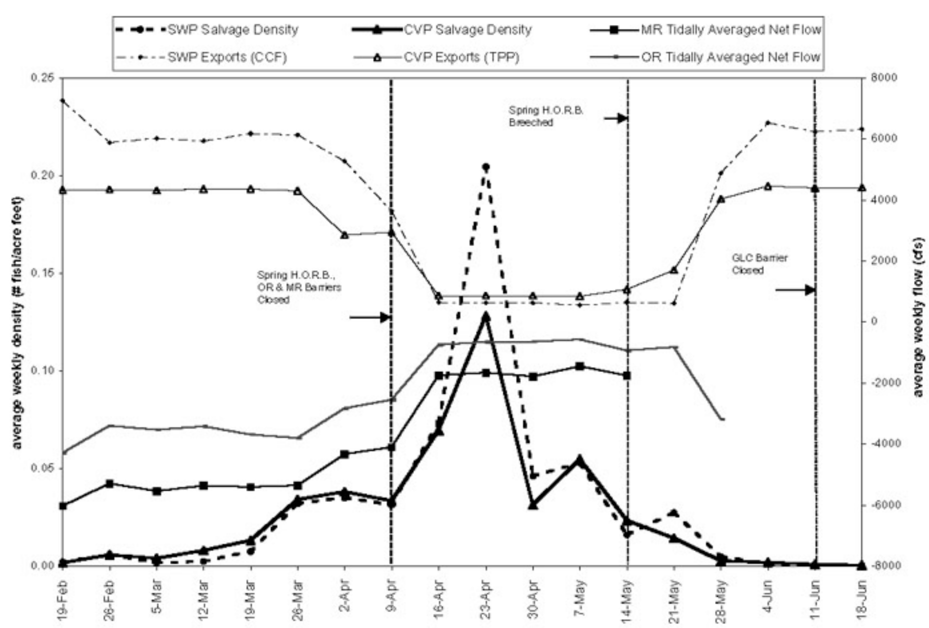


Figure 5-5 Weekly averaged steelhead salvage densities, SWP and CVP exports, central Delta flows and Temporary Barriers Project operations for the weeks beginning 1/1–6/11/03.

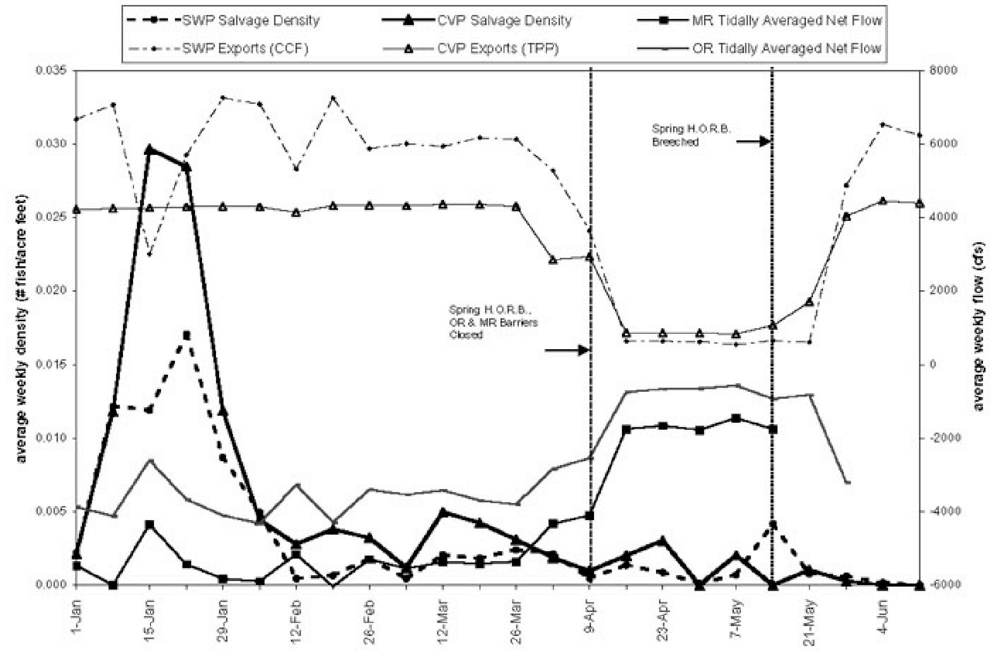
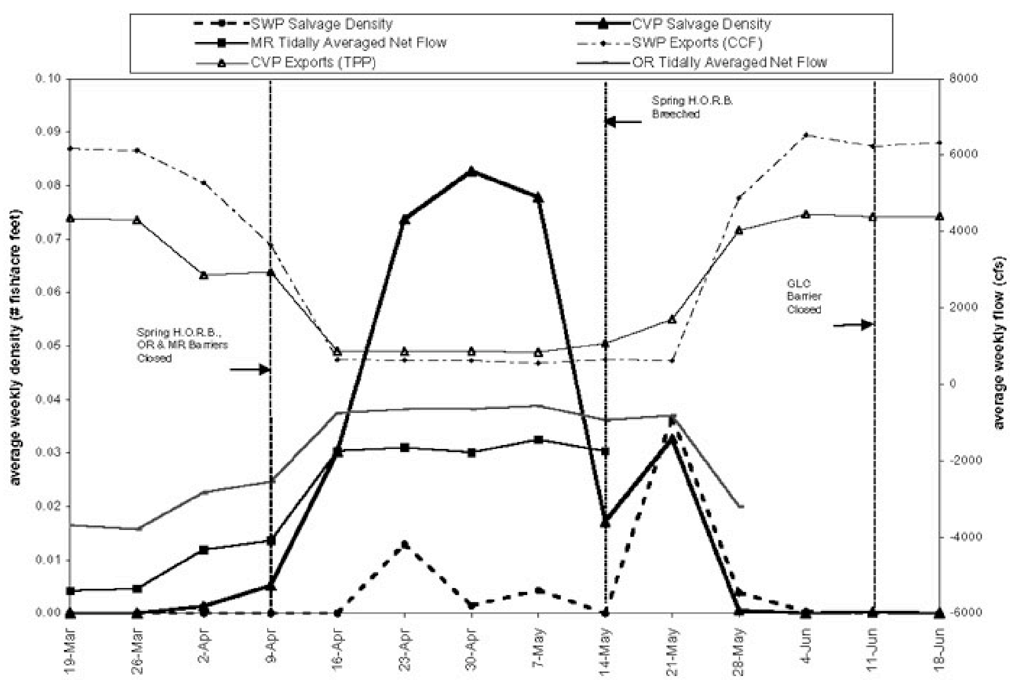


Figure 5-6 Weekly averaged longfin smelt salvage densities, SWP and CVP exports, central Delta flows and Temporary Barriers Project operations for the weeks beginning 3/19 – 6/18/03.



Recommendation

From these observations, it appears that significant correlations may exist between species densities and changes in hydrodynamics brought about by TBP operations. This report recognizes the fact that appearance does not prove significance. This assessment of perceived relationships between TBP operations, central Delta hydrodynamics and species salvage acts as yet another building block for future analyses.

The next step in analysis is to test for correlations between daily salvage densities and central Delta flows during periods defined by specific barrier operations. Instead of testing an entire salvage season for significant relationships among the variables, it should be broken down into segments based on individual barrier operations. The vertical lines that illustrate TBP operations on the species charts will serve as landmarks for dividing each species' salvage season. Depending on the successfulness of this process, such examinations will be part of a retrospective salvage analysis in subsequent monitoring reports.

Resources

DWR. 2002. 2002 South Delta Temporary Barriers Monitoring Report

DWR and USBR, 2003. Draft Biological Assessment for delta smelt and Sacramento splittail for the CVP-OCAP, prepared by the USBR and DWR

Verbal communication with Michael Burns, DWR Bay-Delta Office. March 2004.

Nobriga and others, 2000. Spring 2000 delta smelt salvage and delta hydrodynamics and an introduction of the delta smelt working group's decision tree. IEP Newsletter 14 (2): 42-44.

SRGA, 2003. Observed Chinook salmon salvage at the SWP and CVP Delta Fish Facilities 8/1/01 through 7/31/02. San Joaquin River Group Authority 2002 Annual Technical Report, Figure 5-19.

Chapter 6. Swainson's Hawk

Swainson's hawk surveys were initiated around the Temporary Barriers construction sites on 18 March 2003 for the 2003 construction period. Only two Swainson's hawks were observed in the South Delta on that day. On 26 March, approximately 50 Swainson's hawks were observed in the same area, indicating that they were arriving en masse; Swainson's hawks were observed near all barrier and rock storage sites, but there was no apparent sign of nest construction.

Surveys were continued in the first week of April. More Swainson's hawks were observed, but no nests. On April 7 and 9, Swainson's hawks were observed at the following locations:

- San Joaquin River, building a nest 800+ meters upstream of Head of Old River barrier in a large oak north of the northeast levee;
- San Joaquin River, established territory, no nest, 700 meters downstream of HOR barrier, on east side of river;
- Grant Line Canal, building a nest approximately 100 meters upstream of barrier site in Willow on tip of peninsula on south side of canal;
- Tracy Blvd, established territory 800 meters south of Howard Road rock storage site;
- Old River, building a nest on north levee between the rock storage site and DMC barrier site.

At the Middle River barrier, no Swainson's hawk nest construction or established territory near the barrier site was observed. There was a red tail hawk nest at the confluence of Victoria and Middle River, and a great horned owl nest just downstream of barrier site on instream island.

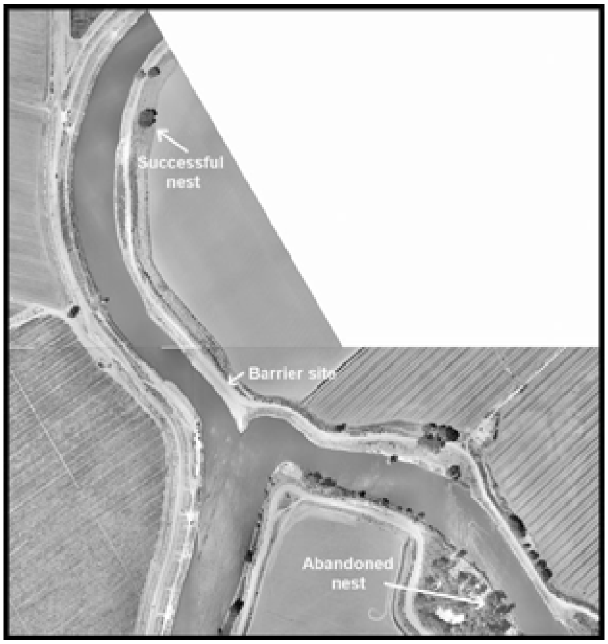
The barrier sites were monitored as required by the Department of Fish and Game Incidental Take Permit. The following is the summary of nest monitoring and incidental observations for the project:

Head of Old River

A pair of Swainson's hawks nested in a large oak about 400 yards northwest of the barrier (Figure 6-1), and fledged at least one young, who was observed perched at the top of the nest tree. The nest itself was virtually impossible to observe, but there was no indication through the adults' behaviors that project activities impacted them.

A pair of Swainson's hawks attempted to nest 700 yards north of the barrier location on the san Joaquin River, but apparently abandoned when DWR repaired the levee across from the nest. Unfortunately, that pair was, and has been, extremely flighty around prolonged human activity, and had failed in previous years as well. They appeared to attempt to re-nest, but by the end of May, neither bird was observed on or around the nest except when they were perched nearby. The nest was inspected in mid and late June, then in early July, and no chicks or adults were observed.

Figure 6-1 2003 nest sites near the Head of Old River Barrier project site.



Grant Line Canal

The pair that has traditionally nested next to the barrier site nested just 100 yards upstream of the barrier's construction site (Figure 6-2). They failed in their first attempt, probably due to late rain, cool weather, but then re-nested in May. In the last week of June, two chicks were observed in the nest, which were approximately two weeks old. On 5 August, I observed one fledgling in a tree near the nest.

Within a week of the closure of the Grant Line barrier, two trees just upstream of the barrier fell. One was the perching snag the pair used, which had been dead for at least 10 years, but the other was a live oak, previously used as a nest tree by this pair. In DWR's Biological Assessment, impacts to water-side trees due to soil saturation was thought to be insignificant, but that conclusion should be re-evaluated.

Figure 6-2 2003 nest site near the Grant Line Canal barrier site, and location of two trees that fell immediately following the barrier's closure in 2003.

Tracy Blvd Nest Site

A pair of Swainson's hawks constructed a nest in a traditional territory _ mile south of the Howard Road rock storage area (Figure 6-3). Adults and young were observed in early June, but high winds apparently caused a few of the main branches in the nest tree to break, and the nest (and young) were lost.

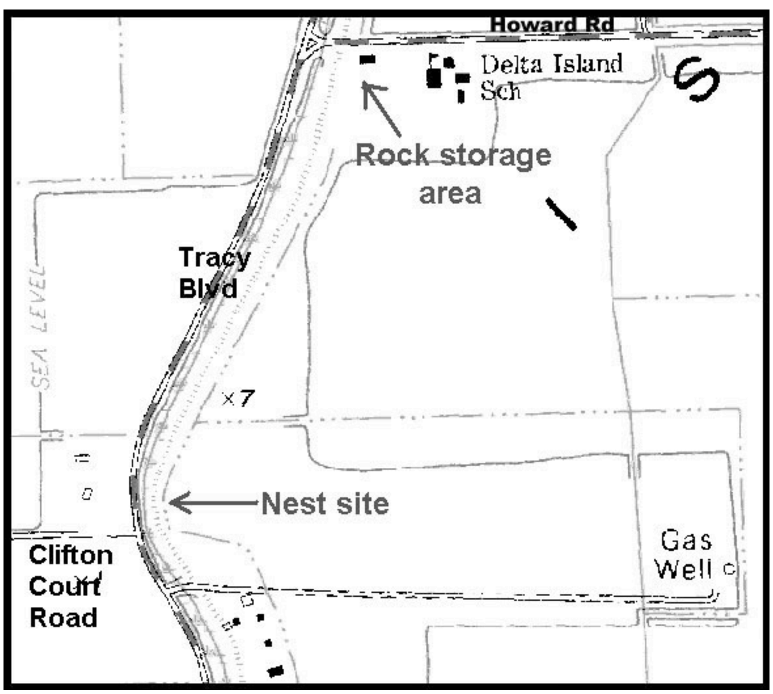
The construction of the new haul road between the Howard Road storage site and the Grant Line barrier is of concern as it creates a traffic sandwich affect for the nest sites along Tracy Blvd. That is, vehicles will be travelling past the nest on both the east and west side, in close proximity to the nest. Dust for the haul road is also a concern for nesting hawks.

Old River at DMC

The pair of Swainson's hawks that used to nest near the barrier is now nesting well upstream (3/4 mile) of the rock storage area. They nested in a small alder, and on June 25, had three young within 1-2 weeks of fledging.

A second pair adopted the first pair's original territory and nested in a willow on the land-side of the southern levee, across form the rock storage site (Figure 6-4). Although they were a bit late and apparently a bit confused (they built multiple nests) they managed to hatch one young which was about 3 weeks old on June 25. They young was seen branched in the second week of July, and is assumed to have fledged.

Figure 6-3 2003 nest site along Tracy Blvd. south of the Howard Road rock storage area.



Middle River

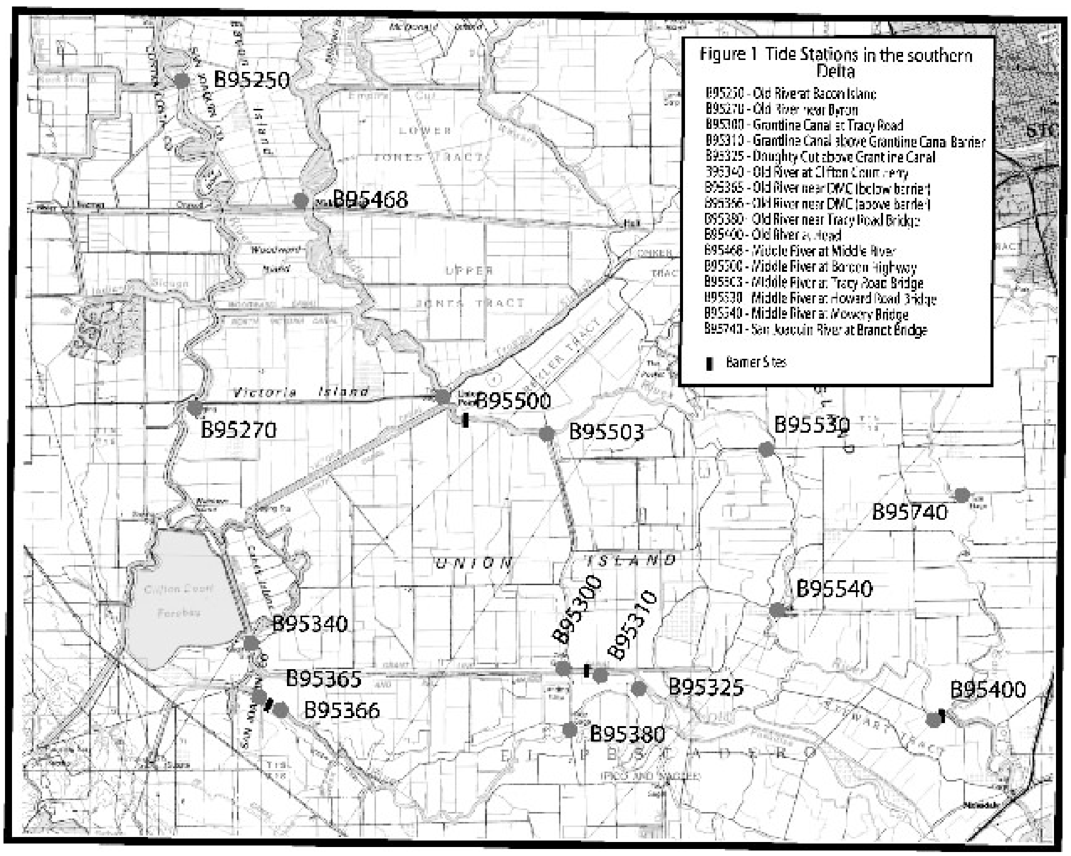
No Swainson's hawks were observed or are known to have nested within 1/2 mile of the Middle River Barrier site. One pair of Swainson's hawks did nest near the junction of Calpack Road and the Victoria Canal levee, and that pair produced 2 young. It will be important to monitor the pair over time, as they may move closer to the Middle River barrier site over time.

Figure 6-4 2003 nest site near the Old River barrier near DMC, and associated rock storage area.

Chapter 7. Water Elevations

The 2003 water elevation monitoring program included operation and maintenance of sixteen tide gauging stations near the barriers as shown in Figure 7-1. The 2003 monitoring program covers the period from January 2003 through December 2003, where stage is monitored at various stations with remote sensors.

Figure 7-1 Tide Stations in the Southern Delta



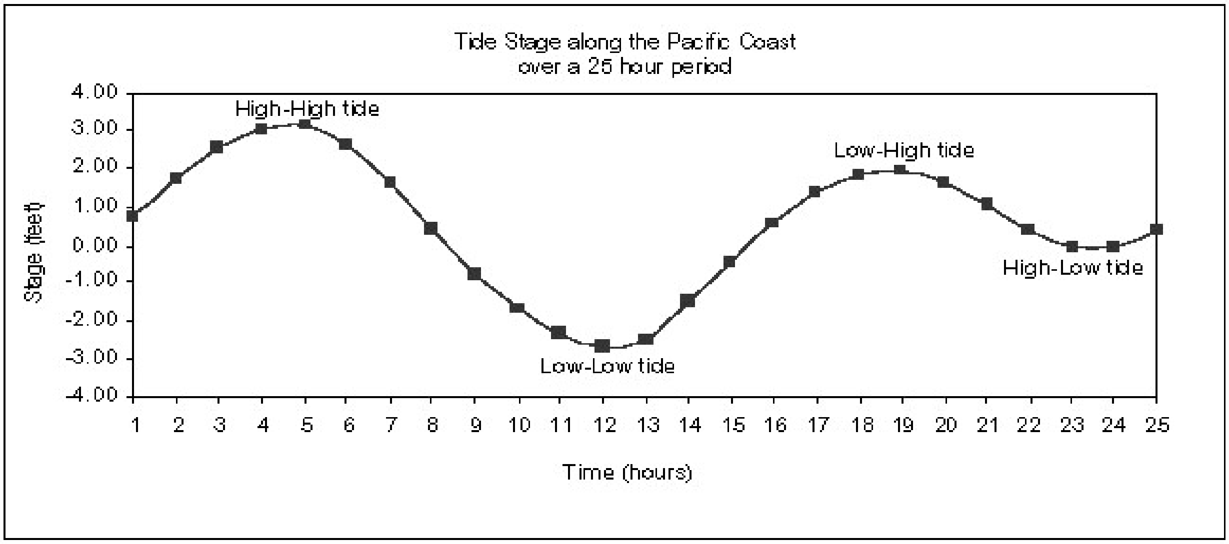
Instrumentation recorded water surface elevation daily at fifteen-minute intervals. Later, the data records were retrieved and downloaded to a computer for subsequent analysis.

Data collected at these stations were used to determine effects of the barriers on the water surface elevations and circulation patterns in the South Delta. Circulation patterns are estimated using the water surface elevation data as an input to the hydrologic math model (DWRSM2). Results of the model can be found in Chapter 9 of this report.

Tides along the Pacific Coast exhibit a cycle of two high and two low tides over an approximately 25- hour period (Figure 7-2). These cycles vary in height throughout the day. Two elements make up a typical tidal curve.

- The tidal range is the difference between the highest and lowest tidal elevations.
- The daily inequality is the difference between the heights of successive high or low tides and the time between corresponding high or low stands of sea level.

Figure 7-2 Tide stage variation over a 25-hour cycle



A biweekly pattern of spring and neap tides is overlaid on top of the daily pattern. Additional patterns occur at longer intervals throughout the year.

Typically, farmers in the south Delta encounter pumping difficulties due to low water elevations during the irrigation season. One objective of the Old River at Tracy, Middle River, and Grant Line Canal barriers is to improve water elevations for agricultural diversions. This goal is achieved by installing barriers with culverts that restrict flow in the downstream direction during (receding) ebb tides, resulting in increased water levels upstream of the barrier. During periods of increasing (flood) tides, the open flap gates allow flow in the upstream direction. Sometimes during high flood tides water also flows over the barrier, thereby further increasing water level upstream of the barrier. The increasing tide replenishes water being lost or diverted for agriculture and will maintain higher water levels during the next receding tide.

The agricultural barriers are constructed of rock with flap-gated culverts to allow flow in the upstream direction. Design of the three barriers varies slightly due to differences in upstream channel geometry.

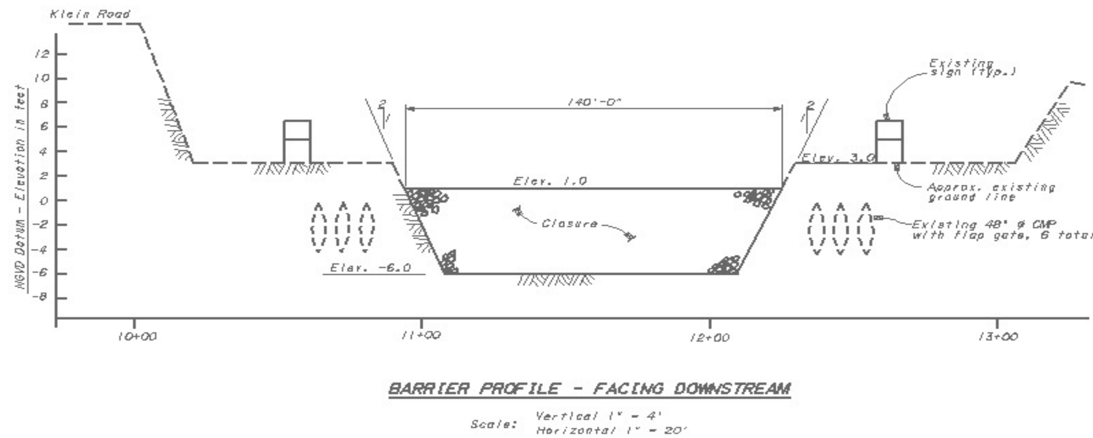
The following are highlights of barrier installation effects:

- At low tide, water surface elevation upstream of the barrier is raised, but the elevation downstream remains nearly the same.
- Extreme high tide water surface elevations upstream of the barrier may be slightly delayed and reduced due to energy losses through the culverts.
- During ebb tides, culvert flap gates seal and retain water behind the barriers.

Middle River Barrier

The Middle River Barrier is constructed to an elevation of +3.0 feet National Geodetic Vertical Datum (NGVD) and has six 48-inch diameter culverts. The center weir is 140 feet wide and constructed to an elevation of +1.0 foot NGVD (Figure 7-3). The center portion of the barrier is removed seasonally, while the culverts and the abutments remain in place year-round. (Three culverts are located in the north abutment and three culverts are located in the south abutment.)

Figure 7-3 Middle River Barrier Profile

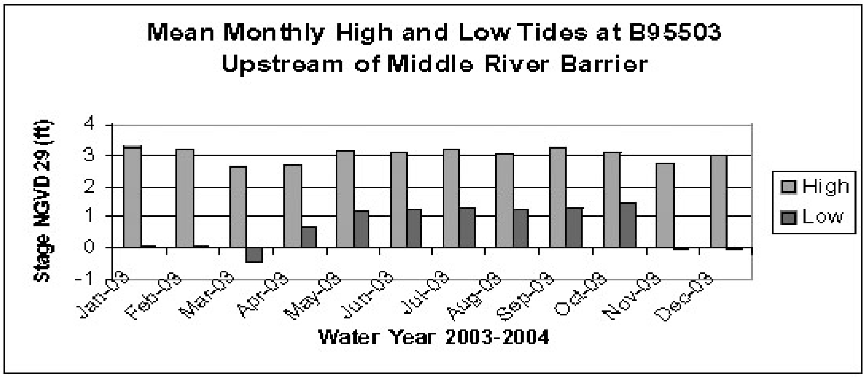


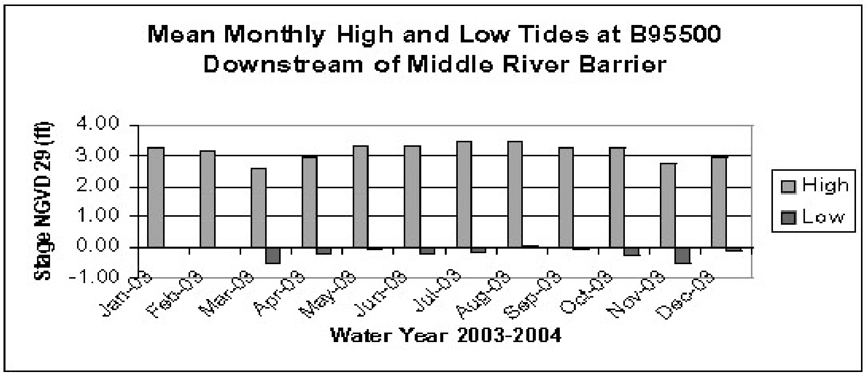
The Middle River (MR) barrier was installed between April 12 and April 15, 2003. The flap gates were tidally operational until November. For the 2003 operation, all three agricultural barriers were allowed to remain until late November. The MR barrier removal work began on November 7, and was fully removed on November 10.

Water level monitoring is conducted at two nearby tide recording stations, B95500 downstream of this barrier at Borden Highway (Highway 4) and at B95503 just upstream of the barrier.

Figure 7-4 shows the mean monthly high tides and mean monthly low tides upstream and downstream of the Middle River barrier from January 2003 to December 2003. The barrier was in operation between April and November 2003. Figure 7-4 shows an increase in mean monthly low water levels of about more than one foot on the upstream end while the barrier was operational. This is a positive effect for irrigators.

Figure 7-4 Water levels upstream and downstream of Middle River barrier





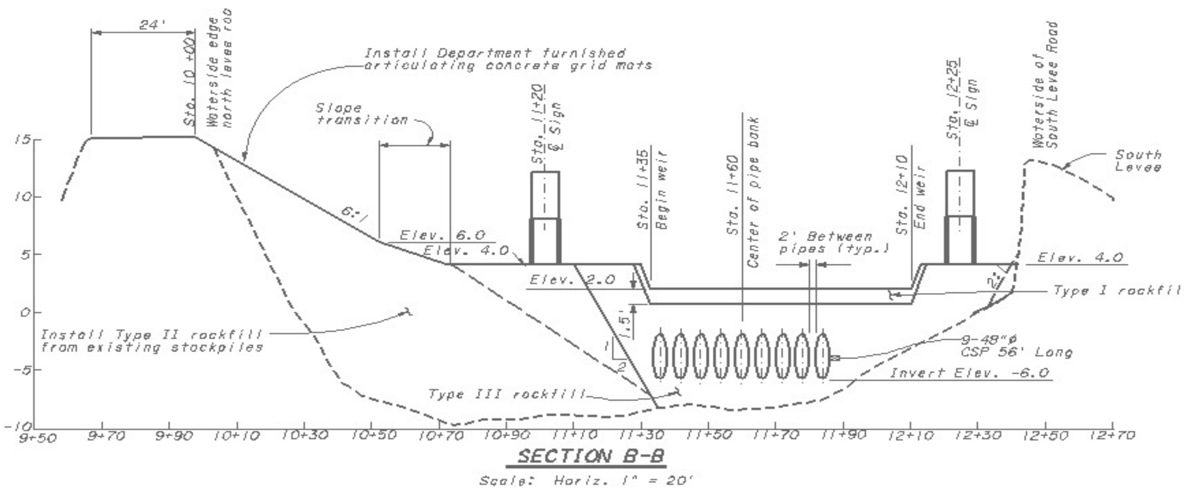
Old River at Tracy

The Old River at Tracy (ORT) barrier is constructed to an elevation of +4.0 feet NGVD and has nine 48-inch diameter culverts. The center weir is 75 feet wide and constructed to an elevation of +2.0 feet NGVD (Figure 7-5). The whole barrier structure is removed seasonally.

The ORT barrier was installed between April 1 and April 22, 2003. The flap gates were operational until late November when the barrier was removed. The barrier removal work began on November 13, and was fully removed on November 25, 2003.

Water level monitoring is conducted at two nearby tide stations, (1) B95365, downstream of the ORT barrier; and (2) B95366 upstream of the barrier. Figure 7-6 shows stages upstream and downstream of the Old River at Tracy barrier from April 2003 to November 2003, when the barrier was operational. Figure 7-6 shows an increase in mean monthly low water levels of more than 1.0 foot for the period between May and October on the upstream end when the barrier was operational. This is positive effect for irrigators.

Figure 7-5 Old River at Tracy barrier profile



Grant Line Canal Barrier

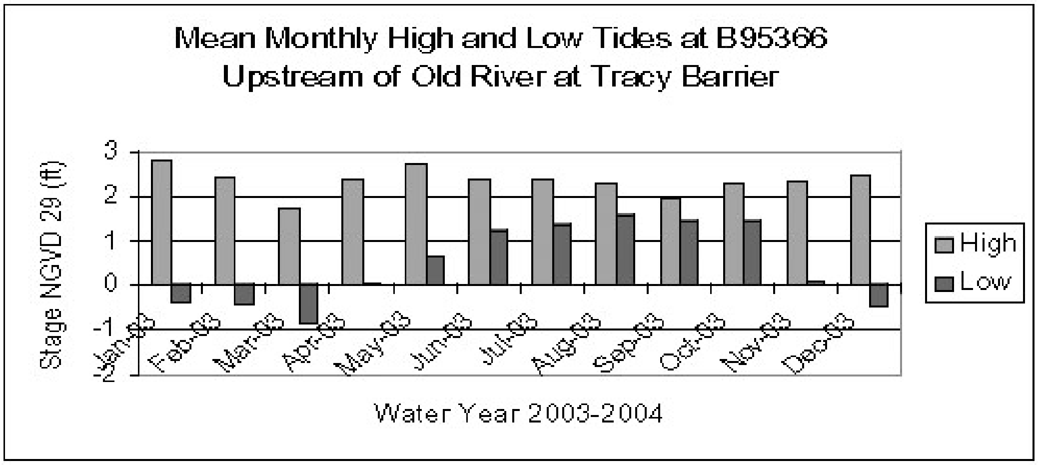
The Grant Line Canal (GLC) barrier is constructed to an elevation of +4.0 NGVD and also has six 48-inch diameter culverts at the southern abutment of the barrier. The center weir is 140 feet wide and constructed to an elevation of +1.0 foot NGVD. In 2003, a 10 feet wide weir was operated on the southern abutment and the flashboards were adjusted on September 16 to allow delta smelt passage (Figure 7-7). The culverts, fish passage weir and the southern abutment of the Grant Line Canal barrier are designed to remain in the channel year round. This will have less disruptive effects to the Swainson's hawk during the construction in spring.

The GLC barrier was installed between April 1 and June 8, 2003. Six flap gates were tied open till June 11 the closure day of the middle portion of the barrier. After June 17, the flap gates resumed normal tidal operation until late November when the barrier was removed. The barrier removal work began on November 10, and was fully removed on November 25, 2003.

Water level monitoring is conducted at two nearby tide recording stations: (1) B95300 just downstream of the barrier, and (2) B95310 upstream of the barrier.

Figure 7-8 shows stages upstream and downstream of the GLC barrier from June 2003 to November 2003, when the barrier was in operation. Figure 7-8 shows an increase in mean monthly low water levels of slightly less than 2.0 feet while the barrier was operational.

Figure 7-6 Water levels upstream and downstream of Old River at Tracy barrier



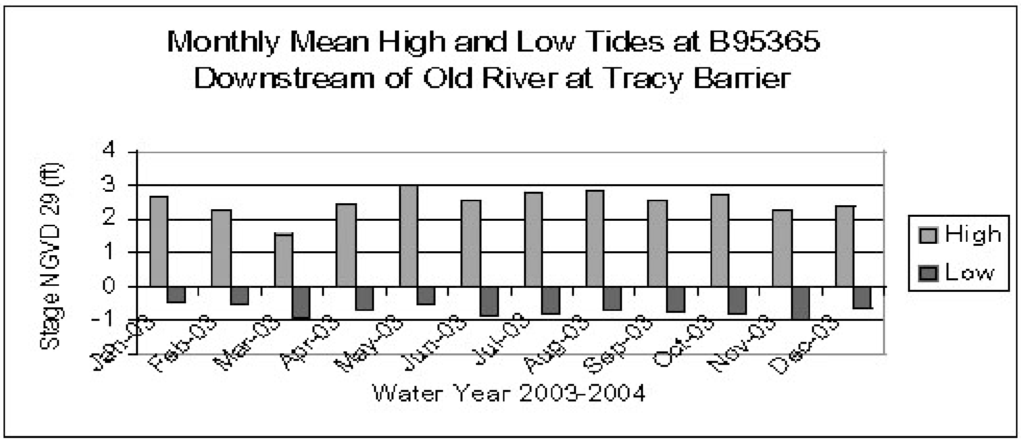


Figure 7-7 Grant Line Canal barrier profile

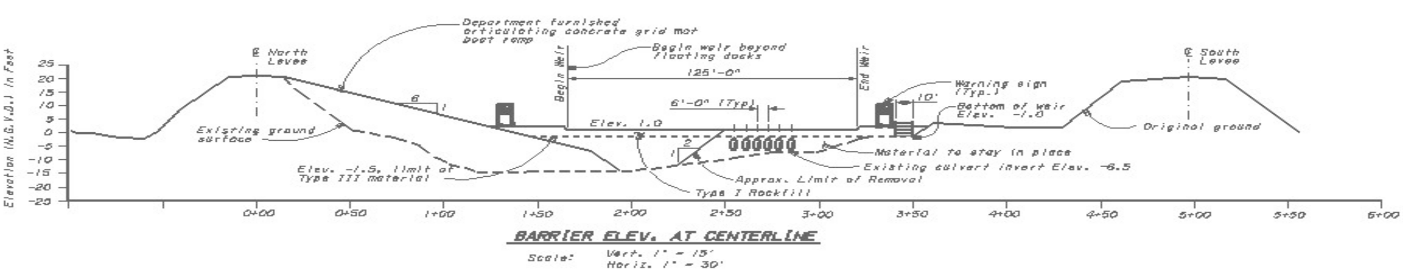
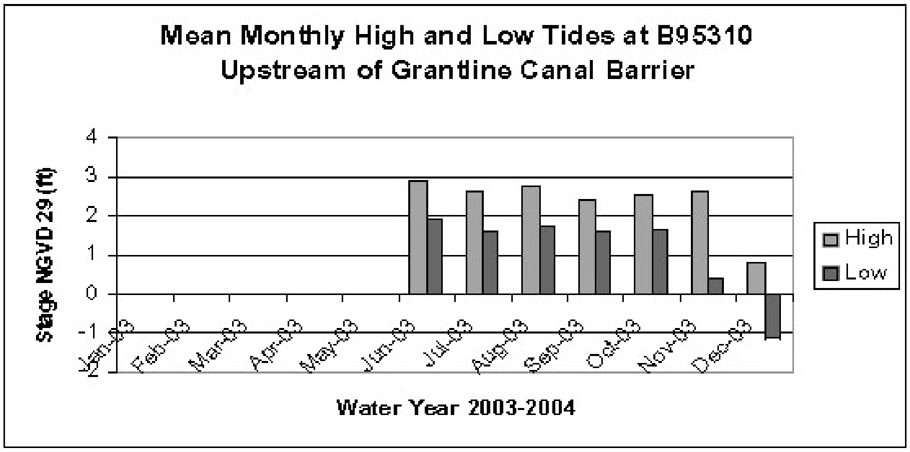
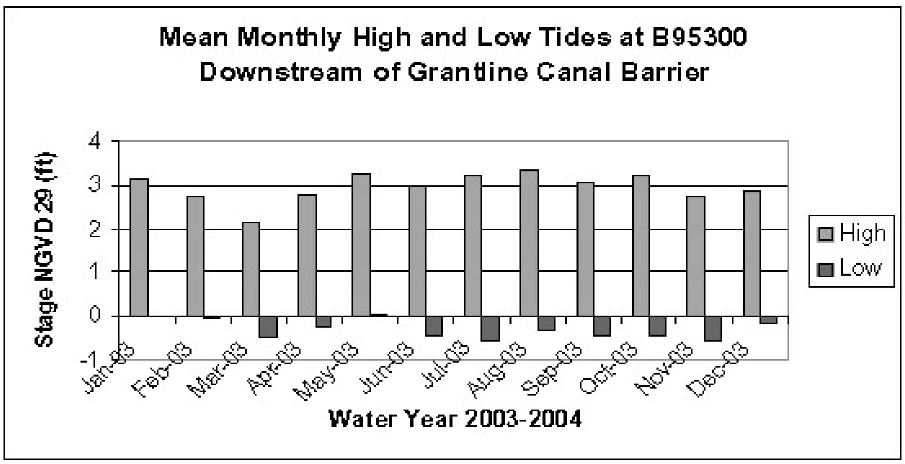


Figure 7-8 Water levels upstream and downstream of Grant Line Canal Barrier

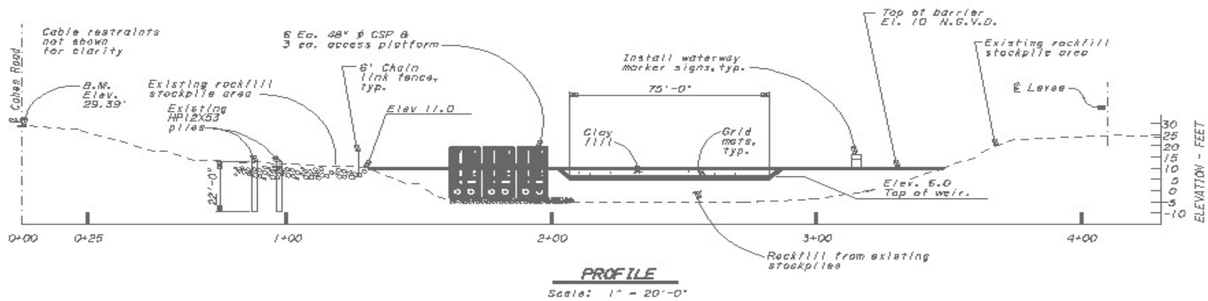




Old River at Head Barrier

The head of Old River barrier (HORB) is designed as a fish barrier to prevent San Joaquin River Chinook Salmon Smolt from migrating down through Old River toward the Central Valley Project and State Water Project export facilities. The spring HORB was originally designed to withstand a San Joaquin River flow of about 3,000 cfs. Through the years, the design and installation of the HORB has been revised on several occasions to accommodate different needs. For 2003 and future years, the barrier design includes two versions. A "low-flow" barrier would be built to a height of ten feet mean sea level (MSL) when San Joaquin River target flows are below 7,000 cfs. A "high-flow" barrier would be built to a height of 11 feet MSL for San Joaquin River target flows of 7,000 cfs and above and additional material would be placed to raise the abutments to 13 feet MSL. Both barrier versions are equipped with six 48-inch diameter operable culverts and an overflow weir back-filled with clay. In 2003, the low-flow version was installed (Figure 7-9).

Figure 7-9 Spring head of Old River barrier profile



The dimensions of the 2003 HORB were the same as the 2002 HORB. The base width of the HORB was 100 feet and the crest elevation was ten feet MSL. The top of HORB was constructed with a 75-foot wide notch, back filled with clay and protected with concrete grid mats. This larger HORB was designed to safely operate with flows corresponding to stages up to 8.5 feet MSL.

To help mitigate anticipated low water levels in the south Delta (downstream of the HORB) caused by the operation of the HORB, six operable culverts were installed in the barrier. During 2003, three culverts were open during the barrier operation.

The spring barrier was installed between April 1 and April 15, 2003. Barrier removal began on May 16 and was completed by June 3, 2003.

The fall HORB barrier was installed between September 2, 2003 and September 15, 2003. Barrier removal started on November 3, 2003 and was completed by November 13, 2003. It was constructed to an elevation of +4.0 feet NGVD and had six 48-inch diameter culverts (Figure 7-10). Figure 7-11 shows water levels in Old River approximately 1000 yards below the Head of Old River barrier, the mean monthly low level was the lowest during the month of April an elevation of 0.5 foot NGVD and a maximum of slightly greater than 2 feet during the month of August. Figure 7-12 shows water level at the intake structure in Tom Paine Slough, the mean monthly low level dipped below zero during the month of March and was well above 1 foot during the period from June through October.

Figure 7-10 Fall head of Old River barrier profile

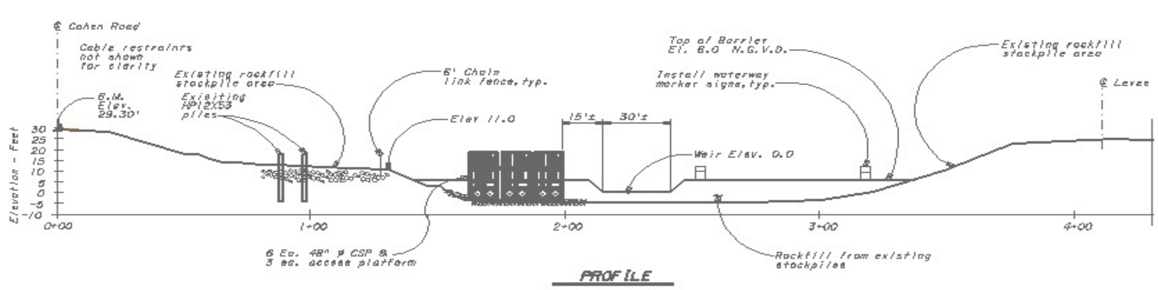


Figure 7-11 Water Levels downstream of Head of Old River Barrier

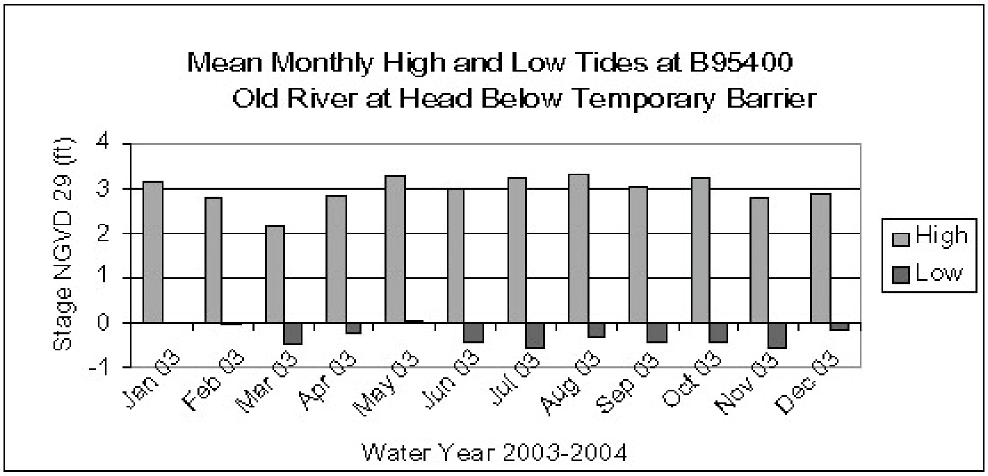
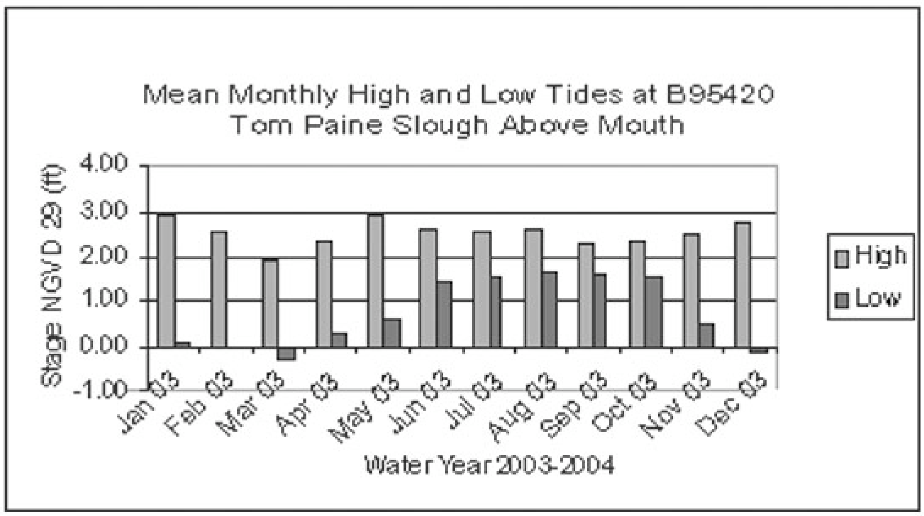


Figure 7-12 Water Levels at Tom Paine Slough above Mouth



Chapter 8. Weekly Water Quality Sampling

Introduction

During the spring, summer and fall of 2003, four temporary rock barriers were installed in the South Delta as part of the South Delta Temporary Barriers Project. DWR continued its weekly water quality sampling program to evaluate the potential impacts of barrier installations and operations upon South Delta water quality and for compliance with the Central Valley Regional Water Quality Control Board permit. The sampling program commenced on April 1st and was completed on December 2nd. The four barriers were all installed on or after April 14th and removed by November 15th.

In addition, continuous monitoring to evaluate water quality impacts of barrier installations and operations in the South Delta was continued in 2003. This program was established for two reasons: first to determine the feasibility of collecting reliable time-series water quality data as opposed to weekly grab sampling data and second, to develop a dynamic understanding of water quality conditions affected by barrier installations, barrier operations, reservoir releases, Forebay gate operations, SWP and CVP pumping operations, agricultural pumping and drainage, municipal effluent loading, hydrology, tidal fluctuations, meteorological conditions, Delta inflows as well as other variables. Continuous water quality sampling was conducted throughout the year at six locations.

Sites

There were ten sampling sites: one on the downstream side of each barrier, one on the upstream side of each barrier, excluding the Old River at Head, and an additional site located further upstream on each of the main river channels (Old River, Middle River, and Grant Line Canal). Figure 8-1 identifies the location of the ten water sampling sites.

Barrier Locations

The Middle River barrier is upstream of the confluence of Middle River, Trapper Slough, and North Canal. The Old River near Delta Mendota Canal (DMC) barrier is eight miles northwest of the town of Tracy and about a mile east of the DMC intake at the Tracy Pumping Plant. The Old River at Head barrier is immediately downstream of the Old and San Joaquin River split. The Grant Line Canal (GLC) barrier is located approximately 400 feet upstream of the Tracy Road Bridge at the east end of the GLC. Figure 8-1 also shows the location of the four temporary barriers.

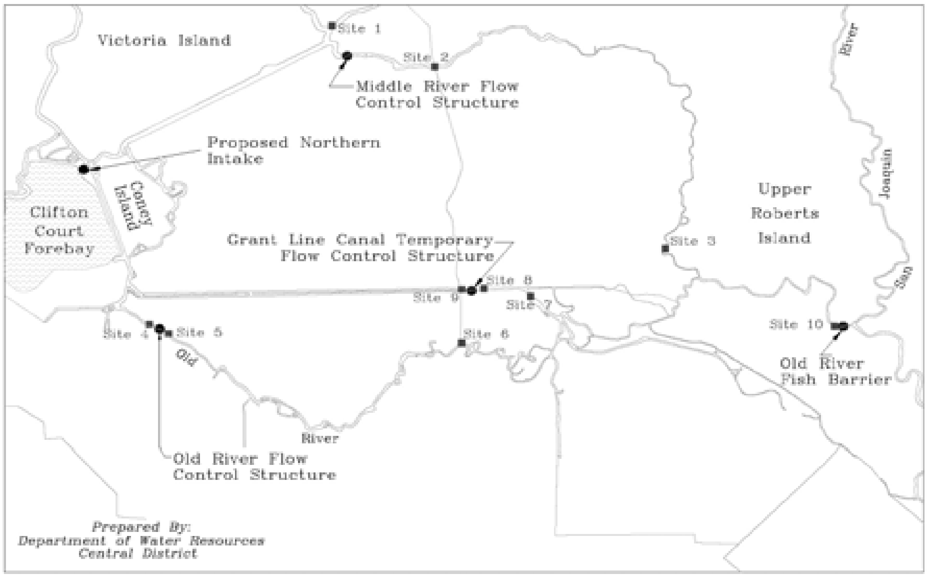
The Middle River, Old River at DMC, and Grant Line Canal barriers were installed to improve water circulation and to increase and stabilize water levels in the South Delta during the agricultural irrigation season. The Old River at Head barrier was constructed to increase net downstream flows in the lower San Joaquin River to aid salmon smolt outmigration through the Delta to the Pacific Ocean.

Sampling Methods

Water sampling was conducted every Tuesday morning between 5:00 AM and 9:00 AM for the entire operational period of the barriers. Channel water was tested at the ten sites using field instruments for temperature, dissolved oxygen, specific electrical conductivity and turbidity.

Field equipment used included YSI-63 and YSI-85 handheld units that measured water temperature and specific conductance, a HACH modified Winkler titration kit to measure dissolved oxygen concentrations, and a HACH 2100P turbidimeter.

Figure 8-1 Map of Discrete Water Quality Sites and Temporary Barrier Locations



Site	Location
1.	Middle River @ Union Point
2.	Middle River @ Tracy Blvd
3.	Middle River @ Undine Road
4.	Old River Downstream of DMC Barrier
5.	Old River Upstream of DMC Barrier
6.	Old River @ Tracy Blvd
7.	Grant Line Canal @ Doughty Cut
8.	Grant Line Canal Above Barrier
9.	Grant Line Canal @ Tracy Blvd
10.	Old River @ Head

Every other Tuesday, filtered and unfiltered (turbidity) samples were collected at the ten sites for analysis at Bryte Lab. Constituents tested for were dissolved ammonia, dissolved nitrite + nitrate, dissolved organic nitrogen, dissolved orthophosphate, turbidity, chlorophyll *a*, and pheophytin *a.*

Weekly water quality data collected at each site is shown in Table 8-1.

Table 8-1 Sampling methods and frequency of the water quality constituents measured at each of the 10 weekly water quality sampling sites.

Constituent	Sampling Method		Sampling Frequency
	Field Instrument	Lab Method[1]	
Water Temperature	YSI-63 or YSI-85	N/A	Weekly
Dissolved Oxygen	HACH Modified Winkler Titration Kit	N/A	Weekly
Specific Electrical Conductivity	YSI-63 or YSI-85	N/A	Weekly
Turbidity	HACH 2100P Turbidimeter	EPA 180.1	Weekly (alternates between field and lab)
Dissolved Ammonia	N/A	EPA 350.1	Bi-Monthly
Dissolved Nitrite + Nitrite	N/A	Modified Standard Method 4500-NO3-F	Bi-Monthly
Dissolved Organic Nitrogen	N/A	EPA 351.2	Bi-Monthly
Dissolved Orthophosphate	N/A	Modified EPA 365.1	Bi-Monthly
Chlorophyll *a*	N/A	Standard Method 10200 H, Spectrometric Determination of Chlorophyll	Bi-Monthly
Pheophytin *a*	N/A	Standard Method 10200 H, Spectrometric Determination of Chlorophyll	Bi-Monthly
[1] Dissolved Nitrite + Nitrate and Dissolved Orthophosphate Lab Methods Modified by DWR-Bryte Lab			

Middle River Barrier

The Middle River barrier was constructed on April 15th, 2003 and removed on November 8th, 2003. Monitoring of the Middle River was conducted at three sites: 1) the Undine Road Bridge (site 3) just downstream of the split between Middle and Old Rivers, 2) Tracy Road Bridge over Middle River (site 2), and 3) at Union Point (site 1) immediately downstream of the Middle River barrier. Figure 8-2 shows the weekly water quality field and lab data for the Middle River. In addition, the data are displayed in Tables 8-2 through 8-4, which show pre-barrier, during and post-barrier sampling events.

Mean water temperatures in Middle River ranged from 19.16°C (Undine Road) to 19.64°C (Union Point). Water temperatures tended to follow season patterns: temperatures began to rise in mid-spring and continued to increase until mid-summer, likely as an effect of increasing air temperatures. Temperatures then gradually declined in late summer and throughout fall. In addition to localized differences, variability in water temperature data for the Middle River may be due to differences in sampling times. The highest recorded temperature was 27.3°C on July 22nd and the lowest was 7.9°C on November 25th, both at the Undine Road station.

Figure 8-2 Middle River - Weekly Water Quality Data

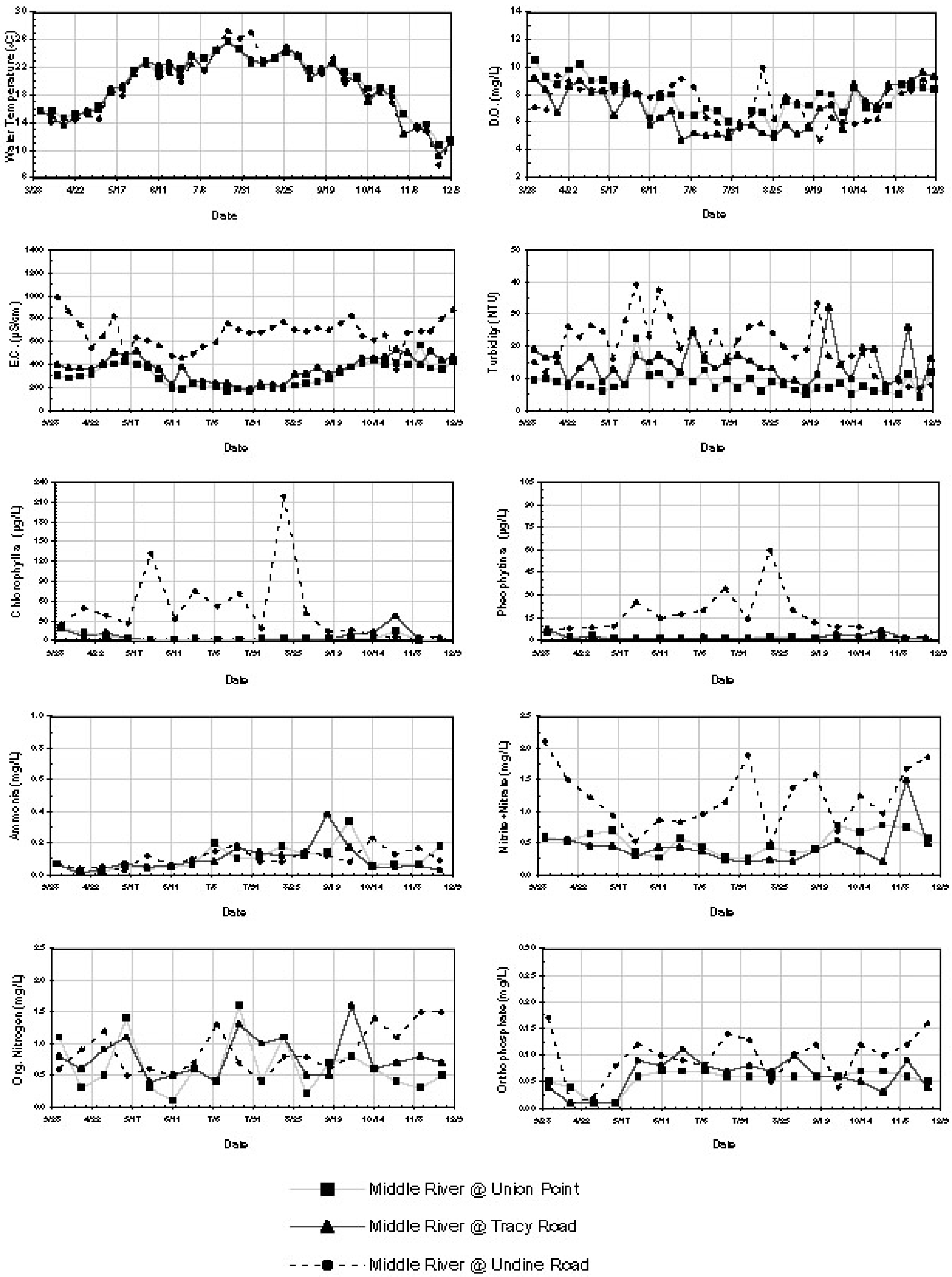


Table 8-2 Middle River at Union Point: 2003 Water Quality Data

	FIELD READINGS					BRYTE LAB RESULTS						
Date & Time (mm/dd/yy PST)	**Temp (°C)**	**DO (mg/L)**	**EC (µS/cm)**	**Turb (NTU)**	**Gage Height (ft)**	**NH_3-N (mg/L)**	**NO_2+ NO_3-N (mg/L)**	**ORG-N (mg/L)**	**PO_4 (mg/L)**	**Turb (NTU)**	**CHL-A (µg/L)**	**PHEO-A (µg/L)**
4/1/03 6:30	15.7	10.5	301		5.20	0.07	0.60	1.1	0.05	9.5	18.90	4.90
4/8/03 4:35	15.7	9.3	282	9.8	4.20							
4/15/03 5:24	14.7	8.7	295		5.85	0.02	0.53	0.3	0.04	9.0	12.40	2.16
4/22/03 5:04	15.3	9.8	310	7.6	5.70							
4/29/03 5:25	15.5	10.2	393		6.08	0.02	0.64	0.5	0.01	8.0	7.76	2.99
5/6/03 5:10	16.3	9.0	403	7.2	5.75							
5/13/03 4:40	18.4	9.1	427		5.74	0.06	0.70	1.4	0.01	6.0	2.19	1.48
5/20/03 5:35	19.1	8.6	401	7.3	5.48							
5/27/03 5:20	21.6	8.4	369		5.50	0.04	0.37	0.3	0.06	8.0	1.43	1.81
6/3/03 4:40	23.0	8.0	277	22.5	5.90							
6/11/03 5:20	21.1	6.3	187		5.40	0.05	0.27	0.1	0.07	11.0	1.51	1.67
6/17/03 4:39	22.0	7.8	181	11.6	5.46							
6/24/03 5:35	21.7	8.0	237		4.20	0.06	0.58	0.6	0.07	8.0	2.36	1.66
6/30/03 5:20	23.5	6.5	203	11.8	6.60							
7/8/03 4:15	23.3	6.5	210		4.52	0.20	0.44	0.4	0.07	9.0	1.93	1.56
7/15/03 5:30	24.4	7.0	171	12.5	6.10							
7/22/03 4:20	25.8	6.8	187		4.56	0.10	0.28	1.6	0.06	7.0	1.76	1.50
7/29/03 5:20	24.7	6.0	173	9.7	7.15							
8/5/03 5:30	22.6		202		3.75	0.11	0.26	0.4	0.06	7.0	2.00	1.83
8/12/03 8:40	22.8	6.8	195	9.9	5.30							
8/19/03 4:25	23.3	6.7	200		3.70	0.18	0.45	1.1	0.06	6.0	3.66	2.78
8/26/03 4:40	24.1	5.1	214	8.8	6.76							
9/2/03 5:20	23.5	7.5	237		3.32	0.13	0.34	0.2	0.06	8.0	2.11	2.14
9/9/03 5:27	21.7	7.3	252	6.3	6.25							
9/16/03 7:50	21.4	7.2	273		5.00	0.14	0.40	0.7	0.06	5.0	2.76	1.46
9/23/03 4:14	22.5	8.1	326	7.0	6.06							
9/30/03 4:16	21.3	8.0	380		2.81	0.34	0.78	0.8	0.06	7.0	2.17	1.60
10/7/03 4:10	20.7	6.7	403	8.6	6.05							
10/14/03 4:30	18.9	8.5	439		3.10	0.06	0.67	0.6	0.07	5.0	2.13	1.38
10/21/03 4:31	19.1	7.0	401	7.5	4.31							
10/28/03 5:10	18.8	6.9	415		3.60	0.07	0.78	0.4	0.07	6.0	14.20	2.38
11/4/03 5:35	15.3	7.2	394	6.1	4.25							
11/12/03 6:35	13.3	8.7	567		3.68	0.07	0.75	0.3	0.06	5.0	1.04	0.59
11/18/03 5:45	13.8	8.5	363	11.2								
11/25/03 5:30	10.8	8.5	358		3.90	0.18	0.58	0.5	0.05	4.0	1.27	0.76
12/2/03 5:30	11.5	8.4	418	11.8	3.41							
Maximum	25.80	10.50	567.00	22.50	7.15	0.34	0.78	1.60	0.07	11.00	18.90	4.90
Minimum	10.80	5.10	171.00	6.10	2.81	0.02	0.26	0.10	0.01	4.00	1.04	0.59
Mean	19.64	7.82	306.77	9.84	4.99	0.11	0.52	0.63	0.06	7.14	4.53	1.93
Range	15.00	5.40	396.00	16.40	4.34	0.32	0.52	1.50	0.06	7.00	17.86	4.31
Standard Deviation	4.04	1.22	100.07	3.77	1.15	0.08	0.18	0.42	0.02	1.85	5.24	0.95
Sample Variance	16.33	1.49	10,013.34	14.18	1.33	0.01	0.03	0.18	0.00	3.41	27.41	0.91

(shaded) = Middle River barrier in place from 4/15/03 - 11/8/03

Table 8-2 Middle River at Union Point: 2003 Water Quality Data (continued)

	Temp (°C)	DO (mg/L)	EC (µS/cm)	Turb (NTU)	Gage Height (ft)	NH_3-N (mg/L)	NO_2+ NO_3-N (mg/L)	ORG-N (mg/L)	PO_4 (mg/L)	Turb (NTU)	CHL-A (µg/L)	PHEO-A (µg/L)
Standard Error	4.07	0.91	87.05	3.70	1.04	0.07	0.18	0.43	0.02	1.90	5.16	0.59
Median	21.20	8.00	297.80	9.25	5.30	0.07	0.56	0.50	0.06	7.00	2.15	1.67
Mode	15.70	8.00	403.00	11.80	4.20	0.07	0.58	0.30	0.06	8.00	#N/A	#N/A
Count	36	35	36	18	35	18	18	18	18	18	18	18
Confidence Interval (95%)*	1.32	0.40	32.69	1.74	0.38	0.04	0.08	0.19	0.01	0.85	2.42	0.44

* Mean (µ) for Temperature = 19.64; 95% Confidence interval is 19.64 ± 1.32 or 18.32 ≤ µ ≤ 20.96. This means the interval between 18.32 and 20.96 has a .95 probability of containing µ.

