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The Resources Agency
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South Delta Temporary Barriers Project

2002 South Delta Temporary Barriers Monitoring Report

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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. The table at the end of this introduction 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 1. Fish Monitoring and Water Quality Analysis

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 2002, however, funding and personnel shortages precluded implementation, therefore the fish monitoring study was not conducted in 2002. 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 2. Fish Entrainment Monitoring at the Head of Old River Barrier

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 3. Salmon Smolt Survival Investigations

This section describes the methods used in conducting the 2002 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 2002 test period.

Chapter 4. Annual Summary Report of SWP and CVP Salvage

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 5. Swainson's Hawk Monitoring and Mitigation

This section describes Swainson's hawk observations and the effects of the barriers construction activities on nesting pairs within ½ mile radius of the sites.

Chapter 6. Water Elevations

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

Chapter 7. South Delta Water Quality

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 8. Hydrologic Modeling

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 2002. The DSM2-simulated stages and flows are then compared to historical data in the south Delta.

Chapter 1. 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 operated during the agricultural season, usually April though November. They are designed for two purposes: (1) a short-term solution for improvement of water level 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 primarily installed in the spring as a fish barrier to prevent fall-run San Joaquin River Chinook salmon smolts from migrating down through Old River towards the Central Valley Project (CVP) and the State Water Project (SWP) export facilities. As a secondary benefit, Central Valley steelhead smolts from the San Joaquin River watershed are prevented from following this course as well. This fourth barrier is also installed in the fall to increase water quality downstream on the San Joaquin River. Of those 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; the spring head of Old River barrier (HORB) was installed in 1992, 1994, 1996, 1997, and 2000-2002; and the fall HORB has been installed off and on since 1968. 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 with the installation of the temporary barriers in the south Delta, however, this project was cancelled due to insufficient data collection and recapture capabilities.

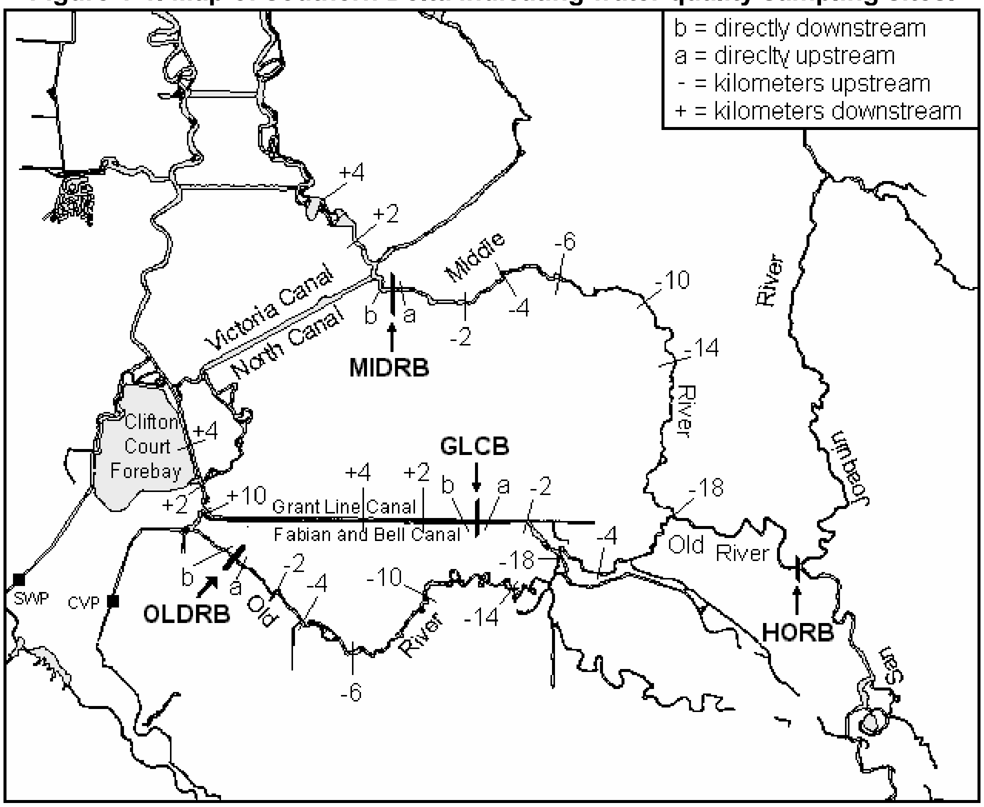
In 2002, fisheries monitoring was not conducted, however, physical water quality parameters were monitored not only for their possible affects on the fisheries but for other pertinent biological information, such as null zones. A null zone occurs when the upstream flow of water negates the downstream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

- Determine water quality profiles of the channels affected by the temporary barriers.
- Determine any null zones within the south Delta.

Materials and Methods

Twenty-seven permanent water quality sampling sites were sampled on Grant Line Canal, Old and Middle Rivers (Figure 1-1). A hydrolab was used to determine water temperature (ºC), dissolved oxygen (the concentration of gaseous oxygen dissolved in water (mg/L)), and specific conductance (the water's ability to conduct an electric current normalized to 25ºC and is directly related to the total dissolved salts or ions (µmhos/cm)). Turbidity was measured using a portable turbidimeter (the degree to which light is scattered by suspended particles (NTU)). A secchi disk was used to measure water clarity (cm). 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.

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



Each channel's water quality parameters were compared over time and location. Three different water quality profiles were graphed for comparison: (1) monthly mean per site per channel per parameter (Figures 1-2 through 1-6); (2) mean per site per channel (Figure 1-7); and (3) mean per month per channel (Figure 1-8). A three-way analysis of variance (ANOVA) was used to compare tide, month, and sampling site. The data used for statistical analysis this year was an average of the four samples taken at each location (sample site) not the raw data, as was used last year. It was felt that this data was a better representation of the south Delta water quality. Further statistical analysis will include pairwise comparison tests (Bonferroni and Tukey) and correlations between all five variables of each channel. Comparison of results between 2001 and 2002 can only be made on graphed data. The statistical data can not be compared due to the change in statistical analysis.

Results and Discussion

The water quality indices from 2002 did not change much compared to those from 2001. All three sets graphs showed similar trends. However, there were some differences that are addressed in the following sections.

Specific Conductance (Figures 1-2A, 1-2B, 1-2C, 1-7A, 1-8A)

As in 2001, the specific conductance of 2002 increased downstream to upstream with Old River having the highest overall specific conductance of all three channels. Also, each channel showed similar patterns of specific conductance for each month, this may indicate a relationship between specific conductance and location (sampling site). The differences begin with Old River's highpoint in specific conductance moving from 10 km downstream of the barrier in 2001 to only 2 km downstream of the barrier in 2002. Middle River had the most change of all three channels and this was a positive change because all months, except March, showed lower specific conductance. March readings skyrocketed upstream of the MIDRB before construction in April. This could have been caused by agricultural activities such as the leaching of agricultural land. Also, Middle River's highpoint in specific conductance remained at 14 km downstream of the barrier. For the most part, Grant Line Canal's specific conductance remained the same as last year's with slight fluctuations.

The ANOVA's performed on all three channels indicated that the mean specific conductance for all sites were significantly different ($P \leq 0.05$). The same statistical analysis was done for the tides and months with similar results. However, the pairwise statistical test indicated that Grant Line Canal's specific conductance measurements were close to being equal for all sites, except for one site 10 km downstream of the barrier.

The water quality monitoring results indicated a possible relationship between specific conductance and location. The high points in specific conductance indicated areas of possible null zones in both Middle and Old Rivers. The ANOVA results indicated that specific conductance varied greatly for all three 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 effect may also be amplified due to the dry year type (water year classification).

Dissolved Oxygen (Figures 1-3A, 1-3B, 1-3C, 1-7B, 1-8B)

The 2002 and 2001 dissolved oxygen values were initially elevated during the spring and then decreased throughout the summer months, before improving again in October. Also, all three channels had similar dissolved oxygen patterns, when averaged per month that suggests a relationship between dissolved oxygen and the time of year. The most important distinctions between the last two years is that for all three channels 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 (4th ed.). Sags in dissolved oxygen for both Old River and Grant Line Canal seemed to be located further downstream than last year, 2 km downstream to 2 km upstream of the barriers. Middle River was similar to last year with its dissolved oxygen sag located approximately 6 km upstream of the barrier. Furthermore, the dissolved oxygen spike that appeared in Middle River last year in May and June at sites 14 and 18 km upstream of the barrier is evident. However, July, August, and September also showed similar spikes this year. This means the increase in dissolved oxygen at these locations is probable due to the oxygen rich water traveling down Old River and not due to the removal of the spring head of Old River barrier, as stated last year.

The ANOVA's performed on all channels indicated the mean dissolved oxygen for all sites and months were significantly different ($P \leq 0.05$). However, the same statistical analysis was done for the tides indicating no significant difference ($P > 0.05$). Furthermore, the pairwise statistical test indicated that Grant Line Canal's dissolved oxygen measurements were was close to being equal for all sites, except one directly downstream of the barrier. The negative correlation between dissolved oxygen and water temperature was evident for Grant Line Canal, Old River, and Middle River with the Pearson's correlation coefficients being -0.72, -0.62, and -0.73, respectively.

Results indicated 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. The ANOVA results indicated that the tides may not have an effect on dissolved oxygen, but location and months have an effect. Also, the negative correlation showed that as the water temperature increased, the dissolved oxygen decreased. Variances in dissolved oxygen may be due to water temperature, water agitation, localized (agricultural) nutrient loading, and primary production.

Water Temperature (Figures 1-5A, 1-5B, 1-5C, 1-8C, 1-9C)

The 2002 water temperatures data is similar to the 2001 data in that the profile for all three channels were initially low in the spring and then elevated throughout the summer, before decreasing again in October. This trend is the exact opposite of the dissolved oxygen profile. All three channels showed approximately identical monthly averages in water temperature that suggests a relationship between water temperature and the time of year. Also, the monthly water temperature (Figure 1-8C) compared to the average monthly air temperature for the Delta (Figure 1-9) shows that the water temperature of all three channels changed along with the air temperature.

The ANOVA's results on the water temperature data was different compared to other parameters. Grant Line Canal and Old River's statistical analysis for all sites and tides indicated no significant difference ($P>0.05$), while months were significantly different ($P\leq0.05$). Middle River's statistical analysis for all sites showed no significant difference, however the tides and months were significantly different ($P\leq0.05$). The negative correlation between water temperature and dissolved oxygen was mentioned in the dissolved oxygen section. There is also a positive correlation between water temperature and turbidity, which is not as strong, but may be worth mentioning with Grant Line Canal, Old River, and Middle River's Pearson coefficients being 0.64, 0.58, and 0.53, respectively.

The results indicated 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 but may affect Middle River's water temperature. The positive correlation between water temperature and turbidity showed that as water temperature increased, turbidity decreased. This correlation could be caused by the increase in recreational activities during the summer months. For example, the warmer months attract more water recreation such as boating, skiing, etc., and more water is used for agricultural purposes. All of the water agitation and use results in increased turbidity. Finally, water temperature seems to follow air temperature based on the graphical data.

Water Clarity (Figures 1-6A, 1-6B, 1-6C, 1-8E, 1-9E)

As in 2001, water clarity or secchi depth in 2002 decreased downstream to upstream with Grant Line Canal having the lowest overall water clarity of all three channels. This same pattern for every month may indicate that water clarity is connected to location (sampling site). In the previous year Old River had an increase in clarity around the barrier not found in this year. Middle River's clarity increased to give it the highest clarity of all three channels.

Most of the ANOVA's performed for water clarity indicated significant differences for the sites, months, and tides. The two exceptions were Grant Line Canal and Old River's statistical analysis that indicated the tides were not significantly different ($P>0.05$). A negative correlation was found between water clarity and turbidity for Grant Line Canal, Old River, and Middle River with the Pearson's correlation coefficients being -0.75, -0.64, and -0.65, respectively.

Results indicated a possible relationship between water clarity (secchi depth) and sampling site. The ANOVA results showed months and sampling sites affecting all three channels but tides had no effect on Grant Line Canal and Old River, while Middle River's water clarity was affected by tides. The slight negative correlation showed that as the water clarity increased, the turbidity decreased and is explained by the fact that turbidity is affected by suspended particles that effect water clarity. Variances in water clarity may be due to algae blooms, suspended solids from agricultural runoff, erosion, bottom feeders, and low flow.

Turbidity (Figures 1-7A, 1-7B, 1-7C, 1-8D, 1-9D)

Turbidity measurements were taken in 2002 and they normally stayed well below 50 NTU's. Old and Middle Rivers had increased turbidity upstream of the barrier June through August. Also, as Middle River had the highest water clarity, it also had the lowest turbidity. Grant Line Canal's turbidity increased downstream of the barrier June through August. This is probably explained by the amount of boating activity downstream of the barrier. The boat wakes collide with the shoreline, stir up the water, and disturb the bottom sediment.

The ANOVA results for all three channels showed that the mean turbidity for both tides were equal ($P>0.05$). However, the same was done for all sites and months with the opposite results. Also, the correlations found between turbidity and temperature, and turbidity and water clarity are stated in those sections, respectively.

Results indicated a possible relationship between turbidity and location. For all three channels, statistical tests showed location and months effected turbidity, however, 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 time of year (month) and the water quality parameters: dissolved oxygen and water temperature, while there is a possible relationship between the location (sampling site) and the water quality parameters: specific conductance, water clarity, and turbidity. Potential null zones are present in all three channels due to sags in dissolved oxygen and highpoints in specific conductance. Statistical tests indicated that the time of year (months) may affect all water quality parameters on all three channels. Location (sampling sites) appears to have no effect on water temperature for all three channels but may have an effect on the other water quality parameters. Furthermore, tides seem to affect Middle Rivers' water quality parameters the most with only dissolved oxygen not being affected by the tides. However, in Old River and Grant Line Canal the tides seem to only affect specific conductance. The reason for this difference in tidal effects may be caused by Old River / Grant Line Canal's proximity to and Middle River's distance from the SWP and CVP export facilities. These facilities may be altering the tidal effects on the water quality parameters due to its water intake during the high tidal cycle. Also, water temperature seems to track the ambient air temperature and thus air temperature may have an indirect effect on dissolved oxygen levels, since there is a correlation between water temperature and dissolved oxygen. 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 dry water year.

Recommendations

A similar study is planned for 2003 to further evaluate the effects of the temporary barriers on the south Delta water quality. Since turbidity and water clarity seem to be affected by similar events and a correlation was found between the two water quality parameters it is recommended that only turbidity be measured and secchi omitted since secchi measurements are more subjective. Also, air temperature will be collected for use in statistical comparisons. Finally, a map of the south Delta's agricultural diversions/returns is still being looked into for comparison of those locations to water quality sampling sites.

Figure 1-2. Specific conductance at each water quality sampling site per month.

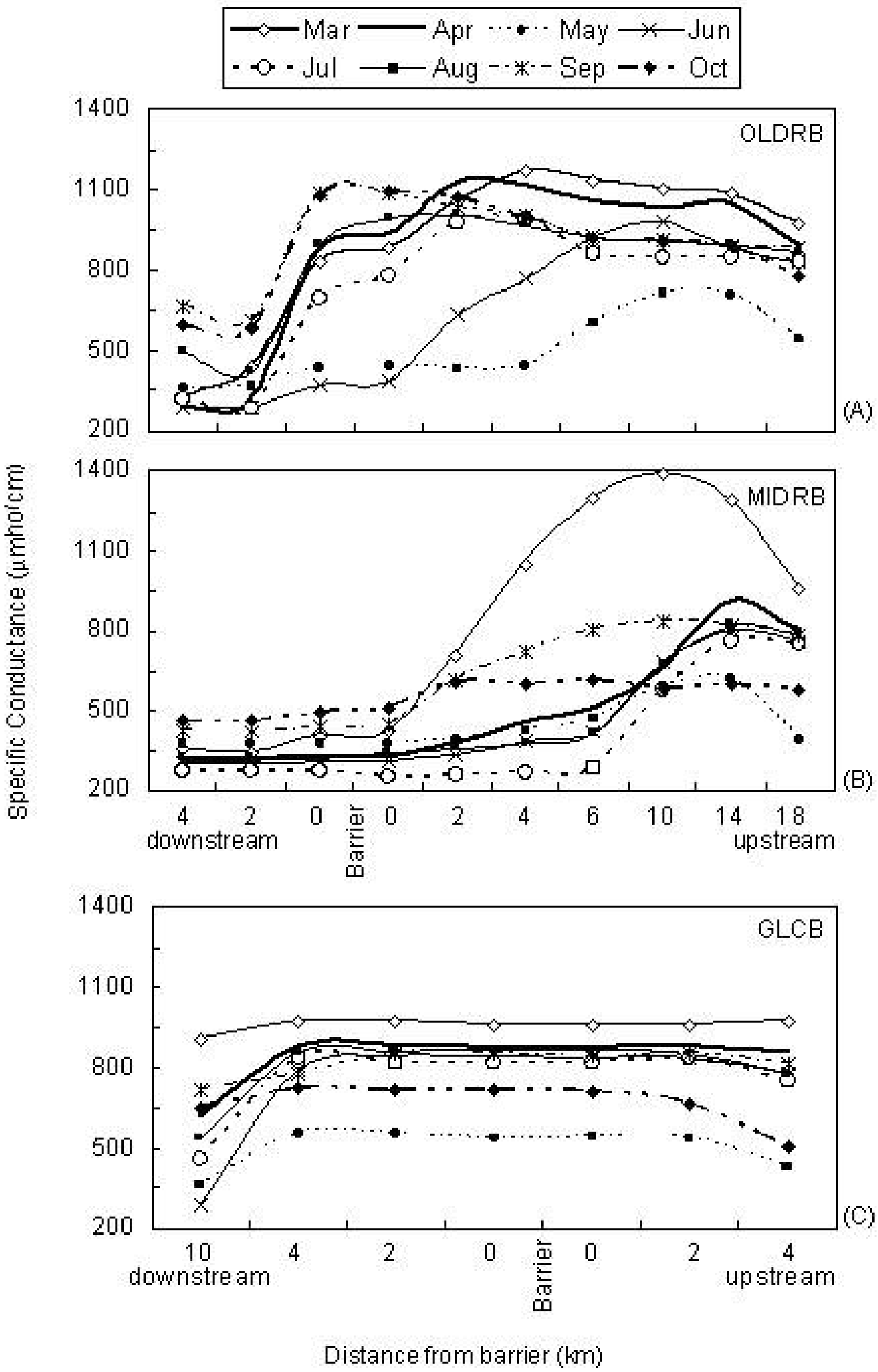


Figure 1-3. Dissolved oxygen at each water quality sampling site per month.

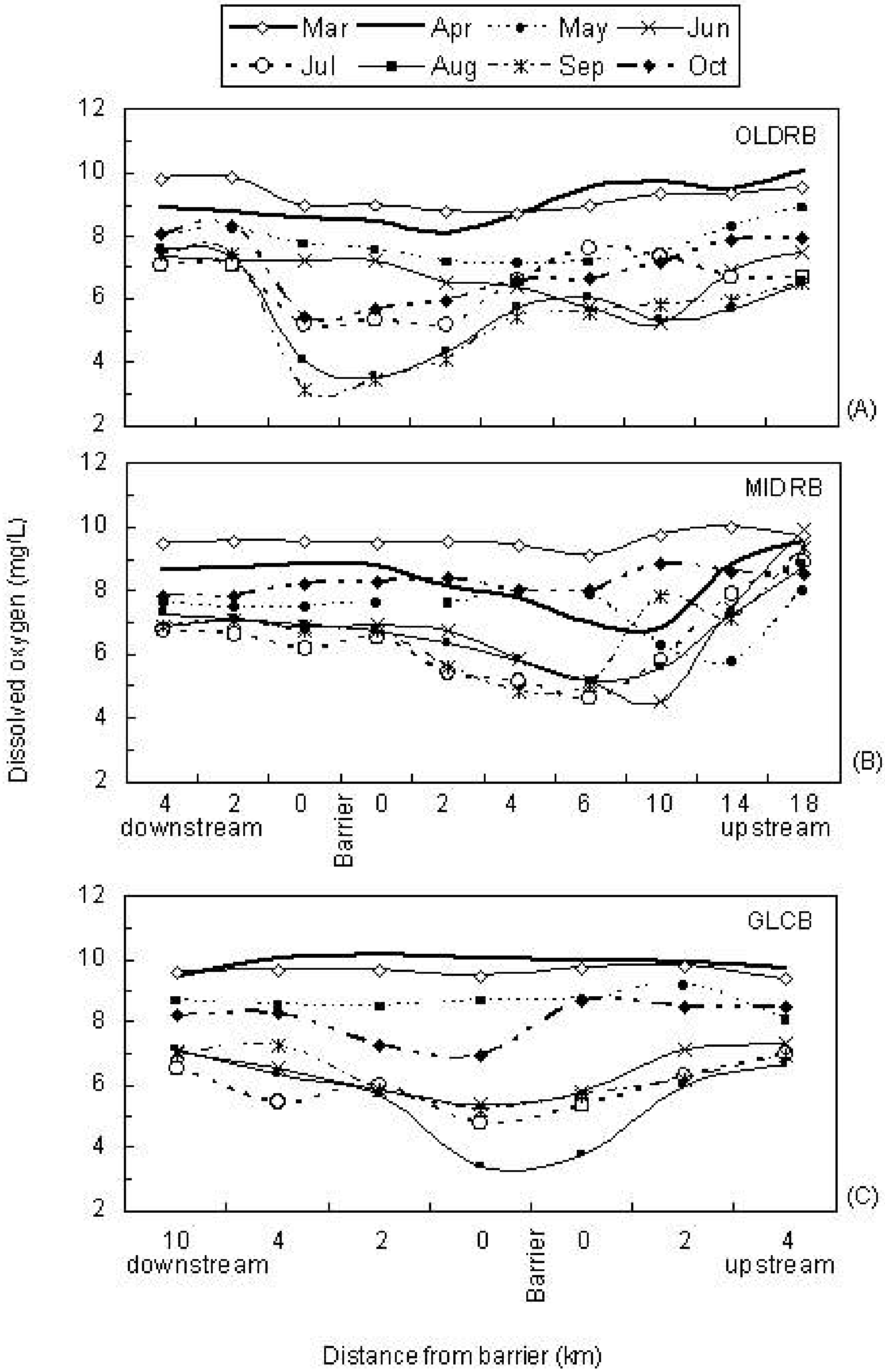


Figure 1-4. Water temperature at each water quality sampling site per month.

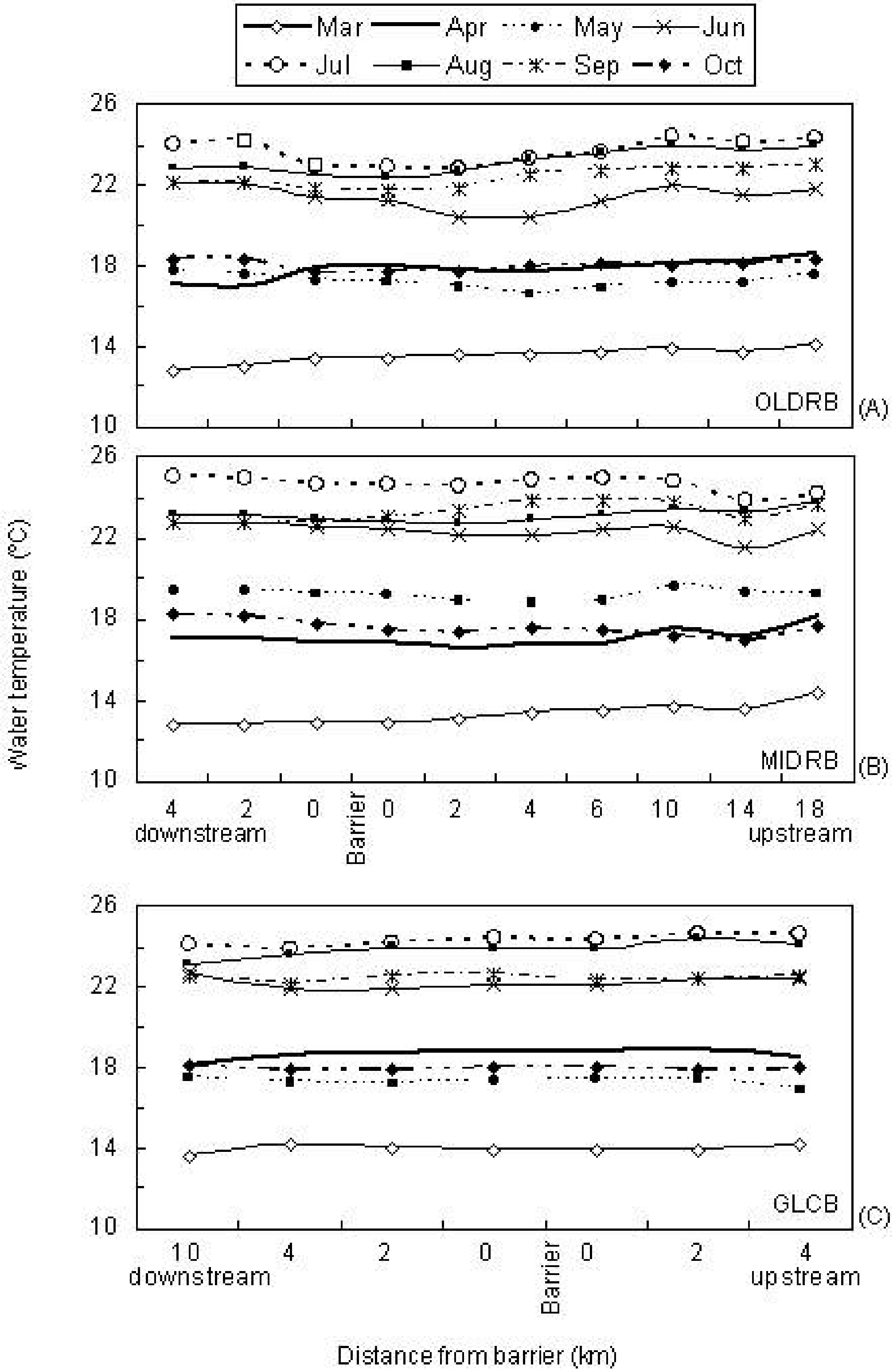


Figure 1-5. Water clarity (secchi depth) at each water quality sampling site per month.

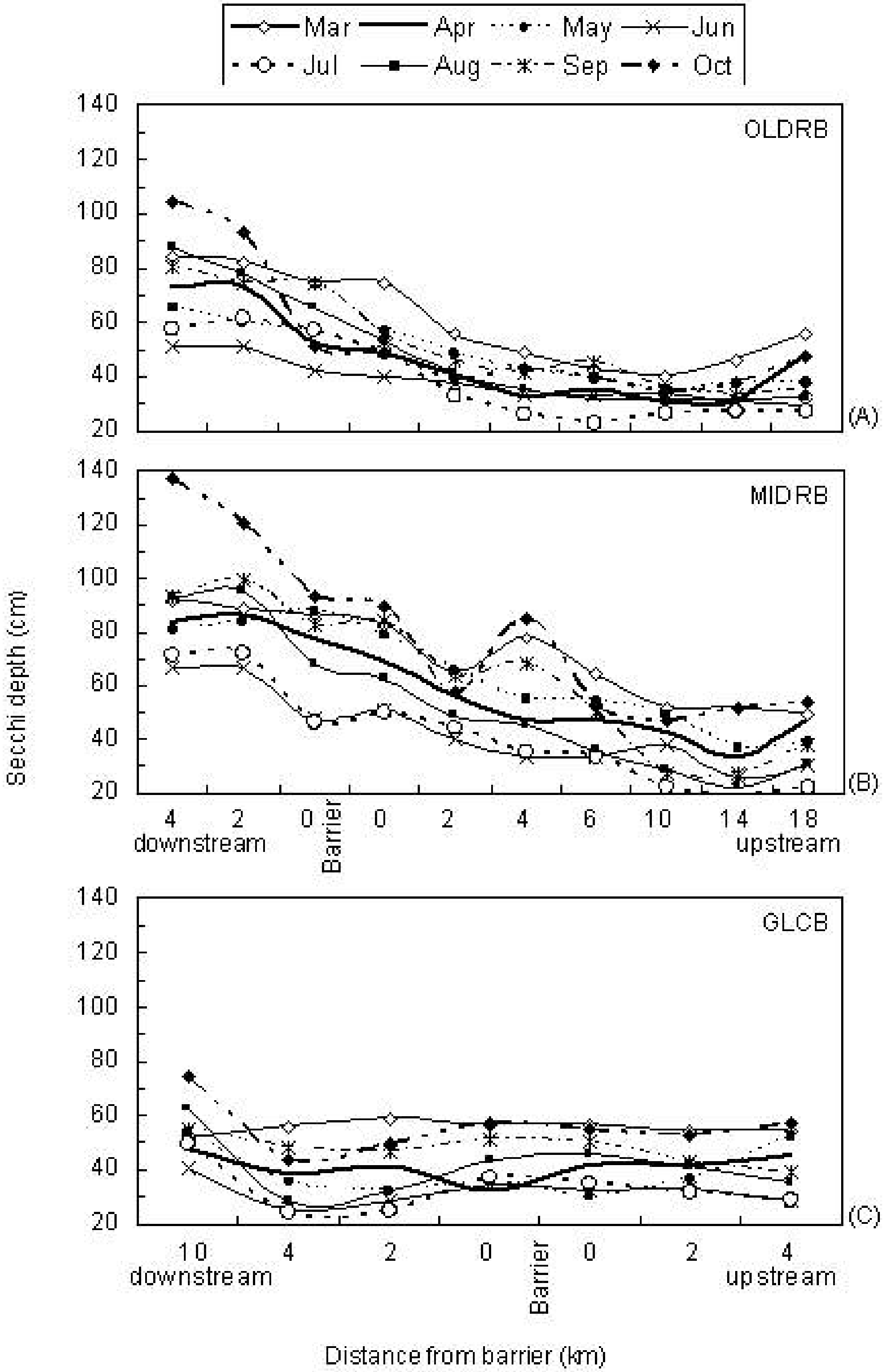


Figure 1-6. Turbidity at each water quality sampling site per month.

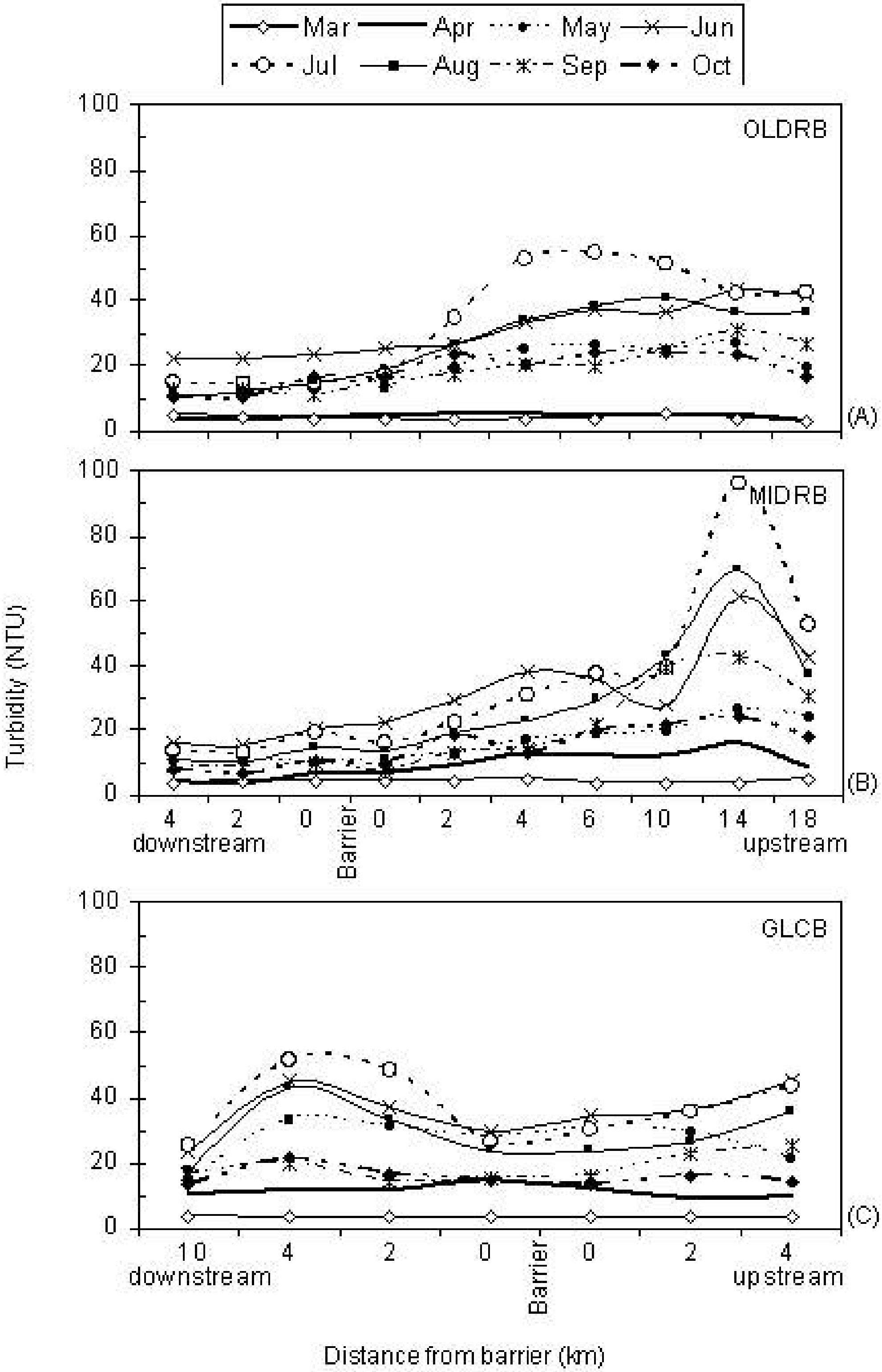


Figure 1-7. Overall water quality parameters at each water quality sampling site. Grant Line Canal was sampled 10km downstream to 4km upstream of the barrier. Old and Middle Rivers were sampled 4km downstream to 18km upstream of the barriers.

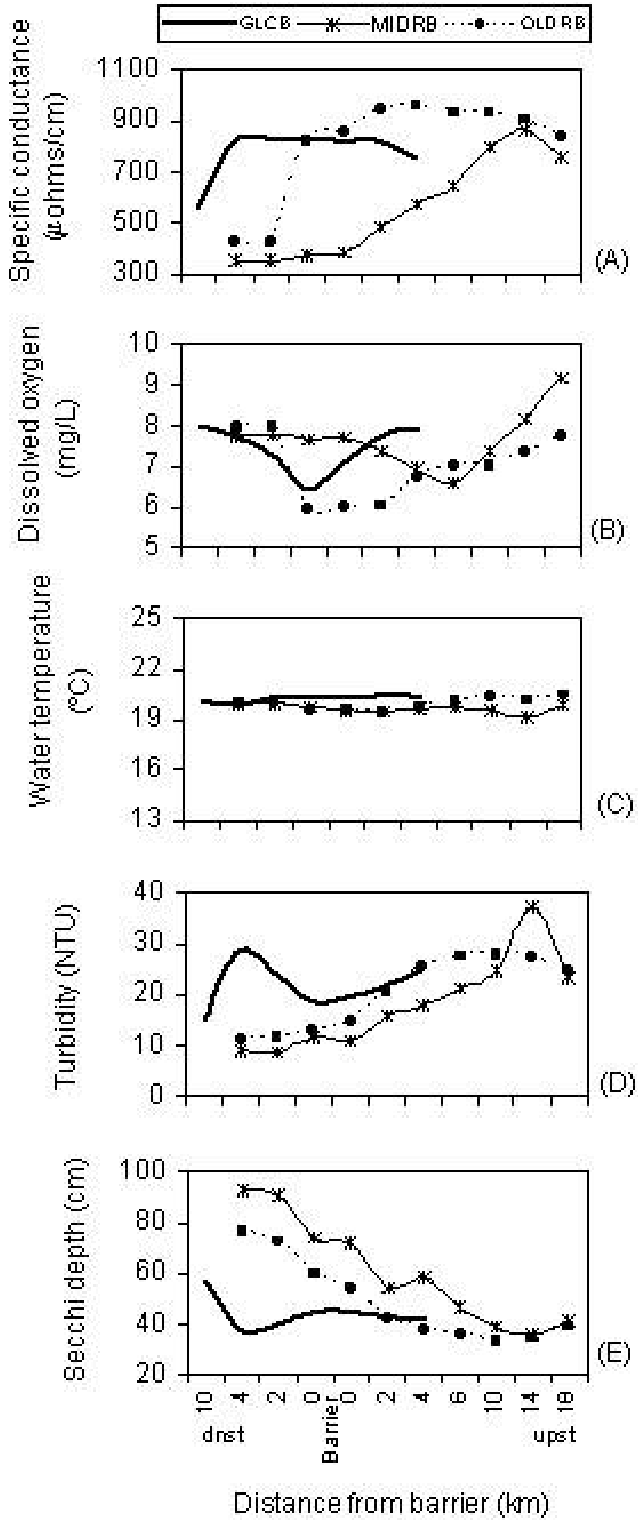


Figure 1-8. Overall water quality parameters for each month.

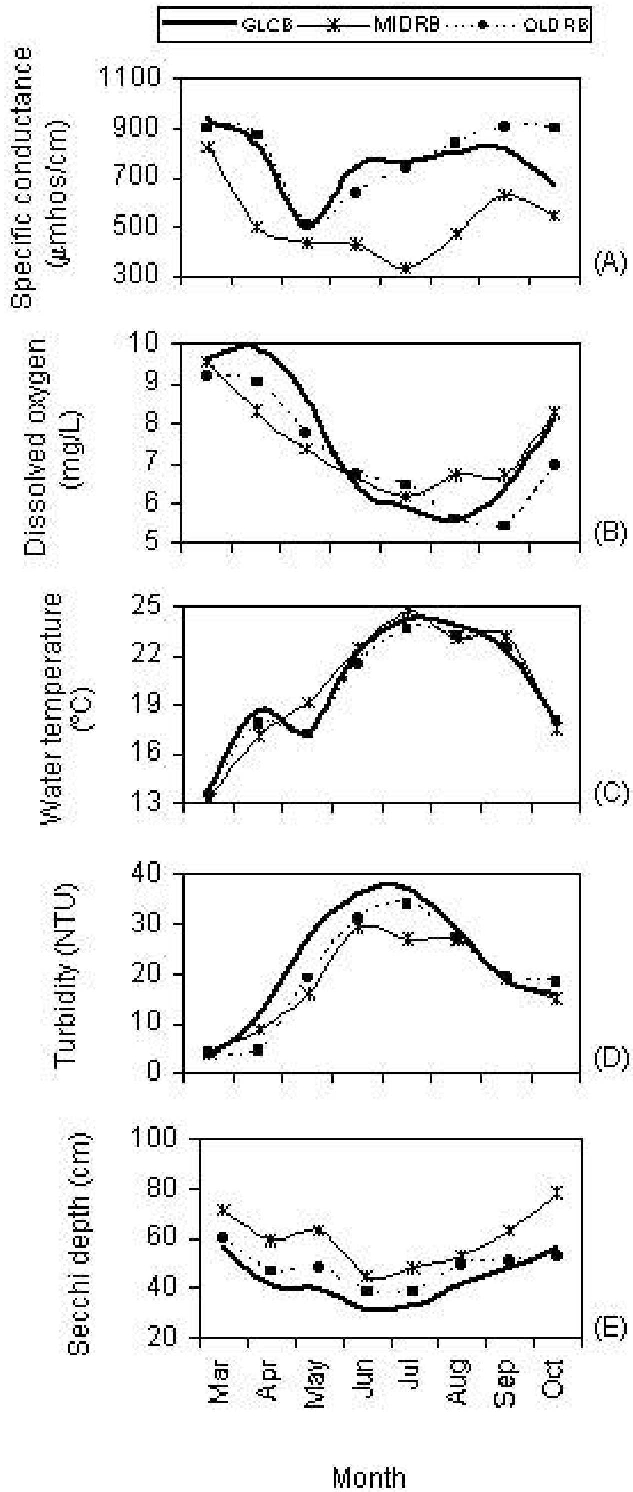
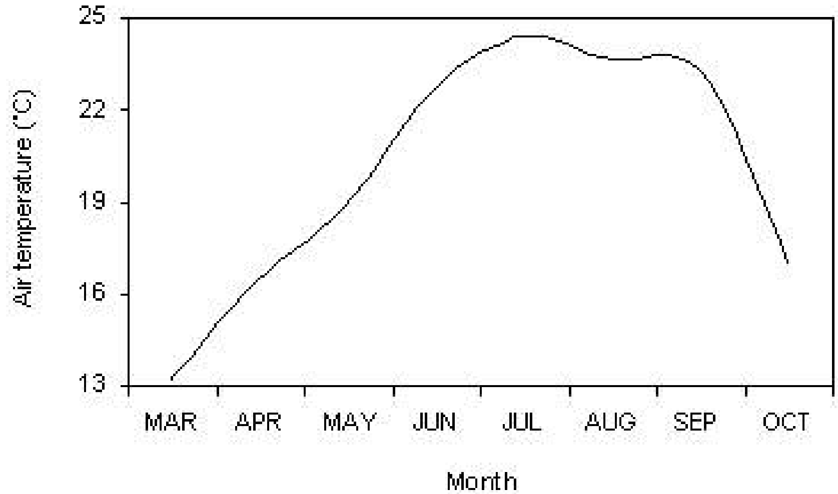


Figure 1-9. Average monthly air temperatures for the south Delta area.

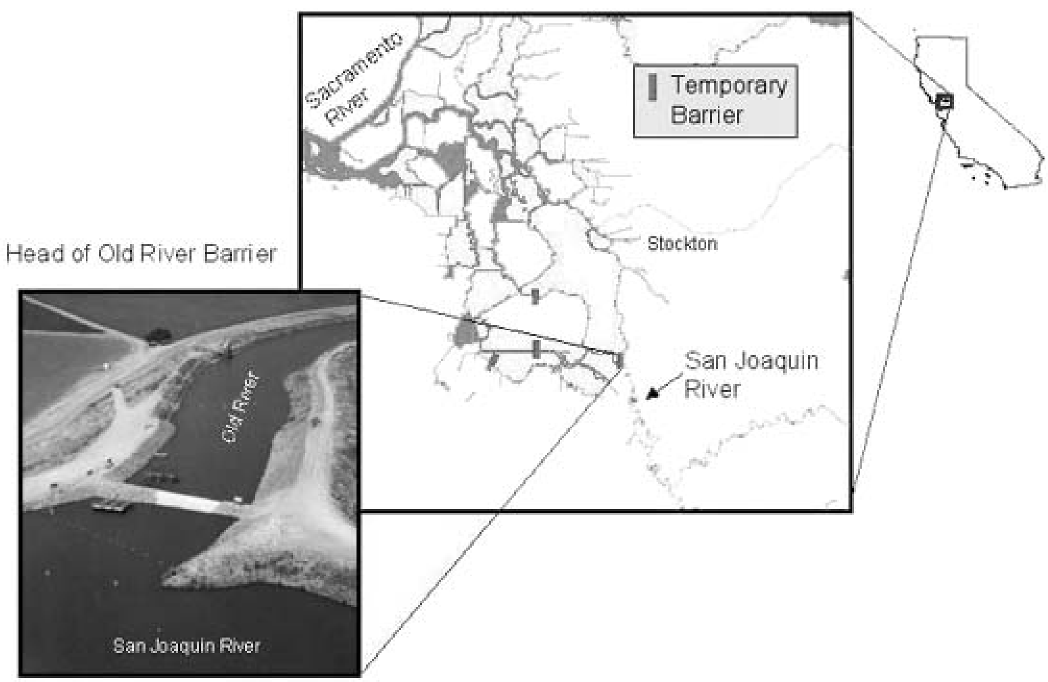


Chapter 2. Fish Entrainment Monitoring at the Head of Old River Barrier

The South Delta Water Management Program was developed in 1990 to achieve two objectives. One objective was to increase water levels and improve circulation patterns and water quality for local agricultural water users in the south Delta. The other objective 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 southern Delta. The South Delta Temporary Barriers Project was implemented to study the effectiveness of temporary barriers in obtaining the objectives of the permanent barriers.

A physical 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 2-1). This barrier is constructed in the spring to block the passage of out-migrating juvenile Chinook salmon *(Oncorhynchus tshawytscha)* into Old River, which leads to the SWP and Central Valley Project export facilities.

Figure 2-1. 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 along upper Old River with 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 allowed approximately 300 cfs to flow through the barrier and down the Old River channel. The DFG, U.S. Fish and Wildlife Service (USFWS), and National Marine Fisheries Service (NOAA Fisheries) 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 that allowed approximately 1,000 cfs to flow through the barrier and down Old River. The culverts were gated and operated to address water level concerns of the SDWA. In 2001, the HORB was modified with trash racks to control the amount of debris diverted 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 2002 HORB was the same as the 2001 HORB. As in the previous year, the barrier was assembled with six culverts that were gated and operated to address water level concerns of the SDWA.

There is much speculation 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 will help assess the fishery impacts of the barrier. Specifically, it will help determine if the modified barrier with culverts is adequate protection for San Joaquin River juvenile Chinook salmon and steelhead emigrating downstream. The 2002 study is designed to increase our understanding of salmon entrainment at the HORB and help develop operational scenarios to minimize the impacts to out-migrating salmon.

During the VAMP 2002 test period, all six culverts in the Head of Old River Barrier (HORB) were operational and remained open. Since the culverts are not screened, juvenile Chinook salmon and other fish species that pass near the culverts are vulnerable to entrainment. A fishery monitoring program was designed and implemented by the DFG to evaluate and quantify fish entrainment at the HORB. The specific objectives of the 2002 fishery investigations were:

- 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 entrained into Old River (Entrainment Monitoring).
- Determine tidal and diel effects on juvenile Chinook salmon entrainment (Entrainment Special Study).

Results of these fishery investigations are intended, in part, to provide information on the design and operation of a future permanent operable barrier at the head of Old River.

Materials and Methods

Chinook salmon from the VAMP releases were used in the Entrainment Monitoring studies. As part of the VAMP 2002 studies, approximately 98,000 VAMP CWT salmon were released at Mossdale on April 18 and approximately 50,000 CWT salmon were released at Durham Ferry on April 19. The same size releases were repeated on April 25

& 26 at Mossdale and Durham Ferry, respectively. 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 channel. The color-marked releases coincided with the two VAMP salmon releases. On the night of April 19, one group 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 25.

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 ¼ inch braided mesh, and five of the nets are 60 feet long and one is 40 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 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 flange. The 40 foot net was attached to culvert number 1 and the 60 foot nets were used on the remaining culverts. The culverts were numbered 1 through 6 with number 1 located next to the shoreline and number 6 located near the middle of the channel (Figure 2-2). On April 18, the flanges, with the attached fyke nets, were lowered down to the culvert outfalls and the live-boxes were attached to the cod-end of the nets to commence sampling.

Figure 2-2. Culvert numbering system for the 2002 HORB.

The fyke nets were checked on every tide change until May 1 (four times per day). From May 1 through May 11, the nets were checked twice a day; in the morning and the evening. On May 12, the nets were removed. The nets were checked by closing the culvert slide gate for a period of 30 to 45 minutes which enabled the live-boxes to be pulled onto a boat so that the fish could be removed and placed into buckets. Once all the nets had been checked and reset, the collected fish were processed. The fish were speciated and counted. Fork lengths (mm) were recorded for up to 50 salmon per live-box. Salmon were checked for a clipped adipose fin and 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. During each net check, culvert number, date, time, water temperature, tidal stage, and diel period was recorded. 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 18 to May 11. The loss index represents the percentage of CWT salmon entrained into the HORB culverts. As in previous years, the loss index is calculated using the equation I=(TC/TR)(TT/ST) where:

TC = Total number of CWT salmon collected in the fyke nets
TR = Total number of CWT released
TT = Total time (hours) during the test period
ST = Total time (hours) sampled at the HORB during the test period

However, this year, for the nine occasions when a culvert was not monitored and/or the sample was lost, the total catch for the missing culvert was estimated by using the average of the other culverts for that sample period. Consequently, all sampling time is accounted for and TT/ST = 1, and the loss index is equal to TC/TR.

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 an index of entrainment vulnerability at the HORB.

Results

The HORB was closed on April 15; however, construction on the barrier continued for another week. Due to the large gravel pad in front of the culverts and/or the ongoing construction and the water currents, gravel was swept through the culverts into the nets during the first three days of sampling. Nine samples were lost or not taken because it required considerable time and effort to retrieve the rock filled net from the bottom of the river. Several of the lost samples occurred during a critical time when the CWT and color-marked salmon were approaching the barrier.

The DFG monitored the HORB culverts for 25 days and collected 381 samples. The nets sampled 3,379 hours out of a possible 3,429 hours. Almost 18,000 fish were collected representing at least 28 species and 14 families of fish. No delta smelt, one juvenile steelhead, and 30 adult splittail were entrained. The most abundant species was Chinook salmon, followed by white catfish (*Ictalurus catus*) (Table 2-1). CWT salmon dominated the catch in April and white catfish dominated the catch in May. Of the 8,467 salmon caught; 5,358 had a CWT; 2,748 were unmarked; and 361 had a color mark.

Table 2-1. The raw abundance and composition of fishes entrained at the HORB in 2002. Chinook salmon catch is divided into CWT VAMP and non-VAMP released salmon, unmarked salmon, and color-marked salmon.

Species		Catch
Cyprinidae		1
Red Shiner		1
Black Bullhead		1
Centrarchidae		1
Steelhead		**1**
American Shad		1
Prickly Sculpin		2
Sacramento Pikeminnow		2
Petromyzontidae		3
White Crappie		4
Tule Perch		4
Shimofuri Goby		5
Warmouth		9
Green Sunfish		10
Largemouth Bass		12
Golden Shiner		14
Sacramento Sucker		15
Black Crappie		19
Redear Sunfish		26
Brown Bullhead		26
Striped Bass		27
Bigscale Logperch		27
Splittail		**30**
Goldfish		37
Inland Silverside		88
Bluegill		118
Common Carp		199
Channel Catfish		560
Threadfin Shad		1,219
White Catfish		6,925
Total Chinook Salmon		**8,467**
CWT VAMP Salmon	4,145	
CWT NonVAMP Salmon	1,213	
Unmarked Salmon	2,748	
Color-Marked Salmon	361	
	Total	**17,854**

This year's CWT salmon entrainment increased 323 % over last year's CWT salmon entrainment (1,268 salmon). Salmon smolts were caught throughout the monitoring period although most of the VAMP released salmon were caught within a couple days of their release (Figure 2-3). During the first VAMP salmon release, it appears most of the Durham Ferry CWT salmon were entrained on the night of April 18 and the Mossdale released salmon were entrained on night of April 19 (Figure 2-4). During the second VAMP release, the Durham Ferry salmon were entrained at a lower rate and few were caught on the night of April 25 (Figure 2-5). In contrast, the Mossdale salmon were entrained at a high rate on the night of April 26. The loss indices for the first Durham Ferry and Mossdale salmon releases were 1.6 % and 1.7 %, respectively. The loss indices for the second Durham Ferry and Mossdale releases were 1.0 % and 2.3 %, respectively. The overall loss index for the VAMP released salmon was 1.5 %. This year's overall loss index is higher than the previous two years' indices of 0.5 % (2000) and 0.8 % (2001).

Figure 2-3. The total daily catch of salmon smolts entrained at the HORB in 2002. The total catch is divided into non-VAMP, VAMP, and unmarked salmon.

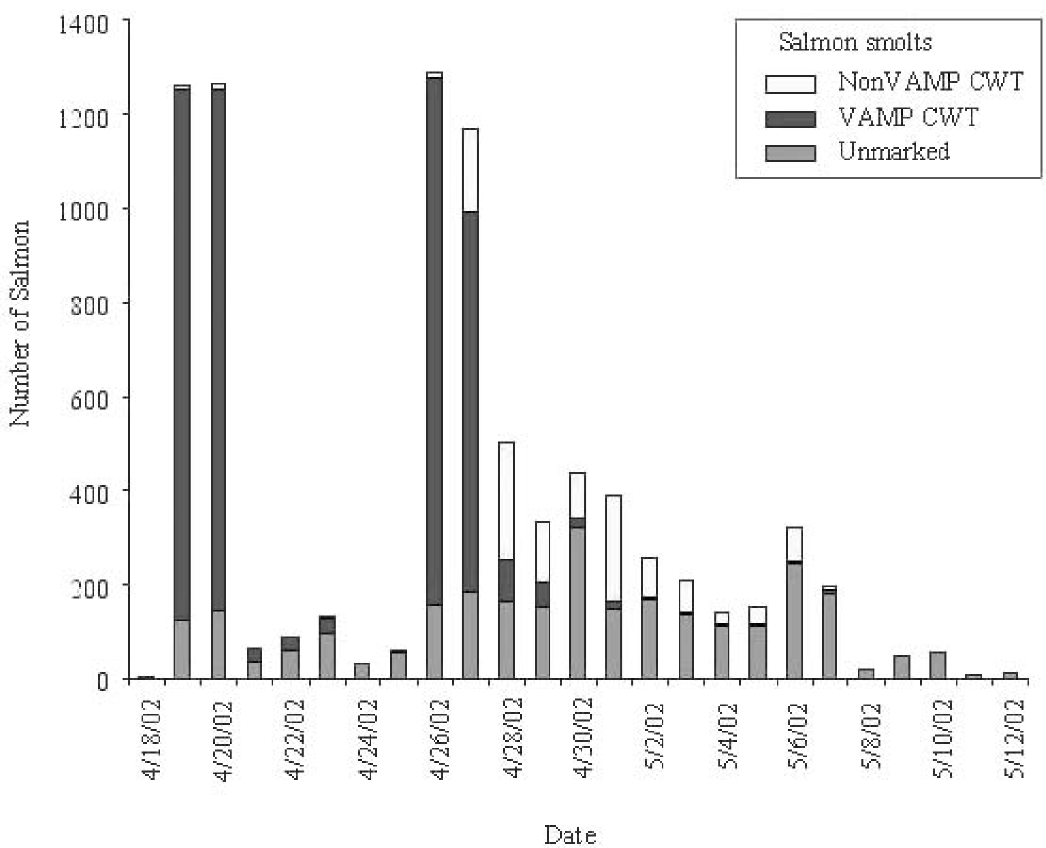


Figure 2-4. Durham Ferry and Mossdale released coded-wire tagged salmon entrainment at the HORB. River stage for Old River is indicated by the line.