Table 8-3 Middle River at Tracy Road: 2003 Water Quality Data

	FIELD READINGS					BRYTE LAB RESULTS						
Date & Time (mm/dd/yy PST)	**Temp (°C)**	**DO (mg/L)**	**EC (µS/cm)**	**Turb (NTU)**	**Gage Height (ft)**	**NH_3-N (mg/L)**	**NO_2+ NO_3-N (mg/L)**	**ORG-N (mg/L)**	**PO_4 (mg/L)**	**Turb (NTU)**	**CHL-A (µg/L)**	**PHEO-A (µg/L)**
4/1/03 7:00	15.7	9.2	398		5.10	0.07	0.56	0.8	0.04	19.0	18.10	7.27
4/8/03 5:00	14.9	8.4	371	16.4	4.30							
4/15/03 5:48	13.6	6.7	366		5.40	0.01	0.55	0.6	0.01	17.0	5.98	1.86
4/22/03 5:30	14.8	8.6	362	8.6								
4/29/03 5:50	15.7	9.0	410		5.50	0.04	0.46	0.9	0.01	13.0	12.00	2.37
5/6/03 5:30	15.9	8.2	508	16.7	5.40							
5/13/03 5:06	18.9	8.3	480		5.68	0.07	0.46	1.1	0.01	9.0	2.89	1.51
5/20/03 5:55	19.2	6.5	518	12.9	5.00							
5/27/03 5:40	21.0	8.0	406		5.55	0.05	0.29	0.4	0.09	8.0	1.78	1.52
6/3/03 5:15	23.0	8.1	362	17.0	5.48							
6/11/03 5:35	22.2	5.8	220		5.60	0.06	0.42	0.5	0.08	15.0	1.69	1.61
6/17/03 5:30	22.7	6.3	380	17.2	5.42							
6/24/03 6:00	20.8	6.8	244		5.05	0.08	0.43	0.6	0.11	15.0	1.47	1.41
6/30/03 5:35	23.8	4.7	257	12.1	6.30							
7/8/03 4:50	21.6	5.2	240		5.01	0.08	0.37	0.4	0.08	25.0	1.47	2.05
7/15/03 5:45	24.4	5.0	239	15.8	5.70							
7/22/03 4:52	25.7	5.1	187		5.25	0.17	0.24	1.3	0.07	13.0	1.81	1.82
7/29/03 5:50	24.6	4.9	191	15.3	6.95							
8/5/03 5:30	23.1	5.9	234		4.80	0.14	0.21	1.0	0.08	17.0	2.02	1.73
8/12/03 8:10	22.5	5.8	223	15.4	5.30							
8/19/03 4:45	23.4	5.2	212		4.78	0.12	0.24	1.1	0.07	13.0	1.87	2.15
8/26/03 5:05	24.9	4.9	317	13.1	6.65							
9/2/03 5:45	23.8	5.8	320		4.70	0.12	0.20	0.5	0.10	9.0	1.56	1.01
9/9/03 5:25	20.3	5.1	374	9.4	6.10							
9/16/03 4:40	21.7	5.6	315		4.60	0.38	0.39	0.5	0.06	7.0	1.39	1.43
9/23/03 4:35	22.7	7.0	355	11.4	5.87							
9/30/03 4:38	20.4	7.3	377		4.40	0.17	0.54	1.6	0.06	32.0	9.16	4.52
10/7/03 4:35	20.3	5.5	461	14.0	5.75							
10/14/03 5:00	17.1	8.7	451		4.50	0.05	0.38	0.6	0.05	10.0	12.20	2.74
10/21/03 4:55	18.9	7.5	463	19.4	4.89							
10/28/03 5:40	17.9	7.2	529		4.61	0.05	0.20	0.7	0.03	19.0	36.80	6.77
11/4/03 6:00	12.2	8.7	504	7.2	4.71							
11/12/03 6:50	13.4	8.8	396		3.85	0.06	1.49	0.8	0.09	10.0	1.35	1.44
11/18/03 6:10	12.9	9.0	521	25.8								
11/25/03 6:05	9.2	9.6	435		4.01	0.03	0.50	0.7	0.04	5.0	1.85	1.04
12/2/03 6:30	11.1	9.3	467	16.3	3.34							

[shaded box] = Middle River barrier in place from 4/15/03 - 11/8/03

Table 8-3 Middle River at Tracy Road: 2003 Water Quality Data (continued)

	Temp (°C)	DO (mg/L)	EC (µS/cm)	Turb (NTU)	Gage Height (ft)	NH_3-N (mg/L)	NO_2+ NO_3-N (mg/L)	ORG-N (mg/L)	PO_4 (mg/L)	Turb (NTU)	CHL-A (µg/L)	PHEO-A (µg/L)
Maximum	25.70	9.60	529.00	25.80	6.95	0.38	1.49	1.60	0.11	32.00	36.80	7.27
Minimum	9.20	4.70	187.00	7.20	3.34	0.01	0.20	0.40	0.01	5.00	1.35	1.01
Mean	19.29	6.99	363.69	14.67	5.16	0.10	0.44	0.78	0.06	14.22	6.41	2.46
Range	16.50	4.90	342.00	18.60	3.61	0.37	1.29	1.20	0.10	27.00	35.45	6.26
Standard Deviation	4.42	1.57	104.72	4.30	0.77	0.08	0.29	0.33	0.03	6.71	9.05	1.84
Sample Variance	19.58	2.47	10,965.99	18.46	0.59	0.01	0.08	0.11	0.00	45.01	81.99	3.38
Standard Error	4.42	0.88	77.02	4.36	0.90	0.09	0.29	0.34	0.03	6.91	8.85	0.95
Median	20.35	6.90	372.50	15.35	5.18	0.07	0.41	0.70	0.07	13.00	1.86	1.78
Mode	15.70	5.80	362.00	#N/A	5.40	0.05	0.46	0.60	0.01	13.00	1.47	#N/A
Count	36	36	36	18	34	18	18	18	18	18	18	18
Confidence Interval (95%)*	1.45	0.51	34.21	1.98	0.26	0.04	0.13	0.15	0.01	3.10	4.18	0.85

* Mean (µ) for Temperature = 19.29; 95% Confidence interval is 19.29 ± 1.45 or 17.84 ≤ µ ≤ 20.74. This means the interval between 17.84 and 20.74 has a .95 probability of containing µ.

Table 8-4 Middle River at Undine Road: 2003 Water Quality Data

	FIELD READINGS					BRYTE LAB RESULTS						
Date & Time (mm/dd/yy PST)	**Temp (°C)**	**DO (mg/L)**	**EC (µS/cm)**	**Turb (NTU)**	**Gage Height (ft)**	**NH_3-N (mg/L)**	**NO_2+ NO_3-N (mg/L)**	**ORG-N (mg/L)**	**PO_4 (mg/L)**	**Turb (NTU)**	**CHL-A (µg/L)**	**PHEO-A (µg/L)**
4/1/03 7:11	15.7	7.1	997		5.02	0.07	2.10	0.6	0.17	15.0	24.90	7.04
4/8/03 5:44	14.1	6.9	866	12.0	4.20							
4/15/03 6:15	14.5	9.4	750		5.56	0.04	1.50	0.9	0.01	15.0	48.90	8.59
4/22/03 5:55	14.4	9.0	543	26.2	4.80							
4/29/03 6:15	15.1	8.4	647		5.71	0.05	1.22	1.2	0.02	23.0	38.20	8.81
5/6/03 6:10	14.5	8.4	823	26.6	5.60							
5/13/03 5:16	18.6	8.4	472		5.75	0.03	0.94	0.5	0.08	25.0	26.20	9.72
5/20/03 5:20	18.0	8.2	640	16.0	4.80							
5/27/03 6:00	21.0	8.9	610		5.85	0.12	0.53	0.6	0.12	28.0	132.00	25.60
6/3/03 5:10	22.3	8.2	568	39.3	5.15							
6/11/03 6:10	20.5	7.8	479		5.91	0.06	0.86	0.5	0.10	23.0	32.80	14.90
6/17/03 5:14	21.2	8.2	461	37.7	5.38							
6/24/03 6:44	19.9	8.7	496		5.42	0.10	0.83	0.7	0.09	29.0	76.00	17.60
6/30/03 5:48	22.5	9.2	553	19.2	6.12							
7/8/03 5:16	21.4	8.6	594		5.26	0.15	0.95	1.3	0.08	24.5	52.00	20.20
7/15/03 6:33	24.6	6.4	762	17.0	5.50							
7/22/0					5.40	0.19	1.15	0.7	0.14	25.0	71.30	34.70
7/29/03 6:10	26.2	5.4	678	16.4	6.43							
8/5/03 6:15	27.1	5.6	685		5.31	0.08	1.89	0.4	0.13	22.0	17.70	13.90
8/12/03 4:50	22.7	6.6	725	26.2	5.43							
8/19/03 6:17	23.5	10.0	781		5.01	0.08	0.48	0.8	0.05	27.0	219.00	59.80
8/26/03 5:48	24.6	6.2	705	24.2	6.41							
9/2/03 6:20	23.7	7.9	695		5.04	0.15	1.38	0.8	0.10	20.0	41.40	20.50
9/9/03 5:45	21.2	7.5	722	16.8	6.00							
9/16/03 5:10	21.0	5.8	702		5.20	0.12	1.59	0.6	0.12	19.0	13.60	12.00
9/23/03 6:15	23.4	4.7	763	33.5	5.50							
9/30/03 6:15	19.7	6.3	831		4.74	0.08	0.68	0.8	0.04	17.0	16.20	9.12
10/7/03 5:11	20.4	6.0	656	14.7	5.45							
10/14/03 5:29	17.8	5.9	618		4.80	0.23	1.25	1.4	0.12	17.0	8.19	9.10
10/21/03 5:35	18.3	6.1	663	17.8	5.00							
10/28/03 6:30	17.1	6.2	355		5.05	0.13	0.97	1.1	0.10	11.0	5.53	3.88
11/4/03 7:05	12.5	8.5	680	8.6	5.15							
11/12/03 6:14	13.0	8.1	691		3.90	0.17	1.68	1.5	0.12	9.0	5.68	1.95
11/18/03 6:10	12.8	8.3	697	7.4	3.20							
11/25/03 7:20	7.9	9.1	808		4.00	0.09	1.86	1.5	0.16	7.0	5.44	1.95
12/2/03 7:15	11.2	8.5	877	8.0	4.00							

(shaded) = Middle River barrier in place from 4/15/03 - 11/8/03

Table 8-4 Middle River at Undine Road: 2003 Water Quality Data (continued)

	Temp (°C)	DO (mg/L)	EC (µS/cm)	Turb (NTU)	Gage Height (ft)	NH_3-N (mg/L)	NO_2+ NO_3-N (mg/L)	ORG-N (mg/L)	PO_4 (mg/L)	Turb (NTU)	CHL-A (µg/L)	PHEO-A (µg/L)
Maximum	27.30	10.00	997.00	39.30	6.43	0.23	2.10	1.50	0.17	29.00	219.00	59.80
Minimum	7.90	4.70	355.00	7.40	3.20	0.03	0.48	0.40	0.01	7.00	5.44	1.95
Mean	19.16	7.51	674.89	20.42	5.20	0.11	1.21	0.88	0.10	19.81	46.39	15.52
Range	19.40	5.30	642.00	31.90	3.23	0.20	1.62	1.10	0.16	22.00	213.56	57.85
Standard Deviation	4.77	1.36	131.54	9.64	0.70	0.05	0.48	0.36	0.04	6.53	53.73	13.89
Sample Variance	22.71	1.84	17,303.87	93.02	0.49	0.00	0.23	0.13	0.00	42.68	2,886.89	193.01
Standard Error	4.79	1.22	132.53	8.78	0.79	0.05	0.49	0.37	0.05	6.51	42.96	5.87
Median	20.15	8.00	688.00	17.40	5.29	0.10	1.19	0.80	0.10	21.00	29.50	10.86
Mode	14.50	8.40	#N/A	26.20	4.80	0.08	#N/A	0.60	0.12	15.00	#N/A	1.95
Count	36	36	36	18	36	18	18	18	18	18	18	18
Confidence Interval (95%)*	1.56	0.44	42.97	4.46	0.23	0.03	0.22	0.17	0.02	3.02	24.82	6.42

* Mean (µ) for Temperature = 19.16; 95% Confidence interval is 19.16 ± 1.56 or 17.60 ≤ µ ≤ 20.72. This means the interval between 17.60 and 20.72 has a .95 probability of containing µ.

Dissolved oxygen (DO) concentrations in the Middle River were low during the summer compared to the spring and fall, in part due to high water temperatures and low San Joaquin River flows. DO concentrations at the Tracy Road site were consistently lower than the other two stations during the summer with values ranging from 4.7 mg/L to 5.8 mg/L from June 30th – September 16th. Three field readings collected at Tracy Road and one reading at Undine Road were less than 5 mg/L. The lowest DO reading was 4.7 mg/L on June 30th and September 23rd at Tracy Road and Undine Road, respectively. The highest DO reading was 10.50 mg/L on April 1st at Union Point. Mean DO concentrations ranged from 6.99 mg/L at Tracy Road to 7.82 mg/L at Union Point.

Specific electrical conductivity values in the Middle River were higher upstream at the Undine Road site than at the Union Point and Tracy Road sites. The greatest differences in upstream and downstream specific conductance values occurred in early spring, mid to late summer, and late fall. Differences in upstream and downstream specific conductance values are likely due to differences in San Joaquin River water and incoming tidal water likely from the Sacramento River. Union Point and Tracy Road specific conductance values were lowest during the summer and tracked closely throughout the monitoring period. Union Point had lower specific electrical conductivity readings than the two upstream sites with values ranging from 171.0 – 567.0 µS/cm and had a mean of 306.8 µS/cm. Comparatively, Tracy Road and Undine Road had means of 363.7 µS/cm and 674.9 µS/cm, respectively. Overall, the minimum-recorded value was 171.0 µS/cm on July 15th at Union Point and the maximum-recorded value was 997.0 µS/cm on April 1st at Undine Road.

Water clarity diminished upstream of the Middle River barrier as turbidity values were higher at the Tracy Road and Undine Road monitoring stations than at the Union Point site. Undine Road was the most turbid site in the Middle River with values ranging from 7.0 – 39.3 NTU and had a mean of 20.1 NTU. Turbidity readings at Undine Road tended to be higher in the summer relative to the other two sites. Union Point readings were consistently the lowest throughout the monitoring period ranging from 4.0 – 22.5 NTU with a mean of 8.5 NTU. Upstream of the barrier at Tracy Road turbidity values ranged from 5.0 – 32.0 NTU with a mean of 14.4 NTU.

Algal biomass, as indicated by chlorophyll *a* concentrations, was higher upstream at the Undine Road site than at the downstream monitoring sites. Chlorophyll *a* levels began to increase in mid-spring and continued to rise until mid summer, reaching a peak of 219.0 µg/L on August 19th. After peaking, chlorophyll *a* levels declined sharply in late summer and fall, reaching a minimum of 5.44 µg/L on November 25th. Overall, chlorophyll *a* at Undine Road averaged 46.4 µg/L. Measured chlorophyll *a* concentrations at Tracy Road and Union Point reached maximums of 36.8 µg/L and 18.9 µg/L on October 28th and April 1st, respectively. There were no noteworthy differences in chlorophyll *a* levels at the aforementioned stations, with averages of 4.53 µg/L at Union Point and 6.41 µg/L at Tracy Road.

When algae die, chlorophyll *a* degrades into byproducts. Pheophytin *a* is a degradation product of chlorophyll *a*. Pheophytin *a* concentrations were noticeably higher at the Undine Road site in comparison to the downstream sites, which would be expected based on the high chlorophyll *a* concentrations at Undine Road. Undine Road had a maximum recorded pheophytin *a* concentration of 59.8 µg/L on August 19th and had a mean of 15.5 µg/L. Measured pheophytin *a* concentrations in the Middle River at Union Point and Tracy Road were low compared to Undine Road with means of 1.93 µg/L and 2.46 µg/L, respectively.

Measured ammonia concentrations in the Middle River were higher in summer and fall than in spring. Except for a few occurrences ammonia concentrations at the three sites tracked well and did not show many differences. Mean ammonia values ranged from 0.10 – 0.11 mg/L. Ammonia concentrations ranged from a maximum of 0.38 mg/L recorded on September 16th and minimum of 0.01 mg/L recorded on April 15th, April 22nd and May 6th , both at Tracy Road.

Nitrite-Nitrate concentrations were greater upstream at the Undine Road site than at the Union Point or Tracy Road sites. Nitrite-nitrate values at Undine Road varied throughout the monitoring period reaching a maximum of 2.10 mg/L on April 1st. Nitrite-nitrate concentrations at the Union Point and Tracy Road sites tracked closely in spring and summer and had higher values in fall. Tracy Road and Union Point reached maximum values of 1.49 mg/L and 0.78 mg/L on November 12th and October 28th , respectively. The mean nitrite-nitrate concentration at Undine Road was 1.21 mg/L, which was more than twice as high as the mean values at Tracy Road and Union Point. Tracy Road had the lowest nitrite-nitrate concentration in the Middle River with an average of 0.44 mg/L.

Organic nitrogen values fluctuated throughout the monitoring period ranging from 0.10 - 1.60 mg/L. The mean organic nitrogen concentration at Undine Road was 0.88 mg/L. Tracy Road had lower organic nitrogen values with an average of 0.78 mg/L. Downstream of the barrier at Union Point organic nitrogen concentrations were the lowest averaging 0.63 mg/L.

The Undine Road site tended to have higher orthophosphate values than the Union Point and Tracy Road sites throughout the monitoring period. Overall, orthophosphate concentrations at Undine Road averaged 0.10 mg/L and reached a maximum of 0.17 mg/L on April 1st. Orthophosphate values at Union Point and Tracy Road tracked relatively closely averaging 0.06 mg/L. Values ranged from 0.01 -0.07 mg/L at Union Point and from 0.01 – 0.11 mg/L at Tracy Road.

Overall, water quality constituents in the Middle River showed marked variation between the stations (Union Point and Tracy Road) downstream and upstream of the barrier and the upstream station near Old River (Undine Road). Middle River at Undine Road had the highest specific electrical conductance, turbidity, chlorophyll *a*, pheophytin *a*, nitrite-nitrate, and orthophosphate values. There were also minor differences in dissolved oxygen, specific electrical conductance, turbidity, and organic nitrogen at the monitoring sites upstream and downstream of the barrier. A number of influences can contribute to these differences such as agricultural pumping and discharges, State Water Project and Central Valley Project exports, barrier operations, etc. Also, variation between incoming tidal water, likely from the Sacramento River, and water flowing down the Middle River, likely from the San Joaquin River, could be another reason why there is distinct variation in water quality constituents between the upstream and downstream sampling locations.

Old River Barrier

The Old River at Head barrier was constructed on April 15th, 2003 and removed on May 16th, 2003, reinstalled on September 20th, 2003, and removed on November 3rd, 2003. This barrier was installed during the spring and fall to aid fish migration in the San Joaquin River. The barrier in the Old River near DMC was constructed on April 14th, 2003, and removed on November 15th, 2003. Monitoring of the Old River was conducted at four sites: 1) Old River at Head (site 10), 2) Tracy Road bridge over Old River (site 6), 3) immediately upstream of the barrier in Old River near DMC (site 5), and 4) immediately downstream of the barrier in Old River near DMC (site 4). Figure 8-3 and Tables 8-5 through 8-8 show the weekly water quality field and lab data for the Old River.

Figure 8-3 Old River - Weekly Water Quality Data

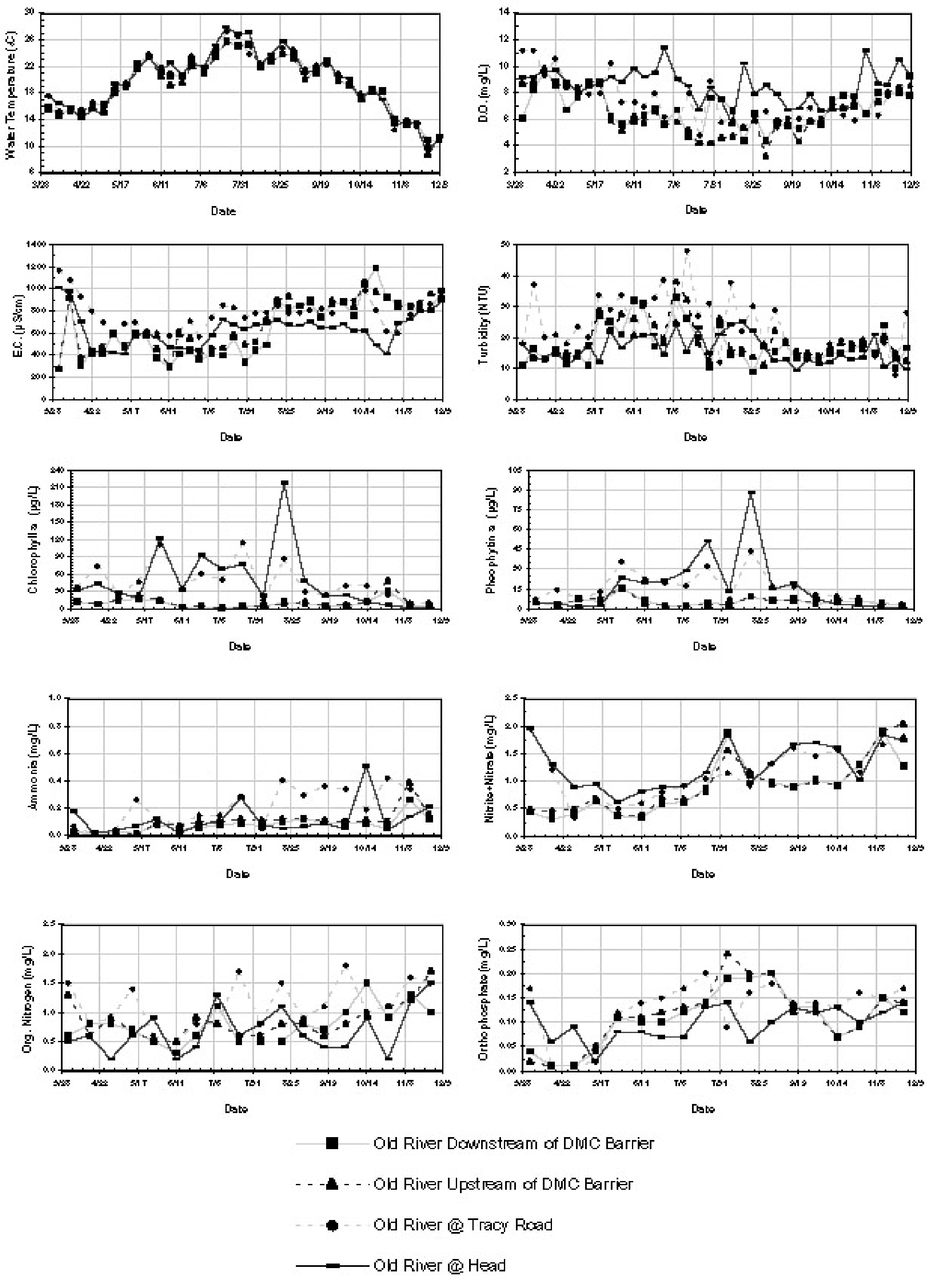


Table 8-5 Old River at DMC - Downstream of Barrier: 2003 Water Quality Data

	FIELD READINGS					BRYTE LAB RESULTS						
Date & Time (mm/dd/yy PST)	**Temp (°C)**	**DO (mg/L)**	**EC (µS/cm)**	**Turb (NTU)**	**Gage Height (ft)**	**NH_3-N (mg/L)**	**NO_2+ NO_3-N (mg/L)**	**ORG-N (mg/L)**	**PO_4 (mg/L)**	**Turb (NTU)**	**CHL-A (µg/L)**	**PHEO-A (µg/L)**
4/1/03 8:20	15.7	6.1	274		3.80	0.03	0.44	0.6	0.04	11.0	11.70	5.03
4/8/03 6:20	14.9	8.2	913	16.2	4.03							
4/15/03 7:45	15.4	9.6	306		4.85	0.01	0.31	0.8	0.01	13.0	7.49	2.41
4/22/03 6:50	14.9	8.8	431	15.2	5.00							
4/29/03 7:09	16.2	6.7	413		5.25	0.03	0.40	0.8	0.01	13.0	15.10	7.12
5/6/03 6:53	16.2	7.6	596	15.0	5.84							
5/13/03 6:30	18.3	8.8	465		4.90	0.02	0.63	0.7	0.04	11.0	17.10	5.67
5/20/03 6:33	19.2	8.8	583	27.0	5.33							
5/27/03 7:43	22.3	6.2	571		4.35	0.08	0.37	0.5	0.11	25.0	13.20	15.40
6/3/03 6:00	23.5	5.6	373	20.9	4.92							
6/11/03 7:00	21.1	5.8	291		4.98	0.05	0.34	0.3	0.10	32.0	2.29	6.11
6/17/03 6:10	20.5	6.3	407	30.8	5.10							
6/24/03 7:50	20.5	6.8	435		2.95	0.06	0.59	0.6	0.10	17.0	3.88	1.86
6/30/03 6:30	23.1	5.6	356	18.0	6.00							
7/8/03 6:40	21.3	6.7	410		5.10	0.08	0.62	1.1	0.12	33.0	1.86	2.16
7/15/03 7:20	23.9	4.7	397	26.2	5.55							
7/22/03 7:00	25.8	4.2	560		3.15	0.09	0.86	0.5	0.14	20.0	3.26	4.56
7/29/03 7:00	25.2	7.6	335	10.3	6.00							
8/5/03 6:55	25.3	7.5	440		3.10	0.07	1.84	0.5	0.19	24.0	3.44	2.89
8/12/03 7:20	22.2	6.6	489	14.2	5.36							
8/19/03 7:11	22.8	4.4	887		2.70	0.10	1.11	0.5	0.19	15.0	11.40	9.23
8/26/03 6:55	23.8	6.4	828	8.8	5.10							
9/2/03 7:27	23.6	4.4	845		3.08	0.12	0.97	0.8	0.20	17.0	8.07	5.92
9/9/03 6:50	20.0	5.7	892	15.2	4.97							
9/16/03 6:15	21.4	5.5	737		3.50	0.10	0.90	0.7	0.13	18.0	5.55	7.32
9/23/03 7:00	22.8	5.3	868	13.2	4.75							
9/30/03 7:09	20.0	5.8	879		2.60	0.09	1.03	1.0	0.13	14.0	3.33	3.62
10/7/03 6:12	19.1	5.6	756	13.0	5.18							
10/14/03 6:25	17.2	7.4	1039		2.53	0.09	0.92	1.5	0.07	15.0	11.60	4.98
10/21/03 6:25	18.6	7.8	1186	15.1	3.10							
10/28/03 7:20	18.2	7.7	917		3.70	0.05	1.30	0.9	0.09	16.0	30.20	5.49
11/4/03 7:50	14.0	6.4	873	17.8	2.70							
11/12/03 7:40	13.3	8.0	847		2.80	0.26	1.90	1.3	0.15	15.0	5.89	4.64
11/18/03 7:35	13.4	7.9	808	23.9	1.90							
11/25/03 8:40	10.9	8.0	805		3.70	0.12	1.27	1.0	0.12	10.0	4.93	2.37
12/2/03 8:05	10.9	7.8	982	16.6	2.20							

(shaded) = Old River near DMC barrier in place from 4/14/03 - 11/15/03.

Table 8-5 Old River at DMC - Downstream of Barrier: 2003 Water Quality Data (continued)

	Temp (°C)	DO (mg/L)	EC (µS/cm)	Turb (NTU)	Gage Height (ft)	NH_3-N (mg/L)	NO_2+ NO_3-N (mg/L)	ORG-N (mg/L)	PO_4 (mg/L)	Turb (NTU)	CHL-A (µg/L)	PHEO-A (µg/L)
Maximum	25.80	9.60	1,186.00	30.80	6.00	0.26	1.90	1.50	0.20	33.00	30.20	15.40
Minimum	10.90	4.20	274.00	8.82	1.90	0.01	0.31	0.30	0.01	10.00	1.86	1.86
Mean	19.32	6.73	644.28	17.63	4.17	0.08	0.88	0.78	0.11	17.72	8.91	5.38
Range	14.90	5.40	912.00	21.98	4.10	0.25	1.59	1.20	0.19	23.00	28.34	13.54
Standard Deviation	4.13	1.38	252.80	5.93	1.20	0.06	0.48	0.31	0.06	6.73	7.07	3.20
Sample Variance	17.02	1.89	63,909.92	35.13	1.44	0.00	0.23	0.10	0.00	45.27	49.94	10.26
Standard Error	4.12	1.10	256.49	5.81	1.32	0.05	0.36	0.30	0.06	6.58	6.76	3.07
Median	20.00	6.65	589.50	15.70	4.55	0.08	0.88	0.75	0.12	15.50	6.69	5.01
Mode	14.90	8.80	#N/A	15.20	5.10	0.09	#N/A	0.50	0.04	15.00	#N/A	#N/A
Count	36	36	36	18	36	18	18	18	18	18	18	18
Confidence Interval (95%)*	1.35	0.45	82.58	2.74	0.39	0.03	0.22	0.14	0.03	3.11	3.26	1.48

* Mean (µ) for Temperature = 19.32; 95% Confidence interval is 19.32 ± 1.35 or 17.97 ≤ µ ≤ 20.67. This means the interval between 17.97 and 20.67 has a .95 probability of containing µ.

Table 8-6 Old River at DMC - Upstream of Barrier: 2003 Water Quality Data

	FIELD READINGS					BRYTE LAB RESULTS						
Date & Time (mm/dd/yy PST)	**Temp (°C)**	**DO (mg/L)**	**EC (µS/cm)**	**Turb (NTU)**	**Gage Height (ft)**	**NH_3-N (mg/L)**	**NO_2+ NO_3-N (mg/L)**	**ORG-N (mg/L)**	**PO_4 (mg/L)**	**Turb (NTU)**	**CHL-A (µg/L)**	**PHEO-A (µg/L)**
4/1/03 8:04	15.5	8.7	274		4.00	0.04	0.47	1.3	0.02	11.0	12.70	6.46
4/8/03 6:40	14.7	8.8	923	13.5	4.32							
4/15/03 7:15	15.3	9.8	377		5.00	0.02	0.46	0.6	0.01	13.0	8.12	3.10
4/22/03 6:30	15.4	8.5	411	14.9	4.62							
4/29/03 6:52	15.7	8.6	474		5.10	0.03	0.49	0.9	0.01	15.0	16.10	6.88
5/6/03 6:40	15.6	8.4	601	14.9	5.15							
5/13/03 6:05	18.1	8.8	493		5.09	0.01	0.68	0.7	0.05	17.0	24.00	7.81
5/20/03 6:10	19.0	8.7	576	28.8	4.60							
5/27/03 6:50	21.7	5.9	576		5.15	0.09	0.37	0.5	0.11	22.0	14.80	16.00
6/3/03 5:40	23.5	5.1	455	27.4	4.65							
6/11/03 6:44	20.6	6.2	293		5.39	0.07	0.38	0.5	0.11	26.0	2.67	3.79
6/17/03 5:55	19.1	5.7	595	31.2	5.00							
6/24/03 7:20	19.5	6.6	555		5.20	0.10	0.68	0.9	0.12	24.0	3.28	2.32
6/30/03 6:16	22.1	5.6	397	19.3	5.59							
7/8/03 5:54	20.9	5.8	465		4.98	0.10	0.67	0.8	0.13	38.0	2.76	2.46
7/15/03 7:00	23.5	5.2	464	32.2	5.05							
7/22/03 6:25	25.7	4.2	577		5.10	0.12	0.79	0.6	0.14	18.0	2.49	3.23
7/29/03 6:40	25.0	4.2	494	12.5	5.80							
8/5/03 6:47	25.2	4.6	520		5.10	0.11	1.56	0.6	0.24	26.0	4.63	3.31
8/12/03 7:00	21.9	4.7	723	16.1	5.40							
8/19/03 6:52	22.8	5.4	889		4.70	0.12	1.16	0.8	0.20	16.0	8.29	9.33
8/26/03 6:32	23.9	5.9	938	13.6	6.60							
9/2/03 7:00	23.2	3.2	844		4.80	0.13	0.94	0.8	0.20	11.0	12.10	5.94
9/9/03 6:25	20.1	5.9	883	22.0	5.25							
9/16/03 6:00	20.9	5.7	744		4.85	0.11	0.89	0.6	0.12	18.0	4.93	6.42
9/23/03 6:45	22.5	4.3	893	15.3	4.70							
9/30/03 6:50	19.9	5.9	883		4.39	0.10	0.99	0.8	0.12	15.0	6.73	5.07
10/7/03 5:55	19.1	5.7	835	14.1	4.80							
10/14/03 6:00	17.8	7.2	1062		4.50	0.11	0.92	1.0	0.07	16.0	10.80	6.64
10/21/03 6:05	18.2	6.9	971	18.1	4.30							
10/28/03 7:03	18.2	7.2	917		4.65	0.10	1.29	1.1	0.09	18.0	49.20	7.60
11/4/03 7:40	14.0	6.4	843	16.4	4.85							
11/12/03 7:05	13.6	7.3	837		3.60	0.39	1.91	1.2	0.15	15.0	5.90	3.28
11/18/03 7:02	13.2	8.0	870	20.3	2.10							
11/25/03 8:15	9.9	8.4	954		3.50	0.15	2.04	1.7	0.14	15.0	9.60	2.95
12/2/03 7:50	10.9	9.2	938	12.5	2.46							

[shaded] = Old River near DMC barrier in place from 4/14/03 - 11/15/03.

Table 8-6 Old River at DMC - Upstream of Barrier: 2003 Water Quality Data (continued)

	Temp (°C)	DO (mg/L)	EC (µS/cm)	Turb (NTU)	Gage Height (ft)	NH_3-N (mg/L)	NO_2+ NO_3-N (mg/L)	ORG-N (mg/L)	PO_4 (mg/L)	Turb (NTU)	CHL-A (µg/L)	PHEO-A (µg/L)
Maximum	25.70	9.80	1,062.0 0	32.20	6.60	0.39	2.04	1.70	0.24	38.00	49.20	16.00
Minimum	9.90	3.20	274.00	12.50	2.10	0.01	0.37	0.50	0.01	11.00	2.49	2.32
Mean	19.06	6.58	681.78	19.06	4.73	0.11	0.93	0.86	0.11	18.56	11.06	5.70
Range	15.80	6.60	788.00	19.70	4.50	0.38	1.67	1.20	0.23	27.00	46.71	13.68
Standard Deviation	4.09	1.70	224.94	6.56	0.83	0.08	0.50	0.31	0.06	6.61	11.06	3.33
Sample Variance	16.71	2.88	50,596. 23	43.04	0.68	0.01	0.25	0.10	0.00	43.67	122.4 3	11.10
Standard Error	4.10	0.95	227.95	6.08	1.09	0.07	0.36	0.26	0.07	6.55	11.05	3.12
Median	19.30	6.05	662.00	16.25	4.85	0.10	0.84	0.80	0.12	16.50	8.21	5.51
Mode	23.50	5.90	576.00	14.90	5.10	0.10	0.68	0.60	0.12	15.00	#N/A	#N/A
Count	36	36	36	18	36	18	18	18	18	18	18	18
Confidence Interval (95%)*	1.34	0.55	73.48	3.03	0.27	0.04	0.23	0.14	0.03	3.05	5.11	1.54

* Mean (µ) for Temperature = 19.06; 95% Confidence interval is 19.06 ± 1.34 or 17.72 ≤ µ ≤ 20.40. This means the interval between 17.72 and 20.40 has a .95 probability of containing µ.

Table 8-7 Old River at Tracy Road: 2003 Water Quality Data

	FIELD READINGS					BRYTE LAB RESULTS						
Date & Time (mm/dd/yy PST)	**Temp (°C)**	**DO (mg/L)**	**EC (µS/cm)**	**Turb (NTU)**	**Gage Height (ft)**	**NH_3-N (mg/L)**	**NO_2+ NO_3-N (mg/L)**	**ORG-N (mg/L)**	**PO_4 (mg/L)**	**Turb (NTU)**	**CHL-A (µg/L)**	**PHEO-A (µg/L)**
4/1/03 8:30	17.6	11.2	1167		4.20	0.07	1.95	1.5	0.17	18.0	38.40	7.19
4/8/03 6:45	15.3	11.2	1082	37.1	4.05							
4/15/03 7:00	15.3	9.3	931		5.60	0.01	1.20	0.8	0.01	20.0	73.80	14.50
4/22/03 6:45	14.9	10.6	802	21.0	4.60							
4/29/03 7:30	16.6	8.4	701		5.50	0.04	0.34	0.9	0.01	18.0	25.20	7.51
5/6/03 6:45	16.2	8.0	594	23.6	5.20							
5/13/03 6:50	19.0	7.9	681		5.35	0.26	0.68	1.4	0.02	20.0	47.20	13.00
5/20/03 7:20	19.6	8.0	702	33.8	5.00							
5/27/03 7:15	21.9	10.2	616		5.35	0.12	0.50	0.6	0.12	29.0	112.00	35.80
6/3/03 6:40	23.8	7.3	600	33.6	4.95							
6/11/03 7:00	21.9	7.3	584		5.40	0.08	0.60	0.5	0.14	21.0	36.20	22.60
6/17/03 6:55	21.0	7.0	623	30.2	5.43							
6/24/03 7:55	20.5	8.0	709		5.30	0.15	0.79	0.8	0.15	33.0	60.50	19.70
6/30/03 7:00	23.6	6.2	569	38.4	6.00							
7/8/03 6:45	21.2	5.8	740		5.50	0.15	0.92	0.8	0.17	25.0	51.90	17.90
7/15/03 7:15	24.8	8.0	855	48.0	5.60							
7/22/03 6:55	27.3	4.8	832		5.10	0.29	1.04	1.7	0.20	27.0	115.00	32.40
7/29/03 7:20	26.5	8.9	741	31.0	6.10							
8/5/03 5:25	23.9	5.8	784		5.05	0.05	1.15	0.8	0.09	12.0	14.60	7.20
8/12/03 6:25	22.5	5.9	785	37.9	5.40							
8/19/03 6:50	23.5	5.4	850		4.90	0.41	0.92	1.5	0.16	22	86.10	44.10
8/26/03 6:42	24.7	6.0	780	30.2	5.78							
9/2/03 7:45	24.6	6.6	788		4.80	0.30	1.31	0.9	0.18	18.0	28.90	17.20
9/9/03 6:40	21.7	5.4	807	29.0	5.40							
9/16/03 6:10	22.2	6.1	821		5.02	0.36	1.61	1.1	0.14	19.0	24.40	16.80
9/23/03 6:16	22.2	6.0	779	15.9	4.80							
9/30/03 6:35	20.9	6.9	896			0.34	1.45	1.8	0.14	13.0	40.40	10.90
10/7/03 6:20	19.9	6.1	896	12.6	4.85							
10/14/03 7:05	17.4	6.8	988		4.53	0.19	1.57	1.0	0.13	18.0	40.30	9.68
10/21/03 6:45	18.3	6.3	810	19.2	4.52							
10/28/03 7:45	18.3	5.9	617		4.70	0.42	1.17	1.1	0.16	16.0	24.40	7.02
11/4/03 7:35	12.5	6.5	598	19.5	4.90							
11/12/03 8:13	14.0	6.3	768		3.80	0.34	1.67	1.6	0.15	14.0	10.10	4.05
11/18/03 7:40	13.1	7.8	855	18.4	2.80							
11/25/03 8:15	9.3	8.4	862		3.41	0.17	1.81	1.5	0.17	8.0	10.80	2.56
12/2/03 8:00	11.0	8.5	930	28.1	3.00							

[shaded] = Old River near DMC barrier in place from 4/14/03 - 11/15/03.

Table 8-7 Old River at Tracy Road: 2003 Water Quality Data (continued)

	Temp (°C)	DO (mg/L)	EC (µS/cm)	Turb (NTU)	Gage Height (ft)	NH_3-N (mg/L)	NO_2+ NO_3-N (mg/L)	ORG-N (mg/L)	PO_4 (mg/L)	Turb (NTU)	CHL-A (µg/L)	PHEO-A (µg/L)
Maximum	27.30	11.20	1,167.00	48.00	6.10	0.42	1.95	1.80	0.20	33.00	115.00	44.10
Minimum	9.30	4.80	569.00	12.60	2.80	0.01	0.34	0.50	0.01	8.00	10.10	2.56
Mean	19.64	7.36	781.75	28.19	4.91	0.21	1.15	1.13	0.13	19.50	46.68	16.12
Range	18.00	6.40	598.00	35.40	3.30	0.41	1.61	1.30	0.19	25.00	104.90	41.54
Standard Deviation	4.45	1.65	139.12	9.29	0.77	0.13	0.47	0.40	0.06	6.19	31.74	11.43
Sample Variance	19.79	2.73	19,354.88	86.28	0.59	0.02	0.22	0.16	0.00	38.26	1,007.39	130.69
Standard Error	4.41	1.52	134.03	9.57	0.85	0.13	0.47	0.35	0.06	6.36	21.56	6.45
Median	20.70	6.95	784.50	29.60	5.02	0.18	1.16	1.05	0.15	18.50	39.35	13.75
Mode	15.30	8.00	855.00	30.20	5.40	0.15	0.92	0.80	0.17	18.00	24.40	#N/A
Count	36	36	36	18	35	18	18	18	18	18	18	18
Confidence Interval (95%)*	1.45	0.54	45.45	4.29	0.25	0.06	0.22	0.18	0.03	2.86	14.66	5.28

* Mean (µ) for Temperature = 19.64; 95% Confidence interval is 19.64 ± 1.45 or $18.19 \le \mu \le 21.09$. This means the interval between 18.19 and 21.09 has a .95 probability of containing µ.

Table 8-8 Old River at Head: 2003 Water Quality Data

	FIELD READINGS					BRYTE LAB RESULTS						
Date & Time (mm/dd/yy PST)	**Temp (°C)**	**DO (mg/L)**	**EC (µS/cm)**	**Turb (NTU)**	**Gage Height (ft)**	**NH_3-N (mg/L)**	**NO_2+ NO_3-N (mg/L)**	**ORG-N (mg/L)**	**PO_4 (mg/L)**	**Turb (NTU)**	**CHL-A (µg/L)**	**PHEO-A (µg/L)**
4/1/03 6:24	17.5	9.1	1011		5.37	0.18	1.96	0.5	0.14	18.0	32.10	3.96
4/8/03 5:00	16.5	9.2	975	13.4	4.40							
4/15/03 5:30	15.8	9.6	705		5.66	0.02	1.30	0.6	0.06	13.0	42.90	3.76
4/22/03 5:00	14.2	9.7	440	16.3	4.85							
4/29/03 5:16	15.5	8.8	434		5.67	0.04	0.89	0.2	0.09	11.0	26.70	1.48
5/6/03 5:24	14.8	8.0	425	13.5	5.44							
5/13/03 4:25	19.4	8.4	410		5.60	0.07	0.94	0.6	0.02	18.0	20.50	2.25
5/20/03 4:40	19.2	8.7	606	12.0	4.90							
5/27/03 5:15	21.3	9.2	602		6.09	0.12	0.62	0.9	0.08	22.0	121.00	23.30
6/3/03 4:30	23.5	8.8	559	16.6	5.52							
6/11/03 5:25	21.3	9.8	475		6.30	0.02	0.81	0.2	0.08	20.0	33.10	19.90
6/17/03 4:20	22.6	9.2	462	20.8	5.92							
6/24/03 5:41	20.6	9.5	459		5.81	0.08	0.89	0.4	0.07	21.0	92.10	21.10
6/30/03 5:11	22.5	11.4	447	14.5	6.56							
7/8/03 4:30	21.9	9.0	582		5.46	0.10	0.90	1.3	0.07	24.0	69.90	28.60
7/15/03 5:45	25.2	8.5	725	15.4	5.84							
7/22/03 4:30	27.9	6.7	676		5.65	0.28	1.15	0.6	0.13	23.0	76.90	51.70
7/29/03 5:30	26.8	8.4	638	14.8	6.56							
8/5/03 5:45	27.1	7.4	675		5.56	0.08	1.91	0.8	0.14	21.0	21.60	13.20
8/12/03 4:15	22.3	5.6	684	24.2	5.90							
8/19/03 5:30	23.8	10.2	719		5.29	0.05	0.97	1.1	0.06	25.0	218.00	88.30
8/26/03 4:50	25.8	7.9	675	22.1	6.49							
9/2/03 5:40	24.2	8.6	669		5.37	0.07	1.31	0.6	0.10	17.0	48.90	14.90
9/9/03 4:50	21.0	7.9	704	12.3	6.14							
9/16/03 4:12	21.5	6.7	648		5.52	0.09	1.67	0.4	0.13	13.0	22.20	19.60
9/23/03 5:33	23.1	6.8	652	9.3	5.21							
9/30/03 5:30	20.4	7.9	682		4.91	0.05	1.70	0.4	0.12	13.0	23.80	7.51
10/7/03 4:16	20.2	6.6	617	11.6	5.20							
10/14/03 4:26	16.8	6.7	618		4.80	0.51	1.61	0.9	0.13	12.0	12.40	3.82
10/21/03 4:35	18.7	6.8	491	14.3	5.00							
10/28/03 5:27	17.0	6.9	411		5.01	0.04	1.02	0.2	0.10	13.0	5.71	2.32
11/4/03 6:30	13.2	11.2	686	13.4	5.43							
11/12/03 5:30	13.8	8.7	723		4.50	0.14	1.84	1.2	0.12	21.0	2.17	1.62
11/18/03 5:25	13.4	8.6	794	10.4	4.00							
11/25/03 6:32	8.6	10.5	811		4.46	0.21	1.74	1.5	0.14	13.0	3.15	1.33
12/2/03 6:34	11.5	9.4	886	9.7	6.53							

(shaded) = Old River Near DMC barrier in place from 4/14/03 - 11/15/03.
Note: Old River @ Head Barrier in place from 4/15/03 - 5/16/03 and from 9/20/03 - 11/3/03.

Table 8-8 Old River at Head: 2003 Water Quality Data (continued)

	Temp (°C)	DO (mg/L)	EC (µS/cm)	Turb (NTU)	Gage Height (ft)	NH_3-N (mg/L)	NO_2+ NO_3-N (mg/L)	ORG-N (mg/L)	PO_4 (mg/L)	Turb (NTU)	CHL-A (µg/L)	PHEO-A (µg/L)
Maximum	27.90	11.40	1,011.0 0	24.20	6.56	0.51	1.96	1.50	0.14	25.00	218.00	88.30
Minimum	8.60	5.60	410.00	9.30	4.00	0.02	0.62	0.20	0.02	11.00	2.17	1.33
Mean	19.69	8.51	632.67	14.70	5.47	0.12	1.29	0.69	0.10	17.67	48.51	17.15
Range	19.30	5.80	601.00	14.90	2.56	0.49	1.34	1.30	0.12	14.00	215.83	86.97
Standard Deviation	4.69	1.35	151.12	4.12	0.64	0.12	0.44	0.39	0.03	4.64	53.31	22.07
Sample Variance	21.97	1.82	22,838. 69	17.01	0.41	0.01	0.19	0.15	0.00	21.53	2,841. 85	486.92
Standard Error	4.67	1.29	153.09	4.09	0.73	0.11	0.42	0.39	0.04	4.62	41.91	10.49
Median	20.50	8.65	650.00	13.90	5.49	0.08	1.23	0.60	0.10	18.00	29.40	10.36
Mode	21.30	9.20	675.00	13.40	5.37	0.02	0.89	0.60	0.14	13.00	#N/A	#N/A
Count	36	36	36	18	36	18	18	18	18	18	18	18
Confidence Interval (95%)*	1.53	0.44	49.37	1.91	0.21	0.06	0.20	0.18	0.02	2.14	24.63	10.19

* Mean (µ) for Temperature = 19.69; 95% Confidence interval is 19.69 ± 1.53 or 18.16 ≤ µ ≤ 21.22. This means the interval between 18.16 and 21.22 has a .95 probability of containing µ.

Water temperature data recorded for the Old River followed seasonal patterns. Generally, temperatures for all four sites increased steadily from spring into early summer, remained elevated throughout the summer and decreased in fall. Temperatures at the four monitoring sites tracked well and there were no notable temperature differences. Mean temperatures during the monitoring period ranged from 19.05 °C at the Upstream of DMC Barrier site to 19.69 °C at the Old River at Head site. The highest recorded temperature was 27.9 °C on July 22nd, and the lowest was 8.6 °C on November 25th, both at the Old River at Head site.

Dissolved oxygen levels were lowest in the summer, in part due to warm water temperatures and low San Joaquin River flows at all the monitoring sites except Old River at Head. During this time period ten field readings collected at the DMC sites, in the immediate vicinity of the barrier, were less than 5 mg/L. The minimum dissolved oxygen value recorded was 3.20 mg/L on September 2nd in the Old River upstream of the DMC barrier. Mean DO concentrations immediately upstream and downstream of the DMC Barrier were 6.58 mg/L and 6.74 mg/L, respectively, showing little variation. Old River at Tracy Road tended to have higher DO concentrations then at the sites near the barrier and had an average DO concentration of 7.36 mg/L. One field reading collected at Tracy Road was less than 5 mg/L. Old River at Head had consistently higher DO concentrations in comparison to the other three sites on Old River averaging 8.51 mg/L. Readings at the Head site were elevated throughout the monitoring period with no observable pattern. The high summer DO readings at Old River at Head were probably a result of the photosynthetic activity of phytoplankton. A maximum DO reading of 11.40 mg/L was recorded on June 30th, and a minimum value of 5.60 mg/L was recorded on August 12th, at Old River at Head site.

From early April until mid August specific conductance at Tracy Road was higher than the other monitoring locations, which all tracked relatively closely. From mid August through early November specific electrical conductivity readings tended to be lower at the Old River at Head site than the other locations. Immediately upstream and downstream of the DMC Barrier there were minimal differences in specific conductance with means of 682 and 644 µS/cm, respectively. Values then increased upstream at the Tracy Road site averaging 782 µS/cm. Finally, specific electrical conductivity values at Old River at Head, the furthest upstream site, were lower than the other sites averaging 633 µS/cm. The lowest recorded specific electrical conductivity reading for the Old River was 274 µS/cm on April 1st at the Downstream and Upstream of DMC Barrier sites and the highest was 1,186 µS/cm on October 21st at the Downstream of DMC Barrier site.

Turbidity values in the Old River were highest during the late spring and summer. Tracy Road had the highest turbidity readings during this time period and had a mean of 23.8 NTU. In the immediate vicinity of the barrier turbidity readings averaged 18.8 NTU at the upstream site and 17.7 NTU at the downstream site. The Head site averaged 16.2 NTU. The lowest recorded turbidity value was 8.0 NTU on November 25th, and the highest was 48.0 NTU on July 15th, both at Tracy Road.

Chlorophyll *a* concentrations were highest at the Old River at Head and Tracy Road sites. Values at Head began increasing in mid-May, remained high throughout the summer and began decreasing in early fall. The mean at the Head site was 48.5 µg/L during the monitoring period. Elevated chlorophyll *a* concentrations were also observed at Tracy Road during the summer. The mean chlorophyll *a* concentration at Tracy Road was 46.7 µg/L. Immediately upstream and downstream of the DMC barrier chlorophyll *a* concentrations were comparatively low, averaging 11.06 µg/L and 8.91 µg/L, respectively. A maximum chlorophyll *a* value of 218 µg/L was recorded on August 19th at Old River at Head and a minimum of 1.86 µg/L was recorded on July 8th at the Downstream of DMC Barrier site. Trends in pheophytin *a* concentrations mimicked those seen in the chlorophyll *a* concentrations at all four Old River sites.

Ammonia concentrations tracked well between all four sampling locations during the spring and early summer after which Tracy Road tended to have higher concentrations for the remainder of the monitoring period. Values at Tracy Road ranged from 0.01 - 0.42 mg/L with a mean of 0.21 mg/L, while values further upstream at the Head site ranged from 0.02 - 0.51 mg/L with a mean of 0.12 mg/L. The maximum measured ammonia concentration was 0.51 on October 14th, in the Old River at Head. Values immediately upstream and downstream of the barrier showed little variation averaging 0.11 mg/L and 0.08 mg/L, respectively.

Nitrite-nitrate levels tended to increase at all four monitoring sites from late spring through the fall. Old River at Head had the highest nitrite-nitrate concentrations with an average of 1.29 mg/L. Old River at Head reached a maximum value of 1.96 mg/L on April 1st, before the barrier was installed. Old River at Tracy Road had lower concentrations than Head with an average of 1.15 mg/L. Generally, when compared to the other two monitoring locations, the DMC sites had the lowest nitrite-nitrate concentrations throughout the monitoring period with mean values of 0.93 mg/L and 0.88 mg/L. A minimum of 0.31 mg/L was recorded on April 15th at the Downstream of DMC Barrier site.

Organic nitrogen concentrations showed no distinct patterns during the monitoring period. The minimum organic nitrogen concentration in the Old River was 0.20 mg/L reported on April 29th, June 11th, and October 28th at Head, and the maximum was 1.80 mg/L reported on September 30th at Tracy Road. Old River at Head had the lowest organic nitrogen concentrations during the sampling period with a mean of 0.69 mg/L, while Tracy Road had the highest concentrations with a mean of 1.13 mg/L. Mean organic nitrogen concentrations at the Upstream and Downstream of DMC barrier sites were 0.86 mg/L and 0.78 mg/L, respectively.

Orthophosphate values at all sites ranged from 0.01 - 0.24 mg/L and were consistently lower at the Head site from mid spring through mid summer. Orthophosphate concentrations at the other sites seemed to be elevated during the summer reaching a peak value of 0.24 mg/L on August 5th, at the Upstream of DMC Barrier site. Overall, the highest mean was 0.13 mg/L at the Tracy Road site and the lowest was 0.10 mg/L at the Head site.

Overall, there were not any notable differences in the water quality constituents at the sites immediately upstream and downstream of the DMC barrier; however, water quality constituents did vary considerably upstream at the Tracy Road and Head sites. Specific conductance, turbidity, and organic nitrogen concentrations tended to be higher at the Tracy Road site in comparison to the downstream sites near the DMC barrier and the upstream site, Old River at Head. Relative to the other three Old River monitoring sites, the Old River at Head site had higher dissolved oxygen concentrations and lower turbidity values. Both the Old River at Head and Tracy Road sites had greater chlorophyll *a* / pheophytin *a* and nitrite-nitrate concentrations relative to the sites just upstream and downstream of the DMC barrier.

Grant Line Canal Barrier

The Grant Line Canal barrier was constructed on June 10th, 2003 and removed on November 10th, 2003. Monitoring of Grant Line Canal consisted of three sites: 1) in Doughty Cut immediately upstream of Grant Line Canal (site 7, 2) immediately upstream of the barrier (site 8 and 3) Tracy Road bridge over Grant Line Canal (site 9). Figure 8-4 and Tables 8-9 through 8-11 show the weekly water quality field and lab data for Grant Line Canal.