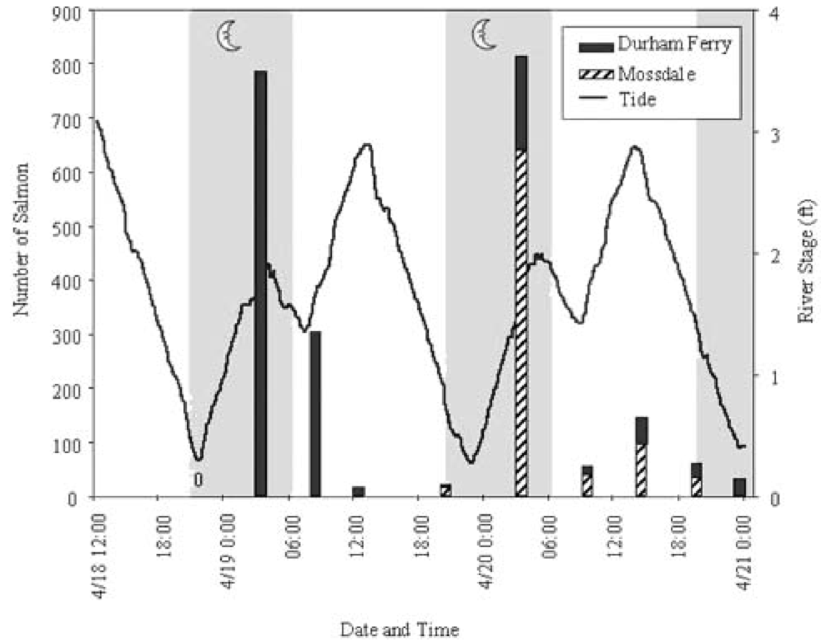
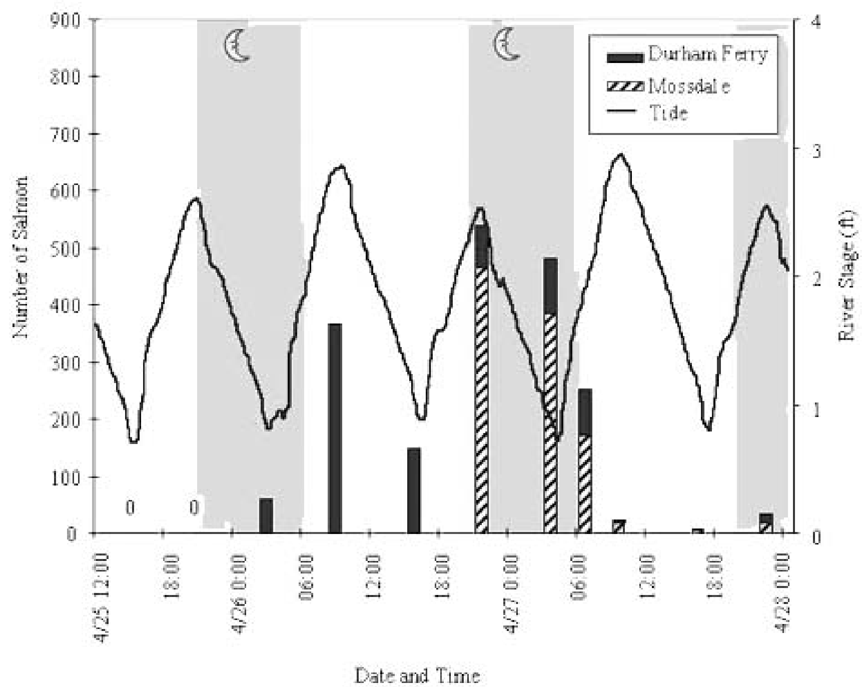
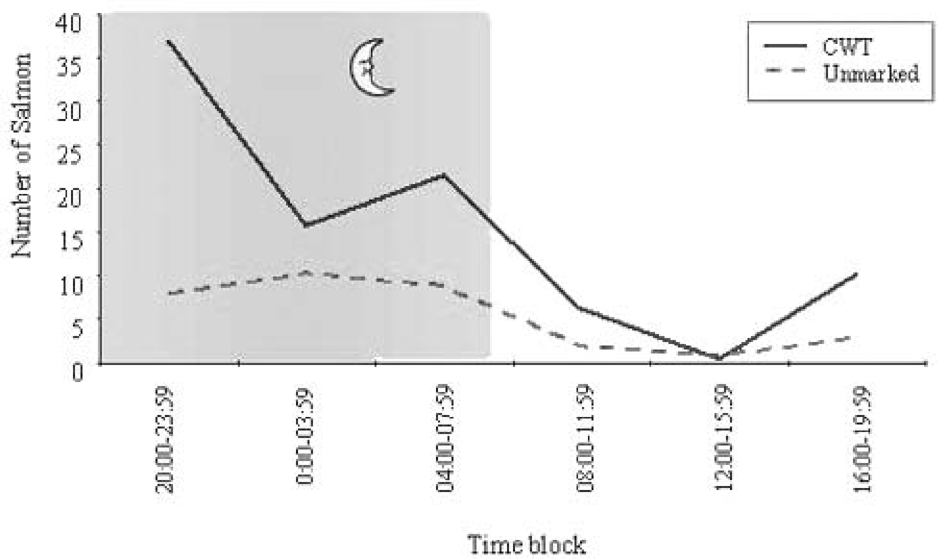


Figure 2-5. Durham Ferry and Mossdale released coded-wire tagged salmon entrainment at the head of Old River barrier. River stage for Old River is indicated by the line.



Entrainment of the VAMP released salmon peaked during the late evening to midnight time block, and bottomed out in the afternoon at less than a fish per hour (Figure 2-6). The unmarked smolts had a steady rate of entrainment through the night and a relatively low rate during the day. For the entire monitoring duration, the average CPUE for the VAMP smolts per culvert was 1.6 ± 4.0. The highest CPUEs occurred soon after the VAMP releases, with a max CPUE of 32.5 on April 19. The average unmarked smolt CPUE (0.9 ± 1.3) was much lower than the VAMP CPUE. The highest unmarked CPUEs occurred in late April and early May, with a max CPUE of 7.5 on April 30.

Figure 2-6. The average number of CWT and unmarked salmon caught over 24 hours, grouped into 4 hour time blocks.



To address tidal and diel effects, color-marked smolts were released on various tidal and diel period combinations. The first releases went well; however, some problems were encountered during the second release when an unknown number of smolts escaped from the holding pens before their intended release. The color-marked salmon were entrained at the HORB within 5 hours of their release. Entrainment rates were higher for the first releases (2.3 %) than the second releases (1.0 %), but the overall entrainment rate (1.7 %) was similar to the entrainment of the CWT smolts (Table 2-2). More smolts were caught at night than during the day, and more smolts were entrained during the flood than the ebb tide.

Table 2-2. 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	Fish Entrained	(Percent)
First Releases (19 & 20 April)					
	3,032	Night	Flood	159	(5.2)
	3,009	Night	Ebb	46	(1.5)
	3,281	Day	Flood	15	(0.5)
	3,008	Day	Ebb	62	(2.1)
Total	**12,330**			**282**	**(2.3)**
Second Releases (25 & 26 April)					
	2,990	Night	Flood	71	(2.4)
	3,000	Night	Ebb	10	(0.3)
	3,000	Day	Flood	39	(1.3)
	3,000	Day	Ebb	5	(0.2)
Total	**11,990**			**125**	**(1.0)**

Salmon entrainment through the middle culvert was high this year (Table 2-3). The remaining culverts entrained a similar amount of salmon, although the outside culverts (numbers 1 and 6) had a slightly lower overall entrainment. Similarly, threadfin shad (*Dorosoma petensense*) had the highest entrainment through the middle culverts. Catfish entrainment differed from salmon entrainment in that roughly half of the white catfish were entrained in culvert number 2 and very few were entrained in the adjacent culverts. Approximately 40 % of the channel catfish (*Ictalurus punctatus*) were entrained in culvert number 6, the culvert closest to the channel.

Table 2-3. The percentage of the total catch, by species, entrained in each culvert. Chinook salmon is divided into marked and unmarked fish. The total catch was adjusted for missing culvert data.

	Culvert Number						
	1	2	3	4	5	6	Total
Chinook Salmon							
CWT (VAMP only)	10%	19%	15%	29%	17%	11%	4,490
Color-marked	6%	17%	14%	27%	21%	14%	406
No mark	16%	11%	23%	25%	14%	11%	2,798
Threadfin shad	15%	12%	35%	22%	13%	4%	1,240
White catfish	2%	51%	8%	4%	16%	19%	6,932
Channel catfish	5%	20%	12%	10%	11%	41%	563

A current velocity meter (Swoffer Instruments, Inc., model 2100) was used on three occasions to get estimates of flows through each of the culverts. Between 4 and 10 replicate flow measurement were made per culvert. Velocity measurements were made near a low slack tide, a high slack tide, and on the ebb that was close to high slack. Due to the staff shortage and time constraints, only the ebb flow estimates occurred while we were monitoring the fyke nets. The other two measurements took place after the fyke nets were removed at the end of the monitoring period. Results from the limited data gathered suggest culverts 2 through 6 had similar flows, and that culvert 1 averaged a little over 10 cfs less than the others (Table 2-4). Flows through the culverts were twice as high during low tide than high tide.

Table 2-4. The average flow per culvert (cfs) taken on three separate occasions at the HORB.

		Culvert number						
Date	**Tide**	**1**	**2**	**3**	**4**	**5**	**6**	**Average**
16-May	High slack	34	42	46	43	42	44	42
15-May	Ebb	48	55	57	53	63	58	56
7-May	Low slack	70	92	88	92	91	90	87

Discussion

Despite a staff shortage and some sampling difficulties, the DFG successfully monitored fish entrainment at the HORB. Although the culvert monitoring duration increased 38 % over 2001, the amount of fish entrained tripled. The increased catch was due primarily to Chinook salmon, white catfish and threadfin shad which together comprised 93 % of the total entrainment. More CWT salmon were released this year than in previous years and the proportion of salmon entrained (loss index) was higher than in previous years. The higher loss index this year could be due, in part, to less accumulation of debris in front of the culverts; the lower VAMP flows on the San Joaquin River which results in a higher proportion of the river flowing through the culverts; other environmental factors; and factors related to the barrier configuration and operation which may affect the hydraulics surrounding the barrier.

The loss indices within the two 2002 VAMP salmon releases varied. The loss indices for the first VAMP salmon release at Durham Ferry and Mossdale were similar. The loss indices for the second VAMP release were considerably different. The second Durham Ferry salmon release had a low loss index (1.0 %) whereas the second Mossdale release, the following day, had a relatively high loss index (2.3 %). The low loss index of the second Durham Ferry release was due to the low entrainment of salmon on the night of their release. In contrast, most of the entrained Mossdale salmon were caught the night of their release and they had a relatively high loss index. Typically, VAMP salmon entrainment is highest the night of their release.

The difference in the second VAMP loss indices could be due to slightly different salmon migration routes down the San Joaquin River, differential mortality, temporary debris obstruction of the culverts, and a combination of other environmental and behavioral factors. The majority of the Durham Ferry salmon could have migrated down the center or far side of the channel and avoided the HORB, and the Mossdale fish could have migrated closer to the HORB and were entrained. However, the Mossdale Kodiak Trawl (MKT) results indicate a similar catch trend between releases that were observed at the HORB. The MKT samples for fish in the middle of the San Joaquin River, just upstream of the HORB. The MKT caught 573 CWT salmon from the first Durham Ferry release and only 250 salmon from the second release. The MKT caught fewer Mossdale CWT salmon from the first release (24) compared to the second release (41). The MKT data suggests the lower loss indices at the HORB could be reflective of fewer salmon migrating pass the barrier. It is possible the second Durham Ferry released salmon experienced a high rate of mortality before reaching the HORB. The potential source of mortality affecting the second release group is unknown.

In contrast with the loss indices at the HORB, survival estimates from Chipps Island and Antioch (San Joaquin River Group Authority 2002) suggest the second VAMP salmon release at Durham Ferry had a slightly higher survival than the release at Mossdale. The apparently higher numbers of Mossdale salmon at the HORB did not translate to higher survival through the Delta. Conversely, the lower number of Durham Ferry salmon did not translate into a lower survival estimate through the Delta.

More CWT salmon were caught at night than during the day, and more were caught on the flood than the ebb tide. Both the VAMP salmon and unmarked salmon entrainment was relatively low in the afternoon. The larger catch of VAMP salmon at night could be confounded by their daytime release upstream of the barrier. Due to the timing of the VAMP release and the distance of the release sites from the HORB, most of these fish probably reach the barrier at night.

Tidal stage may effect entrainment. The river stage gage near the HORB on Old River (data available at http://cdec.water.ca.gov), indicated a relatively low tide near dusk during the first VAMP releases. The low tide creates a large head difference between water levels upstream and downstream of the barrier. The amount of water passing through the culverts depends on this head difference. Although the head difference at the HORB was shrinking on the ensuing flood tide after dusk, the CWT salmon approaching the barrier were still experiencing a large head difference. Over the next seven hours, on both nights (the ensuing high tide was still relatively low), entrainment of VAMP salmon was high. During the second VAMP release, the high tides occurred at dusk which resulted in less head difference as the smolts were approaching the barrier. This may have affected the number of smolts entrained at the barrier. Even with this smaller head difference, more smolts were still entrained at night than during the day.

Results from the Entrainment Special Study are similar to last year's Entrainment Special Study results. 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, although a large number of color-marked salmon were entrained on the day-ebb during the first release. As with the VAMP released salmon, more salmon were entrained during the first release than the second release. However, some color-marked salmon escaping their live-cages confounded the lower entrainment index for the second release.

Results from the 2002 Entrainment Monitoring Study and the Entrainment Special Study suggest salmon are more vulnerable to entrainment at night and on the flood tide. Even the unmarked salmon entrainment is higher at night than during the day. However, the VAMP salmon releases are not timed to address tidal-diel effects and their daytime releases may confound the diel results. The tidal effects on entrainment are still unclear. Water velocities through the culverts are greatest near a low slack tide which should result in the highest entrainment. This was not always the case. Some of the highest catches occurred during the flood. The changing hydraulics surrounding the barrier as the tide changes effects flows near the culverts which could affect entrainment. Salmon smolt behavior and relative abundance near the barrier probably plays an important role in entrainment vulnerability.

Overall, the highest salmon entrainment occurred in culvert number 4 and the lowest in culvert numbers 1and 6. In contrast, in 2001, culvert number 6 entrained the most fish and entrainment in each culvert decreased as the culverts got closer to shore. The lower flow through culvert number 1 agrees with the lower catch of salmon. Since the remaining culverts had similar flows, the reason for the high entrainment in culvert number 4 and the low entrainment in culvert number 6 is still unclear. Another pelagic fish, the threadfin shad, also had higher entrainment in the middle culverts. In contrast, the more benthic catfish had the highest entrainment in the outer culverts, in particular culvert numbers 2 and 6.

The reason for the difference in culvert entrainment this year from last year is also unclear. Lower flows on the San Joaquin River and slight differences in culvert angles could affect the flow through the culvert and thus, entrainment. The high entrainment of white catfish this year compared to last year was also unexpected. Some of the white catfish were ripe with eggs suggesting that they could have been trying to spawn near the culverts and were entrained.

Recommendations for future studies: unfortunately, the first VAMP release occurred while the HORB was under construction. A lot of time was wasted and several samples lost due to gravel accumulation in the nets. Future VAMP salmon studies should schedule their salmon releases after the completion of the barrier, typically 5 days after the HORB is "closed". To better address diel affects, VAMP should schedule one of the Mossdale releases at night. A night release, instead of the usual day release, could tease out some the diel effects. A more systematic monitoring of flows through the culverts during future VAMP salmon releases would also help us understand salmon entrainment as related to tide. Future studies should also assess juvenile Chinook salmon mortality associated with the barrier.

Literature Cited

San Joaquin River Group Authority. 2002. 2002 Annual Technical Report on Implementation and Monitoring of the San Joaquin River Agreement and the Vernalis Adaptive Management Plan. Sacramento, California.

Chapter 3. Salmon Smolt Survival Investigations

This chapter discusses salmon smolt survival investigations that were conducted as part of the 2002 Vernalis Adaptive Management Plan (VAMP 2002). One of the primary objectives of the VAMP program is to identify the respective roles of San Joaquin River flow, and SWP and CVP export rates with the HORB in place on the survival of juvenile Chinook salmon emigrating from San Joaquin River tributaries. This section describes the methods used in conducting the VAMP 2002 Chinook salmon smolt survival investigations, and presents results of the calculated survival indices and absolute survival estimates for juvenile Chinook salmon during the VAMP 2002 test period. Additional data and information related to the salmon survival investigations are presented in Appendix A.

Coded-Wire Tagging

Merced River Hatchery Chinook salmon smolts, released as part of VAMP 2002, were coded-wire tagged (CWT) between March and early April. After the salmon were tagged, they were held in the hatchery for up to 21 days before being released. A sub-sample of the salmon were measured for length and checked for retention of the CWTs a day or two prior to release. The sub-sample was typically comprised of 100 to 300 salmon collected from the top, middle, and bottom of the release group's raceway. Each tag code within a release group was held separately at the hatchery with the exception of the two Durham Ferry releases, where each release was made up of four tag codes that were held together in one section of the raceway.

Although tag retention is usually quite high, as a double check on the tag detector, all salmon from the sub-sample that had no tag detected were sacrificed. These sacrificed salmon were dissected to determine whether they contained an un-magnetized tag. A separate sub-sample of 25 salmon was sacrificed from each release group; the tags were removed and read to detect any incorrect tag codes in the raceways. Table 3-1 summarizes results of the CWT retention rate and the estimate of the effective numbers of salmon released to calculate survival indices. Tag retention rates were determined to be similar to last year, with an overall loss rate of 9.5% among all VAMP groups. The tag retention loss rates varied from 0.5% to 15%. It is recommended that this loss rate be reduced for future VAMP studies.

CWT Releases

Two sets of CWT salmon releases were made as part of the 2002 VAMP experiment. The first set occurred at 1215 hours on April 18 at Durham Ferry, at 1535 hours on April 19 at Mossdale and at 1010 hours on April 22 at Jersey Point. The second set of releases was made at Durham Ferry at 1050 hours on April 25, Mossdale at 1620 hours on April 26, and Jersey Point at 1535 hours on April 30.

Table 3-1 Coded Wire Tag Retention Rates and Effective Release Numbers for Juvenile Salmon Released for VAMP 2002

Release Date	Tag Code	Release Site	Avg FL (mm)	Number Tagged	Total Loss	Tag Retention	Number Released	Effect Release
4/18/02	06-44-71	Durham Ferry	83	25251	123	95.19%	25128	23919
4/18/02	06-44-72	Durham Ferry	83	26576	129	95.19%	26447	25175
4/18/02	06-44-73	Durham Ferry	83	25201	123	95.19%	25078	23872
4/18/02	06-44-74	Durham Ferry	83	26124	127	95.19%	25997	24747
4/19/02	06-44-57	Mossdale	84	25864	227	99.52%	25637	25514
4/19/02	06-44-58	Mossdale	82	26301	251	97.01%	26050	25271
4/22/02	06-44-59	Jersey Point	85	25793	262	97.14%	25531	24801
4/22/02	06-44-60	Jersey Point	83	25339	269	96.24%	25070	24127
4/25/02	06-44-70	Durham Ferry	80	25969	138	95.54%	25831	24679
4/25/02	06-44-75	Durham Ferry	80	25947	138	95.54%	25809	24658
4/25/02	06-44-76	Durham Ferry	80	26078	139	95.54%	25939	24782
4/25/02	06-44-77	Durham Ferry	80	25654	136	95.54%	25518	24380
4/26/02	06-44-78	Mossdale	79	26357	281	94.03%	26076	24519
4/26/02	06-44-79	Mossdale	81	25977	261	96.52%	25716	24821
4/30/02	06-44-80	Jersey Point	82	25328	295	96.00%	25033	24032
4/30/02	06-44-81	Jersey Point	82	25483	289	90.82%	25194	22881

Approximately 100,000 salmon, in four distinct tag lots of about 25,000 fish, were released at Durham Ferry, while approximately 50,000 fish, in two tag lots, were used at each Mossdale and Jersey Point release (Table 3-1). Prior to VAMP 2000, each release was made such that all tag lots were trucked from the hatchery mixed and released as a single group. However, during VAMP 2000, 2001 and 2002, a new transport trailer with three tanks allowed each separate CWT lot to be transported to its release site in a separate tank and distinctly released. As mentioned earlier, the four tag lots comprising each of the groups released at Durham Ferry were already mixed at the hatchery and were therefore transported in a large single tank release truck. This year 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 the release to allow the tagged salmon time to disperse from the release site.

Releases at Jersey Point were made at the beginning of the flood tide to increase dispersion of the tagged fish before they passed Antioch and Chipps Island. Releases at Mossdale and Durham Ferry were not made on any specific tidal condition.

The water temperature both in the hatchery truck and in the receiving waters was measured at the release site immediately prior to release. These, as well as additional release and recovery data, are provided in Table 3-2.

Table 3-2 Release and Recovery Information for Coded Wire Tag Groups Released for VAMP 2002

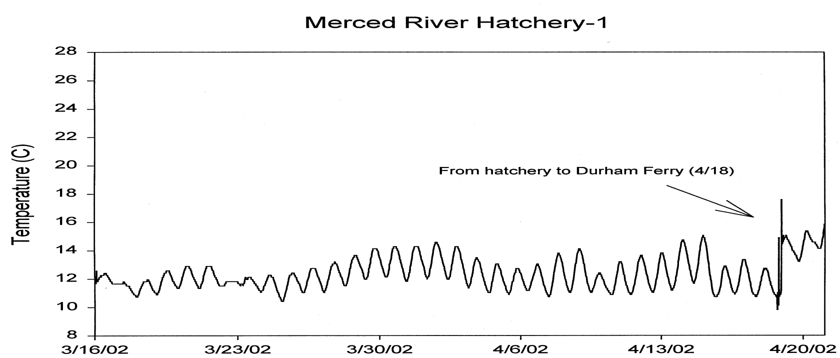
(See oversized table at the end of the chapter.)

Water Temperature Monitoring

Water temperature was monitored during the VAMP 2002 study using individual computerized temperature recorders (e.g., Onset Stowaway Temperature Monitoring/Data Loggers). The water temperature was 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). Water temperature was recorded at 24-minute intervals throughout the period of the VAMP 2002 investigations. Water temperature was also recorded within the hatchery raceways at the Merced River Hatchery coincident with the period when juvenile Chinook salmon were being tagged.

Results of water temperature monitoring within the Merced River Hatchery showed that juvenile Chinook salmon were reared in and acclimated to water temperatures of approximately 11-14 C (52-57 F) prior to release into the lower San Joaquin River Figure 3-1. Results of water temperature monitoring at Durham Ferry, Mossdale, and Jersey Point following the first and second sets of VAMP 2002 releases are compared in Figures 3-2, 3-3, and 3-4. Results of water temperature monitoring showed that water temperatures at the release locations and throughout the lower San Joaquin River and delta (Appendix A) 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 2002 investigations (More complete temperature coverage for the Delta can be found on the CDEC website. Temperatures at Jersey Point may have influence of tidal and Sacramento River flows which may be lower than the interior of the Delta or the south Delta).

Figure 3-1 Results of Water Temperature Monitoring at the Merced River Fish Hatchery



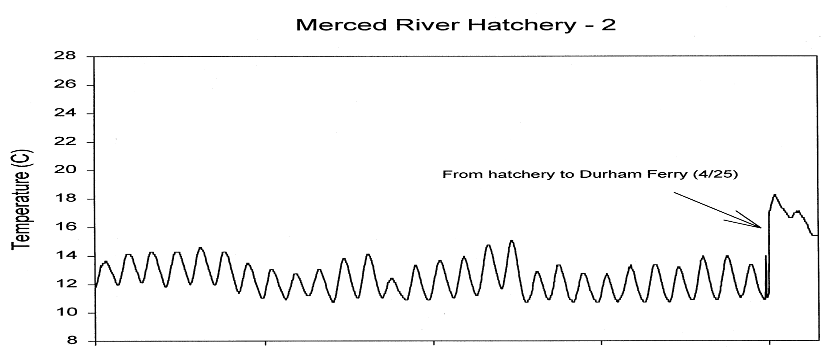


Figure 3-2 Water Temperature Monitoring Results at Durham Ferry

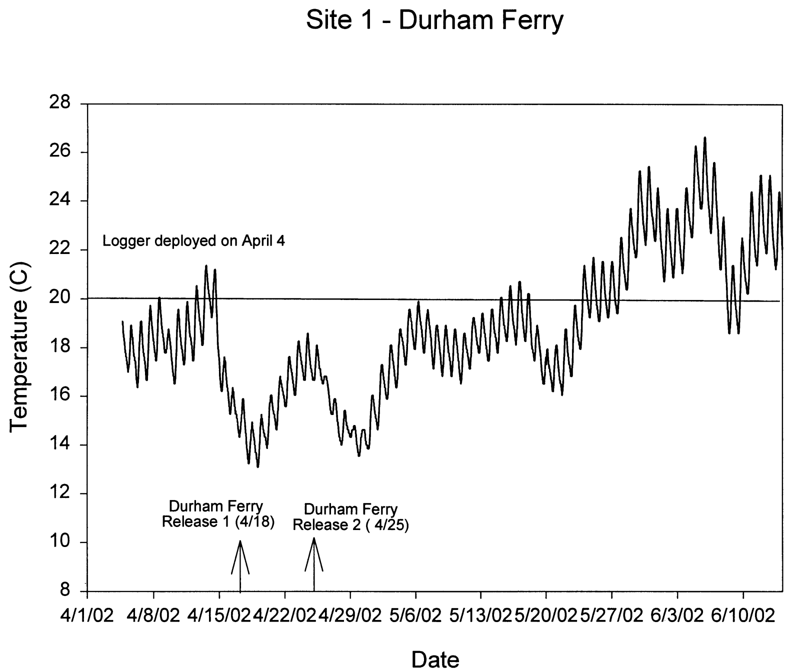


Figure 3-3 Water Temperature Monitoring Results at Mossdale

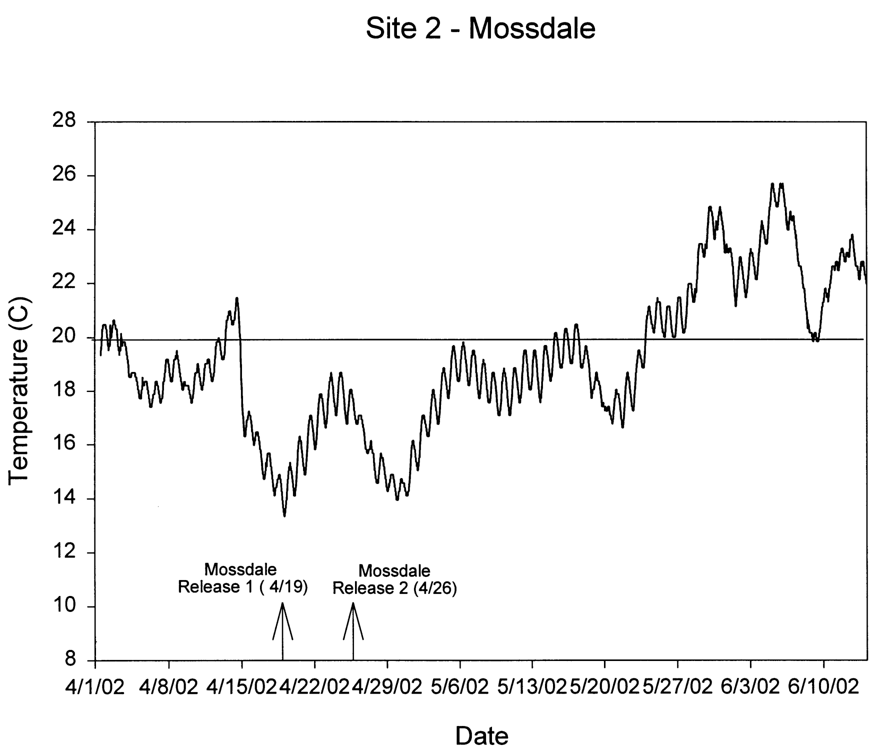
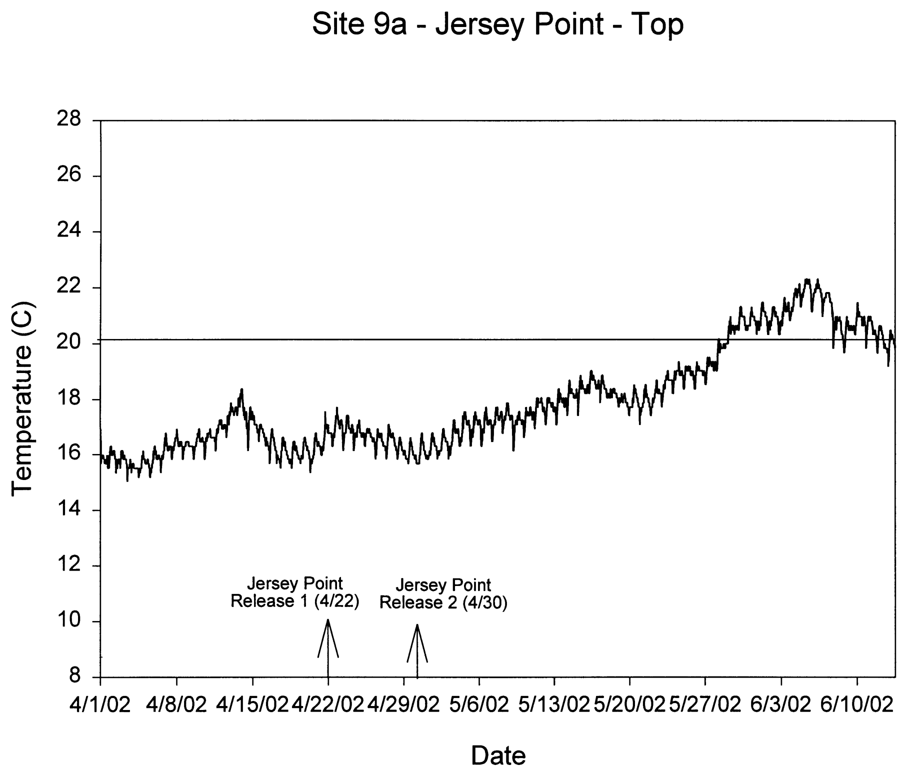


Figure 3-4 Water Temperature Monitoring Results at Jersey Point



Post-Release-Live-Car Studies

Survival and Condition

The post-release survival and condition of marked salmon was evaluated as part of the VAMP program using sub-samples of marked salmon from each release group. Approximately 200 salmon from each tag code were held at the respective release site in net pens for 48 hours after release and were evaluated for overall short-term mortality which might be associated with the handling, transport and release process. In addition to the 200 salmon held for 48 hours, 25 salmon from each tag code were evaluated for condition immediately after release. Another 25 salmon were held and evaluated using the same condition parameters after the 48-hour holding period. The remaining salmon were measured, weighed and sacrificed for further coded wire tag verification if necessary. Due to the mixed tag codes in the Durham Ferry releases two net pens with approximately 200 fish each were held in order to maintain consistency with the other net pen studies. To assess overall condition, fork length in millimeters, weight in grams, and six other characteristics as described in Table 3-3 were examined. Obvious abnormalities or deformities were also noted.

Table 3-3 Smolt Condition Characteristics

	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)

Results of the evaluations of marked fish in the net pens, both immediately after release and 48 hours later, showed few abnormalities in the condition assessed characteristics, which are shown in Appendix A. Scale loss ranged from 1-40% and averaged 5.7%. All fish examined were noted to have normal coloration, no fin hemorrhaging, normal eye characteristics and normal gill color. Of the 1,433 salmon assessed, four (0.3%) were found to have a poor or incomplete fin clip. A total of three fish had some type of deformity, two of which had eroded pectoral fins (not uncommon for hatchery raised fish) and one that had a partial operculum. The percentage of salmon deformed within the sample group (0.2%) was within the normal range for hatchery-raised fish.

Out of 2301 fish examined as part of this year's VAMP net pen experiments, no mortalities were observed.

Tag Quality Control

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. The additional 200+ fish from each release that were held were archived in a freezer. Though rare, on few occasions in the past, salmon from different release groups have been mixed at some point prior to release. While performing quality control checks on the April 18 Durham Ferry releases, one errant tag code was discovered. A total of 201 tags were read to verify tag code purity. After reading all tags, it was determined that the apparent error was likely the result of tags being lost and found, and not reported as lost, in the lab. All remaining fish will be held for a period to allow tag processing for further evaluation if necessary.

Physiology

Physiological studies were conducted on samples of the juvenile salmon used in the VAMP study by the California-Nevada Fish Health Center (Nichols and Foot 2002). These results are summarized below.

Physiological tests were conducted on a subset of the smolts released at Durham Ferry, Mossdale and Jersey Point at the hatchery before transport to the release site and after they had been held in the live cars for approximately 24 hours. At the hatchery, 144 fish were examined for virus, systemic bacteria, gill Na^{+}/K^{+} Adenosine TriPhosphotase (ATPase) activity, blood hematocrit value, plasma total protein concentration, plasma chloride concentration, external and internal signs of disease, and other abnormalities. From live cars, a total of 216 fish were assessed for gill ATPase activity, plasma total protein concentration, plasma chloride concentration, internal and external abnormalities, and *Tetracapsula bryosalmonae* (*Tb*) prevalence of infection. No bacterial or viral pathogens were detected in any of the fish examined. Overall 93 of 201 (46%) of fish examined were infected with the kidney parasite *Tb*, the myxosporean causing Proliferative Kidney Disease (PKD). Infection rates ranged from 29% to 70% among individual release groups with 99% of infected fish in the early stage of PKD (Clifton-Hadley et. al. 1987). This stage was characterized by the initial invasion of the kidney blood sinuses by the parasite and minor inflammatory changes. No evidence of anemia was seen in the blood hematocrit values from any of the live car groups but the disease may progress even after the fish enter salt water (Hedrick and Aronstien 1987) and PKD related anemia could arise weeks after release.

Gill Na^+/K^+-ATPase activity levels were similar among and between hatchery and live car groups. There was no significant change in the 1-6 days between hatchery and 24-hour post-release samples. All sample groups demonstrated elevated gill ATPase activity consistent with salmon in an advanced stage of smoltification.

Plasma total protein concentrations of some individual fish were slightly elevated, although no protein values were outside of normal ranges for juvenile Chinook. Elevated plasma protein values would not necessarily indicate reduced survival for the affected fish but rather exposure to environmental stressors. Possible reasons for this site effect include variations in time since last feeding (mild starvation), differences in transport, or site-specific water quality.

Plasma chloride values further supported the “stress event” observed in the hatchery total protein values. All live car groups had depressed plasma chloride values relative to baseline hatchery values ($p<0.001$, t-test) indicating they were under stress probably due to sampling. Hatchery fish were dip netted directly from the raceway and quickly euthanized, while capture from the live car took longer. Even with this added stress of sampling, plasma chloride values of live car groups remained within the normal range for juvenile salmonids.

In summary, all 6 release groups were in good health and at a similar state of smolt development when sampled at the hatchery and 24-hours post-release. No biologically significant differences were observed in pathogen infections, gill Na^+/K^+-ATPase activities, or blood chemistry values. Early infections of *Tb* were common, with clinical signs of Proliferative Kidney Disease (PKD) in only 1% of fish examined. Short-term survival of all groups was not likely to be impacted by their health. Health problems resulting from PKD (e.g. anemia) could have arisen several weeks post-release but are not discussed as part of the report.

CWT Recovery Efforts

CWT salmon were recaptured at Antioch and Chipps Island, at CVP and SWP fish salvage facilities and during sampling at upper Old River near the barrier (See Figure 1-1). CWT 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 pending CWT processing. Coded-wire tag processing was done by USFWS (Stockton) for fish recovered at Chipps Island, Antioch, and SWP/CVP salvage facilities. DFG Bay Delta Branch and Region IV assisted in processing the fish captured at the HORB fyke nets.

Coded wire tag processing entails dissecting each tagged fish to obtain the half (0.5 millimeter) or full (1 millimeter) cylindrical tag from the snout. Tags are then placed under a dissecting microscope and the numbers are read and recorded in a database. Tags were read twice, with any discrepancies resolved by a third reader. All tags are archived for future reference. It should be noted that many tags recovered at Chipps Island, Antioch, SWP/CVP salvage, and other locations are from coded wire tag releases not affiliated with VAMP. Since it is unknown until after reading the tag, which tags are from the VAMP study, all tags recovered are read.

SWP/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 the CWT salmon recovered in the raw salvage collections were sacrificed for tag decoding. 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 CVP and SWP salvage estimates of marked salmon released as part of the VAMP 2002 studies are shown in Table 3-2. Salvage numbers at both the CVP and SWP were higher in 2002 than in 2001 but continued to be lower than salvage numbers in years without the HORB installed. It is likely that the smolts migrated to the CVP and SWP via Turner or Columbia Cuts; the downstream confluences of Middle River with the lower San Joaquin River downstream of the head of Old River.

Antioch Recapture Sampling

Fishery sampling was conducted in the vicinity of Antioch on the lower San Joaquin River 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 six feet deep and 25 feet wide. The net was towed between two skiffs, 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 sample was approximately 20 minutes in duration.

All fish collected were transferred immediately from the Kodiak trawl to buckets filled with river water, where the fish were held during processing. Data collected during each trawl included fish identification, measuring the fork length of fish collected, tow start time, duration and location in the channel. Mortality and damage to fish collected was 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 unmarked salmon, steelhead, delta smelt, splittail, and other fish were released at a location downstream of the sampling site immediately after identification, enumeration and measurement.

Sampling at Antioch was initiated April 4 and continued through May 15. Each day between 5:00 a.m. and 9:00 p.m., anywhere from 8 to 31, 20-minute tows were conducted. All told, 1,088 Kodiak trawl samples were collected, representing a total sampling duration of 21,582 minutes. During the sampling, a total of 6,134 unmarked juvenile Chinook salmon and 1,822 salmon with an adipose fin clip (CWT) were collected. In addition, 963 Delta smelt, 195 splittail, and 50 unmarked steelhead, and 52 adipose-clipped steelhead were caught in the sampling.

Chipps Island Recapture Sampling

As part of VAMP recovery efforts at Chipps Island, trawling shifts were conducted twice daily between April 4 and May 28, once daily from May 29 to June 8, and once daily Monday through Friday from June 9 through the end of the month. The first shift was begun just before dawn, while the second shift ended at or after sunset in order to incorporate the crepuscular periods of Chinook movement. It is hypothesized, based on an analysis of salmon smolts caught during twenty-four hour sampling at Jersey Point in 1997, that a greater number of salmon would be caught around dawn and dusk. Both targeting this crepuscular period and doubling the total trawl effort at Chipps Island were intended to increase the numbers of CWT salmon recaptured and reduce the variability in VAMP survival indices. This second shift has been conducted during the spring releases since 1998.

The trawl at Chipps Island was towed at the surface using a net with a mouth opening 10 feet deep by 30 feet wide, with a total net length of 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 was variable mesh net starting with 4-inch mesh at the mouth and ending with a ¼ inch cod end.

To sample across the channel, trawling at Chipps Island was conducted in three distinct lanes, one each in 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. This lane was chosen at random or selected by the boat operator based on flow conditions.

Coded wire tagged salmon released as part of the VAMP program were recovered at Chipps Island between April 24 and May 19. A total of 182 VAMP CWT salmon were recovered at Chipps Island. During the April 24 and May 19 VAMP recovery period, a total of 6,463 unmarked salmon, 1164 CWT salmon from other non-VAMP experiments, 165 delta smelt, 360 Sacramento splittail, 15 clipped steelhead, and 15 non-clipped steelhead, were also collected at Chipps Island.

VAMP Chinook Salmon CWT 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 were calculated by dividing the number of CWT salmon recovered (R) by the effective number released (E) and multiplying the fraction of time (T) and channel width (W) sampled as shown by the formula (R/E)*T*W. The fraction of the channel width sampled at Chipps Island (0.00769) was the net width (30 feet) divided by an estimate of the channel width (3,900 feet). The fraction of the channel width sampled at Antioch (0.01388) was also based on the net width (25 feet) and an estimate of the channel width (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 percent of time sampled for the VAMP 2002 release groups at Chipps Island was about 27 percent, while at Antioch it averaged 39 percent.

Survival indices were calculated for each separate tag code to provide a sense of the variability associated with the overall group survival index. To generate the group survival index, the recovery numbers and release numbers are combined for the tag codes within a release group. This results in a slightly different index than would be generated by taking the mean of the survival indices of the individual tag codes within a group.

The individual and group survival indices to Antioch and Chipps Island of the CWT salmon released as part of VAMP 2002 are shown in Table 3-3. As in past years, survival indices from the release locations to Antioch were sometimes lower than to Chipps Island. It is expected that indices to Antioch would be greater than to Chipps Island since Antioch is closer to the release locations and the percent of time sampled is greater and the channel width is narrower at Antioch. It may be the inherent variability associated with catching the marked fish that sometimes causes more to be caught at Chipps Island.

The first and second Durham Ferry releases had survival indices to Antioch of 0.12 and 0.04, respectively. Survival indices to Chipps Island were 0.11 for the first group and 0.08 for the second. While differences between the two groups at Chipps Island did not appear meaningful, those at Antioch did. The individual tag code survival indices at Antioch for the two groups did not overlap thus there appeared to be a difference in survival between the first and second Durham Ferry groups.

The two Mossdale releases showed similar differences between the first and second releases. The first and second releases had survival indices to Antioch of 0.15 and 0.03 and 0.12 and 0.05 to Chipps Island, respectively. Again none of the individual tag code survival indices overlapped between groups indicating a real difference between the two groups at both recovery locations.

Similarly, the two Jersey Point groups also appeared to survive at different rates; with the first group surviving at a higher rate than the second. The first group released on April 22 had a survival index to Antioch of 0.72. The second group released on April 30 had an index to Antioch of 0.29. Chipps Island recoveries demonstrated the same apparent difference between groups with the first group having an index of 0.83 and the second group having an index of 0.48.

Why survival was lower for the second groups (releases at Durham Ferry, Mossdale, and Jersey Point), relative to the first groups is unknown. Flow and export conditions were similar for both sets of releases. Water temperatures increased for the releases in the second group, but increases were small and all temperatures at release were below 65 degrees Fahrenheit (Table 3-3).

Absolute Chinook Salmon Survival Estimates And Differential Combined Recovery Rates

More important than the difference in survival indices between sets of releases is the comparison of absolute survival estimates, where the survival indices of the upstream release groups are divided by the survival indices of the downstream groups (recovered at the same location). It is most useful for comparisons between groups, recovery locations and years.

In 2002, we have also used the differential combined recovery rates as an estimate of survival. The combined recovery rate for each release group was obtained by summing the recoveries from Antioch and Chipps Island and dividing by the number released. The differential combined recovery rate was the combined recovery rate of an upstream group relative to the downstream group and is another way to estimate survival between release locations. The differential recovery rate is similar to calculating absolute survival estimates, but does not expand each estimate by the fraction of the time and space sampled. The differential recovery rates and the absolute survival estimates should not be very different, as; 1) the fraction of the time sampled is similar between groups within a recovery location; and 2) the fraction of space 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 may result in differences using the two methods in estimating survival.

Variance and standard errors were also calculated for the differential combined recovery rates based on the Delta method provided by Dr. Ken Newman (pers. comm). The differential recovery rates plus or minus two standard errors are roughly equivalent to the 95% confidence intervals. Plus or minus one standard error equates to roughly the 68% confidence intervals. (Ken Newman, personal communication). It is not clear how similar variances, standard errors or confidence intervals could be generated using the absolute survival estimates.

In comparing survival between reaches and replicates the confidence intervals were used to determine if estimates were significantly different. If the 95% confidence intervals overlapped they were not considered statistically different. Differences observed using the lower level of confidence 68% are noted.

The use of absolute survival estimates and differential combined recovery rates are more powerful for use in comparing survival rates, since the use of ratios between upstream and downstream groups theoretically standardizes for differences in catch efficiency between recovery locations and/or years. Both types of estimates of survival have been calculated for VAMP 2002. An additional estimate of absolute survival will be possible from recoveries in the ocean fishery, 2 to 4 years following release.

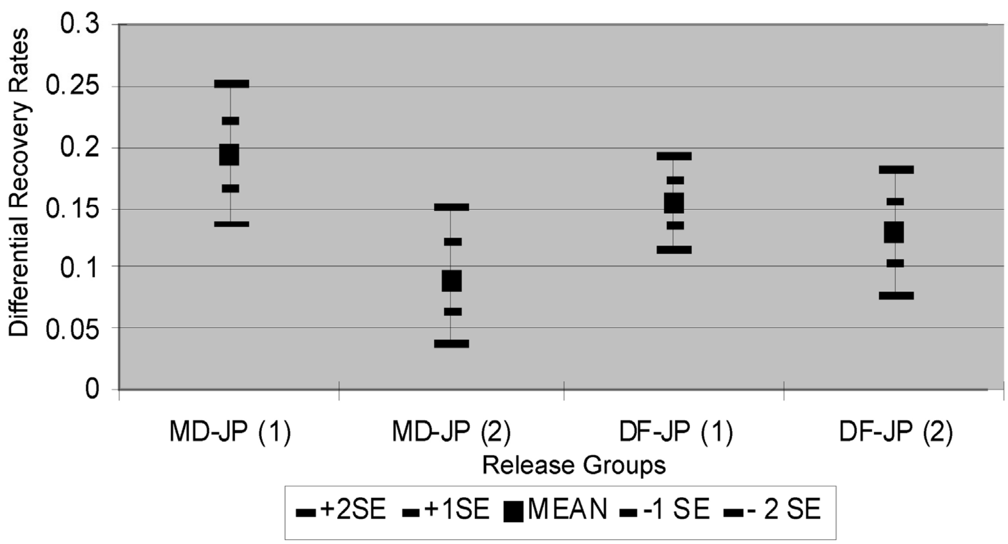
Although the survival indices indicated that the first groups released survived at a higher rate than the second group, comparisons using the absolute estimates of survival moderated this difference (Table 3-2). Absolute survival between Durham Ferry and Mossdale and Jersey Point was still somewhat higher for the first releases using the Antioch recovery information. Absolute survival for the two sets of releases was similar using the Chipps Island recovery information, but it is uncertain if these differences are significant.

Results using the differential combined recovery rates also indicated the first groups appeared to survive at a higher rate than the second groups, with the first Durham Ferry and Mossdale groups relative to Jersey Point being higher than the second groups (Table 3-4). Estimates of 95% confidence intervals indicated differences were not significant at the $p<0.05$ level. The first Mossdale to Jersey Point estimate was greater than the second using the lower level of confidence (68%) (Table 3-4 and Figure 3-5).

Table 3-4. 2002 Smolt Survival Differential Recovery Rates

See oversized table at the end of the chapter.

Figure 3-5 Differential Recovery Rates of CWT Smolts Released at Mossdale and Jersey Point (MD-JP) and Durham Ferry and Jersey Point (DF-JP) for the First (1) and Second (2) Groups in 2002. The Estimate and Plus and Minus 1 and 2 Standard Error(s) is Provided.

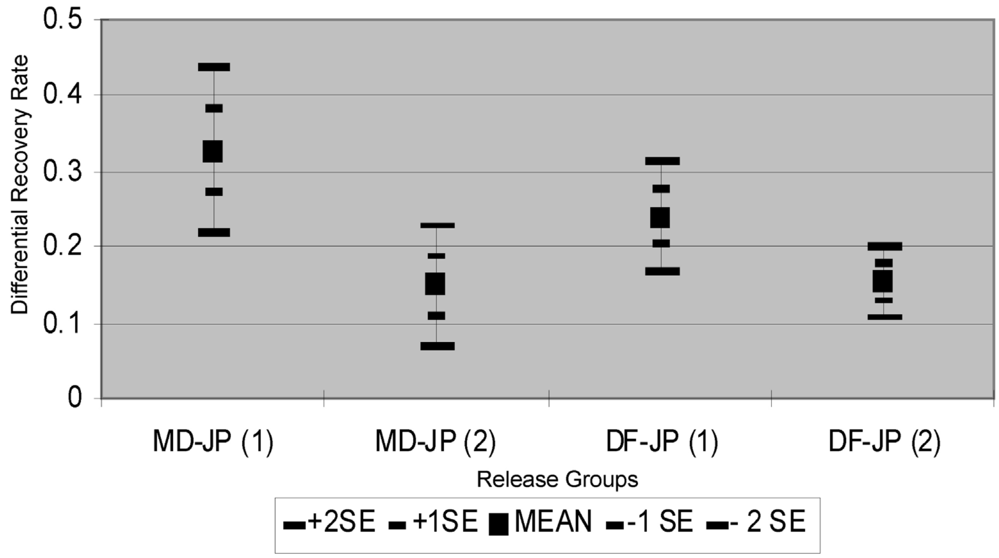


One surprise was that the second group released at Durham Ferry appeared to survive at a higher rate than the second group released at Mossdale. This result was shown using both absolute survival estimates and differential combined recovery rates of the Durham Ferry groups relative to the Mossdale groups (Tables 3-2 and 3-4). However, the difference in recovery rates was not significant at either the 68 percent or 95 percent confidence level. Durham Ferry is 11 miles further upstream than Mossdale and is expected to include additional mortality.

Both differential recovery rate estimates of survival between Durham Ferry and Mossdale were not significantly different from each other using either confidence levels (Table 3-4). Thus the differential recovery rates of the two groups were combined and survival between Durham Ferry and Mossdale was estimated at 0.89. These data appear to show that there is substantial variability within recovery rate estimates and that survival was relatively high between the two locations.

In 2000 it did appear that survival was less for groups released at Durham Ferry relative to those released at Mossdale using the absolute survival estimates generated from information at Antioch. This difference led to the recommendation of making releases at both Durham Ferry and Mossdale in future years. When looking at the 2000 data using combined differential recovery rates, the variability was such it was not clear that survival was greater for the Mossdale group. The recovery rate of the first Mossdale group relative to the first Jersey Point group was not significantly different (at the p<0.05 level) from the first Durham Ferry group relative to the first Jersey Point group. The same was true for the second set of releases. The first Mossdale / Jersey Point recovery rate was significantly different than the second Durham Ferry / Jersey Point group at both levels of significance (Figure 3-6).

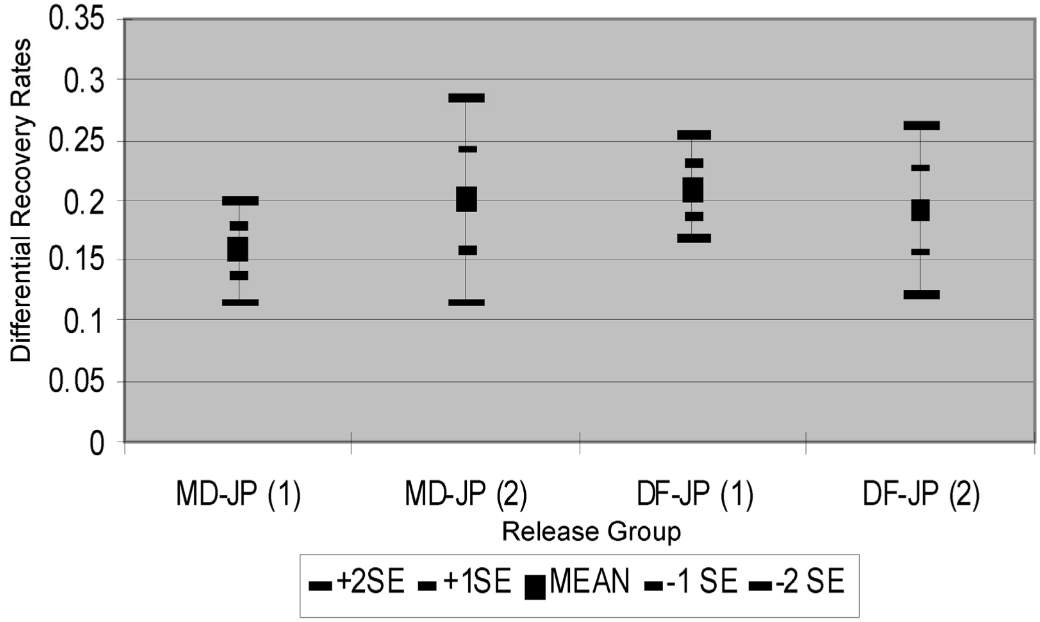
Figure 3-6 Differential Recovery Rates of CWT Smolts Released at Mossdale and Jersey Point (MD-JP) and Durham Ferry and Jersey Point (DF-JP) for the First (1) and Second (2) groups in 2000. The Estimate and Plus and Minus 1 and 2 Standard Error(s) is Provided.



In 2001 and 2002 differential recovery rates indicated that survival between Durham Ferry and Jersey Point and Mossdale and Jersey Point was not statistically different (p<0.05), thus we can infer survival between Durham Ferry and Mossdale was high in these years. Surprisingly, the survival was higher in 2001 for the first Durham Ferry group relative to the Jersey Point group than the first Mossdale group relative to the Jersey Point group using the lower level of significance (Figure 3-7). It is uncertain how the Durham Ferry groups could survive at a higher rate than the Mossdale groups, but it probably is possible. Continuation of releasing groups at both sites will allow detection of mortality between Durham Ferry and Mossdale if it does occur and becomes significant in the future. If survival between locations is shown not to be statistically significant then groups can be combined.

In 2002, absolute survival for the Durham Ferry and Mossdale groups relative to the Jersey Point groups ranged between 0.09 and 0.21 and averaged 0.14. Differential recovery rates ranged between 0.09 and 0.19. As mentioned earlier, the combined recovery rates relative to the Jersey Point groups were not significantly different between the Durham Ferry and Mossdale groups using the 95% confidence levels. Thus it may be appropriate to combine these recovery rate estimates. Similarly, if replicates are not statistically different, they could be combined. The confidence intervals around each differential recovery rate provides a means to assess whether groups should be combined.

Figure 3-7 Differential Recovery Rates of CWT smolts released at Mossdale and Jersey Point (MD-JP) and Durham Ferry and Jersey Point (DF-JP) for the first (1) and second (2) groups in 2001. The estimate and plus and minus 1 and 2 standard error(s) is provided.



Differential recovery rates of the first and second Durham Ferry groups relative to the Jersey Point releases were not statistically different. Similarly, differential recovery rates for the first and second Mossdale groups relative to the Jersey Point groups were also not significantly different. (Note the two replicates from Mossdale to Jersey Point were significantly different using a 68% confidence interval.) In addition, the differential recovery rates of the Durham Ferry / Jersey Point estimates were not significantly different than the Mossdale / Jersey Point estimates, thus a combined estimate was generated (Table 3-4). The combined Durham Ferry/Mossdale to Jersey Point estimate of survival using the combined differential recovery rates was 0.15 – not much different than the average absolute estimate of survival (0.14).

Similar estimates of differential recovery rates with the 95% confidence intervals were calculated for past VAMP years (2000 and 2001)(Tables 3-5 and 3-6). (Note there was an error in the 2001 Annual Report in reporting these estimates. They have been recalculated and included in this report.) Differential recovery rate replicates in those years were also not significantly different from each other at the 95 percent confidence level. Thus they were combined into one estimate of recovery rate for the Durham Ferry/Mossdale groups relative to the Jersey Point groups. Some replicates were significantly different at a lower significance level (~68% or one standard deviation from the mean). For instance, the Mossdale to Jersey Point and Durham Ferry to Jersey Point replicates in 2000 were significantly different at this lower level of significance. In addition, the combined Durham Ferry / Jersey Point estimates were significantly lower than the Mossdale / Jersey Point estimates in 2001 at this lower level of confidence.

Table 3-5. 2000 Smolt Survival Differential Recovery Rates (see table at end of chapter.)

Table 3-6. 2001 Smolt Survival Differential Recovery Rates (see table at end of chapter.)

Transit Time

Data on transit times for marked salmon from the release to recapture sites during VAMP 2001 is summarized in graphic form in Appendix A. CWT salmon released April 18 at Durham Ferry took between 7 and 19 days to arrive at Antioch and 8 to 22 days to arrive at Chipps Island. The April 19th release at Mossdale release took between 6 and 11 days to arrive at Antioch and 7 and 17 days to reach Chipps Island. Jersey Point release groups were recovered between 2 and 14 days after release at Antioch and between 2 and 21 days at Chipps Island. The April 25 Durham Ferry release group arrived at Antioch between 7 and 18 days and between 7 and 15 days at Chipps Island. The April 26 release group at Mossdale was recovered at Antioch between 7 and 14 days and between 9 and 19 days at Chipps Island. The second Jersey Point release group was recovered between 1 and 14 days after release at Antioch and 1 and 19 days after release at Chipps Island. The transit time from release location to Antioch and Chipps Island of both sets of releases was similar. It is interesting that the Jersey Point groups were recovered over as long or longer period than those released upstream.

Transit times appeared slower in 2002, than in 2001. In 2001, recovery dates were as early as 4 days after releases were made at Durham Ferry and Mossdale. River flows were lower in 2002 than in 2001 (approximately 3,300 cfs versus 4,200 cfs, respectively), which may have increased travel time in 2002. The number of individual recoveries by tag code and the number of minutes towed per day for both Antioch and Chipps Island recoveries are shown in Appendix A-4.

Role of Flow and Exports on Absolute Survival and Recovery Rates

The historical April through June San Joaquin River flows and flows relative to exports were correlated to adult escapement in the San Joaquin basin 2 ½ years later (Figures 3-8 and 3-9). Both relationships are statistically significant ($p<0.01$) with the flow/exports variable accounting for slightly more of the variability than the relationship with flow alone ($r^2= 0.44$ vs. $r^2 = 0.58$, respectively). These relationships appear to indicate that adult escapement in the San Joaquin basin was affected by the amount of flow in the San Joaquin River and exports from the CVP and SWP during the spring months when the juveniles migrated through the river and Delta to the ocean. VAMP was designed to further define the mechanisms behind this relationship using smolt survival through the Delta and testing lower San Joaquin River flows with the presence of the HORB.

Figure 3-8 Flow at Vernalis (Mean April 15-June 15) Between 1951-1998 Versus San Joaquin Basin Escapement (2 1/2 Years Later).

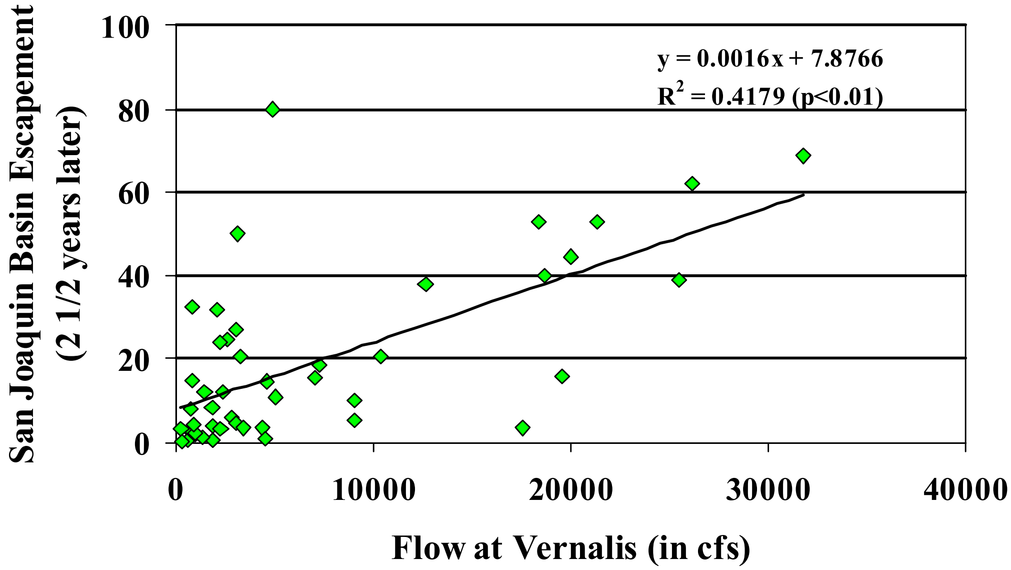
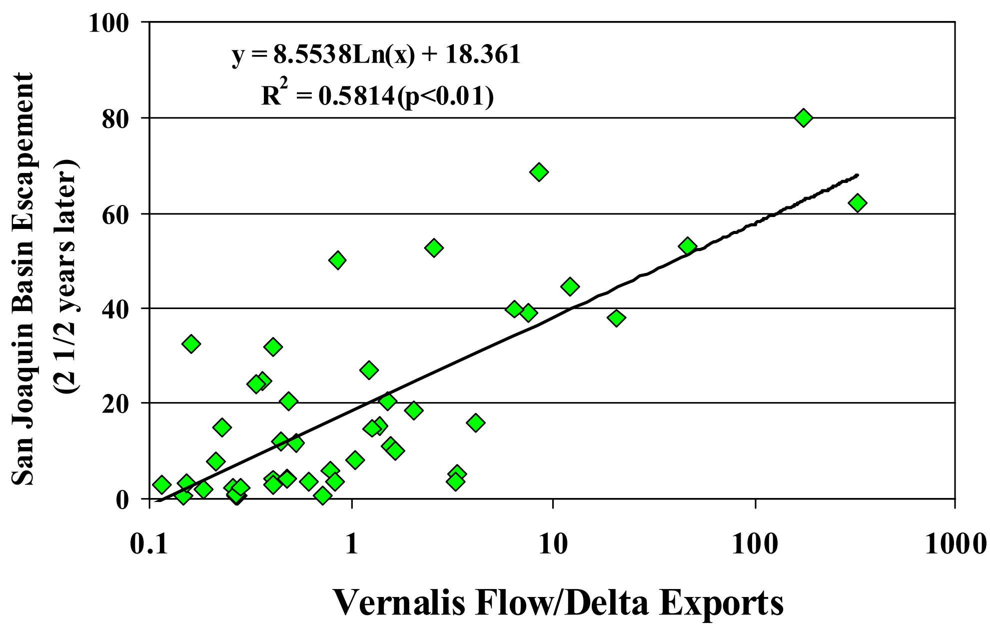


Figure 3-9 Mean Spring Flows/Delta Exports (Mean April 15-June 15) Between 1951-1998 and San Joaquin Basin Escapement (2 1/2 Years Later).



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 and complementary studies in the south delta were conducted prior to the official implementation of VAMP.

The differential relative recovery rates of all releases each year were combined, as they were not significantly different from each other at the 95 percent confidence level. These combined estimates and their 95 percent confidence intervals for the three years of VAMP releases (2000 – 2002) are shown in relation to the log of the average San Joaquin River flow at Vernalis on Figure 3-10. The average river flow was from the two-10 day periods after release. Data obtained in 1994 and 1997 are added but do not have comparable confidence intervals at this time. The relative recovery rates with the confidence intervals are also shown in comparison to average Vernalis flow/combined exports for the 10 days after release (Figure 3-11). The relationship of relative recovery rate to San Joaquin River flow is improved by incorporating exports. Relationships without the 1994 and 1997 are similar (Figures 3-10 and 3-11). While recovery rates do appear to increase as flows and flows relative to exports increase ($p<0.05$) data points that have confidence intervals around them do not appear significantly different from each other.

Figure 3-10 Survival (Plus and Minus 1 and 2 SE) From Durham Ferry/Mossdale to Jersey Point With HORB in Place Versus Flow at Vernalis, 2000-2002. 2000-2002 Vernalis Flows Were Averaged for Both 10 day Periods After Release. 1994 and 1997 Data are Added but do not Have SE. The Equation Without the 1994 and 1997 Data Added is Similar at $y=0.0621\text{Ln}(x) - 0.3445$ ($R^2=0.6371$).

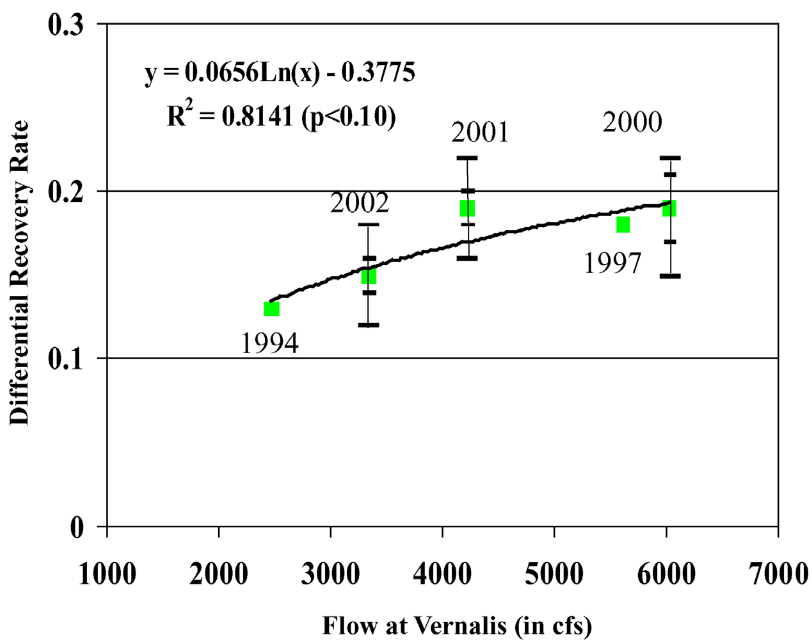
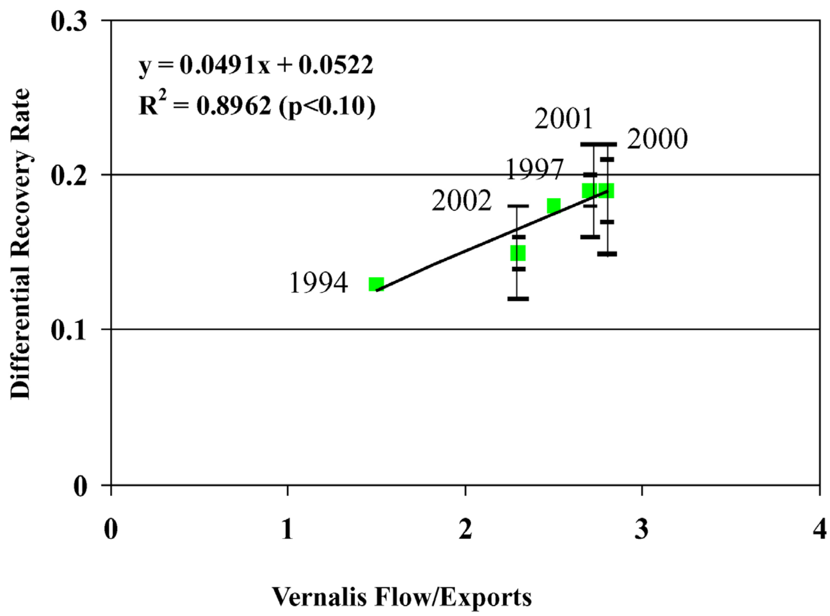


Figure 3-11 Survival (Plus and Minus 1 and 2 SE) From Durham Ferry/Mossdale to Jersey Point With HORB in Place, Versus Inflow at Vernalis/exports, Average of Both 10 day Periods After Release, 2000-2002. 1994 and 1997 Data are Added but do not Have SE. The Equation Without 1994 and 1997 is y=0.0857x – 0.0462, R^2=0.9643.



Given the relatively high variability inherent in conducting salmon smolt survival studies within the lower San Joaquin River and Delta, and modeling conducting by Ken Newman (November, 2001) the lack of statistically significant differences between relative recovery rates from similar flow-export conditions was not unexpected. Results of these analyses underscore the importance of collecting salmon smolt survival data under the most extreme flow-export conditions identified as VAMP targets. Flows of 7,000 cfs and exports of 1,500 cfs would provide the highest flow/export ratio (4.7) to test and increase our chances of detecting significant differences in recovery rates between VAMP targets.

The role of HORB on survival

The relationship to date between absolute survival between Mossdale and Jersey Point and San Joaquin River flow at Vernalis and exports with and without the barrier in upper Old River is shown in Figure 3-12. Differential recovery rates are not reported since without barrier releases do not have comparable estimates. Thus while comparisons can be made between regression lines, variance around each data point is not yet available. Two regression lines have been developed based on survival data with and without the HORB. Statistically neither regression line is significant, although prior to adding the data from 1999, the without barrier relationship was significant. The barrier appears to generally increase survival at any one flow or export level, although the survival was high in 1999 without a barrier. We have hypothesized that data collected in 1999, could be biased high as sampling was interrupted during collection of the downstream control group (Brandes, 2000).

Figure 3-12 Estimates of Survival Versus Vernalis Flow/Exports With and Without a HORB.

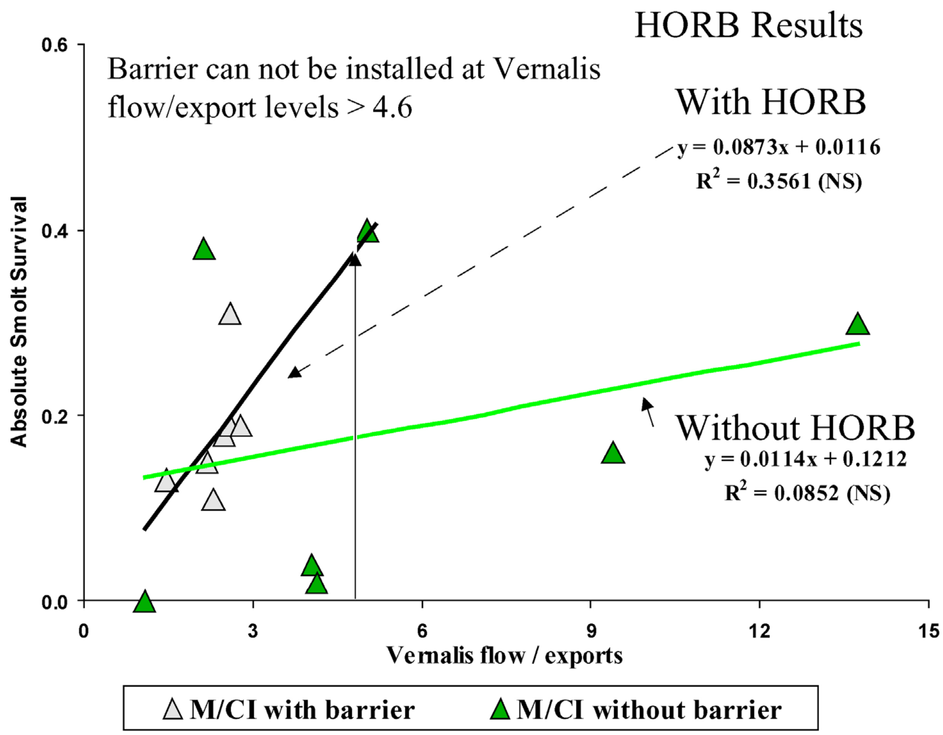


Figure 3-12 shows the relationship between absolute salmon smolt survival and San Joaquin River flow at Vernalis with the HORB. A better estimate of flow would be the net flow on the San Joaquin River downstream of upper Old River because of the different permeability of the HORB (culvert operations) over the years. The estimated flow in the San Joaquin River downstream of upper Old River would better reflect the river flow the juvenile salmon experience as they migrate down the San Joaquin River. This estimate has been calculated in past years by subtracting the estimated mean daily flow in upper Old River 840 feet downstream of the barrier from the USGS gaged mean daily flow at Vernalis.

It appears as exports increase relative to flow, survival (differential recovery rates) decreases. Although the relationship is significant the individual recovery rates are not significantly different from one another. One source of variability that could be reduced is the variable permeability of the HORB within and among years. During the five years the barrier has been installed (and comparable survival studies conducted) the design and permeability has 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 culverts open during the first Mossdale and Durham Ferry releases and four culverts open during the second Durham Ferry release. In 2001 and 2002, six culverts were installed and operated throughout the VAMP test period. It is estimated that approximately 400 cfs of San Joaquin River flow moved through the culverts in 2001 and 2002 (Simon Kwan, personal communication). The amount of water flowing through the culverts is based on the head differential between the San Joaquin River and Old River. This changes as flow/stage on the river changes and as the tide changes, even if all 6 culverts remain open for the remaining 9 years of the study. The varying designs and changes in the culvert operations of the barrier add variability to the survival measurements, making it more difficult to detect significant differences between closely related flow/export ratios.

In the five years of measuring survival with the barrier in place, the flow/export ratio has only varied from 1.5 (1994) to 2.9. These are very small differences in target conditions of which to measure survival. The ratios in the relationship between flow/export and adult escapement vary from 0.1 to 1000.

Ocean Recovery Information from Recent Years

Ocean recovery data of CWT salmon groups can contribute to a more complete understanding and evaluation of salmon smolt survival studies. These data can provide another independent estimate of the ratio of survival of a test release group relative to a control release group, or "absolute survival", and can be compared with estimates based on juvenile salmon recoveries at Chipps Island and Antioch. Past recoveries at Jersey Point (1997–1999) can not be compared since the Jersey Point trawling site was located upstream of the Jersey Point release site and a ratio between the upstream and downstream sites can not be generated. Recovery from trawling at Antioch began in 2000. The ocean harvest data may be particularly reliable due to the number of tag 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 2001. The ocean CWT recovery data accumulate over a 1-4 year period following the year a study release is made as nearly all of a given year class of salmon have either been harvested or spawned by age 5. Consequently, these data are essentially complete for releases made through 1996 and 1997 and partially available for CWT releases made from 1998-2000. Once the data for these and later releases are available they will be used to compare the three independent estimates of survival (using Antioch, Chipps Island, and ocean recoveries) based on VAMP releases starting in 2000.

Survival estimates based on ocean recoveries for salmon produced at the Merced River Hatchery, and released as part of south delta survival evaluations from 1996-2000 were compared to survival estimates based on Chipps Island and Antioch recoveries (Table 3-7). Releases over that period were made at several locations: Dos Reis (on the San Joaquin River downstream of the upper Old River junction), Mossdale, Durham Ferry, and Jersey Point. Ocean absolute survival ratios were very similar to those at Chipps Island for the releases made in 1996, and 1999, and 2000 and at Antioch for the Mossdale and second Durham Ferry releases in 2000. Although ocean absolute survival ratios were higher than those to Chipps Island were for releases in 1997 and 1998 and to Antioch for the first Durham Ferry release in 2000, they were generally similar (in the mid-range of survival).

Results of this comparative analysis of survival estimates for Chinook salmon produced in the Merced River Hatchery show: (1) there is generally good agreement between survival estimates based on juvenile CWT salmon recoveries in Chipps Island and Antioch trawling and adult recoveries from the ocean fishery, (2) survival estimates using Chipps Island or Antioch recoveries were lower in some years than estimates based on ocean recoveries, 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 valuable in evaluating the biological benefits of changes in flow and export rates under VAMP.

Table 3-7. Survival Indices Based on Chipps Island, Antioch and Ocean Recoveries of Merced Hatchery Salmon Released as Part of South Delta Studies Between 1996 and 2000

Release Year	San Joaquin River (Merced River Origin) Tag No.	Release Number	Release Site	Release Date	Chipps Is. Recovs.	Antioch Recovs.	Expanded Adult Ocean Recovs. (Age 1+ To 4+)	Chipps Island	Antioch	Ocean Catch
		Juvenile Salmon CWT Releases						Juvenile Salmon CWT Survival Estimates		
1996	H61110412	25,633	DOS REIS	01MAY96	2		3			
	H61110413	28,192	DOS REIS	01MAY96	3		37			
	H61110414	18,533	DOS REIS	01MAY96	1		8			
	H61110415	36,037	DOS REIS	01MAY96	5		10			
	H61110501	53,337	JERSEY PT	03MAY96	39		187			
	Effective Release	107,961	DOS REIS		11		58	0.14		0.15
	Effective Release	51,737	JERSEY PT		39		187			
1997	H62545	50,695	DOS REIS	29APR97	9		183			
	H62546	55,315	DOS REIS	29APR97	7		167			
	H62547	51,588	JERSEY PT	02MAY97	27		351			
	Effective Release	106,010	DOS REIS		16		350	0.29		0.49
	Effective Release	51,588	JERSEY PT		27		351			
	H62548	46,728	DOS REIS	08MAY97	5		91	0.28		0.48
	H62549	47,254	JERSEY PT	12MAY97	18		191			
1998	61110809	26,465	MOSSDALE	16APR98	25		61			
	61110810	25,264	MOSSDALE	16APR98	31		40			
	61110811	25,926	MOSSDALE	16APR98	32		58			
	61110806	26,215	DOS REIS	17APR98	33		47			
	61110807	26,366	DOS REIS	17APR98	23		35			
	61110808	24,792	DOS REIS	17APR98	34		61			
	61110812	24,598	JERSEY PT	20APR98	87		110			
	61110813	25,673	JERSEY PT	20APR98	100		90			
	Effective Release	77,655	MOSSDALE		88		159	0.30		0.51
	Effective Release	77,373	DOS REIS		90		143	0.31		0.46
	Effective Release	50,271	JERSEY PT		187		200			
1999	064606	25,005	MOSSDALE	20APR99	2		57			
	062642	24,715	MOSSDALE	19APR99	8		101			
	062643	24,725	MOSSDALE	19APR99	15		119			
	062644	25,433	MOSSDALE	19APR99	13		112			
	062645	25,014	DOS REIS	19APR99	20		138			
	062646	24,841	DOS REIS	19APR99	19		191			
	0601110815	24,927	JERSEY PT	21APR99	34		244			
	062647	24,193	JERSEY PT	21APR99	25		302			
	Effective Release	99,878	MOSSDALE		38		389	0.32		0.35
	Effective Release	49,855	DOS REIS		39		329	0.65		0.59
	Effective Release	49,120	JERSEY PT		59		546			

Table 3-7 (cont.)

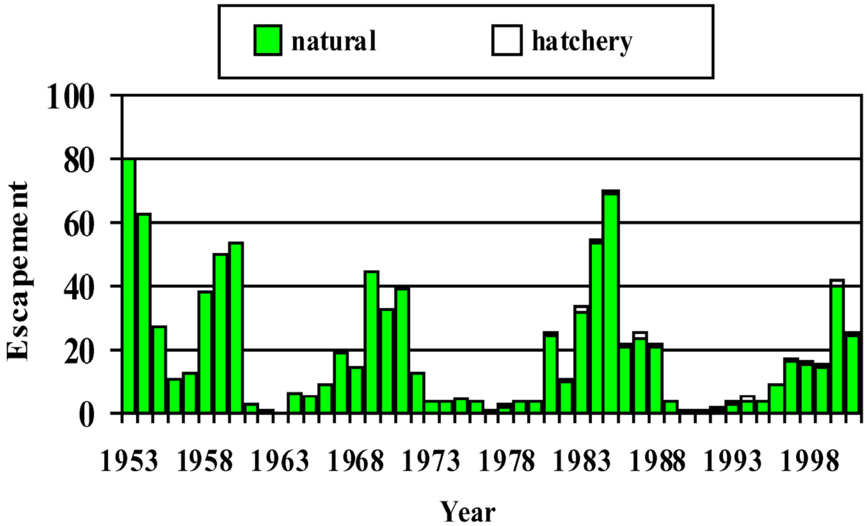
Release Year	San Joaquin River (Merced River Origin) Tag No.	Release Number	Release Site	Release Date	Chipps Is. Recovs.	Antioch Recovs.	Expanded Adult Ocean Recovs. (Age 1+ To 4+)	Chipps Island	Antioch	Ocean Catch
	Juvenile Salmon CWT Releases							Juvenile Salmon CWT Survival Estimates		
2000	06-45-63	24,457	DURHAM FERRY	17-Apr-00	11	11	10			
	06-04-01	23,529	DURHAM FERRY	17-Apr-00	7	6	10			
	06-04-02	24,177	DURHAM FERRY	17-Apr-00	10	10	20			
	06-44-01	23,465	MOSSDALE	18-Apr-00	9	14	10			
	06-04-02	22,784	MOSSDALE	18-Apr-00	9	16	9			
	06-44-03	25,527	JERSEY PT	20-Apr-00	24	50	50			
	06-04-04	25,824	JERSEY PT	20-Apr-00	41	47	24			
	Effective Release	72,163	DURHAM FERRY		28	27	40	0.31	0.20	0.38
	Effective Release	46,249	MOSSDALE		18	30	19	0.31	0.34	0.29
	Effective Release	51,351	JERSEY PT		65	97	74			
	601060914	23,698	DURHAM FERRY	28-Apr-00	7	8	4			
	601060915	26,805	DURHAM FERRY	28-Apr-00	5	15	4			
	0601110814	23,889	DURHAM FERRY	28-Apr-00	10	8	0			
	0601061001	25,572	JERSEY PT	1-May-00	48	76	14			
	0601061002	24,661	JERSEY PT	1-May-00	30	76	32			
	Effective Release	74,392	DURHAM FERRY		22	31	8	0.19	0.14	0.12
	Effective Release	50,233	JERSEY PT		78	152	46			

Note: Ocean recoveries are based on data through 2001

San Joaquin River Salmon Protection

One of the VAMP objectives is to provide improved conditions and increased 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 hoped that these actions to improve conditions for the juveniles would translate to greater adult escapement in future years, especially during low flows, when escapement 2 ½ years later has been extremely low in the San Joaquin basin (Figure 3-13).

Figure 3-13 Natural and Hatchery Escapement Returning to the San Joaquin Basin Between 1953 and 2001.



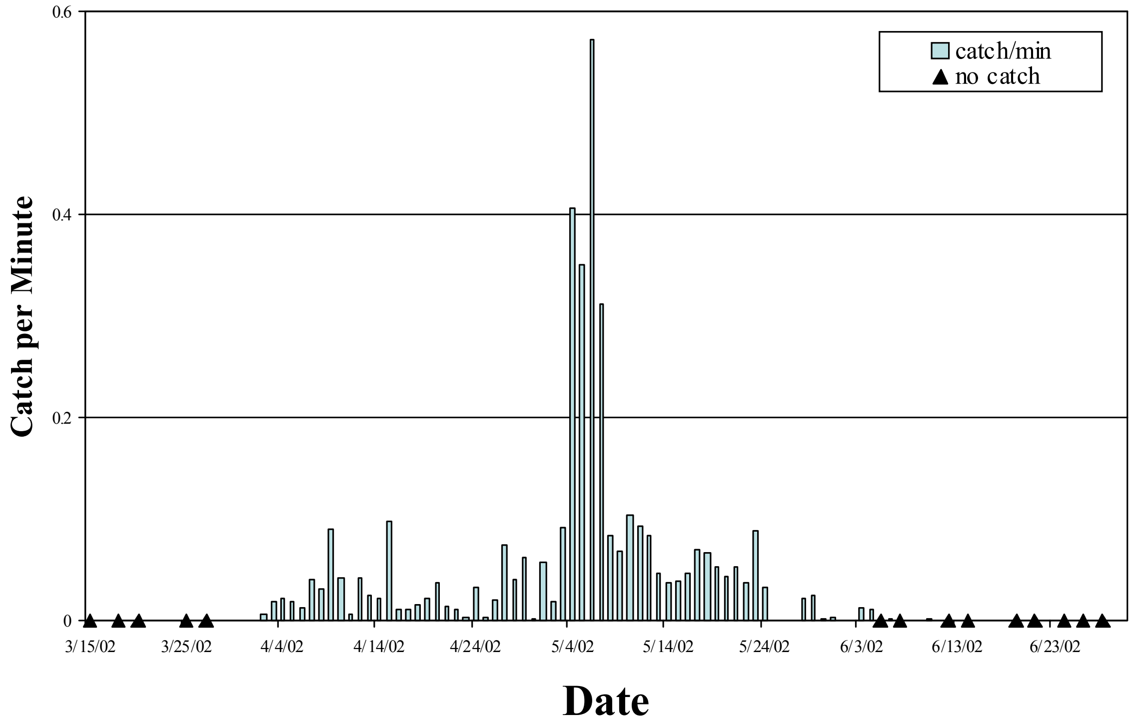
To determine if VAMP in 2002 was successful in protecting juvenile salmon emigrating from the San Joaquin River tributaries, estimates of survival were compared with VAMP and in the absence of VAMP. Catches of unmarked salmon at Mossdale and in salvage at the CVP and SWP facilities were also compared prior to and during the VAMP period.

Unmarked Salmon Recovered at Mossdale

In assessing VAMP's objective to provide increased protection for the natural production of juvenile salmon migrating from the San Joaquin River tributaries, an estimate of survival was calculated with VAMP and in the absence of VAMP. The equation of survival to flow/exports was used to estimate survival under both conditions (Figure 3-11). With VAMP the flow/export ratio during the VAMP period was 2.3. This flow/export ratio generated a survival of 0.15. Without the export curtailments and flow augmentation due to VAMP the flow/export rate was estimated to be 0.35 (given the barrier was still in without the VAMP flow and exports). At this level of flow/export rate survival was estimated to have been 0.08. The export curtailments and increase in flows from VAMP essentially doubled survival from 0.08 to 0.15.

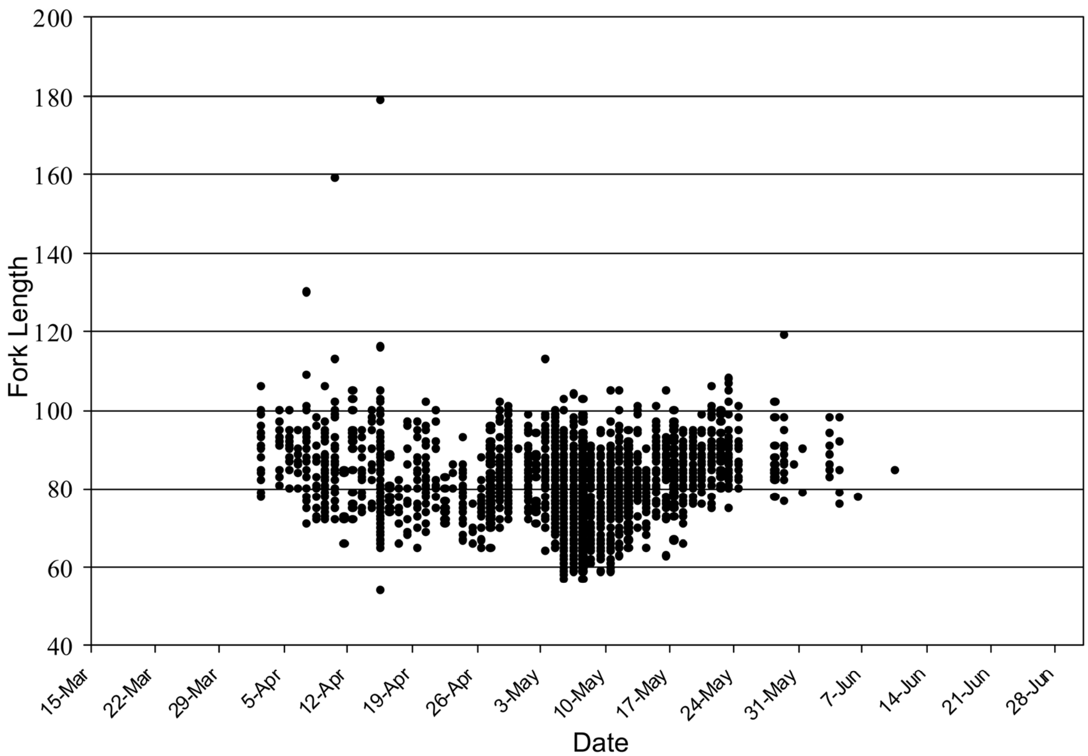
The original time period for VAMP (April 15 to May 15) was chosen based on historical data that indicated a high percentage of the juvenile salmon emigrating from the San Joaquin tributaries were passing into the delta at Mossdale during that time period. The average catch per minute per day of unmarked juvenile salmon caught in Kodiak trawling at Mossdale between March 15 and June 30, 2002 is shown in Figure 3-14. Unmarked salmon do not have an adipose clip and could be fish from the Merced River Hatchery or juveniles from natural spawning. An assessment of the percent of catch per unit effort over time indicated that the majority of juvenile salmon (77%) migrated past Mossdale during the VAMP period. Delaying removal of the HORB until May 24, continuing export curtailments and ramping exports into early June protected an even greater percent of the population (91%). Reducing flows may stimulate movement of the juvenile salmon out of the system. Continuing the export curtailments and keeping the barrier in place for a week after the VAMP period provided some protection to these later out-migrants. These additional protection measures after the VAMP period appear to have been beneficial to protecting a greater proportion of the population of unmarked juvenile salmon emigrating from the San Joaquin basin.

Figure 3-14 Catch Per Cubic Meter of all Unmarked Juvenile Chinook Salmon in the Mossdale Kodiak Trawl, March 15, 2002 Through June 30, 2002.



Each unique size in millimeters of the juvenile salmon migrating past Mossdale between March 15 and June 30 is shown in Figure 3-15. In early April there were large juvenile salmon observed in the catch. These may be yearlings that have over-summered in the San Joaquin tributaries. Additional protection in early April may be warranted for this component of the population.

Figure 3-15 Individual Fork Lengths for Unmarked Juvenile Chinook in the Mossdale Kodiak Trawl, March 15, 2002 Through June 30, 2002.



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 downstream in the western Sacramento-San Joaquin delta. The untagged salmon are either naturally produced or are 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 at the facilities to provide some general indications.

The salvage at the facilities is based on expansions from sub-samples taken throughout the day. Approximately 4-5 salmon 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 50–80% of the number salvaged, or about 6– 8 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 or additional mortality associated with trucking and handling. Salvage density of salmon is the number of salvaged fish per acre-foot of water pumped.

The number 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 and density of juvenile salmon salvaged and lost. Density may be the best indicator of when the most juvenile salmon were moving through the salvage system.

A review of the weekly salvage data around the 2002 VAMP period indicates that the highest salvage and losses occurred during the second week of May at the SWP and in the second week prior to the VAMP period at the CVP (Figures 3-16 and 3-17). Salmon density was highest in the first week of the VAMP period at the CVP facility, which also had high densities in the two preceding weeks, and in the fourth week of the VAMP period at the SWP facility (Figure 3-18).

The salvage, loss and density information indicates that the salmon protection measures of VAMP may have been beneficial if they were implemented in the first half of April, similar to 2000 and 2001. Reducing exports during this earlier period of time would not only provide better conditions for juvenile salmon emigrating from the San Joaquin River basin, but from the Sacramento River basin as well. Juvenile spring-, winter-, and fall- run Chinook salmon migrate through the Delta in early April from the Sacramento River basin. Compared to the previous two years, salvage, losses, and density were several times lower in 2002, indicating that overall juvenile abundance was much less this year at the fish facilities.

Figure 3-16 2002 SWP Salmon Salvage and Loss.

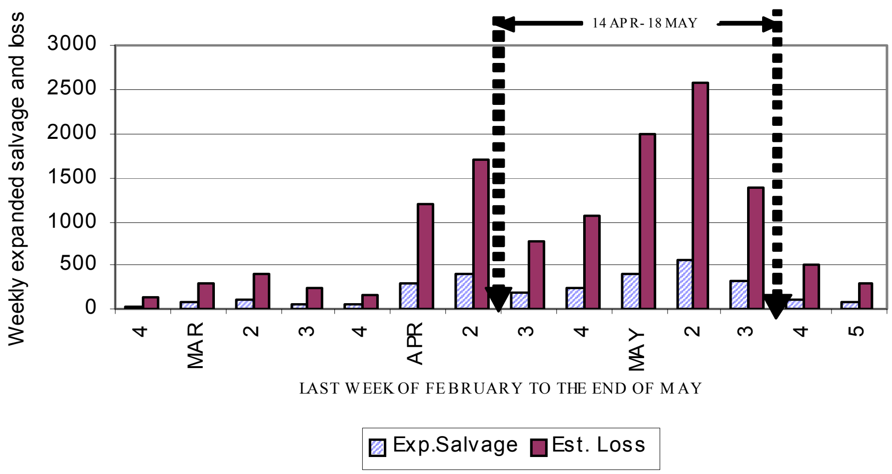


Figure 3-17 2002 CVP Salmon Salvage and Loss.

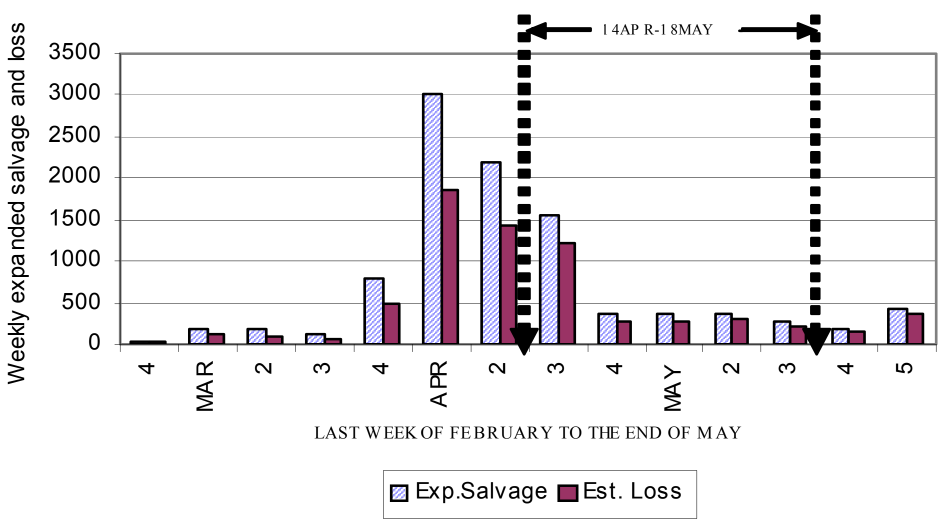
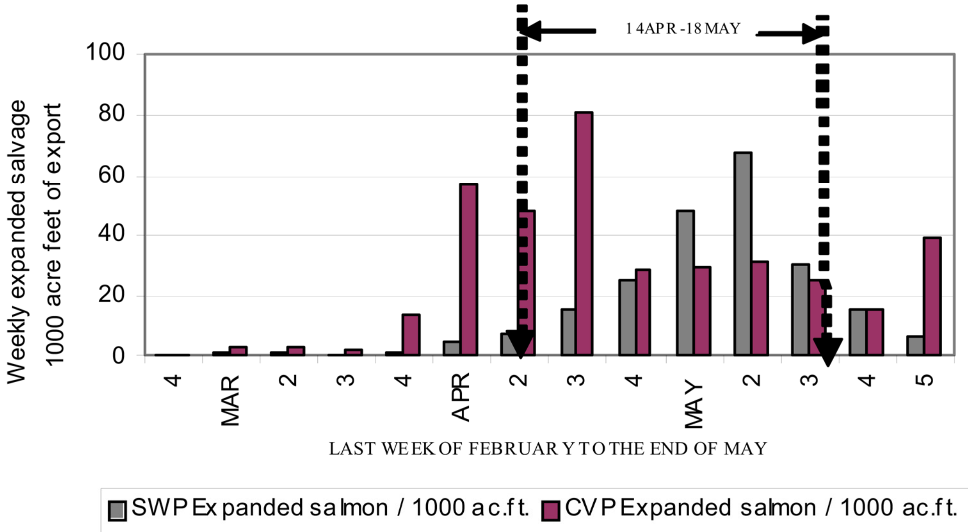
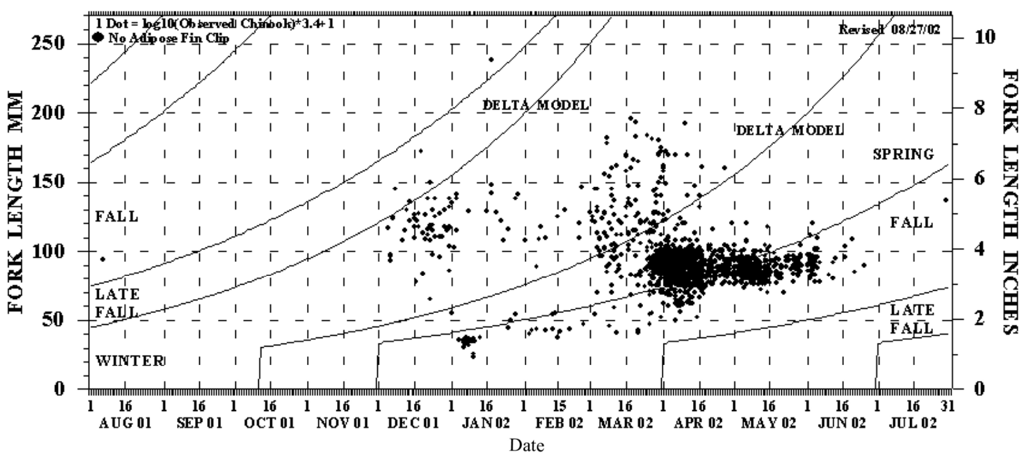


Figure 3-18 2002 SWP & CVP Expanded Salmon Salvage Density.



The size distribution of unmarked salmon during April and May in the Mossdale trawl (Figure 3-15) and at the salvage facilities (Figure 3-19: Source E. Chappell, DWR) were generally similar in 2002, as was observed in 2001.

Figure 3-19 Observed Chinook Salvage at the SWP & CVP Delta Fish Facilities 8/01/01 through 7/31/02.



Results of this analysis showed that the 2002 VAMP experiment coincided with the majority of the salmon smolt emigration. Reductions in SWP and CVP exports and increased San Joaquin River flow provided improved conditions for salmon survival, although starting the VAMP period two weeks earlier may have had substantial benefits. Additional VAMP studies are required, however, to improve quantification of biological benefits over a broader range of environmental conditions.

Summary and Recommendations

The variability in survival (recovery rates) at any one flow or flow/export level with the HORB makes any preliminary conclusions uncertain based on VAMP results to date. Measuring survival within the narrow ranges of flow and export targets within the VAMP design further limits our ability to detect significant differences between targets. Future studies should prioritize, to the extent possible, flows of 7000 cfs and exports of 1500 cfs to achieve the highest target ratio (4.7) within the VAMP design to better enable us to determine the role of flow and export on salmon smolt survival. It is recommended that these conditions be tested as soon as possible to determine if VAMP should continue or if the study design needs to be changed. It is uncertain how such a condition can be prescribed independently of the hydrology within the existing San Joaquin River Agreement, but the idea should be explored by the VAMP Management Team. Also continued assessment of past data is recommended such that other methodologies or criteria for determining statistical differences between groups may be developed.

Chapter 4. Annual Summary Report of SWP and CVP Salvage

In an attempt to better examine 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 daily salvage densities for 2002 was made. 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 possible method to be used in a future retroactive analysis of temporary barrier operations and fish salvage in the south 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 2002. 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). Water exports for the SWP (Banks Pumping Plant only) and the CVP 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). 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 are graphically represented by vertical lines that identify relative points in time when specific barriers were put into operation (closed) and when each was removed (breeched). Barrier-specific operational adjustments are discussed here, but were not included in the figures.

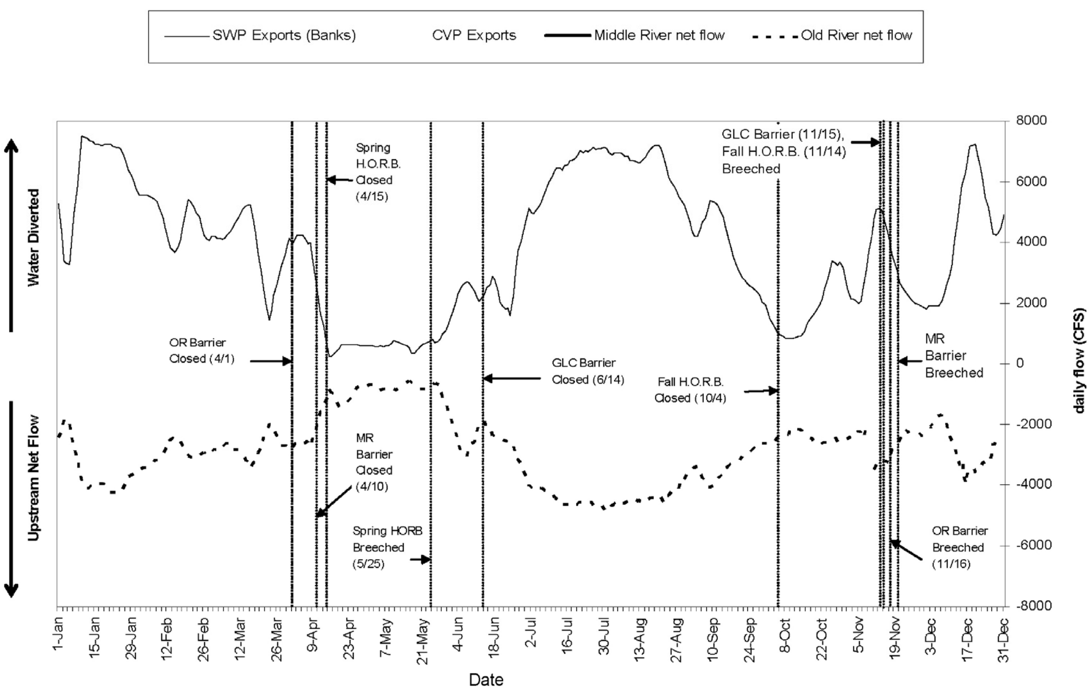
The figures only take into consideration complete barrier installations. Incomplete structures and changes in configuration were not included. Despite this simplification of TBP operations, several uncharted adjustments in barrier structure and operation altered flow by an unknown degree. Such changes were assumed to be insignificant variables relating to fish salvage. The most notable alterations are listed below.

- The Grant Line Canal Barrier installation began April 1, but its center portion was left open due to sufficient water levels upstream. The barrier was closed on June 12 when warm weather and increased diversion rates in the area resulted in significantly lower water levels. The incomplete structure altered flow characteristics in Grant Line Canal from the pre-barrier condition, however, it was likely very slight, and therefore insignificant.
- The Old River and Middle River barriers were notched on September 16 to allow passage of migrating adult salmon over the top of the weir. Flashboards on the Grant Line Canal Barrier were adjusted accordingly for the same purpose.
- The tidal flap gates on the Old River and Middle River barriers were tied open from May
- 22 and 23 through June 1 and 2 respectively, in order to help reduce salvage of delta smelt at the Delta fish facilities.

- The six culverts on the Head of Old River Barrier were left open throughout the spring and fall operation periods in order to protect downstream water levels. No adjustments were made to this configuration in 2002.

Central Delta flows and project exports were plotted as cubic feet per second (cfs) (Figure 4-1). 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 and Tracy (CVP) pumping plants. These flow rates are greater than or equal to zero since water is pumped in only one direction. Central Delta (net) flows can be bi-directional with positive downstream flows and negative upstream flows. In 2002, central Delta flows were always negative, having exhibited daily net movement only in the upstream direction toward the Delta fish facilities. 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 flow curves respond inversely when upstream flow occurs.

Figure 4-1 Seven-day running averages of daily SWP (Banks Pumping Plant only) and CVP exports, central Delta flows and Temporary Barriers Project operations in 2002



The Vernalis Adaptive Management Plan (VAMP) was implemented during the spring of 2002 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, 2002 Annual Technical Report). VAMP maintained moderate central Delta flows from April 15 through May 15.

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 operation season may not have been plotted since the data was not important to this report. For instance, steelhead salvage densities reached relatively low to mid levels during the last two weeks of December. Green sturgeon (*Acipenser medirostris*) were only salvaged on 3/9/02, and therefore were not included in this report.

Data used in the species charts were averaged weekly in order to enhance the visual characterization of significant changes. This modification removed timing discrepancies from barrier operations and SWP and CVP 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 is 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 every group of 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 fish in the CCF is unknown. This further complicates a daily comparison of salvage between the two facilities and other variables, and so project-specific salvage data were not combined for the purpose of this report.

DWR performed a Banks pumping experiment on 5/25/2002 (DAT conference call, 5/28/02). The purpose of the experiment was to try to determine if an increase in delta smelt salvage density at the end of the VAMP export reduction may be caused by the population growing in the Clifton Court Forebay during the month of VAMP. DWR pumped at a relatively high rate (4500 cfs from 0:00 until 06:00, then 3300 cfs until 07:00) from the CCF with the radial gates closed. By not pumping during the rest of the day, the average daily pumping rate averaged out to only 700 cfs. The result was an 8-fold increase in the density of delta smelt salvaged. The management agencies (DFG, USFWS and NMFS) decided that the high salvage density on 5/25/2002 was due primarily to the resident population in the CCF, and also to an increasing delta smelt density outside the Forebay, indicated by the higher salvage density on 5/24/2002.

Since all four races of Chinook salmon are of special concern, they were not separated by race in this comparison. Winter-run length salmon were salvaged from December 2001 through April 2002 (Greene, 2002). This data may be readily compared to the salmon species chart if wanted.

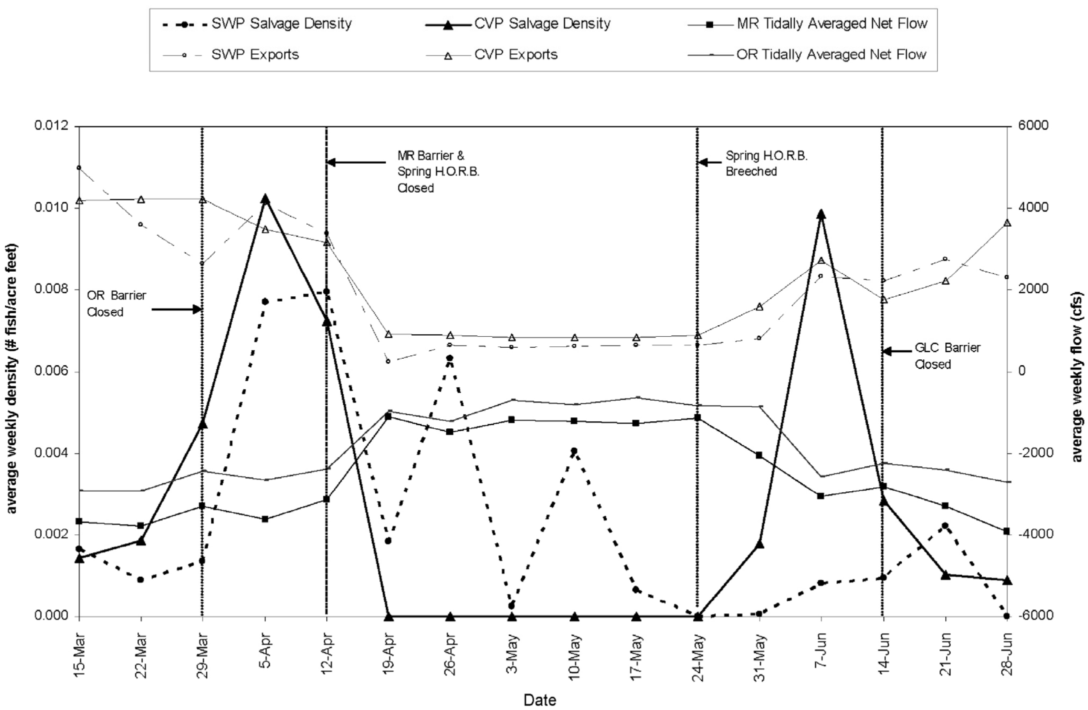
Salvage Observations

After an initial examination, the plots seemed to illustrate that weekly total salvage density appeared normally distributed for most species. This indicates that populations moved, as a whole, through the projects' zone of influence in the south Delta.

An obvious exception was splittail, which exhibited an uneven, bimodal distribution of weekly total salvage densities (Figure 4-2). This pattern is especially discernable in the CVP salvage data, among which, peaks relatively close in value occurred during the weeks of April 5 and June 7. The first of these coincided with the closure of the OR barrier and a moderate rise in SWP exports. The second coincided with a moderate rise in pumping from both projects, and then dropped off significantly as the GLC barrier was finally closed during the week of June 14.

Together, the two peaks in salvage appear to bracket the moderate central Delta flows of the VAMP. This indicates that a significant relationship may exist between splittail salvage (CVP), moderate central Delta flows and low exports. In addition, the Middle River barrier and spring H.O.R.B. were closed during the week prior to the start of the VAMP, and preceded steep drops in total salvage. While the Skinner fish facility salvaged substantial splittail during the VAMP, the Tracy facility salvaged none. By the end of this period, SWP salvage of splittail had decreased to zero, and exhibited only a modest increase as exports and net Delta upstream flows increased. This change in exports and Delta flows followed the breech of the spring H.O.R.B. during the week of May 24. The complete lack of salvage during the May 25 pumping experiment indicates that the splittail density in CCF was very low, if present at all. Together, these observations of splittail salvage are suggestive of several potentially significant relationships within the data. A further examination is warranted.

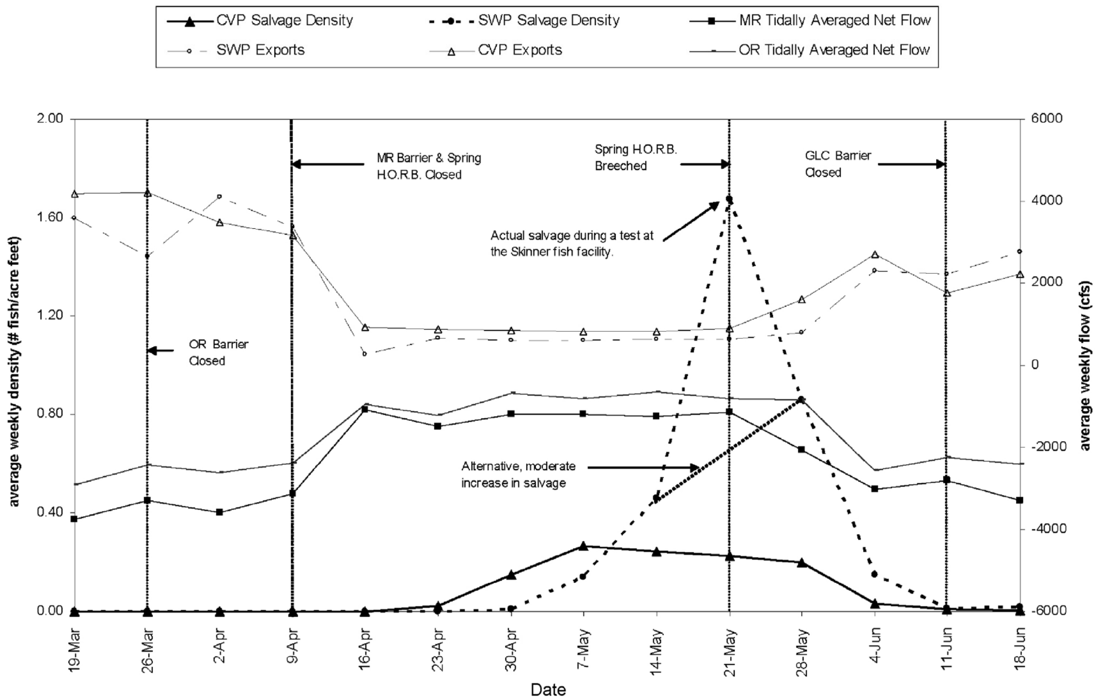
Figure 4-2 Weekly averaged splittail salvage densities, SWP and CVP exports, central Delta flows and Temporary Barriers Project operations for the weeks beginning 3/15 – 6/28/02



Delta smelt densities dropped from low levels at the start of the year to very low levels during January. These were mostly adults, which predominantly move upstream into fresh water areas to spawn in the months from January through March (DWR and USBR, 2003). Typically, young fish 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 for fish to be screened by the facilities (Figure 4-3).

Averaged total salvage density reached its peak during the week of May 24. This peak can be attributed to a single day, 8-fold increase in salvage, during the May 25, 2002 salvage test at the Skinner fish facility. It is also very indicative of a large resident population of delta smelt that held up in the CCF (DAT conference call, 5/28/02).

Figure 4-3 Weekly averaged delta smelt salvage densities, SWP and CVP exports, central Delta flows and Temporary Barriers Project operations for the weeks beginning 3/19 – 6/18/02



The spring H.O.R.B was breeched on the same day; however, because the CCF radial gates were closed during the test, it could not have influenced salvage on this day. By dropping the high and low salvage density values for the week of May 24, the weekly averaged density drops from 1.68 to 0.65 fish/AF. If the study had not taken place, perhaps SWP salvage of delta smelt would have shown an alternative, moderate increase, to a peak value of 0.86 fish/AF for the week of May 31 (Figure 4-3). Given this estimate, it doesn't appear that any obvious changes in salvage or Delta flows occurred with the breech of the spring H.O.R.B. By the time the GLC barrier was finally closed on June 12, delta smelt salvage was relatively over for the season. This likely indicates that the population moved out of the south Delta and the projects' zone of influence.

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

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 a starting point 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 up 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.

Figure 4-4 Weekly averaged Chinook salmon salvage densities, SWP and CVP exports, central Delta flows and Temporary Barriers Project operations for the weeks beginning 2/19 – 6/18/02

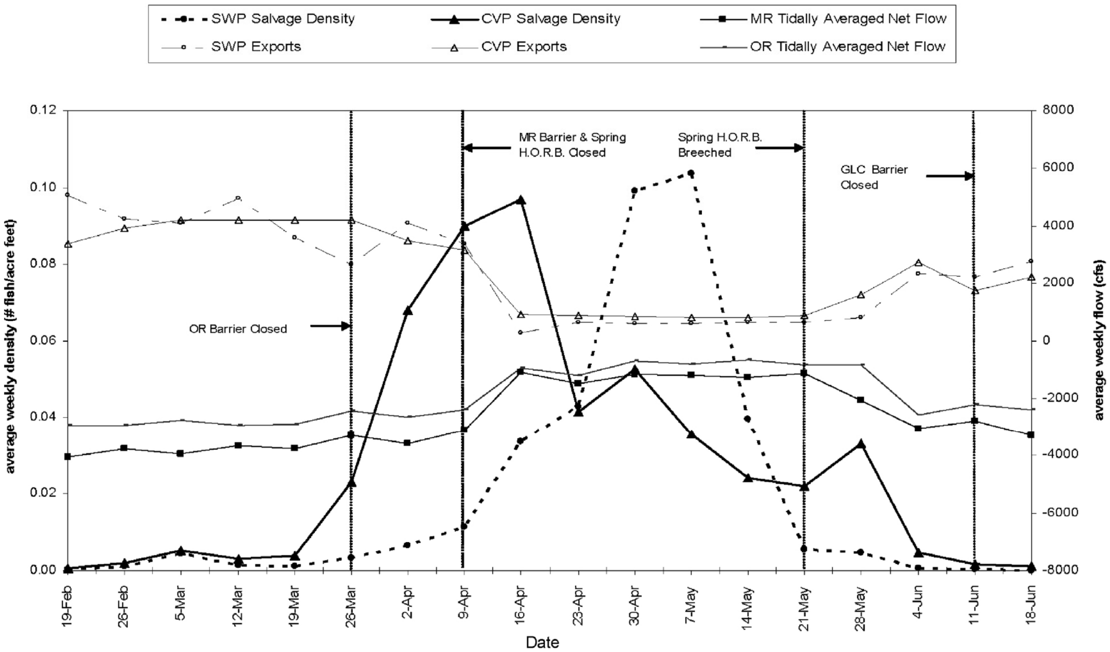


Figure 4-5 Weekly averaged steelhead salvage densities, SWP and CVP exports, central Delta flows and Temporary Barriers Project operations for the weeks beginning 1/1–6/25/02

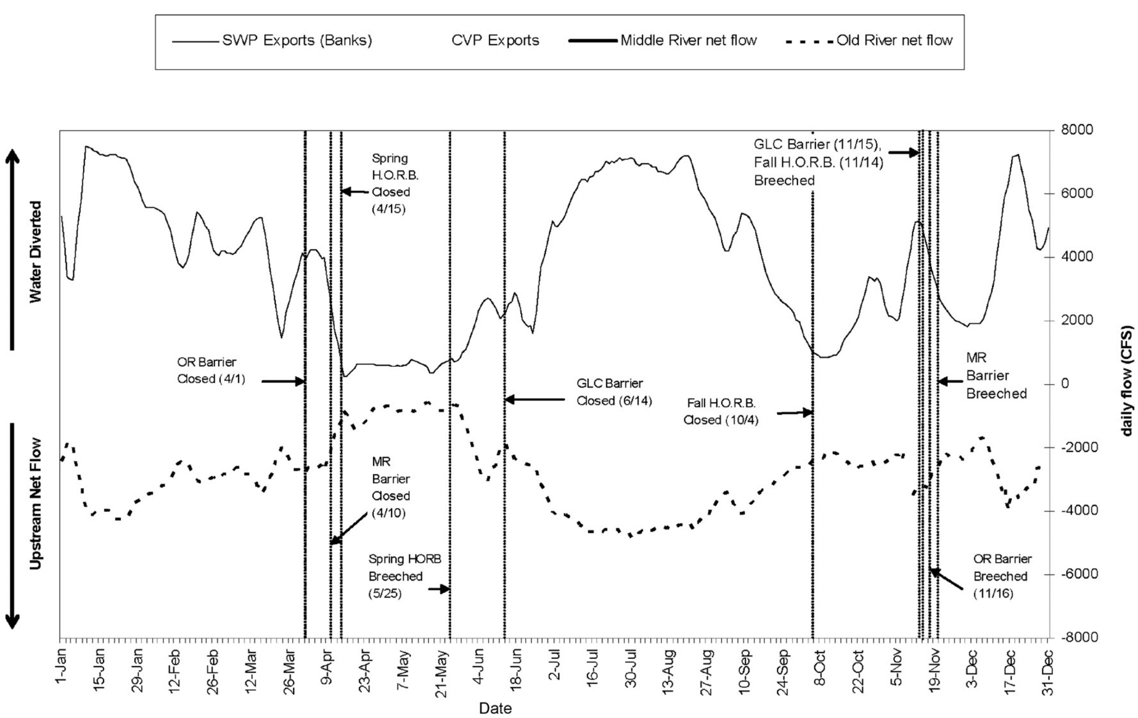
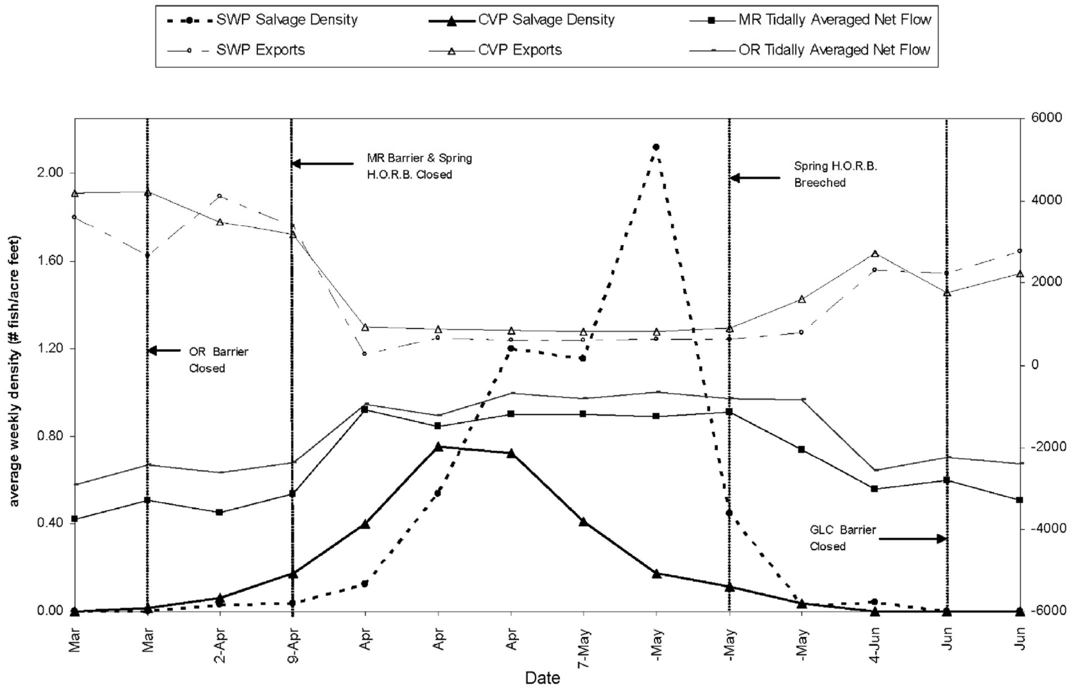


Figure 4-6 Weekly averaged longfin smelt salvage densities, SWP and CVP exports, central Delta flows and Temporary Barriers Project operations for the weeks beginning 3/19 – 6/18/02



Resources

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.