Figure 8-4 Grant Line Canal – Weekly Water Quality Data

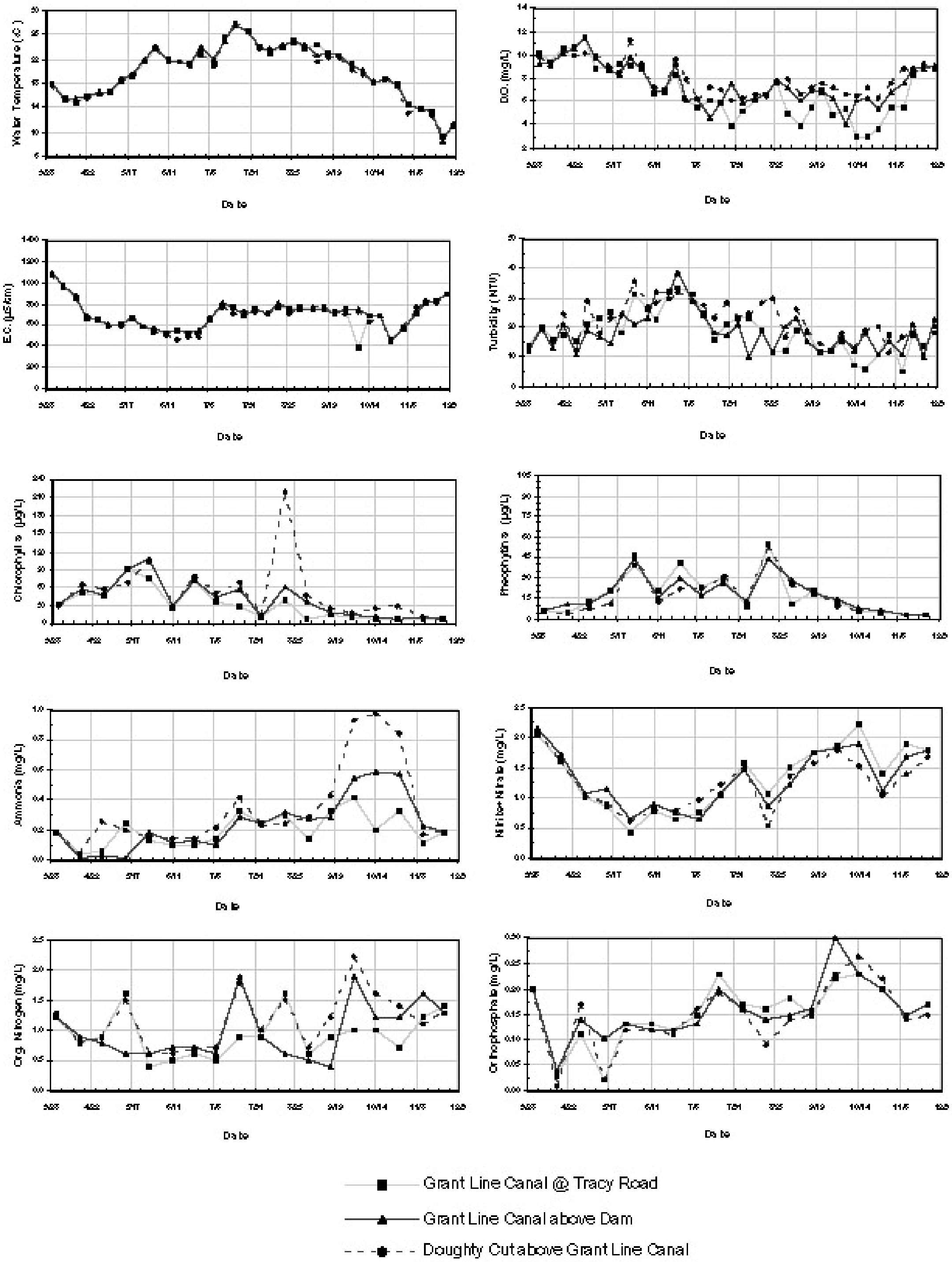


Table 8-9 Grant Line Canal at Tracy Road: 2003 Water Quality Data

	FIELD READINGS					BRYTE LAB RESULTS						
Date & Time (mm/dd/yy PST)	**Temp (°C)**	**DO (mg/L)**	**EC (µS/cm)**	**Turb (NTU)**	**Gage Height (ft)**	**NH_3-N (mg/L)**	**NO_2+ NO_3-N (mg/L)**	**ORG-N (mg/L)**	**PO_4 (mg/L)**	**Turb (NTU)**	**CHL-A (µg/L)**	**PHEO-A (µg/L)**
4/1/03 7:30	18.0	10.2	1071		4.35	0.18	2.04	1.2	0.20	14.0	33.70	6.59
4/8/03 6:25	15.7	9.4	981	20.0	4.32							
4/15/03 6:09	14.7	10.4	861		5.60	0.04	1.60	0.8	0.03	16.0	50.10	4.45
4/22/03 5:45	15.9	10.6	672	17.6	4.48							
4/29/03 6:15	16.4	11.4	654		6.08	0.06	0.99	0.9	0.11	15.0	46.30	12.50
5/6/03 5:45	16.7	8.8	596	20.9	5.60							
5/13/03 5:33	18.5	8.9	609		5.75	0.24	0.84	1.6	0.02	23.0	90.80	20.80
5/20/03 6:10	18.9	9.2	671	25.5	5.35							
5/27/03 6:05	21.6	9.0	589		5.65	0.13	0.42	0.4	0.13	18.0	77.00	39.00
6/3/03 5:35	23.8	9.1	557	30.8	5.78							
6/11/03 6:00	21.9	6.6	528		5.00	0.10	0.80	0.5	0.13	26.0	26.10	19.90
6/17/03 5:50	21.5	6.9	541	22.2	4.90							
6/24/03 6:30	21.1	8.2	525		3.85	0.10	0.65	0.6	0.12	32.0	72.40	40.60
6/30/03 6:00	23.2	6.3	528	33.2	6.60							
7/8/03 5:15	21.2	5.6	648		3.58	0.14	0.74	0.5	0.15	31.0	36.70	23.00
7/15/03 6:00	25.5	6.0	798	24.5	6.00							
7/22/03 5:30	27.4	5.9	765		4.70	0.33	1.04	0.9	0.23	16.0	29.10	29.80
7/29/03 6:10	26.5	3.8	691	21.3	6.15							
8/5/03 6:15	24.1	5.1	742		3.60	0.24	1.58	0.9	0.17	23.0	10.50	9.86
8/12/03 5:15	22.8	6.1	710	23.0	5.42							
8/19/03 5:16	23.9	6.6	775		3.60	0.30	1.07	1.6	0.16	19.0	40.50	54.80
8/26/03 5:25	24.9	7.5	751	11.8	6.10							
9/2/03 6:15	23.6	5.0	765		3.57	0.14	1.49	0.6	0.18	12.0	8.07	10.90
9/9/03 5:45	24.3	3.8	746	18.9	6.50							
9/16/03 5:00	22.8	5.5	767			0.33	1.74	0.9	0.15	18.0	13.80	21.00
9/23/03 5:15	22.6	7.0	703	11.4								
9/30/03 5:05	21.2	4.7	751			0.41	1.84	1.0	0.22	12.0	11.20	12.20
10/7/03 4:55	19.9	5.3	394	15.5								
10/14/03 5:30	18.1	3.0	681			0.20	2.23	1.0	0.23	7.0	5.46	5.84
10/21/03 5:20	18.8	3.0	688	6.0								
10/28/03 6:03	18.0	3.7	476			0.33	1.41	0.7	0.20	11.0	8.84	5.01
11/4/03 6:17	14.3	5.6	564	17.4								
11/12/03 7:10	13.7	5.6	714		3.20	0.12	1.90	1.2	0.15	5.0	7.91	3.26
11/18/03 6:30	13.4	8.3	820	17.4	3.43							
11/25/03 6:40	9.3	8.8	828		3.44	0.18	1.79	1.4	0.17	14.0	8.13	2.98
12/2/03 7:00	11.0	8.9	885	18.2								

(shaded) = Grant Line Canal barrier in place from 6/10/03 - 11/10/03.

Table 8-9 Grant Line Canal at Tracy Road: 2003 Water Quality Data (continued)

Date & Time (mm/dd/yy PST)	Temp (°C)	DO (mg/L)	EC (µS/cm)	Turb (NTU)	Gage Height (ft)	NH_3-N (mg/L)	NO_2+ NO_3-N (mg/L)	ORG-N (mg/L)	PO_4 (mg/L)	Turb (NTU)	CHL-A (µg/L)	PHEO-A (µg/L)
Maximum	27.40	11.40	1,071.00	33.20	6.60	0.41	2.23	1.60	0.23	32.00	90.80	54.80
Minimum	9.30	3.00	394.00	6.02	3.20	0.04	0.42	0.40	0.02	5.00	5.46	2.98
Mean	19.87	6.94	695.69	19.76	4.91	0.20	1.34	0.93	0.15	17.33	32.03	17.92
Range	18.10	8.40	677.00	27.18	3.40	0.37	1.81	1.20	0.21	27.00	85.34	51.82
Standard Deviation	4.44	2.28	139.46	6.59	1.08	0.11	0.54	0.36	0.06	7.40	26.54	14.84
Sample Variance	19.68	5.18	19,448.56	43.37	1.18	0.01	0.29	0.13	0.00	54.82	704.52	220.26
Standard Error	4.42	2.09	136.99	6.65	0.91	0.09	0.53	0.34	0.06	6.98	22.91	12.72
Median	21.15	6.60	697.00	19.45	5.00	0.18	1.45	0.90	0.16	16.00	27.60	12.35
Mode	18.00	5.60	528.00	17.40	5.60	0.33	#N/A	0.90	0.15	14.00	#N/A	#N/A
Count	36	36	36	18	27	18	18	18	18	18	18	18
Confidence Interval (95%)*	1.45	0.74	45.56	3.04	0.41	0.05	0.25	0.17	0.03	3.42	12.26	6.86

* Mean (µ) for Temperature = 19.87; 95% Confidence interval is 19.87 ± 1.45 or 18.42 ≤ µ ≤ 21.32. This means the interval between 18.42 and 21.32 has a .95 probability of containing µ.

Table 8-10 Grant Line Canal Above Barrier: 2003 Water Quality Data

	FIELD READINGS					BRYTE LAB RESULTS						
Date & Time (mm/dd/yy PST)	Temp (°C)	DO (mg/L)	EC (µS/cm)	Turb (NTU)	Gage Height (ft)	NH_3-N (mg/L)	NO_2+ NO_3-N (mg/L)	ORG-N (mg/L)	PO_4 (mg/L)	Turb (NTU)	CHL-A (µg/L)	PHEO-A (µg/L)
4/1/03 7:50	18.0	9.2	1089		4.30	0.18	2.14	1.2	0.20	12.0	33.90	6.87
4/8/03 5:45	15.3	9.2	973	19.3	4.25							
4/15/03 6:25	15.4	10.2	868		5.60	0.01	1.70	0.9	0.04	13.0	58.00	10.80
4/22/03 6:00	15.9	10.4	675	21.2	4.82							
4/29/03 6:30	16.7	11.4	651		6.10	0.03	1.08	0.8	0.14	11.0	46.40	10.30
5/6/03 6:00	16.7	9.8	602	19.2	5.60							
5/13/03 5:47	18.7	8.7	612		5.75	0.02	1.14	0.6	0.10	17.0	88.50	20.50
5/20/03 6:30	19.4	8.2	676	14.4	5.35							
5/27/03 6:20	21.8	9.8	595		5.67	0.18	0.65	0.6	0.13	25.0	107.00	44.30
6/3/03 5:55	24.1	8.9	577	21.3	5.78							
6/11/03 6:12	21.7	7.0	525		5.00	0.12	0.89	0.7	0.12	23.0	30.10	16.10
6/17/03 6:10	21.4	6.8	541	32.1	4.90							
6/24/03 7:00	21.2	9.2	525		3.85	0.13	0.76	0.7	0.12	32.0	70.80	30.40
6/30/03 6:15	23.9	6.0	539	38.2	6.60							
7/8/03 5:35	21.9	6.3	653		3.53	0.10	0.66	0.6	0.13	29.0	44.60	17.00
7/15/03 6:15	24.9	4.6	803	24.1	6.00							
7/22/03 6:04	27.5	5.9	776		4.70	0.29	1.06	1.9	0.20	18.0	58.30	26.80
7/29/03 6:30	26.4	7.6	685	17.7	6.15							
8/5/03 6:25	23.9	5.9	746		4.60	0.24	1.45	0.9	0.16	21.0	11.60	12.00
8/12/03 5:30	23.3	6.3	713	10.5	5.42							
8/19/03 5:38	24.2	6.7	810		3.60	0.32	0.84	0.6	0.14	19.0	60.20	43.70
8/26/03 5:40	24.8	7.8	747	11.7	6.00							
9/2/03 6:40	24.4	7.2	747		3.35	0.27	1.22	0.5	0.15	20.0	35.70	27.60
9/9/03 5:50	22.5	6.0	750	22.9	6.50							
9/16/03 5:15	22.9	7.0	758			0.28	1.76	0.4	0.16	15.0	16.30	18.90
9/23/03 5:02	22.5	6.8	710	11.3								
9/30/03 5:30	21.0	6.2	753			0.54	1.82	1.9	0.30	12.0	12.80	13.70
10/7/03 5:10	20.1	4.1	741	16.7								
10/14/03 5:50	18.1	6.1	686			0.58	1.91	1.2	0.23	12.0	10.00	7.47
10/21/03 5:35	18.6	6.2	683	17.9								
10/28/03 6:20	17.7	5.3	442			0.57	1.12	1.2	0.20	11.0	8.88	5.64
11/4/03 6:30	14.5	6.8	560	15.1								
11/12/03 7:30	13.8	7.6	712			0.23	1.67	1.6	0.15	11.0	9.04	3.37
11/18/03 6:45	13.4	8.9	820	21.2	3.38							
11/25/03 7:05	8.4	8.9	839		3.40	0.19	1.79	1.3	0.17	10.0	7.75	3.32
12/2/03 7:12	11.2	9.1	891	22.3								

[shaded box] = Grant Line Canal barrier in place from 6/10/03 - 11/10/03.

Table 8-10 Grant Line Canal Above Barrier: 2003 Water Quality Data (continued)

	Temp (°C)	DO (mg/L)	EC (µS/cm)	Turb (NTU)	Gage Height (ft)	NH_3-N (mg/L)	NO_2+ NO_3-N (mg/L)	ORG-N (mg/L)	PO_4 (mg/L)	Turb (NTU)	CHL-A (µg/L)	PHEO-A (µg/L)
Maximum	27.50	11.40	1,089.00	38.20	6.60	0.58	2.14	1.90	0.30	32.00	107.00	44.30
Minimum	8.40	4.10	442.00	10.50	3.35	0.01	0.65	0.40	0.04	10.00	7.75	3.32
Mean	19.89	7.56	707.58	19.84	5.01	0.24	1.31	0.98	0.16	17.28	39.44	17.71
Range	19.10	7.30	647.00	27.70	3.25	0.57	1.49	1.50	0.26	22.00	99.25	40.98
Standard Deviation	4.46	1.74	132.73	6.96	1.03	0.18	0.47	0.46	0.06	6.64	29.75	12.53
Sample Variance	19.92	3.02	17,618.02	48.48	1.07	0.03	0.22	0.22	0.00	44.09	884.83	156.96
Standard Error	4.43	1.55	133.19	6.90	0.95	0.09	0.46	0.43	0.04	6.35	26.00	8.67
Median	21.10	7.10	711.00	19.25	5.18	0.21	1.18	0.85	0.15	16.00	34.80	14.90
Mode	16.70	9.20	525.00	21.20	5.60	0.18	#N/A	0.60	0.20	12.00	#N/A	#N/A
Count	36	36	36	18	26	18	18	18	18	18	18	18
Confidence Interval (95%)*	1.46	0.57	43.36	3.22	0.40	0.08	0.22	0.21	0.03	3.07	13.74	5.79

* Mean (µ) for Temperature = 19.89; 95% Confidence interval is 19.89 ± 1.46 or 18.43 ≤ µ ≤ 21.35. This means the interval between 18.43 and 21.35 has a .95 probability of containing µ.

Table 8-11 Doughty Cut Above Grant Line Canal: 2003 Water Quality Data

	FIELD READINGS					BRYTE LAB RESULTS						
Date & Time (mm/dd/yy PST)	**Temp (°C)**	**DO (mg/L)**	**EC (µS/cm)**	**Turb (NTU)**	**Gage Height (ft)**	**NH_3-N (mg/L)**	**NO_2+ NO_3-N (mg/L)**	**ORG-N (mg/L)**	**PO_4 (mg/L)**	**Turb (NTU)**	**CHL-A (µg/L)**	**PHEO-A (µg/L)**
4/1/03 8:05	17.6	9.8	1070		4.25	0.18	2.12	1.3	0.20	12.0	29.20	6.82
4/8/03 6:25	15.1	9.0	957	19.9	4.19							
4/15/03 6:44	15.3	10.4	855		5.55	0.04	1.60	0.8	0.01	15.0	65.10	5.02
4/22/03 6:25	15.5	10.0	696	24.3	4.60							
4/29/03 7:00	16.4	10.1	646		5.80	0.26	1.02	0.9	0.17	12.0	57.00	8.01
5/6/03 6:25	16.5	10.0	608	29.2	5.55							
5/13/03 6:15	18.5	9.0	581		5.60	0.20	0.88	1.5	0.02	18.0	69.20	10.30
5/20/03 7:01	19.4	8.4	675	23.2	5.38							
5/27/03 6:45	21.7	11.2	598		5.36	0.16	0.61	0.6	0.12	24.0	104.00	46.70
6/3/03 5:15	23.8	9.2	521	35.4	5.50							
6/11/03 6:40	21.4	7.2	507		5.38	0.14	0.77	0.6	0.12	27.0	27.40	12.40
6/17/03 6:35	21.7	7.0	459	28.5	5.58							
6/24/03 7:30	20.9	9.6	496		5.20	0.14	0.79	0.7	0.11	30.0	78.80	22.30
6/30/03 6:40	22.7	8.0	486	31.7	6.26							
7/8/03 6:10	21.0	6.3	665		4.98	0.21	0.95	0.7	0.16	29.0	49.50	22.30
7/15/03 6:55	25.1	7.2	771	27.8	5.50							
7/22/03 6:31	27.8	6.9	715		5.10	0.42	1.23	1.8	0.19	23.0	66.50	31.50
7/29/03 6:50	26.6	6.0	721	28.4	6.28							
8/5/03 6:55	23.8	6.2	727		5.10	0.23	1.51	1.0	0.16	23.0	13.70	12.60
8/12/03 5:55	23.5	6.6	720	24.3	6.42							
8/19/03 6:10	23.9	6.4	791		4.90	0.24	0.55	1.5	0.09	28.0	217.00	53.00
8/26/03 6:16	24.9	7.8	719	29.6	6.93							
9/2/03 7:20	24.2	7.9	750		4.85	0.29	1.36	0.7	0.14	17.0	47.60	24.90
9/9/03 6:20	21.6	6.7	769	25.9	5.50							
9/16/03 5:40	22.1	7.1	761		5.00	0.43	1.58	1.2	0.15	19.0	25.10	20.10
9/23/03 5:45	22.2	7.5	733	14.6	4.80							
9/30/03 6:10	20.1	7.2	713		4.30	0.93	1.79	2.2	0.23	12.0	18.60	9.88
10/7/03 5:45	19.3	6.7	738	18.2	4.95							
10/14/03 6:40	18.3	6.5	638		4.50	0.97	1.54	1.6	0.26	13.0	26.30	6.29
10/21/03 6:05	18.6	7.2	680	19.0	4.82							
10/28/03 7:10	17.6	6.2	447		4.80	0.84	1.04	1.4	0.22	20.0	29.30	6.07
11/4/03 7:00	13.1	7.5	594	11.6	5.00							
11/12/03 7:50	13.6	8.9	778		3.72	0.17	1.38	1.1	0.14	17.0	10.00	3.39
11/18/03 7:13	12.7	8.4	830	18.4	2.55							
11/25/03 7:45	9.2	9.2	808		3.45	0.19	1.67	1.3	0.15	11.0	7.75	2.38
12/2/03 7:35	11.0	8.9	892	20.1	3.08							

(shaded) = Grant Line Canal barrier in place from 6/10/03 - 11/10/03.

Table 8-11 Doughty Cut Above Grant Line Canal: 2003 Water Quality Data (continued)

	Temp (°C)	DO (mg/L)	EC (µS/cm)	Turb (NTU)	Gage Height (ft)	NH_3-N (mg/L)	NO_2+ NO_3-N (mg/L)	ORG-N (mg/L)	PO_4 (mg/L)	Turb (NTU)	CHL-A (µg/L)	PHEO-A (µg/L)
Maximum	27.80	11.20	1,070.00	35.40	6.93	0.97	2.12	2.20	0.26	30.00	217.00	53.00
Minimum	9.20	6.00	447.00	11.60	2.55	0.04	0.55	0.60	0.01	11.00	7.75	2.38
Mean	19.63	8.01	697.64	23.89	5.02	0.34	1.24	1.16	0.15	19.44	52.34	16.89
Range	18.60	5.20	623.00	23.80	4.38	0.93	1.57	1.60	0.25	19.00	209.25	50.62
Standard Deviation	4.48	1.42	137.27	6.28	0.90	0.28	0.44	0.45	0.06	6.38	48.93	14.58
Sample Variance	20.08	2.02	18,843.72	39.42	0.80	0.08	0.19	0.21	0.00	40.73	2,394.26	212.56
Standard Error	4.44	1.27	138.00	5.78	0.93	0.28	0.44	0.43	0.06	6.32	44.04	8.71
Median	20.50	7.65	717.00	24.30	5.05	0.22	1.30	1.15	0.15	18.50	38.45	11.35
Mode	17.60	7.20	#N/A	24.30	5.50	0.14	#N/A	0.70	0.12	12.00	#N/A	22.30
Count	36	36	36	18	36	18	18	18	18	18	18	18
Confidence Interval (95%)*	1.46	0.46	44.84	2.90	0.29	0.13	0.20	0.21	0.03	2.95	22.60	6.74

* Mean (µ) for Temperature = 19.63; 95% Confidence interval is 19.63 ± 1.46 or 18.17 ≤ µ ≤ 21.09. This means the interval between 18.17 and 21.09 has a .95 probability of containing µ.

There were no notable water temperature differences between the GLC sites**.** A maximum temperature of 27.8 °C was recorded at Doughty Cut on July 22nd and a minimum temperature of 8.4 °C was recorded at GLC Above Barrier on November 25th. Mean water temperatures ranged from 19.63 to 19.89 °C at the three monitoring stations. Similar to the Middle River and Old River water temperatures in GLC tended to follow seasonal patterns.

Dissolved oxygen levels tended to be lower in the summer through mid fall, especially at the GLC at Tracy Road site, and higher in spring and late fall. DO concentrations at Doughty Cut were slightly higher than at GLC Above Barrier and noticeably higher than at Tracy Road averaging 7.99 mg/L and reaching a maximum of 11.20 mg/L on May 27th. DO at GLC Above Barrier was slightly lower than at Doughty Cut with an average of 7.56 mg/L and a maximum of 11.40 mg/L was recorded on April 29th. Two field readings collected at the aforementioned site were below 5 mg/L. GLC at Tracy Road had lower DO concentrations than the other two sites with an average of 6.99 mg/L. The maximum recorded DO at Tracy Road was 11.40 mg/L on April 29th. Five field readings collected at Tracy Road were below 5 mg/L. The minimum DO value for GLC was 3.00 mg/L recorded on October 14th and 21st at Tracy Road. DO concentrations at Tracy Road tended to be lowest in the early and mid fall while the barrier was operational.

Generally, specific conductance values decreased from April 1st- June 30th, remained relatively constant in the summer and early fall before rising in mid to late fall. Specific conductance readings were similar at all three GLC stations. Data at the three GLC stations, on average, showed little variation with mean values ranging from 698 µS/cm at Doughty Cut to 708 µS/cm at GLC Above Barrier. The three GLC stations recorded their maximum specific electrical conductivity value on April 1st before barrier installation. Overall, values ranged from a low of 394 µS/cm at the Tracy Road site to a high of 1089 µS/cm at the GLC Above Barrier site.

Turbidity readings were highest from late May through early July and then decreased gradually for the remainder of the monitoring period. Turbidity values varied slightly between sites with values for all three monitoring stations averaging about 19.5 NTU. The GLC Above Barrier had a maximum reading of 38.2 NTU on June 30th and Tracy Road had a minimum reading of 5.0 NTU on November 12th.

Chlorophyll *a* concentrations followed the same general trend at the three GLC sites, except on August 19th, when a maximum value of 217.0 µg/L was recorded at Doughty Cut. Algal biomass was highest at the three GLC stations from April 1st through late August. Mean chlorophyll *a* concentrations ranged from a high of 52.3 µg/L at Doughty Cut to a low of 32.0 µg/L at Tracy Road. Trends in pheophytin *a* concentrations were similar to those seen in chlorophyll *a* concentrations for the three monitoring stations. The maximum pheophytin *a* value in GLC was 54.8 µg/L reported on August 19th at Tracy Road and the minimum was 2.38µg/L reported on November 25th, at Doughty Cut.

Ammonia concentrations at all three stations reached a minimum on April 15th, and then tended to increase until October 14th. Ammonia concentrations ranged from 0.01 - 0.97 mg/L and were higher in Doughty Cut. The mean ammonia concentration at Doughty Cut was 0.34 mg/L. Concentrations of ammonia upstream and downstream of the GLC Barrier did not vary appreciably with mean values of 0.24 mg/L and 0.20 mg/L, respectively. Overall, ammonia concentrations were highest in early to mid fall.

Nitrite-nitrate values ranged from 0.42 - 2.23 mg/L with the lowest concentrations recorded in late spring through early summer and the highest concentrations recorded in late summer through fall. Mean values ranged from 1.24 mg/L at Doughty Cut to 1.34 mg/L at Tracy Road. Nitrite-nitrate concentrations at all three GLC sites tracked closely and there was not much variation between sites.

Organic nitrogen values ranged from 0.40 – 2.20 mg/L and were higher during late summer and early fall at Doughty Cut. The mean organic nitrogen concentration at Doughty Cut was 1.16 mg/L. There were only very minor differences in organic nitrogen concentrations at the sites in the immediate vicinity of the barrier. The GLC Above Barrier and Tracy Road sites had means of 0.98 mg/L and 0.93 mg/L, respectively. Overall, organic nitrogen concentrations were higher in fall.

Orthophosphate values were similar at all three stations. Values tended to increase during the summer through early fall. GLC orthophosphate concentrations ranged from 0.01 - 0.30 mg/L. Mean values ranged from 0.15 mg/L at Doughty Cut and Tracy Road to 0.16 mg/L at GLC Above Barrier.

Generally, water quality constituents measured at the three GLC sites tracked closely with each other and did not show any notable differences; however, there were a few exceptions. DO concentrations downstream of the barrier at Tracy Road tended to be low in the early and mid fall relative to the upstream sites. Also, at Doughty Cut ammonia concentrations were elevated relative to the sites near the barrier from early to mid fall.

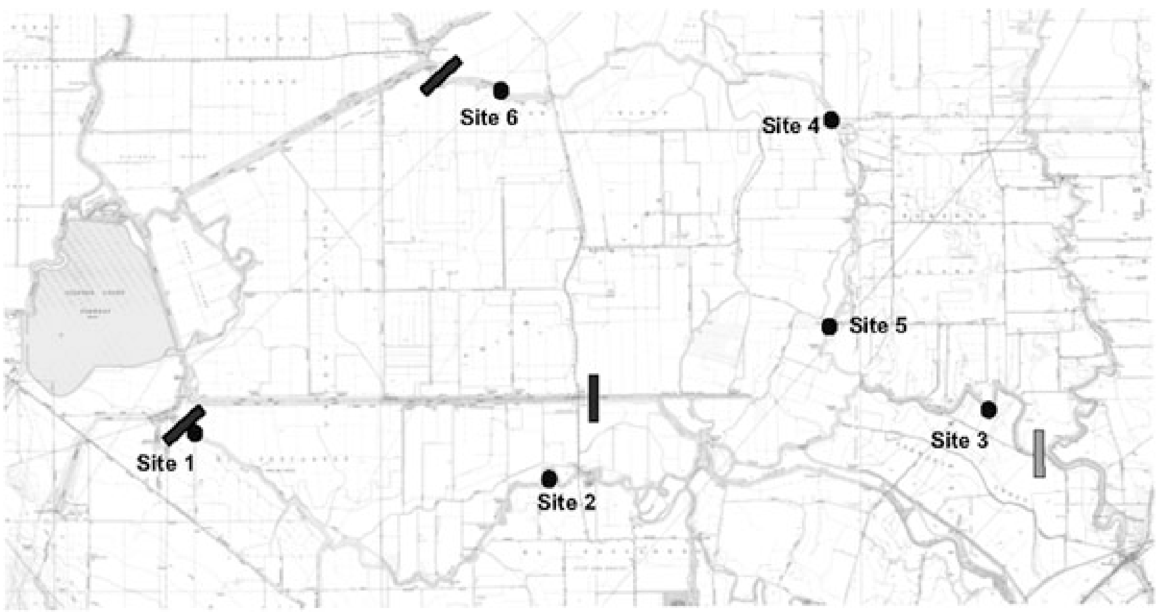
Continuous Water Quality Monitoring

Continuous monitoring to evaluate water quality impacts of barrier installations and operations in the South Delta was continued in 2003. This program was established for two reasons: first to determine the feasibility of collecting reliable time-series water quality data as opposed to weekly grab sampling data and second, to develop a dynamic understanding of water quality conditions affected by barrier installations, barrier operations, reservoir releases, Forebay gate operations, SWP and CVP pumping operations, agricultural pumping and drainage, municipal effluent loading, hydrology, tidal fluctuations, Delta inflows as well as other variables. Continuous monitoring is capable of providing more information to identify variations and trends in water quality constituents over time; as more than 2900 data points (15-minute sampling frequency) can be gathered over a period of a month versus four or five data points from weekly grab sampling. Such a wealth of data can assist in making more informed decisions in the South Delta. There are six permanent continuous monitoring stations that record water temperature, dissolved oxygen, pH, specific conductance, and turbidity data year around.

Sites

Three monitoring sites are located on the Old River: one on a pump platform just upstream of the barrier near the Delta Mendota Canal (DMC), one on a private boat dock at the Tracy Wildlife Association (TWA), and one on a pump-platform approximately two miles downstream of Old River at Head. Three monitoring sites are located on the Middle River: one on a pump platform in the Middle River just upstream of the Howard Road Bridge crossing, one on a pump platform in the Middle River just upstream of the Undine Road Bridge crossing, and one on a pump platform about _ mile downstream the of Tracy Road Bridge crossing. See Figure 8-5 for site locations. Station coordinates are shown in Table 8-12.

Figure 8-5 Map of South Delta Continuous Water Quality Monitoring Sites



SITE	LOCATION
1.	Old River near Delta Mendota Canal
2.	Old River at Tracy Wildlife Association
3.	Old River near Head
4.	Middle River at Howard Road
5.	Middle River at Undine Road
6.	Middle River near Tracy Road

Table 8-12 Continuous Monitoring Station Coordinates

Continuous Monitoring Station	Latitude (N)	Longitude (W)	Date Established
Middle River at Undine Road	37º 50' 02.4"	121º 23' 08.6"	2002
Middle River at Howard Road	37º 52' 34.5"	121º 23' 00.1"	1999
Middle River near Tracy Road	37º 52' 52.8"	121º 28' 02.7"	2003
Old River near Head	37º 49' 09.5"	121º 21' 37.2"	2001
Old River at Tracy Wildlife Association	37º 48' 10.2"	121º 27' 26.8"	1999
Old River upstream of Delta Mendota Canal Barrier	37º 48' 37.0"	121º 32' 32.0"	2000

Instrumentation

Yellow Springs Instruments 6600 “sondes” (continuous multi-parameter water quality monitoring instruments) were operated during the year to gather data at six sites in the South Delta. YSI 6600 sondes are approximately two feet long and three and half inches in diameter. They are completely submersible and self-contained, operating on a minimum of 9 volts of battery power from 8 C-cell alkaline batteries. They are capable of measuring up to 15 water quality parameters including water temperature, dissolved oxygen, pH, specific conductance, turbidity, chlorophyll, depth, open-channel flow, nitrate, ammonium/ammonia, oxidation/reduction potential, chloride, salinity, total dissolved solids, and electrical conductivity. Deployment data are logged in each sonde’s internal memory. Sondes are capable of sampling at many different user-specified frequencies. During 2000, an hourly sampling frequency was used for all stations, approximately 732 samples per month. In 2001, the sampling frequency was changed to every fifteen minutes, approximately 2920 samples per month.

The constituents measured at the six South Delta continuous monitoring sites were water temperature, dissolved oxygen, pH, specific conductance, and turbidity. As in 2000-02, continuous monitoring in 2003 proved to be a good test of the YSI 6600 sondes for time-series data collection within the Delta. Weekly field data gathered from each site confirmed the accuracy, reliability, and longevity of the instruments for Delta waterway’s use. In 2003, a discrete monitoring component was added at the six South Delta sites. Similar to the weekly water quality sampling the constituents tested for were dissolved ammonia, dissolved nitrite + nitrate, dissolved organic nitrogen, dissolved orthophosphate, chlorophyll *a*, and pheophytin *a*. All discrete samples were analyzed by Bryte Laboratory.

A sonde can be powered by a new set of batteries from one to three months, depending upon the number of parameters being monitored, the sampling frequency, and the water temperature. However, during the summer months biological growth can foul certain probes within a week, the dissolved oxygen probe being the most susceptible to fouling. Thus, a sonde’s deployment period can be limited either by operational style and/or ambient conditions within the water-body under study. In 2003, Central District staff shipped eight 6600 sondes back to YSI for an upgrade to the new 6600 EDS (Extended Deployment System) model. The upgrade included a wiper that wipes the dissolved oxygen, pH and conductivity sensors, which reduced the amount of biological fouling on the probes. This further ensured the collection of accurate and precise data. For this project, a three-week deployment period was used year-round as our standard for monitoring stations in the South Delta. It is important to note however, that monitoring sites were visited weekly by Central District staff for routine maintenance and field verification of instrument operation. Field equipment used included a YSI-63 handheld unit that measured water temperature, pH, and specific conductance, a HACH modified Winkler titration kit to check dissolved oxygen concentrations, and a HACH 2100P turbidimeter.

Sonde data can be downloaded in the field either by laptop computer or with a YSI-610 or YSI-650 interfacing hand-held unit. Usually though, each sonde was exchanged in the field with a fresh lab-calibrated instrument, then downloaded and post-deployed in the Central District lab. Post-deployments were performed to determine probe drift and biofouling errors by checking individual probe readings against calibration standards, which ultimately verified instrument accuracy. In general, probe drift has not posed a problem with these instruments.

Installations

At each monitoring site, a sonde is vertically housed within a 4" diameter PVC pipe, in the water column, suspended at a depth of approximately 3 feet. To discourage vandalism the pipes are covered at the top with an end-cap and locked shut with two Masterlocks through two 0.5"-diameter bolts. Installation pipes were drilled with 2.25" diameter holes along the length of the pipe and spaced approximately 8" – 10" on center. Four sets of holes were drilled longitudinally at 90º angles from each other. These holes allow ambient water to adequately contact the sonde sensors to ensure high quality data collection. At each site, the sonde installation pipe is either lag-bolted into an existing float structure (e.g. wooden boat dock) or steel-banded to a pump platform durable enough to withstand long-term usage.

Upon inspection of the 2000/2001 installations, a considerable amount of biological growth in the form of algae, bryophytes, and freshwater sponges had completely covered the solid-surface areas of the pipes and even managed to partially cover over some of the exchange-holes. It was recommended by YSI technicians that antifouling paint could dramatically decrease the amount of biological growth on the installation pipes, thereby reducing the possible formation of microcosms within the pipes that do not share the same water quality conditions as the surrounding ambient water. Visual inspections of the installation pipes in 2002-3 showed that antifouling paint has been an effective tool in decreasing biological growth.

Continuous Monitoring Data

Water year 2003 (October 1st, 2002 – September 30th, 2003) was classified as a below normal year for the San Joaquin Valley. Unimpaired runoff was 4.88 million acre-feet and runoff was greatest from April though July. For the Sacramento Valley water year 2003 was classified as an above normal year and unimpaired runoff totaled 19.18 million acre-feet. San Joaquin River flows past Vernalis were highest from April 15th – May 15th averaging 3,223 cfs. Figure 8-6 shows flow and specific conductance data for the San Joaquin River at Vernalis in 2003. Flows were lowest from July 1st - October 1st averaging about 1430 cfs. Total daily exports for the Central Valley Project (CVP) and State Water Project (SWP) averaged 10,642 cfs from January through September except in April and May when exports averaged 4336 cfs and 2342 cfs, respectively. Figure 8-7 depicts total daily exports (cfs) for the SWP and CVP. From October through December daily exports averaged 7,884 cfs.

The USEPA has established National Ambient Water Quality Criteria for inorganic constituents such as dissolved oxygen and pH to protect freshwater aquatic life. It must be stated that there is considerable variability in dissolved oxygen tolerances amongst fish and other aquatic life. For a warm water system like the Delta, dissolved oxygen criteria for early aquatic life stages (embryos, larvae, and less than 30-day old juveniles) was set at 5 mg/L and for other life stages (older juveniles and adults) the dissolved oxygen criterion is 3 mg/L. The recommended criterion for pH is an instantaneous maximum between 6.5 and 9.0. The agricultural water limit for specific conductance is 700 µS/cm. Discussion of dissolved oxygen, pH and specific conductance continuous water quality data for 2003 will focus on these criteria.

Figure 8-6 Flow and specific conductance in the San Joaquin River at Vernalis

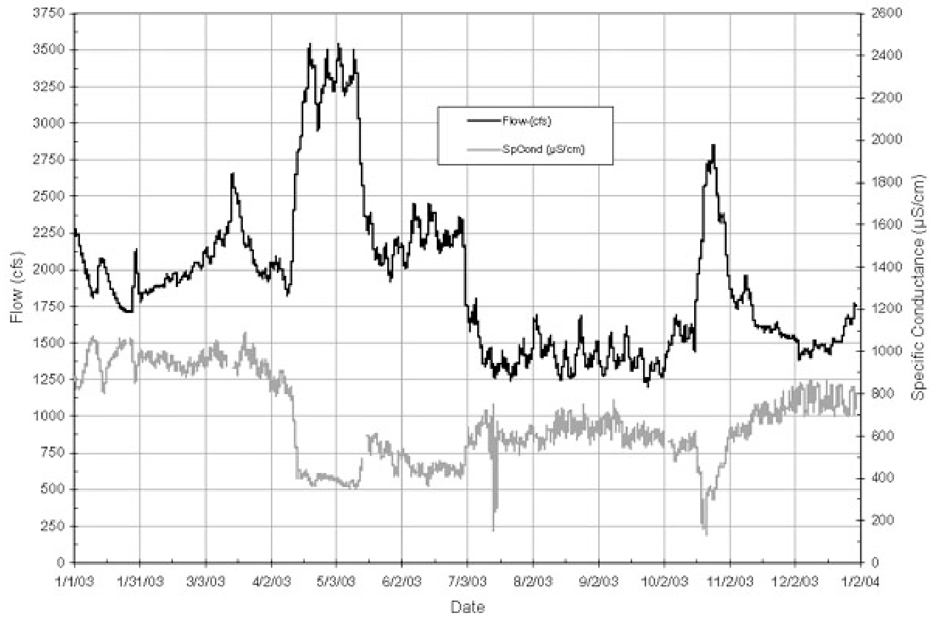
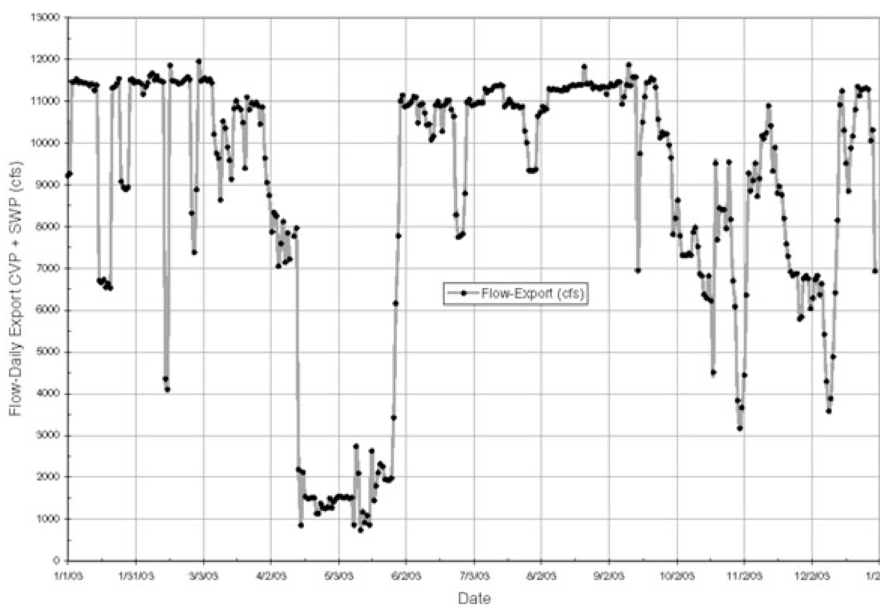


Figure 8-7 Total Daily Exports: State Water Project and Central Valley Project



Middle River at Undine Road

Water temperatures in the Middle River at Undine Road reached a maximum of 30.65 °C on July 22nd at 15:30 PST and a minimum of 6.80 °C on December 29th at 9:15 PST. See Figure 8-8. A visual comparison of the 2003 water temperature plots for each of the three Middle River monitoring sites reveals similar trends. This would seem reasonable as all three sites are located within 10 miles of each other and thus are subject to relatively similar meteorological conditions throughout the year. The finer perturbations of water temperatures at each site would hence be related to site-specific conditions. Temperature patterns at Undine Road followed seasonal trends, with the highest temperatures occurring in summer and the lowest in late fall and winter. The mean temperature for the monitoring period was 17.81 °C.

Dissolved oxygen data for the Middle River at Undine Road during 2003 are also plotted in Figure 8-8. DO concentrations reached a maximum of 19.91 mg/L on August 17th at 15:15 PST and were at a minimum of 2.46 mg/L on July 31st at 9:45 PST. There were 316 instances during late spring through late fall when the sonde(s) recorded DO concentrations less than 5 mg/L with six of those occurrences below 3 mg/L. There was one field reading (modified Winkler titration) that was less than the 5 mg/L water quality objective (4.7 mg/L recorded on August 1st at 8:45 PST). The lowest monthly mean DO was 8.35 mg/L in September and the highest was 11.00 mg/L in August. During the late spring through early fall, DO concentrations showed marked diel variation. In mid-fall through winter there was less pronounced diel variation in DO values, which may be to due to the fact there is less daily variation in water temperature and generally, lower chlorophyll *a* / pheophytin *a* levels (less algal biomass) during the colder months. The overall mean DO concentration for Undine Road was 9.90 mg/L.

During a typical summer day, DO concentrations reached a maximum in the late afternoon and a minimum during the early morning. Figure 8-9 portrays DO concentrations and water temperature for Undine Road from August 27th – August 29th. DO concentrations and water temperatures tended to be directly proportional (Figure 8-9) during periods of the late spring through early fall. Since oxygen solubility decreases as temperature increases it would be expected that DO concentrations would be inversely related; however, that was not the case in Figure 8-9. The diel variation in dissolved oxygen concentrations illustrated in Figure 8-9 is likely, in part due to algal photosynthesis and respiration. Dissolved oxygen concentrations were supersaturated throughout the mid-spring and summer when chlorophyll *a* levels ranged from 16.8 – 170 µg/L. Figure 8-10 shows discrete chlorophyll *a* and pheophytin *a* concentrations at the three Middle River sites for 2003. The maximum chlorophyll *a* value recorded at the Undine Road site was 170 µg/L on August 29th. Figure 8-11 depicts DO % saturation from August 27th – August 29th. The maximum DO % saturation was 252% on August 27th at 15:15 PST.

Figure 8-8 also depicts 2003 pH data in the Middle River at Undine Road. Recorded pH data ranged from a high of 9.59 on August 20th at 15:45 PST to a low of 7.30 on January 12th at 4:45 PST. No pH values greater than 9.0 were recorded after September 8th and the maximum field reading recorded was 9.22. Two field readings recorded pH values greater than 9. In 2003, pH at Undine Road averaged 8.00 and the highest monthly mean pH was 8.60 in June.

Figure 8-8 Middle River at Undine Road: Water temperature, dissolved oxygen and pH continuous water quality data

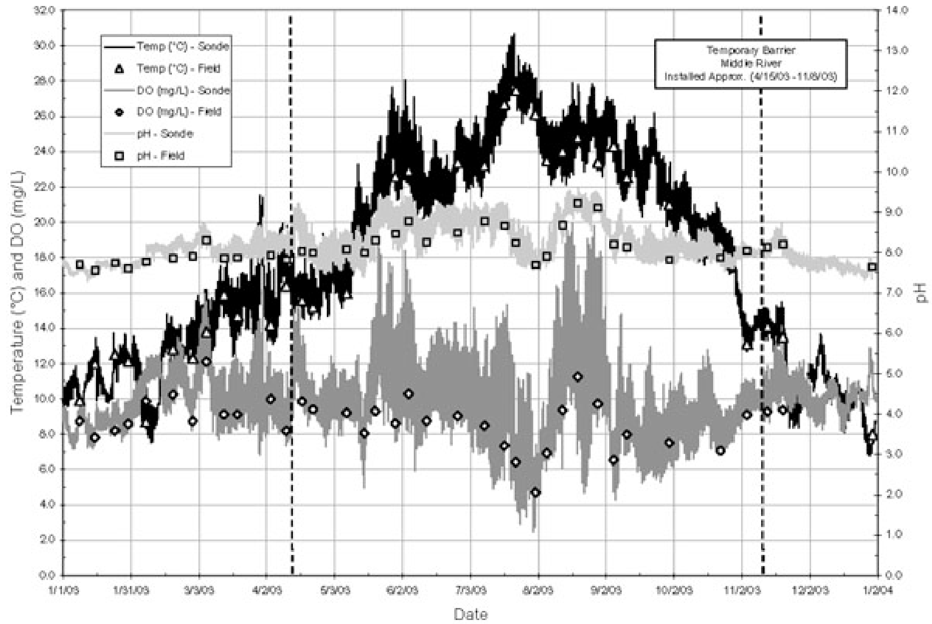


Figure 8-9 Dissolved oxygen and water temperature from August 27th-29th, 2003: Middle River at Undine Road

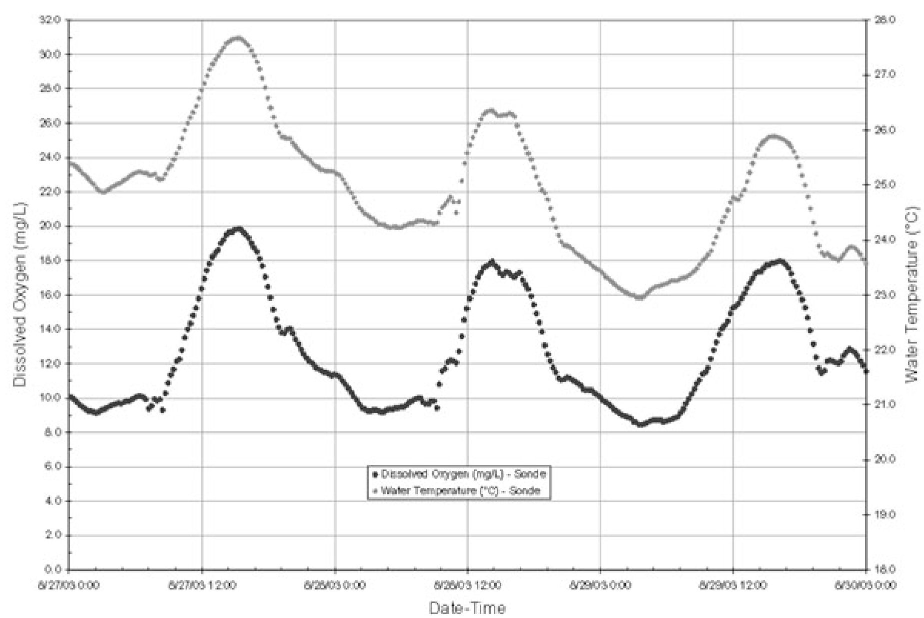
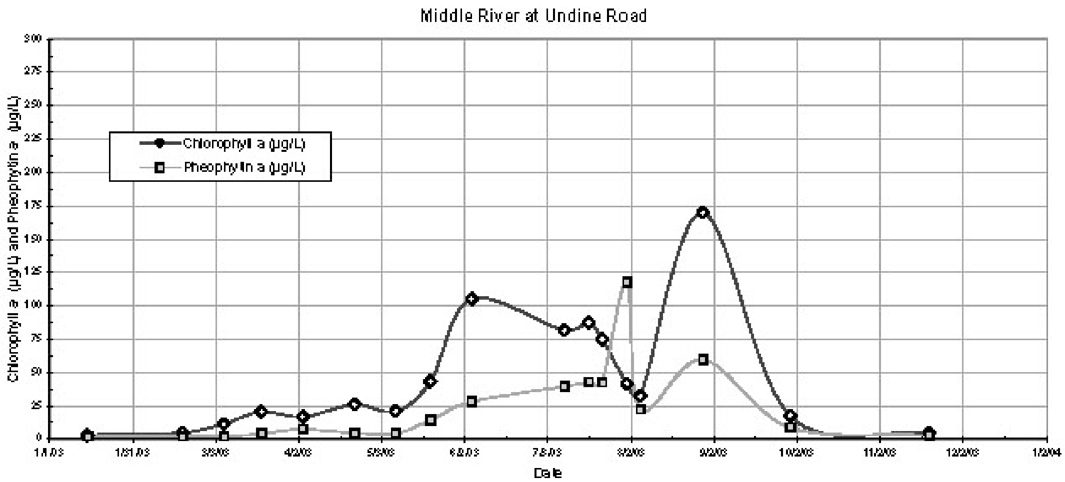
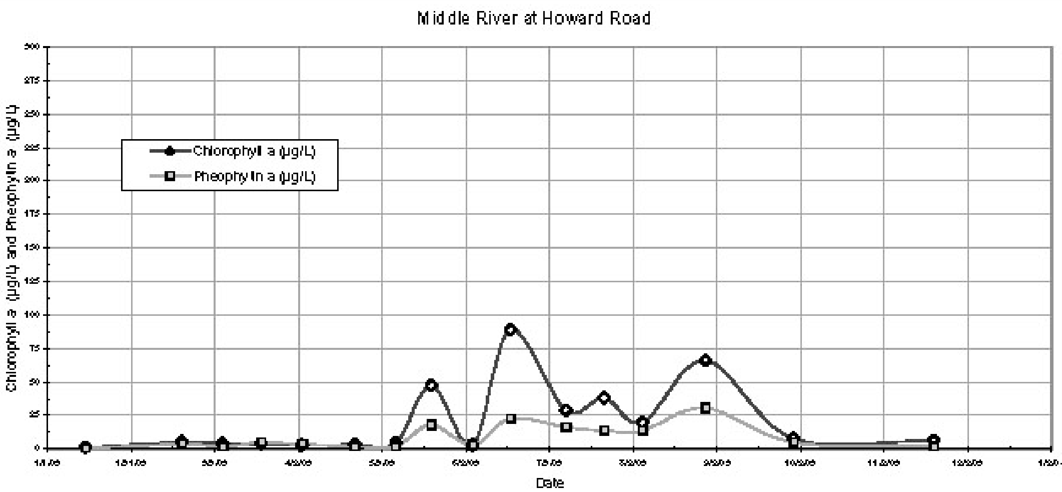


Figure 8-10 2003 Discrete Chlorophyll a and Pheophytin a data for the Middle River Monitoring Sites





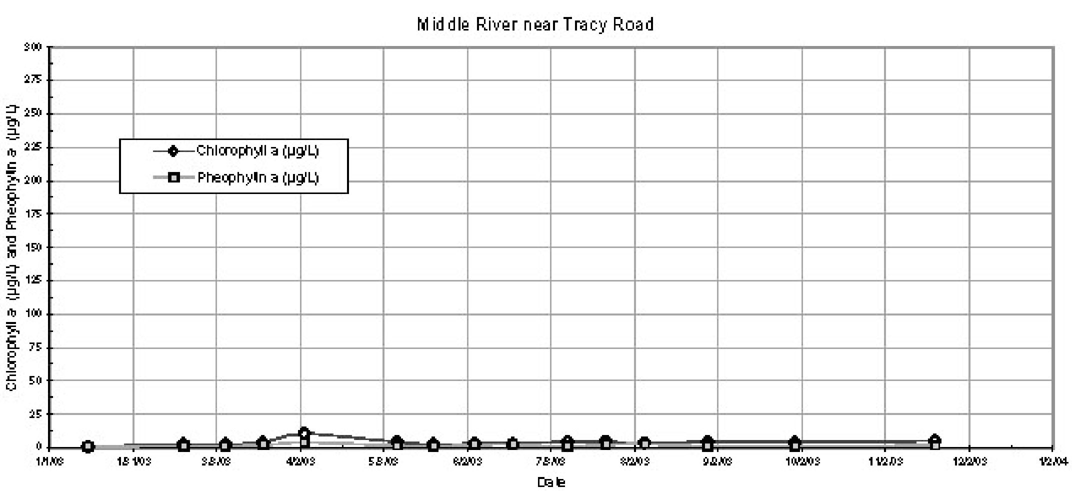


Figure 8-11 Dissolved Oxygen % Saturation from August 27th-29th, 2003: Middle River at Undine Road

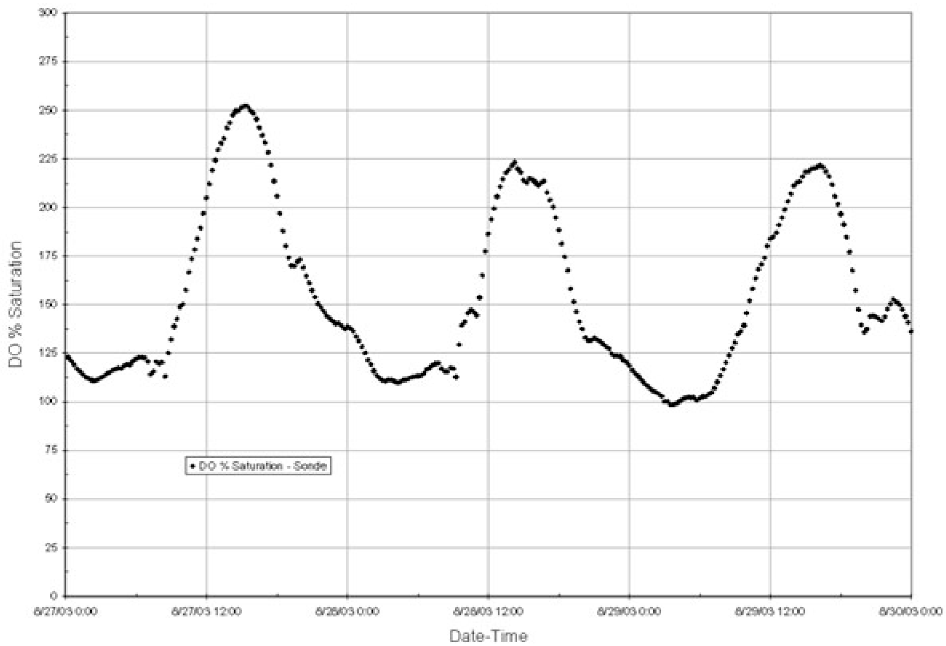
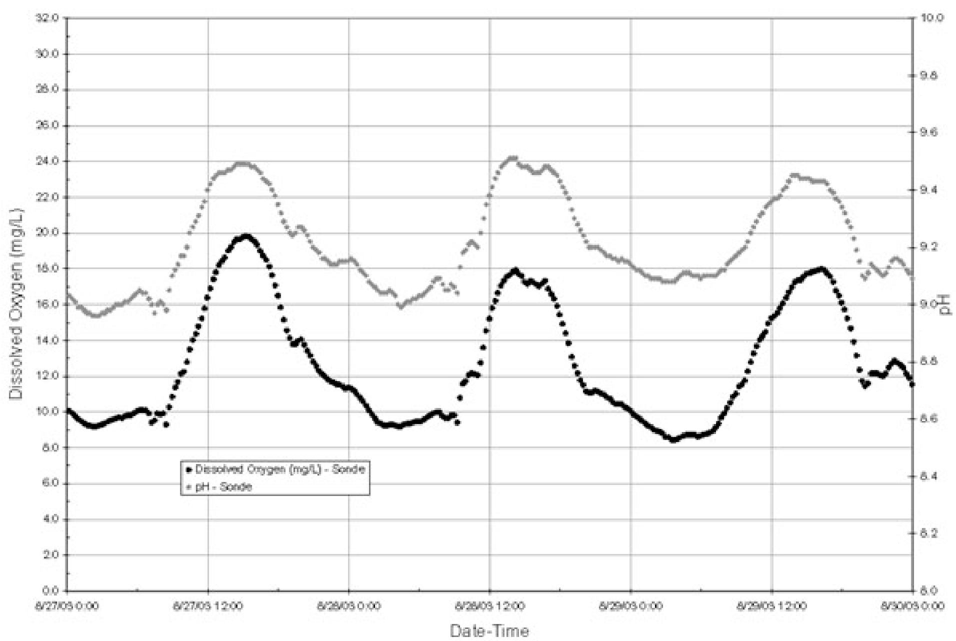


Figure 8-12 Dissolved oxygen and pH from August 27th-29th, 2003: Middle River at Undine Road



Similar to water temperature and dissolved oxygen data, pH data exhibited greater diel fluctuations during mid spring through early fall, and noticeably less during fall and winter. pH seemed to have a direct relationship with dissolved oxygen. Figure 8-12 shows a plot of dissolved oxygen and pH data for August 27th – August 29th. As DO concentrations increased, pH increased and vice versus. This is likely a direct function of algal productivity in that as algae consume CO_2 from water they produce dissolved oxygen as a byproduct of primary productivity. Less CO_2 in the water drives the pH higher, as the water becomes more alkaline. pH readings greater than 9.0 were only recorded from mid spring through late summer when water temperatures were warm and chlorophyll a levels high (Figure 8-10). From April 14th through September 8th there were 2,827 pH readings ≥ 9.0.

Specific conductance data for the Undine Road site is shown in Figure 8-13. A maximum of 2520.8 µS/cm was recorded on January 12th at 5:00 PST. The minimum-recorded specific conductance was 349.5 µS/cm on October 28th at 11:00 PST. The mean for the monitoring period was 839.9 µS/cm. Monthly mean values were the highest from January through March when the barriers were not installed. January had the highest specific conductance values with a mean of 1450.9 µS/cm. In April and May there was an increase in San Joaquin River flows past Vernalis and a decrease in SWP and CVP daily exports (Figures 8-6 and 8-7). Specific conductance decreased considerably during this period; from an average of 1247.5 µS/cm in March to 766.0 µS/cm and 572.0 µS/cm in April and May, respectively. Throughout the summer specific conductance values began to rise due in part to low San Joaquin River flows, CVP and SWP pumping, and agricultural pumping and return flows. While the barriers were operational the highest monthly mean was 725.3 µS/cm in September. In October there was an increase in San Joaquin River flows, a decrease in CVP and SWP pumping and decrease in specific conductance values. After the barriers were taken out in November specific conductance values began to rise for the remainder of the year.

Figure 8-13 also exhibits turbidity data at this site. Turbidities ranged from a high of 160.1 NTU on June 8th at 1:30 PST to a low of 2.8 NTU on February 2nd at 4:15 PST. Turbidity readings were highest from mid-spring until mid-summer and lowest from late fall through early spring. The lowest average turbidity was 9.2 NTU in February and the highest was 53.9 NTU in June. The overall mean for 2003 was 27.3 NTU.

Middle River at Howard Road

Measured water temperatures in the Middle River at Howard Road during 2003 are shown in Figure 14. Water temperature is predominantly influenced by and tends to follow the same diel pattern as air temperature. Water temperatures tended to rise steadily during the day, peak in the late afternoon/early evening and steadily fall during the night, reaching a minimum in the early morning. Other factors influencing water temperature include local meteorological conditions (i.e. wind speed, solar radiation), water volume, flow, shading from vegetative cover, etc. Water temperatures at Howard Road tended to follow seasonal patterns with the warmest temperatures recorded in the summer and the coolest in winter. Monthly mean water temperatures during the summer ranged from 23.39 °C in September to 26.21 °C in July. The maximum recorded water temperature was 30.74 °C at 16:30 PST on July 21st and the minimum was 7.21 °C on December 30th at 7:30 PST. During the late fall and early winter there was less diel variation in temperature in comparison to the summer, probably, because of shorter winter days and less air temperature variation.

Dissolved oxygen concentrations in the Middle River at Howard Road for 2003 are also plotted in Figure 8-14. DO concentrations reached a maximum of 18.12 mg/L on August 16th at 18:15 PST and were at a minimum of 0.07 mg/L on May 29th at 7:00 PST. There were 2620 instances during late spring through early fall when the sonde recorded DO concentrations less than 5 mg/L with 387 of those occurrences below 3 mg/L. Seven field readings (modified Winkler titration) collected during summer were less than 5 mg/L. No field readings were less than 3 mg/L. In general, field readings corresponded well with sonde readings. Since, on average, there is only one field reading for every 672 “continuous” readings, the sonde was able to record periods of low DO concentrations at this site that were not recorded during field visits. The lowest recorded field reading was 3.0 mg/L on May 30th at 9:00 PST.