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

Greene, S. 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.

Summary of DAT (Data Assessment Team) conference call, 5/28/02.

Chapter 5. Swainson's Hawk Monitoring and Mitigation

Monitoring

Surveys for nesting Swainson's hawks were initiated on March 22, 2002 within a radius of ½ mile from all Temporary Barrier sites and project staging/storage facilities as required by the DFG Incidental Take Permit. Surveys and monitoring were completed 5 and 3 days prior to the initiation of construction activities to determine the status of and the potential to impact nesting Swainson's hawks.

Construction of the Head of Old River barrier was initiated on April 1; construction on each of the three agricultural barriers was initiated between April 2 and 12. An Environmental Education Session was provided at each barrier site for which there was potential to impact protected terrestrial species.

Prior to the initiation of construction at the barriers, pre-nesting Swainson's hawk pairs were observed within ½ mile of Grant Line Canal barrier and Head of Old River Barrier, as well as about ½ mile from each of the rock storage areas; each pair was monitored through the construction period of the respective barrier/storage area, as per the specifications listed within the ITP. No pre-nesting Swainson's hawks were observed within ½ mile of the Middle River barrier.

A Swainson's hawk pair initiated nesting activities about 700 meters downstream of the Head of Old River Barrier on the San Joaquin River. The nest was constructed in a large cottonwood on the east side of the river, but the female was never observed on the nest. This pair has failed for each of the three years they have been observed, apparently unable to complete the nesting cycle. There is no indication that construction activities affect this pair, as they are buffered from almost all sound and visual disturbances originating at the barrier site.

The pair that traditionally nested closest to the barrier site was not observed this year. They may have moved away from the nest site, or one or both of the pair may have died and the nest site was abandoned. A Swainson's hawk was observed in an old nest tree (Oak) 450 meters downstream in which the before-mentioned pair nested in 1996, but no nest was constructed in that tree to my knowledge.

Swainson's hawks nested on Grant Line Canal 300 meters upstream of the barrier site in the same oak tree used in 2000. One active young was last observed in the nest on June 26, two weeks after the barrier was completed and activities at the site ended, and the young was presumed to have fledged.

Swainson's hawks were observed at the same nest tree used and abandoned in 2001, along Tracy Boulevard, 600 meters south of the Grant Line Canal barrier rock storage site on Howard Road. That nest site was likely abandoned in 2001 when the majority of the riparian corridor burned. Although the pair began nesting in 2002, they disappeared sometime after May 8 and were not observed at the nest site again.

There were no Swainson's hawks observed nesting, or attempting to nest, within ½ mile of either the Middle River Barrier or Old River (DMC) barrier.

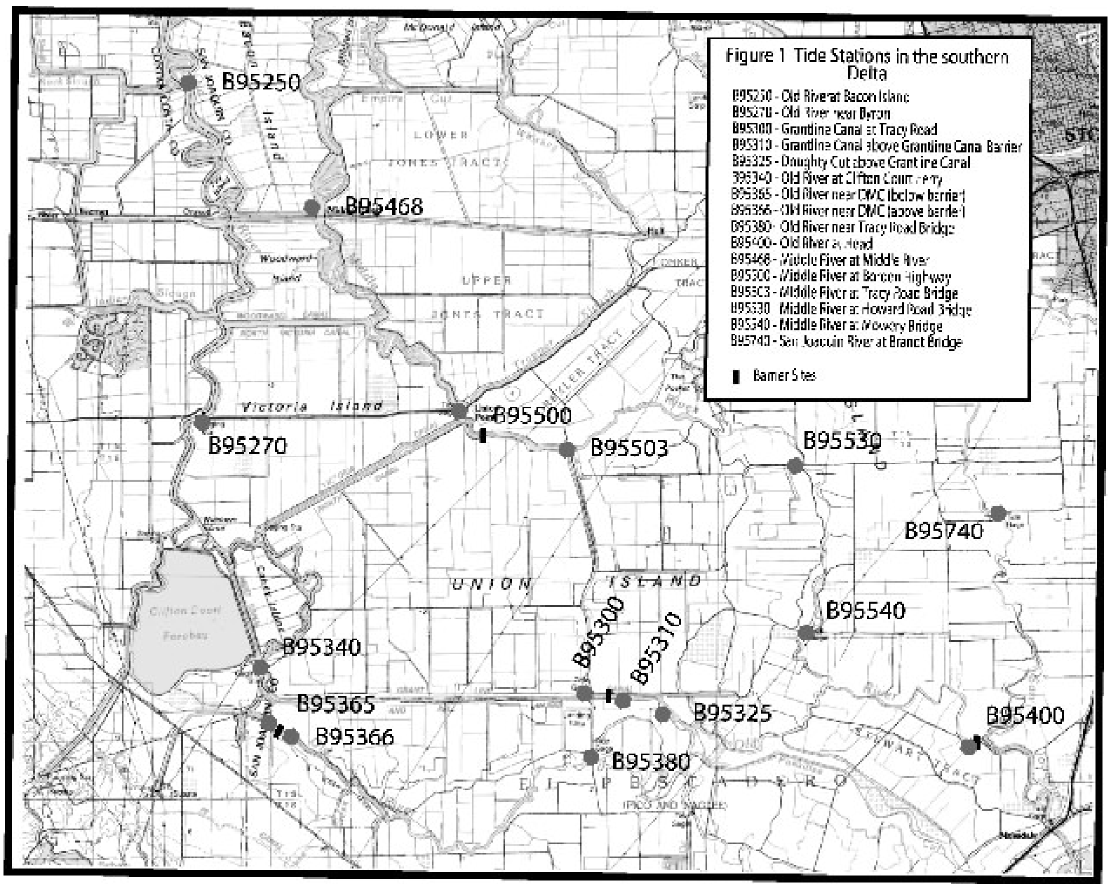
Mitigation

Swainson's hawk mitigation funds received for the 2002 construction season will be used for a population genetics study to determine the genetic relationship between Central Valley Swainson's hawks and Swainson's hawks in the Great Basin, Great Plains, Arizona, and Canada.

Chapter 6. Water Elevations

The 2002 water elevation monitoring program included operation and maintenance of sixteen tide gauging stations near the barriers as shown in Figure 6-1. The 2002 monitoring program covers the period from October 2001 through December 2002, where stage is monitored at various stations with remote sensors.

Figure 6-1. Tide Stations in the Southern Delta



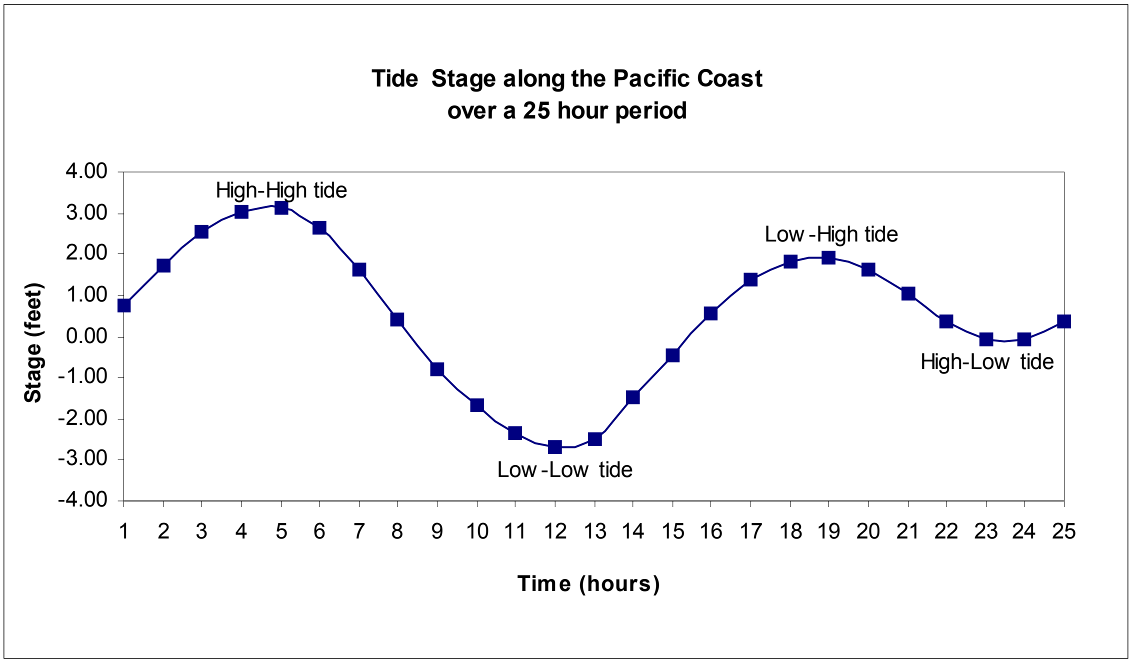
Instrumentation recorded water surface elevation daily at fifteen-minute intervals. Later, the data records were retrieved and downloaded to a computer for subsequent analysis.

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 elsewhere in this report.

Tides along the Pacific Coast exhibit a cycle of two high and two low tides over an approximately 25- hour period (Figure 6-2). 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 6-2 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.

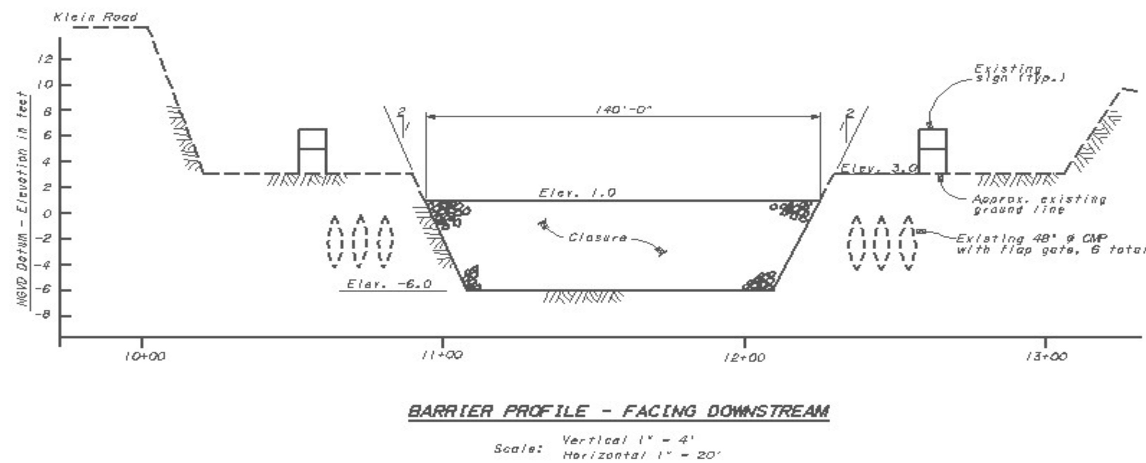
The following are highlights of barrier installation effects:

- 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 6-3). 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 6-3 Middle River Barrier Profile

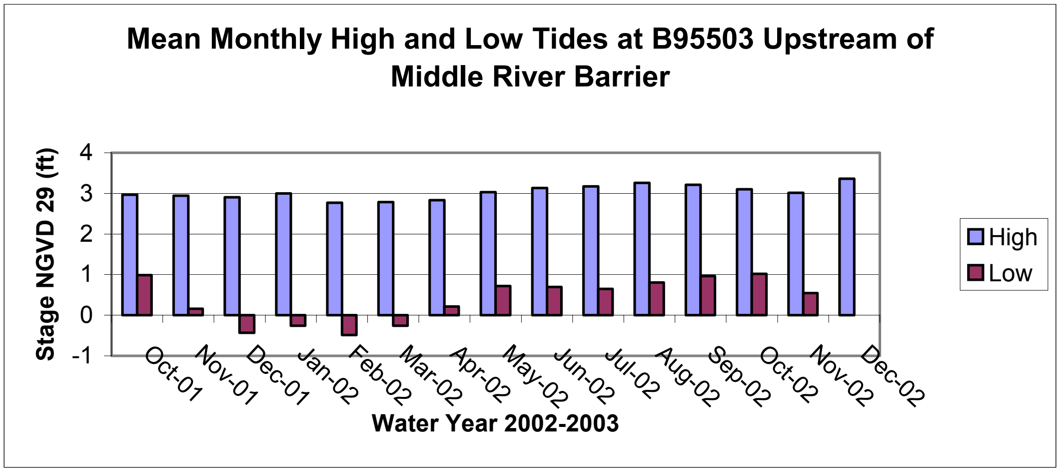


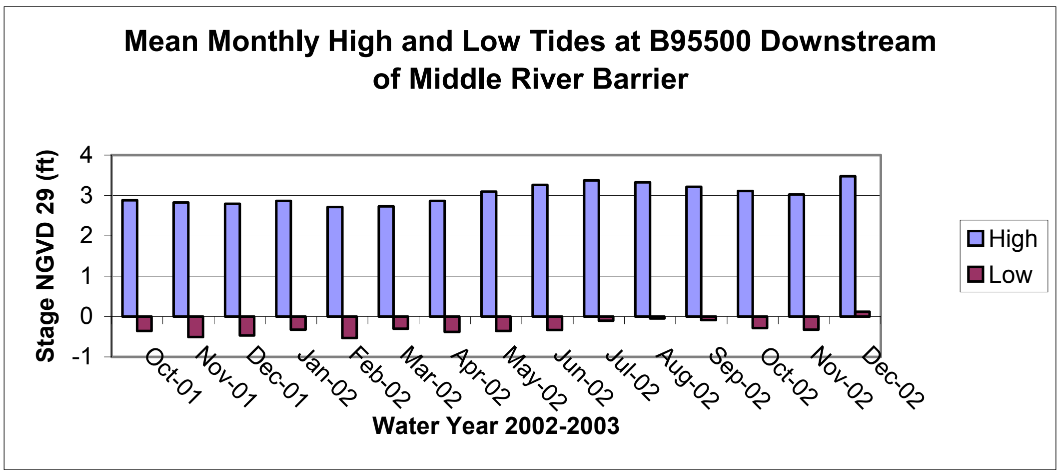
The Middle River (MR) barrier was installed between April 10 and April 15, 2002. The flap gates were tidally operational until November. For the 2002 operation, all three agricultural barriers were allowed to remain until late November. The MR barrier removal work began on November 20, and was fully removed on November 23.

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 6-4 shows the mean monthly high tides and mean monthly low tides upstream and downstream of the Middle River barrier from April 2002 to November 2002, when the barrier was operational. Figure 6-4 shows an increase in mean monthly low water levels of about one foot on the upstream end while the barrier was operational. This is a positive effect for irrigators.

Figure 6-4 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 6-5). The whole barrier structure is removed seasonally.

The ORT barrier was installed between April 1 and April 18, 2002. The flap gates were operational until late November when the barrier was removed. The barrier removal work began on November 16, and was fully removed on November 29, 2002.

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 6-6 shows stages upstream and downstream of the Old River at Tracy barrier from April 2002 to November 2002, when the barrier was operational. Figure 6-6 shows an increase in mean monthly low water levels of more than 1.0 foot for the period between June and October on the upstream end when the barrier was operational. This is positive effect for irrigators.

Figure 6-5 Old River at Tracy barrier profile

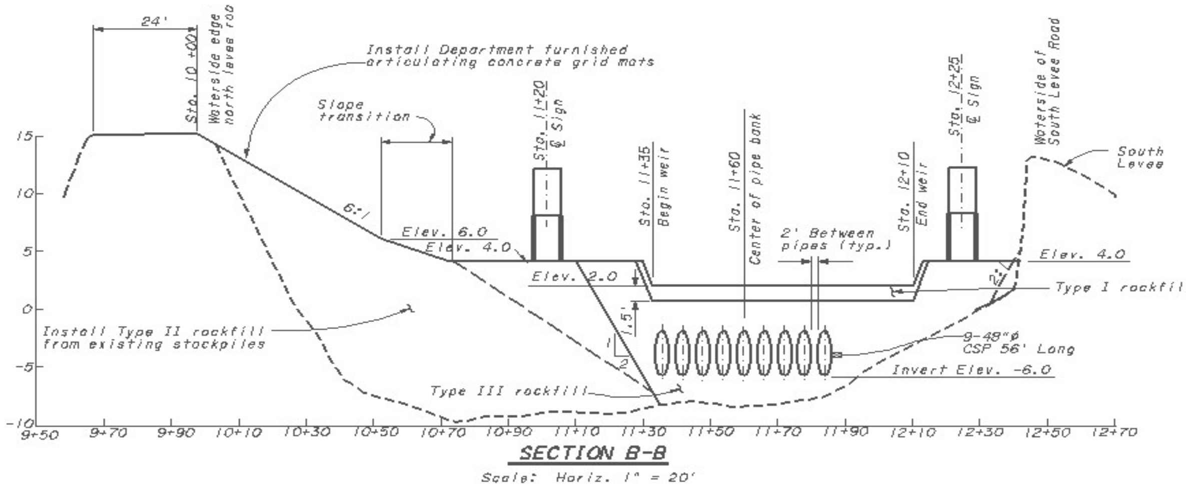
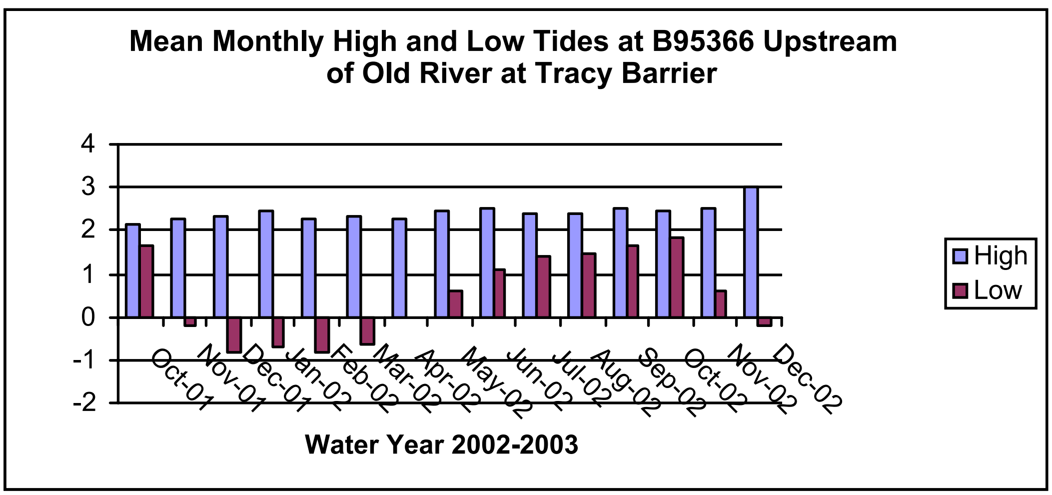
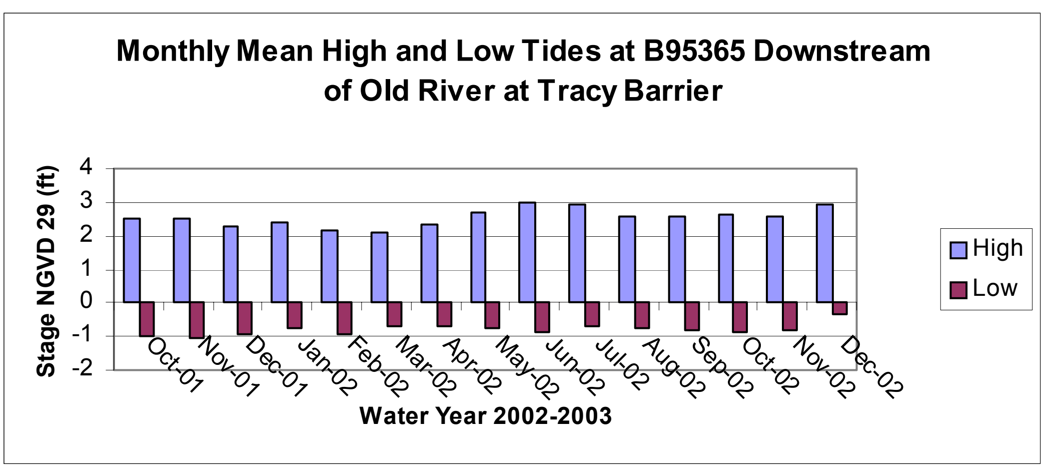


Figure 6-6 Water levels upstream and downstream of Old River at Tracy Barrier





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 2002, a 10 feet wide weir was constructed on the southern abutment to allow delta smelt passage (Figure 6-7). 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 12, 2002. Six flap gates were tied open till June 12 the closure day of the middle portion of the barrier. After June 12, the flap gates resumed normal tidal operation until late November when the barrier was removed. The barrier removal work began on November 14, and was fully removed on November 25, 2002.

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 6-7 Grant Line Canal barrier profile

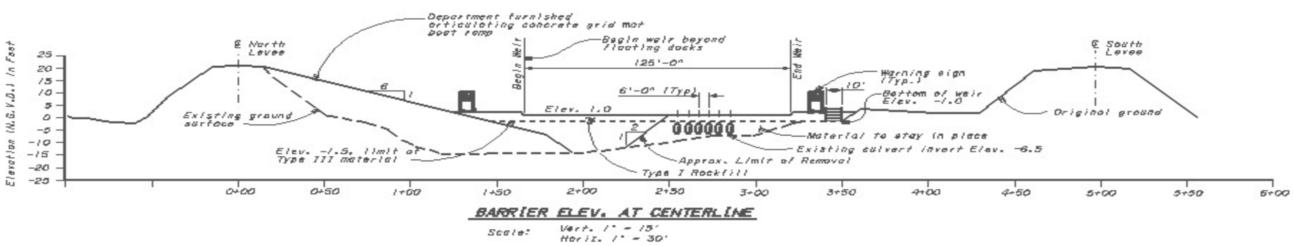
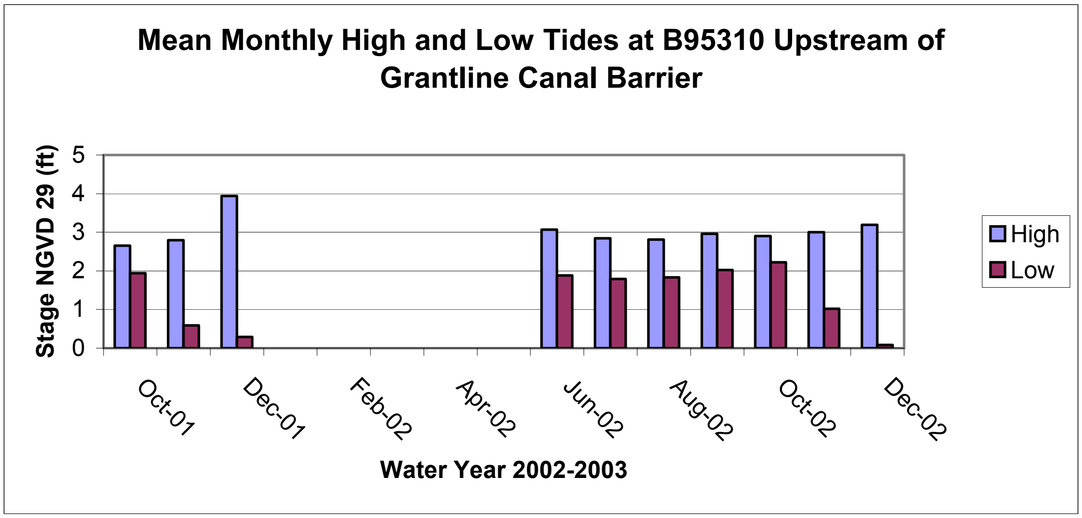
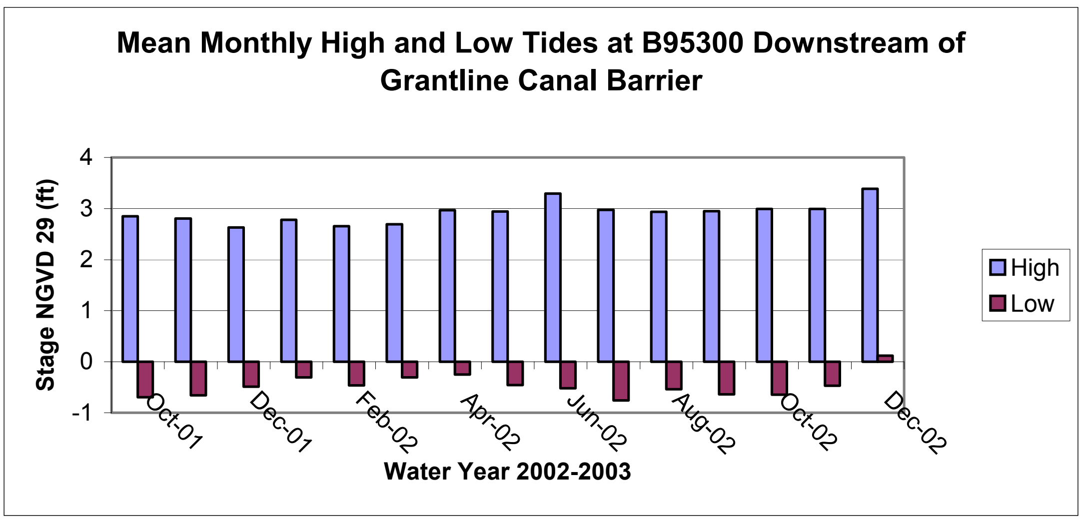


Figure 6-8 shows stages upstream and downstream of the GLC barrier from June 2002 to November 2002, when the barrier was in operation. Figure 6-8 shows an increase in mean monthly low water levels of about 2.0 feet while the barrier was operational.

Figure 6-8 Water levels upstream and downstream of Grant Line Canal barrier

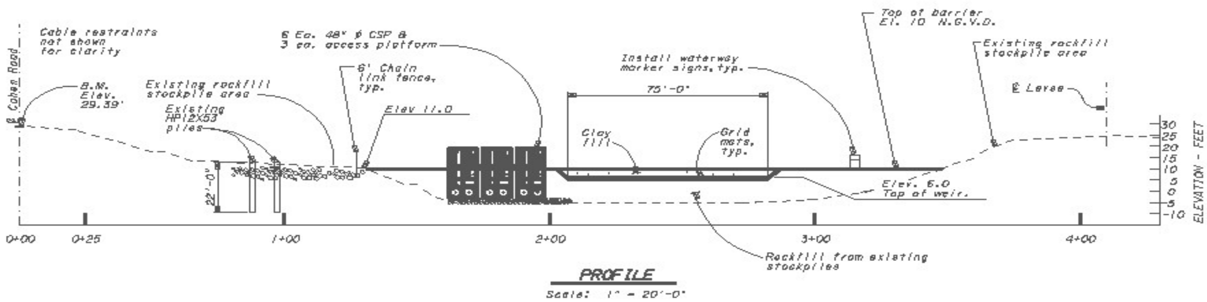




Old River at Head Barrier

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 2002 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 2002, the low-flow version was installed (Figure 6-9).

Figure 6-9 Spring head of Old River barrier profile



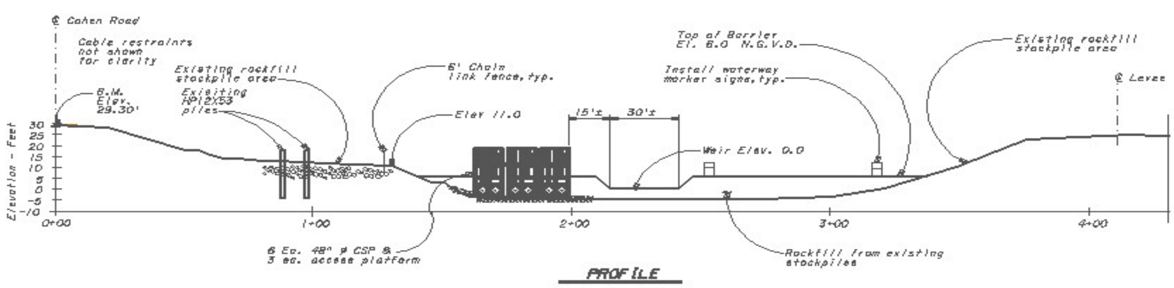
The dimensions of the 2002 HORB were the same as the 2001 HORB. The base width of the HORB was 100 feet and the crest elevation was ten feet MSL. The top of HORB was constructed with a 75-foot wide notch, back filled with clay and protected with concrete grid mats. This larger HORB was designed to safely 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 2002, all six culverts were open during the barrier operation.

The spring barrier was installed between April 2 and April 18, 2002. Barrier removal began on May 22 and was completed by June 7, 2002.

The fall HORB barrier was installed between September 24, 2001 and October 4, 2002. Barrier removal November 11and was completed by November 21. It was constructed to an elevation of +4.0 NGVD and had six 48-inch diameter culverts (Figure 6-10).

Figure 6-10 Fall head of Old River barrier profile



Chapter 7. 2002 South Delta Water Quality

Weekly Water Quality Sampling

During the spring, summer and fall of 2002, four temporary rock barriers were installed in the South Delta as part of the South Delta Temporary Barriers Project. DWR implemented a water quality sampling program to evaluate the potential impacts of barrier installations upon South Delta water quality. The sampling program commenced on March 26th and was completed on December 3rd. The four barriers were all installed on or after April 15th and removed by November 21st. The Head of Old River Barrier (HORB) differed from the three agricultural barriers in its duration of operation. It was operated for 34 days in spring (April 18 to May 22) and 38 days in fall (October 4 to November 11), having been breached for the intervening period.

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 much further upstream on each of the main river channels (Old River, Middle River, and Grant Line Canal). Figure 7-1 identifies the location of the four temporary barriers and the ten water sampling sites.

The Middle River barrier is upstream of the confluence of Middle River, Trapper Slough, and North Canal. The Old River at Tracy barrier is eight miles northwest of the town of Tracy and about a mile east of the Delta Mendota Canal 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.

The Middle River, Old River at Tracy, and Grant Line Canal barriers were primarily 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 out-migration in the San Joaquin River, and ultimately through the Delta to the Pacific Ocean. The operation of the HORB also benefits San Joaquin River basin steelhead during their emigration to the ocean.

Water sampling was conducted every Tuesday morning between 6:00 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. Every other Tuesday, filtered samples were collected at the ten sites for analysis by Bryte Lab. Constituents tested for were:

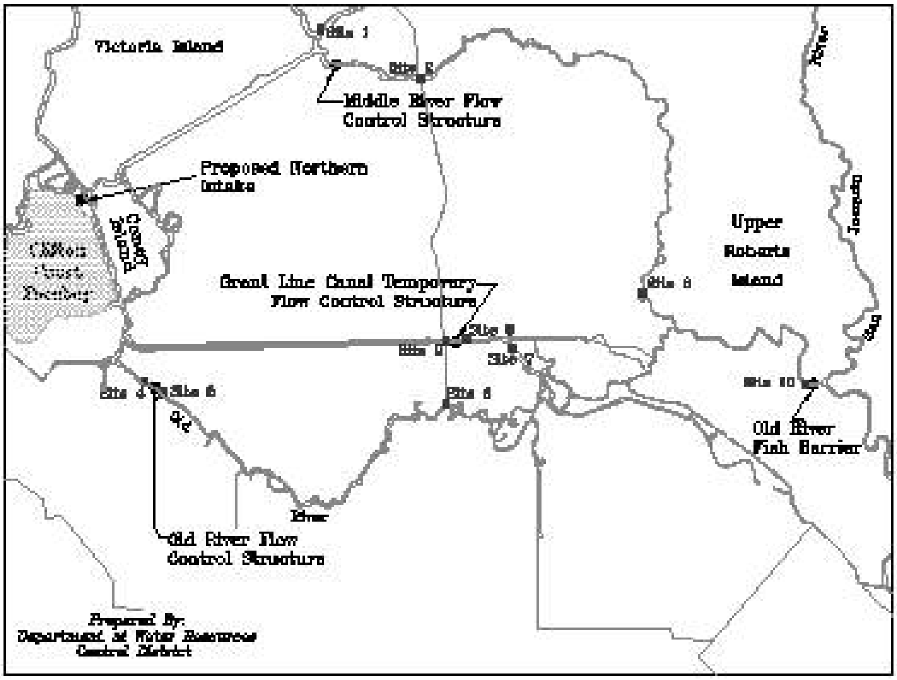
- Dissolved ammonia
- Dissolved nitrite + nitrate
- Dissolved organic nitrogen
- Dissolved orthophosphate
- Turbidity
- Chlorophyll a
- Pheophytin a

Middle River Barrier

The Middle River barrier was constructed on April 15th, 2002 and removed on November 21st, 2002. 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 7-2 shows the results of the weekly water quality testing for the Middle

River while the barrier was in place. In addition, the data are displayed in Tables 7-1 through 7–3, which show pre-barrier, during and post-barrier sampling events.

Figure 7-1 Map of water quality sampling sites and temporary barriers in the South Delta



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

Middle River water temperatures began to steadily increase in mid-spring and continued to rise until early July, likely as an effect of increasing air temperatures and solar irradiation. Summer temperatures were consistently high, averaging over 20°C. Temperatures gradually declined in late summer and then sharply throughout fall with average temperatures decreasing about 10°C. Mean water temperatures were within 1°C for all three sites, which indicates there were only minor temperature differences between monitoring locations. In addition to localized differences, variability in water temperature data for the Middle River monitoring stations may be due to differences in sampling times. While the barrier was operational the highest recorded temperature was 25.7 °C on July 2nd and the lowest was 11.5 °C on November 19th, both at the Undine Road station.

There were no discernible trends in dissolved oxygen concentrations at the Undine Road and Union Point sites, but there was an evident pattern at the Tracy Road site. Dissolved oxygen (DO) readings at Tracy Road tended to decline beginning in mid-June and were consistently low until early September, probably as a result of warm summer water temperatures and decreased flow down the San Joaquin River. DO concentrations at Tracy Road during the summer were consistently lower than at Undine Road and Union Point. Four field readings collected at Tracy Road were less than 5 mg/L. No field readings at Undine Road and Union Point were less than 5.50 mg/L. The lowest DO reading was 4.0 mg/L on August 13th and the highest DO reading was 11.40 mg/L on November 5th, both at Tracy Road. The mean DO values for Undine Road and Union Point were 7.80 mg/L and 7.41, respectively. Tracy Road had the lowest DO concentration in the Middle River with a mean of 6.68 mg/L. The barrier appeared to have an impact on upstream DO levels in the Middle River during the summer since readings at Union Point (just downstream of the barrier) were consistently higher than readings at the Tracy Road site (just upstream of the barrier).

Specific electrical conductivity values were clearly higher upstream of the barrier at the Undine Road site from the late spring through summer. Conversely, values at the Tracy Road and Union Point sites were strikingly lower and comparable until late summer. Beginning in late August specific conductance at Tracy Road tended to be noticeably higher than at Union Point and in some instances higher than at Undine Road. Union Point had consistently lower and less variable specific electrical conductivity readings than the two upstream sites with a mean of 377 µS/cm and a standard deviation of 88.0 µS/cm. Comparatively, Tracy Road and Undine Road had means of 489 µS/cm and 700 µS/cm and standard deviations of 187.7 µS/cm and 145.6 µS/cm, respectively. At the Undine Road site there was a marked increase in specific electrical conductivity from mid-spring into early summer with values increasing from 374 µS/cm on April 30th to 801 µS/cm on June 18th. Values were fairly constant the remainder of the summer and began to fall slightly in late September before rising again in mid-November. At the Tracy Road and Union Point sites specific conductance declined from late spring into early summer with values rising again in early August. Overall, the minimum-recorded value was 240 µS/cm on July 23rd at Union Point and the maximum-recorded value was 884 µS/cm on November 19th at Undine Road.

Water clarity seemed to diminish upstream of the 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 on the Middle River with values ranging from 4.4 to 43.0 NTU and a mean of about 20.5 NTU. Turbidity readings at Undine Road tended to be higher in the summer relative to the other two sites. During the spring and fall turbidity values at the three Middle River sites were, comparatively, similar. Turbidity readings at Union Point were consistently the lowest throughout the monitoring period ranging from 4.0 to 16.0 NTU with a mean of about 8.9 NTU. Just upstream of the barrier at Tracy Road turbidity values ranged from 7.5 to 31.7 NTU with a mean of about 15.5 NTU.

Figure 7-2 2002 Weekly Water Quality Data with Middle River Barrier in Place

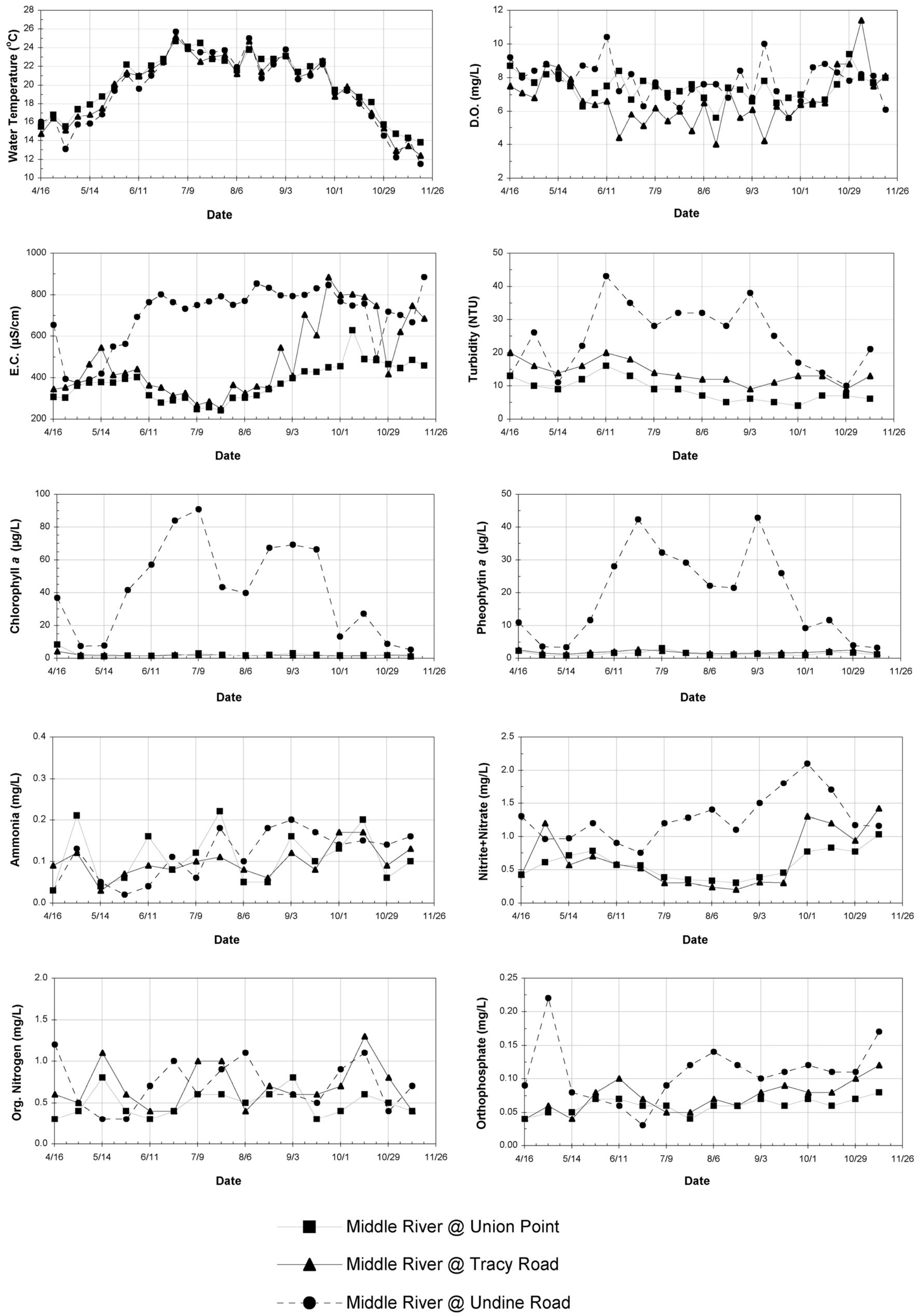


Table 7-1 Middle River at Union Point: 2002 Water Quality Data

CALIFORNIA DEPARTMENT OF WATER RESOURCES - CENTRAL DISTRICT

MIDDLE RIVER @ TRACY ROAD (B9D75291273)
South Delta Temporary Barriers Project - 2002 Weekly Water Quality Sampling Data

	FIELD READINGS					BRYTE LAB RESULTS						
DATE & TIME (mm/dd/yy PST)	TEMP. (°C)	D.O. (mg/L)	E.C. (uS/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 (ug/L)	PHEO.-A (ug/L)
3/26/02 6:25	12.9	9.2	514	10.2	4.75							
4/2/02 6:43	17.4	8.2	467		5.30	0.15	0.79	0.6	0.07	11.0	2.87	2.22
4/9/02 5:00	17.4	7.7	434	23.3	4.91							
4/16/02 5:58	14.7	7.5	344		4.50	0.09	0.42	0.6	0.04	20.0	4.18	2.51
4/23/02 5:10	16.4	7.1	352	17.6	4.80							
4/30/02 5:32	15.1	6.8	375		4.80	0.12	1.20	0.5	0.06	16.0	1.88	1.55
5/7/02 5:04	16.6	8.8	465	15.5	5.30							
5/14/02 5:00	16.8	8.6	543		5.38	0.03	0.57	1.1	0.04	13.9	1.77	1.19
5/21/02 5:15	17.5	7.9	413	15.6	5.05							
5/28/02 5:10	20.1	6.6	422		6.12	0.07	0.70	0.6	0.08	16.0	1.59	1.70
6/4/02 5:35	21.3	6.4	441	16.6	4.80							
6/11/02 5:12	21.0	6.6	362		5.75	0.09	0.58	0.4	0.10	20.0	1.54	2.04
6/18/02 5:00	21.7	4.4	352	31.7	4.40							
6/25/02 5:48	22.5	5.8	313		6.70	0.08	0.52	0.4	0.07	18.0	2.08	2.67
7/2/02 6:58	25.2	5.1	325	18.7	4.82							
7/9/02 6:02	23.9	6.2	267		6.10	0.10	0.30	1.0	0.05	14.0	1.87	2.23
7/16/02 7:35	22.5	5.4	283	26.0	4.45							
7/23/02 5:59	23.0	6.0	250		6.92	0.11	0.30	1.0	0.05	13.0	2.01	1.63
7/30/02 7:03	23.2	4.8	365	19.5	4.65							
8/6/02 7:30	21.2	6.5	325		4.90	0.08	0.24	0.4	0.07	12.0	1.42	1.39
8/13/02 5:25	24.7	4.0	357	21.8								
8/20/02 7:09	21.4	7.4	349		5.40	0.06	0.20	0.7	0.06	12.0	1.92	1.42
8/27/02 5:20	22.8	5.6	543	24.5								
9/3/02 5:37	23.1	6.1	408		5.00	0.12	0.31	0.6	0.08	9.0	1.59	1.54
9/10/02 5:42	20.8	4.2	703	9.3	4.00							
9/17/02 5:35	21.3	6.3	604		5.20	0.08	0.30	0.6	0.09	11.0	1.60	1.67
9/24/02 5:48	22.6	5.6	883	14.6	4.12							
10/1/02 5:50	18.8	6.4	799		4.50	0.17	1.30	0.7	0.08	13.0	1.45	1.73
10/8/02 5:08	19.8	6.6	802	12.4	4.05							
10/15/02 5:30	18.7	6.5	790		4.70	0.17	1.20	1.3	0.08	13.0	1.55	2.13
10/22/02 5:20	17.0	8.8	747	10.0	4.30							
10/29/02 7:05	15.3	8.8	416		4.25	0.09	0.94	0.8	0.10	9.0	1.94	2.52
11/5/02 6:35	12.9	11.4	620	7.5	4.70							
11/12/02 6:10	13.4	7.5	747		4.20	0.13	1.42	0.4	0.12	13.0	1.77	1.46
11/19/02 6:20	12.4	8.1	685	12.1	4.30							
11/26/02 6:10	11.6	9.7	676			0.05	1.10	1.1	0.10	11.0	1.53	1.98
12/3/02 6:45	10.3	8.6	527	10.5	4.65							

[shaded box] = Middle River barrier in place from 4/15/02 - 11/21/02.

	TEMP. (°C)	D.O. (mg/L)	E.C. (uS/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 (ug/L)	PHEO.-A (ug/L)
MAXIMUM	25.20	11.40	883.00	31.70	6.92	0.17	1.42	1.30	0.12	20.00	4.18	2.67
MINIMUM	12.40	4.00	250.00	7.50	4.00	0.03	0.20	0.40	0.04	9.00	1.42	1.19
MEAN	19.62	6.68	489.06	17.09	4.94	0.10	0.66	0.69	0.07	13.93	1.89	1.84
Range	12.80	7.40	633.00	24.20	2.92	0.14	1.22	0.90	0.08	11.00	2.76	1.48
Standard Deviation	3.62	1.56	187.70	6.53	0.75	0.04	0.42	0.28	0.02	3.34	0.65	0.45
Sample Variance	13.10	2.44	35,232.13	42.64	0.57	0.00	0.18	0.08	0.00	11.13	0.42	0.21
Standard Error	3.64	0.98	186.61	5.00	0.40	0.04	0.34	0.29	0.02	3.34	0.59	0.41
Median	20.90	6.50	414.50	16.10	4.80	0.09	0.55	0.60	0.08	13.00	1.77	1.69
Mode	21.30	8.80	352.00	#N/A	4.80	0.09	0.30	0.60	0.08	13.00	1.77	#N/A
Kurtosis	-0.87	1.40	-0.90	0.20	0.94	0.44	-1.03	-0.12	-0.34	-0.24	12.32	-0.86
Skewness	-0.49	0.76	0.71	0.66	1.16	0.46	0.72	0.85	0.30	0.51	3.34	0.61
Count	32	32	32	16	30	16	16	16	16	16	16	16
Confidence Level (95%)	1.25	0.54	65.03	3.20	0.27	0.02	0.21	0.14	0.01	1.63	0.32	0.22

* All descriptive statistics were calculated from data recorded while the Middle River barrier was in place.

Table 7-2 Middle River at Tracy Road: 2002 Water Quality Data

CALIFORNIA DEPARTMENT OF WATER RESOURCES - CENTRAL DISTRICT

MIDDLE RIVER @ TRACY ROAD (B9D75291273)

South Delta Temporary Barriers Project - 2002 Weekly Water Quality Sampling Data

	FIELD READINGS					BRYTE LAB RESULTS						
DATE & TIME (mm/dd/yy PST)	TEMP. (°C)	D.O. (mg/L)	E.C. (uS/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 (ug/L)	PHEO.-A (ug/L)
3/26/02 6:25	12.9	9.2	514	10.2	4.75							
4/2/02 6:43	17.4	8.2	467		5.30	0.15	0.79	0.6	0.07	11.0	2.87	2.22
4/9/02 5:00	17.4	7.7	434	23.3	4.91							
4/16/02 5:58	14.7	7.5	344		4.50	0.09	0.42	0.6	0.04	20.0	4.18	2.51
4/23/02 5:10	16.4	7.1	352	17.6	4.80							
4/30/02 5:32	15.1	6.8	375		4.80	0.12	1.20	0.5	0.06	16.0	1.88	1.55
5/7/02 5:04	16.6	8.8	465	15.5	5.30							
5/14/02 5:00	16.8	8.6	543		5.38	0.03	0.57	1.1	0.04	13.9	1.77	1.19
5/21/02 5:15	17.5	7.9	413	15.6	5.05							
5/28/02 5:10	20.1	6.6	422		6.12	0.07	0.70	0.6	0.08	16.0	1.59	1.70
6/4/02 5:35	21.3	6.4	441	16.6	4.80							
6/11/02 5:12	21.0	6.6	362		5.75	0.09	0.58	0.4	0.10	20.0	1.54	2.04
6/18/02 5:00	21.7	4.4	352	31.7	4.40							
6/25/02 5:48	22.5	5.8	313		6.70	0.08	0.52	0.4	0.07	18.0	2.08	2.67
7/2/02 6:58	25.2	5.1	325	18.7	4.82							
7/9/02 6:02	23.9	6.2	267		6.10	0.10	0.30	1.0	0.05	14.0	1.87	2.23
7/16/02 7:35	22.5	5.4	283	26.0	4.45							
7/23/02 5:59	23.0	6.0	250		6.92	0.11	0.30	1.0	0.05	13.0	2.01	1.63
7/30/02 7:03	23.2	4.8	365	19.5	4.65							
8/6/02 7:30	21.2	6.5	325		4.90	0.08	0.24	0.4	0.07	12.0	1.42	1.39
8/13/02 5:25	24.7	4.0	357	21.8								
8/20/02 7:09	21.4	7.4	349		5.40	0.06	0.20	0.7	0.06	12.0	1.92	1.42
8/27/02 5:20	22.8	5.6	543	24.5								
9/3/02 5:37	23.1	6.1	408		5.00	0.12	0.31	0.6	0.08	9.0	1.59	1.54
9/10/02 5:42	20.8	4.2	703	9.3	4.00							
9/17/02 5:35	21.3	6.3	604		5.20	0.08	0.30	0.6	0.09	11.0	1.60	1.67
9/24/02 5:48	22.6	5.6	883	14.6	4.12							
10/1/02 5:50	18.8	6.4	799		4.50	0.17	1.30	0.7	0.08	13.0	1.45	1.73
10/8/02 5:08	19.8	6.6	802	12.4	4.05							
10/15/02 5:30	18.7	6.5	790		4.70	0.17	1.20	1.3	0.08	13.0	1.55	2.13
10/22/02 5:20	17.0	8.8	747	10.0	4.30							
10/29/02 7:05	15.3	8.8	416		4.25	0.09	0.94	0.8	0.10	9.0	1.94	2.52
11/5/02 6:35	12.9	11.4	620	7.5	4.70							
11/12/02 6:10	13.4	7.5	747		4.20	0.13	1.42	0.4	0.12	13.0	1.77	1.46
11/19/02 6:20	12.4	8.1	685	12.1	4.30							
11/26/02 6:10	11.6	9.7	676			0.05	1.10	1.1	0.10	11.0	1.53	1.98
12/3/02 6:45	10.3	8.6	527	10.5	4.65							

= Middle River barrier in place from 4/15/02 - 11/21/02.

	TEMP. (°C)	D.O. (mg/L)	E.C. (uS/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 (ug/L)	PHEO.-A (ug/L)
MAXIMUM	25.20	11.40	883.00	31.70	6.92	0.17	1.42	1.30	0.12	20.00	4.18	2.67
MINIMUM	12.40	4.00	250.00	7.50	4.00	0.03	0.20	0.40	0.04	9.00	1.42	1.19
MEAN	19.62	6.68	489.06	17.09	4.94	0.10	0.66	0.69	0.07	13.93	1.89	1.84
Range	12.80	7.40	633.00	24.20	2.92	0.14	1.22	0.90	0.08	11.00	2.76	1.48
Standard Deviation	3.62	1.56	187.70	6.53	0.75	0.04	0.42	0.28	0.02	3.34	0.65	0.45
Sample Variance	13.10	2.44	35,232.13	42.64	0.57	0.00	0.18	0.08	0.00	11.13	0.42	0.21
Standard Error	3.64	0.98	186.61	5.00	0.40	0.04	0.34	0.29	0.02	3.34	0.59	0.41
Median	20.90	6.50	414.50	16.10	4.80	0.09	0.55	0.60	0.08	13.00	1.77	1.69
Mode	21.30	8.80	352.00	#N/A	4.80	0.09	0.30	0.60	0.08	13.00	1.77	#N/A
Kurtosis	-0.87	1.40	-0.90	0.20	0.94	0.44	-1.03	-0.12	-0.34	-0.24	12.32	-0.86
Skewness	-0.49	0.76	0.71	0.66	1.16	0.46	0.72	0.85	0.30	0.51	3.34	0.61
Count	32	32	32	16	30	16	16	16	16	16	16	16
Confidence Level (95%)	1.25	0.54	65.03	3.20	0.27	0.02	0.21	0.14	0.01	1.63	0.32	0.22

* All descriptive statistics were calculated from data recorded while the Middle River barrier was in place.

Table 7-3 Middle River at Undine Road: 2002 Water Quality Data

CALIFORNIA DEPARTMENT OF WATER RESOURCES - CENTRAL DISTRICT

MIDDLE RIVER @ UNDINE ROAD (B9D75011230)
South Delta Temporary Barriers Project - 2002 Weekly Water Quality Sampling Data

	FIELD READINGS					BRYTE LAB RESULTS						
DATE & TIME (mm/dd/yy PST)	TEMP. (°C)	D.O. (mg/L)	E.C. (uS/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 (ug/L)	PHEO.-A (ug/L)
3/26/02 7:23	13.2	7.5	946	10.8	5.02							
4/2/02 6:54	17.7	7.8	993		4.86	0.06	1.30	1.0	0.09	26.0	57.80	15.30
4/9/02 5:31	17.1	8.1	866	20.6	4.62							
4/16/02 6:21	16.0	9.2	653		4.53	0.03	1.30	1.2	0.09	13.0	36.70	10.90
4/23/02 5:35	16.5	8.0	393	10.3	4.60							
4/30/02 5:30	13.1	8.4	374		4.41	0.13	0.96	0.5	0.22	26.0	7.43	3.60
5/7/02 5:33	15.7	8.8	391	12.2	5.20							
5/14/02 5:50	15.8	7.9	419		5.30	0.05	0.97	0.3	0.08	11.0	7.75	3.37
5/21/02 5:31	16.8	7.6	548	8.9	5.43							
5/28/02 5:53	19.4	8.7	561		6.00	0.02	1.20	0.3	0.07	22.0	41.40	11.60
6/4/02 5:40	21.1	8.5	692	24.3	5.35							
6/11/02 5:40	19.6	10.4	764		5.44	0.04	0.90	0.7	0.06	43.0	57.10	28.00
6/18/02 5:55	21.0	7.2	801	24.8	5.00							
6/25/02 5:34	22.4	8.2	764		5.94	0.11	0.75	1.0	0.03	35.0	83.80	42.30
7/2/02 7:41	25.7	6.3	732	20.0	4.35							
7/9/02 6:30	23.9	7.7	750		6.30	0.06	1.20	0.6	0.09	28.0	90.80	32.20
7/16/02 8:10	23.5	6.8	767	22.2	4.40							
7/23/02 6:45	23.5	6.2	792		6.74	0.18	1.28	0.9	0.12	32.0	43.20	29.10
7/30/02 7:50	23.7	7.3	751	18.7	4.70							
8/6/02 6:40	21.9	7.6	770		6.06	0.10	1.40	1.1	0.14	32.0	39.70	22.10
8/13/02 5:45	25.0	7.6	853	34.8	4.75							
8/20/02 7:35	20.7	6.8	833		6.00	0.18	1.10	0.6	0.12	28.0	67.20	21.40
8/27/02 5:45	22.2	8.4	796	15.5	4.38							
9/3/02 6:03	23.8	6.8	793		5.78	0.20	1.50	0.6	0.10	38.0	69.10	42.80
9/10/02 5:55	20.6	10.0	799	15.9	4.64							
9/17/02 5:57	21.0	7.2	831		5.81	0.17	1.80	0.5	0.11	25.0	66.30	25.90
9/24/02 6:30	22.2	5.6	846	11.8	4.85							
10/1/02 6:05	19.1	6.6	767		5.64	0.14	2.10	0.9	0.12	17.0	13.20	9.22
10/8/02 5:50	19.4	8.6	747	19.0	4.80							
10/15/02 6:16	18.0	8.8	757		5.37	0.15	1.70	1.1	0.11	14.0	27.10	11.60
10/22/02 5:40	16.6	8.3	493	10.8	5.02							
10/29/02 7:34	14.5	7.8	718		5.04	0.14	1.17	0.4	0.11	10.0	8.81	3.91
11/5/02 7:10	12.2	8.2	701	6.3	5.10							
11/12/02 6:45	14.2	8.1	666		5.10	0.16	1.16	0.7	0.17	21.0	5.16	3.17
11/19/02 7:15	11.5	6.1	884	4.4	8.43							
11/26/02 6:40	11.4	7.7	922		3.30	0.25	1.60	1.1	0.14	8.0	7.04	2.31
12/3/02 6:25	10.1	9.3	924	33.7	4.35							

(shaded) = Middle River barrier in place from 4/15/02 - 11/21/02.

	TEMP. (°C)	D.O. (mg/L)	E.C. (uS/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 (ug/L)	PHEO.-A (ug/L)
MAXIMUM	25.70	10.40	884.00	34.80	8.43	0.20	2.10	1.20	0.22	43.00	90.80	42.80
MINIMUM	11.50	5.60	374.00	4.35	4.35	0.02	0.75	0.30	0.03	10.00	5.16	3.17
MEAN	19.39	7.80	700.19	16.24	5.33	0.12	1.28	0.71	0.11	24.69	41.55	18.82
Range	14.20	4.80	510.00	30.45	4.08	0.18	1.35	0.90	0.19	33.00	85.64	39.63
Standard Deviation	3.91	1.09	145.63	7.92	0.84	0.06	0.35	0.29	0.04	9.94	28.55	13.56
Sample Variance	15.26	1.19	21,206.74	62.78	0.70	0.00	0.13	0.08	0.00	98.90	815.13	183.97
Standard Error	3.94	1.07	138.65	7.65	0.88	0.06	0.34	0.29	0.05	10.17	22.24	6.15
Median	20.10	7.85	754.00	15.70	5.15	0.14	1.20	0.65	0.11	25.50	40.55	16.50
Mode	19.40	7.60	764.00	#N/A	6.00	0.18	1.20	0.60	0.12	28.00	#N/A	11.60
Kurtosis	-0.85	0.13	0.31	0.47	4.86	-1.29	0.61	-1.12	1.97	-0.87	-1.19	-0.98
Skewness	-0.37	0.17	-1.19	0.65	1.74	-0.38	0.86	0.23	0.84	0.11	0.21	0.45
Count	32	32	32	16	32	16	16	16	16	16	16	16
Confidence Level (95%)	1.35	0.38	50.46	3.88	0.29	0.03	0.17	0.14	0.02	4.87	13.99	6.65

* All descriptive statistics were calculated from data recorded while the Middle River barrier was in place.

Algal biomass, as represented by chlorophyll *a* concentration, was considerably higher upstream at the Undine Road site than at the monitoring sites near the barrier. Chlorophyll *a* levels began to increase in mid-spring and continued to rise until early summer, reaching a peak of 90.8 µg/L on July 9th. After peaking, chlorophyll *a* levels remained relatively high throughout the summer and then declined sharply in fall, reaching a minimum of 5.16 µg/L on November 12th. Overall, chlorophyll *a* at Undine Road averaged 41.6 µg/L. Measured chlorophyll *a* concentrations at Tracy Road and Union Point reached maximums of 4.18 µg/L and 8.39 µg/L on April 16th, respectively. There were not any noticeable differences in chlorophyll *a* levels at the aforementioned stations, which averaged under 3 µg/L while the Middle River barrier was in place.

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. The maximum recorded pheophytin *a* concentration was 42.8 µg/L on September 3rd and the highest mean was 18.8 µg/L, both at the Undine Road site. Measured pheophytin *a* concentrations in the Middle River at Union Point and Tracy Road were relatively low compared to Undine Road while the barrier was in place averaging 1.39 µg/L and 1.84 µg/L, respectively. Note that the minimum pheophytin *a* concentration at Undine Road was greater than the maximum values at Union Point and Tracy Road.

The Middle River barrier, probably, did not have an effect on ammonia concentrations since values at the three monitoring stations showed no discernible pattern and the means were within 0.02 mg/L of each other. The highest mean was 0.12 mg/L at Undine Road and the lowest was 0.10 mg/L at Tracy Road. Measured ammonia concentrations ranged from a maximum of 0.22 mg/L recorded on July 23rd at Union Point to a minimum of 0.02 mg/L recorded on May 28th at Undine 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 began to increase in early summer and peaked in early fall reaching a maximum of 2.10 mg/L on October 1st, after which concentrations began to decrease. Conversely, at the Union Point and Tracy Road sites nitrite-nitrate concentrations decreased slightly from early summer to early fall reaching a low of 0.20 mg/L on August 20th at Tracy Road. Concentrations then tended to increase the remainder of the monitoring period with Tracy Road and Union Point reaching maximum values of 1.42 mg/L and 1.03 mg/L, receptively, on November 12th. The mean nitrite-nitrate concentration at Undine Road was 1.28 mg/L, which was twice as high as the mean at Tracy Road, just upstream of the Middle River barrier. Union Point had the lowest nitrite-nitrate concentration in the Middle River with an average of 0.58 mg/L.

Organic nitrogen values fluctuated throughout the monitoring period ranging from 0.30 to 1.30 mg/L. The mean organic nitrogen concentration at Undine Road was 0.71 mg/L. Tracy Road had slightly lower organic nitrogen values with an average of 0.69 mg/L. Downstream of the barrier at Union Point organic nitrogen concentrations tended to be lower averaging 0.49 mg/L.

The Undine Road site tended to have higher orthophosphate values than Union Point and Tracy Road sites for a majority of the monitoring period. Overall, orthophosphate concentrations at Undine Road averaged 0.11 mg/L and reached a maximum of 0.22 mg/L on April 30th. Orthophosphate values at this site also had a far greater range (0.19 mg/L) than either Tracy Road (0.08 mg/L) or Union Point (0.04 mg/L). Orthophosphate values at Union Point and Tracy Road seemed to be fairly consistent and tracked relatively closely while the barriers where in place. Overall, values at Union Point and Tracy Road averaged 0.06 mg/L and 0.07 mg/L and reached maximums of 0.08 mg/L and 0.12 mg/L on November 12th, respectively.

Overall, the Middle River barrier may have had an impact on water quality within the immediate vicinity of barrier and the first few miles upstream. There were noticeable differences in dissolved oxygen, specific electrical conductance, turbidity, and organic nitrogen at the monitoring sites just upstream and downstream of the barrier. There were also appreciable differences in specific electrical conductance, turbidity, chlorophyll *a*, pheophytin *a*, nitrite-nitrate, and orthophosphate at the Undine Road site in comparison to the Union Point and Tracy Road sites. Differences may be due to barrier installations. When the sites just upstream and downstream of the Middle River barrier show a pattern of differences for a water quality constituent such as dissolved oxygen it may indicate the barrier, at least in part, is influencing that constituent. However, they could also be due to some localized event(s), such as agricultural return flows and/or tidal influence. Likely, a combination of influences is contributing to differences seen in water quality constituents in the Middle River.

Old River Barrier

The Old River at Head barrier was constructed on April 15th, 2002 and removed on May 27th, 2002, reinstalled on October 4th, 2002, and removed on November 15th, 2002. 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 15th, 2002, and removed on November 17th, 2002. Monitoring of 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 7-3 and Tables 7-4 through 7-7 show the results of the weekly water quality testing on Old River.

Water temperature data recorded for the Old River tended to follow seasonal patterns. Generally, temperatures for all four sites increased steadily from spring into early summer, remained elevated throughout the summer and decreased in the fall. Temperatures at the four monitoring sites tracked well and there were not any notable temperature differences. The highest mean temperature during the monitoring period was 20.23 °C at Old River at Tracy Road, which was about 0.5 °C higher than the lowest mean temperature of 19.71 °C at the Upstream of DMC Barrier site. While the barriers were operational the highest recorded temperature was 25.6 °C on July 2nd and August 13th, and the lowest was 11.7 °C on November 5th, both at the Old River at Head site.

Dissolved oxygen levels began to decline in June and seemed to sag from early July through mid-October at all the monitoring sites except Old River at Head. During this time period nineteen field readings collected at the DMC sites, in the immediate vicinity of the barrier, were less than 5 mg/L and three were less than 3 mg/L. The minimum dissolved oxygen recorded was 2.10 mg/L on September 24th in the Old River downstream of the DMC barrier. Mean DO concentrations immediately upstream and downstream of the DMC Barrier were 5.68 and 5.59 mg/L, respectively, showing little variation. Old River at Tracy Road tended to have slightly higher DO concentrations then at the sites near the barrier with an average DO concentration of 6.23 mg/L. Six field readings collected at Tracy Road were less than 5 mg/L; none were lower than 3 mg/L. Old River at Head had consistently higher DO concentrations in comparison to the other three sites on Old River averaging 9.25 mg/L. The mean DO concentration at the Head site was higher than the maximum values recorded at the other three monitoring locations. Readings at the Head site were elevated throughout the monitoring period with no observable pattern. DO concentrations at the Old River at Head site reached a maximum of 12.40 mg/L on June 11th and a minimum of 7.00 mg/L on October 29th.

Figure 7-3 2002 Weekly Water Quality Data with Old River near DMC Barrier in Place

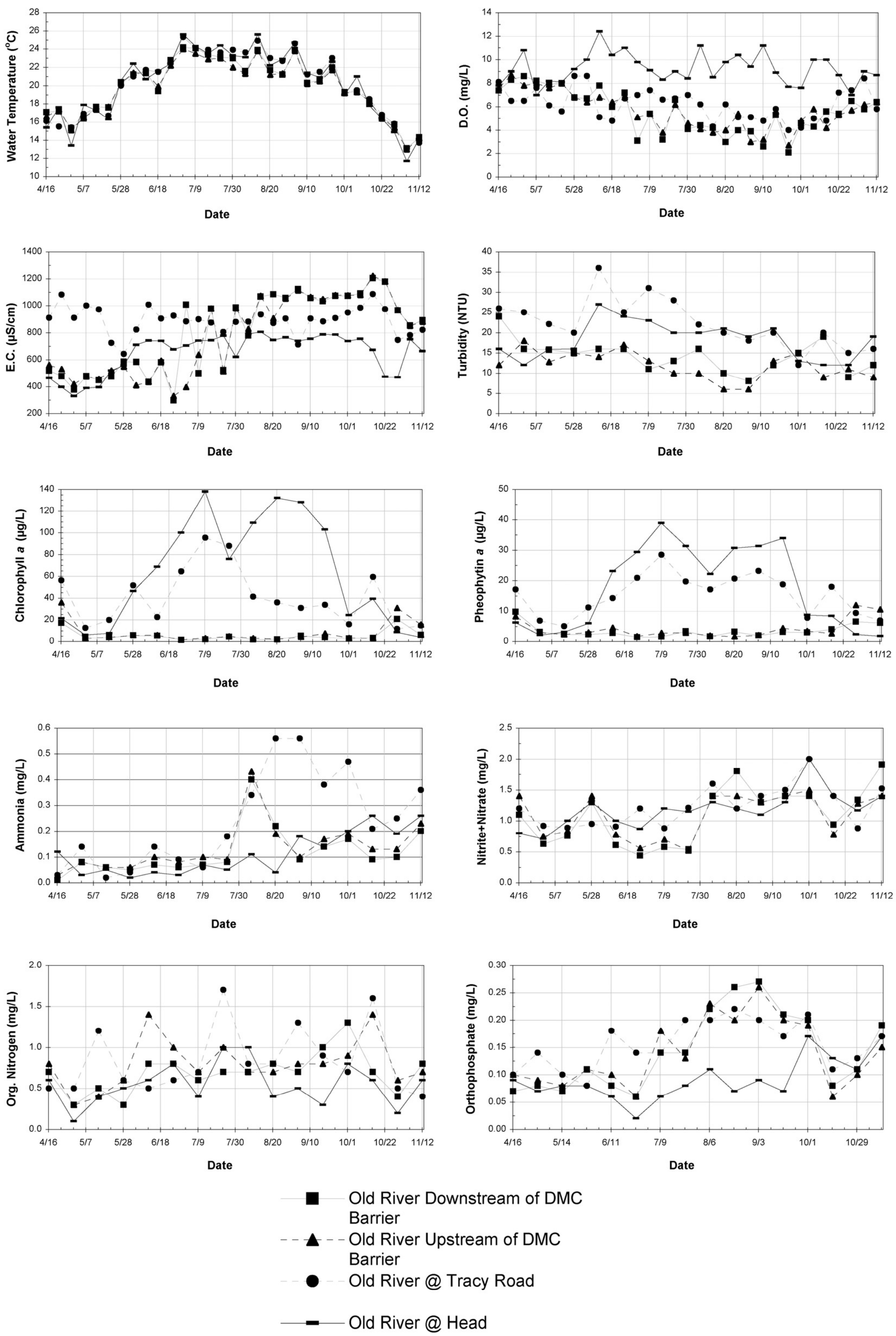


Table 7-4 Old River at DMC Downstream of Barrier: 2002 Water Quality Data

CALIFORNIA DEPARTMENT OF WATER RESOURCES - CENTRAL DISTRICT

OLD RIVER @ DMC DOWNSTREAM OF BARRIER (B9D74871328)
South Delta Temporary Barriers Project - 2002 Weekly Water Quality Sampling Data

	FIELD READINGS					BRYTE LAB RESULTS						
DATE & TIME (mm/dd/yy PST)	TEMP. (°C)	D.O. (mg/L)	E.C. (uS/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 (ug/L)	PHEO.-A (ug/L)
3/26/02 8:11	13.7	8.1	517	7.0	3.85							
4/2/02 7:55	18.1	8.7	657		4.82	0.07	0.96	0.7	0.06	13.0	16.20	4.74
4/9/02 6:20	17.1	8.6	871	14.5	4.10							
4/16/02 8:00	17.1	7.4	519		5.58	<.01	1.10	0.7	0.07	24.0	17.30	9.80
4/23/02 6:18	17.2	8.3	479	17.5	4.23							
4/30/02 6:37	15.3	8.6	376		5.42	0.08	0.63	0.3	0.08	16.0	3.20	3.12
5/7/02 6:25	16.4	8.2	479	17.0	4.32							
5/14/02 6:45	17.7	7.9	450		5.92	0.06	0.76	0.5	0.07	15.8	3.84	2.39
5/21/02 6:18	17.6	8.0	476	14.4	4.01							
5/28/02 7:05	20.3	6.8	586		6.60	0.05	1.30	0.3	0.11	15.0	5.70	2.37
6/4/02 6:30	21.2	6.7	583	12.8	3.25							
6/11/02 6:40	21.5	7.8	436		6.10	0.07	0.61	0.8	0.08	16.0	5.30	2.85
6/18/02 6:44	19.4	6.0	580	22.3	3.96							
6/25/02 6:33	22.8	7.2	298		6.48	0.06	0.44	0.8	0.06	16.0	1.63	1.41
7/2/02 8:36	24.2	3.1	1007	11.4	3.32							
7/9/02 7:45	24.1	5.4	499		4.10	0.07	0.58	0.6	0.14	11.0	2.03	1.60
7/16/02 9:10	23.4	3.2	977	15.3	3.45							
7/23/02 8:00	23.1	6.6	523		5.74	0.08	0.54	0.7	0.14	13.0	4.41	3.43
7/30/02 8:40	23.0	4.1	986	15.3	3.98							
8/6/02 7:43	21.6	4.4	777		4.65	0.40	1.40	0.7	0.22	16.0	1.87	1.66
8/13/02 6:50	23.9	4.2	1069	3.3	3.67							
8/20/02 8:37	21.7	3.0	1086		3.38	0.22	1.80	0.8	0.26	10.0	1.94	3.20
8/27/02 7:22	21.2	4.0	1059	9.1	3.95							
9/3/02 7:00	23.9	3.9	1125		2.96	0.09	1.30	0.7	0.27	8.0	5.27	2.01
9/10/02 6:40	20.3	2.6	1057	9.5	3.90							
9/17/02 7:04	20.6	5.3	1034		3.36	0.14	1.40	1.0	0.21	12.0	3.81	3.13
9/24/02 7:20	22.0	2.1	1074	4.3	4.10							
10/1/02 6:53	19.3	4.6	1073		3.19	0.17	1.40	1.3	0.20	15.0	2.98	2.99
10/8/02 6:50	19.3	4.3	1091	9.0	4.00							
10/15/02 7:24	18.3	5.6	1206		2.98	0.09	0.94	0.7	0.08	19.0	3.40	4.03
10/22/02 7:00	16.4	5.4	1179	7.4	3.52							
10/29/02 8:35	15.7	6.5	966		2.62	0.10	1.34	0.4	0.11	9.0	20.80	6.53
11/5/02 8:05	13.1	5.8	852	7.7	3.95							
11/12/02 7:44	14.3	6.4	891		1.70	0.20	1.91	0.8	0.19	12.0	6.24	6.19
11/19/02 8:06	12.6	5.4	924	11.8	3.35							
11/26/02 7:45	12.0	6.9	1069		2.20	0.21	1.90	1.2	0.14	13.0	8.81	4.47
12/3/02 7:40	11.7	8.6	457.0	9.8	4.35							

[shaded box] = Old River near DMC barrier in place from 4/15/02 - 11/17/02.

	TEMP. (°C)	D.O. (mg/L)	E.C. (uS/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 (ug/L)	PHEO.-A (ug/L)
MAXIMUM	24.20	8.60	1,206.00	22.30	6.60	0.40	1.91	1.30	0.27	24.00	20.80	9.80
MINIMUM	13.10	2.10	298.00	3.34	1.70	0.01	0.44	0.30	0.06	8.00	1.63	1.41
MEAN	19.87	5.59	799.77	11.76	4.14	0.12	1.09	0.69	0.14	14.24	5.61	3.54
Range	11.10	6.50	908.00	18.96	4.90	0.39	1.47	1.00	0.21	16.00	19.17	8.39
Standard Deviation	3.14	1.86	290.04	5.25	1.17	0.09	0.46	0.25	0.07	4.00	5.47	2.21
Sample Variance	9.85	3.47	84,122.78	27.59	1.37	0.01	0.21	0.06	0.01	16.02	29.97	4.90
Standard Error	3.18	1.59	175.04	3.77	0.33	0.09	0.39	0.25	0.07	3.23	5.64	1.31
Median	20.30	5.60	891.00	11.40	3.96	0.09	1.20	0.70	0.13	15.00	3.83	3.06
Mode	16.40	5.40	479.00	15.30	4.10	0.08	1.40	0.70	0.08	16.00	#N/A	#N/A
Kurtosis	-0.83	-1.07	-1.64	-0.39	0.00	5.10	-1.06	1.30	-1.19	1.10	4.38	3.42
Skewness	-0.40	-0.10	-0.23	0.23	0.56	2.13	0.16	0.48	0.51	0.65	2.25	1.82
Count	31	31	31	15	31	15	16	16	16	16	16	16
Confidence Level (95%)	1.10	0.66	102.10	2.66	0.41	0.05	0.23	0.12	0.04	1.96	2.68	1.08

* All descriptive statistics were calculated from data recorded while the Old River Near DMC barrier was in place.

Table 7-5 Old River at DMC Upstream of Barrier: 2002 Water Quality Data

CALIFORNIA DEPARTMENT OF WATER RESOURCES - CENTRAL DISTRICT

OLD RIVER @ DMC UPSTREAM OF BARRIER (B9D74861325)
South Delta Temporary Barriers Project - 2002 Weekly Water Quality Sampling Data

	FIELD READINGS					BRYTE LAB RESULTS						
DATE & TIME (mm/dd/yy PST)	TEMP. (°C)	D.O. (mg/L)	E.C. (uS/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 (ug/L)	PHEO.-A (ug/L)
3/26/02 7:57	13.5	8.0	543	6.7	4.12							
4/2/02 7:40	17.5	8.8	654		4.80	0.08	1.20	0.8	0.06	13.0	17.80	4.31
4/9/02 6:04	17.5	8.3	882	14.9	4.16							
4/16/02 7:24	16.6	7.6	561		4.57	0.03	1.40	0.8	0.10	12.0	35.90	8.32
4/23/02 6:05	17.4	8.7	529	15.8	4.20							
4/30/02 6:11	15.1	7.8	419		4.38	0.08	0.75	0.3	0.09	18.0	2.94	3.01
5/7/02 6:14	16.5	8.0	477	15.6	4.32							
5/14/02 6:31	17.4	7.6	457		4.90	0.06	0.84	0.4	0.08	12.8	3.90	2.37
5/21/02 5:45	17.7	8.0	520	13.8	5.10							
5/28/02 6:40	20.3	6.8	549		5.82	0.06	1.40	0.6	0.11	15.0	5.76	2.97
6/4/02 6:15	21.4	6.4	410	13.4	4.98							
6/11/02 6:18	21.4	6.8	436		4.88	0.10	0.78	1.4	0.10	14.0	6.03	4.55
6/18/02 6:27	19.9	6.4	593	20.4	4.75							
6/25/02 6:18	22.2	6.8	331		5.90	0.08	0.56	1.0	0.06	17.0	1.60	1.70
7/2/02 8:18	24.0	5.1	397	14.8	4.90							
7/9/02 7:15	23.5	5.4	637		5.45	0.10	0.70	0.7	0.18	13.0	3.17	2.87
7/16/02 8:50	22.9	3.8	979	18.9	4.35							
7/23/02 7:25	23.0	6.2	513		6.00	0.09	0.52	1.0	0.13	10.0	4.93	2.91
7/30/02 8:20	22.0	4.6	982	16.3	4.60							
8/6/02 7:24	21.3	4.1	827		6.65	0.43	1.40	0.7	0.23	10.0	3.07	1.99
8/13/02 6:25	23.8	3.8	1074	8.9	4.69							
8/20/02 8:17	21.2	4.0	906		5.68	0.19	1.40	0.7	0.20	6.0	2.06	1.64
8/27/02 7:05	21.3	5.4	1054	10.4	4.28							
9/3/02 6:40	23.8	3.0	1115		5.50	0.10	1.30	0.8	0.26	6.0	4.30	2.15
9/10/02 6:28	20.2	3.2	1065	9.6	4.50							
9/17/02 6:40	20.5	5.6	1049		5.41	0.17	1.40	0.8	0.20	13.0	7.43	4.40
9/24/02 7:04	21.7	2.7	1079	4.9	4.75							
10/1/02 6:42	19.2	4.8	1077		5.45	0.19	1.50	0.9	0.19	15.0	3.26	3.49
10/8/02 6:35	19.3	5.8	1080	16.7	4.70							
10/15/02 7:00	18.3	4.2	1222		5.19	0.13	0.78	1.4	0.06	9.0	3.05	2.67
10/22/02 6:40	16.4	5.3	1180	14.5	5.00							
10/29/02 8:17	15.4	5.7	969		5.35	0.13	1.28	0.6	0.10	11.0	30.90	12.00
11/5/02 7:50	13.0	6.2	851	9.7	5.05							
11/12/02 7:20	14.2	6.4	882		5.00	0.23	1.40	0.7	0.15	9.0	15.70	10.60
11/19/02 7:50	12.4	5.3	960	13.7	3.35							
11/26/02 7:20	12.1	6.7	1068		2.10	0.30	1.90	1.6	0.14	24.0	6.88	4.83
12/3/02 7:30	11.3	8.6	452	15.3	4.40							

= Old River near DMC barrier in place from 4/15/02 - 11/17/02.

	TEMP. (°C)	D.O. (mg/L)	E.C. (uS/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 (ug/L)	PHEO.-A (ug/L)
MAXIMUM	24.00	8.70	1,222.00	20.40	6.65	0.43	1.50	1.40	0.26	18.00	35.90	12.00
MINIMUM	13.00	2.70	331.00	4.90	4.20	0.03	0.52	0.30	0.06	6.00	1.60	1.64
MEAN	19.71	5.68	781.29	13.58	5.04	0.14	1.09	0.80	0.14	11.93	8.38	4.23
Range	11.00	6.00	891.00	15.50	2.45	0.40	0.98	1.10	0.20	12.00	34.30	10.36
Standard Deviation	3.06	1.60	288.01	4.15	0.58	0.10	0.36	0.30	0.06	3.51	10.35	3.20
Sample Variance	9.34	2.57	82,950.55	17.26	0.33	0.01	0.13	0.09	0.00	12.30	107.03	10.22
Standard Error	3.09	1.38	197.18	4.01	0.30	0.08	0.34	0.30	0.06	3.14	10.66	1.66
Median	20.30	5.70	851.00	14.50	4.98	0.10	1.29	0.75	0.12	12.40	4.10	2.94
Mode	17.40	6.80	#N/A	#N/A	4.90	0.10	1.40	0.70	0.10	15.00	#N/A	#N/A
Kurtosis	-0.72	-0.80	-1.66	-0.12	0.54	5.58	-1.78	0.71	-0.98	-0.51	3.62	1.76
Skewness	-0.48	-0.06	-0.09	-0.43	0.78	2.09	-0.38	0.68	0.47	-0.10	2.14	1.69
Count	31	31	31	15	31	16	16	16	16	16	16	16
Confidence Level (95%)	1.08	0.56	101.39	2.10	0.20	0.05	0.18	0.15	0.03	1.72	5.07	1.57

* All descriptive statistics were calculated from data recorded while the Old River Near DMC barrier was in place.

Table 7-6 Old River at Tracy Road: 2002 Water Quality Data

CALIFORNIA DEPARTMENT OF WATER RESOURCES - CENTRAL DISTRICT

OLD RIVER @ TRACY ROAD (B9D74831269)
South Delta Temporary Barriers Project - 2002 Weekly Water Quality Sampling Data

	FIELD READINGS					BRYTE LAB RESULTS						
DATE & TIME (mm/dd/yy PST)	TEMP. (°C)	D.O. (mg/L)	E.C. (uS/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 (ug/L)	PHEO.-A (ug/L)
3/26/02 7:46	14.7	9.7	1016	19.0	4.42							
4/2/02 8:09	19.3	10.8	1168		4.50	0.02	0.85	0.4	0.05	15.0	63.80	11.10
4/9/02 6:35	18.2	9.9	814	36.2	4.05							
4/16/02 7:30	16.1	8.1	910		4.60	0.03	1.20	0.5	0.10	26.0	56.30	17.10
4/23/02 6:25	15.5	6.5	1082	26.2	4.40							
4/30/02 7:00	15.4	6.5	909		4.65	0.14	0.92	0.5	0.14	25.0	12.60	6.84
5/7/02 6:14	16.9	7.6	1000	31.3	4.68							
5/14/02 6:40	17.6	6.1	972		4.99	0.02	0.89	1.2	0.10	22.1	19.90	5.03
5/21/02 6:42	16.7	5.6	724	20.4	4.92							
5/28/02 6:45	20.0	8.6	642		5.92	0.04	0.95	0.6	0.08	20.0	51.70	11.20
6/4/02 7:00	21.0	8.6	822	32.6	4.90							
6/11/02 6:38	21.7	5.1	1007		5.10	0.14	0.91	0.5	0.18	36.0	22.50	14.30
6/18/02 6:23	21.5	4.8	905	32.6	5.00							
6/25/02 7:34	22.6	6.7	925		6.70	0.09	1.20	0.6	0.14	25.0	64.50	20.90
7/2/02 8:14	25.3	7.0	883	28.5	4.42							
7/9/02 7:27	24.1	7.4	899		5.50	0.06	0.88	0.7	0.14	31.0	95.40	28.50
7/16/02 8:50	23.9	6.6	874	29.4	4.54							
7/23/02 7:30	23.6	6.7	805		6.50	0.18	1.21	1.7	0.20	28.0	87.80	19.70
7/30/02 8:21	23.9	7.0	880	34.5	4.80							
8/6/02 9:00	23.6	6.2	882		5.65	0.34	1.60	0.8	0.20	22.0	41.20	17.10
8/13/02 7:00	24.9	4.3	935	29.1	4.67							
8/20/02 9:00	23.0	6.2	870		5.55	0.56	1.20	0.8	0.22	20.0	36.10	20.70
8/27/02 6:30	22.7	5.1	905	33.0	4.40							
9/3/02 7:20	24.6	5.1	712		5.45	0.56	1.40	1.3	0.20	18.0	30.90	23.20
9/10/02 7:15	21.2	4.8	905	29.1								
9/17/02 7:15	21.5	5.8	883		5.50	0.38	1.50	0.9	0.17	20.0	33.80	18.80
9/24/02 7:10	23.0	4.0	908	19.1	4.90							
10/1/02 7:20	19.3	4.2	948		5.40	0.47	2.00	0.7	0.21	12.0	15.80	7.80
10/8/02 6:55	19.5	5.0	985	21.4	4.93							
10/15/02 7:10	18.5	4.8	1086		5.20	0.21	1.40	1.6	0.11	20.0	59.30	18.00
10/22/02 7:10	16.8	7.2	973	16.5	5.10							
10/29/02 8:47	15.8	7.4	746		5.30	0.25	0.88	0.5	0.13	15.0	11.80	9.38
11/5/02 8:30	13.1	8.4	781	17.1	5.60							
11/12/02 8:10	13.7	5.8	820		5.05	0.36	1.52	0.4	0.17	16.0	14.90	6.94
11/19/02 8:00	12.7	7.1	670	18.4	3.51							
11/26/02 7:55	11.7	8.2	925		2.17	0.32	1.70	0.9	0.16	27.0	12.20	8.55
12/3/02 8:35	11.3	7.8	743	15.7	3.68							

= Old River near DMC barrier in place from 4/15/02 - 11/17/02.

	TEMP. (°C)	D.O. (mg/L)	E.C. (uS/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 (ug/L)	PHEO.-A (ug/L)
MAXIMUM	25.30	8.60	1,086.00	34.50	6.70	0.56	2.00	1.70	0.22	36.00	95.40	28.50
MINIMUM	13.10	4.00	642.00	16.50	4.40	0.02	0.88	0.40	0.08	12.00	11.80	5.03
MEAN	20.23	6.23	889.61	26.72	5.14	0.24	1.23	0.83	0.16	22.26	40.91	15.34
Range	12.20	4.60	444.00	18.00	2.30	0.54	1.12	1.30	0.14	24.00	83.60	23.47
Standard Deviation	3.60	1.32	100.53	6.18	0.57	0.19	0.33	0.41	0.04	6.13	26.24	6.82
Sample Variance	12.93	1.73	10,106.18	38.24	0.32	0.03	0.11	0.16	0.00	37.53	688.40	46.57
Standard Error	3.66	1.28	96.01	6.38	0.28	0.19	0.25	0.42	0.05	6.31	23.71	4.68
Median	21.20	6.20	905.00	29.10	5.03	0.20	1.20	0.70	0.16	21.00	34.95	17.10
Mode	21.50	5.10	905.00	32.60	4.40	0.14	1.20	0.50	0.14	20.00	#N/A	17.10
Kurtosis	-1.10	-0.86	0.49	-1.26	1.23	-0.97	0.35	0.23	-1.25	0.45	-0.20	-0.84
Skewness	-0.41	0.14	-0.38	-0.53	1.05	0.54	0.79	1.15	-0.17	0.57	0.81	0.05
Count	31	31	31	15	30	16	16	16	16	16	16	16
Confidence Level (95%)	1.27	0.46	35.39	3.13	0.20	0.09	0.16	0.20	0.02	3.00	12.86	3.34

* All descriptive statistics were calculated from data recorded while the Old River Near DMC barrier was in place.

Table 7-7 Old River at Head: 2002 Water Quality Data

CALIFORNIA DEPARTMENT OF WATER RESOURCES - CENTRAL DISTRICT

OLD RIVER @ HEAD (B9D74851200)
South Delta Temporary Barriers Project - 2002 Weekly Water Quality Sampling Data

	FIELD READINGS					BRYTE LAB RESULTS						
DATE	TEMP. (°C)	D.O. (mg/L)	E.C. (uS/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 (ug/L)	PHEO.-A (ug/L)
3/26/02 6:17	14.8	8.2	941	8.7	5.46							
4/2/02 5:54	19.4	9.2	936		5.00	0.02	1.40	0.7	0.07	16.0	64.10	6.57
4/9/02 4:46	19.2	9.1	830	12.1	5.02							
4/16/02 5:11	15.4	7.8	465		4.47	0.12	0.80	0.6	0.09	16.0	21.40	6.21
4/23/02 4:50	17.6	9.0	398	9.3	4.81							
4/30/02 4:50	13.4	10.8	330		4.30	0.03	0.71	0.1	0.07	12.0	6.27	2.15
5/7/02 4:50	17.9	7.0	389	12.1	5.04							
5/14/02 5:00	17.3	8.2	396		5.01	0.05	1.00	0.4	0.08	15.9	7.62	3.18
5/21/02 4:54	16.3	8.1	520	11.9	5.60							
5/28/02 5:05	20.6	9.2	556		6.00	0.02	1.30	0.5	0.08	16.0	46.40	6.03
6/4/02 4:50	22.4	10.0	710	16.2	5.58							
6/11/02 5:00	20.7	12.4	742		5.48	0.04	1.00	0.6	0.06	27.0	68.70	23.10
6/18/02 5:06	21.6	10.4	739	15.3	5.20							
6/25/02 4:48	22.4	11.0	676		6.12	0.03	0.87	0.8	0.02	24.0	100.00	29.30
7/2/02 6:52	25.6	9.8	704	20.2	4.81							
7/9/02 5:35	24.3	9.1	740		6.18	0.07	1.20	0.4	0.06	23.0	138.00	38.90
7/16/02 7:23	23.5	8.3	744	17.8	4.26							
7/23/02 5:50	24.4	9.0	777		6.69	0.05	1.15	1.0	0.08	20.0	75.70	31.30
7/30/02 6:54	23.3	8.4	621	23.1	5.20							
8/6/02 8:50	23.1	11.2	791		5.80	0.11	1.30	1.0	0.11	20.0	109.00	22.20
8/13/02 6:05	25.6	8.5	806	22.0	5.09							
8/20/02 6:48	22.2	9.8	745		6.19	0.04	1.20	0.4	0.07	21.0	132.00	30.70
8/27/02 5:07	22.9	10.4	765	11.7	4.74							
9/3/02 5:10	24.7	9.4	739		6.02	0.18	1.10	0.5	0.09	19.0	128.00	31.30
9/10/02 5:16	21.4	11.2	755	11.9	5.01							
9/17/02 4:55	20.9	8.9	786		5.93	0.14	1.30	0.3	0.07	21.0	103.00	33.90
9/24/02 5:44	22.6	7.7	785	8.5	5.40							
10/1/02 5:24	19.0	7.6	737		5.92	0.20	2.00	0.8	0.17	13.0	24.20	8.74
10/8/02 5:00	21.0	10.0	754	12.3	5.23							
10/15/02 5:30	17.8	10.0	673		5.59	0.26	1.40	0.6	0.13	12.0	39.40	8.47
10/22/02 4:40	16.4	8.7	472	10.9	5.50							
10/29/02 6:27	14.9	7.0	469		5.82	0.19	1.17	0.2	0.11	12.0	8.65	2.33
11/5/02 6:30	11.7	9.0	751	8.6	5.48							
11/12/02 6:00	14.1	8.7	663		5.40	0.26	1.40	0.6	0.17	19.0	3.97	1.81
11/19/02 6:35	12.5	9.6	876	14.2	4.61							
11/26/02 5:50	12.7	8.5	919		3.80	0.16	1.70	0.4	0.13	13.0	8.57	2.30
12/3/02 5:40	10.8	10.9	953	6.3								

[shaded] = Old River Near DMC barrier in place from 4/15/02 - 11/17/02.

Note: Old River @ Head Barrier in place from 4/15/02 - 5/27/02 and from 10/4/02 - 11/15/02.

	TEMP. (°C)	D.O. (mg/L)	E.C. (uS/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 (ug/L)	PHEO.-A (ug/L)
MAXIMUM	25.60	12.40	806.00	23.10	6.69	0.26	2.00	1.00	0.17	27.00	138.00	38.90
MINIMUM	11.70	7.00	330.00	8.50	4.26	0.02	0.71	0.10	0.02	12.00	3.97	1.81
MEAN	20.16	9.25	651.55	14.12	5.42	0.11	1.18	0.55	0.09	18.18	63.27	17.48
Range	13.90	5.40	476.00	14.60	2.43	0.24	1.29	0.90	0.15	15.00	134.03	37.09
Standard Deviation	3.82	1.30	145.12	4.76	0.59	0.08	0.30	0.26	0.04	4.58	49.45	13.68
Sample Variance	14.59	1.70	21,059.12	22.69	0.34	0.01	0.09	0.07	0.00	20.99	2,445.39	187.27
Standard Error	3.88	1.28	138.36	4.78	0.37	0.09	0.26	0.25	0.04	3.99	37.23	4.78
Median	21.00	9.00	737.00	12.10	5.48	0.09	1.19	0.55	0.08	19.00	57.55	15.47
Mode	22.40	9.00	739.00	11.90	4.81	0.03	1.30	0.60	0.07	12.00	#N/A	31.30
Kurtosis	-0.71	-0.19	-0.54	-0.65	-0.32	-1.00	2.92	-0.32	0.71	-0.76	-1.59	-1.82
Skewness	-0.54	0.35	-0.96	0.73	-0.11	0.63	1.05	0.24	0.73	0.14	0.22	0.17
Count	31	31	31	15	31	16	16	16	16	16	16	16
Confidence Level (95%)	1.34	0.46	51.08	2.41	0.21	0.04	0.15	0.13	0.02	2.25	24.23	6.71

* All descriptive statistics were calculated from data recorded while the Old River Near DMC barrier was in place.

From mid-April until late May specific conductance at Tracy Road was high relative to the other monitoring locations, which all tracked closely. There were no distinct patterns from early June until early August. During the remainder of the monitoring period specific electrical conductivity readings tended to be low at the Old River at Head site, high at the Old River at Tracy Road site, and intermediate at the upstream and downstream of the DMC barrier sites. Immediately upstream and downstream of the DMC Barrier there were minimal differences in specific conductance with means of 781 and 800 µS/cm, respectively. Specific conductance in the immediate vicinity of the barrier was more variable than at the upstream locations. Values then increased noticeably upstream at the Tracy Road site averaging 889 µS/cm. Finally, specific electrical conductivity values at Old River at Head, the furthest upstream site, were considerably lower than the other sites averaging 652 µS/cm. The lowest recorded specific electrical conductivity reading for the Old River was 298 µS/cm on June 25th at the Downstream of DMC Barrier site and the highest was 1,222 µS/cm on October 15th at the Upstream of DMC Barrier site.

Tracy Road was the most turbid site on the Old River. Readings at Tracy Road averaged about 24.5 NTU and were consistently higher than at the other three sites from mid-spring until mid-summer. Comparatively, the next most turbid site was Old River at Head where the mean turbidity was about 16.0 NTU. Water clarity was highest in the immediate vicinity of the barrier with turbidity readings averaging about 12.8 NTU at the upstream site and about 13.0 NTU at the downstream site. The lowest recorded turbidity was 3.3 NTU on August 13th at the Downstream of DMC Barrier site. The highest turbidity value recorded for the Old River was 36.0 NTU on June 11th at Tracy Road. Overall, differences in turbidity between sites were more evident during the summer months than in spring and fall.

Algal biomass, as represented by chlorophyll *a* concentrations, was most evident 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 Old River at Head site was 63.3 µg/L while the barrier/s were in place. Elevated chlorophyll *a* concentrations were also observed at Tracy Road during the summer. The average concentration at Tracy Road was 40.9 µg/L. Immediately upstream and downstream of the DMC barrier chlorophyll *a* concentrations were, comparatively, very low averaging 8.38 and 5.61 µg/L, respectively. Chlorophyll *a* values reached a maximum of 138 µg/L on July 9th at Old River at Head and a minimum of 1.60 µg/L on June 25th at the Upstream of DMC Barrier site. Trends in pheophytin *a* concentrations mimicked those seen in the chlorophyll *a* concentrations at all four Old River sites.

No evident patterns in ammonia can be seem from mid-spring through early summer, after which there was a marked increase in ammonia concentrations at all the Old River sites, especially at Tracy Road. Ammonia concentrations at Tracy Road were considerably higher than at the other monitoring sites from late August through early October. Values at Tracy Road ranged from 0.02 - 0.56 mg/L with a mean of 0.24 mg/L, while values further upstream at the Head site ranged from 0.02 - 0.26 mg/L with a mean of 0.11 mg/L. Values immediately upstream and downstream of the barrier showed little variation. Ammonia concentrations upstream of DMC barrier ranged from 0.03 - 0.43 mg/L with an average of 0.14 mg/L, while values downstream ranged from 0.01 - 0.40 mg/L with an average of 0.12 mg/L.

Nitrite-Nitrate levels seemed to vary somewhat erratically at all four monitoring sites while the barrier/s were operational. Similar to ammonia, nitrite-nitrate concentrations appeared to increase during mid-summer. Old River at Tracy Road had the highest nitrite-nitrate concentrations with an average of 1.23 mg/L and a maximum of 2.00 mg/L recorded on October 1st. Old River at Head had slightly lower concentrations than Tracy Road with an average of 1.18 mg/L. Generally, when compared to the other two monitoring locations, the DMC sites had slightly lower nitrite-nitrate concentrations throughout the monitoring period with a minimum of 0.44 mg/L recorded on June 25th at the Downstream of DMC Barrier site. Variation just upstream or downstream of the DMC barrier was negligible with both sites having a mean of 1.09 mg/L.

Levels of organic nitrogen did not show any discernible patterns during the monitoring period. The minimum organic nitrogen value in the Old River was 0.10 mg/L reported on April 30th at the Old River at Head, and the maximum was 1.70 mg/L reported on July 23rd at Tracy Road. Old River at Head tended to have the lowest organic nitrogen concentrations during the sampling period with a mean of 0.55 mg/L, while Tracy Road tended to have the highest concentrations with a mean of 0.83 mg/L. Mean organic nitrogen concentrations at the Upstream and Downstream of DMC barrier sites were 0.80 mg/L and 0.69 mg/L, respectively.

Orthophosphate values at all sites ranged from 0.02 - 0.27 mg/L and were consistently lower at the Head site, especially during the summer. Orthophosphate concentrations at the other sites seemed to be elevated during the summer reaching a peak value of 0.27 mg/L on September 3rd at the Downstream of DMC Barrier site. A minimum value of 0.02 mg/L was recorded in the Old River on June 25th at the Old River at Head site. Overall the highest mean was 0.16 mg/L at the Tracy Road site and the lowest was 0.09 mg/L at the Head site.

Overall, there did not seem to be any significant water quality impacts in the immediate vicinity of the barrier in the Old River near DMC; however, water quality constituents did vary considerably upstream at the Tracy Road and Head sites. Specific conductance, turbidity, and ammonia concentrations tended to be higher at the Tracy Road site in comparison 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 considerably higher dissolved oxygen concentrations, lower specific electrical conductivity values and lower concentrations of orthophosphate and organic nitrogen. Overall, both the Old River at Head and Tracy Road sites were more turbid and had greater chlorophyll *a* / pheophytin *a* concentrations relative to the sites just upstream and downstream of the Old River near DMC barrier.

Grant Line Canal Barrier

The Grant Line Canal barrier was constructed on June 12th, 2002 and removed on November 16th, 2002. 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 7-4 and Tables 7-8 through 7-10 show the results of the weekly water quality testing on Grant Line Canal.

Placement of the barrier did not appear to have an impact on water temperature in Grant Line Canal. A maximum temperature of 25.8 °C was recorded at Doughty Cut on July 2nd and a minimum temperature of 13.3 °C was recorded at Doughty Cut and GLC Above Barrier on November 5th and 12th, respectively. Mean water temperature varied by 0.28°C between the three monitoring stations. Summer temperatures were warm averaging over 20.0 °C, began to sharply decrease in the early fall.

Dissolved oxygen levels tended to be lower in the summer, especially at the GLC at Tracy Road site, and higher in mid-fall. DO concentrations at Doughty Cut were slightly higher than at GLC Above Barrier and noticeably higher than at Tracy Road averaging 6.66 mg/L and reaching a maximum of 8.80 mg/L on October 29th. There was only one occurrence at Doughty Cut where the DO was below 5 mg/L. DO at GLC Above Barrier was slightly lower than at Doughty Cut with an average of 6.24 mg/L and a maximum of 9.00 mg/L recorded on November 5th. Three field readings collected at the aforementioned site were below 5 mg/L. GLC at Tracy Road had notably lower DO concentrations than the other two sites with an average of 5.35 mg/L. The maximum recorded DO at Tracy Road was 6.70 mg/L on November 12th. Seven field readings collected at Tracy Road were below 5 mg/L. The minimum DO value for GLC was 3.40 mg/L recorded at all three sites. It should be noted that DO concentrations only dropped below 7.0 mg/L once at each station pre- and post- GLC Barrier installation.

Figure 7-4 2002 Weekly Water Quality Data with Grant Line Canal Barrier in Place

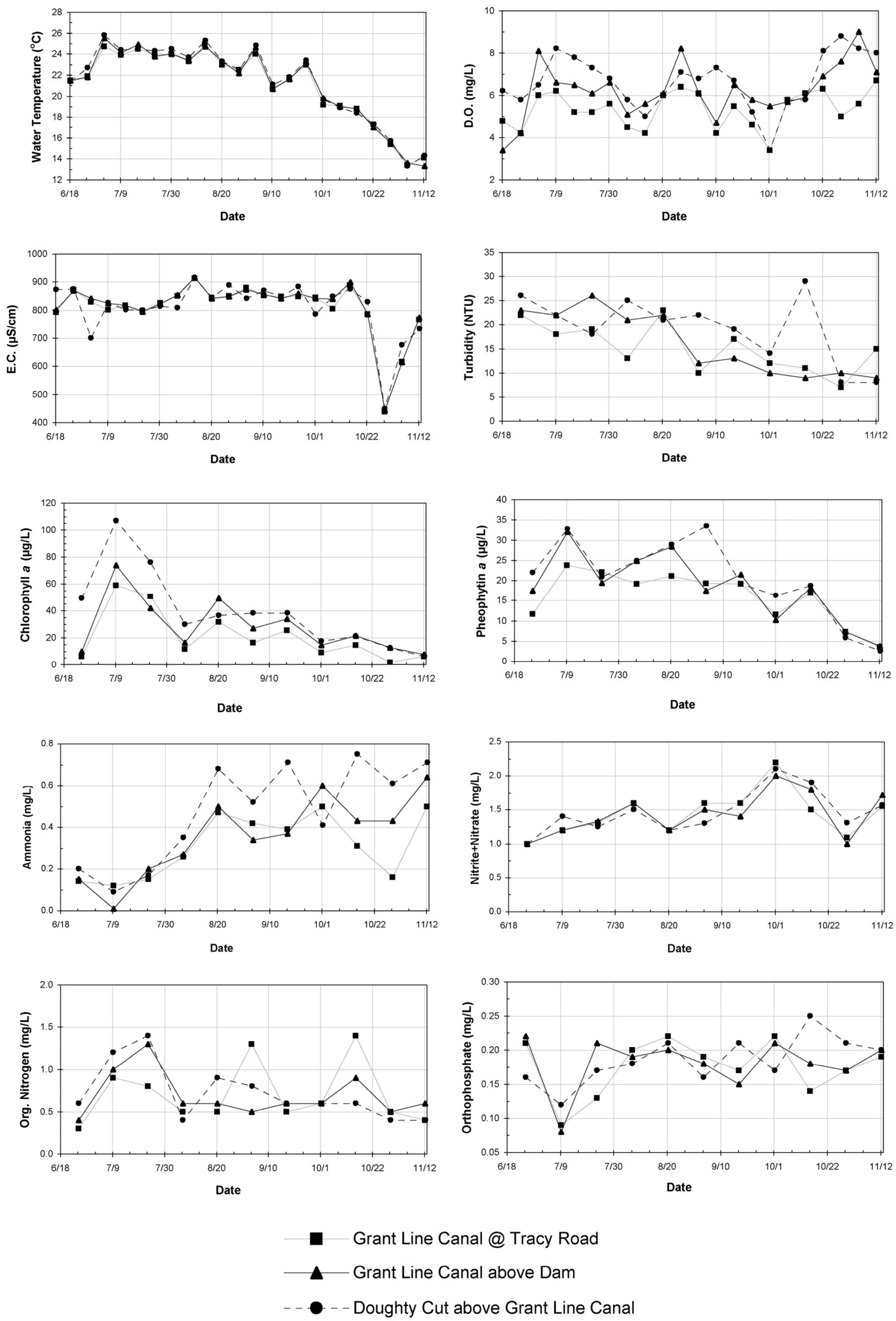


Table 7-8 Grant Line Canal at Tracy Road: 2002 Water Quality Data

CALIFORNIA DEPARTMENT OF WATER RESOURCES - CENTRAL DISTRICT

GRANT LINE CANAL @ TRACY ROAD (B9D74921269)
South Delta Temporary Barriers Project - 2002 Weekly Water Quality Sampling Data

	FIELD READINGS					BRYTE LAB RESULTS						
DATE & TIME (mm/dd/yy PST)	TEMP. (°C)	D.O. (mg/L)	E.C. (uS/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 (ug/L)	PHEO.-A (ug/L)
3/26/02 6:45	14.8	9.2	951	23.1	4.62							
4/2/02 7:03	19.5	9.6	1019		4.30	0.21	1.50	0.8	0.12	13.0	63.80	10.80
4/9/02 5:35	18.7	9.7	856	19.4								
4/16/02 6:30	17.4	8.1	740		5.18	0.14	0.96	0.5	0.12	13.0	57.20	13.50
4/23/02 5:34	15.0	8.2	584	23.8	5.02							
4/30/02 5:59	15.4	7.2	533		5.25	0.46	1.20	0.4	0.19	19.0	18.00	7.45
5/7/02 5:19	17.1	8.8	550	23.0	5.32							
5/14/02 5:30	17.6	9.3	547		5.62	0.14	1.10	0.8	0.14	21.0	30.00	6.26
5/21/02 5:32	17.8	6.7	649	27.9	4.80							
5/28/02 5:31	20.1	8.7	591		6.22	0.06	1.00	0.6	0.09	14.0	41.60	8.78
6/4/02 6:00	21.9	8.0	759	23.6	3.90							
6/11/02 5:25	21.1	9.6	820		5.95	0.04	0.86	0.4	0.10	28.0	66.60	31.50
6/18/02 5:23	21.5	4.8	793	30.0	3.85							
6/25/02 6:13	21.9	4.2	873		6.85	0.14	1.00	0.3	0.21	22.0	6.34	11.60
7/2/02 7:16	24.7	6.0	829	20.2	3.86							
7/9/02 6:23	23.9	6.2	802		5.52	0.12	1.20	0.9	0.09	18.0	58.80	23.70
7/16/02 7:50	24.5	5.2	817	23.0	3.80							
7/23/02 6:20	23.9	5.2	798		6.20	0.15	1.31	0.8	0.13	19.0	50.60	22.10
7/30/02 7:17	24.0	5.6	825	21.0	3.54							
8/6/02 8:00	23.3	4.5	850		4.92	0.26	1.60	0.5	0.20	13.0	11.50	19.10
8/13/02 5:40	24.9	4.2	913	15.2	3.11							
8/20/02 7:30	23.0	6.0	843		4.38	0.47	1.20	0.5	0.22	23.0	31.60	21.10
8/27/02 5:35	22.5	6.4	850	17.1	3.63							
9/3/02 5:59	24.0	6.1	879		4.04	0.42	1.60	1.3	0.19	10.0	16.50	19.30
9/10/02 6:00	20.7	4.2	851	12.0	4.02							
9/17/02 6:00	21.7	5.5	848		4.31	0.39	1.60	0.5	0.17	17.0	25.40	19.20
9/24/02 6:05	23.0	4.6	849	10.9	3.85							
10/1/02 6:15	19.2	3.4	844		3.75	0.50	2.20	0.6	0.22	12.0	9.10	11.50
10/8/02 5:30	19.1	5.8	804	11.5	3.50							
10/15/02 5:55	18.8	6.1	889		3.75	0.31	1.50	1.4	0.14	11.0	14.70	16.80
10/22/02 5:50	17.3	6.3	785	14.6	3.80							
10/29/02 7:33	15.4	5.0	439		2.58	0.16	1.09	0.5	0.17	7.0	2.00	7.30
11/5/02 7:05	13.4	5.6	616	8.8	3.98							
11/12/02 6:35	14.1	6.7	766			0.50	1.55	0.4	0.19	15.0	6.14	3.57
11/19/02 6:45	12.9	8.2	884	20.0	3.50							
11/26/02 6:35	12.5	9.3	910		2.73	0.20	1.60	0.8	0.13	18.0	8.89	1.76
12/3/02 7:10	11.4	9.0	615	17.5	3.43							

= Grant Line Canal barrier in place from 6/12/02 - 11/16/02.

	TEMP. (°C)	D.O. (mg/L)	E.C. (uS/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 (ug/L)	PHEO.-A (ug/L)
MAXIMUM	24.90	6.70	913.00	30.00	6.85	0.50	2.20	1.40	0.22	23.00	58.80	23.70
MINIMUM	13.40	3.40	439.00	8.80	2.58	0.12	1.00	0.30	0.09	7.00	2.00	3.57
MEAN	21.13	5.35	807.41	16.75	4.15	0.31	1.44	0.70	0.18	15.18	21.15	15.93
Range	11.50	3.30	474.00	21.20	4.27	0.38	1.20	1.10	0.13	16.00	56.80	20.13
Standard Deviation	3.48	0.88	101.07	6.32	0.99	0.15	0.33	0.36	0.04	5.10	18.77	6.51
Sample Variance	12.14	0.78	10,215.68	39.93	0.98	0.02	0.11	0.13	0.00	25.96	352.50	42.36
Standard Error	2.10	0.89	103.13	6.50	0.28	0.14	0.26	0.38	0.04	5.37	17.16	4.26
Median	22.20	5.55	836.00	15.20	3.85	0.31	1.50	0.50	0.19	15.00	14.70	19.10
Mode	23.90	4.20	850.00	#N/A	3.85	0.50	1.60	0.50	0.22	#N/A	#N/A	#N/A
Kurtosis	0.03	-0.63	8.67	0.35	2.29	-1.86	1.61	0.16	0.27	-0.95	0.32	-0.51
Skewness	-1.02	-0.49	-2.75	0.83	1.44	-0.01	0.95	1.13	-0.92	0.07	1.17	-0.78
Count	22	22	22	11	21	11	11	11	11	11	11	11
Confidence Level (95%)	1.46	0.37	42.23	3.73	0.42	0.09	0.20	0.21	0.02	3.01	11.10	3.85

* All descriptive statistics were calculated from data recorded while the Grant Line Canal barrier was in place.