Figure 8-13 Middle River at Undine Road: Specific conductance and turbidity continuous water quality data

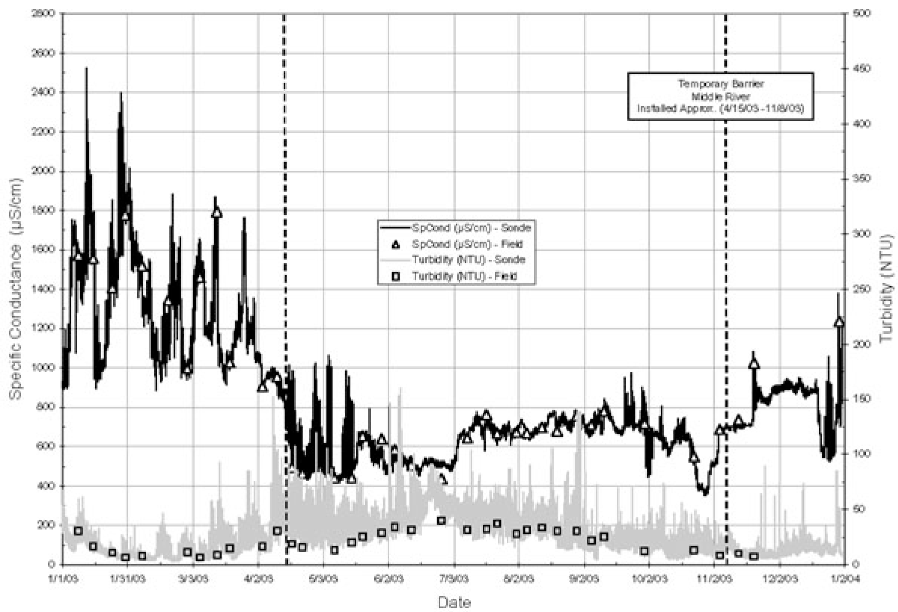
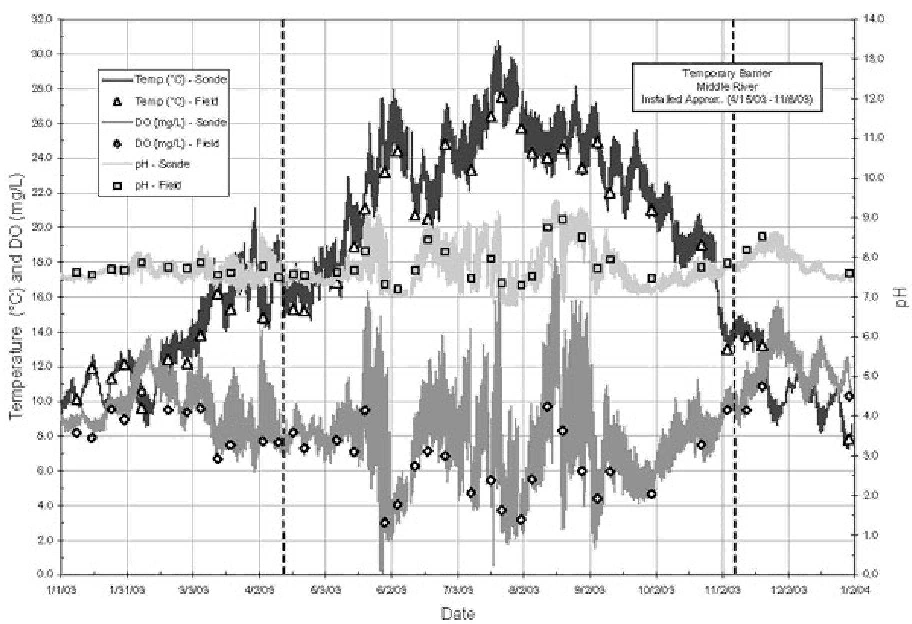


Figure 8-14 Middle River at Howard Road: Water temperature, dissolved oxygen and pH continuous water quality data



Typically, summer DO readings showed marked diel variation with the highest concentrations occurring in the late afternoon and lowest during the early morning when algal biomass as indicated by chlorophyll a concentrations was high. Refer back to Figure 8-10. The lowest monthly mean DO was 6.25 mg/L in September and the highest was 11.84 mg/L in December. The higher DO concentrations seen during mid-fall through winter can in part be attributed to increased oxygen solubility in cooler waters and higher San Joaquin River flows past Vernalis. DO concentrations in fall and winter also showed less diel variation, likely as an effect of less diel variation in water temperature and lower primary productivity. The overall mean DO concentration for Howard Road was 8.94 mg/L.

Figure 8-14 also depicts 2003 pH data in the Middle River at Howard Road. Recorded pH data ranged from a high of 9.43 on August 17th at 17:00 PST to a low of 6.77 on July 26th at 6:45 PST. No pH values greater than 9.0 were recorded after August 31st and the maximum field reading recorded was 8.96. From May 22nd through August 31st there were 534 pH readings ≥ 9.0. Similar to water temperature and dissolved oxygen data, continuous pH data revealed greater diel fluctuations during mid spring through summer, and noticeably less during the fall and winter. For 2003, pH at Howard Road averaged 7.57 and the highest monthly mean pH was 7.98 in November.

Figure 8-15 portrays measured specific conductance data for 2003 at the Howard Road site. A maximum of 1877.8 µS/cm was recorded on January 17th at 3:30 PST. The minimum-recorded specific conductance was 227.7 µS/cm on July 26th at 4:15 PST. The mean for the monitoring period was 690.8 µS/cm. Daily variation in specific conductance values, likely in part due to tidal influences and San Joaquin River flows, was most pronounced from January through the construction of the Middle River Barrier. In months when the temporary barrier was not in place monthly specific conductance values ranged from a minimum of 698.1 µS/cm in December to a maximum of 1235.7 µS/cm in January. While the barrier was operational monthly mean values ranged from a low of 490.5 µS/cm in June to a high of 686.7 µS/cm in August.

Figure 8-15 also depicts turbidity data at this site. Turbidities ranged from a high of 274.5 NTU on July 23rd at 2:00 PST to a low of 2.6 NTU on November 20th at 11:30 PST. Several times in 2003, turbidities exhibited pulse-peaks. Generally, single turbidity spikes can be attributed to a foreign object, such as a leaf or fish passing before the optic sensors as the instrument is taking a reading. These anomalies are usually omitted. However, there are moments during the year where several continuous readings reveal a peaking-trend. The largest of these incidences occurred on July 23rd. Such occurrences during colder months are generally attributed to storm events, whereas during summer months these peaks in part can be attributed to algal blooms. Yet, in highly productive agricultural regions such as the Delta these turbidity peaks may also be caused by agricultural drainage near the monitoring site(s). The overall mean was about 23.2 NTU. Turbidity values were high throughout the summer months with mean values ranging from a low of 24.6 NTU in September to a high of 44.0 NTU in June. In the fall turbidity values decreased sharply, averaging 6.0 NTU in November.

Middle River near Tracy Road

Water temperatures in the Middle River near Tracy Road reached a maximum of 29.44 °C on July 20th at 16:45 PST and a minimum of 7.40 °C on December 30th at 7:00 PST. See Figure 8-16. Temperature patterns at the Tracy Road monitoring station were similar to those previously discussed. July water temperatures were the warmest averaging 25.59 °C, while December temperatures were the coldest averaging 10.38 °C. The mean water temperature during the monitoring period was 17.66 °C.

Dissolved oxygen data for the Middle River near Tracy Road during 2003 are also plotted in Figure 8-16. DO concentrations reached a maximum of 13.58 mg/L on May 10th at 14:30 PST and were at a minimum of 3.11 mg/L on August 28th at 2:45 PST. There were 305 instances during the summer when the sonde(s) recorded DO concentrations less than 5 mg/L and none below 3 mg/L. No field readings (modified Winkler titration) were less than 5 mg/L, with the lowest being 5.30 mg/L. The lowest monthly mean was 6.55 mg/L in August and the highest was 10.81 mg/L in December. In 2003, the mean DO concentration for Tracy Road was 8.76 mg/L. Dissolved oxygen concentrations at Tracy Road were lowest during the warm summer months and highest during the winter. Summer DO readings were the lowest during the year in part because DO saturation decreases as water temperature increases. In comparison to the upstream Middle River monitoring stations diel variation in DO concentrations was less pronounced during the summer. Algal biomass as indicated by chlorophyll *a* was considerably less at Tracy Road. Refer back to Figure 8-10. Chlorophyll *a* concentrations averaged 44.9 µg/L at Undine Road, 20.8 µg/L at Howard Road and 3.9 µg/L at Tracy Road.

Figure 8-15 Middle River at Howard Road: Specific conductance and turbidity continuous water quality data

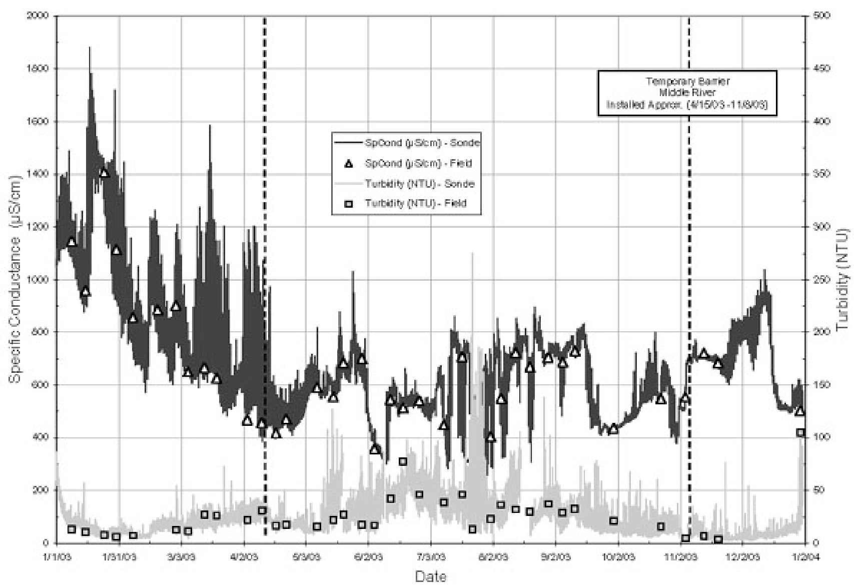


Figure 8-16 Middle River near Tracy Road: Water temperature, dissolved oxygen and pH continuous water quality data

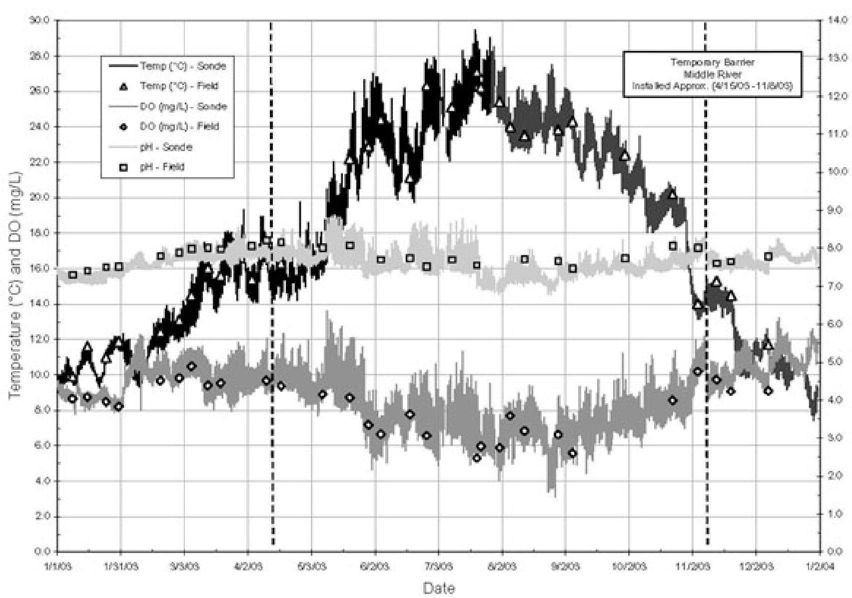


Figure 8-16 also displays 2003 pH data in the Middle River near Tracy Road. Recorded pH data ranged from a high of 8.83 on May 12th at 17:30 PST to a low of 6.78 on August 1st at 5:00 PST. No pH values greater than 9.0 were recorded and the highest recorded field reading was 8.2. In 2003, pH at Tracy Road averaged 7.50 and the highest monthly mean pH was 7.86 in April.

Specific conductance data for the Tracy Road monitoring station is shown in Figure 8-17. A maximum of 993.6 µS/cm was recorded on January 2 at 2:45 PST. The minimum-recorded specific conductance was 169.8 µS/cm on July 25 at 3:45 PST. The mean for the monitoring period was 376.0 µS/cm. Specific conductance values recorded at the Tracy Road site showed the greatest daily variation of the three Middle River sites until the barrier was installed on April 15th. Daily variation in specific conductance at Tracy Road is likely due to tidal influences and differences between upstream and downstream specific conductance. Specific conductance was highest in months when the barrier was not installed with a maximum monthly mean of 507.8 µS/cm recorded in January. Summer specific conductance values were the lowest, with July having the lowest monthly mean in 2003 of 217.1 µS/cm.

Figure 8-17 also depicts turbidity data at this site. Turbidities ranged from a high of 82.2 NTU on November 15th at 9:15 PST to a low of 0.0 NTU on November 3rd at 16:15 PST. The minimum of 0.0 NTU was the result of very clear water and slight probe drift. Generally, turbidity readings were lowest from October through December and were highest in January and April. The minimum monthly average was 3.7 NTU in October. Turbidity values at Tracy Road were the lowest in the Middle River with an average of 12.5 NTU for 2003 about half the average of Howard Road and Undine Road. Summer turbidities were not elevated at Tracy Road in comparison to the upstream sites.

Old River Near Head

Water temperatures in the Old River near Head reached a maximum of 30.42 °C on July 22nd at 12:45 PST and a minimum of 8.02 °C on December 30th at 2:45 PST. See Figure 8-18. Temperature patterns at the Head monitoring station were similar to those previously discussed. July water temperatures were the warmest averaging 26.11 °C, while December temperatures were the coldest averaging 10.81 °C. The mean water temperature during the monitoring period was 17.97 °C.

Dissolved oxygen data for the Old River near Head during 2003 are also plotted in Figure 8-18. DO concentrations reached a maximum of 20.09 mg/L on August 25th at 14:30 PST and were at a minimum of 2.41 mg/L on July 31st at 23:45 PST. There were 96 instances during the summer through early fall when the sonde(s) recorded DO concentrations less than 5 mg/L with six of those occurrences below 3 mg/L. No field readings (modified Winkler titration) were less than 5 mg/L, with the lowest being 5.40 mg/L. The lowest monthly mean was 8.82 mg/L in July and the highest was 11.06 mg/L in August. The mean DO concentration for Head in 2003 was 9.89 mg/L. Diel variation in DO concentrations was most pronounced during the late spring through early fall with values fluctuating considerably, where as in late fall and winter there was clearly less variation. Chlorophyll *a* levels were high during the summer averaging over 60 µg/L indicating high algal biomass. Figure 8-19 shows discrete chlorophyll *a* and pheophytin *a* concentrations at the three Old River sites for 2003. The highest chlorophyll *a* concentration was 293.5 µg/L on August 20.

Figure 8-18 also displays 2003 pH data in the Old River near Head. Recorded pH data ranged from a high of 9.56 on August 20th at 13:00 PST to a low of 7.50 on October 27th at 20:30 PST. From May 22nd through August 30th there were 1,486 pH readings > 9.0. No pH values greater than 9.0 were recorded after August 30th and the maximum field reading recorded was 9.12. One pH field reading was greater than 9.0. In 2003, pH at Head averaged 7.99 and the highest monthly mean pH was 8.48 in June. pH values > 9.0 only occurred during the late spring through mid-to-late summer when chlorophyll a concentrations were high.

Specific conductance data for the Head monitoring station is shown in Figure 8-20. A maximum of 1285.7 µS/cm was recorded on January 28th at 5:00 PST. The minimum-recorded specific conductance was 351.7 µS/cm on October 27th at 20:30 PST. The mean for the monitoring period was 760.3 µS/cm. Specific conductance at the Head monitoring station is probably influenced primarily by the San Joaquin River. A visual comparison between Figure 8-22 and Figure 6 shows that the specific conductance patterns at this site and at the San Joaquin River at Vernalis are quite similar. In months when the barrier(s) were not installed specific conductance ranged from 883.1 µS/cm to 1075.6 µS/cm. While the barrier(s) were operational monthly specific conductance values ranged from 514 µS/cm in June to 689.4 µS/cm in September.

Figure 8-20 also depicts turbidity data at this site. Turbidities ranged from a high of 152.0 NTU on July 18th at 22:30 PST to a low of 4.3 NTU on September 30th at 15:15 PST. Generally, monthly mean turbidity readings were highest in the winter and summer (23.3 – 35.4) and lowest in fall (10.4 – 18.6). In 2003, turbidity at the Old River near Head averaged 23.8 NTU.

Figure 8-17 Middle River near Tracy Road: Specific conductance and turbidity continuous water quality data

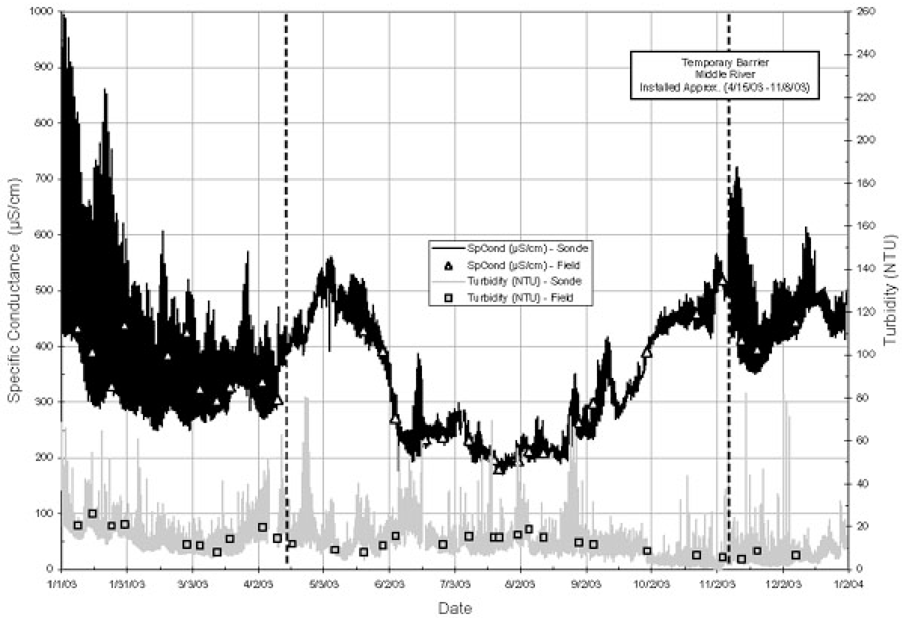


Figure 8-18 Old River near Head: Water temperature, dissolved oxygen and pH continuous water quality data

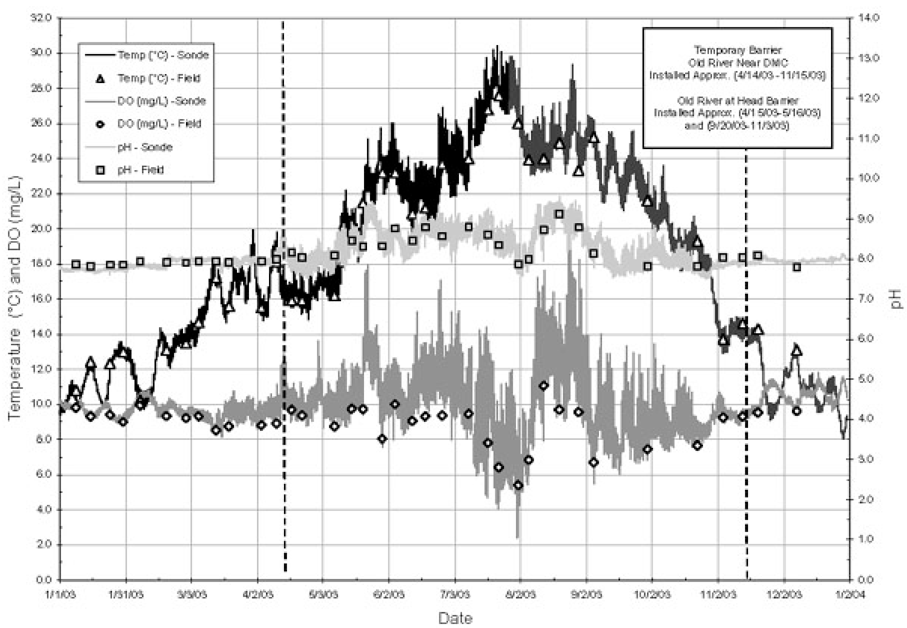
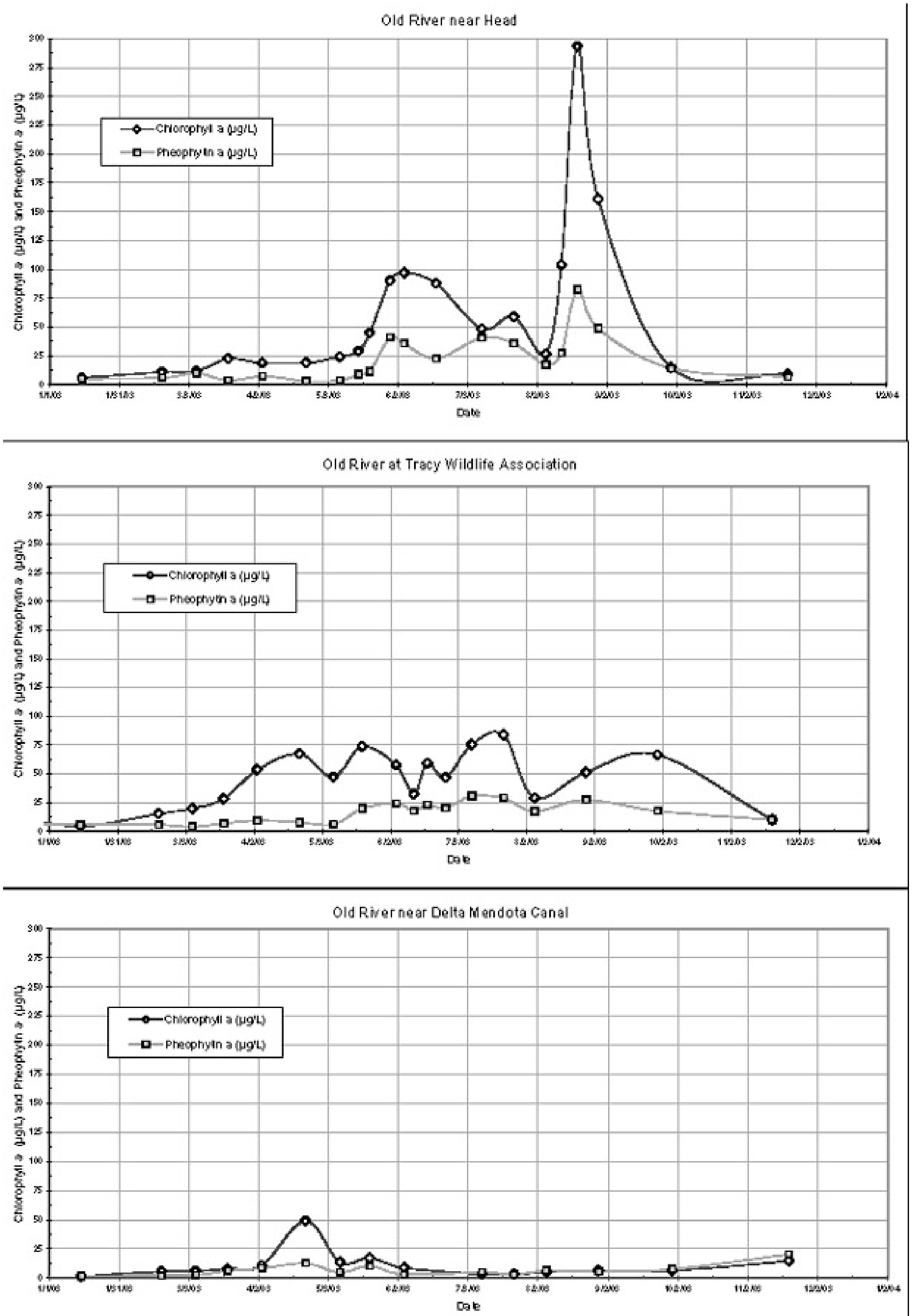


Figure 8-19 2003 Discrete Chlorophyll *a* and Pheophytin *a* data for the Old River Monitoring Sites



Old River at Tracy Wildlife Association

Water temperatures in the Old River at TWA reached a maximum of 30.52 °C on July 21st at 13:15 PST and a minimum of 7.59 °C on December 30th at 6:15 PST. See Figure 8-21. Temperature patterns at the TWA monitoring station are similar to those previously discussed. July water temperatures were the warmest averaging 25.81 °C, while December temperatures were the coldest averaging 10.43 °C. The mean water temperature during the monitoring period was 18.03 °C.

Dissolved oxygen data for the Old River at TWA during 2003 are also plotted in Figure 8-21. DO concentrations reached a maximum of 17.94 mg/L on April 9th at 15:45 PST and were at a minimum of 0.06 mg/L on August 5th at 6:00 PST. There were 3,295 instances during the summer through early fall when the sonde(s) recorded DO concentrations less than 5 mg/L with 1,110 of those occurrences below 3 mg/L. Three field readings (modified Winkler titration) were less than 5 mg/L and one was below 3 mg/L, with the lowest being 1.86 mg/L. There were two events where dissolved oxygen levels were extremely low for an extended period of time, both with periods where DO was essentially zero. The first occurred from July 24th – August 8th and the second from August 21st – August 27th with averages of 3.54 mg/L and 2.80 mg/L, respectively. The lowest monthly DO mean was 4.60 mg/L in September and the highest was 11.40 mg/L in April. The overall mean DO concentration for TWA was 8.18 mg/L. Diel variation in DO concentrations was most evident during the late spring through early fall, whereas in late fall and early winter there was noticeably less variation. Diel variation in DO concentrations was likely in part due to algal photosynthesis and respiration. Chlorophyll *a* levels were high during the summer averaging over 50 µg/L indicating high algal biomass. Refer back to Figure 8-19.

Figure 8-21 also depicts 2003 pH data in the Old River at TWA. Recorded pH data ranged from a high of 9.09 on May 23rd at 16:15 PST to a low of 6.82 on July 3rd at 20:15 PST. Also, similar to DO, pH values show noticeably less fluctuation during the late fall, winter and early spring in comparison to summer and early fall. From May 22nd through May 26th there were 31 pH readings > 9.0. No pH values greater than 9.0 were recorded after May 26th and the maximum field reading recorded was 8.62. In 2003, pH at TWA averaged 7.71 and the highest monthly mean was 8.11 in April.

Specific conductance data for the TWA site is shown in Figure 8-22. A maximum of 1457.1 µS/cm was recorded on December 17th at 23:00 PST. The minimum-recorded specific conductance was 497.4 µS/cm on November 2nd at 9:45 PST. The mean for the monitoring period was 881.6 µS/cm. Generally, there was less daily variability when the barrier(s) were not installed. Monthly average specific conductance values were higher when the barrier(s) were not installed ranging from 990.7 µS/cm in December to 1134.0 µS/cm in March. Specific conductance values decreased in April likely in part due to increased flows in the San Joaquin River past Vernalis and less CVP and SWP pumping. Values averaged less than 700 µS/cm in May and June, after which values tended to increase for the remainder of the period, except for a brief period in late October-early November, probably as a result of increased San Joaquin River flows.

Figure 8-20 Old River near Head: Specific conductance and turbidity continuous water quality data

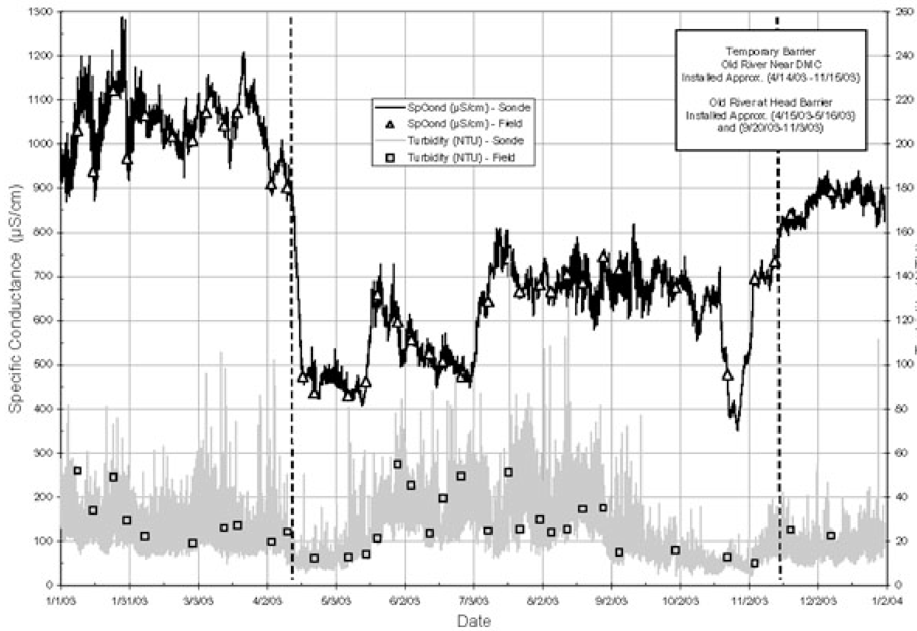


Figure 8-21 Old River at Tracy Wildlife Association: Water temperature, dissolved oxygen and pH continuous water quality data

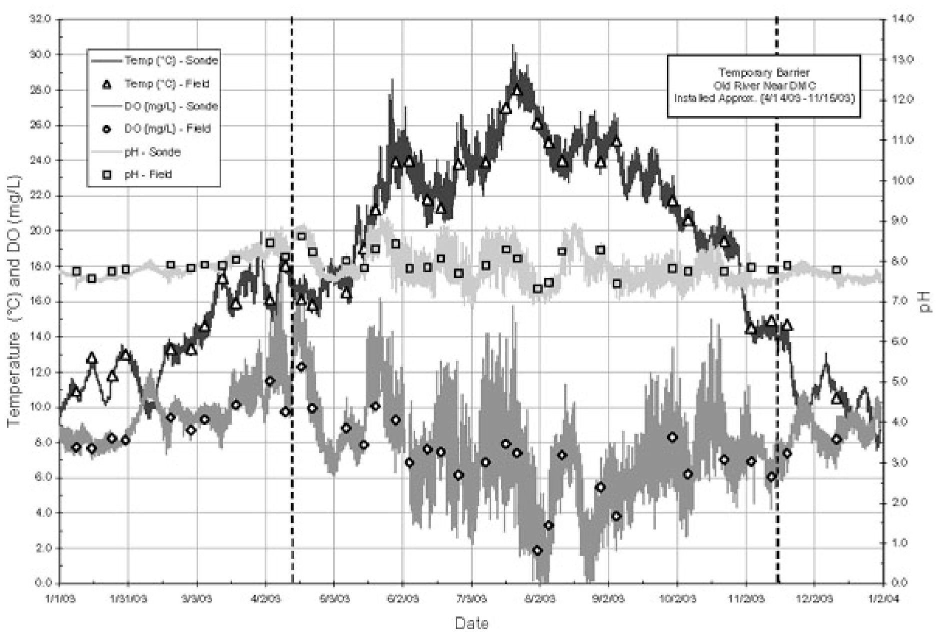


Figure 8-22 also depicts turbidity data at this site. Turbidities ranged from a high of 280.0 NTU on August 8th at 21:15 PST to a low of 5.7 NTU on November 25th at 6:15 PST. Generally, turbidity readings were higher in the summer averaging over 30 NTU, while values in fall, winter and spring averaged about 20 NTU. The lowest monthly mean turbidity was 17.0 NTU in both November and December and the overall mean was about 25.7 NTU.

Old River Near Delta Mendota Canal

Water temperatures in the Old River near DMC reached a maximum of 27.06 °C on July 26th at 18:45 PST and a minimum of 8.15 °C on December 30th at 7:45 PST. See Figure 8-23. Temperature patterns at the DMC monitoring station are similar to those previously discussed. July water temperatures were the warmest averaging 23.79 °C, while December temperatures were the coldest averaging 10.50 °C. The mean temperature during the monitoring period was 17.25 °C. Mean summer water temperatures in the Old River near DMC were 1-2 °C lower in comparison to the upstream monitoring locations.

Dissolved oxygen data for the Old River near DMC during 2003 are also plotted in Figure 8-23. DO concentrations reached a maximum of 15.13 mg/L on April 8th at 17:45 PST and were at a minimum of 0.47 mg/L on September 23rd at 12:45 PST. There were 6,429 instances during late spring through early fall when the sonde(s) recorded DO concentrations less than 5 mg/L with 1,034 of those occurrences below 3 mg/L. Five field readings (modified Winkler titration) were less than 5 mg/L and none were below 3 mg/L, with the lowest being 3.86 mg/L. Mean DO concentrations in July and August were less than 5 mg/L. The lowest monthly mean was 4.27 mg/L in July and the highest was 9.89 mg/L in March. DO concentrations seemed to sag during the summer months when water temperatures were high, San Joaquin River flows past Vernalis were low and when the barriers were operational before increasing in late fall and early winter. The overall mean DO concentration for DMC was 7.46 mg/L. Similar to Middle River near Tracy Road, downstream chlorophyll *a* concentrations at DMC were considerably lower than the upstream sites. Refer back to Figure 8-19. Chlorophyll *a* concentrations averaged 58.9 µg/L at Head, 45.7 µg/L at Tracy Wildlife Association and 10.6 µg/L at DMC.

2003 pH data in the Old River near DMC is shown in Figure 8-23. Recorded pH data ranged from a high of 8.88 on April 8th at 17:45 to a low of 7.15 on June 10th at 18:45 PST and November 14th at 21:30 PST.

Figure 8-22 Old River at Tracy Wildlife Association: Specific conductance and turbidity continuous water quality data

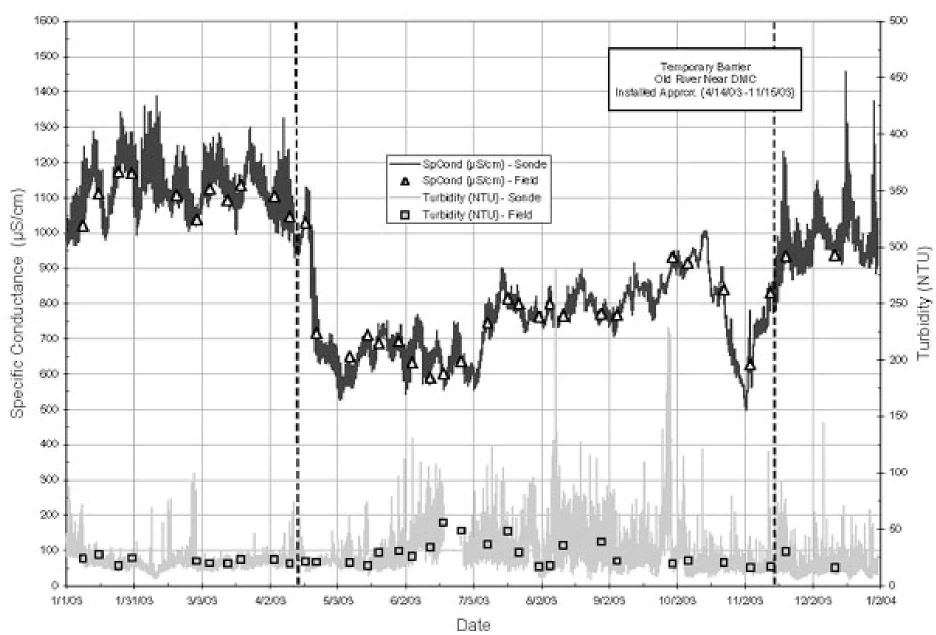
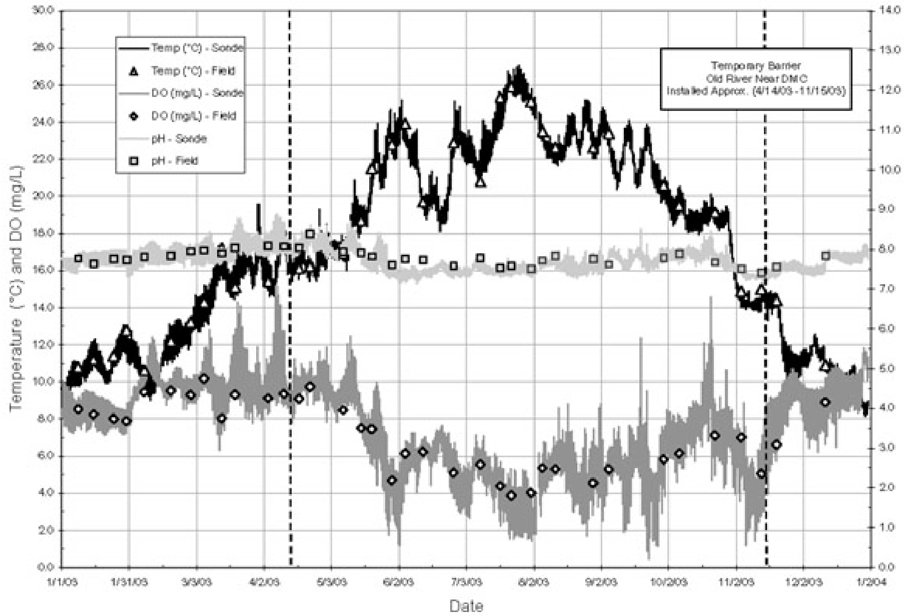


Figure 8-23 Old River Barrier near Delta Mendota Canal: Water temperature, dissolved oxygen and pH continuous water quality data

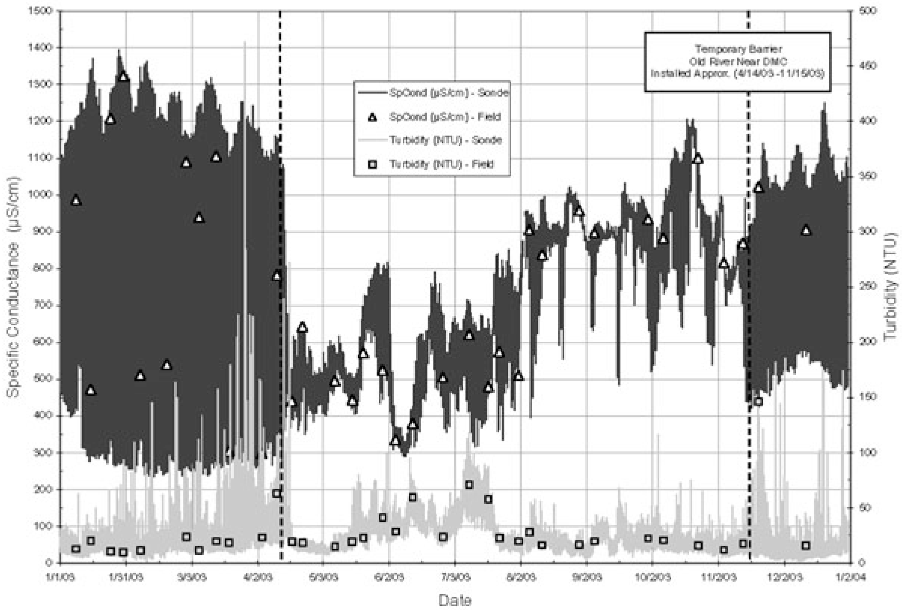


No pH values greater than 9.0 were recorded and the maximum field reading was 8.39. In 2003, pH at DMC averaged 7.65, and the highest monthly mean was 8.09 in April.

Figure 8-24 illustrates specific conductance data for 2003 at the DMC site. A maximum of 1392.9 µS/cm was recorded on January 28th at 5:00 PST. The minimum-recorded specific conductance was 233.8 µS/cm on February 13th at 15:30 PST. The mean for the monitoring period was 773.6 µS/cm. In months when the barrier was not installed daily specific conductance values fluctuated by about 800 µS/cm. The daily fluctuations of about 800 µS/cm are due to specific conductance differences between upstream water and incoming tidal water. Incoming tidal water was lower in specific conductance than water flowing down Old River. While the barrier was operational there was less variation in specific conductance values. From April to July monthly specific conductance averages were less than 700 µS/cm ranging from 502.9 µS/cm to 612.6 µS/cm while the barrier(s) were operational. During the rest of year specific conductance averaged over 750 µS/cm. Specific conductance values increased throughout the summer and early fall. The highest monthly average was 931.7 µS/cm in October.

Figure 8-24 also shows turbidity data at this site. Turbidities ranged from a high of 470.9 NTU on March 27th at 16:15 PST to a low of 1.4 NTU on February 10th at 6:00 PST. Turbidity readings averaged a high of 42.3 NTU in July and averaged a low of 13.3 NTU in December. Generally, summer turbidity readings were the highest, especially in June and July. During the monitoring period the average turbidity reading was 23.4 NTU.

Figure 8-24 Old River Barrier near Delta Mendota Canal: Specific conductance and turbidity continuous water quality data



Conclusions

Tables 8-13A and 8-13B provide a basic statistical summary of the 2003 water quality data collected from the six continuous monitoring sites. The monthly maximum, average, minimum, and standard deviation is displayed for each water quality parameter. Yearly statistics are included at the bottom of the table. Additionally, Figures 8-25 through 8-34 show graphical representations of the data in Tables 8-13A and 8-13B. Refer to these tables and figures in the following discussion of 2003 time-series water quality data for the South Delta. Table 8-14 provides a basic statistical summary of the constituents: dissolved ammonia, dissolved nitrite + nitrate, dissolved organic nitrogen, dissolved orthophosphate, chlorophyll *a*, and pheophytin *a*. The constituents in Table 8-14 were collected on a discrete basis at each of the six continuous site locations and were analyzed by Bryte Lab.

Water temperature readings in the Middle River and Old River were primarily influenced by air temperature and followed seasonal patterns. Temperature variation between the six continuous sites was likely due to site-specific localized differences. At all six monitoring locations water temperature readings tracked closely throughout the year. Refer to Figures 8-25 and 8-26 and Tables 8-13A and 8-13B. Temperatures in the Old River near DMC during the summer were 1-2 °C lower in comparison to the upstream monitoring locations in the Old River. In 2003, mean water temperatures ranged from 17.25 ºC at the Old River near DMC to 18.03 ºC at the Old River at TWA.

From January through April and in December there were no sonde(s) dissolved oxygen readings below 5.0 mg/L at the six monitoring stations; however during the summer there were numerous readings below 5.0 mg/L and 3.0 mg/L, especially in the Old River at the TWA and near DMC sites. Low dissolved oxygen concentrations during the summer are likely in part due to warm water temperatures and low flows down the San Joaquin River. In July and August mean DO values were 4.27 mg/L and 4.87 mg/L, respectively at the DMC site and 4.60 mg/L in August at TWA. Further analysis needs to be done at the Old River near DMC Barrier and

TWA locations to determine why DO concentrations fall below 5.0 mg/L. Middle River at Undine Road and Old River near Head had high summer DO concentrations relative to the downstream monitoring locations, likely due to algal photosynthesis that resulted in supersaturated conditions. Diel variation was most pronounced in the late spring through early fall at locations where algal biomass as represented by chlorophyll *a* was high and when diel variation in water temperature was most evident. Refer to Figures 8-27 and 8-28 and Tables 8-13A and 8-13B. Table 8-14 shows average chlorophyll *a* and pheophytin *a* concentrations for 2003 at each monitoring station.

pH values > 9.0 were recorded at all the continuous monitoring stations except for Old River near DMC and Middle River near Tracy Road. High algal biomass during the spring, summer, and early fall at the upstream monitoring locations relative to the downstream locations may have contributed to the higher pH values. The Middle River at Undine Road and Old River near Head sites had the highest pH values, especially in the summer whereas the other sites tended to have lower pH averages during the summer. pH values > 9.0 were only recorded from April through September. Similar to DO concentrations diel variation in pH values was most pronounced from late spring through early fall. See Figures 8-29 and 8-30 and Tables 8-13A, 8-13B and 8-14.

While the temporary barriers were operational specific conductance was lower in the Middle River. Old River specific conductance tended to be the lowest in April through July while the barriers were operational. The highest specific conductance values were recorded from January through March when the barriers were not installed. The most noteworthy decreases in specific conductance occurred from April to May and in October likely due to increased flows down the San Joaquin River past Vernalis, decreases in CVP and SWP exports in the spring and fall and the installation and operation of the temporary barriers. Specific conductance in the Middle River averaged less than 700 µS/cm while the barrier(s) were operational (April 15th – November 8th) at all three sites, except for Undine Road in August and September. Middle River near Tracy Road had the lowest specific conductance in 2003 with an average of 376 µS/cm. Comparatively, the next lowest mean was 690.8 µS/cm at Undine Road. The low specific conductance values recorded at the Middle River near Tracy Road are likely because incoming tidal water (likely from the Sacramento River) at that site is lower in specific conductance than water flowing down Middle River. Specific conductance values in Old River averaged less than 700 µS/cm: while the barrier was operational at Head, from May to June at TWA, and from April through July at DMC. Overall, in 2003 average specific conductance in the South Delta was higher in the Old River. Monthly differences in specific conductivity between stations can be reviewed in Figure 8-31 and 8-32 and Tables 8-13A and 8-13B.

In general, turbidity at all six sites was lower during fall and winter and higher during the spring and summer. High summer turbidity readings were seen at all sites except Middle River near Tracy Road. Turbidity readings during the summer may have been higher, partially because of increased primary productivity (algal biomass). The Middle River near Tracy Road site had the highest average water clarity (least turbid) during the 2003 sampling period. In 2003, turbidity values near Tracy Road averaged 12.5 NTU, about 10 NTU lower than at any other site. Mean turbidity readings at the other five sites ranged from 23.2 NTU to 27.3 NTU. Figures 33 and 34 and Tables 13A and 13B shows statistics of the turbidity data recorded at each of the six South Delta continuous monitoring sites.

Table 8-13A Statistical Summary of 2003 Middle River Continuous Water Quality Data

Month	Water Temperature (°C)			Dissolved Oxygen (mg/L)			pH		
	UNDINE	HOWARD	TRACY	UNDINE	HOWARD	TRACY	UNDINE	HOWARD	TRACY
Jan.- Max.	13.74	12.79	12.16	9.97	10.54	9.66	7.85	7.80	7.50
Jan.- Avg.	11.24	10.95	10.52	8.63	9.10	8.75	7.60	7.58	7.24
Jan. - Min.	9.16	9.18	9.03	7.17	8.14	7.77	7.30	7.36	7.04
Jan.- S.D.	1.04	0.89	0.78	0.60	0.53	0.32	0.10	0.10	0.10
Feb.- Max.	14.79	14.03	13.89	13.43	13.81	12.25	8.44	8.13	8.03
Feb.- Avg.	11.69	11.71	11.60	10.87	11.01	10.26	7.97	7.70	7.60
Feb.- Min.	7.52	8.57	9.31	8.24	8.33	7.98	7.50	7.33	7.24
Feb.- S.D	1.82	1.42	1.02	1.01	1.07	0.70	0.20	0.15	0.15
Mar.- Max.	21.46	21.13	19.31	16.16	12.61	11.82	8.85	8.28	8.54
Mar.- Avg.	15.31	16.03	15.27	10.63	9.03	10.01	8.10	7.56	7.85
Mar.- Min.	12.02	12.52	12.13	6.84	5.94	7.94	7.72	7.13	7.47
Mar.- S.D	1.57	1.71	1.50	1.66	1.36	0.77	0.22	0.21	0.15
Apr.- Max.	19.94	19.84	19.70	15.23	14.08	12.29	9.21	8.58	8.50
Apr.- Avg.	16.25	16.52	15.80	10.14	8.34	9.88	8.14	7.53	7.86
Apr.- Min.	13.12	14.16	14.10	7.32	6.13	8.19	7.44	7.22	7.55
Apr.- S.D	1.29	1.08	1.00	1.25	0.97	0.60	0.31	0.21	0.16
May- Max.	27.61	27.43	26.66	19.08	16.31	13.58	9.39	9.07	8.83
May- Avg.	19.97	20.55	19.82	10.66	8.74	9.29	8.13	7.62	7.79
May - Min.	15.13	15.95	15.36	4.94	0.07	5.59	7.40	7.06	7.20
May - S.D.	2.73	2.70	2.78	2.11	2.15	1.26	0.47	0.47	0.34
Jun.- Max.	28.03	27.90	27.89	18.39	13.76	10.24	9.39	8.86	8.68
Jun.- Avg.	22.64	23.60	23.27	10.74	7.29	7.30	8.60	7.46	7.57
Jun. - Min.	19.44	19.83	19.76	5.96	1.97	4.65	7.87	7.00	7.29
Jun.- S.D.	1.56	1.82	1.70	1.90	2.62	0.99	0.31	0.55	0.28
Jul.- Max.	30.65	30.74	29.44	15.31	17.25	11.30	9.24	9.17	8.76
Jul.- Avg.	25.86	26.21	25.59	8.75	7.42	6.90	8.34	7.40	7.32
Jul. - Min.	21.45	22.09	22.08	2.46	0.50	4.79	7.57	6.77	6.82
Jul.- S.D.	2.14	1.93	1.38	2.65	2.93	1.09	0.42	0.63	0.36
Aug.- Max.	28.15	28.12	27.47	19.91	18.12	9.39	9.59	9.43	7.98
Aug.- Avg.	24.65	25.15	24.27	11.00	9.04	6.55	8.37	7.78	7.17
Aug. - Min.	22.13	22.92	22.40	2.75	2.36	3.11	7.58	6.88	6.78
Aug.- S.D.	1.26	1.04	0.99	3.76	3.52	1.03	0.56	0.71	0.19
Sep.- Max.	27.08	27.17	26.17	15.17	12.13	11.16	9.05	8.90	8.21
Sep.- Avg.	23.32	23.39	22.82	8.35	6.25	7.10	8.14	7.45	7.44
Sep. - Min.	19.78	20.50	20.26	4.27	1.55	4.44	7.70	7.05	7.13
Sep.- S.D.	1.53	1.44	1.17	1.88	1.70	0.85	0.31	0.46	0.14
Oct.- Max.	22.87	22.64	23.44	12.75	11.25	11.28	8.60	7.99	8.30
Oct.- Avg.	19.39	19.46	19.62	8.71	7.72	8.10	7.95	7.44	7.53
Oct.- Min.	15.28	14.88	15.49	6.15	4.87	5.92	7.55	7.11	7.23
Oct - S.D.	1.50	1.42	1.25	1.20	1.09	0.78	0.22	0.18	0.16
Nov.- Max.	15.91	15.33	15.56	14.10	15.77	12.16	8.70	8.65	8.29
Nov.- Avg.	12.77	12.68	13.25	10.38	11.47	10.14	7.99	7.98	7.67
Nov. - Min.	8.38	8.64	9.81	8.30	8.25	7.86	7.61	7.49	7.35
Nov.- S.D.	1.99	1.93	1.54	0.90	1.78	0.75	0.20	0.29	0.18
Dec.- Max.	13.65	12.52	12.56	12.86	14.00	13.20	7.93	8.28	8.25
Dec.- Avg.	10.12	9.97	10.38	10.02	11.84	10.81	7.65	7.66	7.70
Dec. - Min.	6.80	7.21	7.40	8.12	9.84	8.94	7.32	7.38	7.32
Dec.- S.D.	1.50	1.14	1.02	0.82	0.90	0.70	0.12	0.22	0.17
2003 - Max.	30.65	30.74	29.44	19.91	18.12	13.58	9.59	9.43	8.83
2003 - Avg.	17.81	18.00	17.66	9.90	8.94	8.76	8.00	7.57	7.50
2003 - Min.	6.80	7.21	7.40	2.46	0.07	3.11	7.30	6.77	6.78
2003 - S.D.	5.64	5.81	5.51	2.10	2.54	1.68	0.47	0.46	0.31

Month	Specific Conductance (S/cm)			Turbidity (NTU)		
	UNDINE	HOWARD	TRACY	UNDINE	HOWARD	TRACY
Jan.- Max.	2520.8	1877.8	993.6	67.6	86.3	679
Jan.- Avg.	1450.9	1235.7	507.8	18.5	17.9	208
Jan. - Min.	891.6	868.6	285.5	4.3	5.7	118
Jan.- S.D.	355.5	185.9	150.0	10.5	126	6.4
Feb.- Max.	2015.0	1443.8	606.6	45.7	54.5	607
Feb.- Avg.	1306.6	862.4	360.6	9.2	12.4	129
Feb.- Min.	885.3	572.2	249.6	2.8	4.5	7.2
Feb.- S.D.	247.1	153.3	69.0	5.6	5.5	3.3
Mar.- Max.	1865.5	1583.0	567.8	92.4	72.5	407
Mar.- Avg.	1247.5	749.8	348.0	17.1	20.9	12.4
Mar.- Min.	916.2	484.6	249.4	3.3	5.0	5.4
Mar.- S.D.	205.6	194.2	53.1	113	5.9	42
Apr.- Max.	1082.3	1200.4	529.1	151.2	51.0	800
Apr.- Avg.	766.0	548.7	391.4	40.6	23.6	213
Apr.- Min.	431.4	384.4	269.4	9.8	9.6	8.7
Apr.- S.D.	209.6	162.7	59.3	183	6.7	100
May- Max.	1061.1	1027.3	560.2	104.8	125.1	403
May- Avg.	572.0	630.8	466.1	37.0	25.8	13.4
May - Min.	427.1	477.9	358.5	142	8.6	45
May - S.D.	117.3	81.7	44.3	12.4	145	5.5
Jun.- Max.	800.4	662.5	390.6	160.1	97.3	595
Jun.- Avg.	517.6	490.5	263.2	53.9	44.0	167
Jun.- Min.	449.9	301.0	176.4	219	8.8	76
Jun.- S.D.	28.5	81.1	39.3	15.3	163	6.2
Jul.- Max.	775.2	859.0	296.9	103.3	274.5	690
Jul.- Avg.	662.0	533.4	217.1	46.7	43.3	126
Jul. - Min.	476.7	227.7	169.8	166	8.7	66
Jul.- S.D.	61.2	171.1	28.3	8.6	223	4.8
Aug.- Max.	786.0	895.3	350.0	138.4	137.6	71.1
Aug.- Avg.	709.8	686.7	231.9	35.9	36.9	14.1
Aug.- Min.	632.1	288.7	189.6	13.1	7.2	55
Aug.- S.D.	33.0	119.8	28.9	13.4	153	6.8
Sep.- Max.	970.9	829.6	416.2	83.3	78.4	313
Sep.- Avg.	725.3	623.3	318.3	22.4	24.6	10.4
Sep.- Min.	646.5	411.5	233.2	5.3	8.3	2.6
Sep.- S.D.	49.0	145.2	38.6	6.7	8.6	2.7
Oct.- Max.	806.9	800.8	536.5	73.1	67.0	432
Oct - Avg.	573.7	531.3	452.3	18.3	15.3	3.7
Oct.- Min.	349.5	380.2	390.5	3.8	5.2	0.1
Oct - S.D.	107.0	84.6	25.0	8.6	5.3	2.1
Nov.- Max.	1082.6	851.2	721.6	89.2	76.1	822
Nov.- Avg.	742.4	686.0	472.7	119	6.0	5.4
Nov.- Min.	486.9	407.7	350.1	5.2	2.6	0.0
Nov.- S.D.	110.2	75.4	92.3	5.5	3.5	4.4
Dec.- Max.	1376.5	1036.1	612.6	84.8	104.6	816
Dec.- Avg.	828.2	698.1	463.5	15.3	118	7.8
Dec.- Min.	525.5	494.4	405.3	5.8	3.1	1.7
Dec.- S.D.	136.3	165.7	31.5	7.0	130	4.6
2003 - Max.	2520.8	1877.8	993.6	160.1	274.5	822
2003 - Avg.	839.9	690.8	376.0	27.3	23.2	125
2003 - Min.	349.5	227.7	169.8	2.8	2.6	0.0
2003 - S.D.	343.2	240.3	116.2	17.9	167	7.5

Table 8-13B Statistical Summary of 2003 Old River Continuous Water Quality Data

Month	Water Temperature (ºC)			Dissolved Oxygen (mg/L)			pH		
	HEAD	TWA	DMC	HEAD	TWA	DMC	HEAD	TWA	DMC
Jan.- Max.	13.55	13.51	13.03	10.21	9.06	10.00	7.80	7.78	7.98
Jan.- Avg.	11.25	11.39	10.96	9.64	8.10	8.24	7.72	7.59	7.74
Jan.- Min.	9.40	9.47	9.33	8.91	7.03	7.11	7.60	7.31	7.32
Jan.- S.D.	1.15	1.00	0.88	0.31	0.36	0.62	0.02	0.06	0.16
Feb.- Max.	14.36	14.18	13.54	10.77	12.15	12.40	8.10	8.03	8.20
Feb.- Avg.	12.29	12.10	11.37	9.89	9.82	9.97	7.86	7.76	7.83
Feb.- Min.	9.74	9.35	9.03	9.03	7.35	7.67	7.67	7.46	7.38
Feb. - S.D.	1.35	1.30	1.10	0.41	0.76	0.73	0.09	0.07	0.18
Mar.- Max.	19.92	19.91	19.58	10.75	13.77	14.27	8.07	8.47	8.78
Mar.- Avg.	16.08	16.18	15.43	9.37	10.10	9.89	7.92	7.99	7.97
Mar.- Min.	13.35	13.32	12.70	8.11	7.70	6.33	7.55	7.69	7.58
Mar. - S.D.	1.42	1.42	1.31	0.41	1.02	0.98	0.07	0.16	0.22
Apr.- Max.	19.81	18.98	19.23	13.63	17.94	15.13	8.57	8.92	8.88
Apr.- Avg.	16.49	16.72	16.34	9.95	11.40	9.86	7.92	8.11	8.09
Apr.- Min.	14.81	14.80	14.59	8.59	6.32	7.79	7.53	7.53	7.70
Apr.- S.D.	1.01	0.90	0.75	0.69	2.35	0.99	0.19	0.38	0.20
May- Max.	25.71	28.51	24.65	17.94	16.16	12.43	9.42	9.09	8.69
May- Avg.	19.84	20.08	19.41	10.87	9.37	7.81	8.23	7.88	7.75
May- Min.	15.89	15.87	16.00	7.57	6.15	1.75	7.60	7.24	7.28
May- S.D.	2.55	2.64	2.24	1.51	2.08	2.11	0.42	0.45	0.27
Jun.- Max.	26.91	27.06	25.16	17.07	12.60	7.63	9.33	8.86	7.73
Jun.- Avg.	22.62	22.82	21.31	10.88	7.33	5.73	8.48	7.77	7.41
Jun.- Min.	19.71	20.20	18.10	7.98	2.63	1.19	7.91	6.90	7.15
Jun.- S.D.	1.27	1.41	1.79	1.20	1.96	1.08	0.25	0.32	0.10
Jul.- Max	30.42	30.52	27.06	15.29	15.56	7.11	9.26	8.87	7.76
Jul.- Avg.	26.11	25.81	23.79	8.82	6.70	4.27	8.47	7.69	7.47
Jul.- Min.	21.86	22.03	20.57	2.41	0.18	1.50	7.69	6.82	7.30
Jul.- S.D.	2.04	1.92	1.72	2.24	2.47	1.08	0.27	0.40	0.08
Aug. - Max.	29.34	27.04	25.80	20.09	11.25	8.79	9.56	8.92	8.03
Aug. - Avg.	24.75	24.71	23.17	11.06	4.60	4.87	8.40	7.55	7.54
Aug.- Min.	23.07	22.77	21.65	2.42	0.06	1.43	7.58	6.95	7.26
Aug.- S.D.	0.97	0.87	0.89	2.89	2.50	1.19	0.48	0.53	0.12
Sep.- Max.	26.44	26.54	24.76	13.96	13.22	12.33	8.92	8.28	8.49
Sep.- Avg.	23.31	23.23	22.07	8.83	6.47	5.11	7.98	7.60	7.70
Sep.- Min.	20.90	21.04	19.69	5.53	1.84	0.47	7.54	7.06	7.37
Sep.- S.D.	1.31	1.21	1.16	1.44	1.57	1.30	0.30	0.17	0.14
Oct.- Max.	23.56	21.87	20.95	13.37	14.86	14.52	8.83	8.55	8.46
Oct.- Avg.	19.12	19.51	18.93	8.85	7.43	7.56	7.84	7.62	7.80
Oct.- Min.	14.93	16.16	16.12	7.33	2.69	4.29	7.50	7.06	7.44
Oct.- S.D	1.46	0.98	0.74	0.82	1.62	1.22	0.23	0.21	0.15
Nov.- Max.	15.70	16.33	16.31	11.39	11.23	10.67	8.10	8.18	7.73
Nov.- Avg.	12.86	13.11	13.44	9.92	8.06	6.94	7.90	7.61	7.43
Nov.- Min.	9.10	9.30	9.90	8.79	4.21	1.23	7.76	7.14	7.15
Nov.- S.D.	1.82	1.86	1.52	0.72	1.29	2.20	0.06	0.18	0.12
Dec.- Max.	13.49	13.05	12.56	11.79	10.58	11.81	8.13	7.83	8.13
Dec.- Avg.	10.81	10.43	10.50	10.52	8.80	9.34	7.96	7.63	7.66
Dec.- Min.	8.02	7.59	8.15	9.54	6.55	6.22	7.82	7.34	7.33
Dec.- S.D.	1.18	1.05	0.95	0.43	0.68	1.03	0.05	0.09	0.20
2003- Max.	30.42	30.52	27.06	20.09	17.94	15.13	9.56	9.09	8.88
2003- Avg.	17.97	18.03	17.25	9.89	8.18	7.46	7.99	7.71	7.65
2003- Min.	8.02	7.59	8.15	2.41	0.06	0.47	7.50	6.82	7.15
2003- S.D.	5.44	5.43	4.87	1.56	2.47	2.38	0.40	0.36	0.27