Table 7-9 Grant Line Canal Above Barrier: 2002 Water Quality Data

CALIFORNIA DEPARTMENT OF WATER RESOURCES - CENTRAL DISTRICT

GRANT LINE CANAL ABOVE BARRIER (B9D74921510)
South Delta Temporary Barriers Project - 2002 Weekly Water Quality Sampling Data

	FIELD READINGS					BRYTE LAB RESULTS						
DATE & TIME (mm/dd/yy PST)	TEMP. (°C)	D.O. (mg/L)	E.C. (uS/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 (ug/L)	PHEO.-A (ug/L)
3/26/02 6:53	14.6	9.0	967	19.8	4.61							
4/2/02 7:20	19.6	9.2	1011		4.30	0.19	1.50	0.8	0.12	13.0	57.30	9.77
4/9/02 5:48	18.4	9.6	855	21.7								
4/16/02 6:35	17.4	8.2	750			0.16	1.20	0.6	0.14	33.0	62.60	20.30
4/23/02 5:46	15.8	8.7	581	16.5	5.02							
4/30/02 6:20	15.3	7.5	537		5.25	0.39	0.93	0.4	0.18	21.0	18.70	9.79
5/7/02 5:35	17.0	8.4	541	27.7	5.32							
5/14/02 5:40	16.6	9.4	554		5.62	0.16	1.10	0.8	0.15	25.3	31.70	6.90
5/21/02 5:55	17.4	6.5	662	26.0	4.58							
5/28/02 5:45	20.5	7.4	592		6.22	0.04	0.91	0.5	0.09	13.0	32.60	6.88
6/4/02 6:20	21.4	7.5	770	34.1	3.90							
6/11/02 5:40	20.8	9.6	812		5.95	0.04	0.69	0.3	0.08	32.0	80.10	38.10
6/18/02 5:40	21.5	3.4	802	31.6	3.85							
6/25/02 6:31	21.8	4.2	869		6.85	0.15	1.00	0.4	0.22	23.0	9.75	17.50
7/2/02 7:31	25.5	8.1	842	20.7	3.86							
7/9/02 6:40	24.1	6.6	823		5.52	<.01	1.20	1.0	0.08	22.0	74.00	32.00
7/16/02 8:01	24.9	6.5	817	30.5	3.80							
7/23/02 6:40	23.8	6.1	795		6.15	0.20	1.33	1.3	0.21	26.0	42.00	19.40
7/30/02 7:30	24.0	6.6	822	21.5	3.54							
8/6/02 8:10	23.4	5.1	853		4.92	0.27	1.60	0.6	0.19	21.0	16.20	24.90
8/13/02 6:00	24.7	5.6	916	14.1	3.10							
8/20/02 8:00	23.3	6.1	841		4.38	0.50	1.20	0.6	0.20	22.0	49.00	28.40
8/27/02 5:55	22.2	8.2	849	16.2	3.63							
9/3/02 6:09	24.6	6.1	872		4.04	0.34	1.50	0.5	0.18	12.0	26.90	17.40
9/10/02 6:15	20.7	4.7	856	15.4	4.02							
9/17/02 6:15	21.6	6.5	842		4.29	0.37	1.40	0.6	0.15	13.0	33.80	21.40
9/24/02 6:15	23.2	5.8	858	9.2	3.85							
10/1/02 6:30	19.8	5.5	842		3.75	0.60	2.00	0.6	0.21	10.0	14.60	10.20
10/8/02 5:50	19.0	5.7	839	8.9	3.50							
10/15/02 6:15	18.8	5.9	898		3.75	0.43	1.80	0.9	0.18	9.0	21.60	18.20
10/22/02 6:10	17.0	6.9	785	14.3	3.80							
10/29/02 7:47	15.5	7.6	444		3.85	0.43	1.00	0.5	0.17	10.0	12.90	7.31
11/5/02 7:20	13.6	9.0	614	11.7	3.98							
11/12/02 7:00	13.3	7.1	773			0.64	1.72	0.6	0.20	9.0	7.51	3.78
11/19/02 7:00	12.8	8.1	885	24.3	3.50							
11/26/02 6:50	12.3	8.9	909		2.71	0.19	1.60	0.6	0.13	13.0	8.17	6.12
12/3/02 7:30	11.6	8.8	618	18.2	3.43							

[shaded] = Grant Line Canal barrier in place from 6/12/02 - 11/16/02.

	TEMP. (°C)	D.O. (mg/L)	E.C. (uS/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 (ug/L)	PHEO.-A (ug/L)
MAXIMUM	25.50	9.00	916.00	31.60	6.85	0.64	2.00	1.30	0.22	26.00	74.00	32.00
MINIMUM	13.30	3.40	444.00	8.90	3.10	0.01	1.00	0.40	0.08	9.00	7.51	3.78
MEAN	21.20	6.24	811.45	17.65	4.21	0.36	1.43	0.69	0.18	16.09	28.02	18.23
Range	12.20	5.60	472.00	22.70	3.75	0.63	1.00	0.90	0.14	17.00	66.49	28.22
Standard Deviation	3.63	1.31	100.93	7.73	0.92	0.16	0.33	0.27	0.04	6.64	20.32	8.62
Sample Variance	13.19	1.71	10,187.59	59.82	0.84	0.03	0.11	0.07	0.00	44.09	412.85	74.27
Standard Error	2.21	1.28	90.95	8.15	0.27	0.08	0.30	0.28	0.04	7.00	18.30	5.55
Median	22.00	6.10	841.50	15.40	3.85	0.40	1.40	0.60	0.19	13.00	21.60	18.20
Mode	#N/A	6.10	842.00	#N/A	3.85	0.43	1.00	0.60	0.21	22.00	#N/A	#N/A
Kurtosis	0.05	0.42	8.72	-0.17	2.94	-0.82	-0.85	1.62	4.35	-1.99	1.31	-0.49
Skewness	-0.99	0.02	-2.79	0.88	1.81	0.06	0.26	1.44	-1.91	0.24	1.26	-0.16
Count	22	22	22	11	21	10	11	11	11	11	11	11
Confidence Level (95%)	1.52	0.55	42.18	4.57	0.39	0.10	0.19	0.16	0.02	3.92	12.01	5.09

* All descriptive statistics were calculated from data recorded while the Grant Line Canal barrier was in place.

Table 7-10 Doughty Cut Above Grant Line Canal: 2002 Water Quality Data

CALIFORNIA DEPARTMENT OF WATER RESOURCES - CENTRAL DISTRICT

DOUGHTY CUT ABOVE GRANT LINE CANAL (B9D74911256)
South Delta Temporary Barriers Project - 2002 Weekly Water Quality Sampling Data

	FIELD READINGS					BRYTE LAB RESULTS						
DATE & TIME (mm/dd/yy PST)	TEMP. (°C)	D.O. (mg/L)	E.C. (uS/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 (ug/L)	PHEO.-A (ug/L)
3/26/02 7:05	14.6	8.3	966	12.1	4.50							
4/2/02 7:44	19.4	9.8	1006		4.49	0.10	1.50	0.6	0.10	12.0	65.30	9.45
4/9/02 6:05	18.1	9.3	841	18.0	4.05							
4/16/02 7:07	16.9	8.5	720		4.87	0.17	1.20	0.5	0.14	19.0	58.60	12.90
4/23/02 6:05	15.8	8.3	598	27.3	4.80							
4/30/02 6:44	15.2	7.2	521		4.95	0.34	1.00	0.4	0.16	14.0	19.80	6.77
5/7/02 5:55	17.4	8.5	499	27.2	5.91							
5/14/02 6:11	17.8	9.2	569		5.28	0.12	1.10	0.9	0.13	20.4	32.60	11.70
5/21/02 6:20	17.4	6.9	660	23.4	4.80							
5/28/02 6:13	20.1	8.2	598		6.12	0.18	0.76	0.7	0.09	14.0	41.60	6.89
6/4/02 6:30	21.4	8.0	754	37.7	4.59							
6/11/02 6:05	20.1	9.7	799		5.60	0.12	1.20	0.2	0.09	26.0	71.00	26.90
6/18/02 6:00	21.4	6.2	872	32.5	4.85							
6/25/02 6:58	22.7	5.8	875		6.25	0.20	1.00	0.6	0.16	26.0	49.10	21.90
7/2/02 7:54	25.8	6.5	700	21.0	4.49							
7/9/02 7:02	24.4	8.2	825		5.70	0.09	1.40	1.2	0.12	22.0	107.00	32.70
7/16/02 8:25	24.5	7.8	802	28.5	4.60							
7/23/02 7:00	24.3	7.3	800		6.20	0.17	1.25	1.4	0.17	18.0	76.00	20.90
7/30/02 7:55	24.5	6.8	813	20.6	4.85							
8/6/02 8:40	23.7	5.8	808		5.60	0.35	1.50	0.4	0.18	25.0	29.90	24.90
8/13/02 6:30	25.3	5.0	914	26.3	4.76							
8/20/02 8:30	23.3	6.0	844		5.70	0.68	1.20	0.9	0.21	21.0	36.20	28.90
8/27/02 6:10	22.5	7.1	889	24.4	4.60							
9/3/02 6:54	24.8	6.8	842		5.52	0.52	1.30	0.8	0.16	22.0	38.20	33.50
9/10/02 6:40	21.1	7.3	870	24.5	4.70							
9/17/02 6:50	21.8	6.7	848		5.31	0.71	1.60	0.6	0.21	19.0	38.20	19.10
9/24/02 6:45	23.4	5.2	883	13.8	4.98							
10/1/02 6:50	19.7	3.4	785		5.50	0.41	2.10	0.6	0.17	14.0	17.30	16.30
10/8/02 6:25	18.9	5.8	849	13.6	4.90							
10/15/02 6:38	18.4	5.8	874		5.25	0.75	1.90	0.6	0.25	29.0	21.20	18.70
10/22/02 6:45	17.3	8.1	829	16.6	5.18							
10/29/02 8:18	15.7	8.8	449		5.28	0.61	1.31	0.4	0.21	8.0	12.20	5.85
11/5/02 8:00	13.3	8.2	675	12.5	5.16							
11/12/02 7:30	14.3	8.0	734		5.11	0.71	1.57	0.4	0.20	8.0	6.28	2.51
11/19/02 7:30	12.7	8.4	660	18.3	4.58							
11/26/02 7:20	12.2	8.9	984		2.20	0.20	1.60	0.8	0.13	18.0	13.20	5.73
12/3/02 8:00	12.0	8.2	624	12.0	4.35							

[shaded] = Grant Line Canal barrier in place from 6/12/02 - 11/16/02.

	TEMP. (°C)	D.O. (mg/L)	E.C. (uS/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 (ug/L)	PHEO.-A (ug/L)
MAXIMUM	25.80	8.80	914.00	32.50	6.25	0.75	2.10	1.40	0.25	29.00	107.00	33.50
MINIMUM	13.30	3.40	449.00	12.50	4.49	0.09	1.00	0.40	0.12	8.00	6.28	2.51
MEAN	21.41	6.66	808.18	21.30	5.20	0.47	1.47	0.72	0.19	19.27	39.23	20.48
Range	12.50	5.40	465.00	20.00	1.76	0.66	1.10	1.00	0.13	21.00	100.72	30.99
Standard Deviation	3.67	1.29	100.25	6.62	0.49	0.24	0.32	0.33	0.04	6.89	29.60	9.85
Sample Variance	13.44	1.65	10,049.20	43.78	0.24	0.06	0.10	0.11	0.00	47.42	876.29	97.10
Standard Error	2.19	1.24	89.21	6.48	0.19	0.16	0.31	0.33	0.03	7.25	28.96	7.91
Median	22.60	6.75	835.50	21.00	5.17	0.52	1.40	0.60	0.18	21.00	36.20	20.90
Mode	24.50	5.80	#N/A	#N/A	4.85	0.71	#N/A	0.60	0.21	22.00	38.20	#N/A
Kurtosis	-0.15	0.46	7.45	-1.07	-0.16	-1.48	0.37	0.45	0.43	-0.48	1.80	-0.14
Skewness	-0.93	-0.52	-2.44	0.13	0.60	-0.40	0.76	1.12	-0.01	-0.58	1.36	-0.55
Count	22	22	22	11	22	11	11	11	11	11	11	11
Confidence Level (95%)	1.53	0.54	41.89	3.91	0.20	0.14	0.19	0.20	0.02	4.07	17.49	5.82

* All descriptive statistics were calculated from data recorded while the Grant Line Canal barrier was in place.

Generally, specific conductance remained relatively constant throughout the summer before dramatically decreasing on October 29th, after which values began increasing. Specific conductance seemed to track well at all three GLC stations. Data at the three GLC stations, on average, showed little variation with mean values differing by less than 4 µS/cm. Specific conductance values in GLC averaged around 809 µS/cm while the barrier was in place. The three GLC stations reached their maximum and minimum specific electrical conductivity values on August 13th and October 29th, respectively. Overall, values ranged from a low of 439 µS/cm recorded on October 29th at the Tracy Road site to a high of 916 µS/cm recorded on August 13th at the GLC Above Barrier site.

Turbidity readings were relatively high from late June through late August and then decreased gradually for the remainder of the monitoring period. Turbidity values did not vary much between sites with values for all three monitoring stations averaging around 17.5 NTU. Doughty Cut had a maximum reading of 32.5 NTU on June 18th and Tracy Road had a minimum reading of 7.0 NTU on October 29th, which were the maximum and minimum in GLC while the barrier/s were in place.

Chlorophyll *a* concentrations followed the same general trend at the three GLC sites. Levels peaked on July 9th and then gradually decreased throughout the remainder of the monitoring period. The maximum chlorophyll *a* concentration was 107.0 µg/L measured at the Doughty Cut site. Doughty cut tended to have higher chlorophyll *a* concentrations from mid-June through early August relative to the other two sites. Mean chlorophyll *a* concentration ranged from a high of 39.2 µg/L at Doughty Cut to a low of 21.2 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 33.5 µg/L reported on September 3rd at Doughty Cut and the minimum was 2.51µg/L reported on November 12th, also in Doughty Cut.

After all three stations reached a minimum on July 9th, ammonia concentration increased until August 20th, after which values remained elevated, but did show any distinct pattern. Ammonia concentrations ranged between 0.01-0.75 mg/L and were, generally, higher in Doughty Cut. The mean ammonia concentration at Doughty Cut was 0.47 mg/L. Concentrations of ammonia upstream and downstream of the GLC Barrier did vary much until October 1st when values at Tracy Road tended to be lower. Overall, the mean ammonia concentration at the GLC Above Barrier site was slightly higher than at Tracy Road site.

Nitrite-Nitrate values ranged from 1.00-2.20 mg/L and did not show any clear patterns. Values at all three stations were similar while the barrier was in place and did not reveal any noteworthy differences. The highest mean value was 1.47 mg/L recorded at Doughty Cut, which differed little from the lowest mean value of 1.43 mg/L recorded at GLC Above Barrier.

Organic nitrogen values ranged from 0.30-1.40 mg/L and tracked fairly closely at all three stations, except for two instances where the Tracy Road site had noticeably higher values. The mean organic nitrogen concentration at Doughty Cut was 0.72 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 0.69 mg/L and 0.70 mg/L, respectively. All three sites had a minimum value of 1.0 mg/L. Overall, organic nitrogen concentrations were somewhat higher in July.

Orthophosphate values were similar at all three stations. Values were fairly consistent throughout the summer and fall except for July 9th when each station recorded a minimum value. GLC orthophosphate concentrations ranged from 0.08-0.25 mg/L. The Tracy Road and Above Barrier sites had means of 0.18 mg/L and Doughty Cut had a mean of 0.19 mg/L.

Overall, it appears that the Grant Line Canal Barrier may have had an effect on dissolved oxygen immediately upstream and downstream of Grant Line Canal. DO concentrations downstream of the barrier at Tracy Road were considerably lower than at either of the upstream sites. Three water quality constituents varied further upstream at the Doughty Cut site. At this location ammonia, DO and chlorophyll *a* concentrations where elevated relative to the sites near the barrier. Generally, water quality constituents measured at the three GLC followed the same patterns.

Continuous Water Quality Monitoring

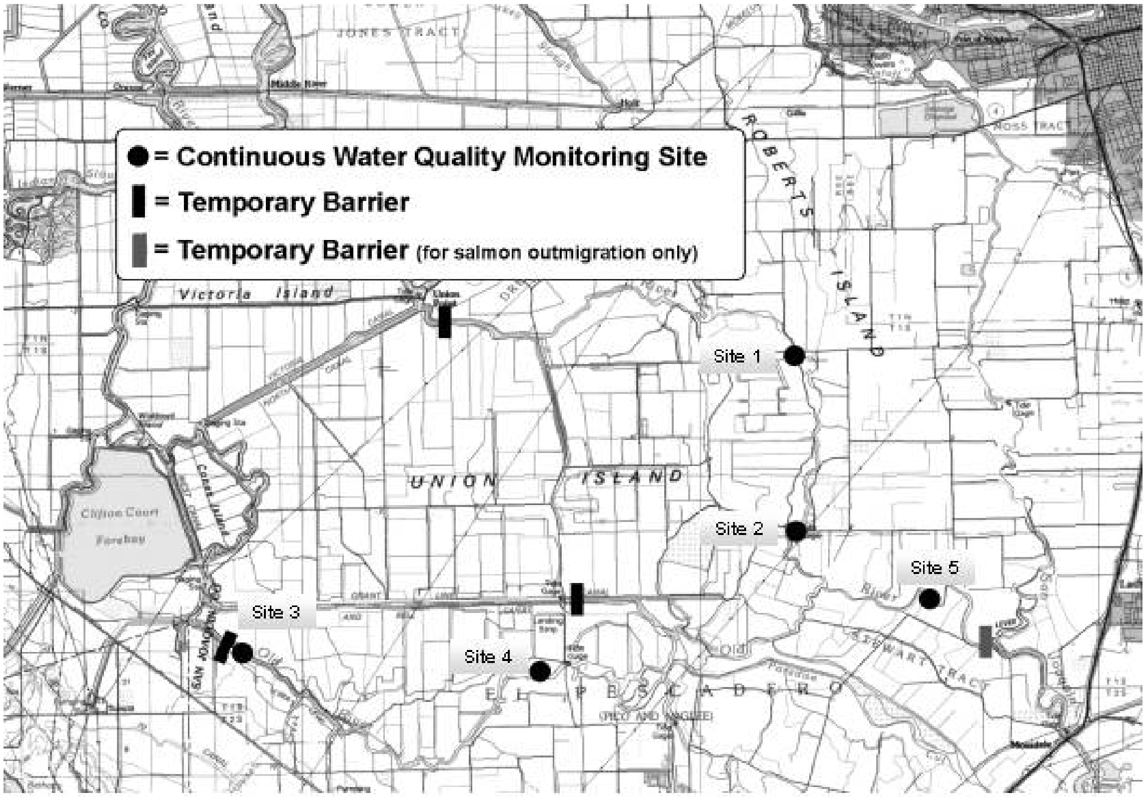
Continuous monitoring to evaluate water quality impacts of barrier installations in the South Delta was continued in 2002. This program was established for two reasons: first to determine the feasibility of collecting reliable time-series water quality data as opposed to weekly grab sampling data and second, to develop a dynamic understanding of water quality conditions due to tidal fluctuations, Delta inflows, agricultural pumping and drainage, municipal effluent loading, SWP and CVP pumping operations, as well as other variables.

The up-front economic costs of collecting weekly grab samples are less expensive in comparison to the purchase of continuous monitoring equipment. However, continuous monitoring is capable of providing more meaningful information of basic water quality parameters; 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 may easily offset the initial instrumentation costs when considering the economic benefits of making more informed decisions.

Sites

Yellow Springs Instruments 6600 “sondes” (continuous multi-parameter water quality monitoring instruments) were operated during the year to gather data at five sites in the South Delta. Three monitoring sites were 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. The fourth site was located on a pump platform in the Middle River just upstream of the Howard Road Bridge crossing. In 2002, a fifth monitoring site located on a pump platform in the Middle River just upstream of the Undine Road Bridge crossing was added. See Figure 7-5 for site locations.

Figure 7-5 Map of South Delta continuous water quality monitoring sites



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

Instrumentation

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 YSI 6600 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.

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. 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 2100 P 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. Biological fouling, however, has caused some problems in the South Delta during the warmer summer months.

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 showed that antifouling paint has been an effective tool in decreasing biological growth.

Data

Water temperature, dissolved oxygen, pH, specific conductance, and turbidity are the water quality parameters measured at all five South Delta continuous monitoring stations. As in 2000 and 2001, continuous monitoring in 2002 proved to be good tests of YSI 6600 sondes for time-series data collection within the Delta. Data gathered from each site confirmed the accuracy, reliability, and longevity of the instruments for Delta waterway’s use. Central District staff became more fluent with the fundamental operation of the YSI instrumentation and their many subtle operational nuances. This led to further development of standardized protocols within Central District for instrument calibration, deployment, field verification, and post-deployment for any monitoring project using such equipment. Central District staff also replaced YSI 6026 turbidity sensors with the new 6136 model. The YSI 6136 turbidity sensor is supposed to correlate more closely with data from the HACH 2100AN, a laboratory meter, which is generally recognized as the standard for turbidity measurement.

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. However, 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. Discussion of dissolved oxygen and pH continuous water quality data for 2002 will focus on these criteria.

It should be noted that continuous monitoring in the South Delta was temporarily discontinued after October 3rd, 2001 and did not commence again until June 4th, 2002 due to limited staff.

Middle River at Howard Road

Measured water temperatures in the Middle River at Howard Road during 2002 are shown in Figure 7-6. Water temperature is predominantly influenced by and tends to follow the same diel pattern as air temperature. Figure 7-7 shows diel variation in water temperature observed in the Middle River at Howard Road during the summer with temperatures steadily rising during the day, peaking in the late afternoon/early evening and steadily falling 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, salinity, and shading from vegetative cover. Water temperatures at Howard Road averaged more than 23.0 °C during the summer, reaching a maximum of 29.1 °C on July 13th at 18:00 PST. Beginning in early fall temperatures decreased and continued to fall for the remainder of the year, with the mean temperature falling from 18.2 °C in October to 9.9 °C in December. The minimum water temperature recorded was 7.5 °C on December 25th at 8:45 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 2002 are also plotted in Figure 7-6. DO concentrations reached a maximum of 15.02 mg/L on August 27th at 17:15 PST and were at a minimum of 2.00 mg/L on August 15th at 2:00 PST. Note that a few portions of the summer and early fall DO data set were not included because excessive biological fouling of the dissolved oxygen probe(s) rendered the data inadmissible during these periods. There were numerous times during the summer when the sonde(s) recorded DO concentrations less than 5 mg/L and some instances below 3 mg/L. Three 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. Typically, summer DO readings showed marked diel variation with the highest concentrations occurring in the late afternoon and lowest during the early morning. This is, likely, the result of water temperature variation and high chlorophyll a / pheophytin a levels, which will be discussed further in the Middle River at Undine Road section. The lowest monthly mean DO was 6.79 mg/L in June and the highest was 10.23 mg/L in December. The higher DO concentrations seen during late fall and early winter can, likely, be attributed to increased oxygen solubility in cooler waters. DO concentrations in fall and early 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 8.74 mg/L.

Figure 7-6 also depicts 2002 pH data in the Middle River at Howard Road. Recorded pH data ranged from a high of 9.23 on July 8th at 23:30 PST to a low of 7.15 on July 6th at 5:00 PST. No pH values greater than 9.0 were recorded after September 16th and the maximum field reading recorded was 8.67. Similar to water temperature and dissolved oxygen data, continuous pH data revealed greater diel fluctuations during the summer, and noticeably less during the fall and winter. For 2002, pH at Howard Road averaged 7.85 and the highest monthly mean pH was 8.25 in September.

Figure 7-6 Middle River at Howard Road: Water temperature, dissolved oxygen and pH continuous water quality data

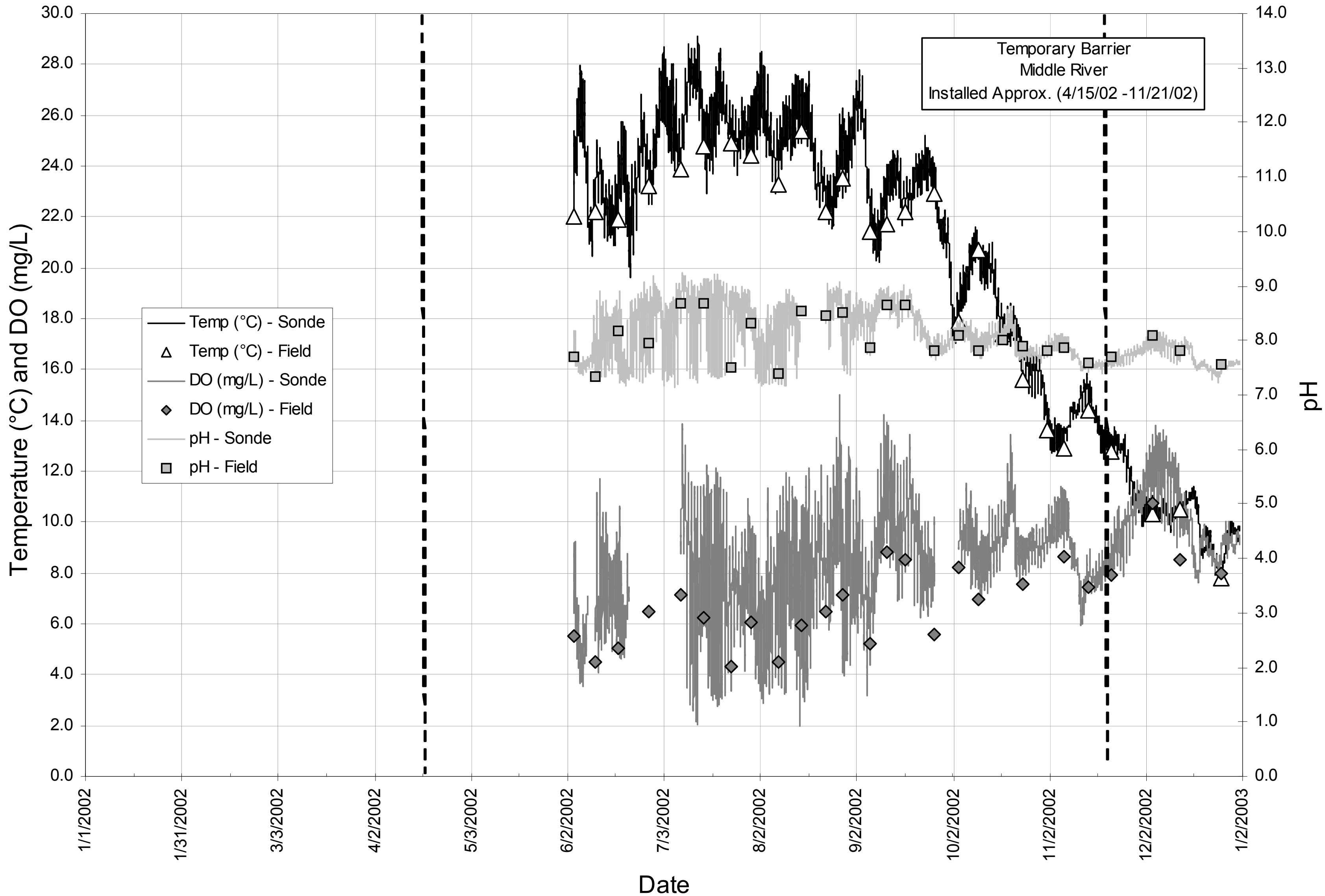


Figure 7-7 Water temperature on June 25th, 2002: Middle River at Howard Road

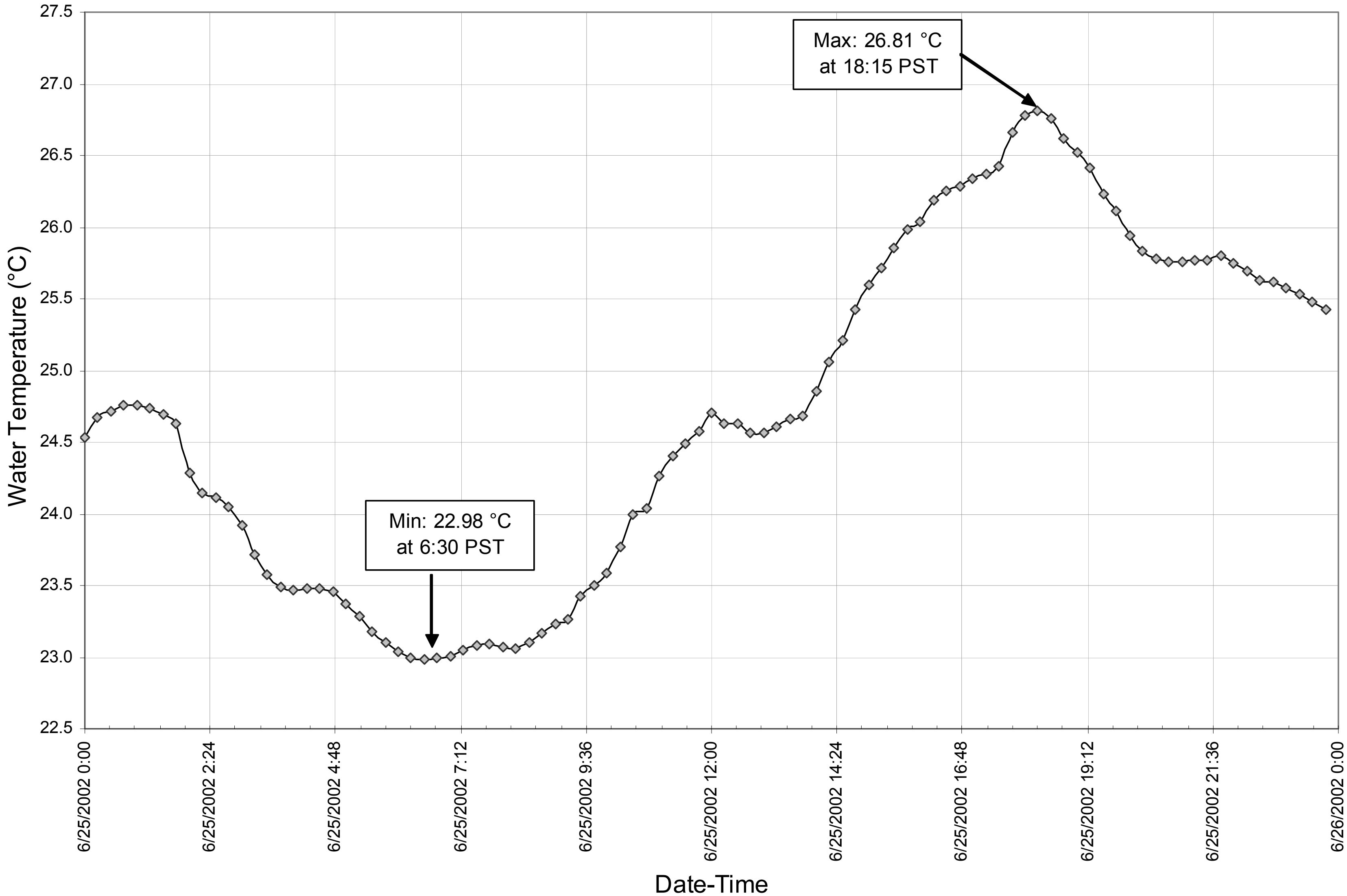


Figure 7-8 portrays measured specific conductance data for 2002 at the Howard Road site. A maximum of 1583.5 µS/cm was recorded on December 25th at 7:30 PST. The minimum-recorded specific conductance was 344.2 µS/cm on July 21st at 3:45 PST. The mean for the monitoring period was 799.7 µS/cm. Diel variation in specific conductance values, likely due to tidal influences and San Joaquin River flows, was most pronounced from June through September. Figure 7-9 is a plot of flow and specific conductance for the San Joaquin River at Vernalis. Generally, when flows were high specific conductance was low and vice versa. From early September until the Middle River Barrier was removed specific conductance values showed less fluctuation, which could be due to the temporary barrier, less tidal influence, and/or incoming tidal water and San Joaquin River water exhibiting less difference in specific conductance values. A dramatic decrease in specific conductance was recorded beginning on October 24th, reaching a minimum of 392.1 µS/cm on October 29th at 8:30 PST after which values began rising. The cause for this abrupt decrease in conductivity values may have been due to increased freshwater flows down the San Joaquin River. After the barrier was removed on November 21st diel variation of specific conductance seemed more pronounced and values began to increase rather sharply. Any number of factors could account for increased specific conductance values during late fall and early winter including low San Joaquin River flows, runoff from storm events and tidal influences.

Figure 7-8 also depicts turbidity data at this site. Turbidities ranged from a high of 332.2 NTU on November 9th at 6:30 PST to a low of 3.2 NTU on November 25th at 22:00 PST. Several times in 2002, 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 November 9th. Such occurrences during colder months are generally attributed to storm events, whereas during summer months these peaks 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). Generally, the barriers did not appear to influence turbidities at this monitoring location. The overall mean was about 36.5 NTU, which is indicative of fairly turbid water. Turbidity values were very high throughout the summer months with mean values greater than 40 NTU. In the fall turbidity values decreased sharply, averaging only 12.7 NTU in November before increasing again in mid-December. Overall, Howard Road had the lowest water clarity of all five South Delta monitoring sites..

Figure 7-8 Middle River at Howard Road: Specific conductance and turbidity continuous water quality data

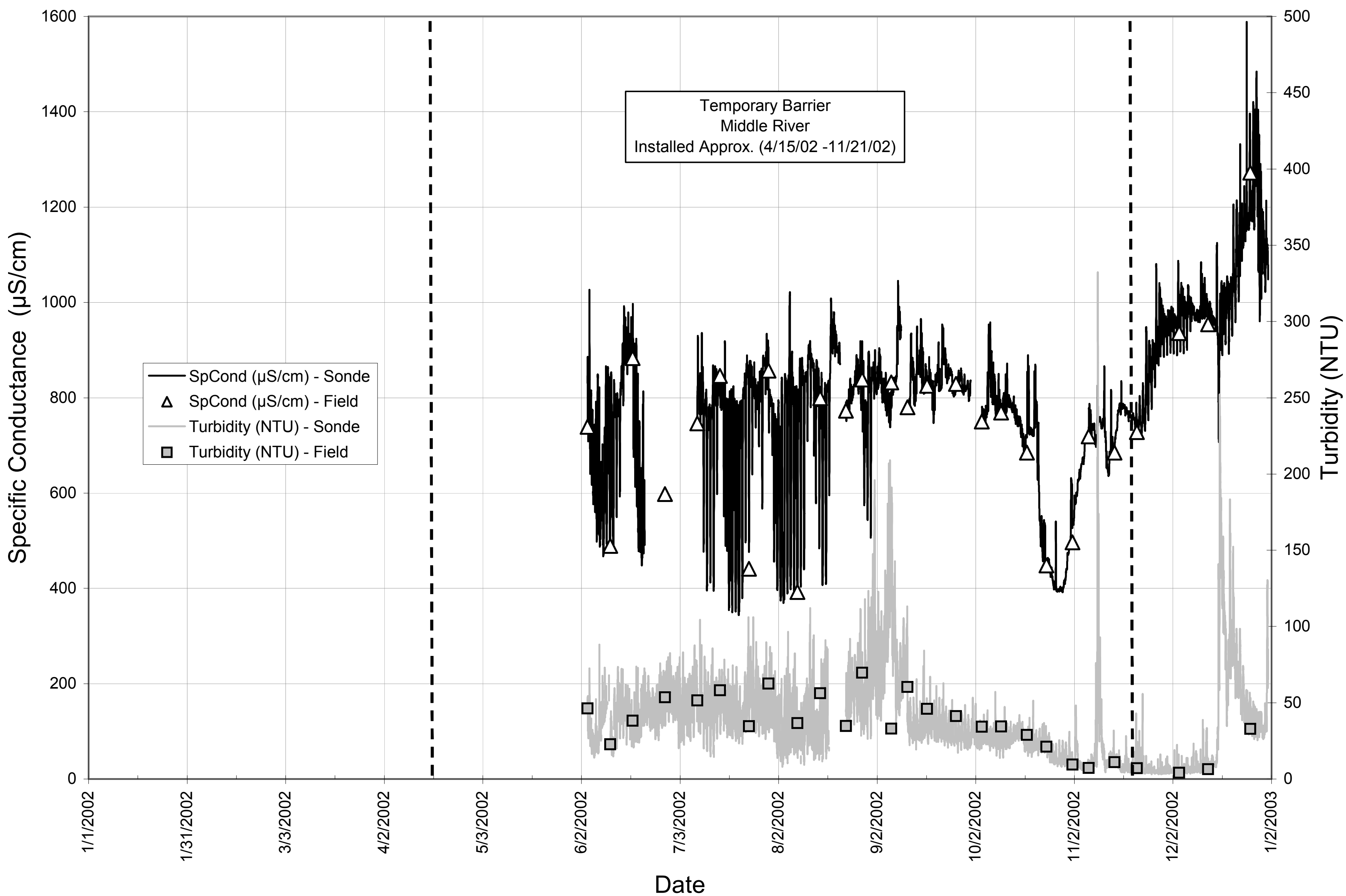
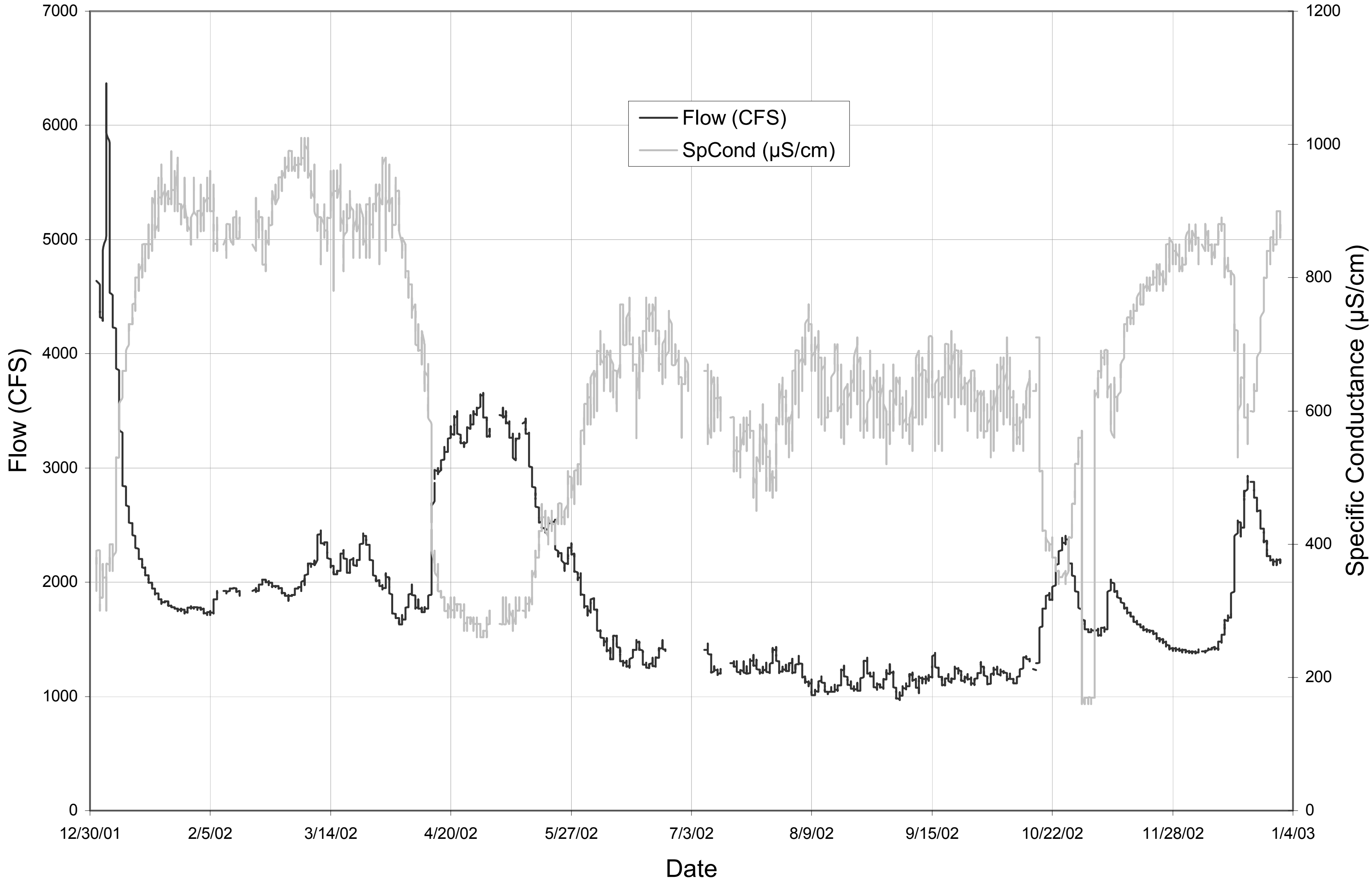


Figure 7-9 Flow and specific conductance in the San Joaquin River at Vernalis



Middle River at Undine Road

Water temperatures in the Middle River at Undine Road reached a maximum of 29.43 °C on July 13th at 14:00 PST and a minimum of 7.61 °C on December 26th at 07:45 PST. See Figure 7-10. A visual comparison of the 2002 water temperature plots for each of the five monitoring sites reveals similar global-scale patterns. This would seem reasonable as all five sites are located within 10 miles of each other and thus are subject to relatively similar atmospheric conditions year in and year out. The finer perturbations of water temperatures at each site would hence be subject to more local-scale phenomena.

Note that the Undine and Howard Road Stations reach their maximum and minimum values within a 24-hour span of each other. Temperature patterns at Undine Road seem to follow seasonal trends, with summer temperatures averaging more than 23°C, decreasing sharply during fall and averaging less than 15°C during late fall/early winter. The mean temperature for the duration of the monitoring period was 19.60 °C.

Dissolved oxygen data for the Middle River at Undine Road during 2002 are also plotted in Figure 7-10. DO concentrations reached a maximum of 17.79 mg/L on June 11th at 16:00 PST and were at a minimum of 3.97 mg/L on July 4th at 4:30 PST. Note that similar to the Howard Road data set a few portions of the summer and early fall DO data set were not included because excessive biological fouling of the dissolved oxygen probe(s) rendered the data inadmissible during these periods. There were only brief 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 5.98 mg/L. The lowest monthly mean DO was 8.65 mg/L in November and the highest was 10.24 mg/L in June. DO concentrations in the fall and early winter show less diel variation, which may be to due to the fact there is less daily variation in water temperature and generally, lower chlorophyll *a* / pheophytin *a* levels during the colder months. The overall mean DO concentration for Undine Road was 9.37 mg/L.

Typically, DO concentrations during the summer reached a maximum in the late afternoon and a minimum during the early morning. This could be attributed, at least in part, to daily water temperature variation and high chlorophyll *a* and pheophytin *a* levels. Dissolved oxygen and water temperature data are plotted in Figure 7-11 for July 9th at 6:30 PST when chlorophyll *a* and pheophytin *a* concentrations were 90.8 µg/L and 32.2 µg/L respectively, indicating a possible algal bloom. Since oxygen solubility decreases as temperature increases it is interesting to note the positive relationship seen between dissolved oxygen and water temperature in Figure 7-11. Temperature and dissolved oxygen reach a minimum and a maximum within 15 minutes of each other. This may indicate that daily fluctuations in dissolved oxygen are primarily due to photosynthesis and respiration during an algal bloom. Further analysis of dissolved oxygen concentrations at high and low chlorophyll *a* and pheophytin *a* concentrations at multiple sites would be needed to make any definitive conclusions. One hour dissolved oxygen and chlorophyll *a* / pheophytin *a* data for 24-hour intervals would be useful in discerning a relationship.

Figure 7-10 also depicts 2002 pH data in the Middle River at Undine Road. Recorded pH data ranged from a high of 9.37 on June 28th at 14:00 PST to a low of 7.28 on October 24th at 9:45 PST. No pH values greater than 9.0 were recorded after September 17th and the maximum field reading recorded was 9.11. Three field readings recorded pH values greater than 9. For duration of monitoring in 2002, pH at Undine Road averaged 7.97 and the highest monthly mean pH was 8.80 in July.

Figure 7-10 Middle River at Undine Road: Water temperature, dissolved oxygen and pH continuous water quality data

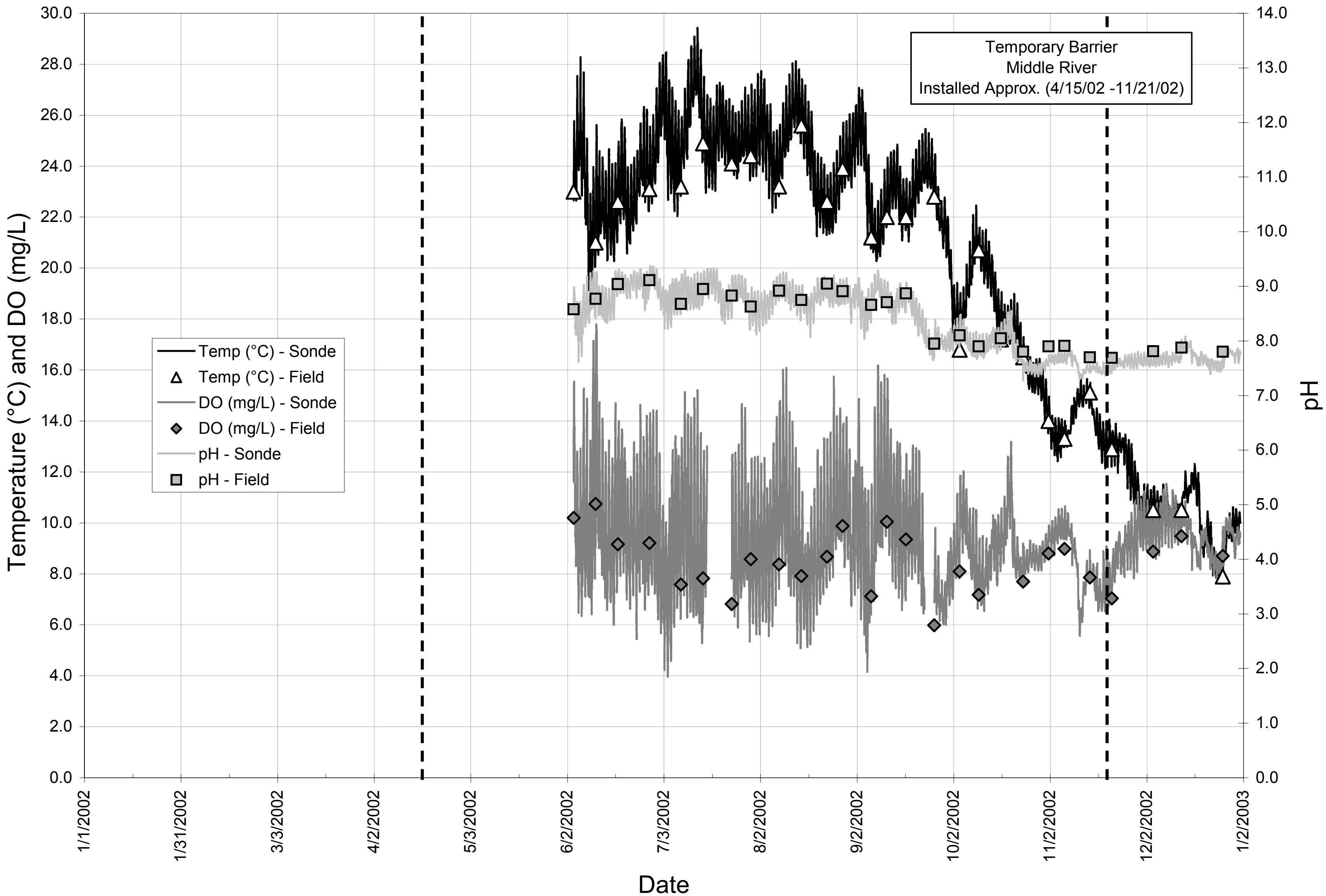
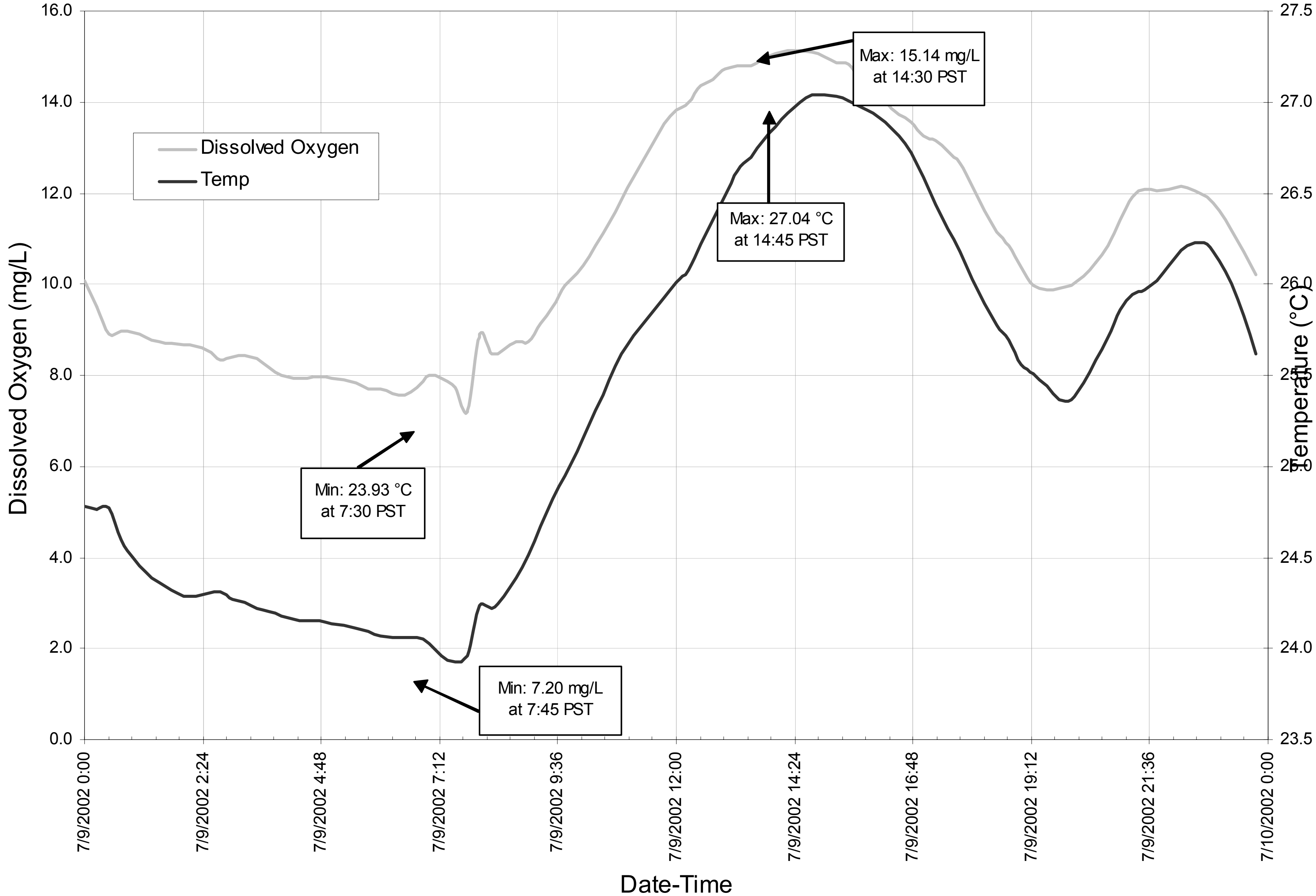


Figure 7-11 Dissolved oxygen and water temperature on July 9th, 2002: Middle River at Undine Road



Similar to water temperature and dissolved oxygen data, pH data exhibited greater diel fluctuations during the summer, and noticeably less during fall and winter. pH seemed to have a direct relationship with dissolved oxygen. Figure 7-12 shows a plot of dissolved oxygen and pH data for August 15th. 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. The chlorophyll *a* and pheophytin *a* concentrations on August 15th at 9:00 PST were 130.0 µg/L and 39.1 µg/L, respectively, possibly indicating a severe algae bloom. Further analysis of dissolved oxygen and pH data at high and low chlorophyll *a* and pheophytin *a* concentrations at multiple sites would be needed to make any definitive conclusions.

Specific conductance data for the Undine Road site is shown in Figure 7-13. A maximum of 1440.8 µS/cm was recorded on December 31st at 8:00 PST. The minimum-recorded specific conductance was 387.7 µS/cm on October 27th at 6:15 PST. The mean for the monitoring period was 776.6 µS/cm. Generally, from early June through mid-October there were no noteworthy oscillations in specific conductance values like there were at Howard Road, probably because of less tidal influence. A notable decrease in specific conductance similar to Howard Road was recorded beginning on October 20th, reaching a minimum on October 27th after which values began rising. Late fall and early winter specific conductance values were elevated compared to the rest of the monitoring period, with December values averaging 885.7 µS/cm.

Figure 7-13 also portrays turbidity data at this site. Turbidities ranged from a high of 297.1 NTU on December 16th at 19:00 PST to a low of 3.9 NTU on November 25th at 11:00 PST. Note that a few portions of the summer and early fall Turbidity data set were not included because excessive biological fouling of the turbidity probe(s) rendered the data inadmissible during these periods. Data missing from October 2nd – 21st was due to turbidity probe malfunction. Generally, turbidity readings were higher in summer and early fall and lower in late fall and early winter. Turbidity spikes in November and December were similar to those noted at the Howard Road monitoring station. The lowest average turbidity was 10.3 NTU in November and the overall mean was about 34.9 NTU.

Old River at Delta Mendota Canal

Water temperatures in the Old River at DMC reached a maximum of 26.95 °C on July 13th at 16:00 PST and a minimum of 8.38 °C on December 26th at 8:45 PST. See Figure 7-14. Temperature patterns at the DMC monitoring station are similar to those previously discussed. July water temperatures were the warmest averaging 23.40 °C, while December temperatures were the coldest averaging 10.56 °C. The mean temperature for the duration of the monitoring period was 18.83 °C. The DMC monitoring station had the lowest mean water temperature of the five continuous sites.

Dissolved oxygen data for the Old River at DMC during 2002 are also plotted in Figure 7-14. DO concentrations reached a maximum of 10.80 mg/L on December 11th at 11:00 PST and were at a minimum of 0.48 mg/L on August 16th at 16:00 PST. There were numerous times during the summer when the sonde(s) recorded DO concentrations less than 5 mg/L and even 3 mg/L. 10 field readings (modified Winkler titration) were less than 5 mg/L and three were below 3 mg/L, with the lowest being 2.12 mg/L. Mean DO concentrations in July, August and September were less than 5 mg/L. The lowest monthly mean was 3.35 mg/L in September and the highest was 9.28 mg/L in December. DO concentrations seemed to sag during the warm summer months before increasing in late fall and early winter. The overall mean DO concentration for DMC was 5.68 mg/L, remarkably lower than the other four stations.