Month	Specific Conductance (S/cm)			Turbidity (NTU)		
	HEAD	TWA	DMC	HEAD	TWA	DMC
Jan.- Max.	1285.7	1340.7	1392.9	81.5	87.4	93.5
Jan.- Avg.	1030.7	1109.1	908.2	28.9	24.3	15.9
Jan.- Min.	870.9	963.7	264.2	14.5	12.9	2.8
Jan.- S.D.	86.4	90.1	382.2	7.9	8.0	7.5
Feb.- Max.	1174.0	1386.4	1363.2	62.8	96.9	162.8
Feb.- Avg.	1033.6	1114.4	871.7	23.3	19.0	18.4
Feb.- Min.	925.6	993.2	233.8	12.3	6.3	1.4
Feb. - S.D.	32.2	65.4	409.8	6.3	6.4	12.2
Mar.- Max.	1208.7	1299.2	1317.1	105.4	46.0	470.9
Mar.- Avg.	1075.2	1134.0	873.4	26.1	20.4	26.1
Mar.- Min.	945.5	998.3	237.3	9.9	12.7	8.1
Mar. - S.D.	44.9	52.1	364.9	9.3	2.9	25.0
Apr.- Max.	1060.6	1324.3	1182.0	101.9	73.3	272.2
Apr.- Avg.	698.8	926.5	612.7	16.1	22.3	26.3
Apr.- Min.	422.4	611.6	255.1	6.0	12.8	7.9
Apr.- S.D.	227.0	176.6	256.5	8.4	4.8	17.8
May- Max.	726.9	749.9	811.8	84.3	107.6	79.8
May- Avg.	523.0	649.8	571.8	24.4	23.4	25.2
May- Min.	408.5	527.7	400.9	7.2	8.9	7.5
May- S.D.	87.1	50.2	106.3	11.6	7.9	14.2
Jun.- Max.	614.8	766.9	816.0	95.2	130.6	98.6
Jun.- Avg.	514.0	647.0	502.9	34.3	40.3	38.1
Jun.- Min.	448.8	544.8	290.7	16.4	14.9	14.8
Jun.- S.D.	31.2	45.2	144.8	9.5	13.5	12.3
Jul.- Max	807.8	899.8	849.1	152.0	122.2	117.7
Jul.- Avg.	670.0	749.5	605.8	35.4	34.2	42.3
Jul.- Min.	448.2	555.1	316.4	12.6	12.4	9.0
Jul.- S.D.	78.3	79.1	100.5	12.7	12.2	22.0
Aug. - Max.	787.9	897.0	1021.3	127.1	280.0	57.5
Aug. - Avg.	684.7	785.9	888.5	34.4	36.2	17.8
Aug.- Min.	578.8	731.1	394.1	13.4	6.4	4.6
Aug.- S.D.	33.6	33.8	96.6	10.2	20.0	7.0
Sep.- Max.	817.5	939.5	1030.6	77.0	228.5	67.6
Sep.- Avg.	689.4	818.2	897.7	17.8	36.8	20.8
Sep.- Min.	604.3	708.4	485.7	4.3	8.8	3.8
Sep.- S.D.	33.1	45.5	67.1	5.8	29.2	8.9
Oct.- Max.	745.5	1005.8	1205.1	35.7	120.4	114.3
Oct.- Avg.	574.8	839.2	931.7	10.4	20.8	19.0
Oct.- Min.	351.7	565.6	522.6	4.8	7.1	6.3
Oct.- S.D.	108.0	119.1	157.9	2.7	11.0	6.3
Nov.- Max.	886.9	1230.6	1139.8	42.1	120.0	181.7
Nov.- Avg.	757.1	819.6	788.9	15.5	17.0	17.2
Nov.- Min.	503.1	497.4	421.0	4.3	5.7	3.0
Nov.- S.D.	91.3	140.5	170.1	5.4	8.3	12.4
Dec.- Max.	937.0	1457.1	1248.3	110.9	144.1	174.5
Dec.- Avg.	883.1	990.7	833.9	18.6	17.0	13.3
Dec.- Min.	813.2	883.8	471.1	8.3	6.1	1.9
Dec.- S.D.	18.6	67.3	222.3	5.8	7.0	12.0
2003- Max.	1285.7	1457.1	1392.9	152.0	280.0	470.9
2003- Avg.	760.3	881.6	773.6	23.8	25.7	23.4
2003- Min.	351.7	497.4	233.8	4.3	5.7	1.4
2003- S.D.	211.1	188.2	278.4	11.6	15.2	16.7

Figure 8-25 2003 Maximums, averages, minimums, and standard deviations for water temperature at the Middle River South Delta continuous monitoring sites

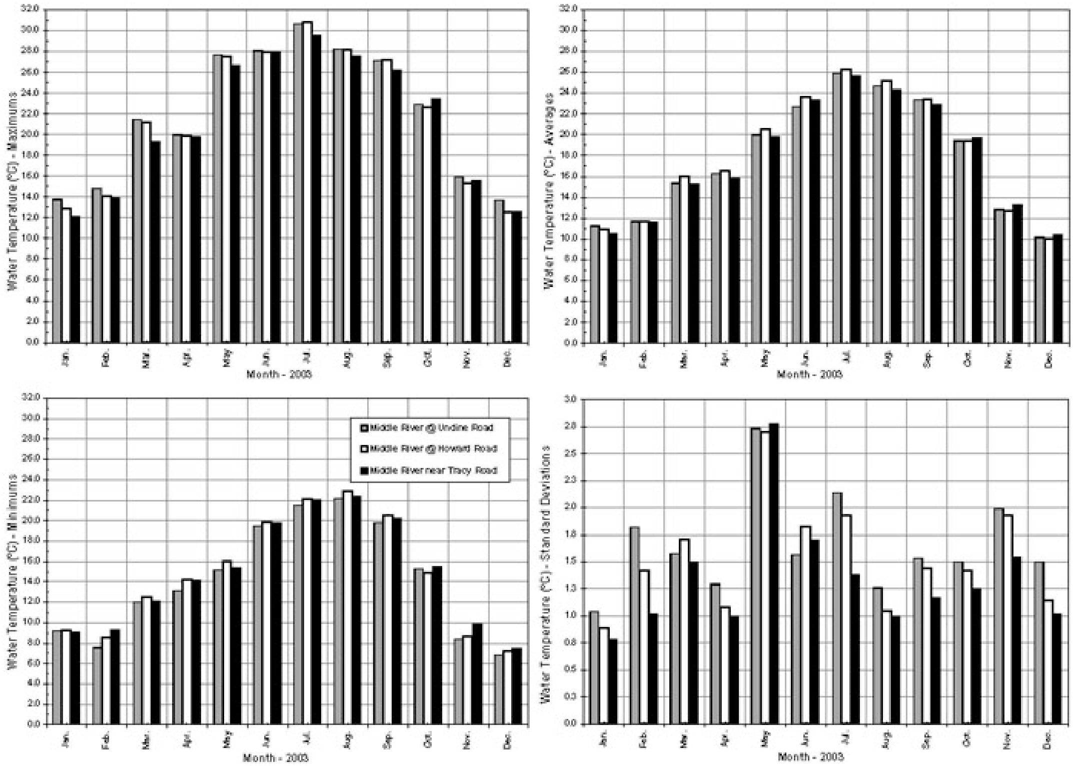


Figure 8-26 2003 Maximums, averages, minimums, and standard deviations for water temperature at the Old River South Delta continuous monitoring sites

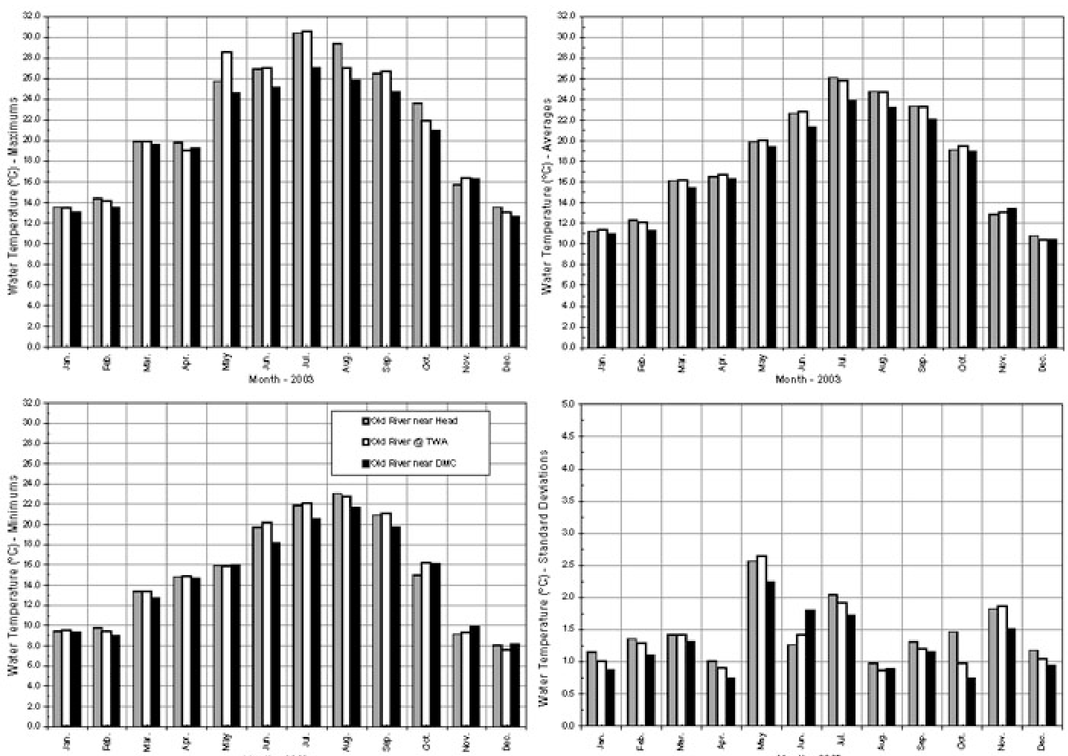


Figure 8-27 2003 Maximums, averages, minimums, and standard deviations for dissolved oxygen at the Middle River South Delta continuous monitoring sites

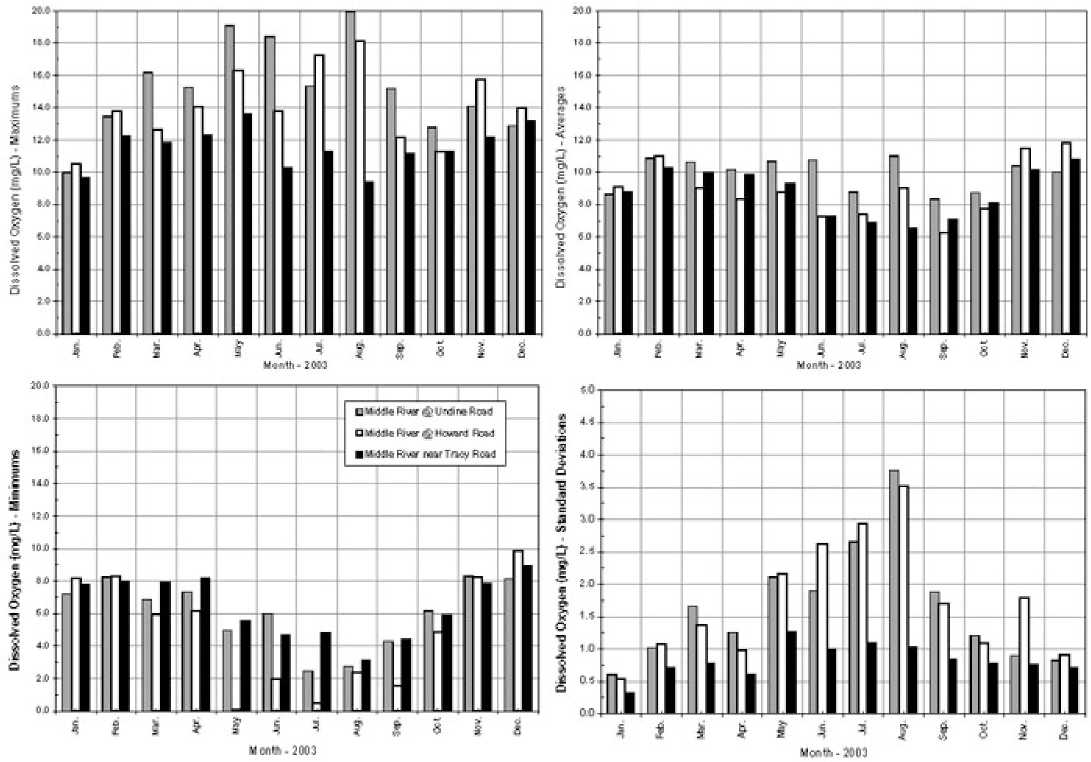


Figure 8-28 2003 Maximums, averages, minimums, and standard deviations for dissolved oxygen at the Old River South Delta continuous monitoring sites

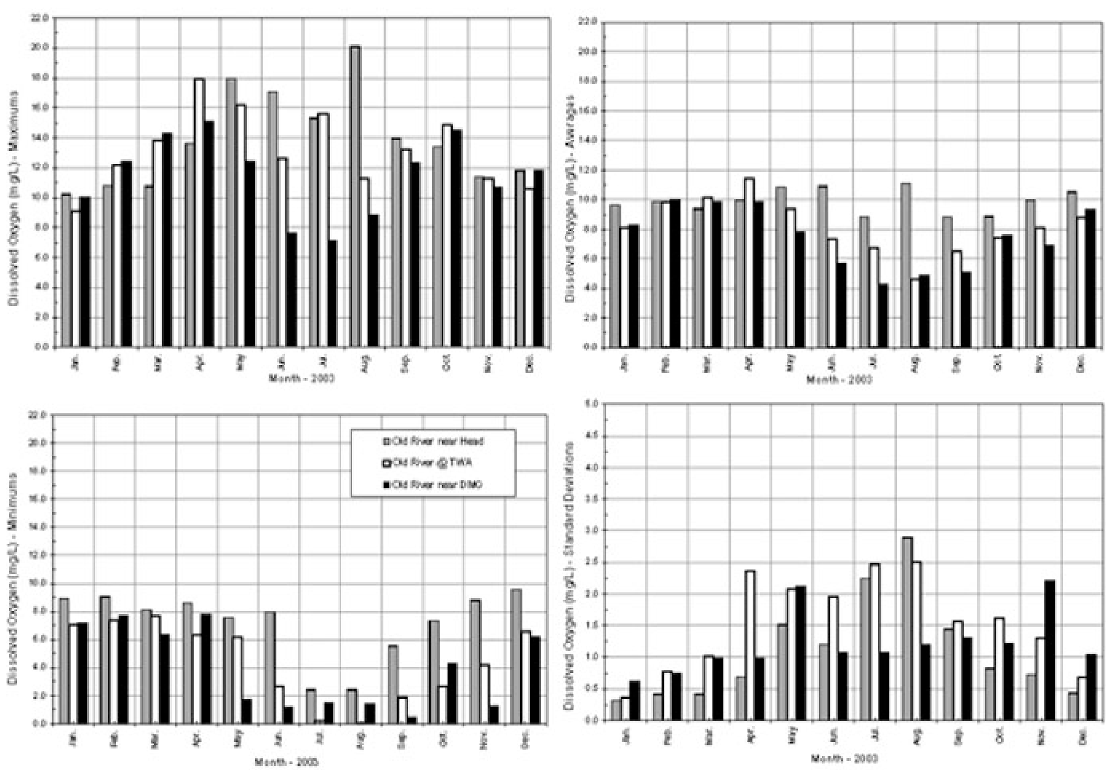


Figure 8-29 2003 Maximums, averages, minimums, and standard deviations for pH at the Middle River South Delta continuous monitoring sites

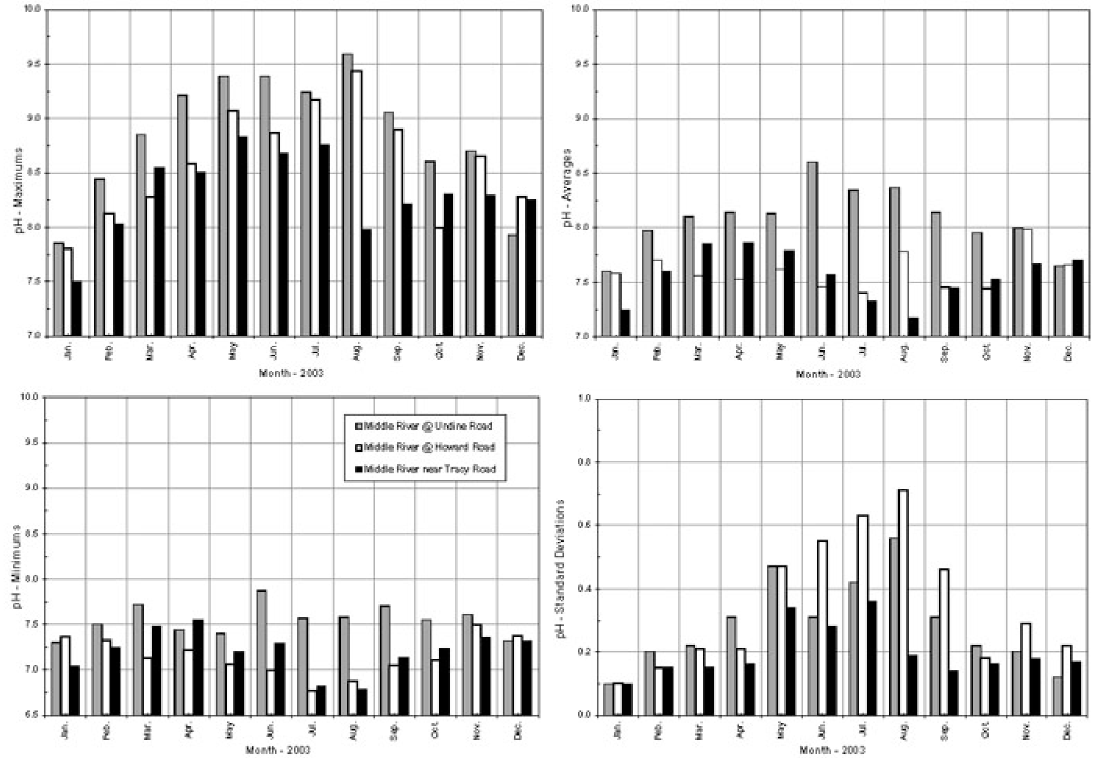


Figure 8-30 2003 Maximums, averages, minimums, and standard deviations for pH at the Old River South Delta continuous monitoring sites

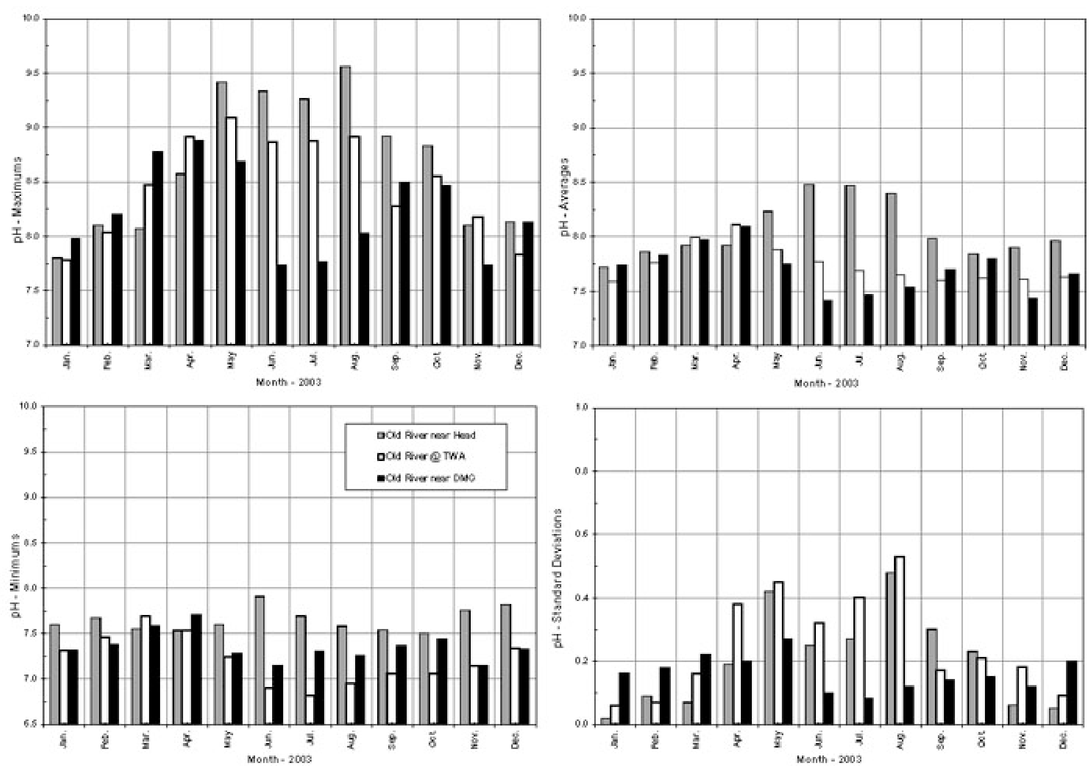


Figure 8-31 2003 Maximums, averages, minimums, and standard deviations for specific conductance at the Middle River South Delta continuous monitoring sites

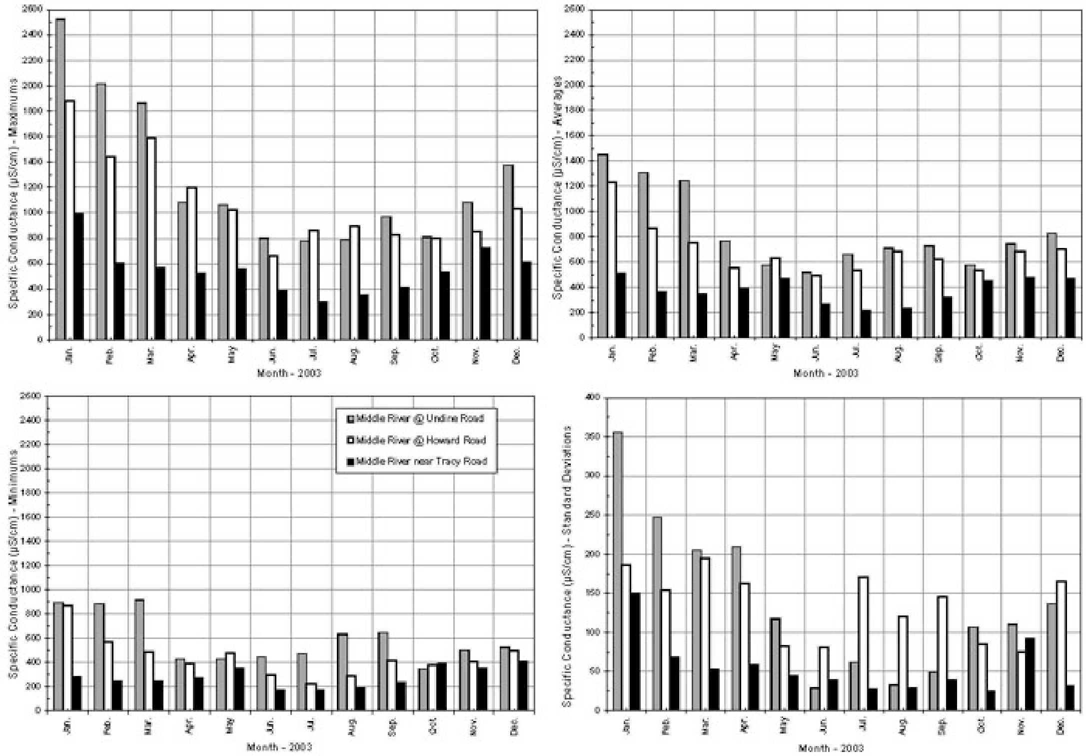


Figure 8-32 2003 Maximums, averages, minimums, and standard deviations for specific conductance at the Old River South Delta continuous monitoring sites

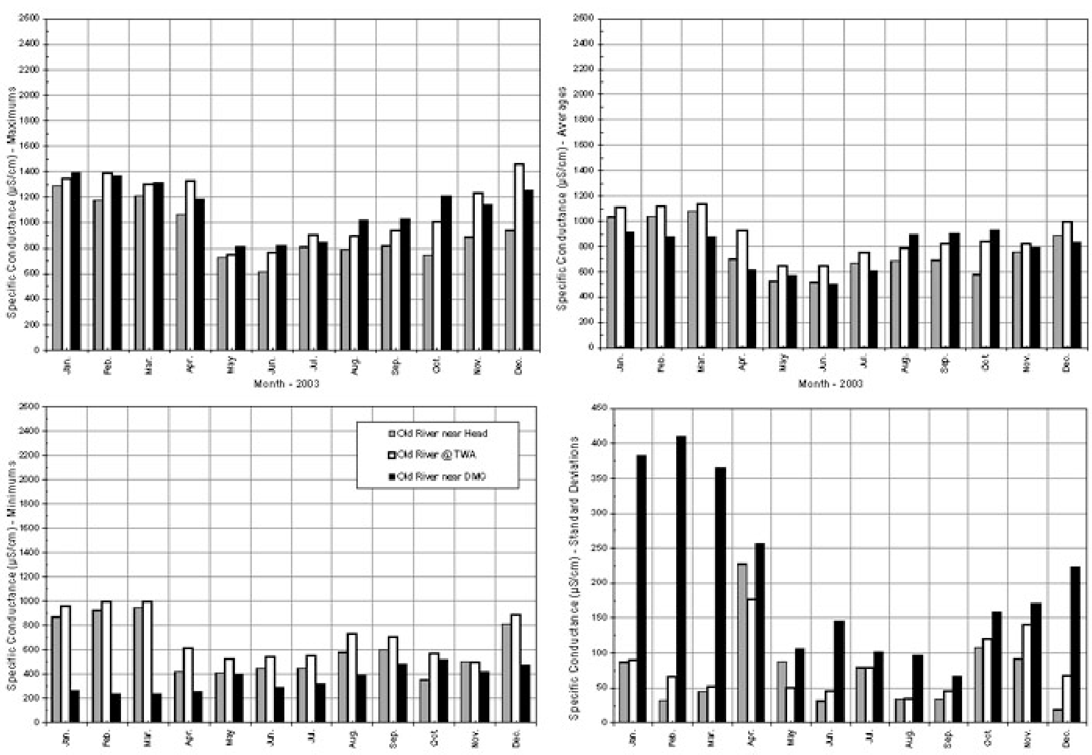


Figure 8-33 2003 Maximums, averages, minimums, and standard deviations for turbidity at the Middle River South Delta continuous monitoring sites

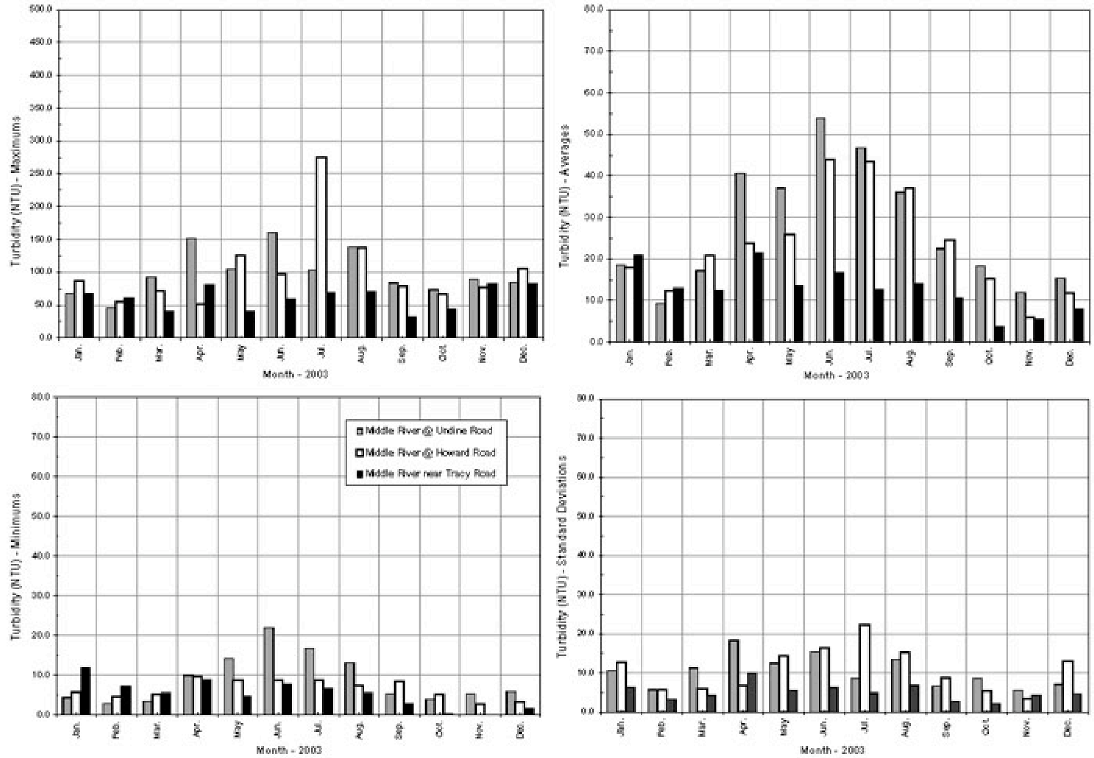


Figure 8-34 2003 Maximums, averages, minimums, and standard deviations for turbidity at the Old River South Delta continuous monitoring sites

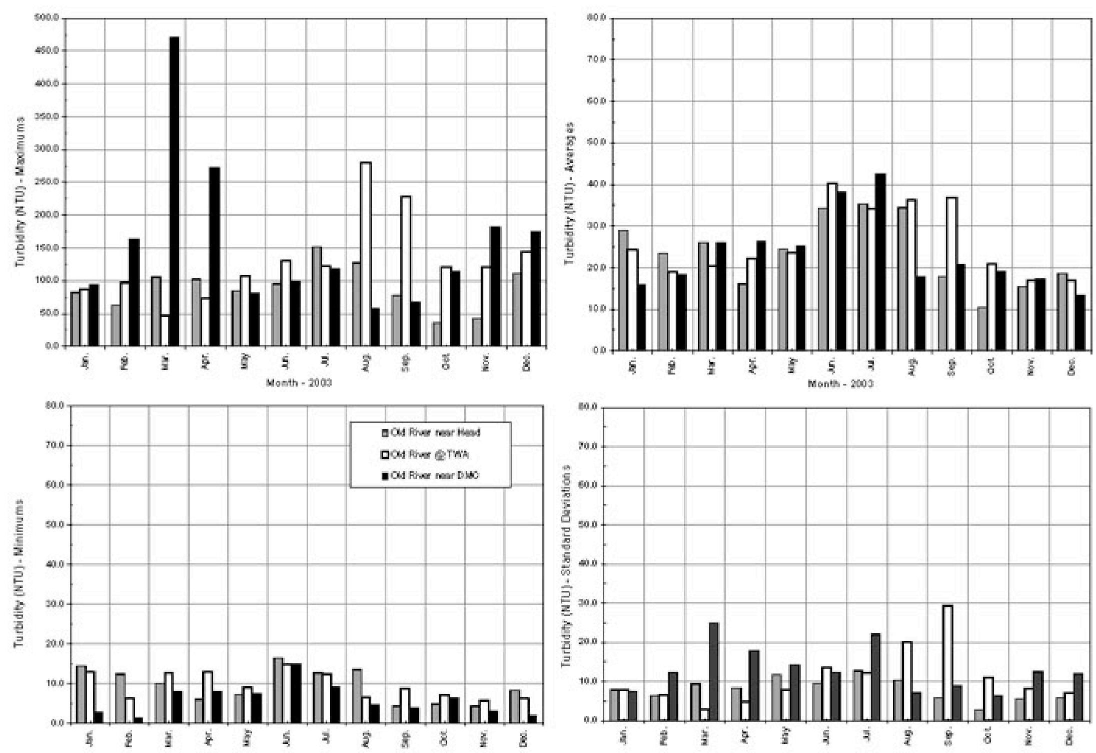


Table 8-14 2003 Discrete Water Quality Data at the six continuous monitoring sites

BRYTE LAB RESULTS						
Station	Middle River at Undine Road - 2003					
Constituent	NH_3-N (mg/L)	NO_2+NO_3-N (mg/L)	ORG.-N (mg/L)	PO_4 (mg/L)	CHL.-A (µg/L)	PHEO.-A (µg/L)
Max	0.13	2.60	1.10	0.17	170.00	118.00
Average	0.06	1.30	0.65	0.10	44.87	23.91
Min	0.01	0.25	0.40	0.03	2.91	2.19
Standard Deviation	0.04	0.59	0.18	0.04	45.18	30.34
Count	15	15	15	15	17	17
Station	Middle River at Howard - 2003					
Constituent	NH_3-N (mg/L)	NO_2+NO_3-N (mg/L)	ORG.-N (mg/L)	PO_4 (mg/L)	CHL.-A (µg/L)	PHEO.-A (µg/L)
Max	0.50	1.70	1.20	0.23	88.90	30.50
Average	0.15	0.76	0.81	0.08	20.79	9.07
Min	0.02	0.41	0.60	0.01	1.10	0.93
Standard Deviation	0.13	0.32	0.20	0.06	26.51	8.99
Count	16	16	16	16	16	16
Station	Middle River near Tracy Road - 2003					
Constituent	NH_3-N (mg/L)	NO_2+NO_3-N (mg/L)	ORG.-N (mg/L)	PO_4 (mg/L)	CHL.-A (µg/L)	PHEO.-A (µg/L)
Max	0.13	1.10	1.30	0.14	10.40	3.97
Average	0.06	0.54	0.54	0.05	3.92	1.80
Min	0.00	0.15	0.30	0.03	0.84	0.92
Standard Deviation	0.03	0.23	0.23	0.03	2.10	0.81
Count	15	15	15	15	15	15
Station	Old River near Head - 2003					
Constituent	NH_3-N (mg/L)	NO_2+NO_3-N (mg/L)	ORG.-N (mg/L)	PO_4 (mg/L)	CHL.-A (µg/L)	PHEO.-A (µg/L)
Max	0.18	2.95	0.80	0.17	293.50	82.70
Average	0.07	1.60	0.64	0.12	58.88	21.61
Min	0.02	0.87	0.40	0.05	5.92	3.40
Standard Deviation	0.04	0.65	0.13	0.04	69.03	20.60
Count	16	16	16	16	20	20
Station	Old River at Tracy Wildlife Association - 2003					
Constituent	NH_3-N (mg/L)	NO_2+NO_3-N (mg/L)	ORG.-N (mg/L)	PO_4 (mg/L)	CHL.-A (µg/L)	PHEO.-A (µg/L)
Max	0.39	2.62	1.50	0.19	83.80	30.50
Average	0.12	1.31	0.74	0.14	45.70	15.68
Min	0.01	0.20	0.50	0.07	4.63	3.84
Standard Deviation	0.12	0.69	0.25	0.04	24.03	8.96
Count	16	16	16	16	18	18

Table 8-14 2003 Discrete Water Quality Data at the six continuous monitoring sites (continued)

Station	Old River near Delta Mendota Canal - 2003					
Constituent	NH_3-N (mg/L)	NO_2+NO_3-N (mg/L)	ORG.-N (mg/L)	PO_4 (mg/L)	CHL.-A (µg/L)	PHEO.-A (µg/L)
Max	0.15	2.18	1.10	0.27	49.00	20.20
Average	0.09	1.06	0.69	0.12	10.59	6.57
Min	0.02	0.48	0.40	0.05	1.00	1.71
Standard Deviation	0.04	0.47	0.21	0.06	11.55	4.90
Count	16	16	16	16	18	18

Recommendations

Expanding the continuous monitoring network to include a few control stations on the downstream side of the barriers would greatly improve the baseline data in the vicinity of the barriers. These stations would measure the same water quality parameters that are already being measured upstream of the barriers. Data generated from these sites could be compared with data generated from sites impounded behind the barriers to assess upstream water quality changes. A possible location to start this expansion would be to place a continuous monitoring station just downstream of the Old River Barrier near DMC, as this location is proximate to an existing installation just upstream of the barrier. If two sites were to be selected, a monitoring site could be located just downstream of the Middle River barrier.

In addition, the next step in developing a greater understanding of South Delta water quality would be to expand the current continuous monitoring network to include Grant Line Canal. Adding sites within Grant Line Canal and Doughty Cut could provide more insight as to potential water quality degradation in Grant Line Canal. Continuous monitoring would complement Central District’s discrete water quality sampling program in this area. Again it would be prudent to install at least two sites, one upstream and one downstream of the GLC barrier to assess potential water quality impacts in the general vicinity of the barrier.

Depth profiling of dissolved oxygen during the summer months at various South Delta locations would be a useful means of determining differences in surface and bottom dissolved oxygen concentrations. Profiling may also help locate dissolved oxygen sinks, where further sampling may be needed to identify causes of degradation. Biochemical oxygen demand (BOD) sampling should be done at all six continuous monitoring sites during the spring, summer and early fall to determine the effect of microorganisms on dissolved oxygen.

Chapter 9. Hydrologic Modeling

This chapter describes the details of the simulation of historical 2003 Delta hydrodynamic conditions as requested by the Temporary Barriers and Lower San Joaquin Section in DWR's Bay-Delta Office. The period of simulation extends from January 1, 2003 to December 31, 2003.

To simulate the hydrodynamics, the Delta Modeling Section used DSM2-Hydro. DSM2-Hydro is a one-dimensional open channel unsteady flow model. It is based on a four-point finite difference solution of equations of momentum and continuity. The solution scheme has proven to be stable. The model network is extended north to Sacramento River at I street, and south to San Joaquin River at Vernalis. The downstream boundary is located at Martinez. A 15-minute time history of stage input at Martinez governs how the tide signal propagates into the Delta.

Boundary conditions

Flow and stage information required at model boundaries were downloaded from the IEP web site (www.iep.water.ca.gov). The IEP database includes data collected by various agencies including DWR and USGS. When duplicate data from more than one agency was available, they were assigned a priority order. As the first option, DSM2 uses data ranked at the highest priority, and then proceeds to those of lower priority if necessary. Priority was assigned based on data availability, quality of the data, and past experience. Input data, visually examined using plotting routines, was occasionally missing. In most cases, alternate sources of data filled any gaps. Resulting key boundary conditions for 2003 are shown in Figures 9-1 through 9-4.

Consumptive use

The Delta Island Consumptive Use (DICU) model provides an estimate of the amount of water diverted from and returned to Delta channels due to agriculture activities. Input to DICU model includes precipitation and pan evaporation data and water year types. The water year type determines which of two possible cropping patterns in the Delta is assumed, which in turn contributes to the estimation of agricultural water needs. This methodology for determining consumptive use values for 2003 has been detailed by Mierzwa (2004).

Figure 9-1 Daily average historical inflow from the Sacramento River, 2003.

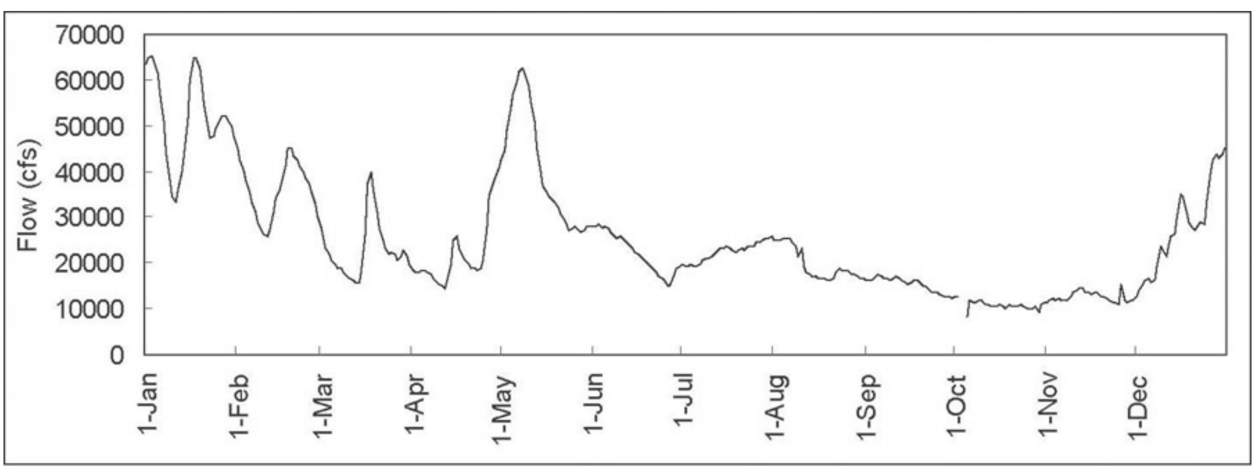


Figure 9-2 Daily average historical inflow from the San Joaquin River, 2003.

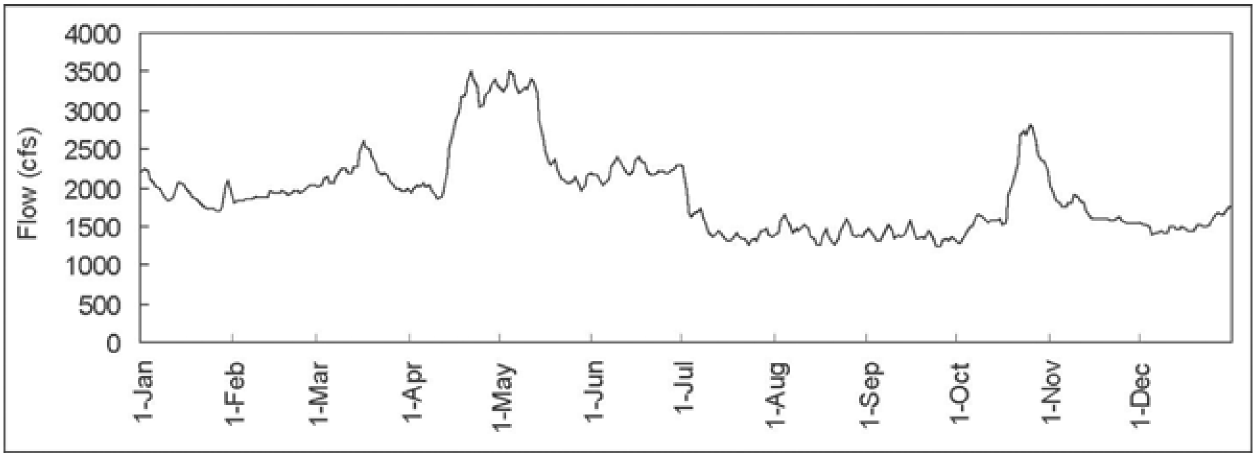


Figure 9-3 Daily average historical pumping at Banks and Delta Pumping plants, 2003.

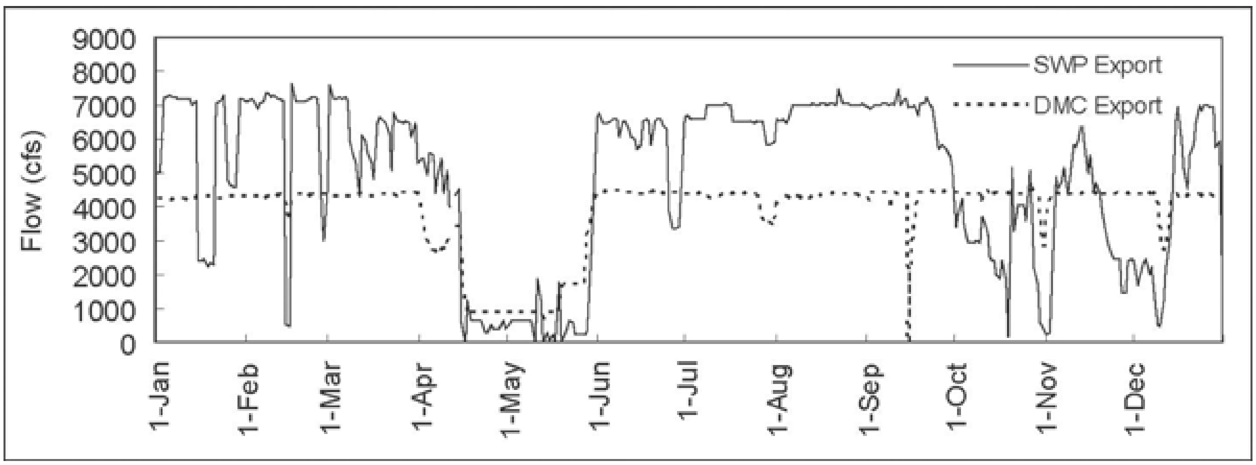
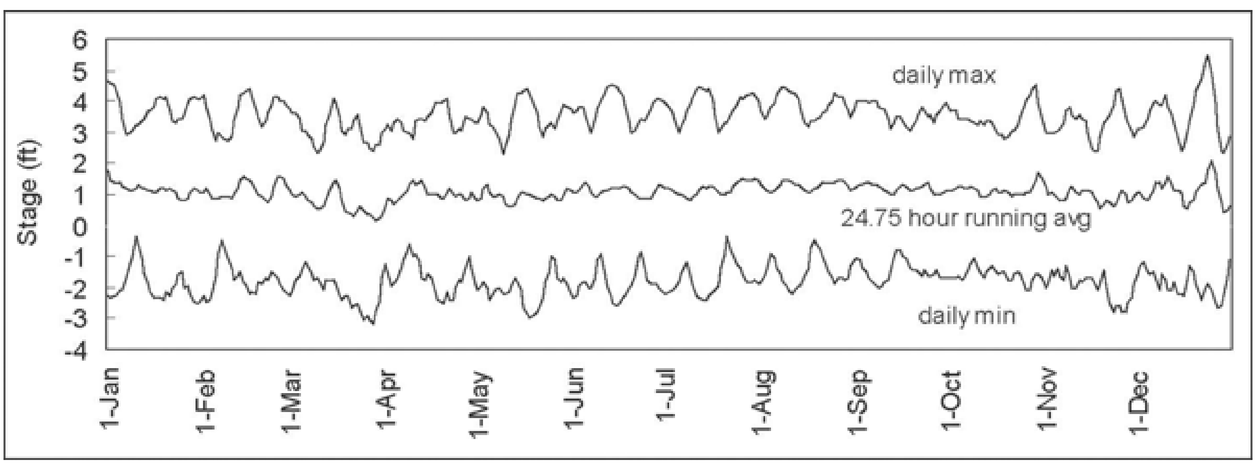


Figure 9-4 Daily maximum, minimum, and 24.75 hour running average of the historical stage at Martinez, 2003.



Delta Structures

All three temporary agricultural barriers were installed in 2003 in addition to the spring and fall barriers at the head of Old River. The fall barrier at the head of Old River varied from the spring barrier by being notched at 0.0 mean sea level. While installation and removal of the temporary barriers may have taken days or weeks, the DSM2 simulation timed the actual installation and removal to effective dates, as inferred from observed water levels. The table below describes the historical and DSM2-assumed operation of all the South Delta Barriers.

Table 9-1 Historical and DSM2-assumed south Delta barriers installation and removal, 2003.

	Installation			Removal		
Barrier	Started	Ended	DSM2	Started	Ended	DSM2
Middle River	4/1/03	4/15/03	4/15/03	11/7/03	11/10/03	11/7/03
Old River near DMC	4/1/03	4/15/03	4/14/03	11/13/03	11/15/03	11/14/03
Grant Line Canal						
Boat Ramp	4/1/03	4/12/03	4/7/03	--	--	--
Full Barrier	6/10/03	6/10/03	6/10/03	11/10/03	11/13/03	11/13/03
Old River @ Head (spring)	4/1/03	4/15/03	4/15/03	5/16/03	5/16/03	5/16/03
Old River @ Head (fall)	9/22/03	9/22/03	9/22/03	11/4/03	11/5/03	11/5/03

The Delta Cross Channel gates were operated in 2003 as according to the table below.

Table 9-2 Historical Delta Cross Channel operation for 2003.

Time Interval					
Date	Time		Date	Time	Status
1/1/03	0000	-	5/30/03	1526	closed
5/30/03	1526	-	6/2/03	0724	open
6/2/03	0724	-	6/6/03	1012	closed
6/6/03	1012	-	6/9/03	0808	open
6/9/03	0808	-	6/12/03	0825	closed
6/12/03	0825	-	12/1/03	1000	open
12/1/03	1000	-	12/31/03	2400	closed

Accuracy of DSM2 Simulation of 2002 Delta Hydrodynamics

DSM2-simulated stages and flows have been compared to historical data at several locations in the south Delta (Figure 9-5). At the time of this report, little flow data were available and field stage data were obtained from DWR's California Data Exchange Center (CDEC) and have not yet been officially screened. For the purpose of this report, obvious errors in the CDEC data were removed. Figure 6 shows the historical and DSM2-simulated daily maximum and minimum stages at 9 locations in the south Delta near barriers and the daily average stage within Clifton Court Forebay. DSM2-simulated stages followed historical stage patterns. The most notable deviation of DSM2-generated stage from field-measured stage occurred inside Clifton Court Forebay in the April 15 – May 15 period when DSM2 failed to reproduce the significant drop is water level inside the forebay. During this time, SWP pumping was low, and presumably the forebay intake gates were not opened as frequently as usual. The DSM2 simulation assumed that, when water is being taken into the forebay, all five intake gates are fully open. Either this assumption or an incorrect accounting of intake gate openings perhaps let too much channel water entering the forebay during April 15 – May 15 period, keeping water levels inside the forebay high. Of course, this conjecture assumes that the field data inside the forebay are correct. In addition to this anomaly, the field-measured minimum stage in Middle River at Howard Road and at RMID027 was consistently about 1 foot higher than DSM2-simulated. Otherwise, DSM2-generated stages (as indicated by daily maximum and minimum stage) generally recreated measured values. At two sites immediately downstream of the temporary barriers on Grantline Canal and Old River (GRL009 and ROLD046), DSM2-generated minimum stages were about _ foot below measured stages during the times that all three agricultural barriers were installed. This may reflect the current configurations of the barriers in DSM2 that fails to account for seepage through the rock barriers, but more investigation is needed to confirm this possibility. No such field stage data were available downstream of the Middle River barrier to expand this analysis. These DSM2 model results do suggest that modeled minimum water levels downstream of temporary barriers may be too low.

Figure 9-5 Locations where 2003 historical and DSM2-simulated hydrodynamics are compared.

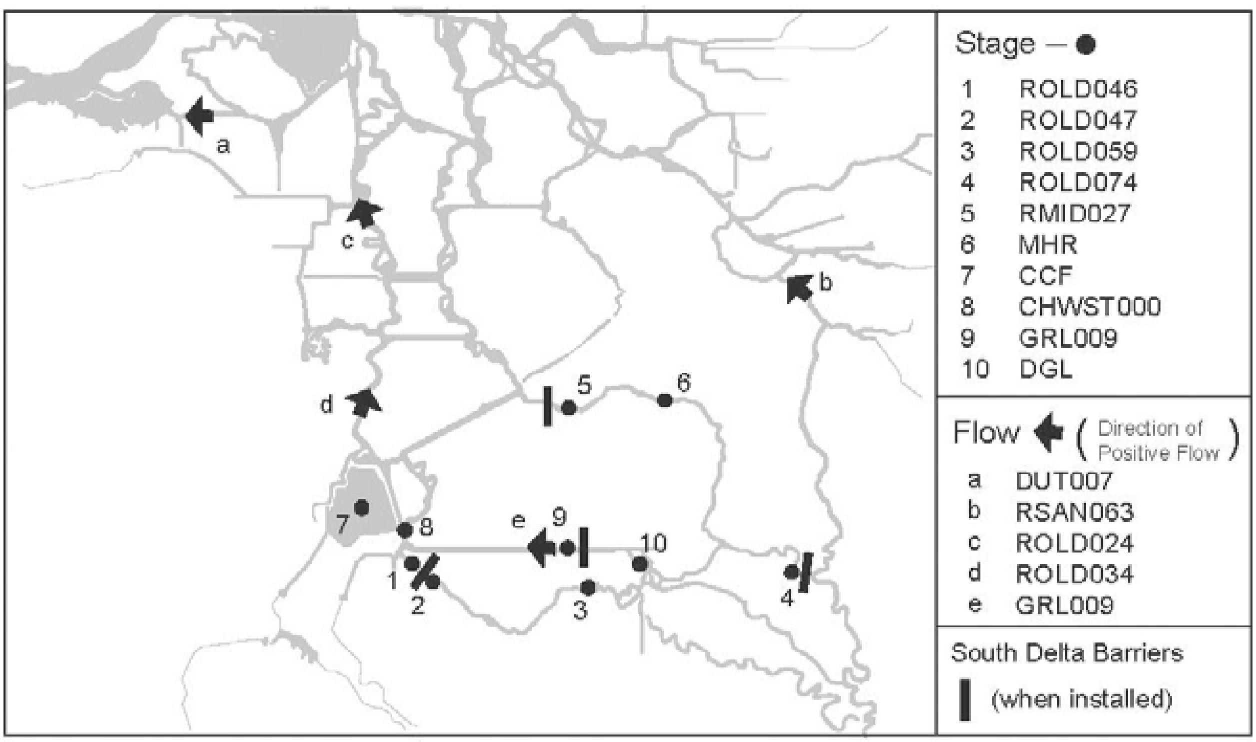


Figure 9-6 Daily maximum and minimum historical and DSM2-simulated stage, 2003.

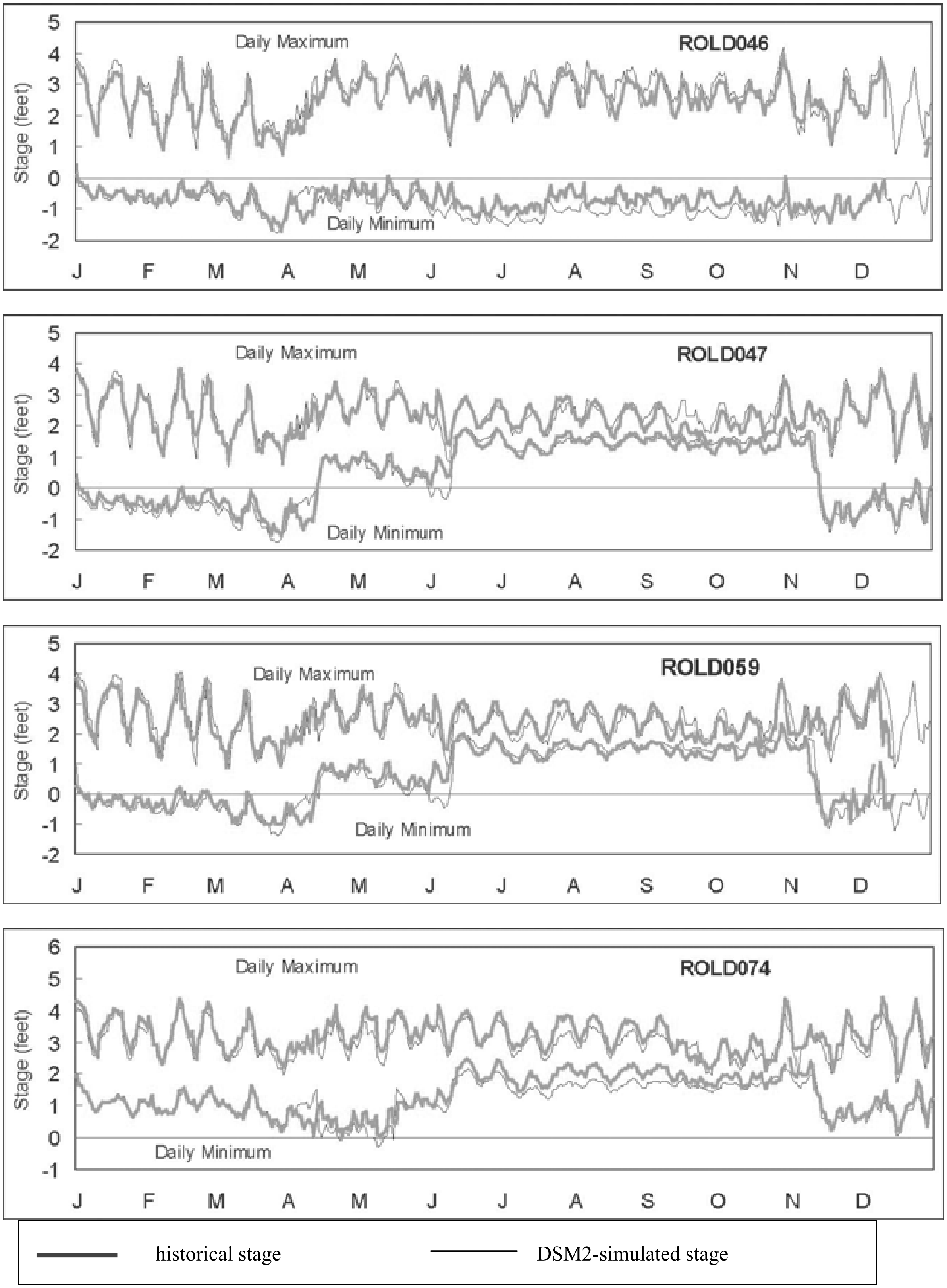


Figure 9-6 (cont.) Daily maximum and minimum historical and DSM2-simulated stage, 2003.

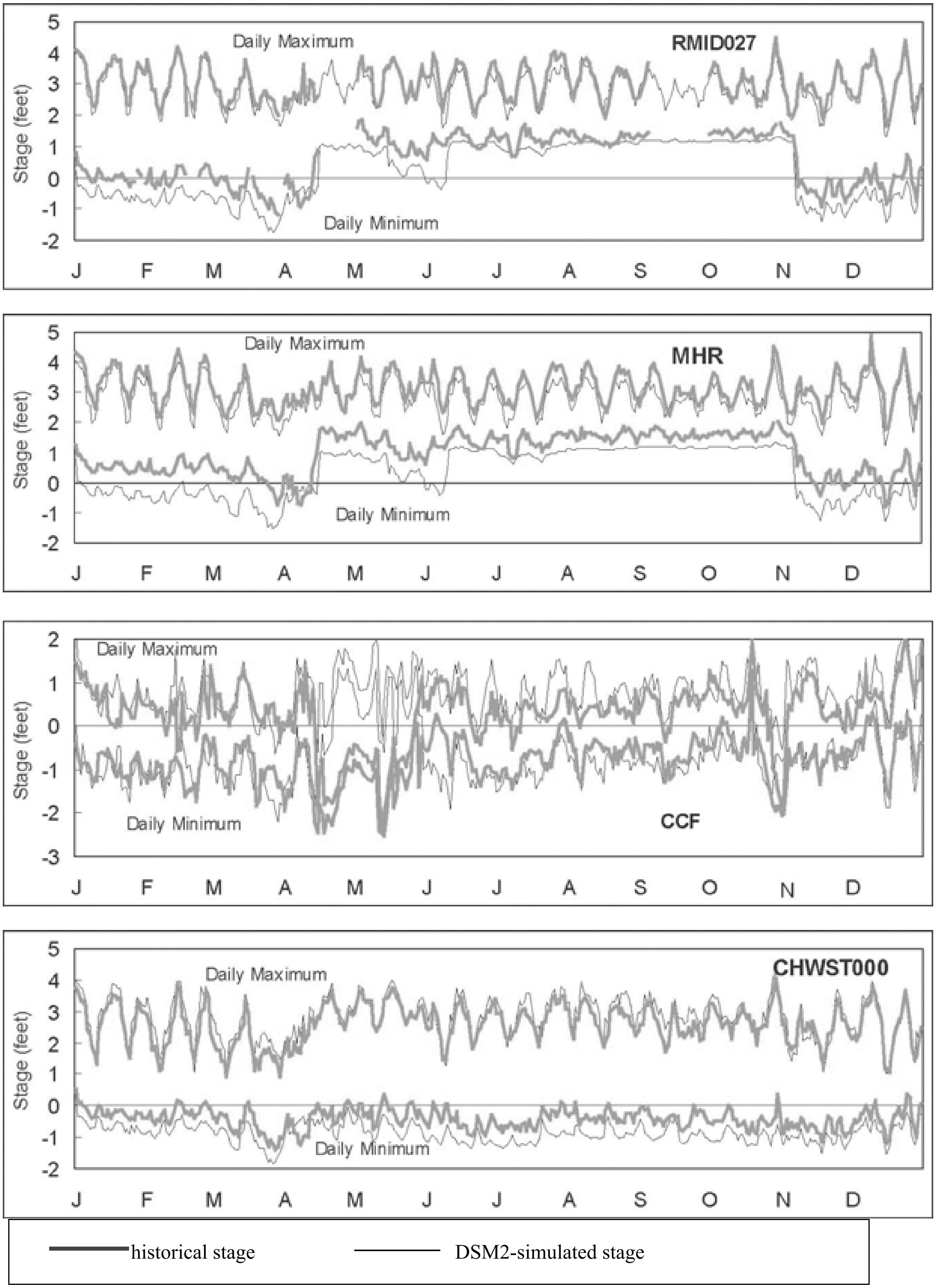


Figure 9-6 (cont.) Daily maximum and minimum historical and DSM2-simulated stage, 2003.

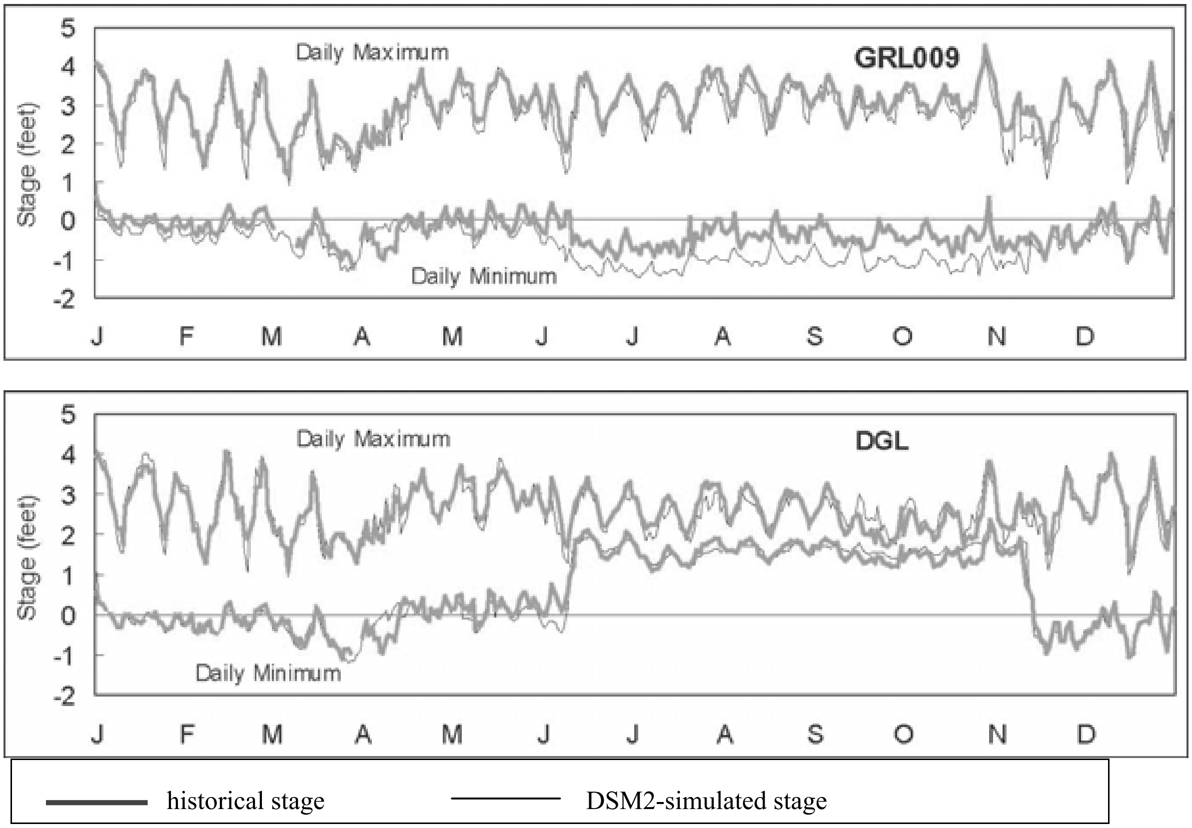


Figure 9-7 shows the historical and DSM2-simulated daily average flows at 8 locations in the Delta. Flows generated by DSM2 compare well to the available historical flows. However, no comparison is yet possible at a location under the influence of a barrier operation. By common sign convention, positive flows refer to downstream flow while negative flow corresponds to upstream flow (see Figure 9-5).

Figure 9-7 Historical and DSM2-simulated flow for 2003.

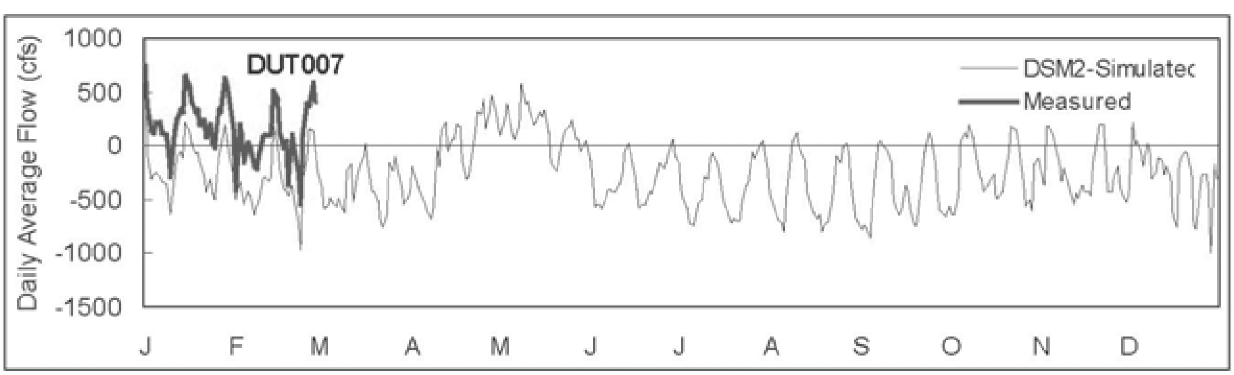
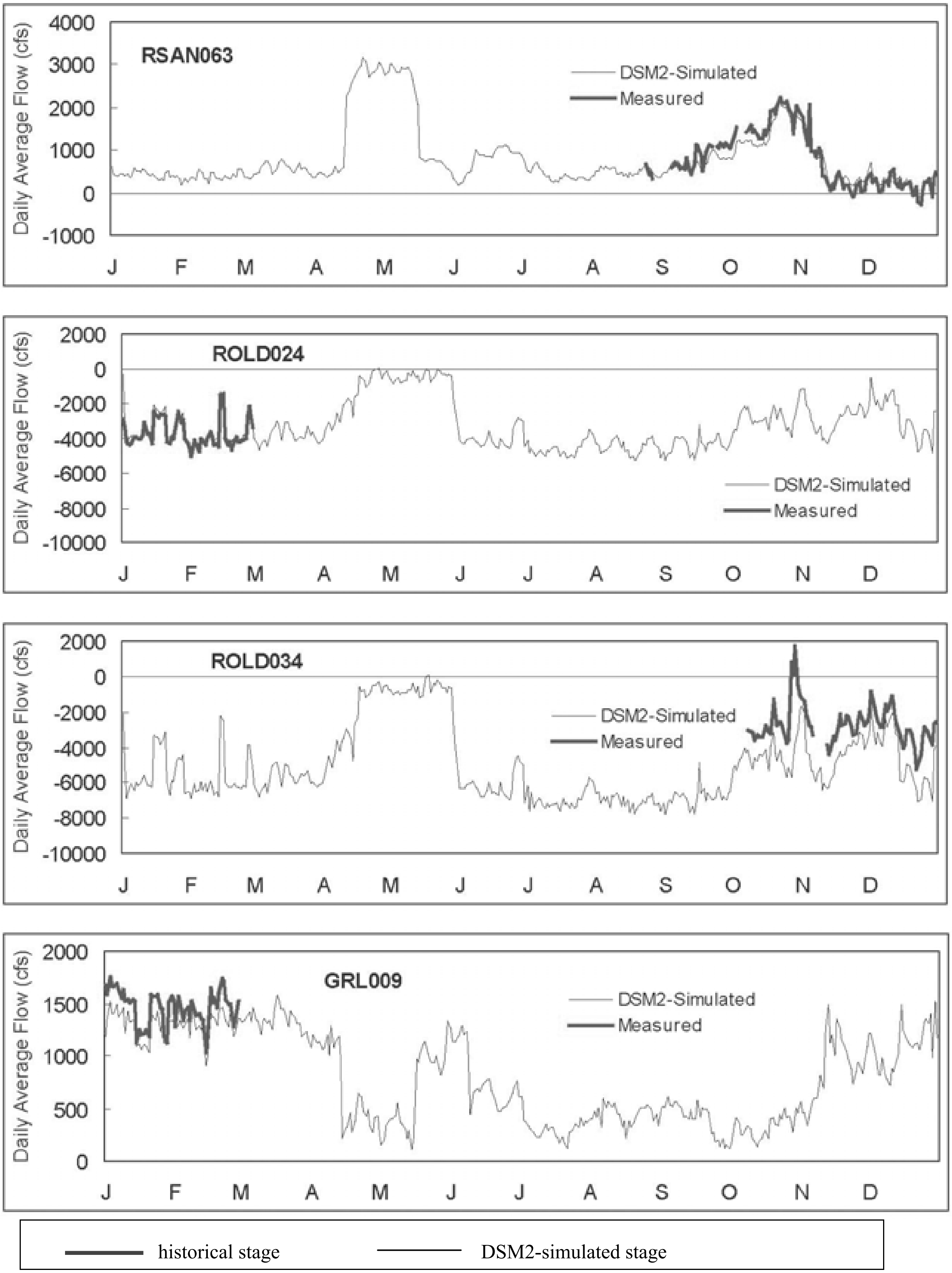


Figure 9-7 (cont.) Historical and DSM2-simulated flow for 2003.



DSM2 Simulation of 2003 Hydrodynamics

In order to aid the interpretation of DSM2-simulated hydrodynamics, 2003 was broken up into 26 periods. These periods primarily correspond to times for which significant Delta inflows and exports were fairly constant and south Delta barrier configurations were unchanging. Exceptions were the periods April 14-15, November 4-6, and November 13-14 which experienced transitions of multiple barrier installation or removal. The 26 periods and their characteristics are shown in the table below.

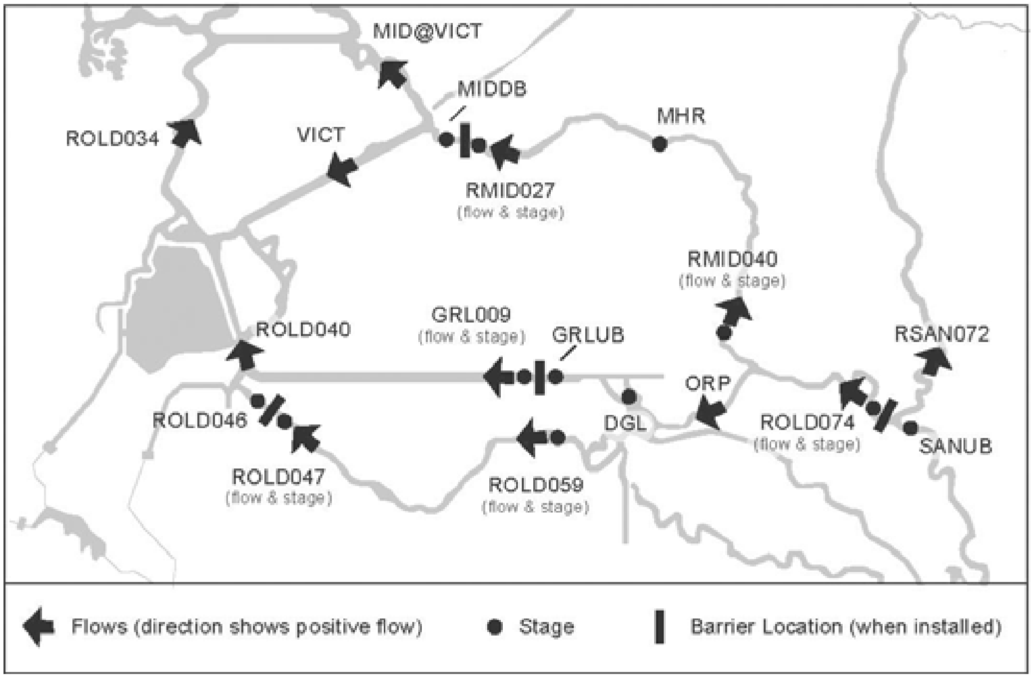
Hourly simulated stage and flow data for each period were used to generate data for box plots which graphically show period minimum, maximum, 25% quartile, 75% quartile, and average values. By typical sign convention, negative flow values correspond to upstream flow. The locations where box plots of stage and flow are presented are shown in Figure 8 with arrows indicating assumed positive flow direction. The numerical values these graphs are based upon are presented in the Appendix B to this report.

The distributions of simulated stages and flow for each of the 24 intervals are shown in Figures 9-9 and 9-10. Stage results are presented upstream and downstream of each barrier location and flows are presented throughout the south Delta in order to convey the general circulation patterns. The minimum stages and the average flows from the distributions of data in Figures 9-9 and 9-10 are shown in Figure 9-11 which graphically presents the flow circulation and minimum water levels caused by the installation of the south Delta barriers in 2003.

Table 9-3 Characteristics of intervals during 2003 for presentation of simulation results

Period		Period Average Flows				Period Barrier Status			
		Sac River + Yolo Bypass (cfs)	San Joaquin River (cfs)	DMC Pumping (cfs)	SWP Pumping (cfs)	MR	OR	GLC	ORH
JAN	1 - 31	58,108	1,930	4,254	5,783	--	--	--	--
FEB	1 - 28	36,113	1,921	4,266	6,351	--	--	--	--
MAR	1 - 31	23,471	2,189	4,347	6,254	--	--	--	--
APR	1 - 13	16,923	1,994	2,966	4,947	--	--	--	--
	14 - 15	26,132	2,633	2,508	2,562	--	IN	--	IN
	16 - 30	27,422	3,230	858	519	IN	IN	--	IN
MAY	1 - 15	54,044	3,249	849	618	IN	IN	--	IN
	16 - 19	34,186	2,369	1,007	496	IN	IN	--	--
	20 - 28	28,591	2,092	1,853	332	IN	IN	--	--
	29 - 31	27,853	2,132	3,966	4,345	IN	IN	--	--
JUN	1 - 8	27,475	2,161	4,441	6,497	IN	IN	--	--
	9 - 24	21,551	2,260	4,395	6,304	IN	IN	IN	--
	25 - 30	16,940	2,240	4,386	4,175	IN	IN	IN	--
JUL	1 - 31	22,351	1,481	4,192	6,592	IN	IN	IN	--
AUG	1 - 31	19,644	1,431	4,300	6,954	IN	IN	IN	--
SEP	1 - 21	16,395	1,409	4,013	7,038	IN	IN	IN	--
	22 - 30	13,271	1,325	4,450	5,974	IN	IN	IN	IN
OCT	1 - 19	11,408	1,564	4,370	2,797	IN	IN	IN	IN
	20 - 27	10,434	2,594	4,385	4,128	IN	IN	IN	IN
	28 - 31	10,628	2,330	3,740	1,203	IN	IN	IN	IN
NOV	1 - 3	11,608	1,930	3,991	827	IN	IN	IN	IN
	4 - 6	11,967	1,778	4,360	4,712	IN	IN	IN	IN/--
	7 - 12	13,296	1,839	4,334	5,317	--	IN	IN/--	--
	13 - 14	14,161	1,664	4,383	6,273	--	IN/--	--	--
	15 - 30	12,274	1,584	4,354	3,237	--	--	--	--
DEC	1 - 31	28,237	1,517	4,143	4,205	--	--	--	--

Figure 9-8 Locations where simulated Delta stages and flows for 2003 are presented.



Discussion

The installation of the temporary barriers in 2003 significantly altered stages and flows in the south Delta. Minimum water levels tended to be raised 1 to 1-1/2 feet in April and May in Middle and Old rivers upstream of the barriers, while minimum water levels immediately downstream of the barrier at the head of Old River fell about 1/2 foot due to the barrier here. Minimum water levels upstream of GRL009 did not improve until the full barrier was installed here in June. Once all three agriculture barriers (Old River, Grant Line Canal, and Middle River) were installed, minimum stages upstream of the barriers further improved about 1/2 foot. These increases in minimum stage were consistent from June 9 to November 3, even when the barrier at the head of Old River was in place from September 22 to November 3. This was probably due to a combination of the Grant Line Canal barrier remaining in place, raising water levels in the reaches of channels bounded by the barriers, and because the fall barrier at the head of Old River was notched at 0.0 msl. Examining both field and DSM2-generated data, minimum water levels immediately downstream of the three agriculture barriers seemed to decrease once the Grant Line Canal barrier was installed; however, considering the previously mentioned DSM2 error at these locations, no definitive conclusion can be made at this time.

In general, the installation of the temporary barriers also resulted in reduced tidal variation in flows near the barriers, a trend once again made more pronounced in Old and Middle River with the installation of the barrier in Grant Line Canal. Each of the barriers still allowed some downstream flow, while both upstream and downstream flow was suppressed at each barrier site.

Figure 9-9 Box Plots showing distribution of DSM2-simulated stages for various periods during 2003.

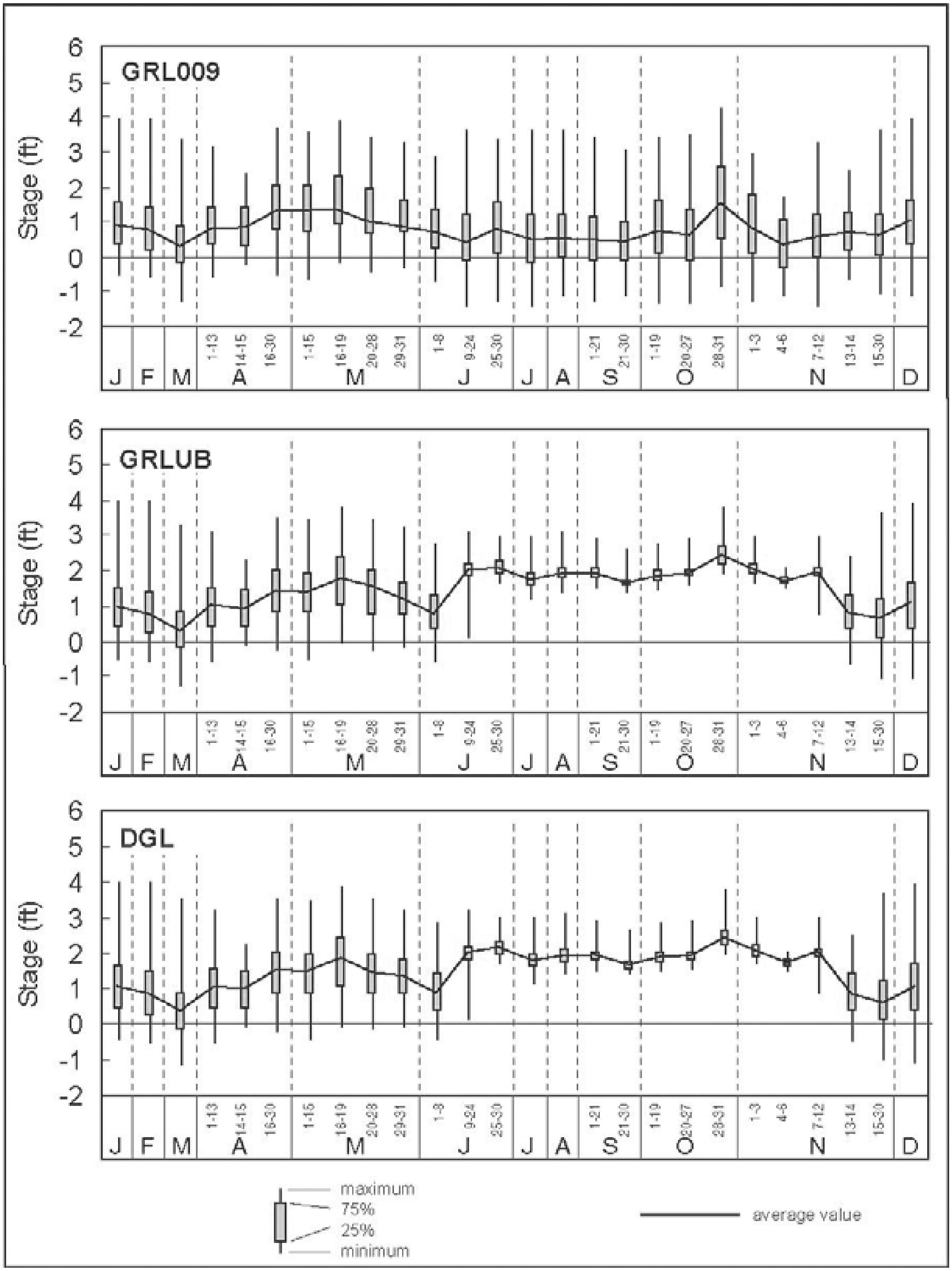


Figure 9-9 (cont.) Box Plots showing distribution of DSM2-simulated stages for various periods during 2003.

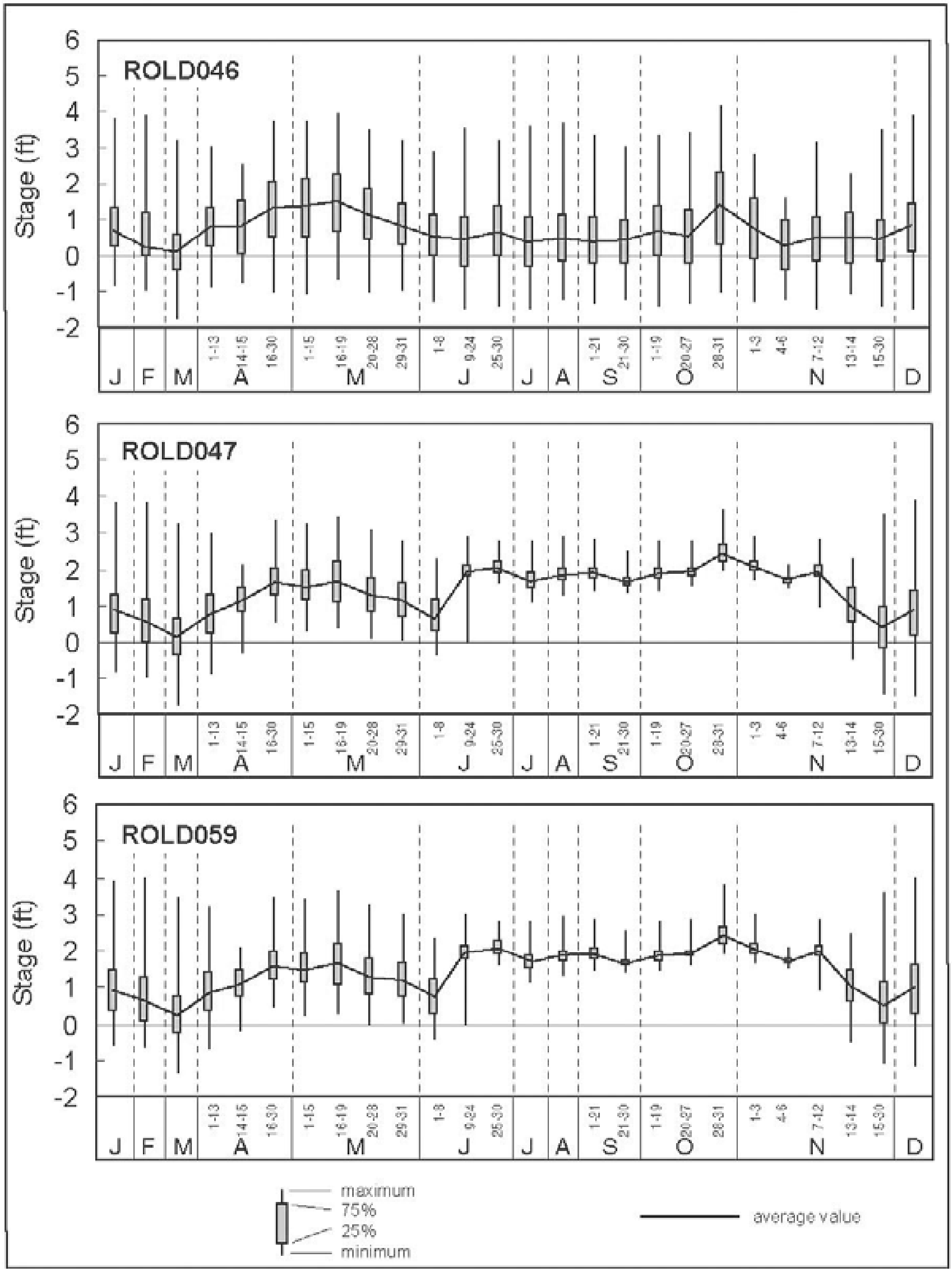


Figure 9-9 (cont.) Box Plots showing distribution of DSM2-simulated stages for various periods during 2003.

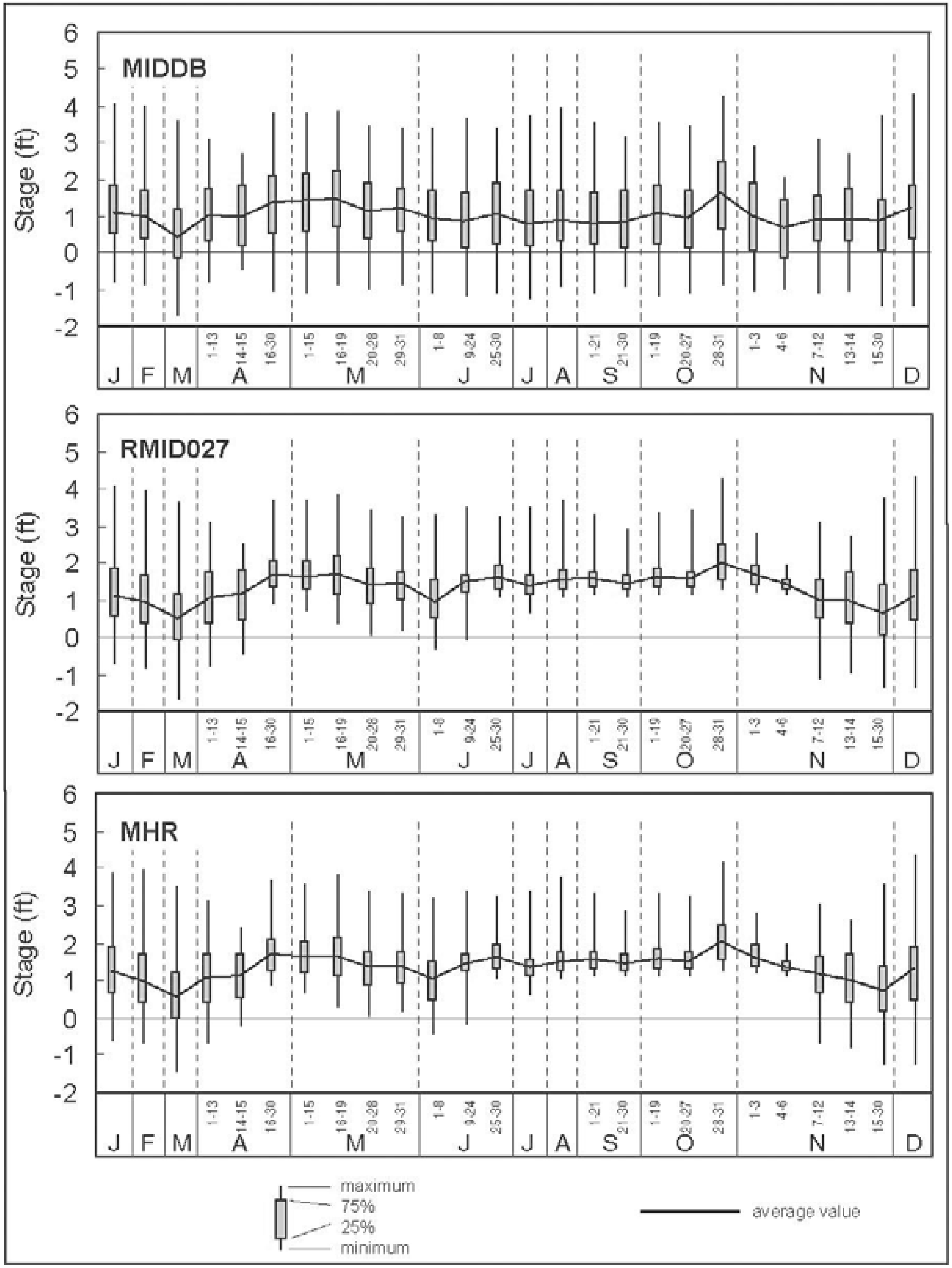


Figure 9-9 (cont.) Box Plots showing distribution of DSM2-simulated stages for various periods during 2003.

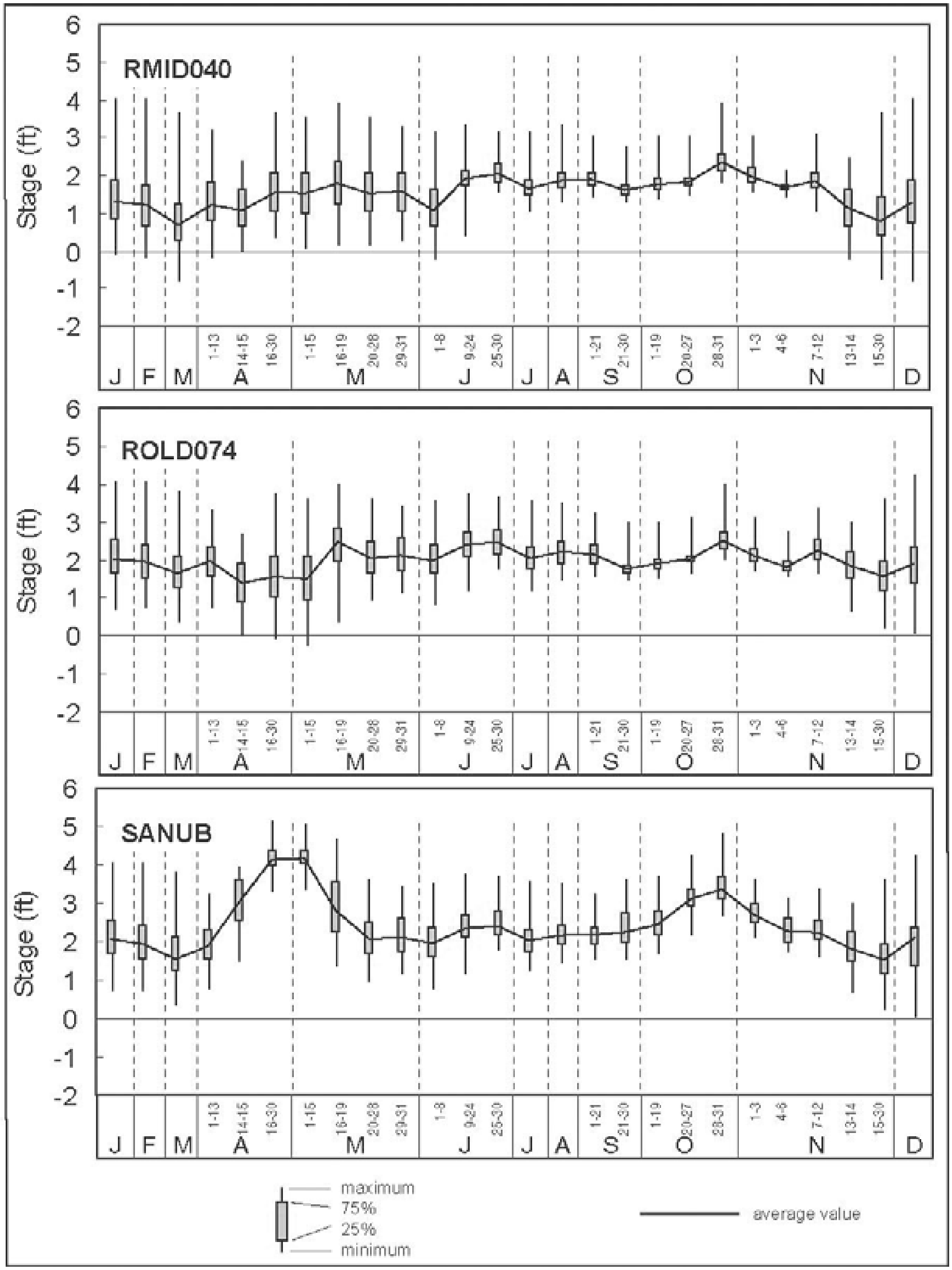


Figure 9-10 Box Plots showing distribution of DSM2-simulated flows for various periods during 2003.

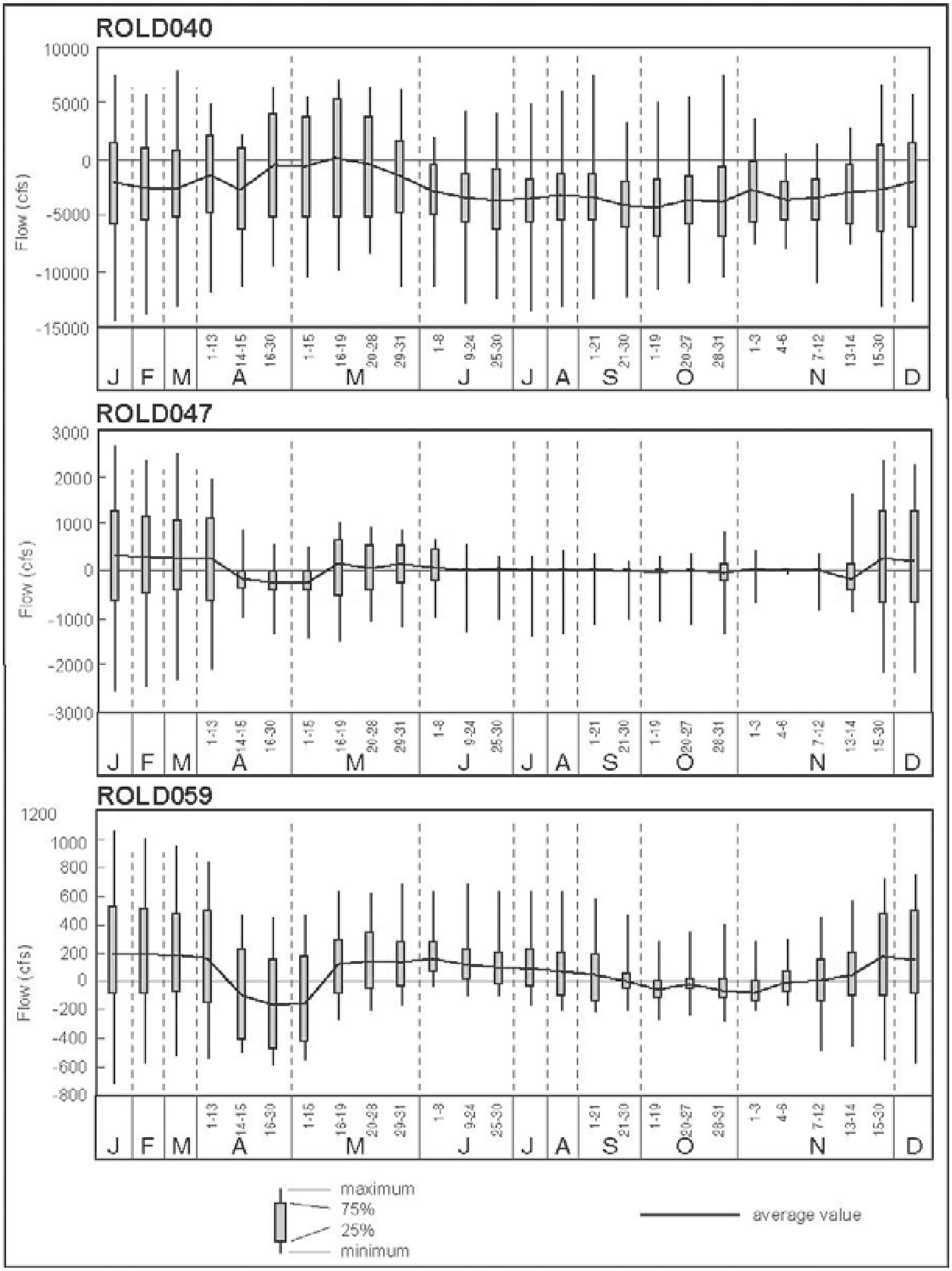


Figure 9-10 (cont.) Box Plots showing distribution of DSM2-simulated flows for various periods during 2003.

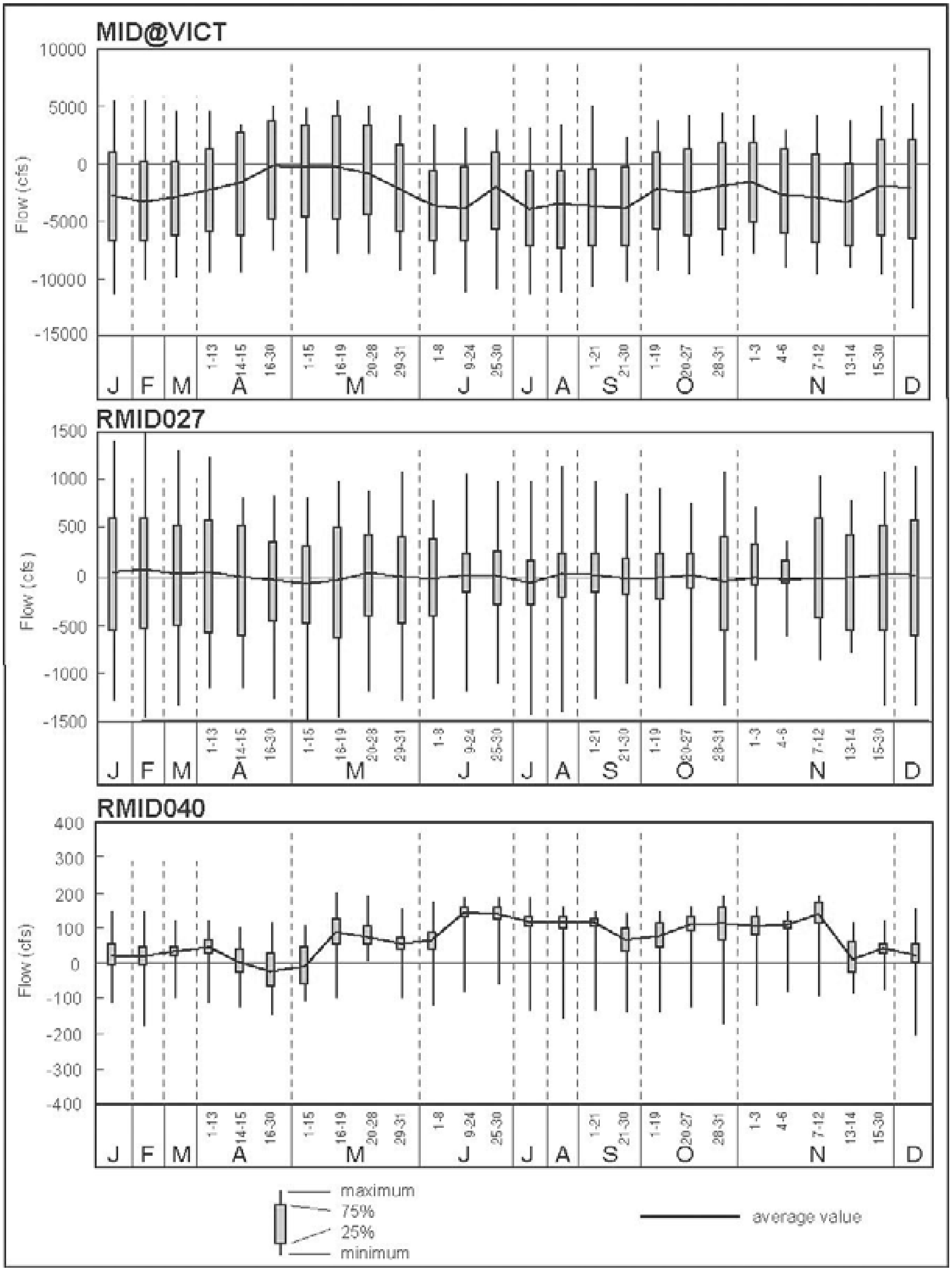


Figure 9-10 (cont.) Box Plots showing distribution of DSM2-simulated flows for various periods during 2003.

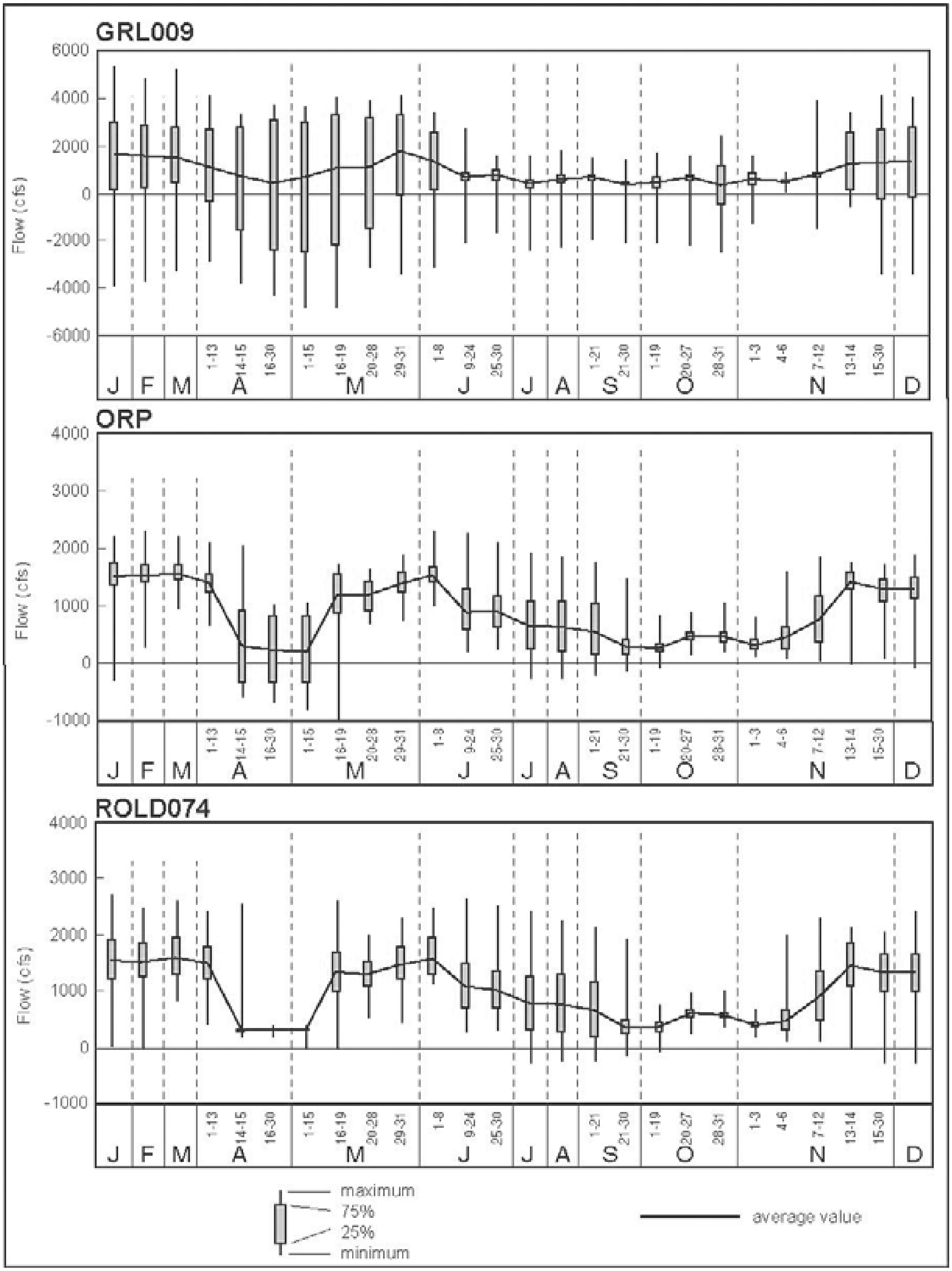


Figure 9-10 (cont.) Box Plots showing distribution of DSM2-simulated flows for various periods during 2003.

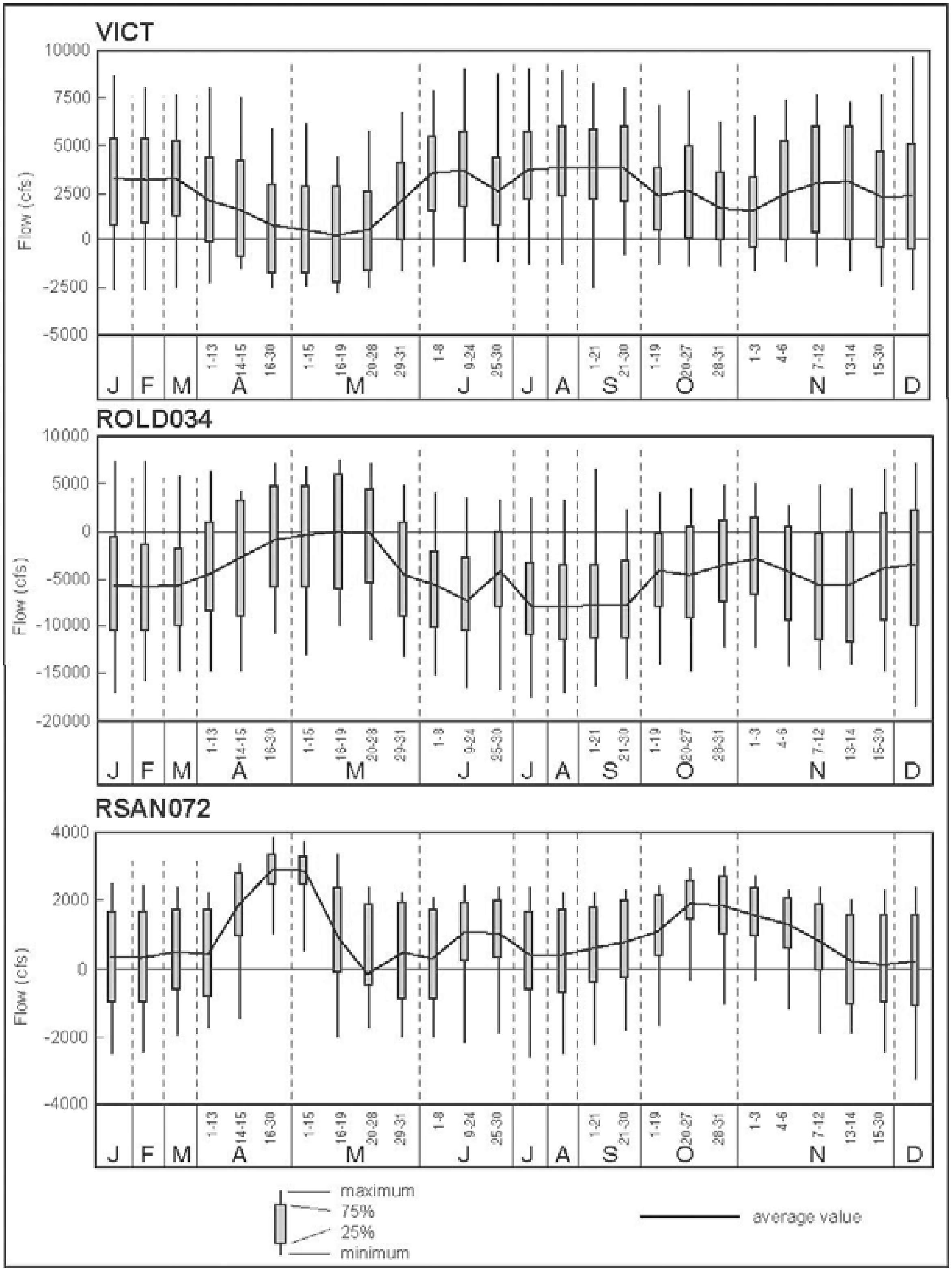


Figure 9-11 DSM2-simulated average flow patterns and minimum stages for 2003.

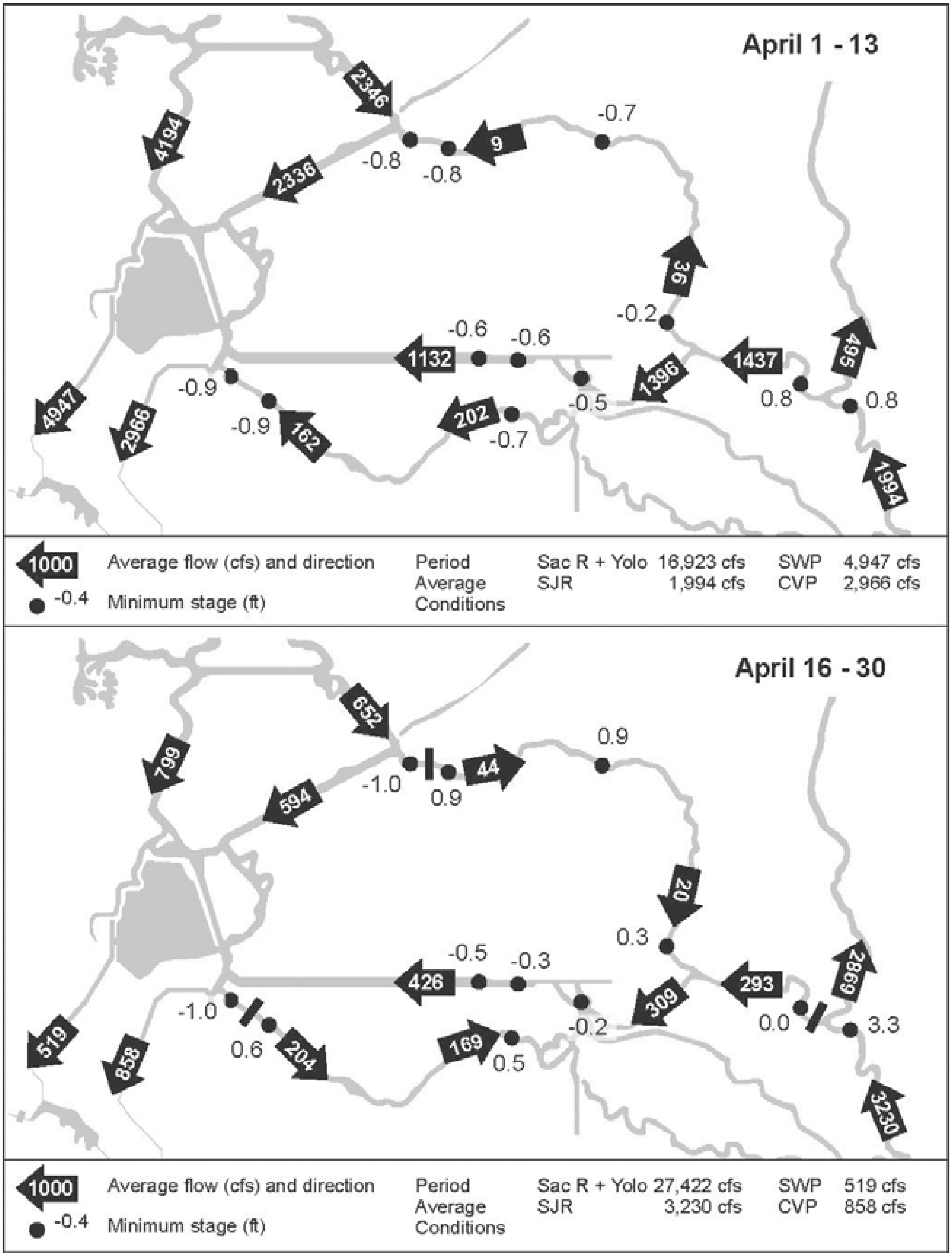


Figure 9-11 (cont.) DSM2-simulated average flow patterns and minimum stages for 2003.

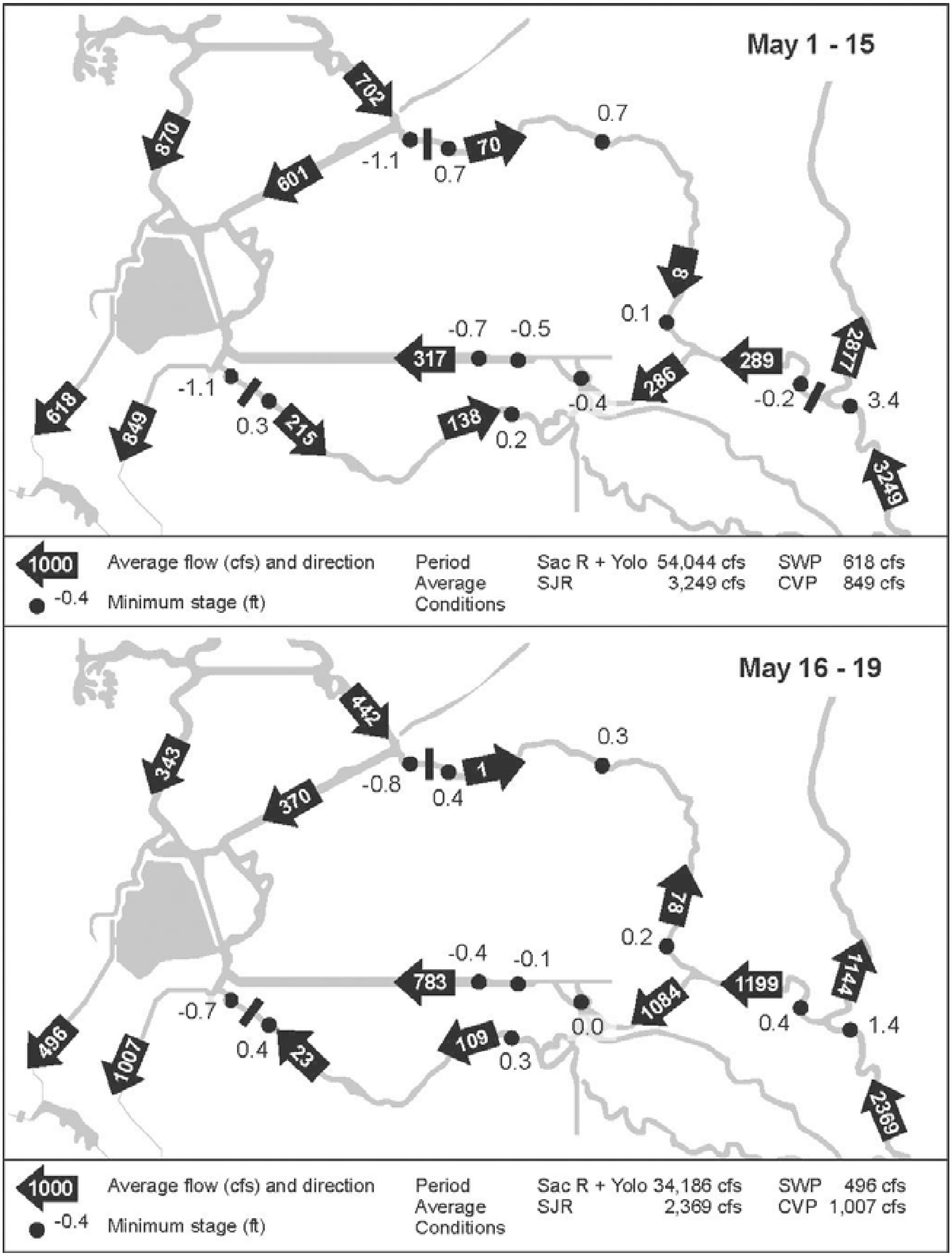
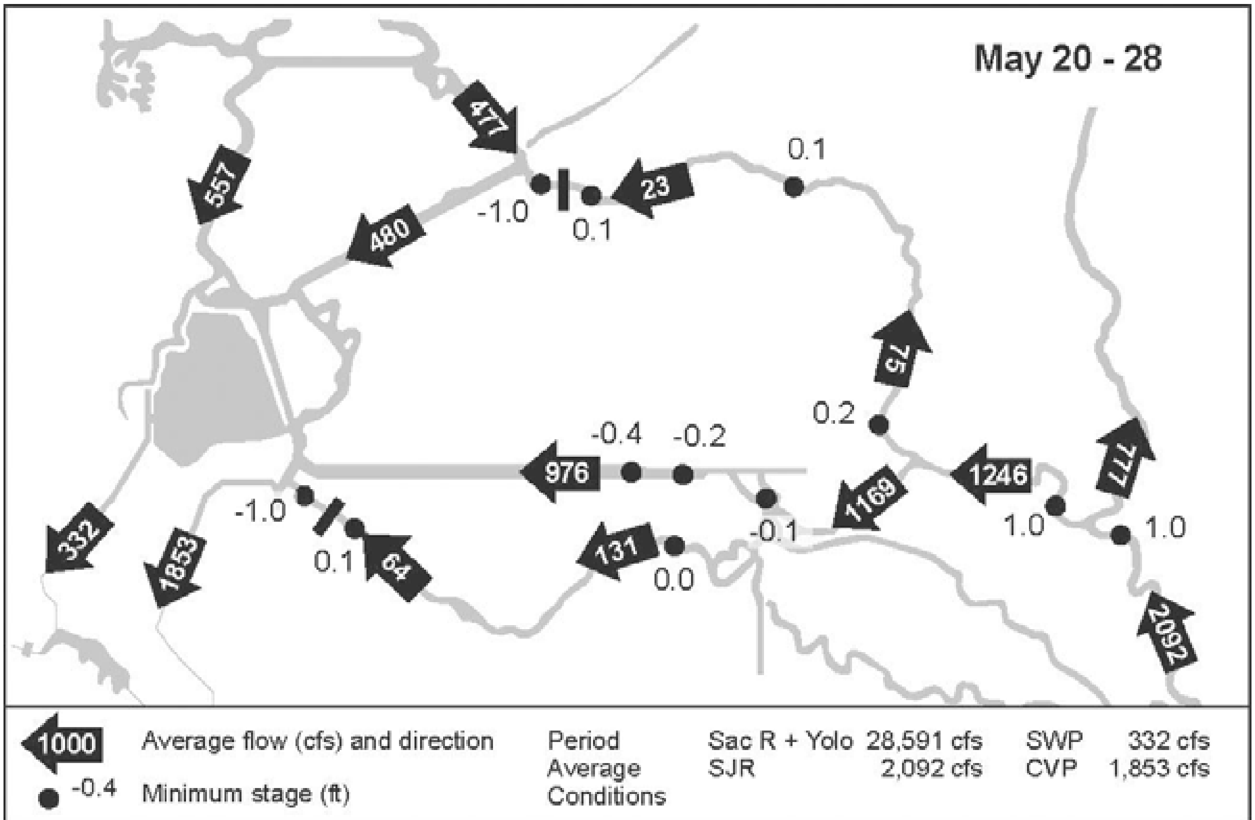


Figure 9-11 (cont.) DSM2-simulated average flow patterns and minimum stages for 2003.



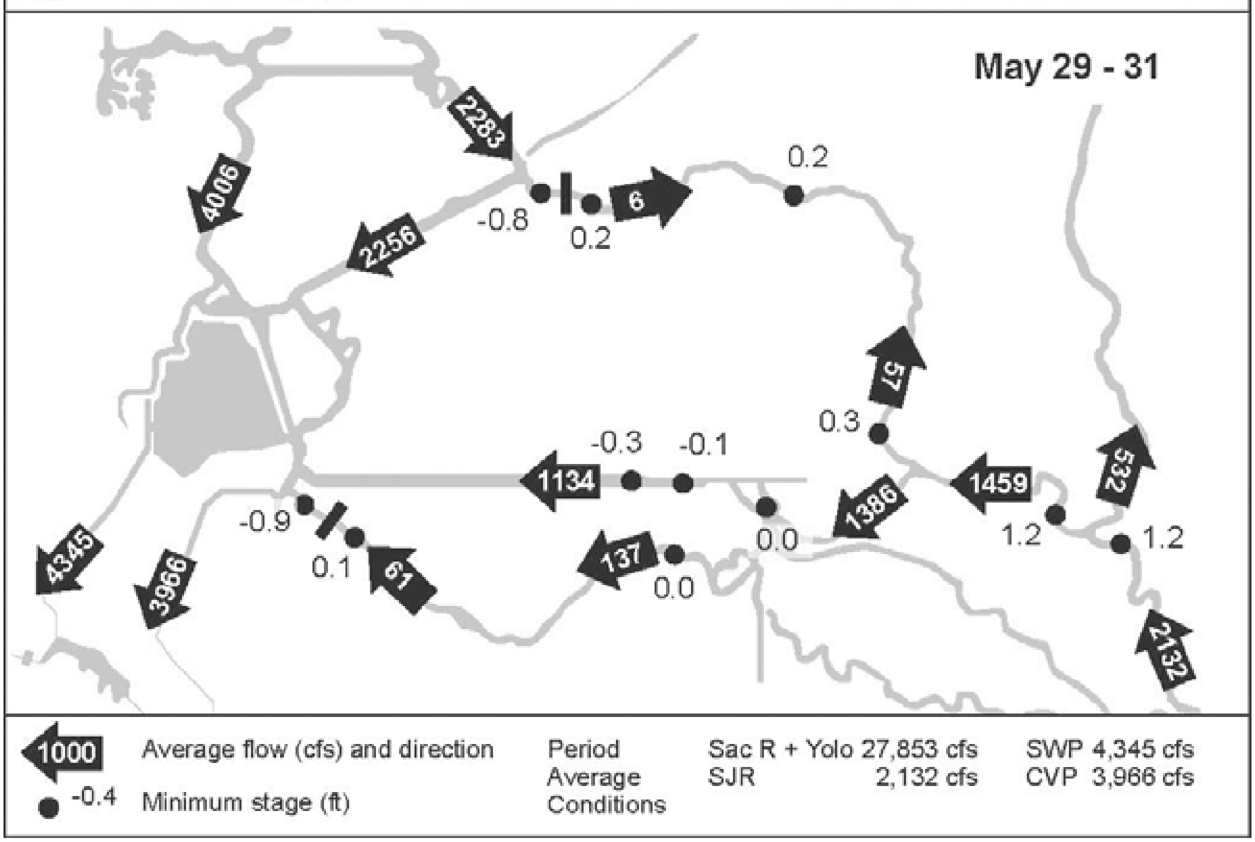


Figure 9-11 (cont.) DSM2-simulated average flow patterns and minimum stages for 2003.