Figure 7-12 Dissolved oxygen and pH on August 15th, 2002: Middle River at Undine Road

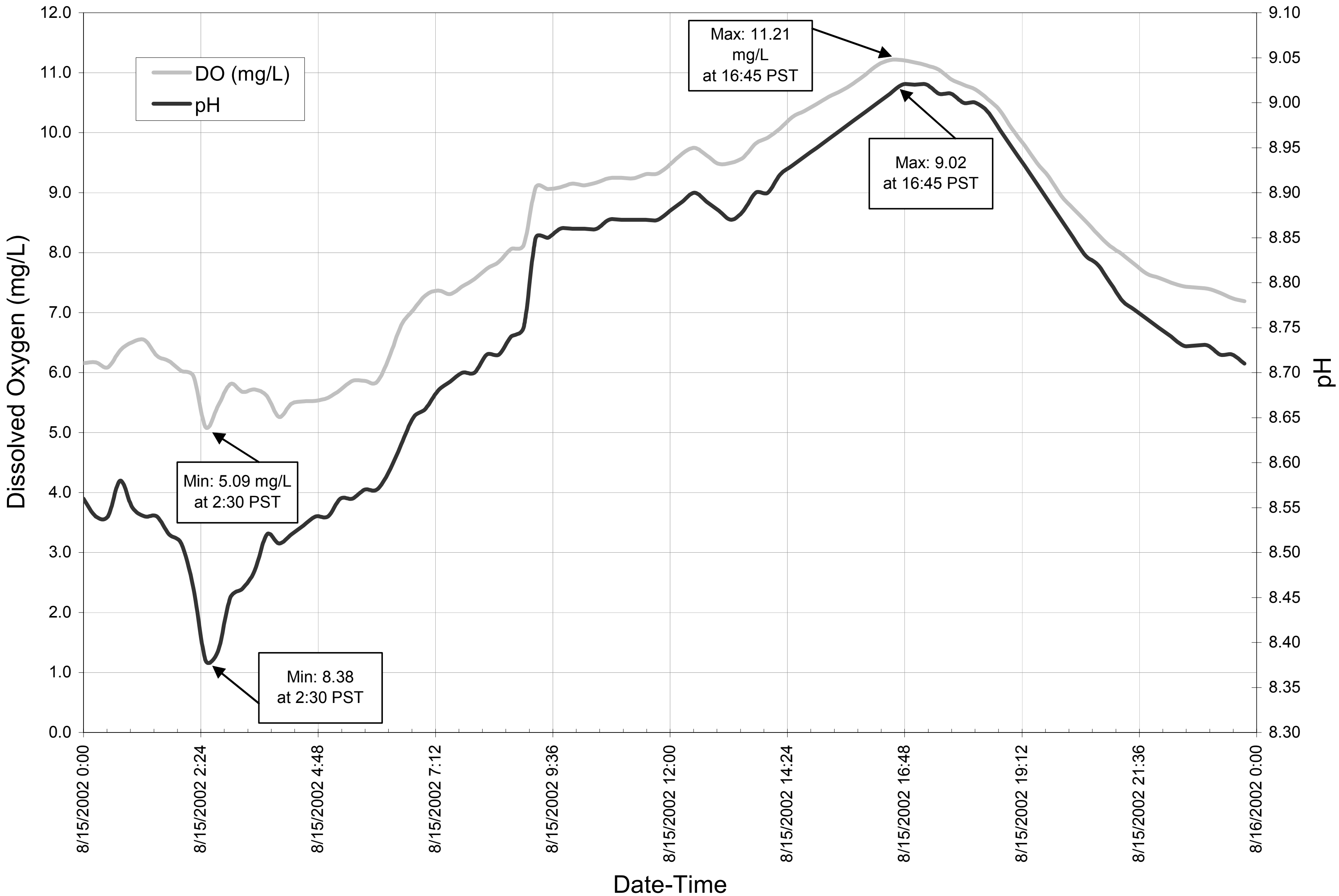


Figure 7-13 Middle River at Undine Road: Specific conductance and turbidity continuous water quality data

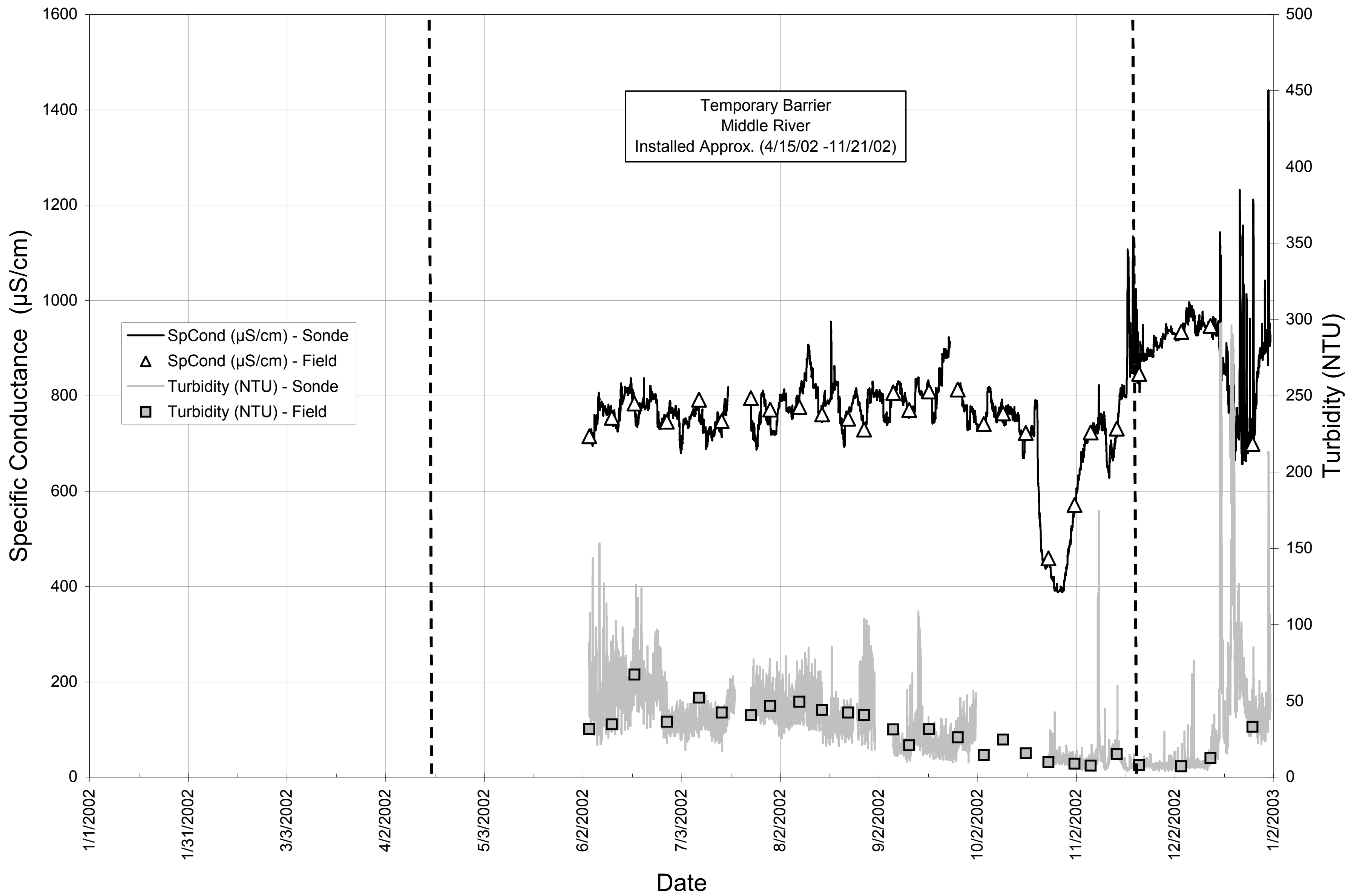
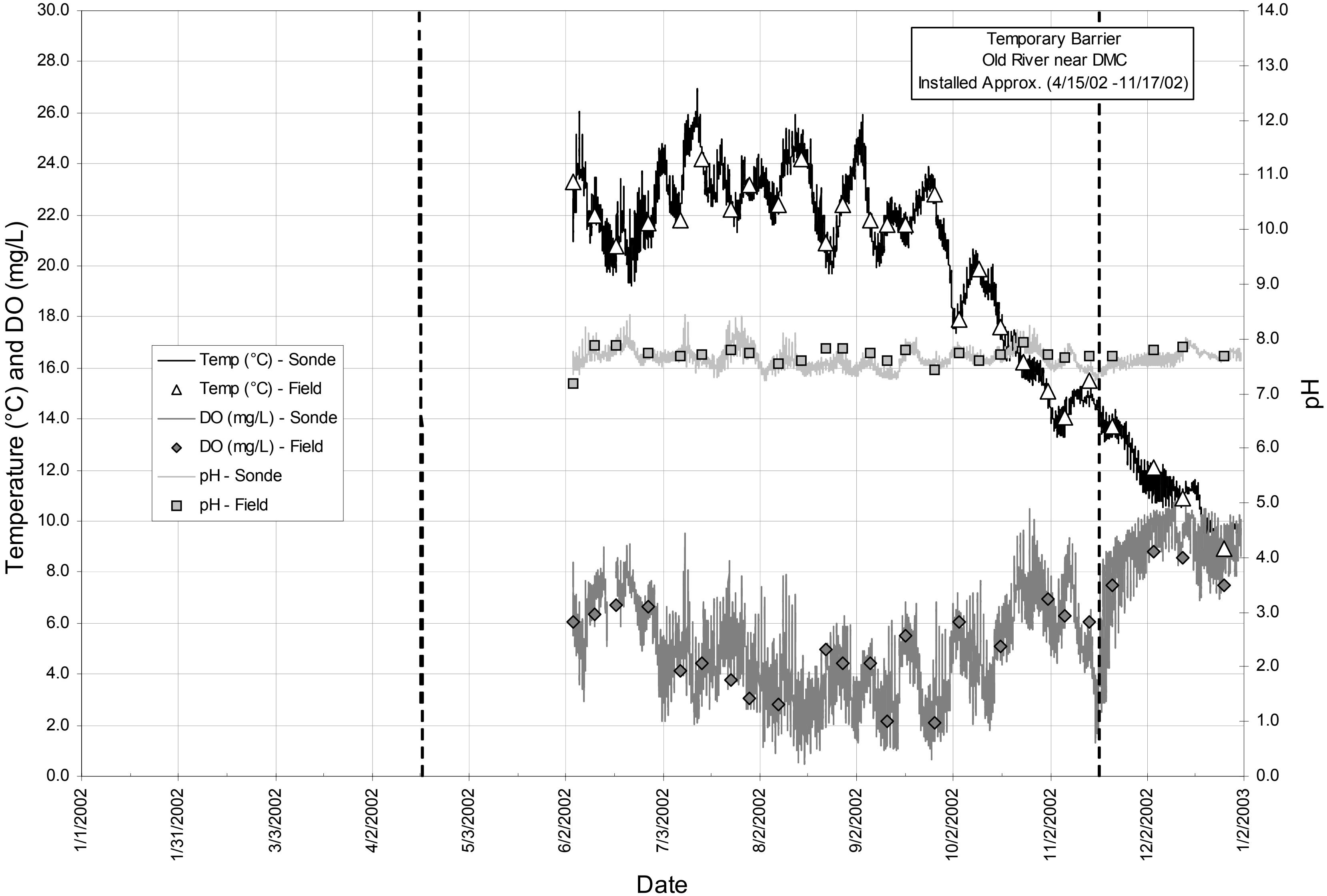


Figure 7-14 Old River at Delta Mendota Canal: Water temperature, dissolved oxygen and pH continuous water quality data



2002 pH data in the Old River at DMC is shown in Figure 7-14. Recorded pH data ranged from a high of 8.45 on June 22nd at 19:15 and July 9th at 21:15 PST to a low of 7.24 on August 4th at 8:00 PST and November 16th at 6:00 PST. No pH values greater than 8.5 were recorded and the maximum field reading was 7.93. For the duration of monitoring in 2002, pH at DMC averaged 7.61 and the highest monthly mean was 7.73 in October. DMC had the lowest mean pH of the five monitoring stations.

Figure 7-15 illustrates specific conductance data for 2002 at the DMC site. A maximum of 1311.6 µS/cm was recorded on October 16th at 13:45 PST. The minimum-recorded specific conductance was 293.8 µS/cm on June 24th at 6:45 PST. The mean for the monitoring period was 869.9 µS/cm. While the barrier was in place dramatic variation in specific conductance values, likely due to tidal influences, can be seen, but not on a daily or consistent basis. However, once the barrier was removed daily shifts in specific conductance values occurred regularly. Monthly mean specific conductance values increased during summer and early fall from a low of 481.5 µS/cm in June to a high of 1084.3 µS/cm in October before decreasing in late fall and early winter.

Figure 7-15 also shows turbidity data at this site. Turbidities ranged from a high of 142.6 NTU on November 24th at 16:15 PST to a low of 2.1 NTU on August 18th at 10:00 PST. Turbidity readings averaged a high of 21.1 NTU in June and averaged a low of 9.9 NTU in August. Generally, summer turbidity readings were the lowest, with values fluctuating more visibly in late fall and early winter. For the monitoring period the average turbidity reading was about 14.8 NTU, which was about 10 NTU's lower than any other site.

Old River at Tracy Wildlife Association

Water temperatures in the Old River at TWA reached a maximum of 28.79 °C on July 20th at 16:45 PST and a minimum of 8.24 °C on December 26th at 8:30 PST. See Figure 7-16. Temperature patterns at the TWA monitoring station are similar to those previously discussed. July water temperatures were the warmest averaging 25.38 °C, while December temperatures were the coldest averaging 10.34 °C. The mean water temperature during the monitoring period was 19.79 °C.

Dissolved oxygen data for the Old River at TWA during 2002 are also plotted in Figure 7-16. DO concentrations reached a maximum of 19.05 mg/L on July 8th at 18:30 PST and were at a minimum of 0.08 mg/L on June 21st at 6:15 PST. There were numerous times during the summer when the sonde(s) recorded DO concentrations less than 5 mg/L and even 3 mg/L. Two field readings (modified Winkler titration) were less than 5 mg/L and none were below 3 mg/L, with the lowest being 4.12 mg/L. The lowest monthly DO mean was 5.92 mg/L in September and the highest was 8.49 mg/L in December. Diel variation in DO concentrations was evident during the summer with values fluctuating wildly, where as in late fall and early winter there is noticeably less variation. The overall mean DO concentration for TWA was 7.14 mg/L.

Figure 7-16 also depicts 2002 pH data in the Old River at TWA. Recorded pH data ranged from a high of 9.28 on July 8th at 18:30 PST to a low of 7.12 on September 27th at 13:15 PST. Note that the pH maximum was recorded at the exact same date and time as the dissolved oxygen maximum. Also, similar to DO, pH values show noticeably less fluctuation during the late fall and early winter in comparison to summer and early fall. No pH values greater than 9.0 were recorded after July 20th and the maximum field reading recorded was 8.65. No field readings were greater than 9. In 2002, pH at TWA averaged 7.76 and the highest monthly mean pH was 8.38 in July.

Figure 7-15 Old River at Delta Mendota Canal: Specific conductance and turbidity continuous water quality data

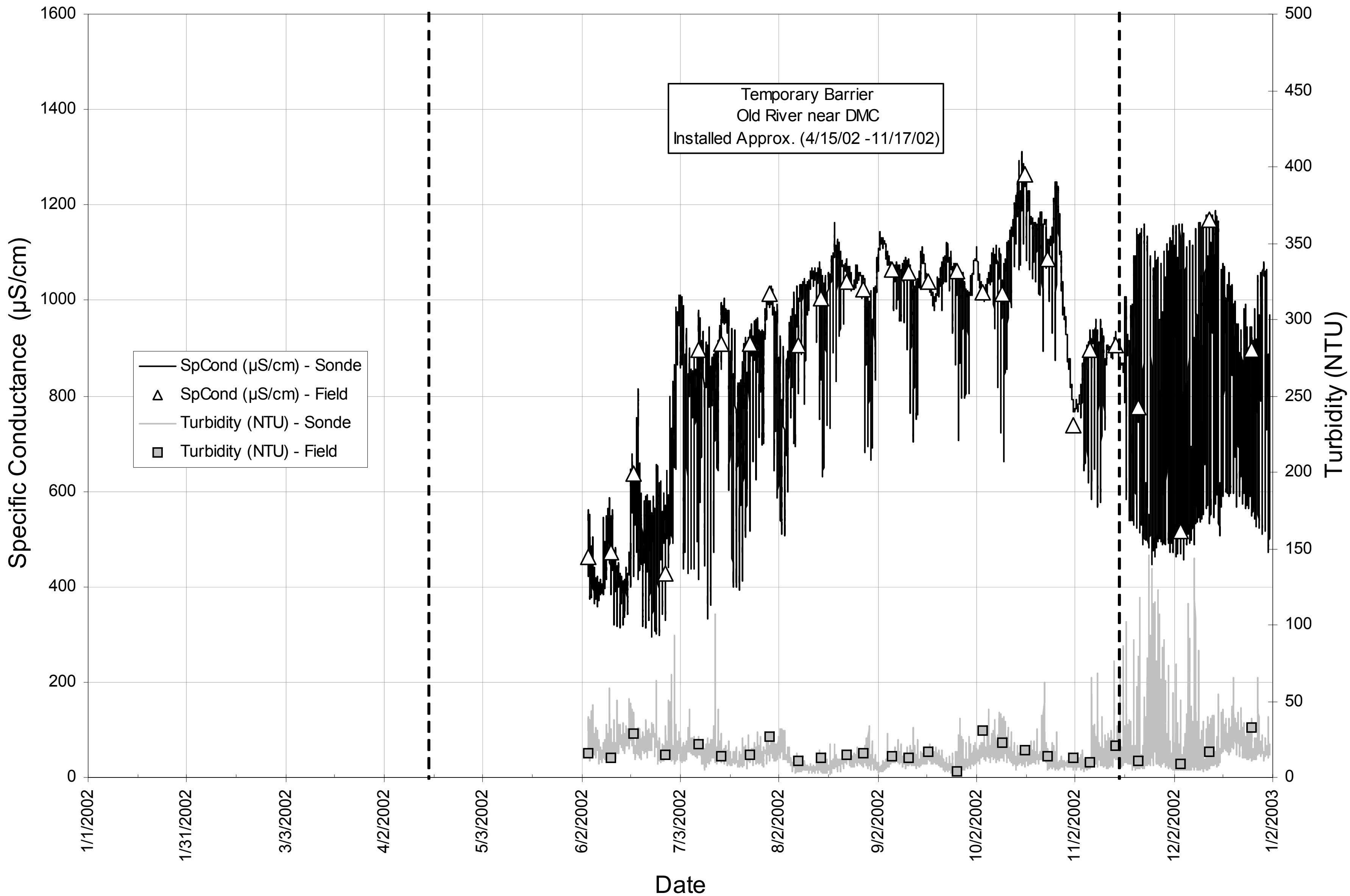
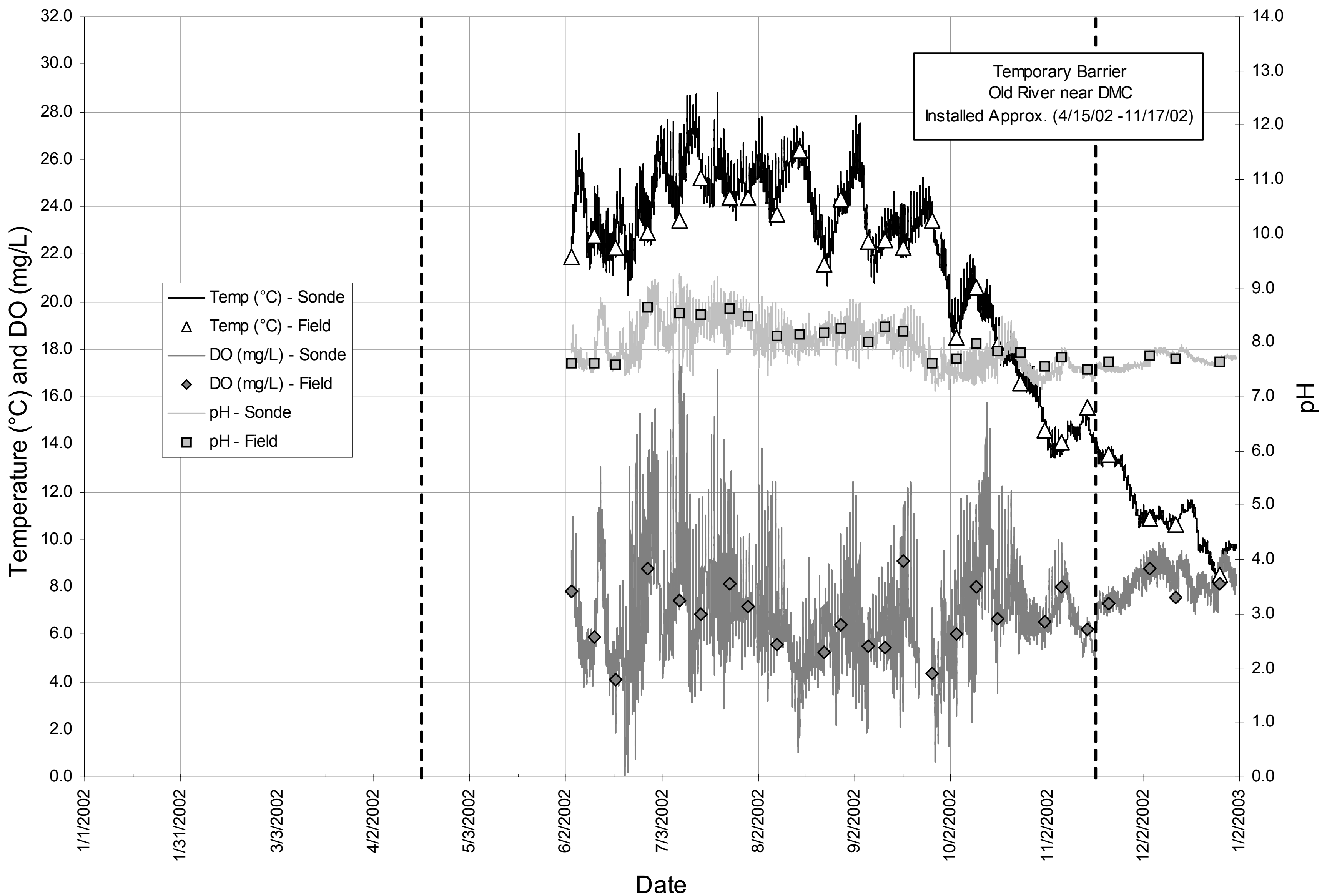


Figure 7-16 Old River at Tracy Wildlife Association: Water temperature, dissolved oxygen and pH continuous water quality data



Specific conductance data for the TWA site is shown in Figure 7-17. A maximum of 1274.8 µS/cm was recorded on November 19th at 23:00 PST. The minimum-recorded specific conductance was 559.1 µS/cm on October 30th at 6:00 PST. The mean for the monitoring period was 909.0 µS/cm. Generally, from early June through mid-October there were no noteworthy oscillations in specific conductance values like there were at DMC, probably because of less tidal influence. A notable decrease in specific conductance similar to the other four stations was recorded beginning on October 23rd, reaching minimum on October 30th after which values began rising. Specific conductance values also showed a marked decrease beginning on December 14th, reaching a minimum on December 20th.

Figure 7-17 also depicts turbidity data at this site. Turbidities ranged from a high of 179.9 NTU on September 21st at 7:15 PST to a low of 7.7 NTU on September 28th at 9:30 PST. Note that a few portions of the summer and early fall Turbidity data set were not included because excessive biological fouling of the turbidity probe(s) rendered the data inadmissible during these periods. Data missing from November 6th – December 4th was due to a turbidity probe malfunction. Generally, turbidity readings were higher in summer and early fall averaging over 29 NTU; however, the mean turbidity in December was 41.2 NTU. The lowest average turbidity was 11.7 NTU in November and the overall mean was about 31.2 NTU.

Old River Near Head

Note: No data was collected at this station from September 28th – October 3rd due to battery failure. Water temperatures in the Old River Near Head reached a maximum of 31.27 °C on July 11th at 15:30 PST and a minimum of 7.86 °C on December 26th at 11:30 PST. See Figure 7-18. Temperature patterns at the Head monitoring station are similar to those previously discussed. July water temperatures were the warmest averaging 25.77 °C, while December temperatures were the coldest averaging 10.44 °C. The mean water temperature during the monitoring period was 19.76 °C.

Dissolved oxygen data for the Old River Near Head during 2002 are also plotted in Figure 7-18. DO concentrations reached a maximum of 17.65 mg/L on June 12th at 15:00 PST and were at a minimum of 3.50 mg/L on October 23rd at 7:15 PST. There were a few times during the summer when the sonde(s) recorded DO concentrations less than 5 mg/L, but none less than 3 mg/L. No field readings (modified Winkler titration) were less than 5 mg/L, with the lowest being 6.66 mg/L. The lowest monthly mean was 7.26 mg/L in October and the highest was 11.33 mg/L in June. Diel variation in DO concentrations was evident during the summer with values fluctuating considerably, where as in late fall and early winter there was clearly less variation. The overall mean DO concentration for Head was 9.50 mg/L, the highest of all five stations.

Figure 7-18 also depicts 2002 pH data in the Old River Near Head. Recorded pH data ranged from a high of 9.56 on June 25th at 17:15 PST to a low of 7.34 on November 21st at 10:30 PST. No pH values greater than 9.0 recorded after September 17th and the maximum field reading recorded was 9.23. Six field readings recorded a pH value greater than 9.0. In 2002, pH at Head averaged 8.03 and the highest monthly mean pH was 9.00 in June. The Head site had the highest mean pH of all the monitoring stations.

Specific conductance data for the Head monitoring station is shown in Figure 7-19. A maximum of 1003.1 µS/cm was recorded on December 10th at 14:45 PST. The minimum-recorded specific conductance was 385.1 µS/cm on October 28th at 10:00 PST. The mean for the monitoring period was 773.2 µS/cm. Generally, from early June through mid-October there were no noteworthy oscillations in specific electrical conductivity, likely, because of less tidal influence. Specific conductance at the Head monitoring station is, probably, primarily influenced by the San Joaquin River. A visual comparison between Figure 7-19 and Figure 7-9 shows that the specific conductance pattern at this site and at the San Joaquin River at Vernalis are quite similar. A notable decrease in specific conductance similar to the other four stations was recorded beginning on October 20th, reaching a minimum on October 28th after which values began rising.

Specific conductance values also showed a marked decrease beginning on December 13th, reaching a minimum on December 19th.

Figure 7-19 also depicts turbidity data at this site. Turbidities ranged from a high of 309.3 NTU on December 16th at 8:45 PST to a low of 5.4 NTU on October 9th at 16:15 PST. Data missing from June 4th – July 7th was due to a turbidity probe malfunction. Generally, turbidity readings were high from June through September averaging over 22 NTU; however, the mean turbidity in December was 40.1 NTU. Turbidity dropped fairly abruptly from September to October with the monthly average decreasing from 22.9 NTU to 8.7 NTU. The overall mean was about 24.5 NTU.

Figure 7-17 Old River at Tracy Wildlife Association: Specific conductance and turbidity continuous water quality data

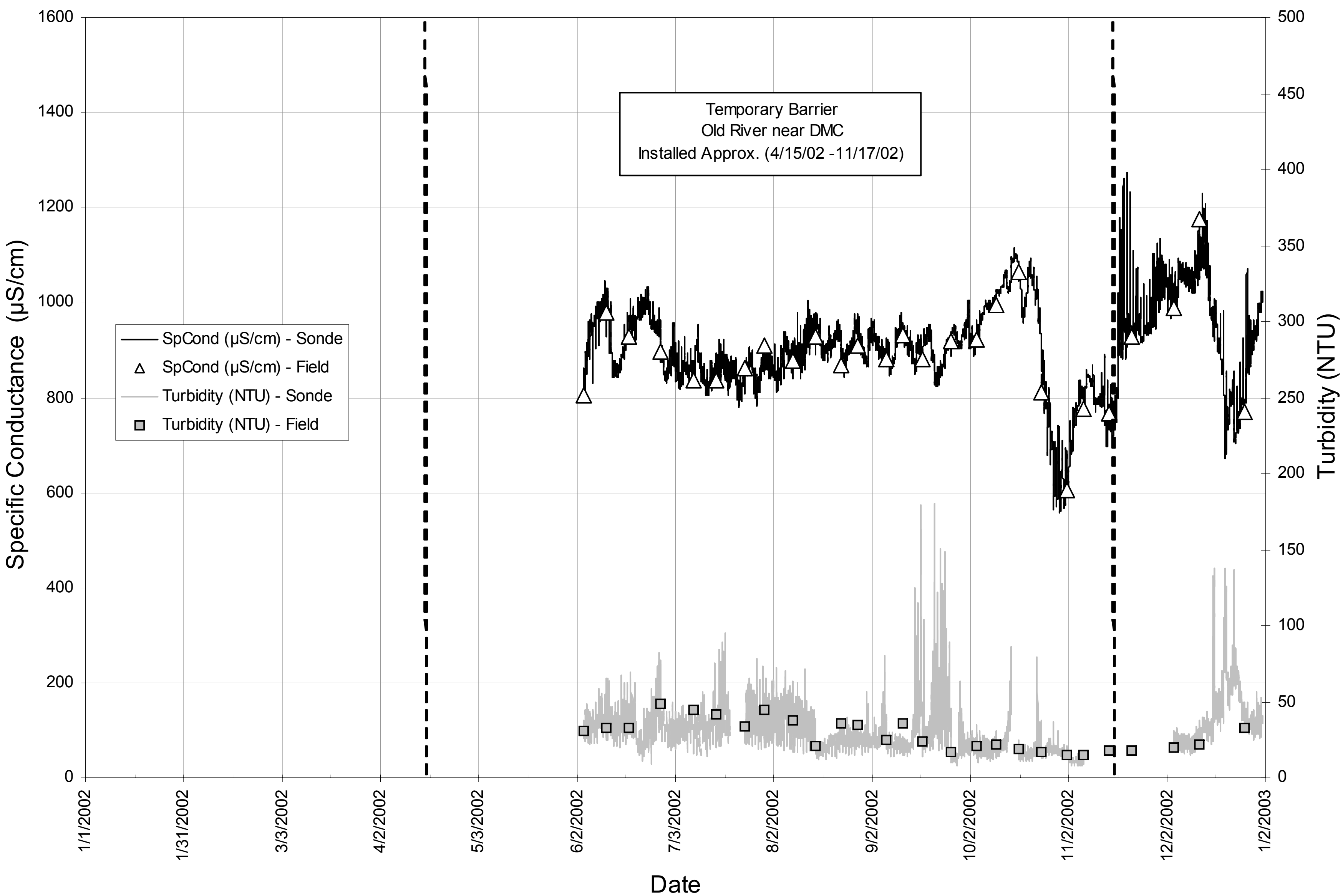


Figure 7-18 Old River near Head: Water temperature, dissolved oxygen and pH continuous water quality data

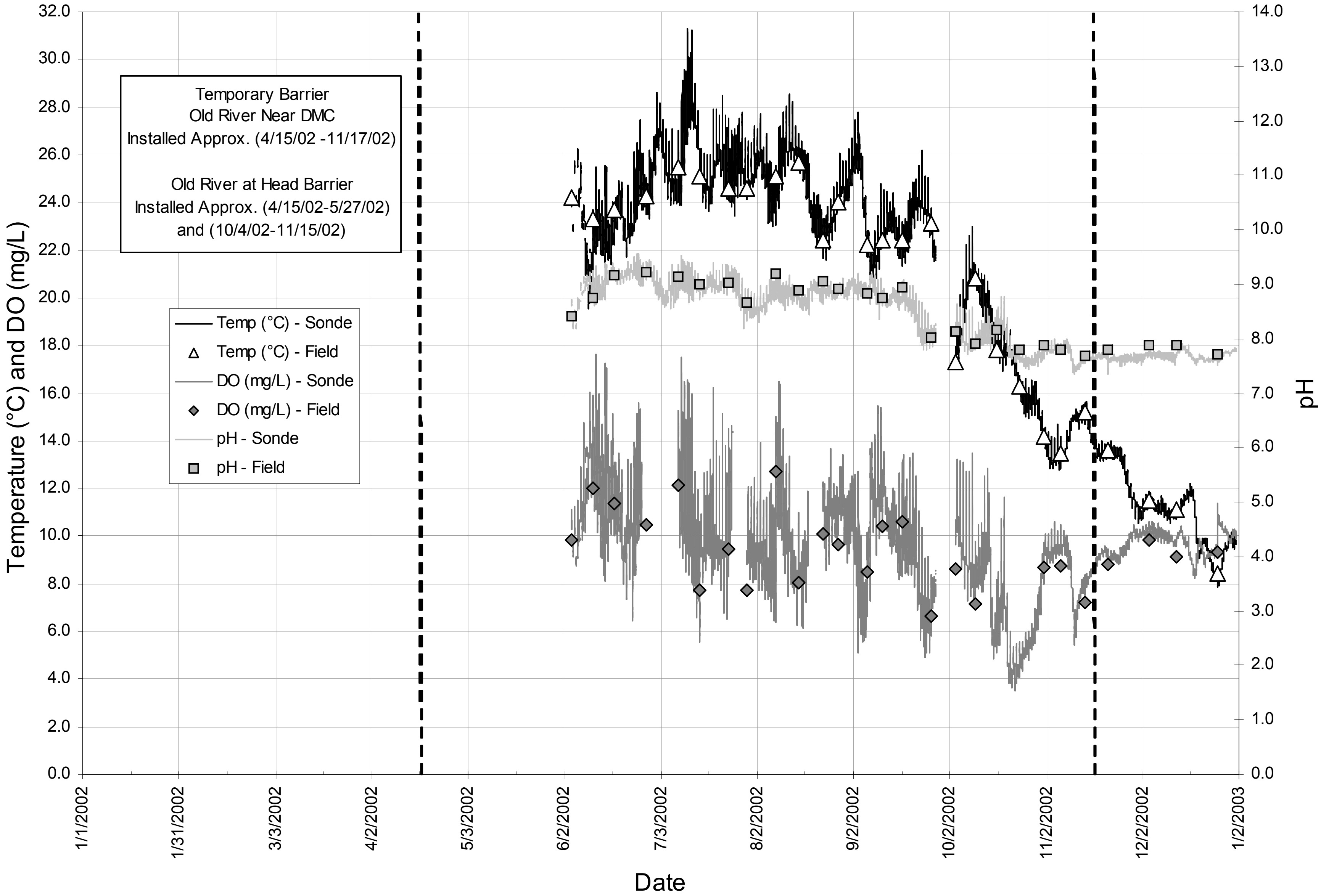
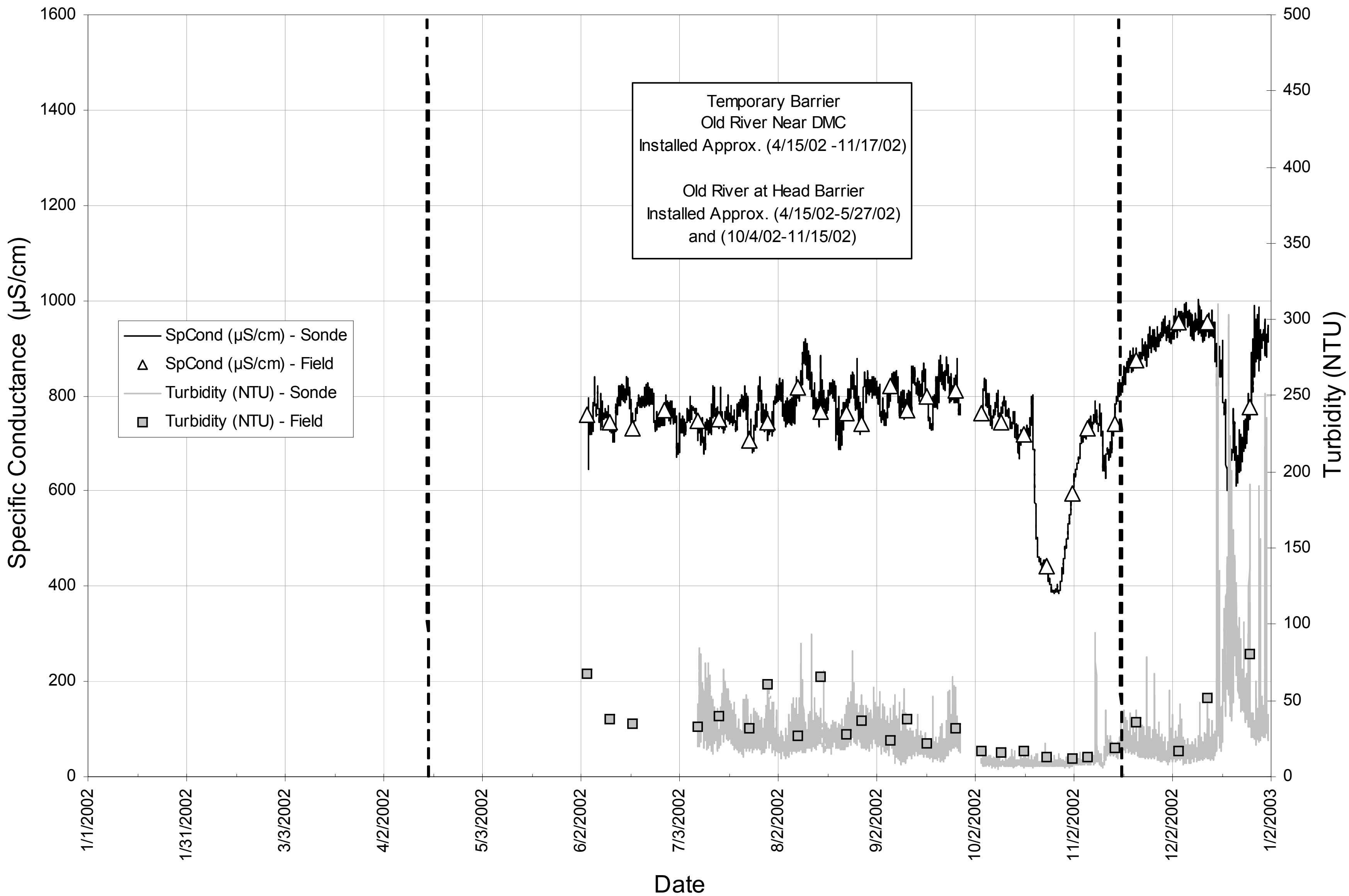


Figure 7-19 Old River near Head: Specific conductance and turbidity continuous water quality data



Conclusions

For all water quality monitoring sites, field data generally corresponded quite well with the continuously measured sonde data. This provides a higher level of confidence that the data obtained during 2002 was generally reliable. There were instances during the hot summer months that field and sonde data discrepancies occurred. Much of this may be due to excessive biological fouling on the sonde probes. Care was taken during weekly field visits to reduce the level of biological fouling. There were occasions however, when the hand-held field instrumentation was not working correctly and thus, a data discrepancy occurred. Generally, errors in field readings were easily detected, as they tended to be off at each site visited throughout the field day. Sonde data that was known to be “corrupted” by biological fouling was omitted. This is why there are a few gaps in the various data sets. Currently, Central District staff is in the process of shipping the 6600 sondes back to YSI for an upgrade to the new 6600 EDS (Extended Deployment System) model. The newer system allows all the probes to be wiped where as only the turbidity probe was wiped before. This should reduce the amount of biological fouling on the probes and further ensure the collection of high quality data.

Tables 7-11A and 7-11B provide a basic statistical summary of the 2002 water quality data collected from the five 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 7-20 through 7-24 show graphical representations of the data in Tables 7-11A and 7-11B. Refer to these tables and figures in the following discussion of 2002 time-series water quality data for the South Delta.

Maximums and minimums for water temperature at all sites tended to occur when expected: they were high during warm summer months, low during winter, and intermediate in fall as temperatures began to decline. Water temperatures were most variable in fall and least variable during winter. Table 7-11A and Figure 7-20 show monthly and yearly water temperature comparisons between all five monitoring sites. There were not many notable temperature differences between stations. Average water temperatures varied by less than 1°C during the monitoring the period, with four stations differing by only 0.22 °C. For 2002, Middle River at Howard Road and Old River at DMC had an average temperature difference of 0.99 °C, the greatest difference between stations. The only station to record a temperature greater than 30.0 °C was Old River Near Head, which recorded a maximum of 31.27 °C on July 11th at 15:30 PST.

Figure 7-21 and Table 7-11A illustrate monthly differences in dissolved oxygen concentrations between the five monitoring locations. Dissolved oxygen concentrations at the Old River Near Head and Middle River at Undine Road were elevated in the summer and winter, and slightly depressed during the fall. DO in the Middle River at Howard Road and the Old River at TWA tended to be low during the summer, before increasing in fall and winter. Old River at DMC had extremely low DO concentrations in the summer months, especially in August and September, after which values increased during fall and winter. High water temperatures alone, probably, would not account for the low dissolved oxygen concentrations seen at the DMC and even TWA sites. Algae and/or microorganisms, especially bacteria may be contributing to low DO concentrations observed at these sites. Average DO concentrations in the Old River decreased from 9.50 mg/L at the upstream site, Head, to 5.68 mg/L at downstream site, DMC, with the intermediate monitoring station, TWA averaging 7.14 mg/L. Generally, variation in DO concentrations was high during the summer and early fall and lower in the late fall and early winter.

During the summer, noticeably higher maximum, minimum and average pH values were seen at the Old River at Head and Middle River at Undine Road sites. From June through August, pH values at the Middle River at Howard Road station were more variable than at the other four stations. Average pH readings at the Old River at DMC monitoring station were consistently low relative to the other South Delta sites from June through September. Generally, pH values were more variable in the summer and early fall than in late fall and early winter. Overall, pH values were high from June through September with some maximums exceeding 9.0, after which values decreased. See Figure 7-22 and Table 7-11A.

Monthly differences in specific conductivity between stations can be reviewed in Figure 7-23 and Table 7-11B. Specific conductance was more variable during June, July, and August at the Middle River at Howard Road and Old River at DMC monitoring sites and just at the DMC site in November and December. Variation in specific conductance was most pronounced at all five South Delta sites from October through November. The highest maximum specific conductance readings occurred in December and the lowest in June. In October, average specific conductance in the Middle River at Howard Road, Middle River at Undine Road and Old River Near Head were notably lower than the other two monitoring sites. Overall, average specific conductance in the South Delta ranged from a low of 773.2 µS/cm at the Old River at Head to a high of 909.0 µS/cm at the Old River at TWA.

Figure 7-24 and Table 7-11B shows statistics of the turbidity data recorded at each of the five South Delta continuous monitoring sites. Due to the nature of the optic turbidity sensors, recorded peak turbidities can be misleading. At the instantaneous time of measurement (every 15 minutes in 2001) suspended sediment and other particles (leaves, fish, etc.) passing in front of the light beam from the optic sensor will influence the reported turbidity data. A mathematical filtering function was utilized for each turbidity sensor to minimize such peak fluctuations, so that a more average picture of turbidity at each site was being recorded. Generally, the data were carefully QC'ed to eliminate anomalous turbidity peaks. Although statistical maximums, minimums, and calculated ranges were determined for each water quality parameter, for turbidity the averages are the most important. The Old River at DMC site had the highest average water clarity (least turbid) during the 2002 sampling period. In general, turbidity at all five sites was lower during fall and higher during summer and early winter. High summer turbidity readings were seen at all sites except DMC. Turbidity was most variable in December, likely due to storm events.

Table 7-11A Statistical Summary: 2002 Continuous Water Quality Data

Month	Water Temperature (¡C)					Dissolved Oxygen (mg/L)					pH				
	DMC	TWA	HEAD	HOWARD	UNDINE	DMC	TWA	HEAD	HOWARD	UNDINE	DMC	TWA	HEAD	HOWARD	UNDINE
Jan. - Max.	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Jan. - Avg.	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Jan. - Min.	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Jan. - S.D.	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Feb. - Max.	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Feb. - Avg.	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Feb. - Min.	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Feb. - S.D.	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Mar. - Max.	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Mar. - Avg.	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Mar. - Min.	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Mar. - S.D.	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Apr. - Max.	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Apr. - Avg.	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Apr. - Min.	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Apr. - S.D.	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
May - Max.	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
May - Avg.	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
May - Min.	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
May - S.D.	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Jun. - Max.	26.05	27.09	27.49	27.96	28.28	9.12	15.52	17.65	11.72	17.79	8.45	9.16	9.56	9.19	9.37
Jun. - Avg.	(21.66)	(23.21)	(23.37)	(23.53)	(23.10)	(6.71)	(6.78)	(11.33)	(6.79)	(10.24)	(7.72)	(7.83)	(9.00)	(7.73)	(8.74)
Jun. - Min.	19.25	20.28	19.54	19.62	19.13	2.93	0.08	6.44	3.55	5.45	7.35	7.39	8.18	7.17	7.62
Jun. - S.D.	1.20	1.21	1.27	1.57	1.65	0.95	2.58	1.85	1.73	2.29	0.14	0.42	0.23	0.54	0.31
Jul. - Max.	26.95	28.79	31.27	29.08	29.43	9.49	19.05	17.53	13.88	15.21	8.45	9.28	9.52	9.23	9.33
Jul. - Avg.	23.40	25.38	25.77	25.98	25.41	4.70	7.88	(10.44)	(7.80)	(9.14)	7.68	8.38	8.88	8.08	8.80
Jul. - Min.	21.34	23.31	23.45	22.90	22.03	2.06	2.91	5.57	2.03	3.97	7.28	7.38	8.20	7.15	8.20
Jul. - S.D.	1.10	1.01	1.26	1.19	1.39	1.11	2.12	1.97	2.35	2.35	0.19	0.24	0.20	0.52	0.23
Aug. - Max.	25.92	27.77	28.54	28.48	28.12	7.88	13.84	16.47	15.02	16.09	8.10	8.85	9.16	9.07	9.26
Aug. - Avg.	22.82	24.57	24.75	24.90	24.42	3.51	6.12	(10.07)	7.77	9.55	7.51	8.08	8.78	(7.87)	8.74
Aug. - Min.	19.68	20.70	21.60	21.52	21.25	0.48	1.00	6.16	2.00	5.09	7.24	7.38	8.31	7.18	8.07
Aug. - S.D.	1.37	1.41	1.35	1.42	1.58	1.27	1.61	1.65	2.40	2.18	0.12	0.19	0.14	0.55	0.20
Sep. - Max.	25.90	27.85	27.80	27.81	27.07	6.84	12.42	15.47	14.21	16.18	8.01	8.79	9.19	9.02	9.29
Sep. - Avg.	22.14	23.24	(23.27)	23.27	23.00	3.35	(5.92)	(9.48)	(9.12)	(9.52)	7.51	7.84	(8.52)	8.25	8.34
Sep. - Min.	19.93	20.81	20.67	20.22	20.27	0.66	0.66	4.91	3.18	4.16	7.26	7.12	7.79	7.65	7.65
Sep. - S.D.	1.20	1.22	1.36	1.50	1.43	1.28	1.69	1.99	1.81	2.26	0.15	0.32	0.33	0.36	0.39
Oct. - Max.	20.63	21.98	23.00	21.61	22.45	10.41	15.74	13.39	13.46	13.18	8.25	8.47	8.77	8.63	8.55
Oct. - Avg.	17.71	18.48	(18.01)	18.19	18.11	5.72	7.37	(7.26)	(9.25)	8.98	7.73	7.52	(7.85)	7.94	7.80
Oct. - Min.	14.95	14.97	14.34	14.02	14.04	1.79	1.27	3.50	6.81	6.54	7.52	7.15	7.44	7.47	7.28
Oct. - S.D.	1.56	1.64	1.95	1.78	1.84	1.57	1.94	2.14	1.03	1.10	0.12	0.24	0.27	0.22	0.28
Nov. - Max.	15.26	15.57	15.62	15.84	15.66	10.10	9.98	10.59	11.63	11.21	7.92	7.90	8.00	8.11	7.83
Nov. - Avg.	13.91	13.72	13.62	13.39	13.41	6.69	7.14	8.97	9.10	8.65	7.52	7.50	7.67	7.69	7.57
Nov. - Min.	11.43	10.96	10.76	10.36	10.40	1.34	4.75	5.45	5.96	5.57	7.24	7.24	7.34	7.38	7.30
Nov. - S.D.	0.85	0.97	0.98	1.18	1.13	1.87	0.92	0.90	1.24	1.12	0.12	0.10	0.11	0.16	0.11
Dec. - Max.	12.38	11.68	12.21	11.42	12.31	10.80	9.87	11.39	13.80	11.54	8.01	7.94	7.93	8.19	8.08
Dec. - Avg.	10.56	10.34	10.44	9.91	10.14	9.28	8.49	9.81	10.23	9.54	7.68	7.72	7.69	7.67	7.68
Dec. - Min.	8.38	8.24	7.86	7.55	7.61	6.90	6.84	8.25	7.63	7.67	7.48	7.51	7.52	7.23	7.39
Dec. - S.D.	1.02	0.88	1.10	0.91	1.04	0.89	0.53	0.50	1.55	0.72	0.10	0.09	0.07	0.22	0.11
2002 - Max.	26.95	28.79	31.27	29.08	29.43	10.8	19.05	17.65	15.02	17.79	8.45	9.28	9.56	9.23	9.37
2002 - Avg.	18.83	19.79	19.76	19.82	19.60	5.68	7.14	9.50	8.74	9.37	7.61	7.76	8.03	7.85	7.97
2002 - Min.	8.38	8.24	7.86	7.55	7.61	0.48	0.08	3.50	2.00	3.97	7.24	7.12	7.34	7.15	7.28
2002 - S.D.	4.81	5.59	5.81	5.95	5.72	2.36	1.93	2.00	2.06	1.86	0.17	0.40	0.60	0.48	0.59

Note: An incomplete monthly data set was used to calculate averages for data surrounded by paratheses. e.g. (34.85)

Table 7-11B Statistical Summary: 2002 Continuous Water Quality Data

Month	Specific Conductance (uS/cm)					Turbidity (NTU)				
	DMC	TWA	HEAD	HOWARD	UNDINE	DMC	TWA	HEAD	HOWARD	UNDINE
Jan. - Max.	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Jan. - Avg.	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Jan. - Min.	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Jan. - S.D.	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Feb. - Max.	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Feb. - Avg.	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Feb. - Min.	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Feb. - S.D.	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Mar. - Max.	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Mar. - Avg.	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Mar. - Min.	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Mar. - S.D.	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Apr. - Max.	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Apr. - Avg.	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Apr. - Min.	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Apr. - S.D.	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
May - Max.	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
May - Avg.	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
May - Min.	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
May - S.D.	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Jun. - Max.	831.1	1044.5	840.0	1026.2	837.1	67.3	82.0	-------	87.8	153.2
Jun. - Avg.	(481.5)	(935.0)	(769.4)	(720.5)	(768.8)	(21.1)	(36.3)	-------	(42.8)	(57.7)
Jun. - Min.	293.8	805.9	647.3	448.2	694.6	8.5	8.9	-------	14.0	21.3
Jun. - S.D.	103.9	53.4	28.1	147.0	27.8	6.8	10.7	-------	13.3	16.0
Jul. - Max.	1028.4	957.2	840.2	935.9	818.4	106.5	95.5	84.2	106.1	77.6
Jul. - Avg.	844.2	857.1	747.7	(748.7)	(744.0)	15.4	(36.1)	(31.4)	46.9	(41.7)
Jul. - Min.	332.1	780.0	672.4	344.2	679.6	5.0	14.2	13.4	14.5	17.1
Jul. - S.D.	139.5	27.7	27.0	132.5	26.9	4.9	11.1	11.3	12.0	9.8
Aug. - Max.	1162.6	1004.2	919.0	1021.4	955.1	34.0	72.2	93.0	147.0	103.3
Aug. - Avg.	966.6	904.6	794.8	766.9	790.7	9.9	29.6	27.2	(42.8)	42.9
Aug. - Min.	506.8	809.7	686.5	369.1	692.7	2.1	12.0	12.2	8.1	17.5
Aug. - S.D.	125.2	33.1	37.3	148.3	37.8	4.7	10.5	7.5	20.4	12.2
Sep. - Max.	1144.6	977.8	883.7	1044.9	922.7	38.6	179.9	65.9	208.8	108.8
Sep. - Avg.	1035.9	905.0	(802.9)	838.8	(800.1)	10.5	29.8	(22.9)	50.6	(25.8)
Sep. - Min.	704.7	824.5	728.1	737.9	727.5	2.4	7.7	7.5	17.3	9.7
Sep. - S.D.	69.7	31.3	30.2	42.6	38.6	3.8	17.7	7.9	31.0	12.9
Oct. - Max.	1311.6	1113.9	835.1	958.1	819.0	62.7	86.1	21.5	57.0	56.5
Oct. - Avg.	1084.3	932.3	(628.6)	655.8	643.2	13.8	(19.4)	(8.7)	24.1	(14.7)
Oct. - Min.	662.2	559.1	385.1	392.1	387.7	4.7	9.9	5.4	8.1	7.6
Oct. - S.D.	108.3	146.3	155.9	163.7	150.4	5.2	6.7	1.5	7.1	8.5
Nov. - Max.	1158.6	1274.8	965.5	1080.3	1134.4	142.6	20.3	93.0	332.2	174.3
Nov. - Avg.	820.1	873.0	797.1	763.1	798.5	17.2	(11.7)	16.1	12.7	10.3
Nov. - Min.	447.9	608.4	561.0	526.4	545.8	3.9	7.8	6.1	3.2	3.9
Nov. - S.D.	175.3	120.7	101.7	101.9	115.0	14.6	2.8	6.7	25.0	9.9
Dec. - Max.	1186.6	1229.2	1003.1	1583.5	1440.8	142.5	137.9	309.3	252.0	297.1
Dec. - Avg.	803.1	958.6	859.8	1043.2	885.7	16.5	(41.2)	40.1	37.9	39.1
Dec. - Min.	456.9	672.5	600.3	707.4	635.9	4.4	15.1	8.2	3.4	4.5
Dec. - S.D.	220.4	122.7	110.4	114.3	109.6	9.3	19.4	40.0	41.9	45.9
2001 - Max.	1311.6	1274.8	1003.1	1583.5	1440.8	142.6	179.9	309.3	332.2	297.1
2001 - Avg.	869.9	909.0	773.2	799.7	776.6	14.8	31.2	24.5	36.5	34.9
2001 - Min.	293.8	559.1	385.1	344.2	387.7	2.1	7.7	5.4	3.2	3.9
2001 - S.D.	229.4	96.6	108.2	173.7	113.2	8.6	15.3	21.2	27.7	27.0

Note: An incomplete monthly data set was used to calculate averages for data surrounded by paratheses. e.g

Figure 7-20 2002 Maximums, averages, minimums, and standard deviations for water temperature at the five South Delta continuous monitoring sites

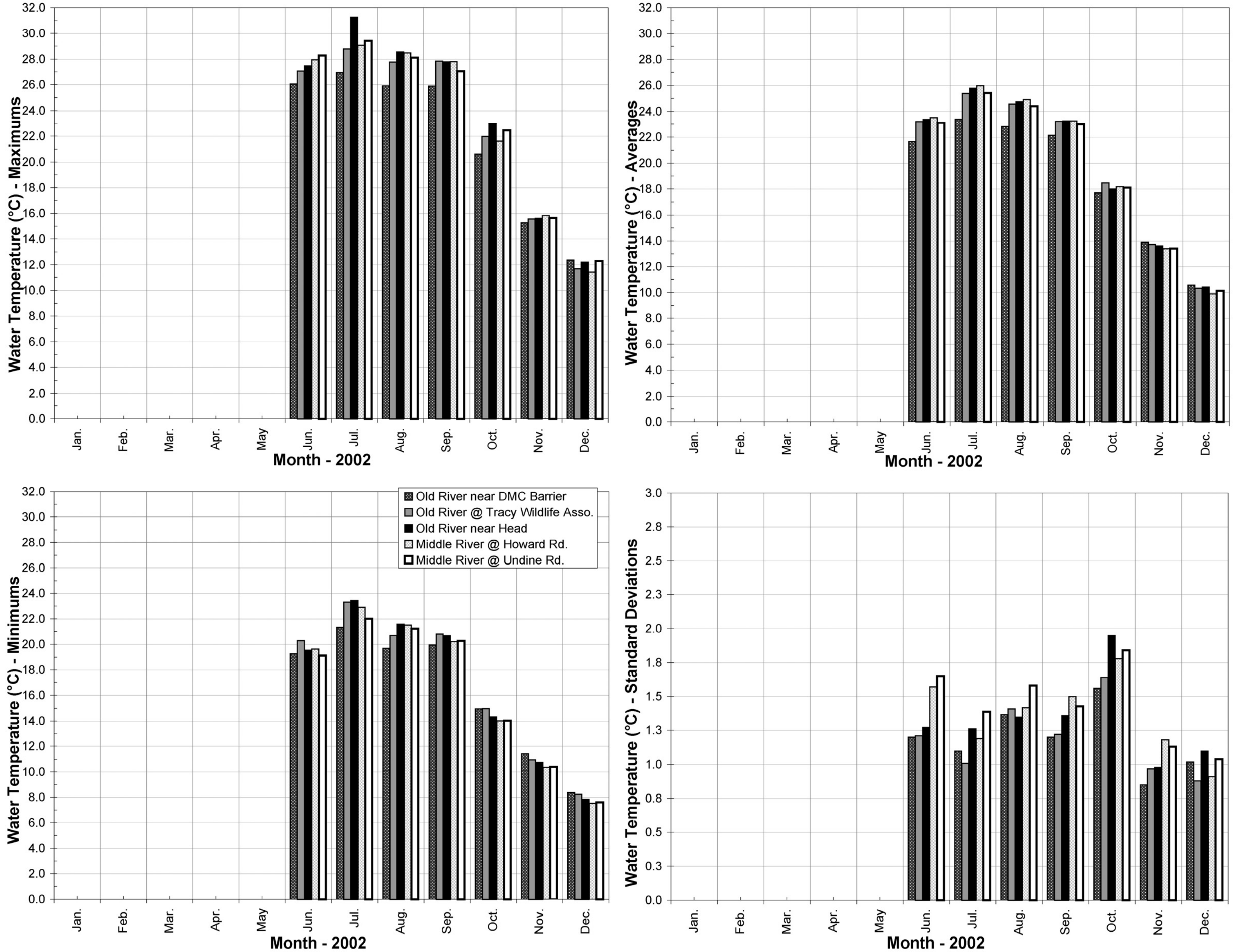


Figure 7-21 2002 Maximums, averages, minimums, and standard deviations for dissolved oxygen at the five South Delta continuous monitoring sites