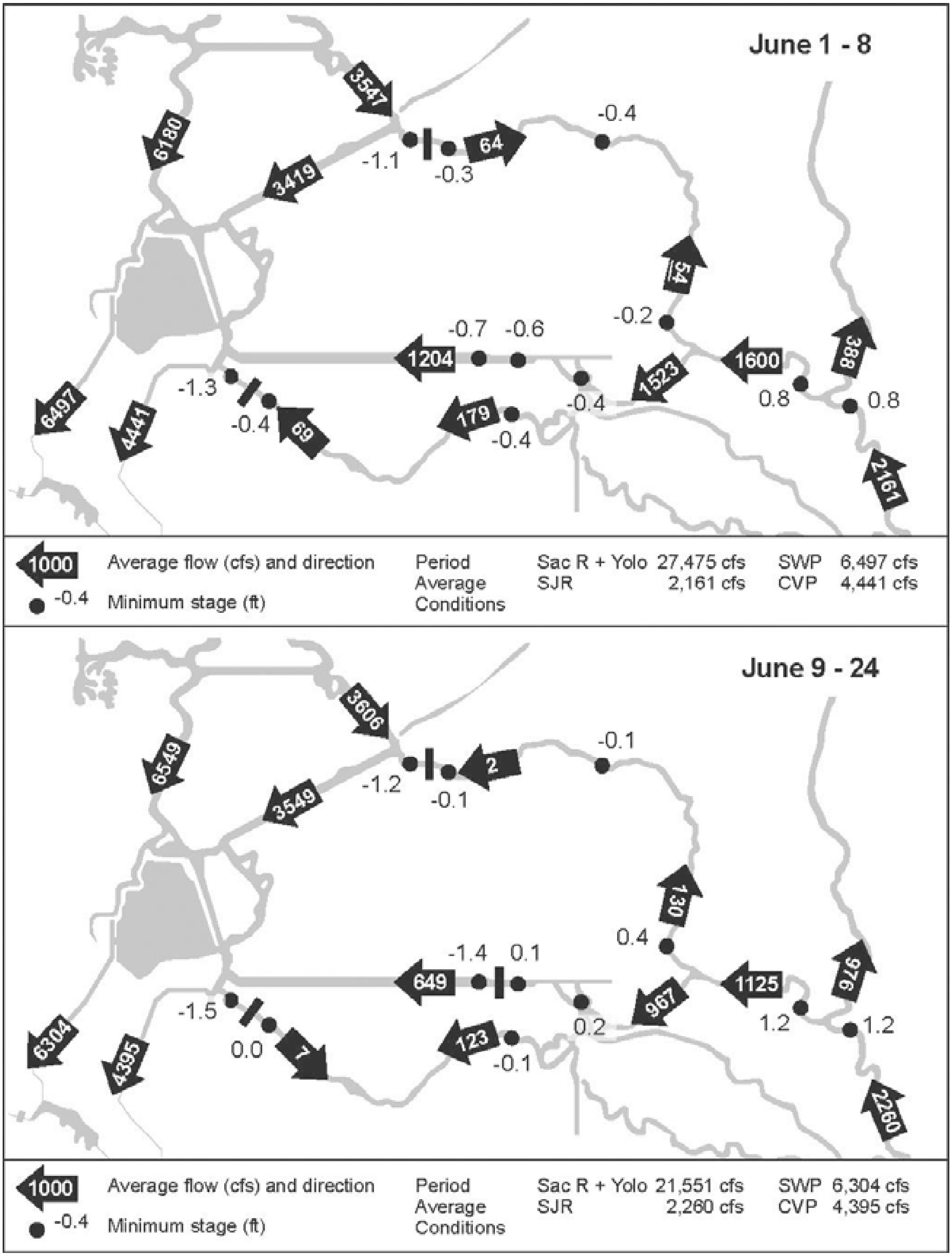


Figure 9-11 (cont.) DSM2-simulated average flow patterns and minimum stages for 2003.

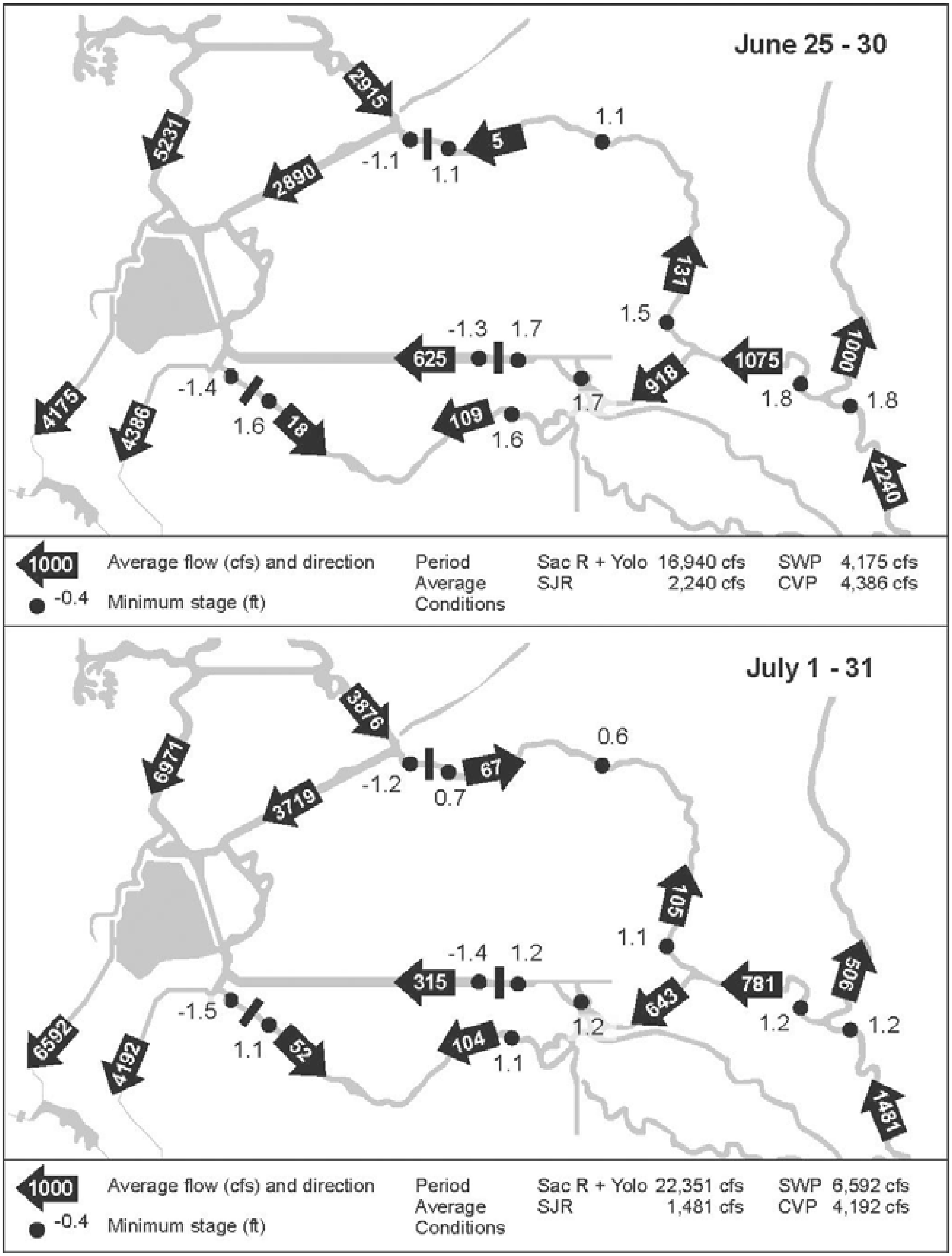


Figure 9-11 (cont.) DSM2-simulated average flow patterns and minimum stages for 2003.

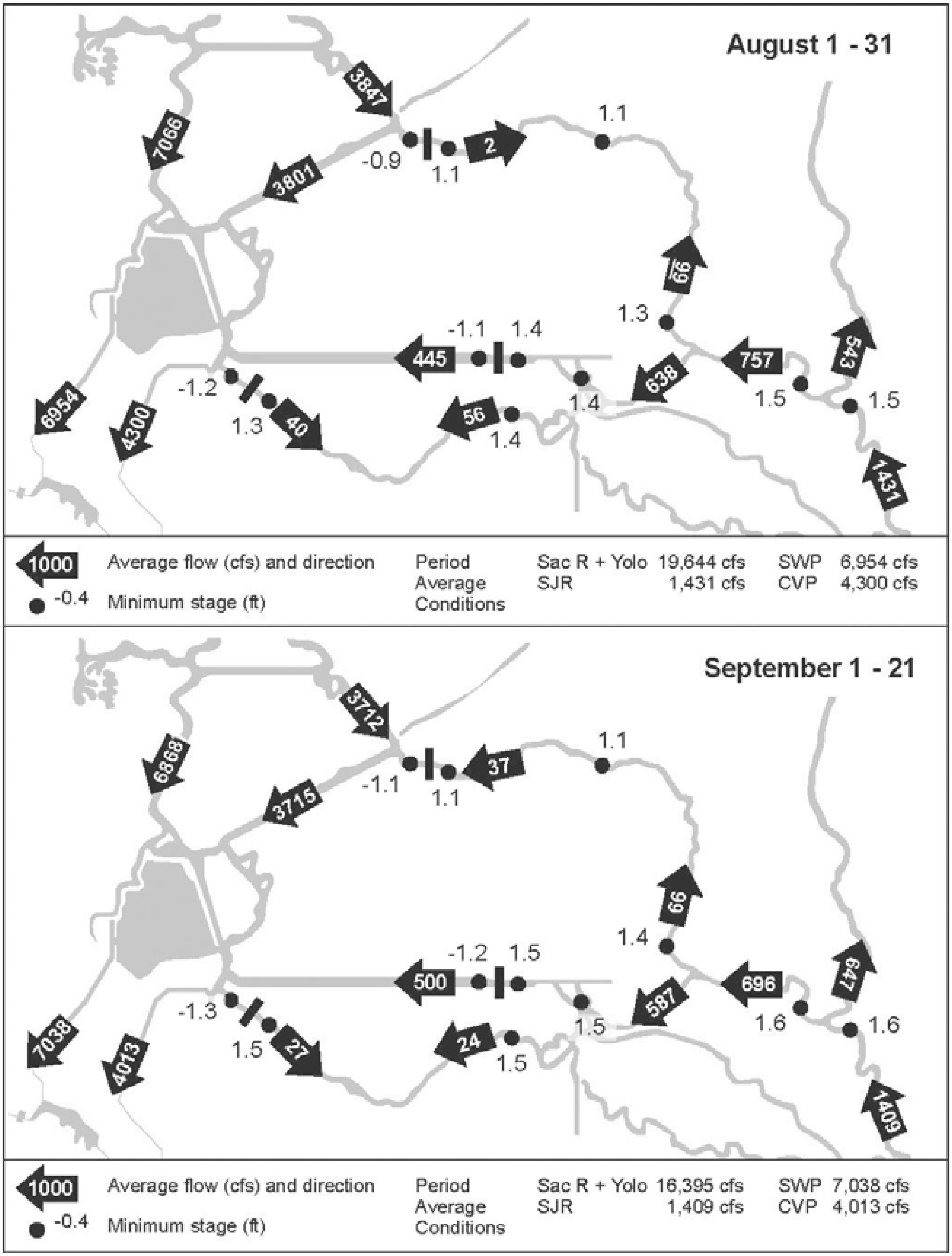


Figure 9-11 (cont.) DSM2-simulated average flow patterns and minimum stages for 2003.

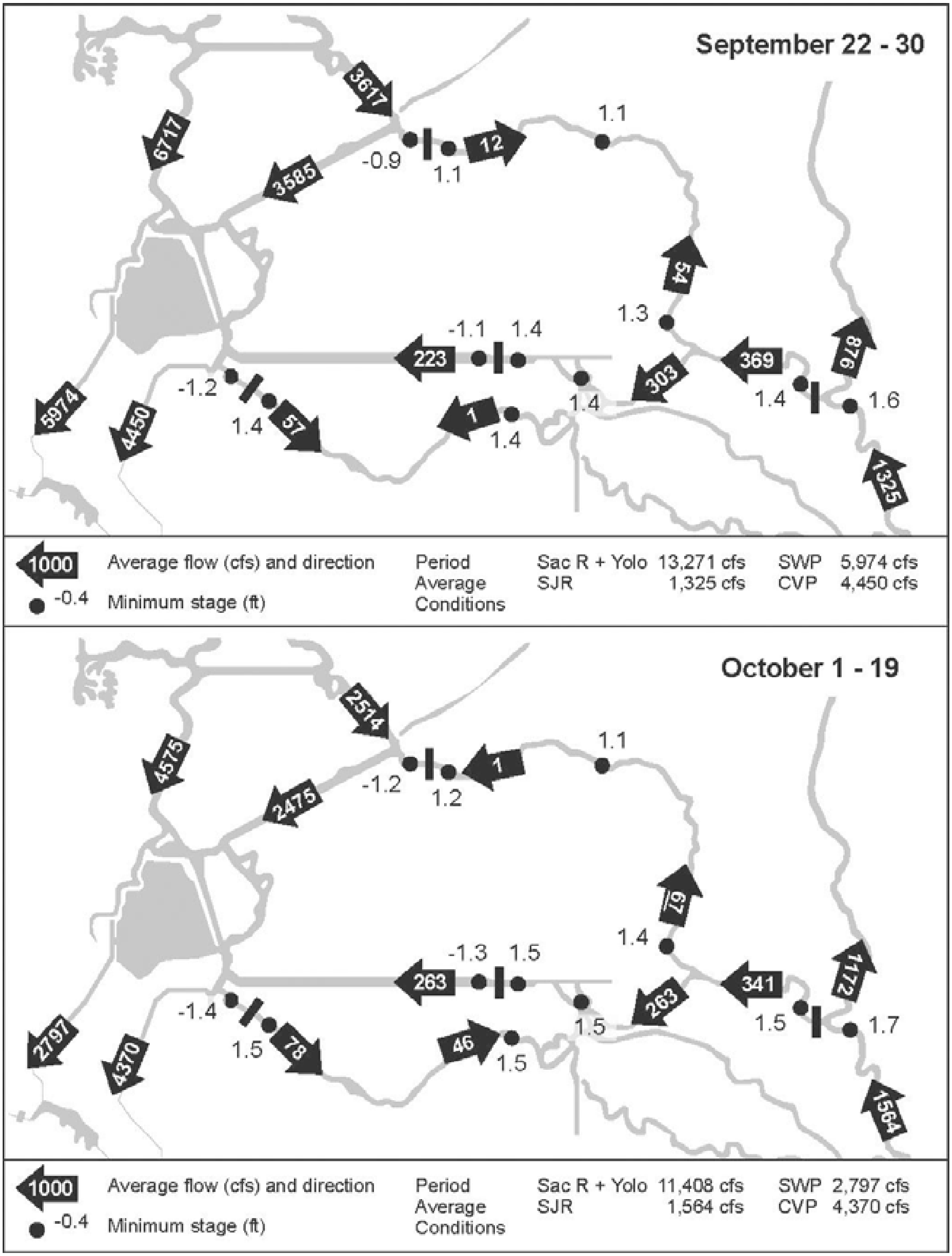


Figure 9-11 (cont.) DSM2-simulated average flow patterns and minimum stages for 2003.

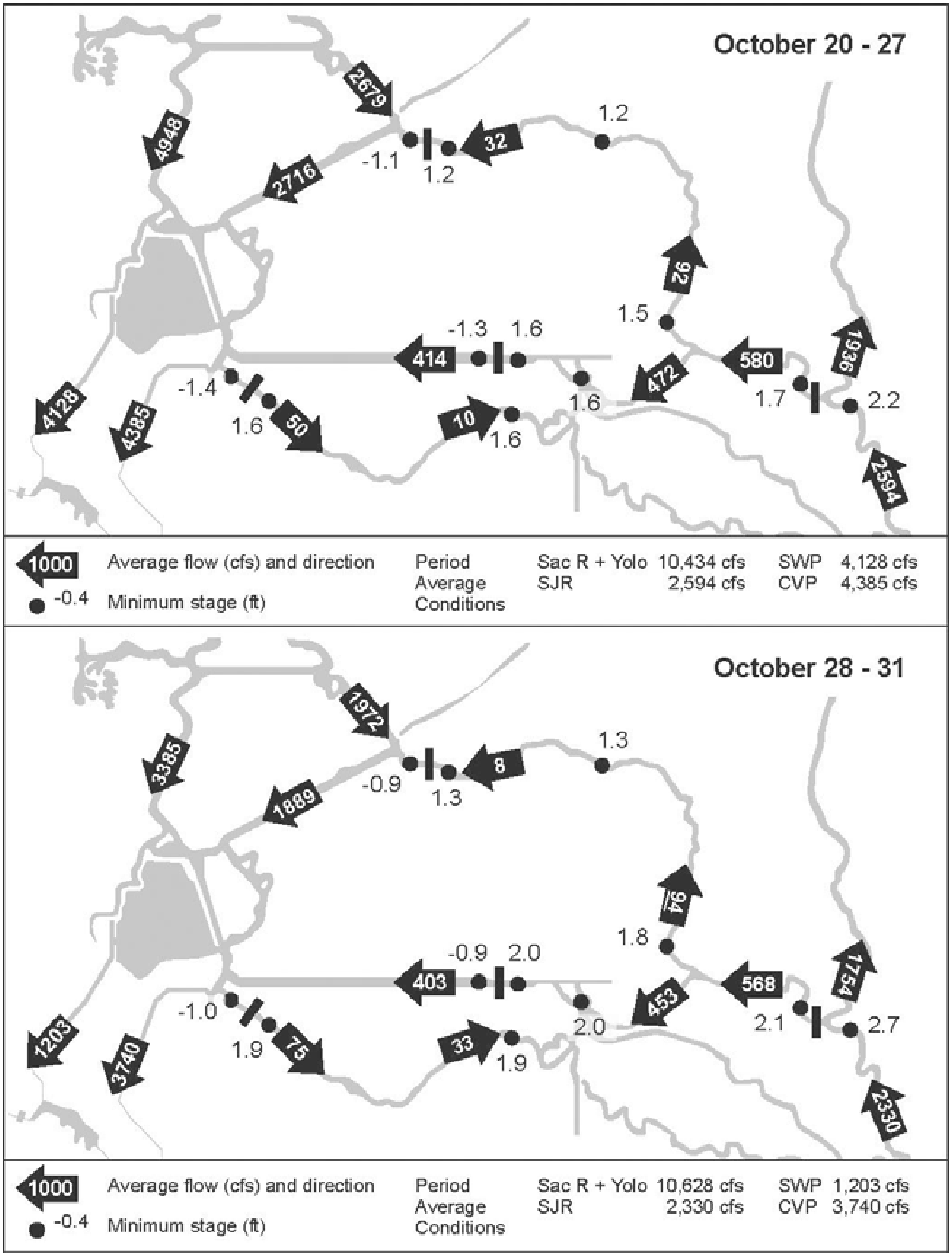


Figure 9-11 (cont.) DSM2-simulated average flow patterns and minimum stages for 2003.

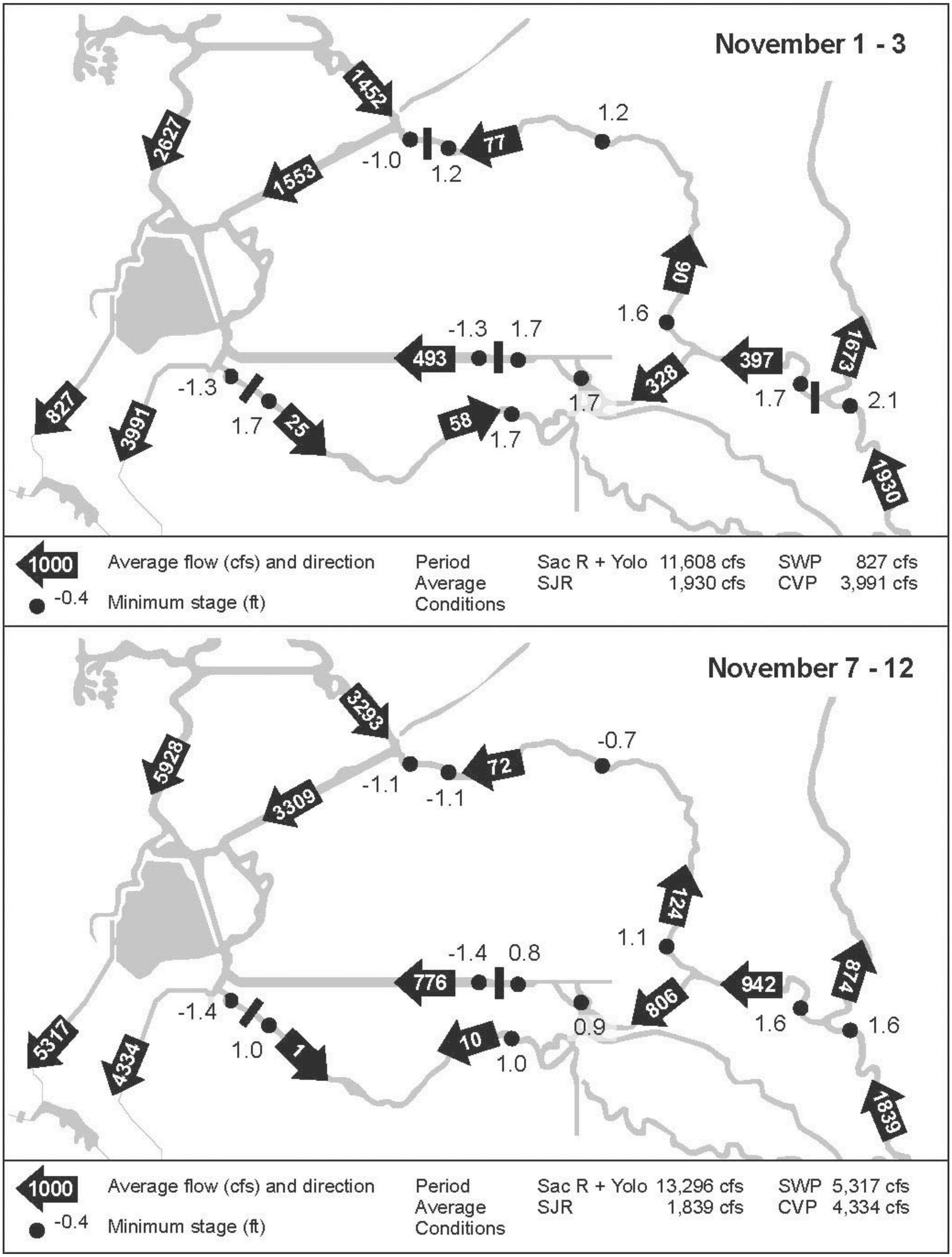
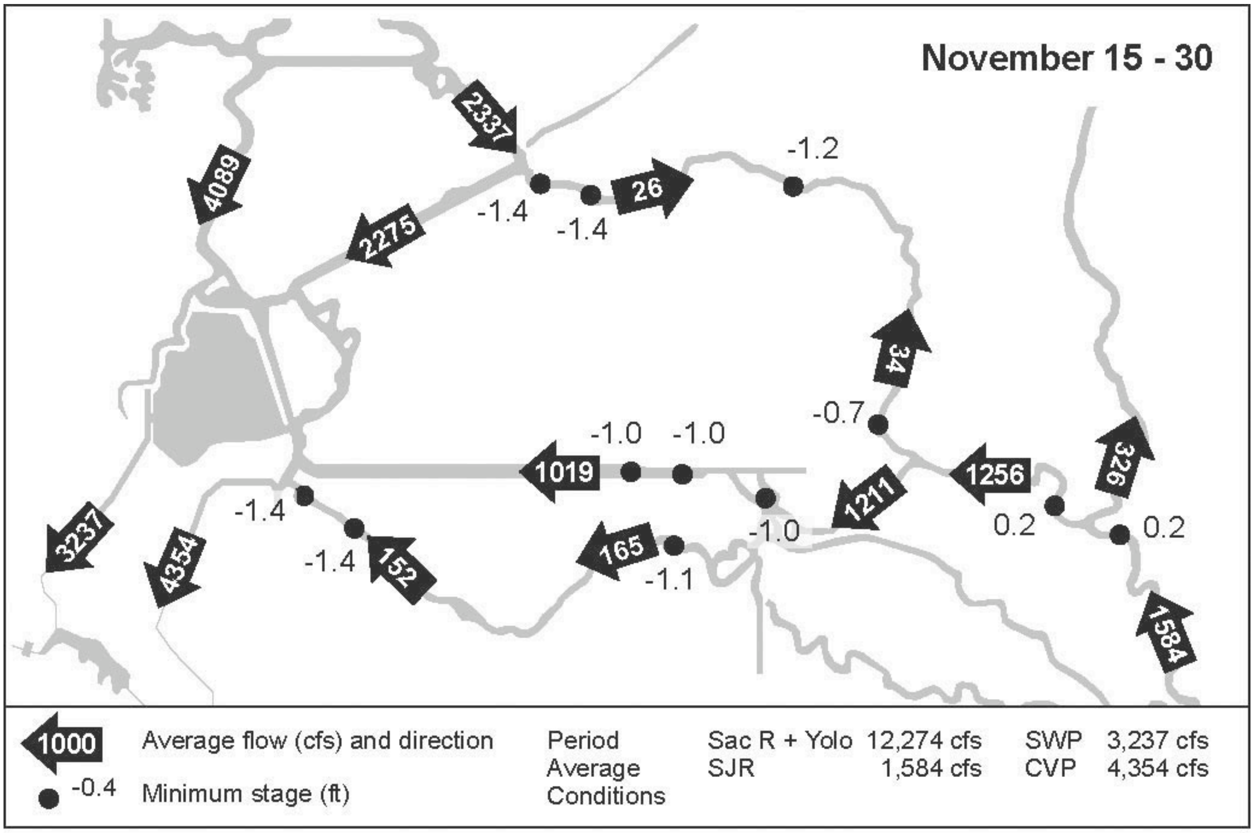


Figure 9-11 (cont.) DSM2-simulated average flow patterns and minimum stages for 2003.

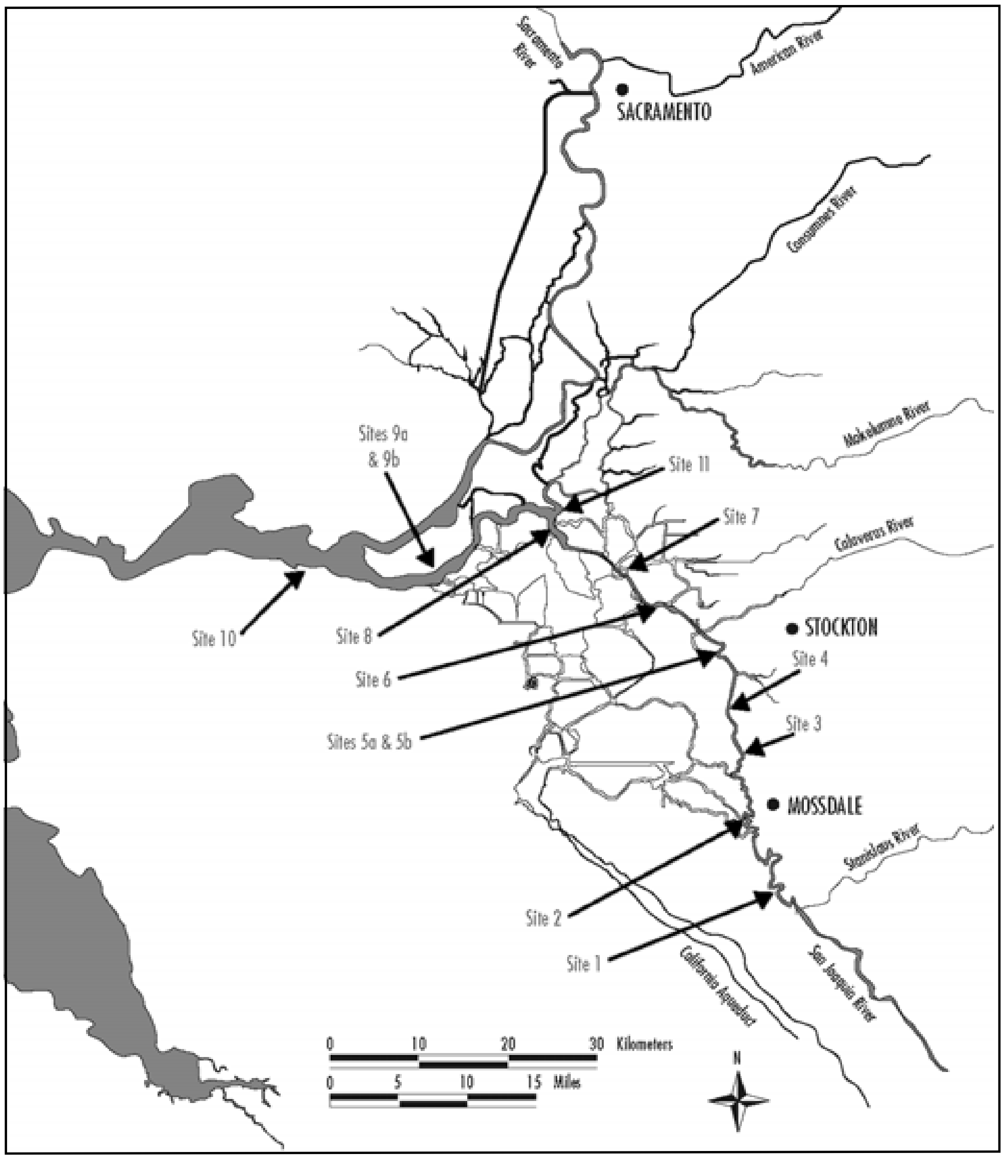


References

Mierzwa, M. (2004). *Input Data Used in WY2003 and Forecast DICU Update*. Memo dated February 3, 2004. California Department of Water Resources, Bay-Delta Office. Sacramento, CA.

Appendix A. Chinook Salmon Survival Investigations

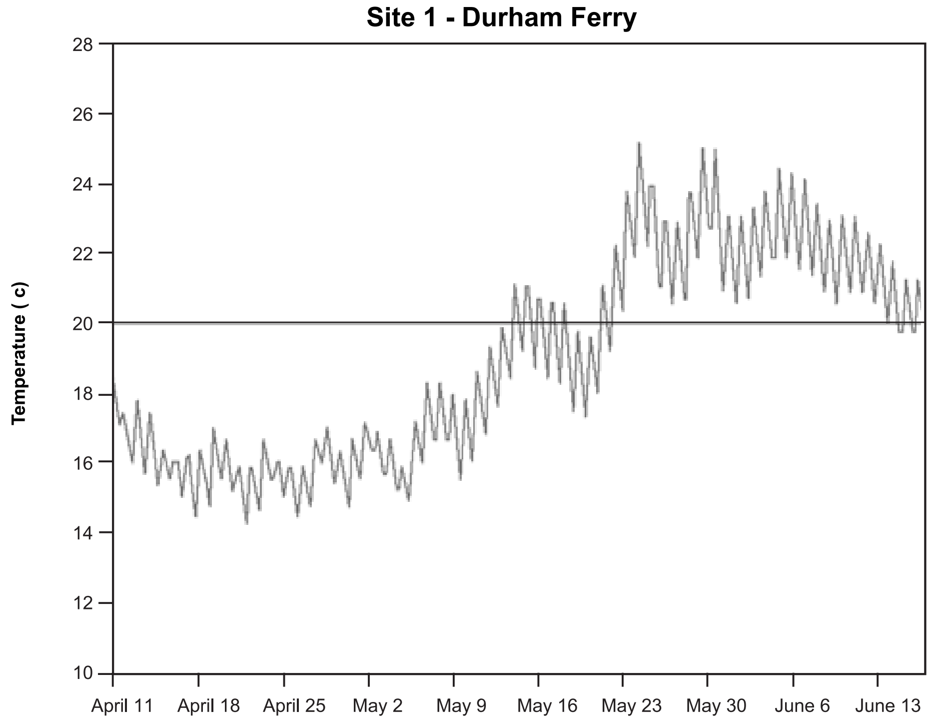
A-1 Water Temperature Monitoring Locations During the VAMP 2003 Experiment Sacramento-San Joaquin Estuary

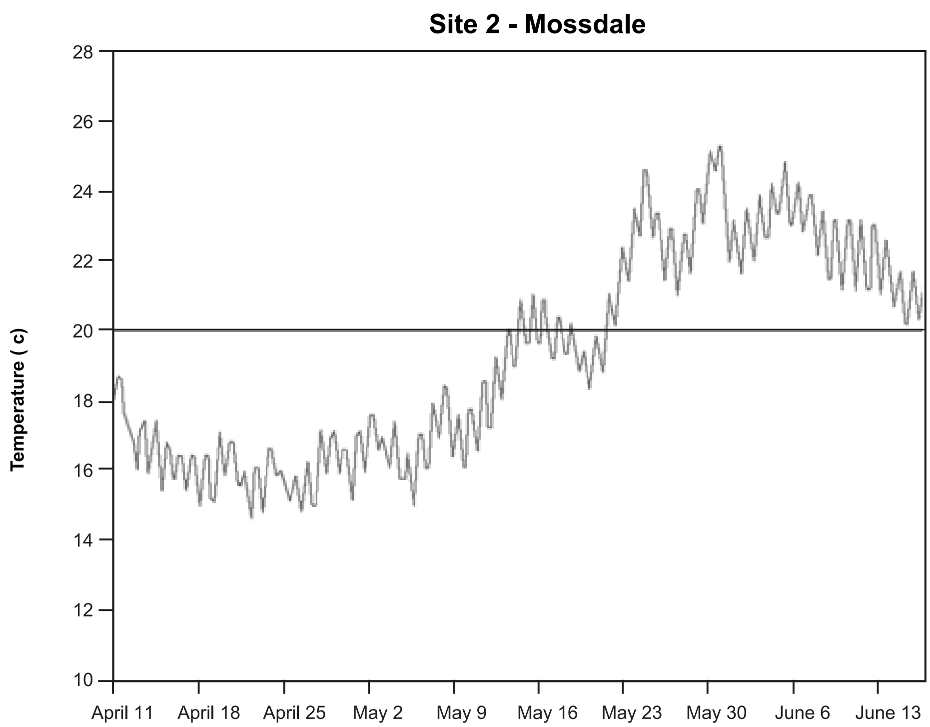


A-1 VAMP 2003 Water Temperature Monitoring Locations

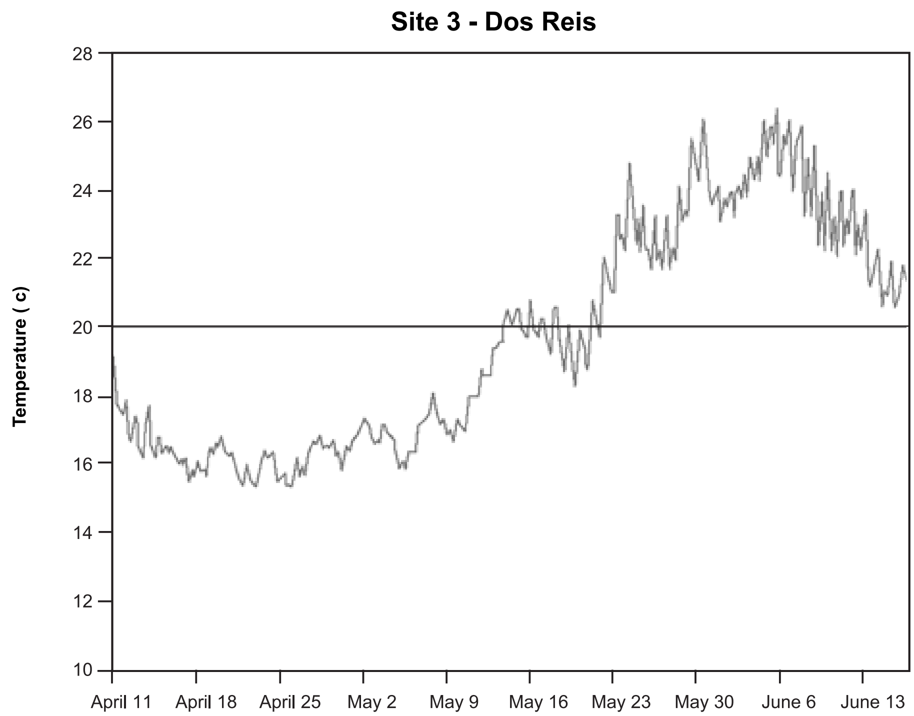
	Temperature Monitoring Location	Latitude	Longitude	Distance from Durham Ferry (mi)	Date Deployed	Date Retrieved	Notes
	Merced River Hatchery -1			n/a	March 21	April 23	In river April 21
	Merced River Hatchery -1			n/a	March 21	April 30	In river April 28
1	Durham Ferry	N37 41.381	W 121 15.657	n/a	April 11	June 15	Logger was buried in silt when retrieved
2	Mossdale	N 37 47.180	W 121 18.425	11.2	April 11	June 15	3-1/2 feet below surface
3	Dos Reis	N37 49.808	W 121 18.665	16.4	April 11	June 15	3 feet below surface
4	DWR Monitoring Station	N 37 51.869	W 121 19.376	19.4	April 11	June 15	3 feet below surface
5a	Confluence–Top	N 37 56.818	W 121 20.285	26.5	April 11	Logger Malfunction	3 feet below surface
5b	Confluence–Bottom	N 37 56.818	W 121 20.285	26.5	April 11		Located on bottom
6	Downstream of Channel Marker 30	N 37 59.776	W 121 25.569	33.3	April 11	June 15	3 feet below surface
7	1/2 mile Upstream of Channel Marker 13	N 38 01.940	W 121 28.769	37.3	April 11	June 15	3 feet below surface
8	Downstream of Channel Marker 36	N 38 04.522	W 121 34.413	44.7	April 11	June 15	3 feet below surface
9a	Jersey Point USGS Gauging Station–Top	N 38 03.172	W121 41.637	56	April 11	Logger Lost	3 feet below surface
10	Chipps Island	N 38 03.084	W 121 55.463	71.5	April 11	June 15	4-1/2 feet below surface
11	Mokelumne River–Lighthouse Marina	N38 06.334	W 121 34.213	40	April 11	June 15	Under pier in 3 feet of water

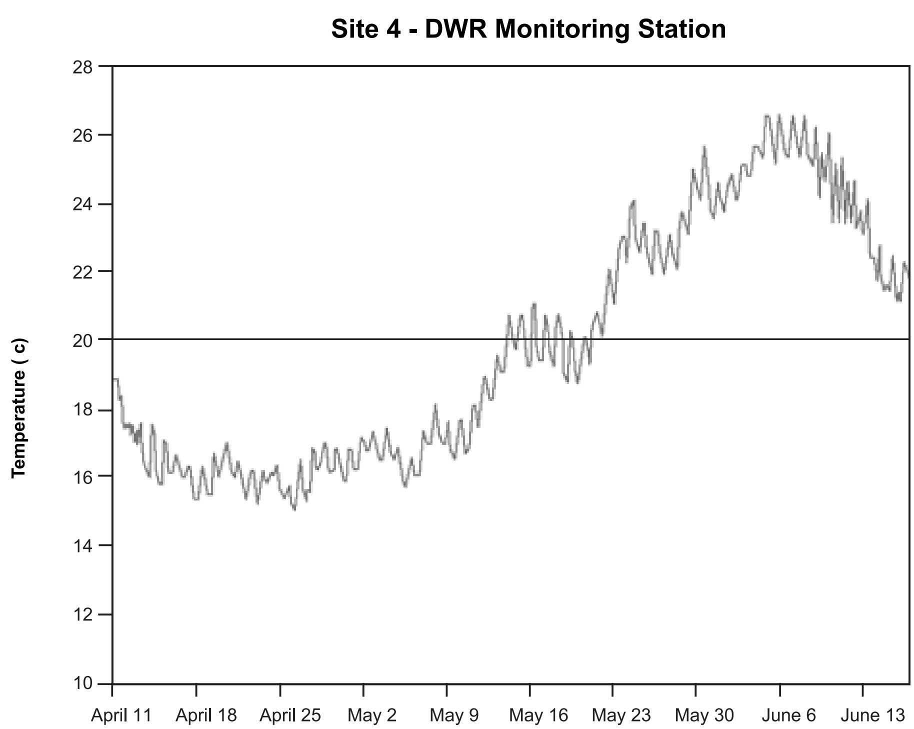
A-2 Water Temperature Monitoring





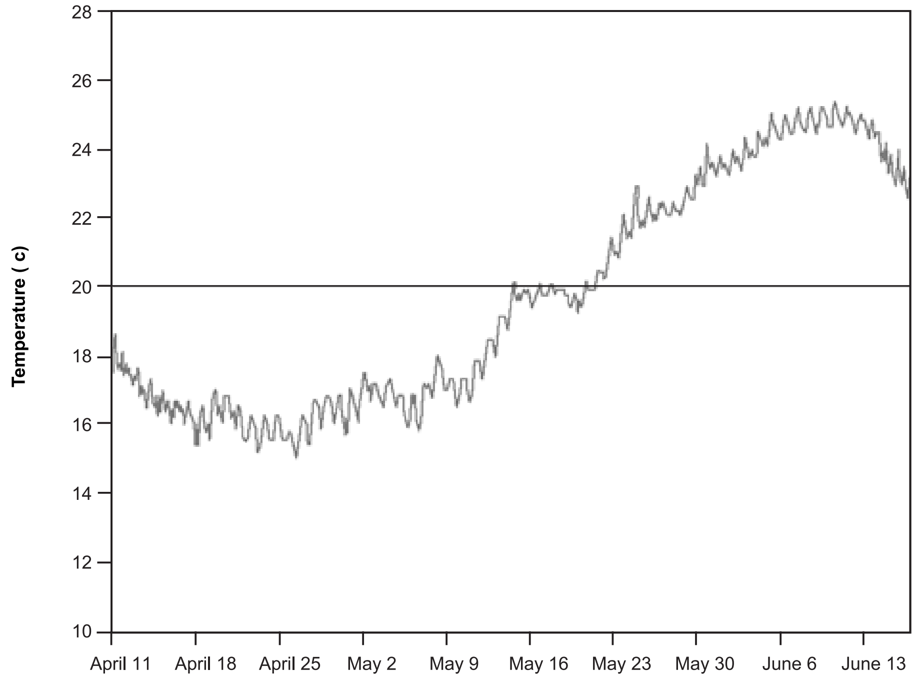
A-2 (cont.) Water Temperature Monitoring



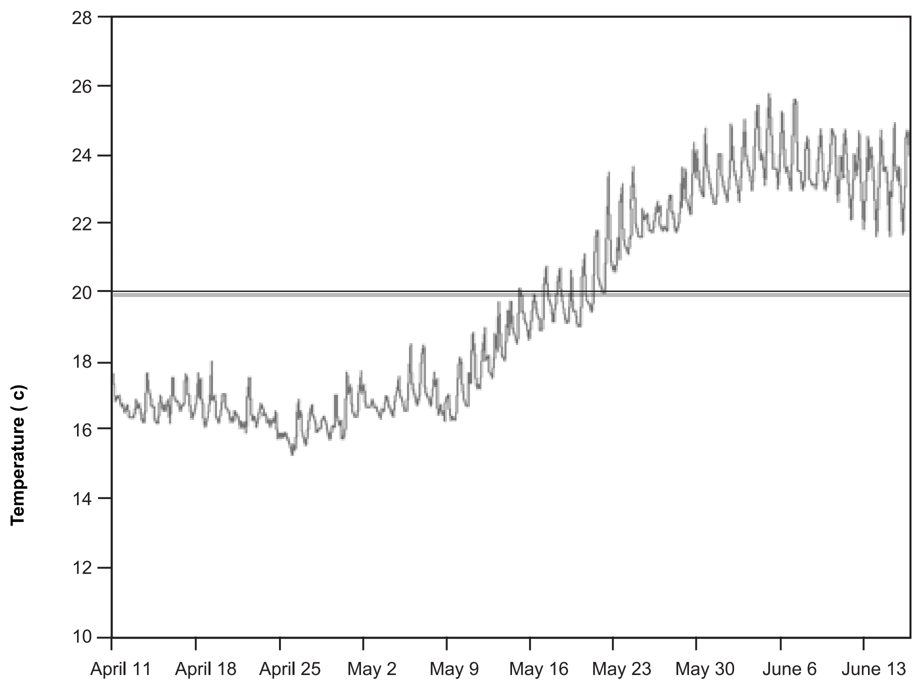


A-2 (cont.) Water Temperature Monitoring

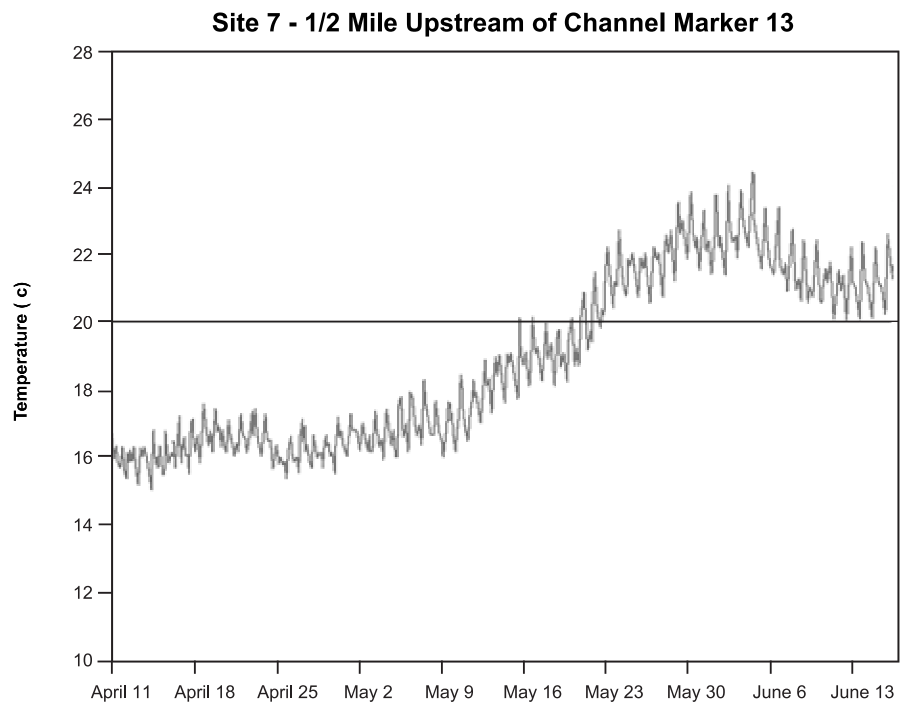
Site 5b - Confluence-Bottom

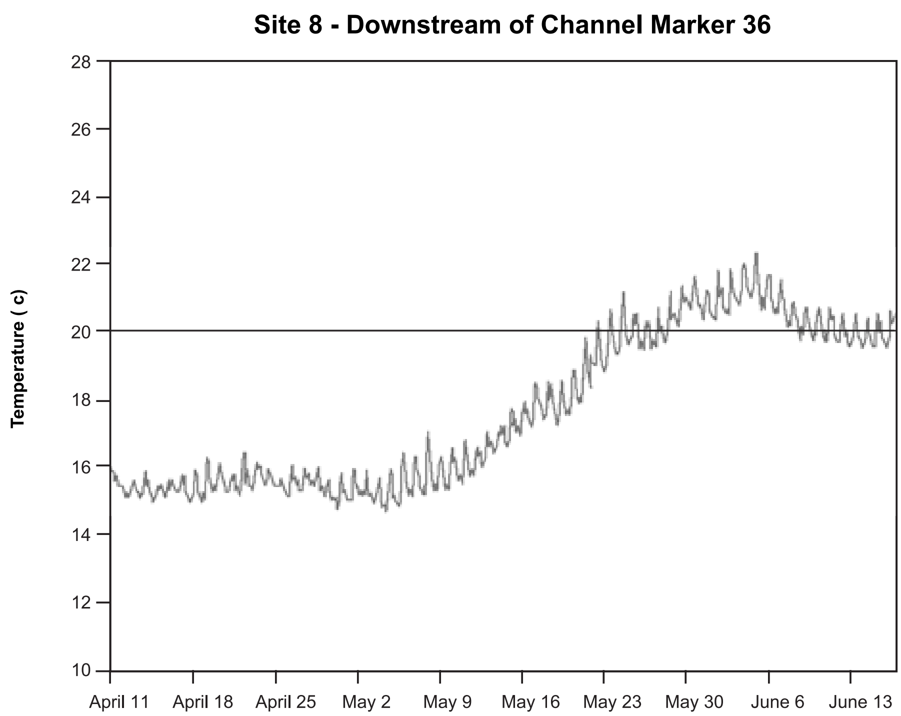


Site 6 - Downstream of Channel Marker 30



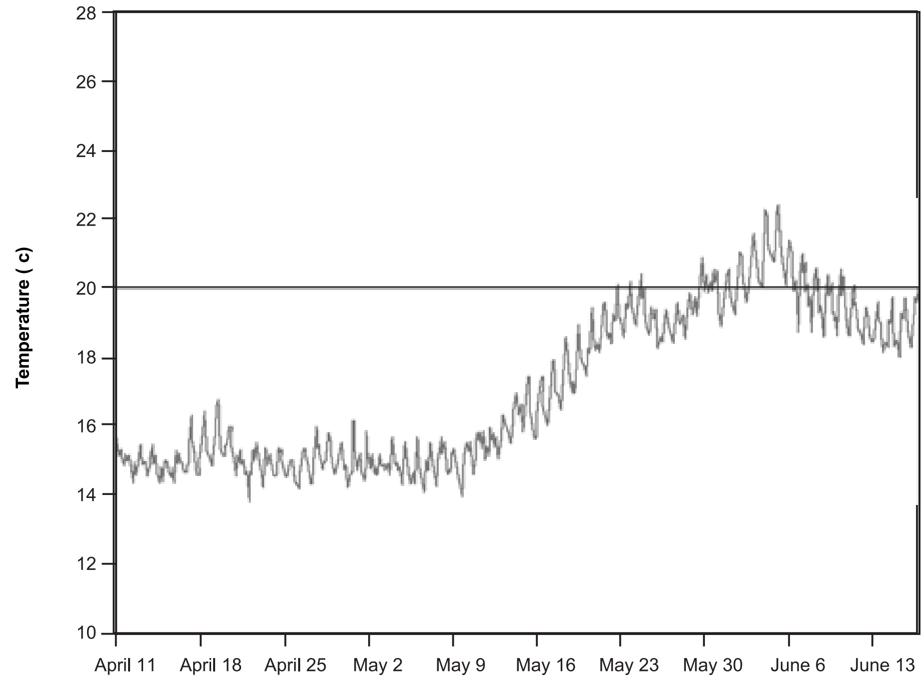
A-2 (cont.) Water Temperature Monitoring



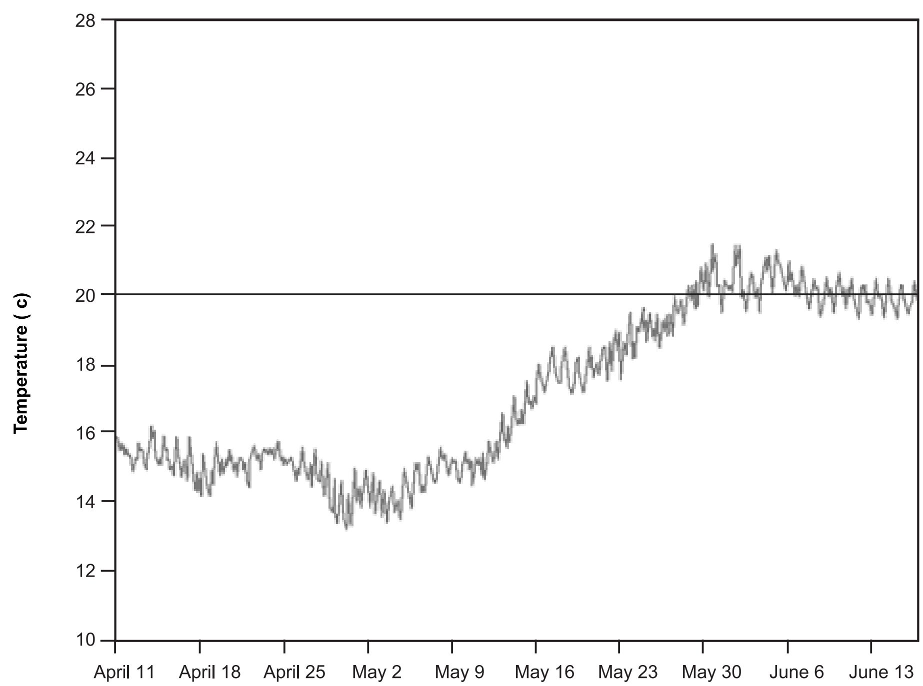


A-2 (cont.) Water Temperature Monitoring

Site 10 - Chipps Island



Site 1 - Mokelumne River



A-3a Results of Net Pen Sampling

Conducted After First Set Juvenile Chinook Salmon Releases, VAMP 2003

	Release Date	Release Location and Number	Coded-wire tag codes(s)	Number in sample	Mean fork length (range in mm)	Mean weight (range in g)	Mean scale loss (range in %)	Color (% normal)	Fin Hemorrhaging (% none)	Eye appearance (% normal)	Gill color (% normal)	Missing adipose fin clips (%)	Partial adipose fin clips (%)	Number of mortalities	Other deformities and comments
Samples at 00 Hours	21 Apr	Durham Ferry[1]	06-02-82 06-02-83 06-27-42	50	85 (72-96)	6.6 (4.2-9.2)	9 (3-25)	98	100	100	100	0	10	0	2 fish had ragged dorsal fins
	22 Apr	Mossdale I	06-27-43	25	86 (74-101)	6.9 (4.3-12.1)	3 (1-6)	100	100	100	100	4	8	0	
			06-27-48	25	88 (78-92)	7.0 (4.5-9.2)	3 (1-8)	100	100	100	100	0	0	0	1 fish with stunted pectoral fin and partial operculum
	25 Apr	Jersey Point I	06-27-44	25	89 (77-98)	7.5 (4.9-9.9)	3 (2-6)	100	100	100	96	0	0	0	1 fish with caudal fin rot
Samples at 48 Hours	21 Apr	Durham Ferry[1,2]	06-02-82 06-02-83 06-27-42	265	86 (68-99)	6.7 (3.3-10.3)	11 (5-30)	100	100	98	100	1.5	9.4	1	2 fish with caudal fin rot, 1 fish with left eye missing, 5 fish with ragged fins, 1 fish with partial operculum
	22 Apr	Mossdale I[2]	06-27-43	234	88 (72-104)	7.2 (3.7-12.0)	8 (4-15)	100	100	96	96	1.7	10.7	1	
			06-27-48	267	85 (65-99)	7.1 (3.0-10.7)	7 (3-15)	100	100	100	96	0.4	1.9	0	1 fish with a split dorsal fin, 2 fish with a partial operculum
	25 Apr	Jersey Point I[2]	06-27-44	200	88 (69-103)	7.5 (2.7-11.3)	4 (2-10)	100	100	100	96	0.0	0.5	7	26 additional fish were released on 4/27/03 without being measured

[1]Coded-wire tag codes for Durham Ferry releases were combined at the hatchery, so reported values are for all three tag codes.

[2]Color, fin hemorrhaging, eye appearance, and gill color were assessed from the first 25 fish for Mossdale and Jersey Point releases at 48 hours. These characteristics were assessed using the first 50 fish from the first Durham Ferry release at 48 hours.

A-3b Results of Net Pen Sampling

Conducted After Second Set Juvenile Chinook Salmon Releases, VAMP 2003

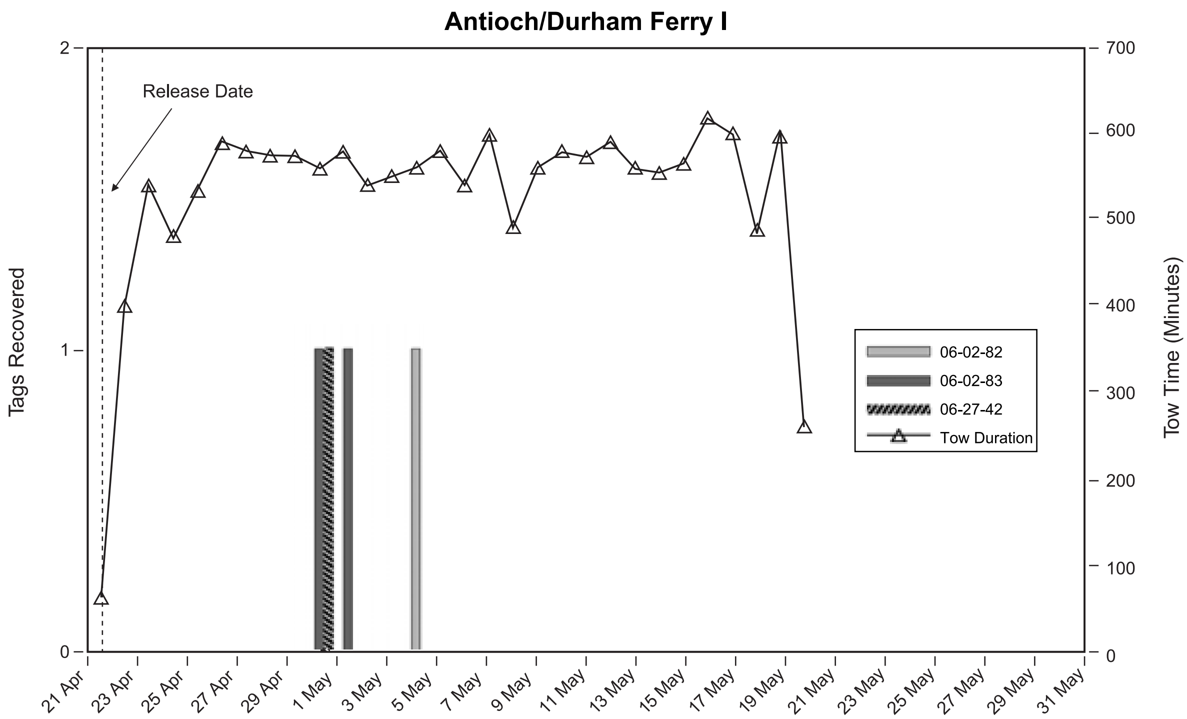
	Release Date	Release Location and Number	Coded-wire tag codes(s)	Number in sample	Mean fork length (range in mm)	Mean weight (range in g)	Mean scale loss (range in %)	Color (% normal)	Fin Hemorrhaging (% none)	Eye appearance (% normal)	Gill color (% normal)	Missing adipose fin clips (%)	Partial adipose fin clips (%)	Number of mortalities	Other deformities and comments
Samples at 00 Hours	28 Apr	Durham Ferry II[1]	06-27-45 06-27-46 06-27-47	50	87 (73-93)	6.9 (3.7-8.4)	14 (3-35)	100	100	98	98	2	2	0	
	29 Apr	Mossdale II	06-27-49	25	86 (78-92)	7.0 (4.4-9.7)	12 (5-35)	100	100	100	88	0	8	0	
			06-27-50	25	88 (78-92)	7.3 (4.8-8.7)	12 (3-25)	100	100	96	100	4	0	0	left eye was missing
	2 May	Jersey Point II	06-27-51	25	88 (79-97)	7.3 (5.0-9.5)	19 (10-35)	100	100	100	88	4	8	0	
Samples at 48 Hours	28 Apr	Durham Ferry II[1,2]	06-27-45 06-27-46 06-27-47	358	87 (73-100)	6.9 (3.6-10.4)	3 (1-5)	100	100	100	98	0.0	1.7	2	
	29 Apr	Mossdale II[2]	06-27-49	33	89 (73-98)	7.5 (3.9-9.4)	10 (5-20)	100	100	100	100	0	0	0	small holes in net pen may have allowed fish to escape
			06-27-50	144	88 (70-102)	7.3 (3.8-10.4)	14 (5-30)	100	100	100	100	0.7	3.5	0	
	2 May	Jersey Point II[2]	06-27-51	236	90 (71-102)	7.8 (4.0-11.3)	4 (2-10)	100	100	100	100	0.8	3.4	0	

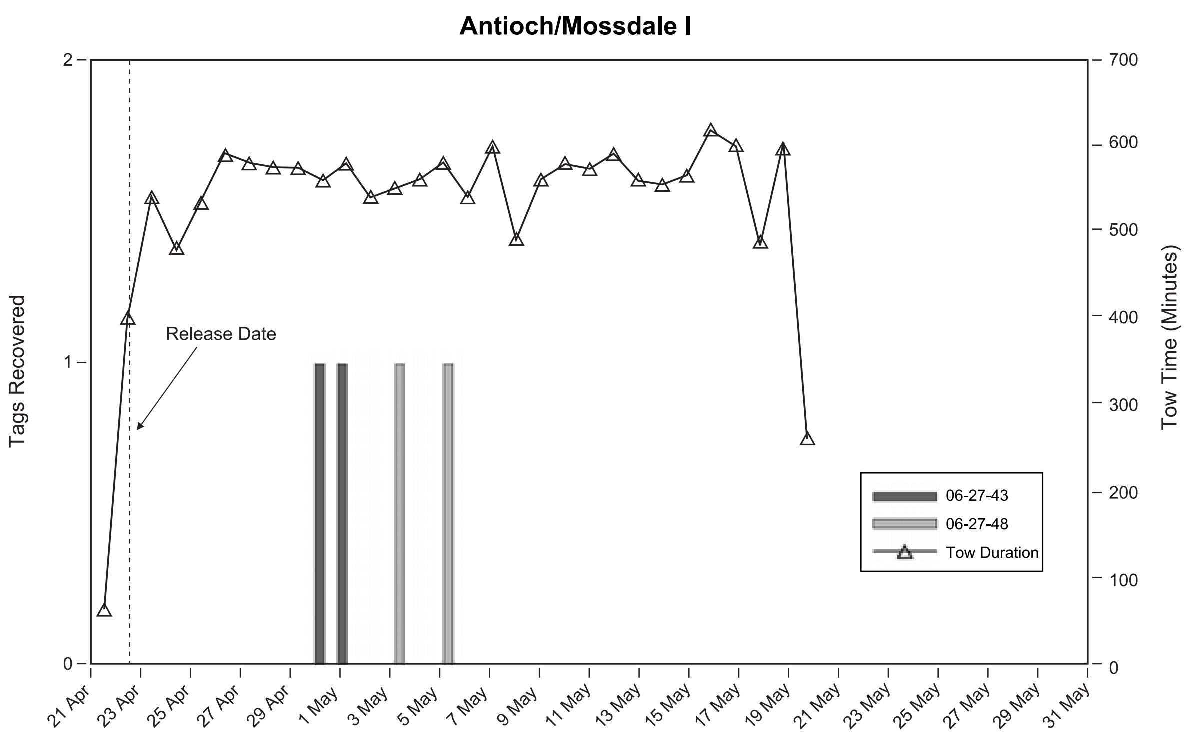
[1] *Coded-wire tag codes for Durham Ferry releases were combined at the hatchery, so reported values are for all three tag codes.*

[2] *Color, fin hemorrhaging, eye appearance, and gill color were assessed from the first 25 fish for Mossdale and Jersey Point releases at 48 hours. These characteristics were assessed using the first 50 fish from the first Durham Ferry release at 48 hours.*

A-4 VAMP 2003 Coded-Wire Tag Recoveries

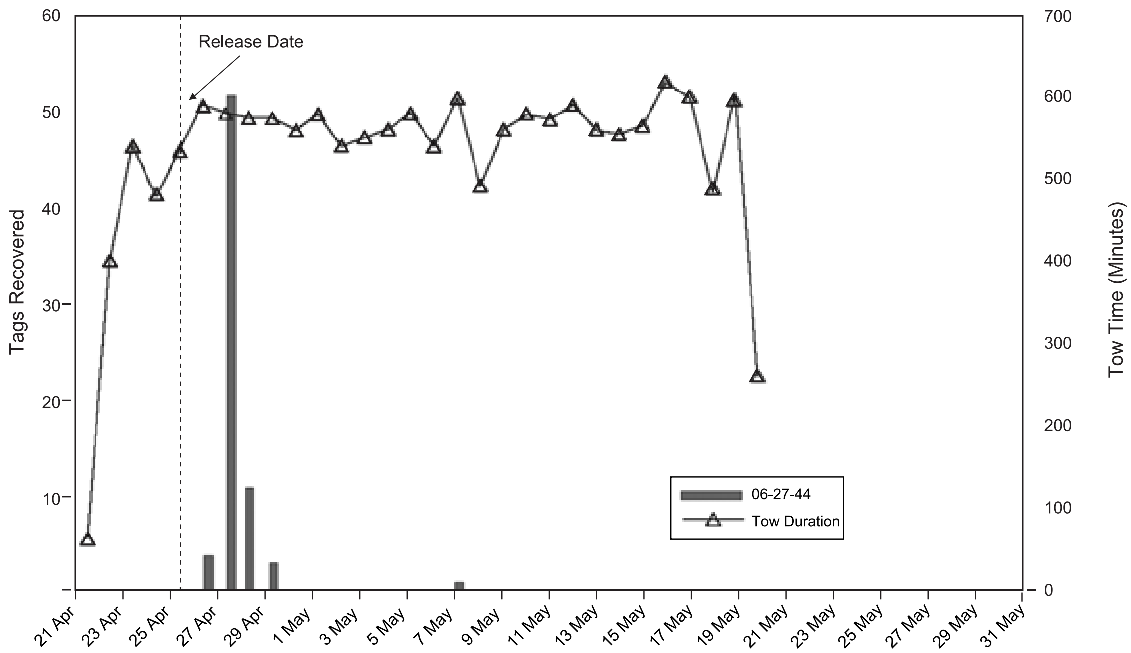
The following graphs are of coded-wire tagged juvenile chinook salmon,from the two sets of VAMP 2003, releases recovered during trawling at Antioch.No coded-wire tagged juveniles were recovered at Antioch from the second Durham Ferry release (on April 28,2003)or the second Mossdale release (on April 29,2003).



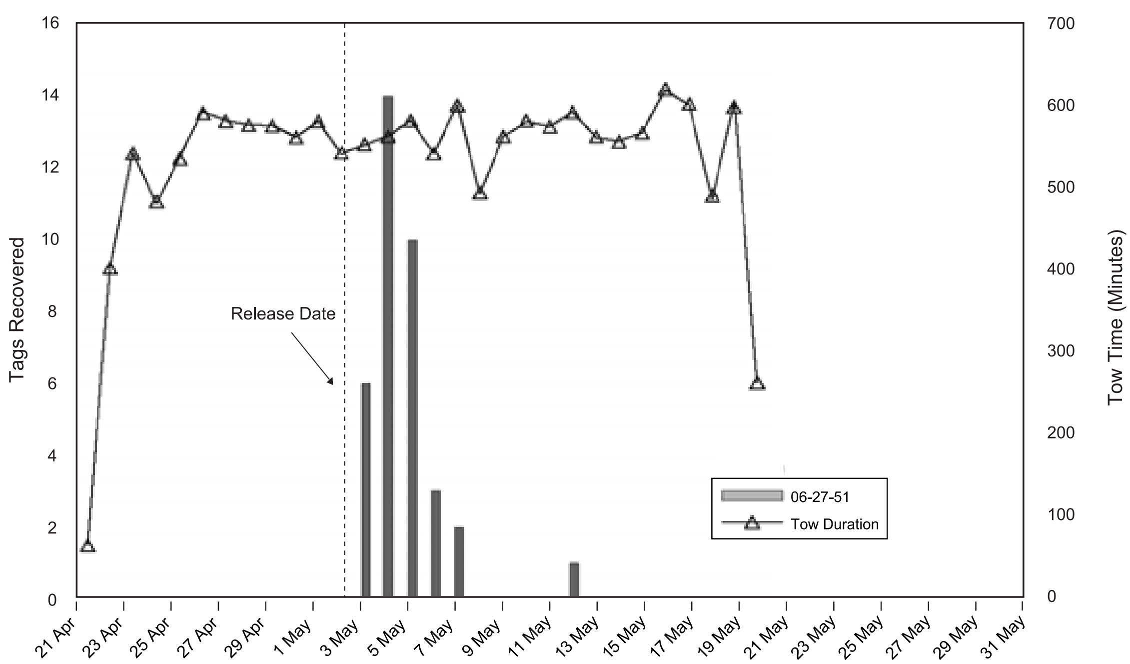


A-4 VAMP 2003 Coded-Wire Tag Recoveries

Antioch/Jersey Point I

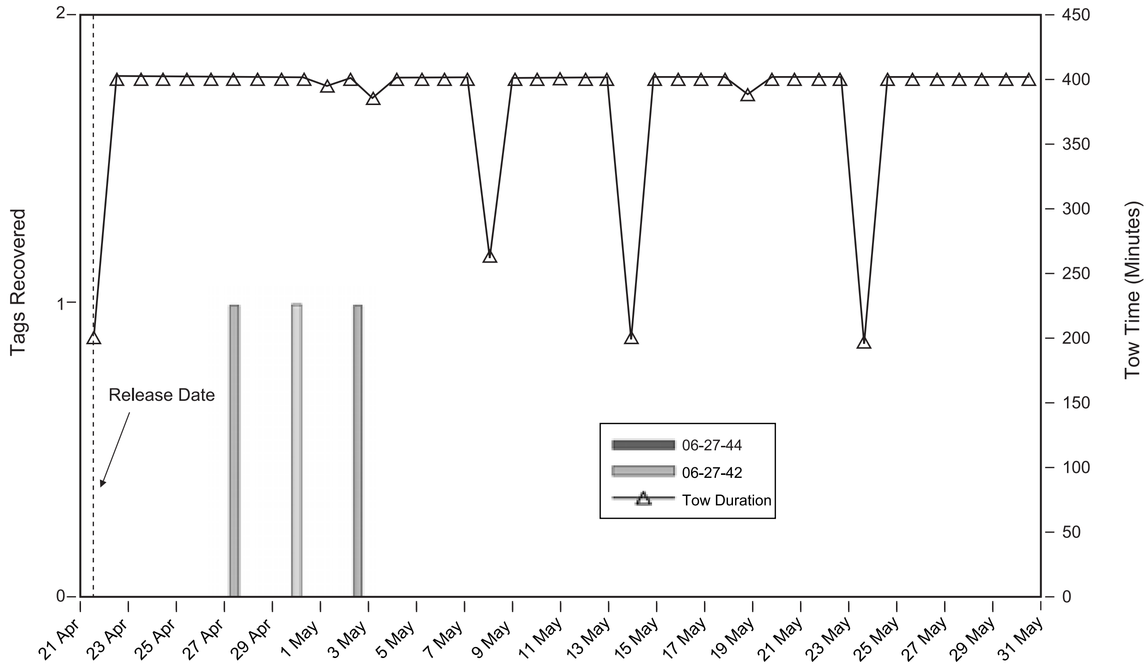


Antioch/Jersey Point II

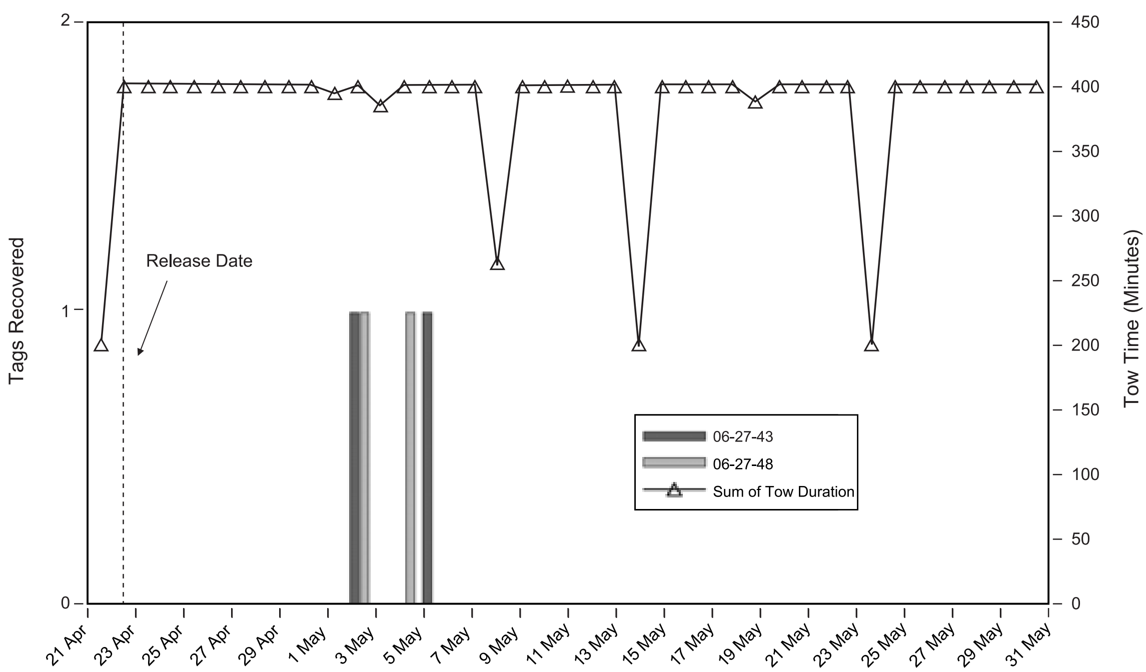


A-4 VAMP 2003 Coded-Wire Tag Recoveries

Chipps Island/Durham Ferry I

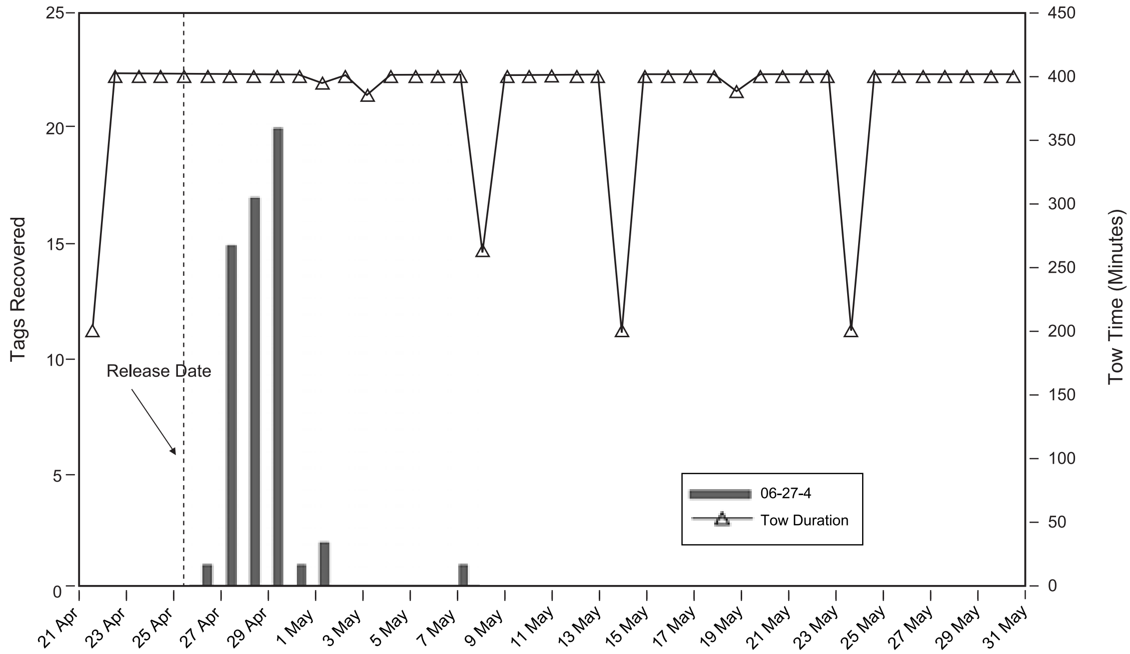


Chipps Island/Mossdale I

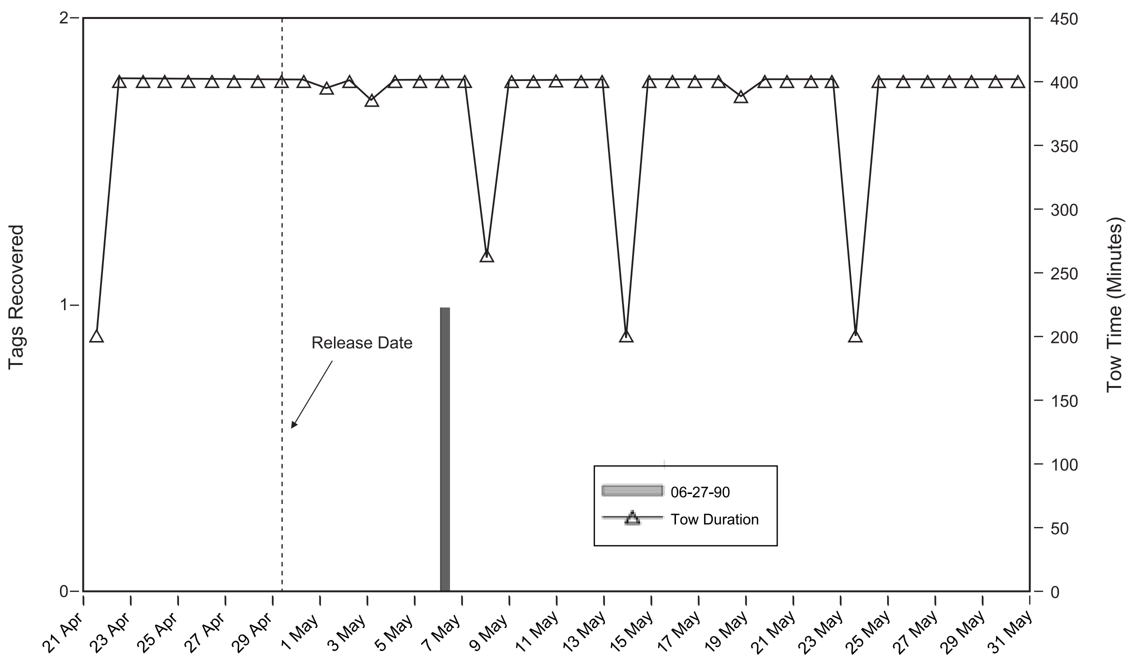


A-4 VAMP 2003 Coded-Wire Tag Recoveries

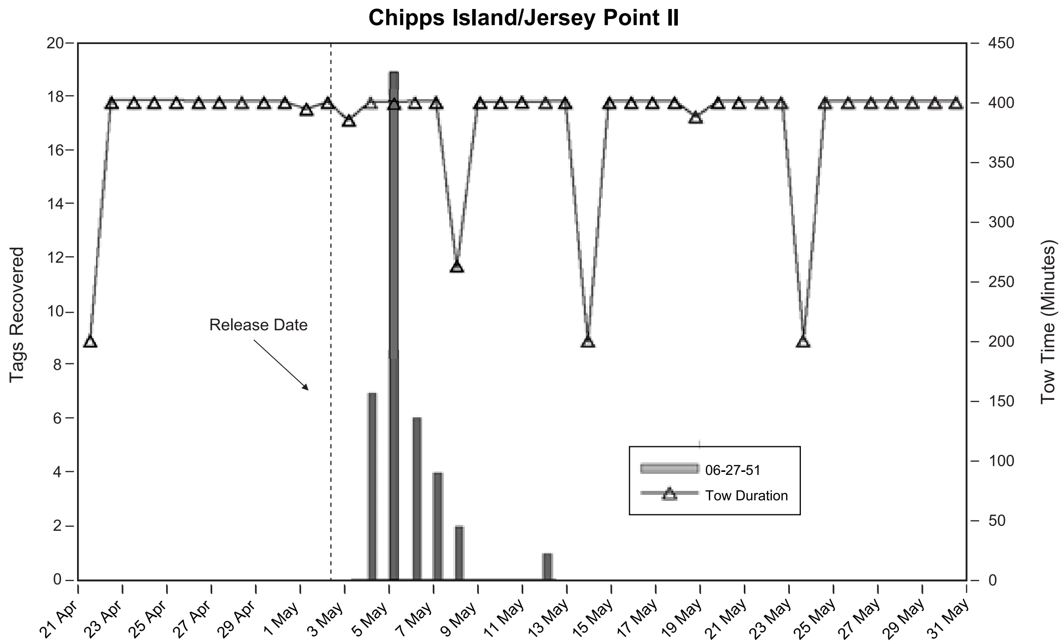
Chipps Island/Jersey Point I



Chipps Island/Mossdale II



A-4 VAMP 2003 Coded-Wire Tag Recoveries



A-5 Recovery Timing of CWT Released as San Joaquin Tributary Studies in 2003

River	Tag code	Release Site/Release Stock	Release Date	Antioch			Chipps Island		
				First day recovered	Last day recovered	Days at large	First day recovered	Last day recovered	Days at large
Merced River	06-44-89	Merced River Fish Facility		4/24/03	4/27/03	14	4/25/03	4/25/03	12
	06-44-90	Merced River Fish Facility		4/26/03	4/26/03	13	4/23/03	4/23/03	10
	06-44-91	Merced River Fish Facility		4/26/03	5/04/03	21	—	—	—
	06-44-92	Merced River Fish Facility		—	—	—	4/29/03	4/29/03	16
		Total	4/13/03	4/24/03	5/04/03	21	4/23/03	4/29/03	16
	06-44-93	Hatfield State Park (lower Merced)		4/24/03	4/27/03	11	4/24/03	4/26/03	10
	06-44-94	Hatfield State Park (lower Merced)		4/25/03	5/03/03	17	4/26/03	4/26/03	10
	06-44-95	Hatfield State Park (lower Merced)		4/23/03	4/26/03	10	4/25/03	5/05/03	19
		Total	4/16/03	4/23/03	5/03/03	17	4/24/03	5/05/03	19
	06-44-96	Merced River Fish Facility		—	—	—	—	—	—
	06-44-97	Merced River Fish Facility		—	—	—	—	—	—
	06-44-98	Merced River Fish Facility		5/11/03	5/11/03	16	—	—	—
	06-44-99	Merced River Fish Facility		—	—	—	—	—	—
		Total	4/25/03	5/11/03	5/11/03	16	—	—	—
	06-45-65	Hatfield State Park (lower Merced)		—	—	—	—	—	—
	06-45-64	Hatfield State Park (lower Merced)		—	—	—	5/07/03	5/10/03	11
	06-45-66	Hatfield State Park (lower Merced)		5/12/03	5/12/03	13	—	—	—
		Total	4/29/03	5/12/03	5/12/03	13	5/07/03	5/10/03	11
	06-27-77	Merced River Fish Facility		—	—	—	5/20/03	5/20/03	16
	06-27-78	Merced River Fish Facility		—	—	—	—	—	—
	06-44-49	Merced River Fish Facility		5/18/03	5/18/03	14	5/17/03	5/17/03	13
	06-44-50	Merced River Fish Facility		—	—	—	5/15/03	5/18/03	14
		Total	5/04/03	5/18/03	5/18/03	14	5/15/03	5/20/03	16
	06-45-46	Hatfield State Park (lower Merced)		—	—	—	5/17/03	5/17/03	10
	06-45-47	Hatfield State Park (lower Merced)		5/15/03	5/17/03	10	—	—	—
	06-45-72	Hatfield State Park (lower Merced)		—	—	—	5/15/03	5/15/03	8
		Total	5/07/03	5/15/03	5/17/03	10	5/15/03	5/17/03	10
Stanislaus River	06-45-67	Knight's Ferry		5/17/03	5/17/03	22	—	—	—
	06-45-68	Knight's Ferry		—	—	—	5/11/03	5/11/03	16
	06-45-69	Knight's Ferry		5/04/03	5/04/03	9	—	—	—
		Total	4/25/03	5/04/03	5/17/03	22	5/11/03	5/11/03	16
	06-45-70	Two Rivers		5/05/03	5/05/03	8	—	—	—
	06-45-71	Two Rivers		5/07/03	5/12/03	15	—	—	—
		Total	4/27-4/28/03	5/05/03	5/12/03	15	—	—	—

Appendix B. Stage and Flow Data

This appendix consists of the stage and flow data that is presented graphically in this report via box plots. The values are derived from hourly simulated stage and flow over each of the 26 time periods in 2003.

Figure B-1 Locations stage and flow data presented for the simulation of 2003 hydrodynamics.

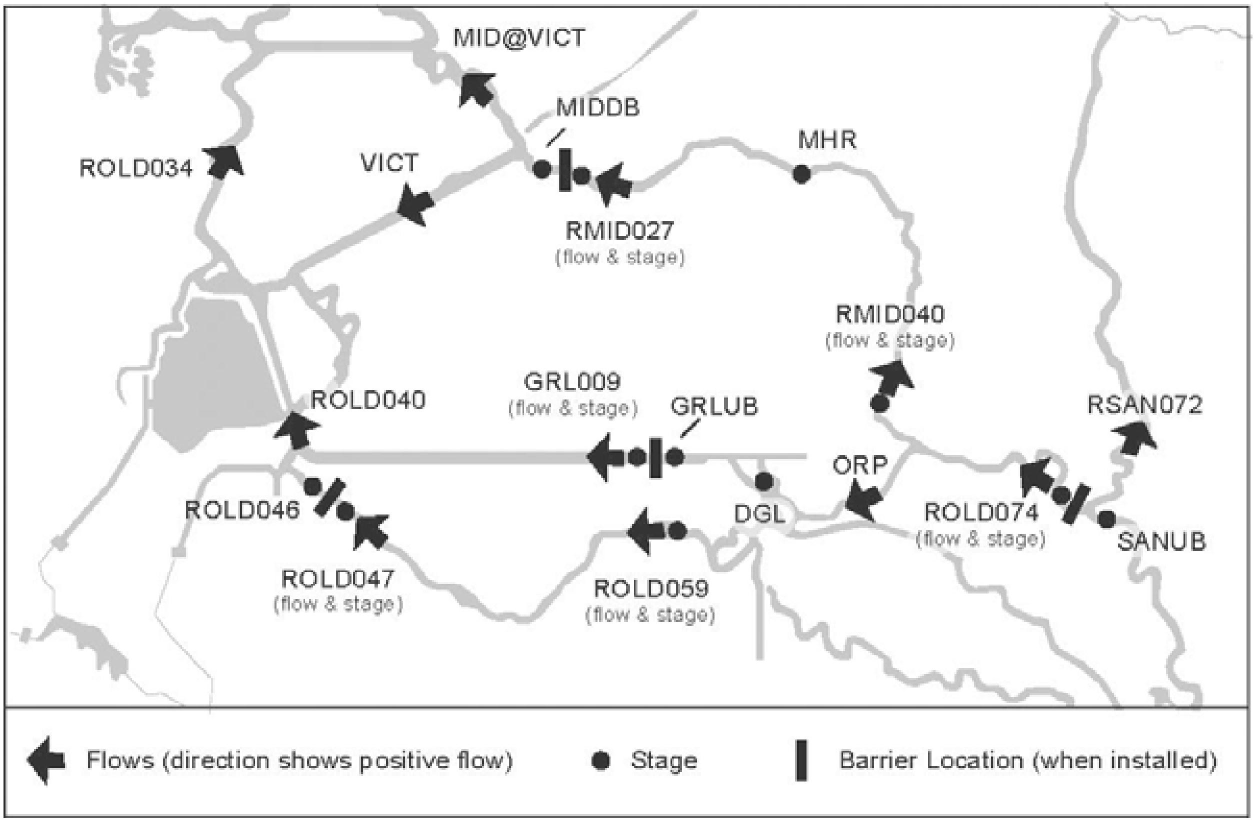


Table B-1 Distribution of stages (feet) by study period in 2003.

		Middle River at Howard Road (MHR)					RMID040					Doughty Cut above Grantline Canal (DGL)				
		Min	25%	Avg	75%	Max	Min	25%	Avg	75%	Max	Min	25%	Avg	75%	Max
Jan	1 - 31	-0.6	0.6	1.3	1.9	3.9	-0.1	0.8	1.5	1.9	4.1	-0.4	0.4	1.1	1.6	4.0
Feb	1 - 28	-0.6	0.4	1.1	1.7	3.9	-0.2	0.6	1.3	1.7	4.0	-0.5	0.2	0.9	1.5	4.0
Mar	1 - 31	-1.4	-0.1	0.6	1.2	3.5	-0.8	0.2	0.8	1.3	3.7	-1.1	-0.2	0.4	0.9	3.5
Apr	1 - 13	-0.7	0.4	1.1	1.7	3.1	-0.2	0.7	1.3	1.8	3.2	-0.5	0.4	1.0	1.5	3.2
	14 - 15	-0.2	0.5	1.1	1.7	2.4	0.0	0.6	1.1	1.6	2.4	0.0	0.4	1.0	1.5	2.3
	16 - 30	0.9	1.2	1.7	2.1	3.7	0.3	1.0	1.6	2.1	3.6	-0.2	0.8	1.5	2.0	3.5
May	1 - 15	0.7	1.2	1.7	2.0	3.5	0.1	0.9	1.5	2.1	3.5	-0.4	0.8	1.4	2.0	3.4
	16 - 19	0.3	1.1	1.7	2.1	3.8	0.2	1.2	1.9	2.4	3.9	0.0	1.0	1.8	2.4	3.8
	20 - 28	0.1	0.8	1.4	1.8	3.3	0.2	1.0	1.6	2.1	3.6	-0.1	0.8	1.4	2.0	3.5
	29 - 31	0.2	0.9	1.4	1.7	3.3	0.3	1.0	1.5	2.1	3.3	0.0	0.8	1.3	1.8	3.2
Jun	1 - 8	-0.4	0.4	1.0	1.5	3.2	-0.2	0.6	1.1	1.6	3.1	-0.4	0.3	0.9	1.4	2.8
	9 - 24	-0.1	1.2	1.5	1.7	3.4	0.4	1.7	1.9	2.1	3.4	0.2	1.8	2.0	2.2	3.2
	25 - 30	1.1	1.2	1.7	2.0	3.2	1.5	1.8	2.1	2.3	3.2	1.7	1.9	2.1	2.3	3.0
Jul	1 - 31	0.6	1.1	1.4	1.6	3.4	1.1	1.4	1.7	1.9	3.1	1.2	1.5	1.8	2.0	3.0
Aug	1 - 31	1.1	1.2	1.6	1.8	3.7	1.3	1.6	1.9	2.0	3.3	1.4	1.7	1.9	2.1	3.1
Sep	1 - 21	1.1	1.3	1.6	1.8	3.3	1.4	1.7	1.9	2.0	3.0	1.5	1.7	1.9	2.1	2.9
	22 - 30	1.1	1.2	1.5	1.7	2.9	1.3	1.5	1.6	1.7	2.8	1.4	1.5	1.7	1.8	2.6
Oct	1 - 19	1.1	1.3	1.6	1.9	3.3	1.4	1.6	1.8	2.0	3.0	1.5	1.7	1.9	2.0	2.8
	20 - 27	1.2	1.3	1.6	1.8	3.3	1.5	1.7	1.9	1.9	3.0	1.6	1.8	1.9	2.0	2.9
	28 - 31	1.3	1.5	2.1	2.5	4.1	1.8	2.0	2.4	2.6	3.9	2.0	2.2	2.5	2.6	3.8
Nov	1 - 3	1.2	1.3	1.7	2.0	2.8	1.6	1.8	2.0	2.2	3.0	1.7	1.9	2.1	2.2	3.0
	4 - 6	1.1	1.2	1.4	1.5	2.0	1.4	1.5	1.7	1.7	2.1	1.5	1.6	1.7	1.8	2.1
	7 - 12	-0.7	0.6	1.1	1.6	3.1	1.1	1.6	1.9	2.1	3.1	0.9	1.8	1.9	2.1	3.0
	13 - 14	-0.8	0.4	1.1	1.7	2.6	-0.2	0.6	1.2	1.6	2.5	-0.5	0.4	1.0	1.4	2.5
	15 - 30	-1.2	0.1	0.8	1.4	3.6	-0.7	0.3	1.0	1.4	3.7	-1.0	0.1	0.8	1.2	3.6
Dec	1 - 31	-1.2	0.5	1.2	1.9	4.3	-0.8	0.6	1.3	1.9	4.0	-1.0	0.4	1.1	1.7	3.9

Table B-1 (cont.) Distribution of stages (feet) by study period in 2003.

		Grantline Canal US of Barrier Site (GRLUB)					ROLD046					ROLD047				
		Min	25%	Avg	75%	Max	Min	25%	Avg	75%	Max	Min	25%	Avg	75%	Max
Jan	1 - 31	-0.5	0.4	1.1	1.5	4.0	-0.8	0.2	0.9	1.3	3.8	-0.8	0.2	0.9	1.3	3.8
Feb	1 - 28	-0.5	0.1	0.9	1.4	4.0	-0.9	-0.1	0.7	1.2	3.8	-0.9	-0.1	0.7	1.2	3.8
Mar	1 - 31	-1.3	-0.2	0.3	0.9	3.3	-1.7	-0.4	0.1	0.6	3.2	-1.7	-0.4	0.1	0.6	3.2
Apr	1 - 13	-0.6	0.4	1.0	1.5	3.1	-0.9	0.2	0.8	1.3	3.0	-0.9	0.2	0.8	1.3	3.0
	14 - 15	-0.1	0.4	1.0	1.5	2.3	-0.7	0.0	0.8	1.5	2.5	-0.3	0.8	1.1	1.5	2.1
	16 - 30	-0.3	0.8	1.4	2.0	3.5	-1.0	0.4	1.3	2.1	3.7	0.6	1.2	1.7	2.0	3.3
May	1 - 15	-0.5	0.8	1.4	2.0	3.5	-1.1	0.5	1.3	2.1	3.7	0.3	1.1	1.6	2.0	3.2
	16 - 19	0.0	1.0	1.7	2.4	3.8	-0.7	0.6	1.5	2.3	3.9	0.4	1.1	1.7	2.2	3.4
	20 - 28	-0.2	0.7	1.4	2.0	3.4	-1.0	0.4	1.1	1.9	3.5	0.1	0.8	1.3	1.8	3.1
	29 - 31	-0.1	0.7	1.3	1.7	3.2	-0.9	0.3	1.0	1.5	3.2	0.1	0.6	1.2	1.7	2.8
Jun	1 - 8	-0.6	0.3	0.9	1.3	2.8	-1.3	-0.1	0.6	1.2	2.9	-0.4	0.2	0.7	1.2	2.3
	9 - 24	0.1	1.8	2.0	2.2	3.1	-1.5	-0.3	0.4	1.1	3.5	0.0	1.7	1.9	2.1	2.9
	25 - 30	1.7	1.9	2.1	2.3	2.9	-1.4	-0.1	0.7	1.4	3.2	1.6	1.9	2.1	2.3	2.7
Jul	1 - 31	1.2	1.5	1.8	2.0	2.9	-1.5	-0.4	0.4	1.1	3.6	1.1	1.5	1.7	1.9	2.7
Aug	1 - 31	1.4	1.7	1.9	2.1	3.1	-1.2	-0.2	0.5	1.1	3.6	1.3	1.7	1.9	2.0	2.9
Sep	1 - 21	1.5	1.7	1.9	2.1	2.9	-1.3	-0.3	0.5	1.1	3.3	1.5	1.7	1.9	2.1	2.8
	22 - 30	1.4	1.5	1.7	1.8	2.6	-1.2	-0.3	0.4	1.0	3.0	1.4	1.5	1.7	1.8	2.5
Oct	1 - 19	1.5	1.7	1.9	2.0	2.8	-1.4	-0.1	0.7	1.4	3.3	1.5	1.7	1.9	2.0	2.7
	20 - 27	1.6	1.8	1.9	2.0	2.9	-1.4	-0.3	0.5	1.3	3.4	1.6	1.8	1.9	2.0	2.8
	28 - 31	2.0	2.1	2.5	2.7	3.8	-1.0	0.3	1.4	2.4	4.2	1.9	2.2	2.5	2.7	3.7
Nov	1 - 3	1.7	1.9	2.1	2.2	3.0	-1.3	-0.1	0.8	1.6	2.8	1.7	1.9	2.1	2.2	2.9
	4 - 6	1.5	1.6	1.7	1.8	2.1	-1.2	-0.5	0.3	1.0	1.6	1.5	1.6	1.7	1.8	2.1
	7 - 12	0.8	1.8	1.9	2.1	2.9	-1.4	-0.2	0.5	1.1	3.1	1.0	1.8	1.9	2.1	2.8
	13 - 14	-0.6	0.3	0.9	1.4	2.4	-1.1	-0.3	0.6	1.2	2.3	-0.5	0.5	1.0	1.5	2.3
	15 - 30	-1.0	0.0	0.7	1.2	3.6	-1.4	-0.2	0.5	1.0	3.5	-1.4	-0.2	0.5	1.0	3.5
Dec	1 - 31	-1.1	0.3	1.0	1.6	3.9	-1.5	0.1	0.8	1.5	3.9	-1.5	0.1	0.8	1.5	3.9

Table B-1 (cont.) Distribution of stages (feet) by study period in 2003.

		Middle River DS of Barrier Site (MIDDB)					GRL009					MID027				
		Min	25%	Avg	75%	Max	Min	25%	Avg	75%	Max	Min	25%	Avg	75%	Max
Jan	1 - 31	-0.8	0.5	1.2	1.9	4.0	-0.5	0.4	1.1	1.5	4.0	-0.7	0.5	1.2	1.9	4.0
Feb	1 - 28	-0.9	0.3	1.1	1.7	4.0	-0.5	0.1	0.9	1.4	4.0	-0.8	0.3	1.1	1.7	4.0
Mar	1 - 31	-1.6	-0.2	0.5	1.2	3.6	-1.3	-0.2	0.3	0.9	3.3	-1.7	-0.1	0.5	1.2	3.6
Apr	1 - 13	-0.8	0.3	1.0	1.8	3.1	-0.6	0.3	0.9	1.4	3.1	-0.8	0.3	1.0	1.8	3.1
	14 - 15	-0.5	0.2	1.1	1.9	2.7	-0.2	0.3	0.9	1.4	2.4	-0.5	0.4	1.1	1.8	2.5
	16 - 30	-1.0	0.4	1.3	2.1	3.8	-0.5	0.7	1.4	2.0	3.7	0.9	1.3	1.7	2.1	3.7
May	1 - 15	-1.1	0.5	1.3	2.2	3.8	-0.7	0.7	1.4	2.0	3.6	0.7	1.2	1.7	2.1	3.7
	16 - 19	-0.8	0.6	1.5	2.3	3.9	-0.1	0.9	1.7	2.3	3.9	0.4	1.1	1.7	2.2	3.8
	20 - 28	-1.0	0.3	1.1	1.9	3.4	-0.4	0.6	1.3	1.9	3.4	0.1	0.8	1.4	1.9	3.4
	29 - 31	-0.8	0.5	1.2	1.7	3.4	-0.3	0.7	1.2	1.6	3.3	0.2	1.0	1.4	1.7	3.2
Jun	1 - 8	-1.1	0.3	1.0	1.7	3.4	-0.7	0.2	0.8	1.3	2.8	-0.3	0.4	1.1	1.5	3.3
	9 - 24	-1.2	0.1	0.9	1.6	3.6	-1.4	-0.2	0.5	1.2	3.6	-0.1	1.2	1.5	1.7	3.5
	25 - 30	-1.1	0.2	1.1	1.9	3.4	-1.3	0.1	0.8	1.6	3.3	1.1	1.2	1.7	1.9	3.2
Jul	1 - 31	-1.2	0.2	0.9	1.7	3.7	-1.4	-0.2	0.5	1.2	3.6	0.7	1.1	1.5	1.7	3.5
Aug	1 - 31	-0.9	0.3	1.0	1.7	3.9	-1.1	-0.1	0.6	1.2	3.6	1.1	1.2	1.6	1.8	3.7
Sep	1 - 21	-1.1	0.2	1.0	1.7	3.5	-1.2	-0.2	0.6	1.1	3.4	1.1	1.3	1.6	1.7	3.3
	22 - 30	-0.9	0.1	0.9	1.7	3.1	-1.1	-0.1	0.5	1.0	3.1	1.1	1.2	1.5	1.7	2.9
Oct	1 - 19	-1.2	0.2	1.0	1.9	3.5	-1.3	0.0	0.8	1.6	3.4	1.2	1.3	1.6	1.8	3.3
	20 - 27	-1.1	0.1	0.9	1.7	3.5	-1.3	-0.1	0.6	1.4	3.5	1.2	1.3	1.6	1.7	3.4
	28 - 31	-0.9	0.6	1.6	2.5	4.3	-0.9	0.4	1.5	2.6	4.2	1.3	1.5	2.1	2.5	4.2
Nov	1 - 3	-1.0	0.0	1.0	1.9	2.9	-1.3	0.0	0.9	1.8	2.9	1.2	1.3	1.7	2.0	2.7
	4 - 6	-0.9	-0.2	0.7	1.4	2.1	-1.1	-0.3	0.4	1.1	1.7	1.1	1.2	1.4	1.5	1.9
	7 - 12	-1.1	0.3	0.9	1.6	3.1	-1.4	-0.1	0.6	1.2	3.3	-1.1	0.5	1.0	1.5	3.1
	13 - 14	-1.0	0.3	1.0	1.8	2.7	-0.6	0.1	0.8	1.3	2.4	-1.0	0.3	1.0	1.7	2.7
	15 - 30	-1.4	0.0	0.8	1.4	3.7	-1.0	0.0	0.7	1.2	3.6	-1.4	0.0	0.8	1.4	3.7
Dec	1 - 31	-1.4	0.4	1.2	1.9	4.3	-1.1	0.3	1.0	1.6	3.9	-1.4	0.4	1.2	1.8	4.3

Table B-1 (cont.) Distribution of stages (feet) by study period in 2003.

		San Joaquin River Upstream of Barrier Site (SANUB)					ROLD059					ROLD074				
		Min	25%	Avg	75%	Max	Min	25%	Avg	75%	Max	Min	25%	Avg	75%	Max
Jan	1 - 31	0.7	1.6	2.1	2.6	4.1	-0.6	0.3	1.0	1.5	3.9	0.7	1.6	2.1	2.6	4.1
Feb	1 - 28	0.8	1.5	2.0	2.4	4.1	-0.6	0.1	0.8	1.3	3.9	0.8	1.5	2.0	2.4	4.1
Mar	1 - 31	0.4	1.2	1.7	2.1	3.8	-1.3	-0.3	0.3	0.8	3.4	0.4	1.2	1.7	2.1	3.8
Apr	1 - 13	0.8	1.5	1.9	2.3	3.3	-0.7	0.3	0.9	1.4	3.2	0.8	1.5	1.9	2.3	3.3
	14 - 15	1.5	2.5	3.1	3.6	4.0	-0.2	0.7	1.1	1.5	2.0	0.0	0.8	1.4	1.9	2.7
	16 - 30	3.3	4.0	4.2	4.4	5.1	0.5	1.2	1.6	2.0	3.5	0.0	0.9	1.6	2.1	3.7
May	1 - 15	3.4	4.0	4.2	4.4	5.0	0.2	1.1	1.6	1.9	3.4	-0.2	0.9	1.5	2.1	3.6
	16 - 19	1.4	2.2	2.8	3.6	4.7	0.3	1.0	1.7	2.2	3.6	0.4	1.9	2.4	2.8	4.0
	20 - 28	1.0	1.6	2.1	2.5	3.6	0.0	0.8	1.3	1.8	3.2	1.0	1.6	2.1	2.5	3.6
	29 - 31	1.2	1.7	2.2	2.6	3.4	0.0	0.7	1.2	1.7	3.0	1.2	1.7	2.2	2.6	3.4
Jun	1 - 8	0.8	1.6	2.0	2.4	3.5	-0.4	0.3	0.8	1.2	2.3	0.8	1.6	2.0	2.4	3.5
	9 - 24	1.2	2.0	2.4	2.7	3.7	-0.1	1.7	1.9	2.1	3.0	1.2	2.0	2.4	2.7	3.7
	25 - 30	1.8	2.1	2.5	2.8	3.7	1.6	1.9	2.1	2.2	2.8	1.8	2.1	2.5	2.8	3.7
Jul	1 - 31	1.2	1.7	2.1	2.3	3.5	1.1	1.5	1.7	1.9	2.8	1.2	1.7	2.1	2.3	3.5
Aug	1 - 31	1.5	1.9	2.2	2.4	3.5	1.4	1.7	1.9	2.0	2.9	1.5	1.9	2.2	2.4	3.5
Sep	1 - 21	1.6	1.9	2.2	2.4	3.2	1.5	1.7	1.9	2.1	2.9	1.6	1.9	2.2	2.4	3.2
	22 - 30	1.6	1.9	2.4	2.7	3.6	1.4	1.5	1.7	1.8	2.5	1.4	1.6	1.7	1.8	3.0
Oct	1 - 19	1.7	2.1	2.5	2.8	3.7	1.5	1.7	1.9	2.0	2.8	1.5	1.7	1.9	2.1	3.0
	20 - 27	2.2	2.9	3.1	3.4	4.2	1.6	1.8	1.9	2.0	2.8	1.7	1.9	2.0	2.1	3.1
	28 - 31	2.7	3.0	3.4	3.7	4.8	1.9	2.1	2.5	2.6	3.8	2.1	2.2	2.6	2.8	4.0
Nov	1 - 3	2.1	2.5	2.8	3.0	3.7	1.7	1.9	2.1	2.2	3.0	1.7	1.9	2.1	2.3	3.1
	4 - 6	1.7	2.0	2.3	2.6	3.1	1.5	1.6	1.7	1.8	2.1	1.6	1.7	1.9	2.0	2.7
	7 - 12	1.6	2.0	2.3	2.5	3.4	1.0	1.8	1.9	2.1	2.9	1.6	2.0	2.3	2.5	3.4
	13 - 14	0.7	1.4	1.9	2.2	3.0	-0.5	0.5	1.0	1.5	2.5	0.7	1.4	1.9	2.2	3.0
	15 - 30	0.2	1.2	1.6	2.0	3.6	-1.1	0.0	0.7	1.1	3.6	0.2	1.2	1.6	2.0	3.6
Dec	1 - 31	0.1	1.3	1.9	2.3	4.2	-1.1	0.3	1.0	1.6	4.0	0.1	1.3	1.9	2.3	4.2

Table B-2 Distribution of flows (cfs) by study period in 2003.

		ROLD059					ROLD047					RMID040				
		Min	25%	Avg	75%	Max	Min	25%	Avg	75%	Max	Min	25%	Avg	75%	Max
Jan	1 - 31	-709	-97	224	520	1042	-2531	-645	230	1252	2621	-110	-13	21	50	145
Feb	1 - 28	-571	-88	223	517	999	-2439	-534	220	1155	2319	-174	-11	20	46	146
Mar	1 - 31	-522	-74	205	476	946	-2296	-480	186	1067	2479	-100	11	28	48	120
Apr	1 - 13	-537	-166	202	502	835	-2096	-658	162	1108	1956	-113	19	36	65	118
	14 - 15	-504	-410	-58	232	461	-949	-424	-156	0	847	-127	-33	5	36	96
	16 - 30	-577	-474	-169	165	450	-1326	-444	-204	0	577	-143	-72	-20	26	109
May	1 - 15	-546	-428	-138	175	461	-1428	-471	-215	0	525	-104	-66	-8	45	103
	16 - 19	-258	-89	109	300	632	-1487	-550	23	643	1016	-97	45	78	125	196
	20 - 28	-198	-53	131	335	617	-1057	-461	64	557	892	4	45	75	108	189
	29 - 31	-161	-38	137	281	684	-1177	-316	61	556	877	-98	35	57	74	149
Jun	1 - 8	-33	63	179	273	636	-987	-262	69	432	663	-117	33	54	82	171
	9 - 24	-89	2	123	223	682	-1251	0	-7	20	554	-82	122	130	157	184
	25 - 30	-89	-24	109	208	635	-1016	0	-18	38	313	-57	120	131	154	183
Jul	1 - 31	-157	-36	104	219	626	-1387	0	-52	0	303	-132	98	105	131	181
Aug	1 - 31	-190	-104	56	207	629	-1339	0	-40	0	395	-160	94	99	128	157
Sep	1 - 21	-214	-144	24	184	576	-1142	0	-27	2	349	-132	96	99	125	145
	22 - 30	-198	-68	1	58	462	-1024	0	-57	0	178	-137	24	54	95	138
Oct	1 - 19	-263	-121	-46	14	281	-1086	-20	-78	0	303	-137	37	67	113	143
	20 - 27	-234	-65	-10	27	349	-1101	0	-50	0	332	-127	85	92	130	157
	28 - 31	-276	-123	-33	21	400	-1315	-266	-75	130	794	-172	56	94	157	187
Nov	1 - 3	-195	-138	-58	-1	275	-656	0	-25	42	399	-117	74	90	131	158
	4 - 6	-159	-72	16	77	297	-27	0	0	0	13	-80	90	90	116	143
	7 - 12	-477	-139	10	154	443	-807	0	-1	8	366	-89	108	124	170	192
	13 - 14	-451	-107	26	213	563	-855	-448	27	150	1633	-86	-32	19	56	112
	15 - 30	-554	-116	165	475	719	-2161	-725	152	1246	2315	-73	22	34	54	120
Dec	1 - 31	-566	-95	187	494	754	-2157	-717	195	1289	2243	-204	-9	21	51	148

Table B-2 (cont.) Distribution of flows (cfs) by study period in 2003.

		VICT					GRL009					ROLD034				
		Min	25%	Avg	75%	Max	Min	25%	Avg	75%	Max	Min	25%	Avg	75%	Max
Jan	1 - 31	-2639	649	2982	5374	8663	-3926	32	1292	2953	5294	-16948	-10594	-5292	-532	7223
Feb	1 - 28	-2561	832	3222	5396	8045	-3647	147	1298	2873	4783	-15750	-10610	-5800	-1322	7200
Mar	1 - 31	-2467	1132	3143	5209	7555	-3239	363	1344	2735	5200	-14593	-10243	-5798	-1805	5760
Apr	1 - 13	-2249	-246	2335	4320	7979	-2899	-419	1132	2676	4042	-14826	-8612	-4194	877	6296
	14 - 15	-1507	-906	2128	4161	7514	-3735	-1701	604	2766	3266	-14811	-9086	-3707	3076	4176
	16 - 30	-2528	-1859	594	2940	5811	-4236	-2486	426	3091	3713	-10708	-6204	-799	4807	6983
May	1 - 15	-2405	-1821	601	2817	6129	-4757	-2522	317	2938	3569	-13009	-6145	-870	4635	6644
	16 - 19	-2787	-2302	370	2809	4380	-4819	-2241	783	3327	4019	-10030	-6443	-343	5932	7604
	20 - 28	-2435	-1724	480	2586	5708	-3084	-1549	976	3140	3876	-11479	-5673	-557	4443	6872
	29 - 31	-1638	-133	2256	4088	6710	-3331	-120	1134	3277	4115	-13246	-9048	-4006	1031	4822
Jun	1 - 8	-1396	1371	3419	5419	7822	-3121	13	1204	2582	3422	-15195	-10483	-6180	-2117	3982
	9 - 24	-1069	1678	3549	5655	8952	-2111	463	649	907	2624	-16567	-10765	-6549	-2841	3337
	25 - 30	-1083	690	2890	4354	8689	-1703	469	625	968	1576	-16654	-8093	-5231	-207	3142
Jul	1 - 31	-1191	2050	3719	5724	8986	-2369	175	315	587	1585	-17392	-11226	-6971	-3397	3354
Aug	1 - 31	-1185	2161	3801	5935	8832	-2232	335	445	720	1786	-16983	-11567	-7066	-3543	3245
Sep	1 - 21	-2426	2088	3715	5900	8268	-1997	421	500	748	1504	-16189	-11477	-6868	-3500	6374
	22 - 30	-680	1884	3585	5933	7931	-2057	216	223	459	1357	-15390	-11509	-6717	-3022	2215
Oct	1 - 19	-1233	423	2475	3861	7142	-2098	120	263	653	1657	-13867	-8215	-4575	-395	3980
	20 - 27	-1380	29	2716	4934	7829	-2134	406	414	717	1535	-14730	-9412	-4948	480	4413
	28 - 31	-1345	-135	1889	3614	6207	-2436	-555	403	1169	2333	-12139	-7527	-3385	1123	4784
Nov	1 - 3	-1632	-405	1553	3355	6478	-1275	295	493	906	1576	-12299	-6918	-2627	1420	4945
	4 - 6	-1144	-41	2799	5171	7376	61	339	442	561	813	-14141	-9607	-5022	417	2811
	7 - 12	-1342	317	3309	5960	7569	-1477	567	776	842	3855	-14520	-11646	-5928	-335	4650
	13 - 14	-1612	-110	3361	6024	7248	-514	99	1306	2548	3335	-13978	-12029	-6063	2	4499
	15 - 30	-2323	-452	2275	4716	7628	-3407	-389	1019	2702	4119	-14731	-9647	-4089	1954	6560
Dec	1 - 31	-2581	-627	2556	5146	9677	-3363	-300	1091	2763	3998	-18563	-10145	-4506	2075	6984

Table B-2 (cont.) Distribution of flows (cfs) by study period in 2003.

		ORP					ROLD074					MID at VICT				
		Min	25%	Avg	75%	Max	Min	25%	Avg	75%	Max	Min	25%	Avg	75%	Max
Jan	1 - 31	-302	1315	1484	1742	2222	16	1174	1500	1904	2702	-11259	-6883	-2944	940	5410
Feb	1 - 28	286	1383	1515	1719	2271	-6	1223	1535	1881	2448	-10055	-6967	-3217	165	5355
Mar	1 - 31	978	1427	1569	1710	2193	835	1286	1603	1927	2571	-9716	-6546	-3161	249	4588
Apr	1 - 13	680	1222	1396	1561	2095	410	1162	1437	1764	2399	-9412	-6078	-2346	1215	4663
	14 - 15	-596	-371	637	931	2059	197	253	637	312	2536	-9461	-6551	-2162	2747	3420
	16 - 30	-656	-383	309	848	986	208	270	293	318	362	-7555	-4952	-652	3697	4971
May	1 - 15	-775	-361	286	831	1024	0	271	289	320	363	-9427	-4706	-702	3388	4698
	16 - 19	-959	846	1084	1551	1700	0	981	1199	1692	2570	-7750	-4921	-442	4221	5428
	20 - 28	714	887	1169	1422	1636	541	1034	1246	1532	1984	-7686	-4521	-477	3432	4947
	29 - 31	762	1211	1386	1580	1858	456	1160	1459	1764	2310	-9262	-6019	-2283	1600	4144
Jun	1 - 8	997	1385	1523	1671	2296	1127	1265	1600	1936	2473	-9502	-6794	-3547	-640	3323
	9 - 24	225	561	967	1303	2244	296	671	1125	1493	2638	-11038	-6811	-3606	-175	3187
	25 - 30	252	569	918	1150	2084	318	661	1075	1366	2526	-10746	-5889	-2915	1038	3018
Jul	1 - 31	-249	212	643	1069	1902	-256	275	781	1284	2429	-11352	-7253	-3876	-574	3057
Aug	1 - 31	-236	180	638	1078	1831	-249	219	757	1292	2234	-11100	-7428	-3847	-554	3236
Sep	1 - 21	-212	123	587	1024	1729	-226	158	696	1190	2125	-10542	-7266	-3712	-461	5037
	22 - 30	-127	143	303	403	1458	-129	190	369	486	1904	-10110	-7369	-3617	-129	2392
Oct	1 - 19	-84	158	263	331	847	-56	221	341	443	757	-9158	-5926	-2514	1001	3768
	20 - 27	174	386	472	548	880	230	504	580	662	983	-9587	-6515	-2679	1328	4134
	28 - 31	189	336	453	561	1024	361	479	568	609	988	-8009	-5739	-1972	1965	4289
Nov	1 - 3	136	221	328	408	775	210	310	397	465	662	-7680	-5289	-1452	1902	4158
	4 - 6	75	227	493	620	1597	125	294	596	659	2008	-8902	-6229	-2706	1314	2994
	7 - 12	24	340	806	1187	1850	100	462	942	1331	2280	-9491	-7158	-3293	791	4150
	13 - 14	2	1239	1391	1571	1770	2	1038	1431	1844	2124	-8925	-7286	-3492	2	3757
	15 - 30	66	1027	1211	1458	1714	-273	951	1256	1665	2042	-9651	-6363	-2337	2164	5000
Dec	1 - 31	-63	1093	1260	1508	1877	-284	948	1284	1660	2399	-12431	-6571	-2551	2122	5225

Table B-2 (cont.) Distribution of flows (cfs) by study period in 2003.

		RMID027					RSAN072					ROLD040				
		Min	25%	Avg	75%	Max	Min	25%	Avg	75%	Max	Min	25%	Avg	75%	Max
Jan	1 - 31	-1267	-593	19	603	1412	-2545	-1024	421	1699	2522	-14437	-5964	-2695	1391	7523
Feb	1 - 28	-1443	-568	4	611	1498	-2410	-1047	383	1688	2456	-13711	-5579	-2750	1087	5716
Mar	1 - 31	-1318	-528	-6	530	1314	-1970	-672	565	1735	2396	-13127	-5334	-2836	730	7887
Apr	1 - 13	-1153	-618	9	588	1221	-1750	-890	495	1703	2250	-11864	-4981	-1803	1992	4777
	14 - 15	-1156	-636	-54	530	813	-1480	888	1692	2796	3060	-11361	-6370	-2960	1120	2126
	16 - 30	-1257	-495	-44	356	839	994	2446	2869	3340	3834	-9355	-5433	-705	4004	6402
May	1 - 15	-1465	-519	-70	308	796	517	2455	2877	3322	3747	-10449	-5388	-788	3803	5487
	16 - 19	-1441	-659	-1	511	983	-2039	-203	1144	2406	3329	-9843	-5454	-182	5207	7075
	20 - 28	-1170	-444	23	435	889	-1713	-513	777	1887	2383	-8459	-5388	-643	3754	6441
	29 - 31	-1275	-502	-6	407	1083	-2032	-964	532	1963	2199	-11447	-4986	-2390	1594	6074
Jun	1 - 8	-1241	-433	-64	373	790	-1993	-982	388	1758	2055	-11441	-5257	-3209	-380	1836
	9 - 24	-1179	-182	2	231	1047	-2183	154	976	1962	2471	-12768	-5894	-3839	-1422	4280
	25 - 30	-1092	-305	5	270	983	-1849	229	1000	2052	2370	-12428	-6360	-3794	-847	4021
Jul	1 - 31	-1416	-304	-67	151	972	-2573	-682	506	1668	2358	-13410	-5823	-4049	-1655	4802
Aug	1 - 31	-1403	-247	-2	227	1124	-2508	-729	543	1733	2210	-13030	-5690	-3920	-1368	5900
Sep	1 - 21	-1249	-174	37	243	983	-2262	-486	647	1775	2199	-12377	-5576	-3583	-1297	7343
	22 - 30	-1096	-214	-12	190	856	-1799	-304	876	2030	2303	-12254	-6173	-4312	-1921	3060
Oct	1 - 19	-1159	-261	1	244	912	-1658	329	1172	2168	2414	-11541	-7044	-4245	-1722	5004
	20 - 27	-1329	-139	32	237	754	-337	1367	1936	2606	2962	-11015	-6101	-3991	-1538	5414
	28 - 31	-1320	-578	8	409	1087	-1035	968	1754	2726	3003	-10616	-7023	-3962	-706	7344
Nov	1 - 3	-867	-113	77	325	715	-334	883	1673	2338	2699	-7580	-5801	-2901	-227	3572
	4 - 6	-619	-76	33	163	369	-1203	525	1239	2067	2293	-7926	-5615	-3819	-1895	385
	7 - 12	-843	-462	72	616	1033	-1896	-87	874	1846	2341	-10859	-5514	-3647	-1661	1138
	13 - 14	-773	-595	-58	439	781	-1868	-1109	239	1561	1991	-7431	-6079	-3078	-538	2678
	15 - 30	-1319	-591	-26	539	1086	-2475	-1053	326	1572	2297	-13086	-6681	-3218	1199	6597
Dec	1 - 31	-1320	-627	-2	576	1118	-3189	-1158	249	1570	2350	-12682	-6310	-2863	1403	5702