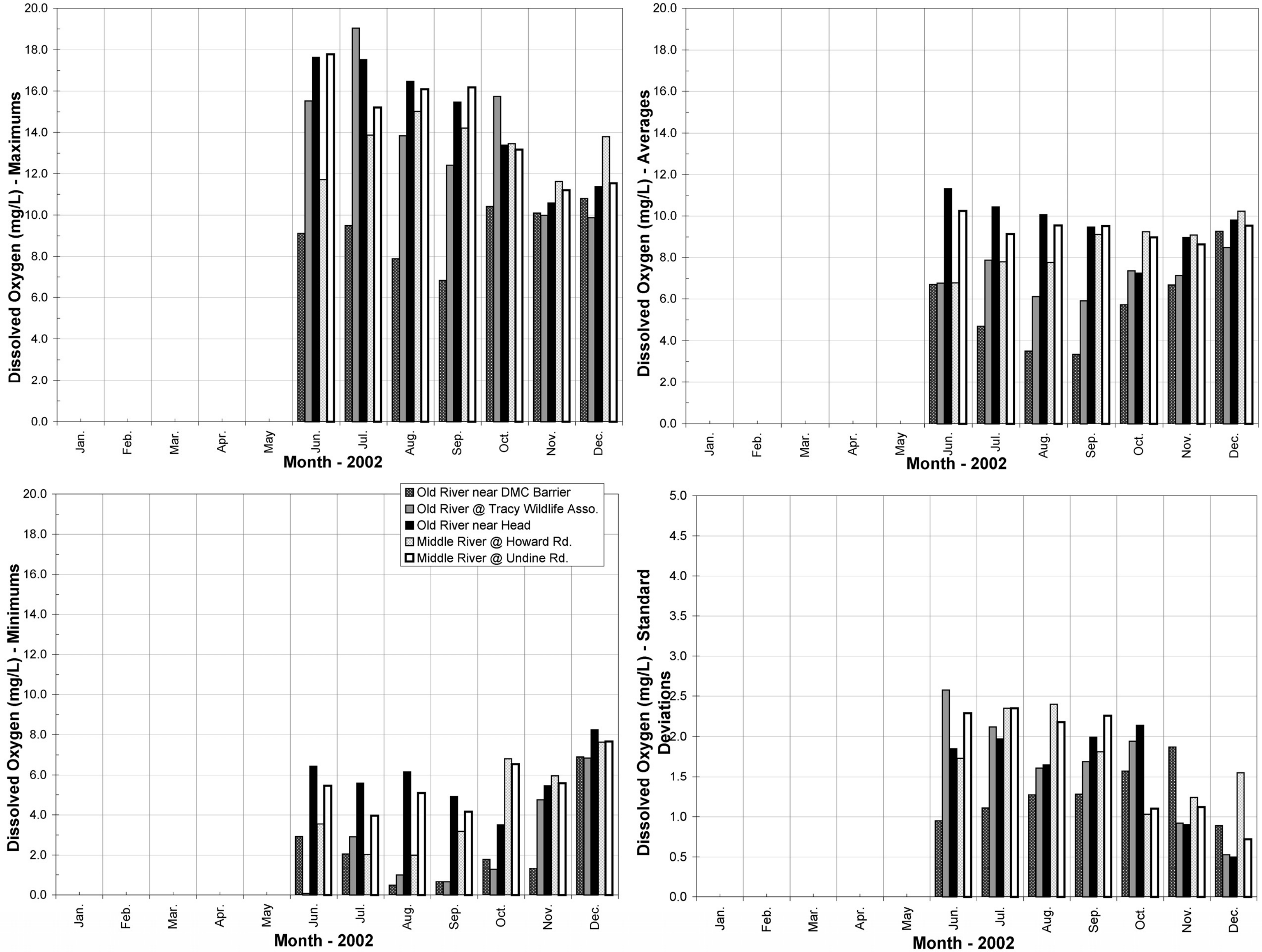


Figure 7-22 2002 Maximums, averages, minimums, and standard deviations for pH at the five South Delta continuous monitoring sites

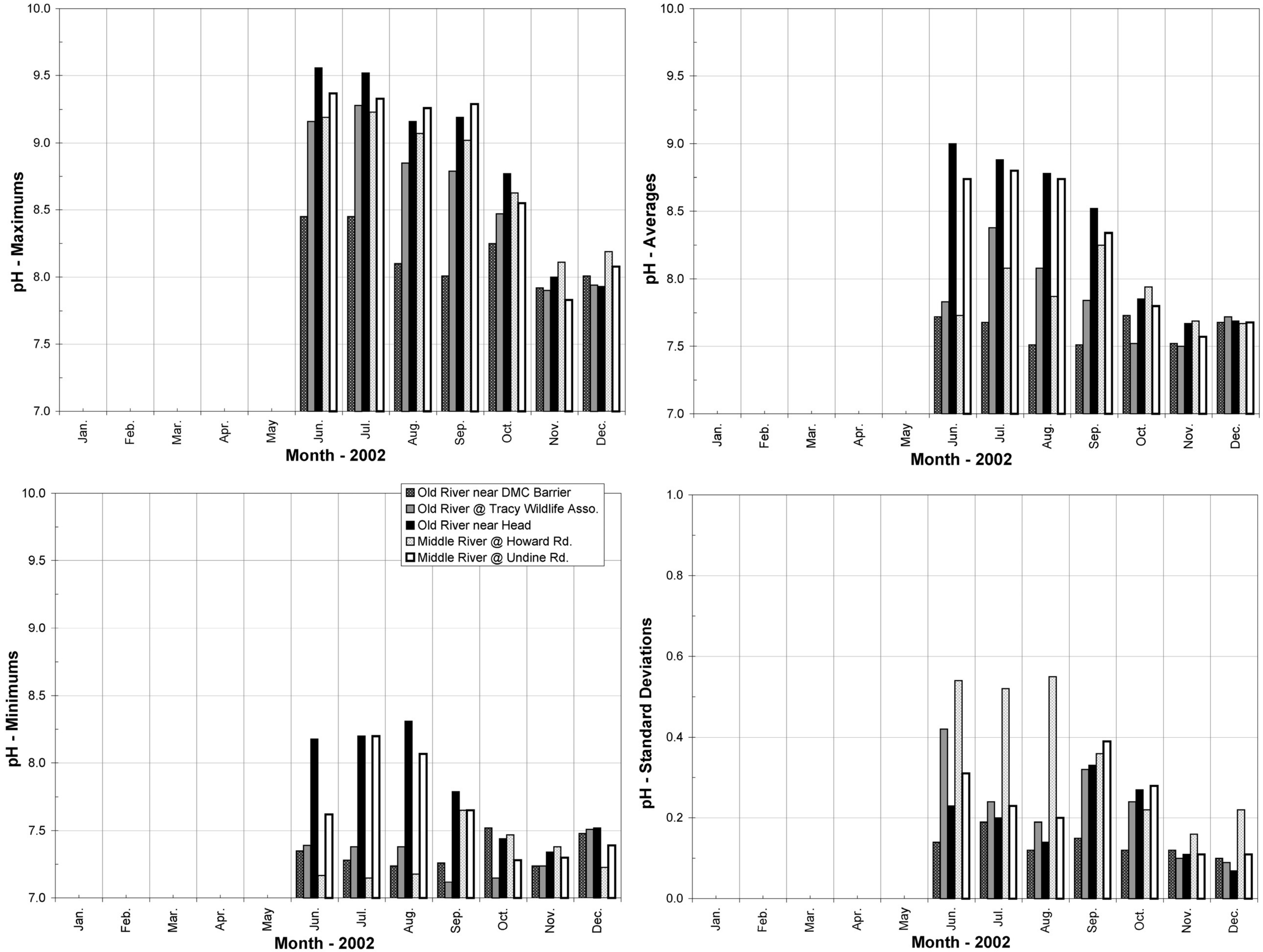


Figure 7-23 2002 Maximums, averages, minimums, and standard deviations for specific conductance at the five South Delta continuous monitoring sites

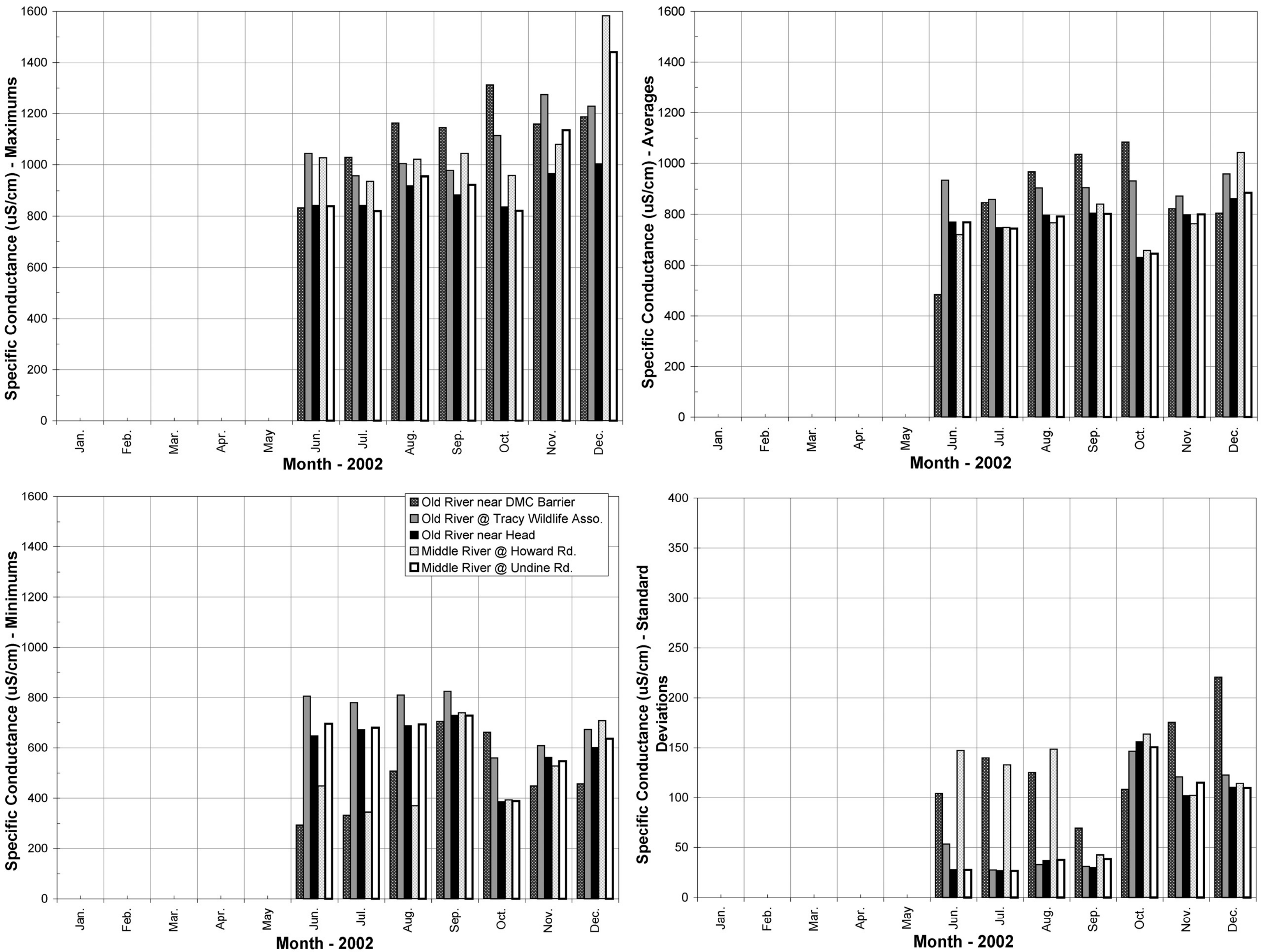
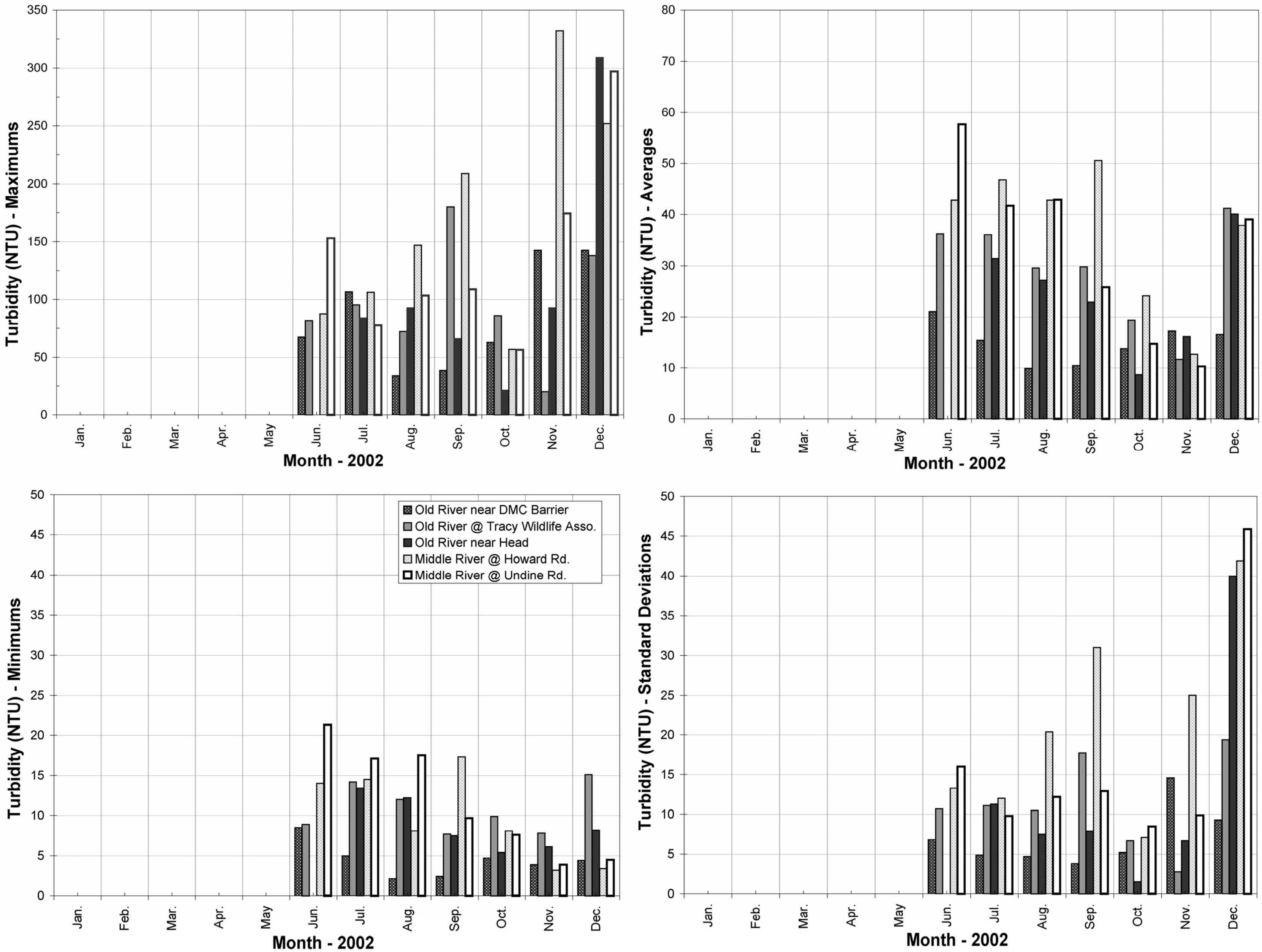


Figure 7-24 2002 Maximums, averages, minimums, and standard deviations for turbidity at the five South Delta continuous monitoring sites



Recommendations

It has been determined that continuous chlorophyll data collection is not a viable option at this time. However, discrete chlorophyll sampling may provide a cost-effective means of determining the presence of algal blooms, especially during the summer. During the summer months phytoplankton samples can also be taken for identification of the most abundant algae species. This information can be used to determine the extent of algal blooms, their severity, and the spatial composition of algal speciation.

During 2000, each monitoring site held the sondes at fixed distances from the top of the installation pipe. Thus, the 2000 data were collected from sondes that were subject to tidally varying depths below the water surface. An attempt was made during 2001 to develop a float system to enable the sondes to remain at a constant/standardized 3 foot (□ 1m) depth below the water surface. However, the float usually got stuck within the installation pipe during the first day of deployment. Thus, the sondes were generally subjected to tidally varying water depths in 2001, as well. In 2002, a smaller diameter cable was used to suspend sondes, which enabled the float to function better; however, there were still problems with the float getting stuck. The development of a reliable float system is still a work in progress.

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 areas of very low DO, where further sampling may be needed to identify causes of degradation, including chlorophyll *a*, pheophytin *a* sampling and biochemical oxygen demand (BOD) testing.

Please see the 2001 Temporary Barriers Report for past recommendations.

Chapter 8. Hydrologic Modeling

This chapter describes the details of a hydrodynamic simulation for 2002 as requested the Temporary Barriers and Lower San Joaquin Section in DWR's Bay-Delta Office. The period of simulation extends from January 1, 2002 to December 31, 2002.

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 penetrates 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. For some data items, duplicate data from more than one agency was available. DSM2 allows input from multiple sources; however, they have to be 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, when visually examined using plotting routines, showed some data missing at certain times. These data were identified. In most cases, alternate sources of data filled the gap. The resulting boundary conditions for 2002 are shown in the figures below.

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 data, pan evaporation data and water year types. DICU hydrology data was extended to include precipitation data for 2002. ET adjustments (evapo-transpiration data) were made for 2002 using monthly pan evaporation data.

Figure 8-1. Daily average historical inflow from the Sacramento River, 2002.

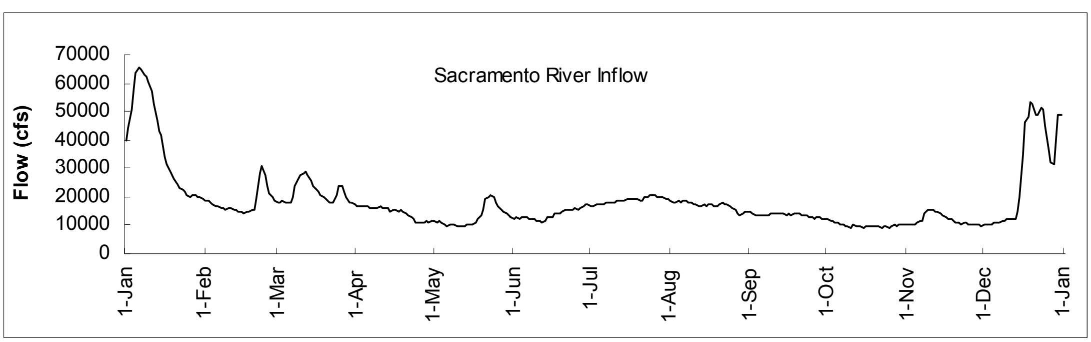


Figure 8-2. Daily average historical inflow from the San Joaquin River, 2002.

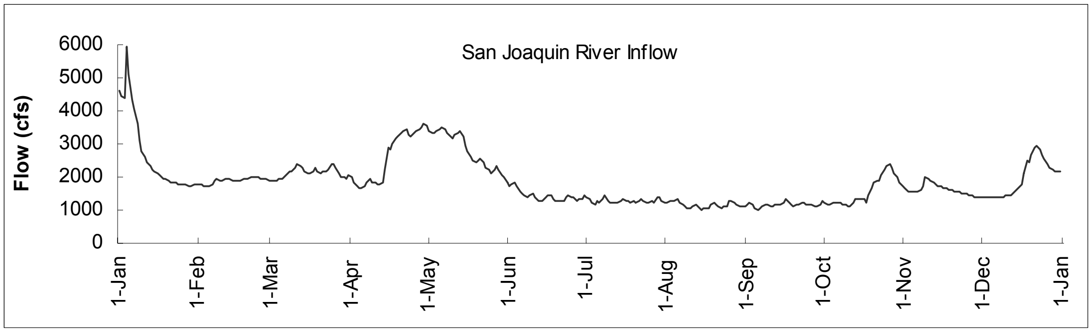


Figure 8-3. Daily average historical pumping at Banks and Delta Pumping plants, 2002.

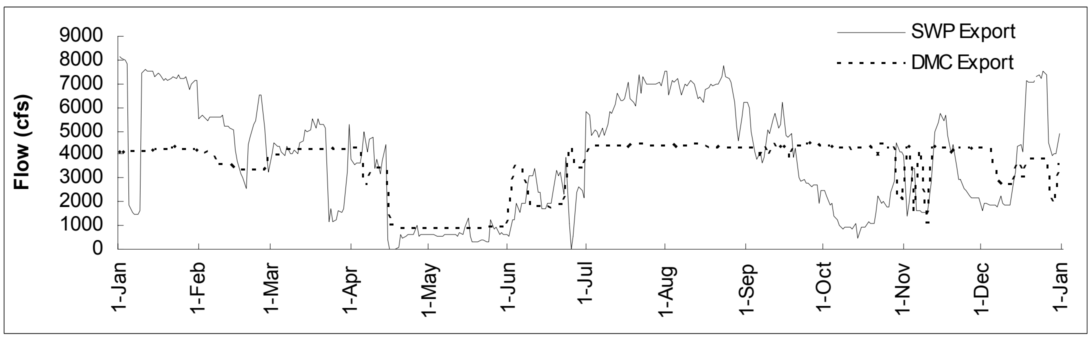
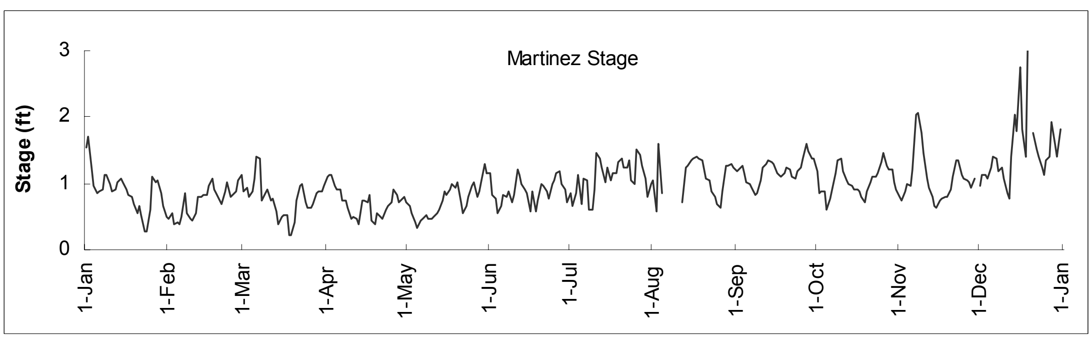


Figure 8-4. Daily average historical stage at Martinez, 2002.



Delta Structures

All three temporary agricultural barriers were installed in 2002 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 8-1. Historical and DSM2-assumed south Delta barriers installation and removal, 2002.

	Installation			Removal		
Barrier	Started	Ended	DSM2	Started	Ended	DSM2
Middle River	4/10/02	4/15/02	4/15/02	11/20/02	11/23/02	11/22/02
Old River near DMC	4/1/02	4/18/02	4/15/02	11/16/02	11/29/02	11/28/02
Grant Line Canal	4/1/02	6/12/02	6/7/02	11/14/02	11/25/02	11/24/02
Old River @ Head (spring)	4/2/02	4/18/02	4/15/02	5/22/02	6/7/02	5/25/02
Old River @ Head (fall)	9/24/02	10/4/02	10/4/02	11/11/02	11/21/02	11/21/02

For a special study to examine the effect of fish movement associated with tidally operating the Delta Cross Channel, the Delta Cross Channel was alternately opened for approximately 9 hours and then closed for approximately 15 hours in June of 2002. Otherwise, the Delta Cross Channel gates were operated in a typical manner (see table below).

Table 8-2. Historical Delta Cross Channel operation for 2002.

Time Interval						Time Interval					
Date	Time		Date	Time	Status	Date	Time		Date	Time	Status
1/1/02	0000	-	5/24/02	0924	closed	6/11/02	0029	-	6/11/02	2225	open
5/24/02	0924	-	5/28/02	0924	open	6/11/02	2225	-	6/12/02	0627	closed
5/28/02	0924	-	5/31/02	0925	closed	6/12/02	0627	-	6/12/02	2225	open
5/31/02	0925	-	6/3/02	1917	open	6/12/02	2225	-	6/13/02	0628	closed
6/3/02	1917	-	6/4/02	0429	closed	6/13/02	0628	-	6/13/02	2225	open
6/4/02	0429	-	6/4/02	1926	open	6/13/02	2225	-	6/14/02	0624	closed
6/4/02	1926	-	6/5/02	0426	closed	6/14/02	0624	-	10/16/02	0735	open
6/5/02	0426	-	6/5/02	1924	open	10/16/02	0735	-	10/19/02	0725	closed
6/5/02	1924	-	6/6/02	0425	closed	10/19/02	0725	-	10/19/02	0730	open
6/6/02	0425	-	6/6/02	1927	open	10/19/02	0730	-	11/12/02	0800	half open
6/6/02	1927	-	6/7/02	0428	closed	11/12/02	0800	-	11/12/02	1500	closed
6/7/02	0428	-	6/9/02	2224	open	11/12/02	1500	-	12/3/02	0800	open
6/9/02	2224	-	6/10/02	0627	closed	12/3/02	0800	-	12/10/02	1300	closed
6/10/02	0627	-	6/10/02	2225	open	12/10/02	1300	-	12/16/02	1100	open
6/10/02	2225	-	6/11/02	0029	closed	12/16/02	1100	-	12/31/03	2400	closed

Accuracy of DSM2 Simulation of 2002 Delta Hydrodynamics

DSM2-simulated stages and flows have been compared to historical data in the south Delta (Figure 8-5). At the time of this report, flow data was generally only available through June of 2002. Figure 8-6 shows the historical and DSM2-simulated daily maximum and minimum stages at 11 locations in the south Delta barriers and the daily average stage within Clifton Court Forebay. With the exception of Middle River at Howard Road (MHR) in November, DSM2-simulated stages followed historical stage patterns. Records show the Middle River barrier being removed in mid-November along with the other barriers, yet recorded stages at MHR remained high. The historical values at MHR are from DWR's California Data Exchange Center (CDEC) and have not yet been screened. Other gages nearby did show the expected decrease in stage in late November, making the CDEC values at MHR during this period somewhat suspect.

Figure 8-5. Locations where 2002 historical and DSM2-simulated hydrodynamics compared.

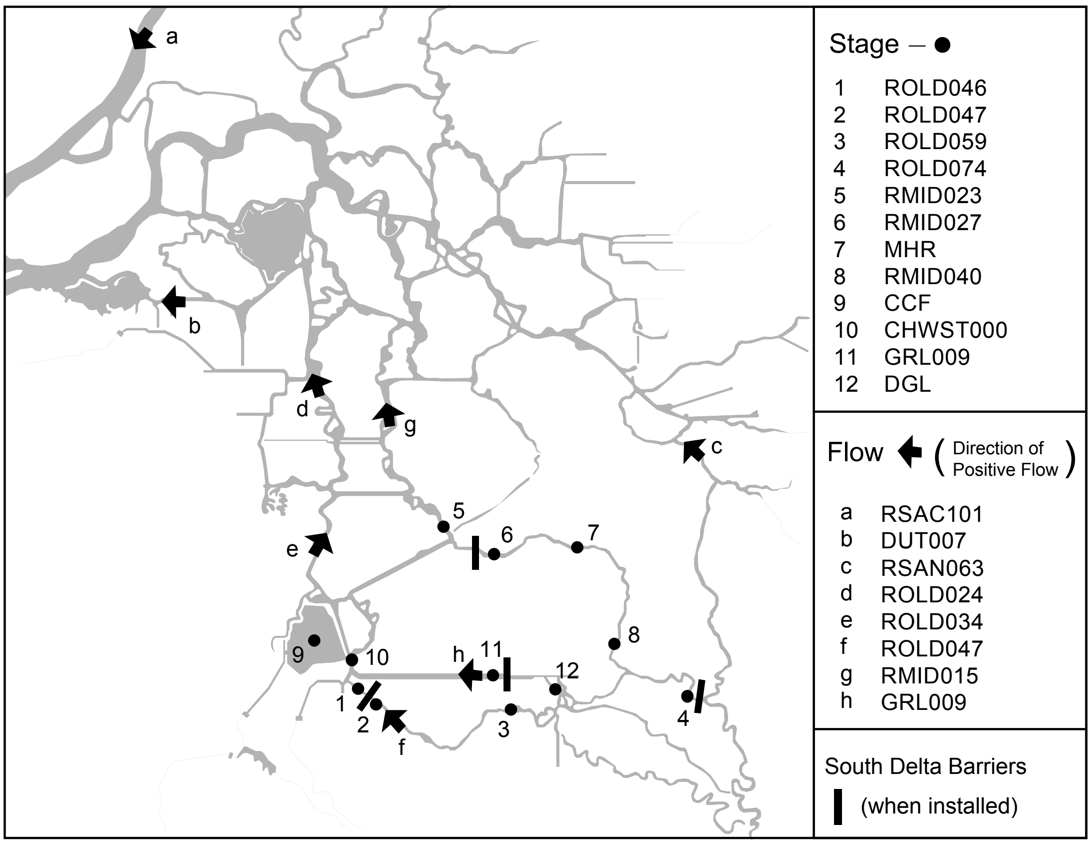


Figure 8-7 shows the historical and DSM2-simulated daily average flows at 8 locations in the Delta. Flows generated by DSM2 compare well to the available historical flows. However, no comparison is yet possible at a location under the influence of a barrier operation. By common sign convention, positive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

Figure 8-6. Daily maximum and minimum historical and DSM2-simulated stage, 2002.

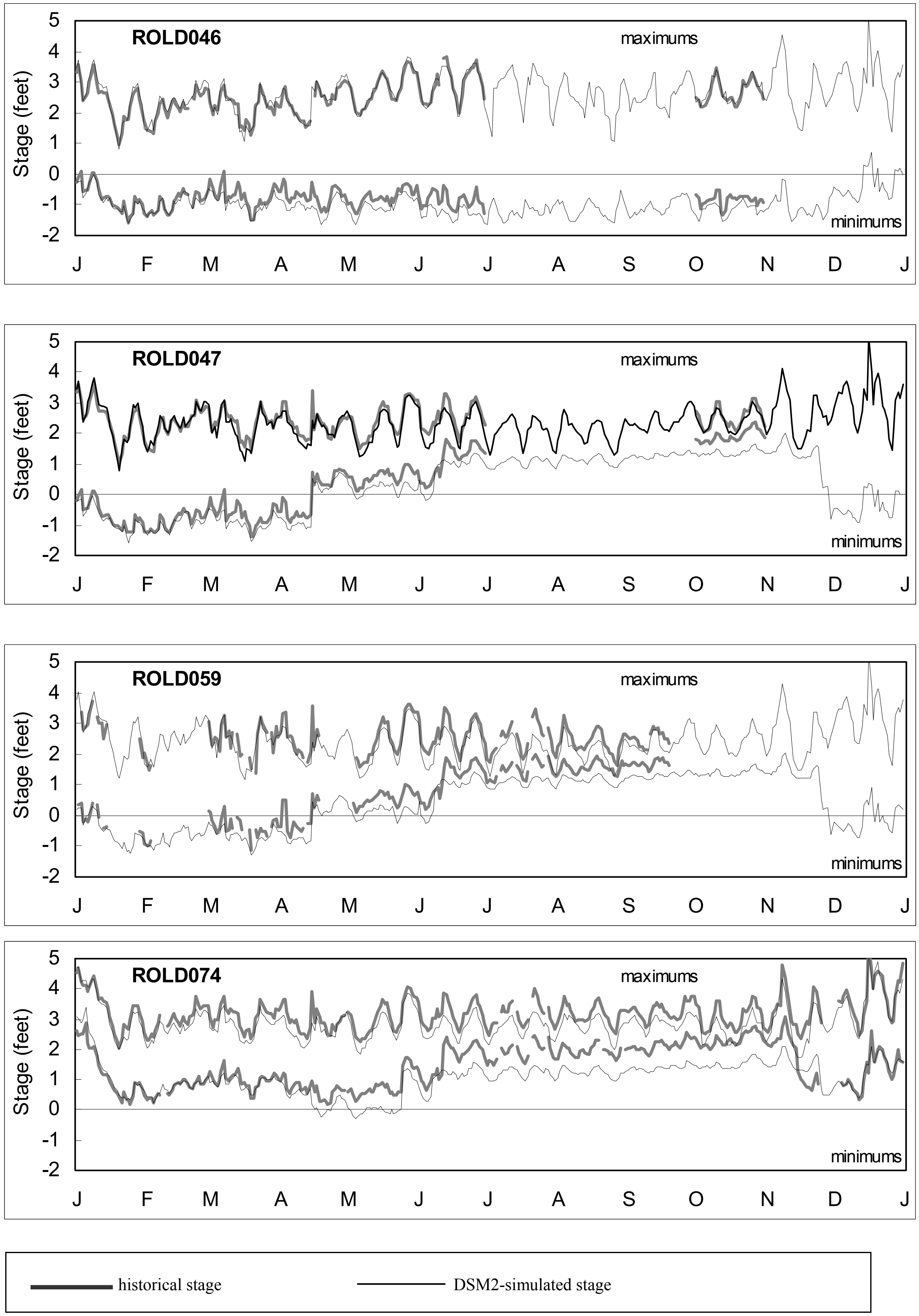


Figure 8-6 cont. Daily maximum and minimum historical and DSM2-simulated stage, 2002.

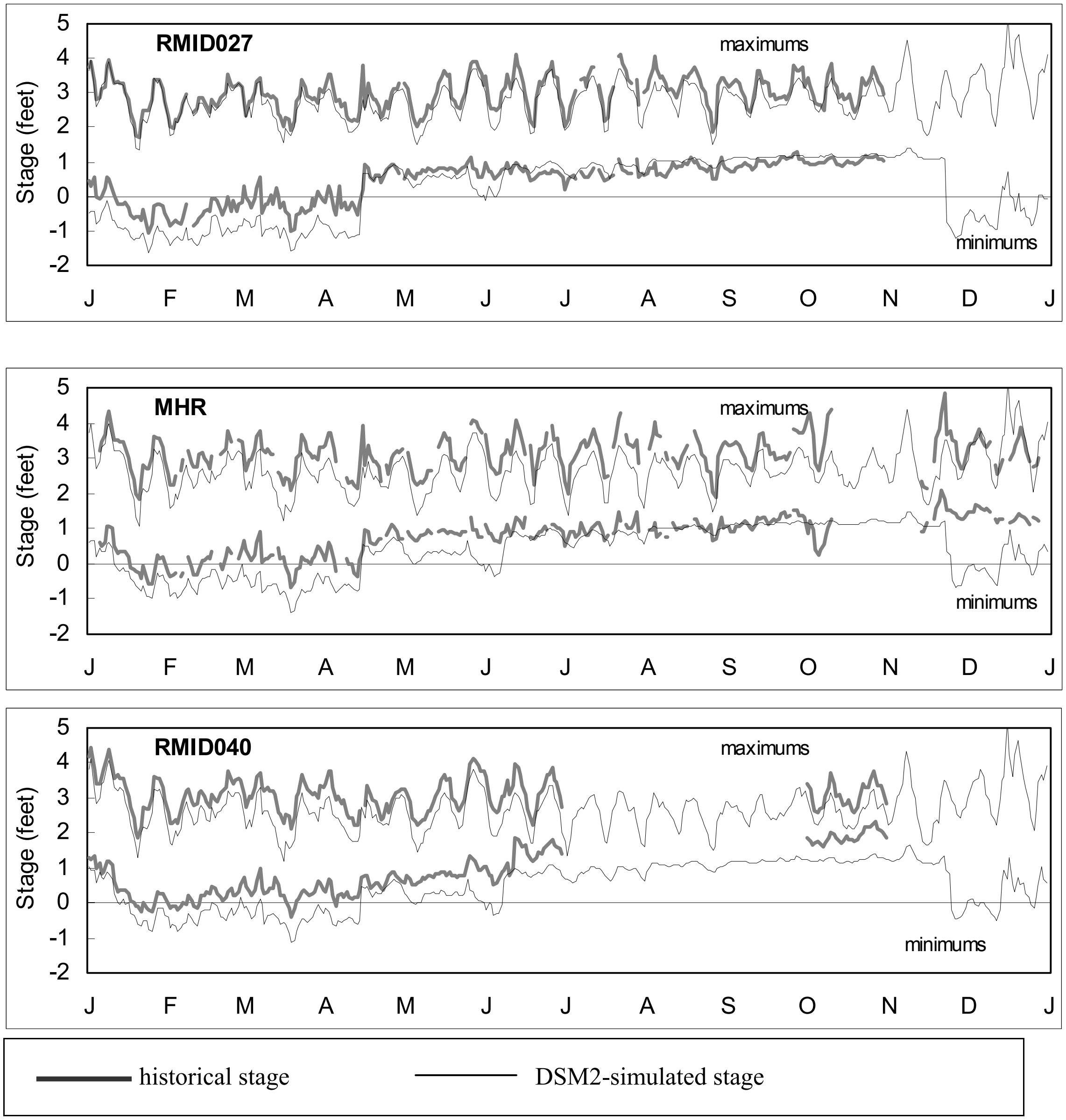


Figure 8-6 cont. Daily maximum and minimum historical and DSM2-simulated stage, 2002.

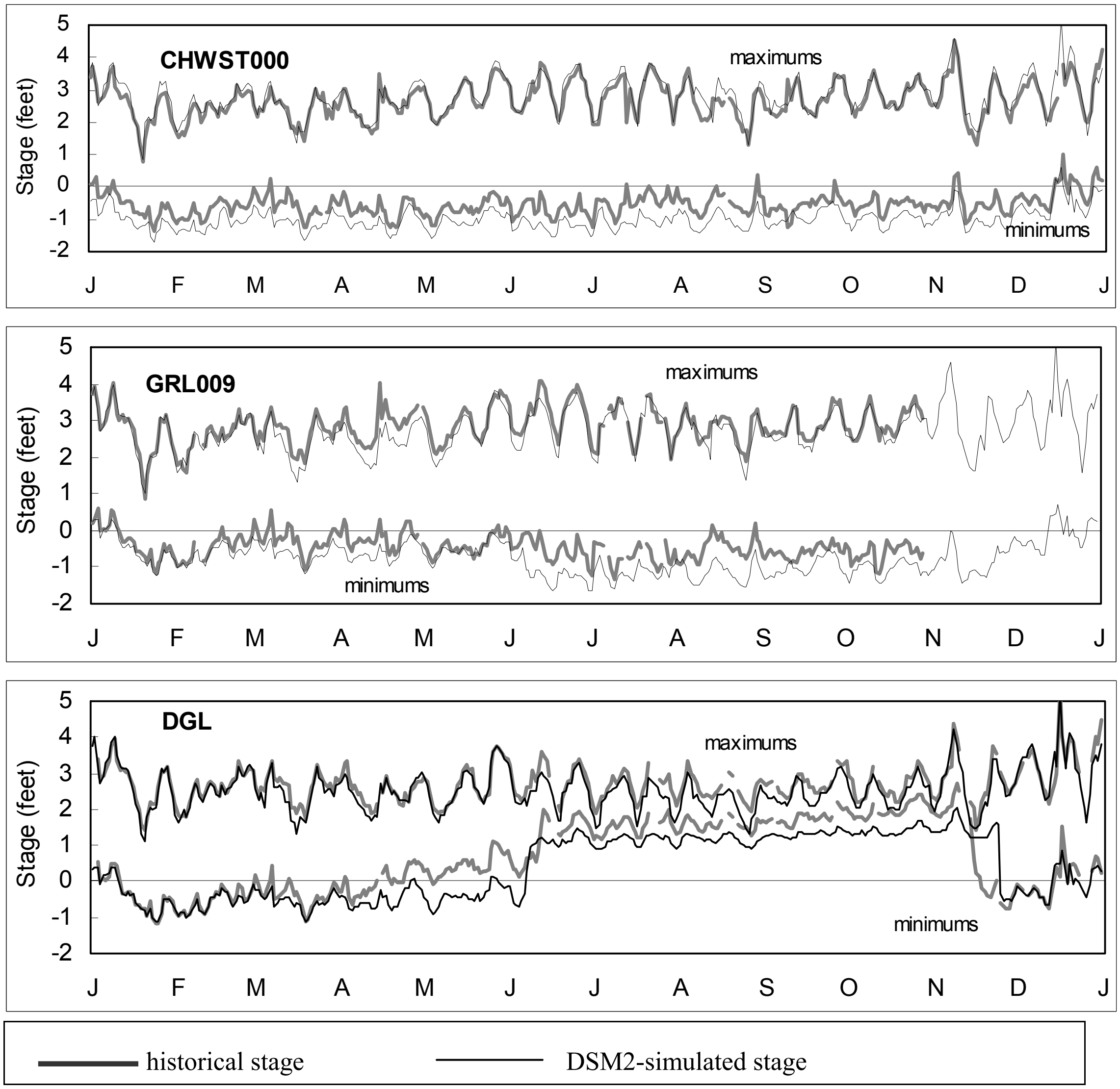


Figure 8-7. Historical and DSM2-simulated flow for Jan-Jul, 2002.

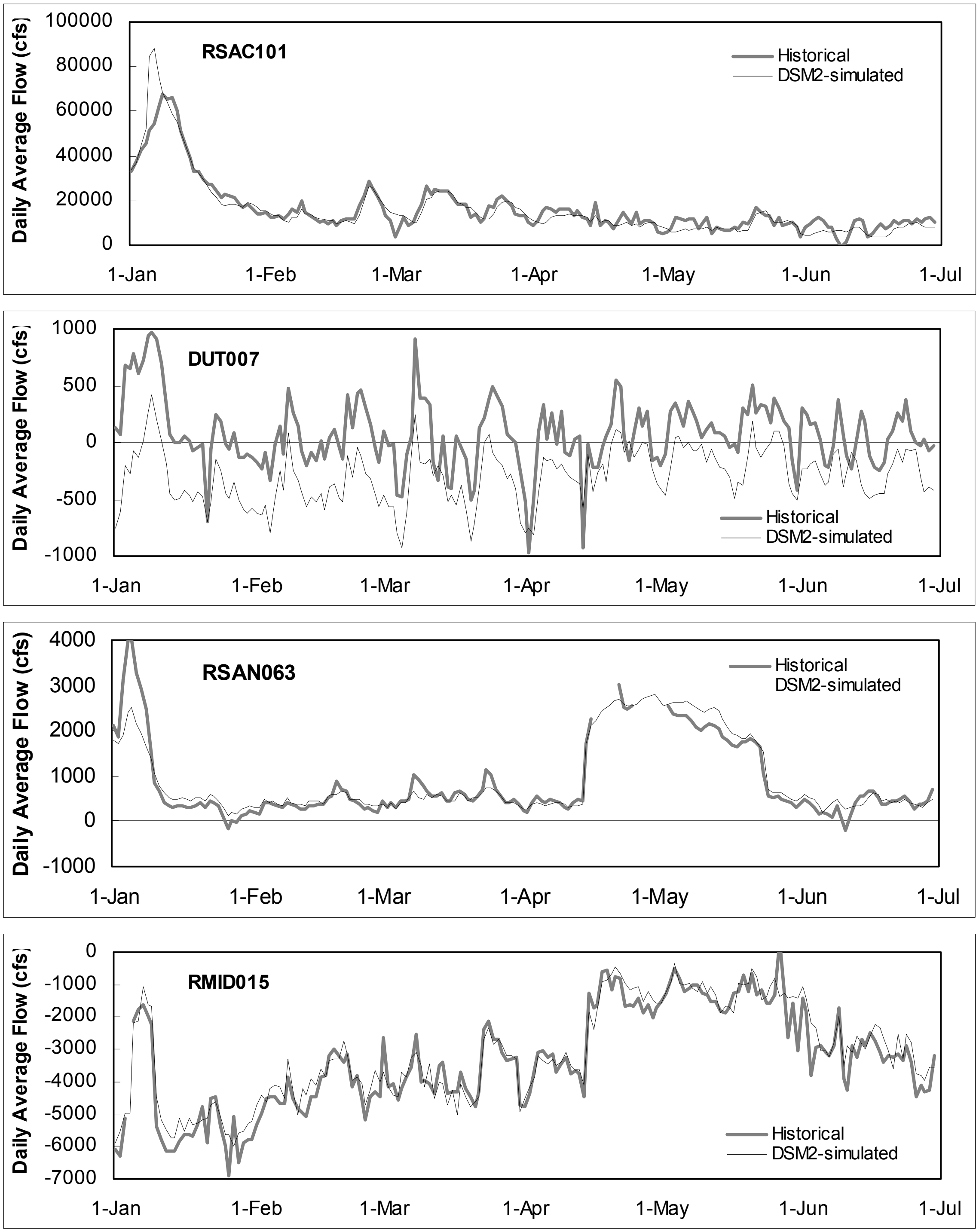
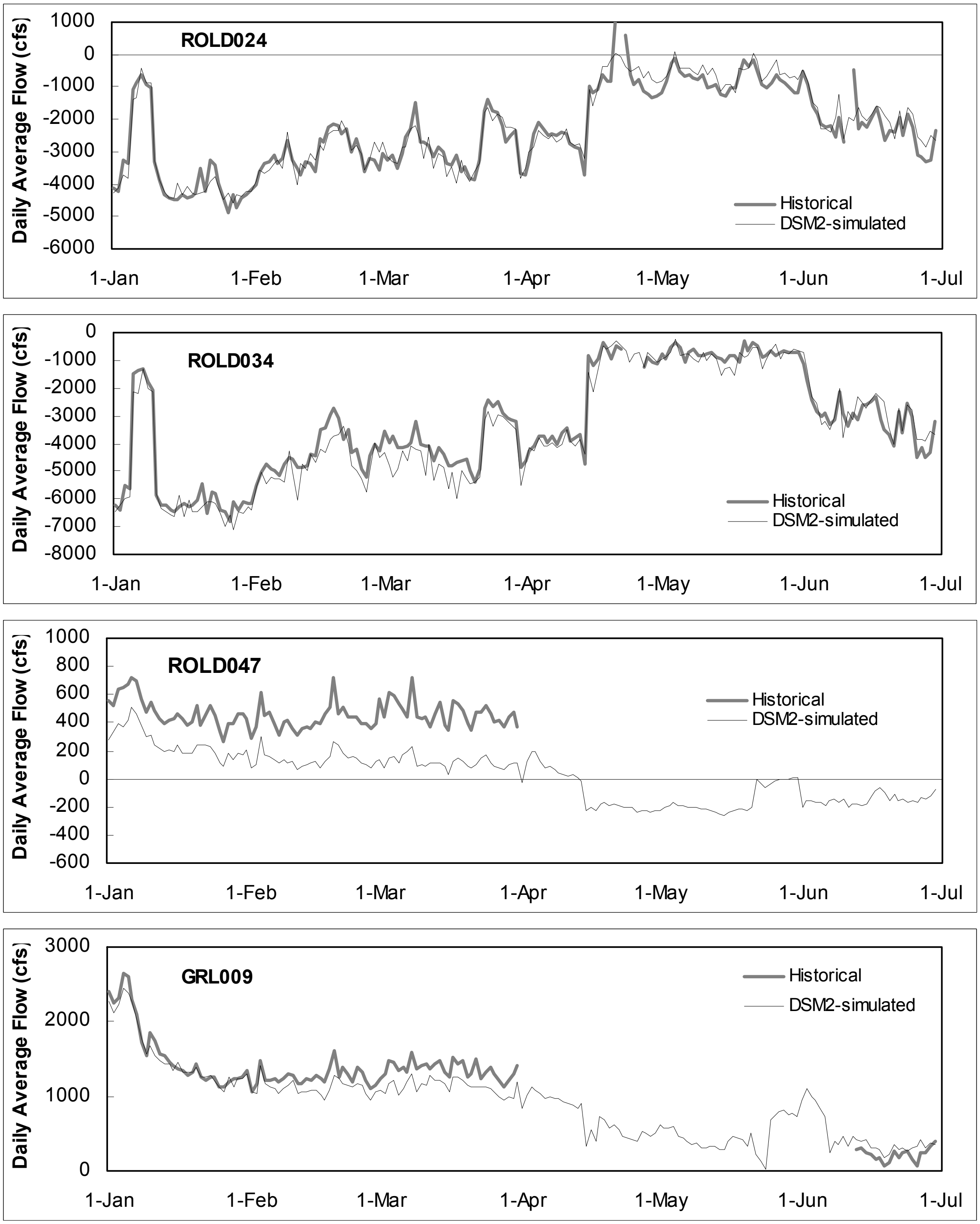


Figure 8-7 cont. Historical and DSM2-simulated flow for Jan-Jul, 2002.



DSM2 Simulation of 2002 Hydrodynamics

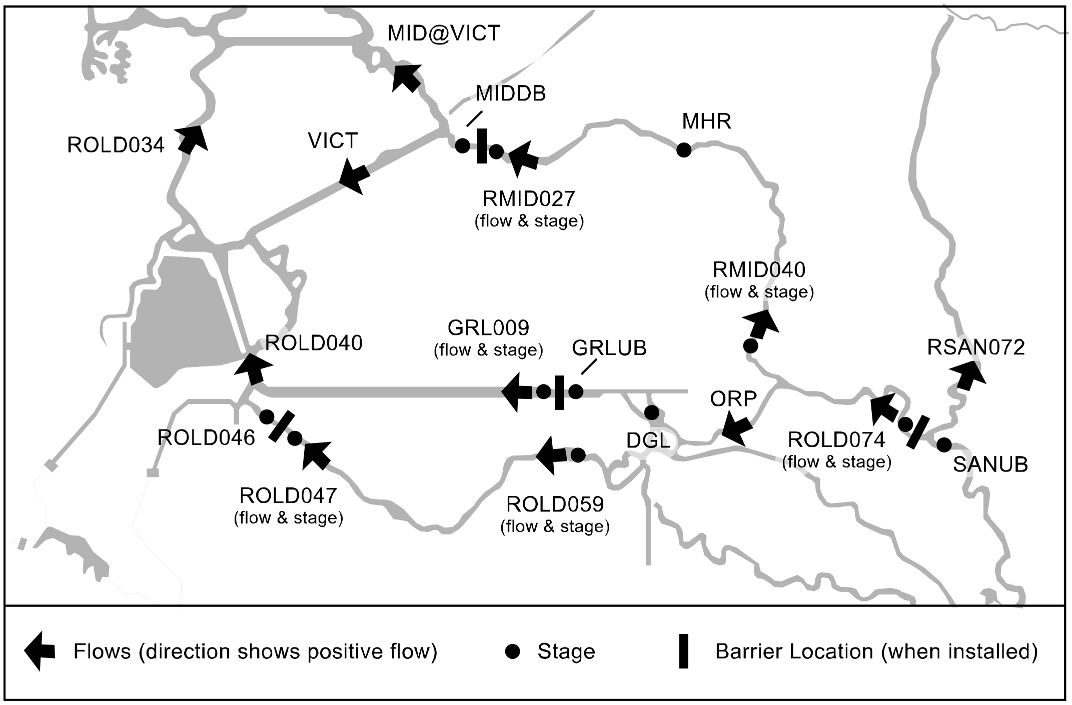
In order to aid the interpretation of DSM2-simulated hydrodynamics, 2002 was broken up into 24 periods. These periods correspond to times for which significant Delta inflows and exports were fairly constant and south Delta barrier configurations were unchanging. These periods and their characteristics are shown in the table below.

Table 8-3. Characteristics of intervals during 2002 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 - 4	52,468	4,849	4,044	8,012	--	--	--	--
	5 - 10	83,533	3,839	4,117	2,581	--	--	--	--
	11 - 31	30,316	1,968	4,172	7,268	--	--	--	--
FEB	1 - 28	18,238	1,895	3,601	4,941	--	--	--	--
MAR	1 - 22	21,846	2,121	4,149	4,630	--	--	--	--
	23 - 31	20,139	2,157	4,209	2,091	--	--	--	--
APR	1 - 14	16,321	1,822	3,501	3,986	--	--	--	--
	15 - 30	13,355	3,218	1,097	693	IN	IN	--	IN
MAY	1 - 24	12,694	3,000	836	573	IN	IN	--	IN
	25 - 31	15,098	2,107	922	805	IN	IN	--	--
JUN	1 - 6	12,653	1,676	3,267	1,580	IN	IN	--	--
	7 - 30	14,105	1,368	2,427	2,331	IN	IN	IN	--
JUL	1 - 31	18,817	1,275	4,348	6,222	IN	IN	IN	--
AUG	1 - 31	16,959	1,150	4,329	6,733	IN	IN	IN	--
SEP	1 - 30	13,554	1,161	4,278	4,131	IN	IN	IN	--
OCT	1 - 3	11,707	1,176	4,321	2,202	IN	IN	IN	--
	4 - 20	9,772	1,306	4,286	1,039	IN	IN	IN	IN
	21 - 31	9,709	2,069	3,698	2,665	IN	IN	IN	IN
NOV	1 - 10	11,913	1,669	2,626	2,196	IN	IN	IN	IN
	11 - 20	13,245	1,712	4,114	4,703	IN	IN	IN	IN
	21 - 28	11,161	1,493	4,254	2,628	IN/--	IN/--	IN/--	--
	29 - 30	21,960	1,411	4,264	2,153	--	--	--	--
DEC	1 - 13	11,406	1,425	3,346	2,063	--	--	--	--
	14 - 31	44,904	2,379	3,312	5,844	--	--	--	--

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 8-8 with arrows indicating assumed positive flow direction. The numerical values these graphs are based upon are presented in the appendix B to this report.

Figure 8-8. Locations where simulated Delta stages and flows for 2002 are presented.



The distributions of simulated stages and flow for each of the 24 intervals are shown in Figures 8-9 and 8-10. 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 8-9 and 8-10 are shown in Figure 8-11 which graphically presents the interaction between flow circulation and water levels caused by the installation of the south Delta barriers in 2002.

Discussion

The installation of the temporary barriers in 2002 significantly altered stages and flows in the south Delta. Minimum water levels tended to be raised 1 to 1-½ 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 ½ foot due to the barrier here. Minimum water levels upstream of GRL009 did not improve until the 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 ½ foot. These increases in minimum stage were consistent during the entire June 7 – November 20 period, even when the barrier at the head of Old River was in place from October 4 – November 20. This is probably due to a combination of the Grant Line Canal barrier remaining in place, raising water levels, and because the fall barrier at the head of Old River was notched at 0.0 msl.

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 8-9. Box Plots showing distribution of DSM2-simulated stages for various periods during 2002.

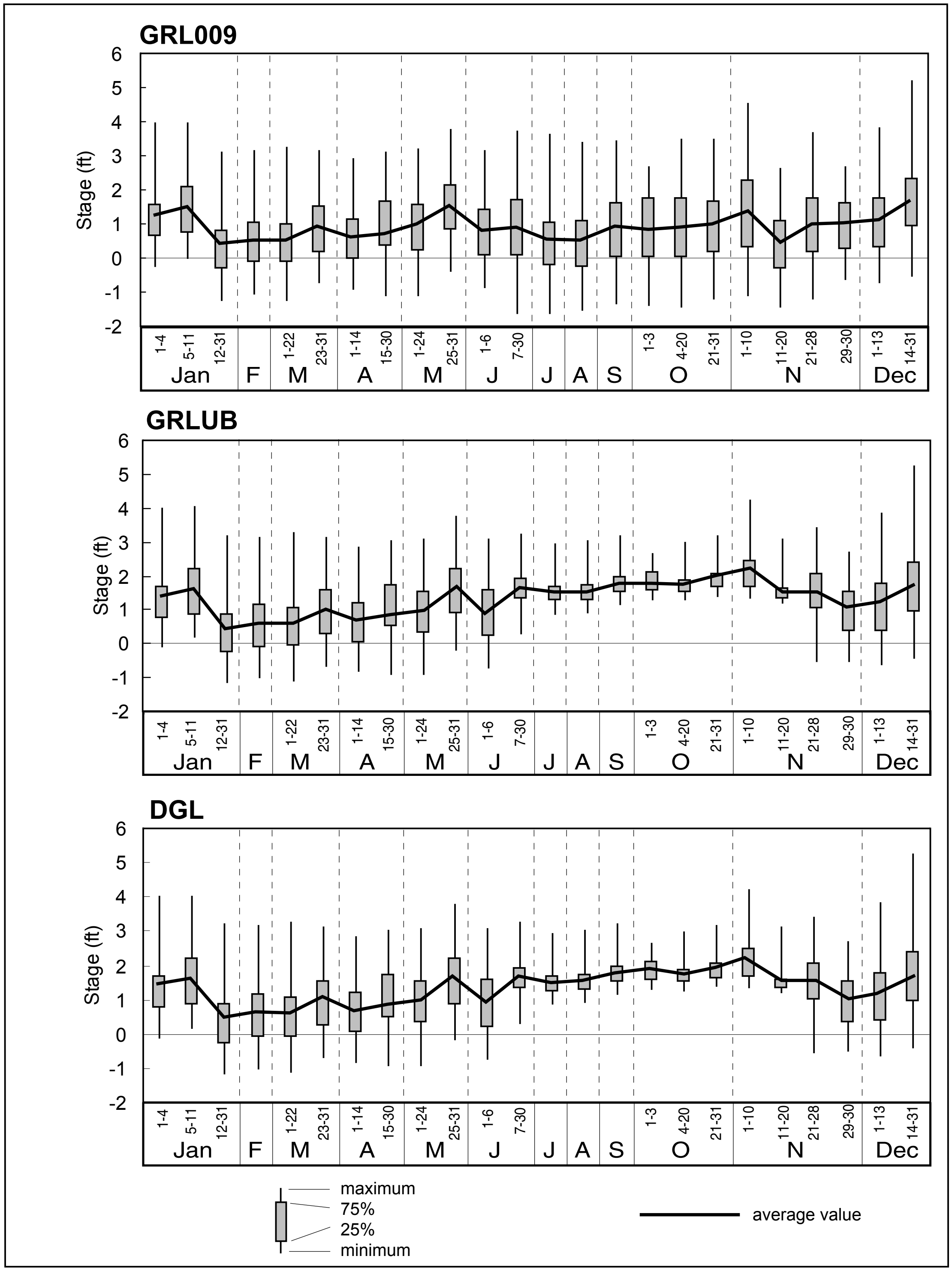


Figure 8-9 cont. Box Plots showing distribution of DSM2-simulated stages for various periods during 2002.

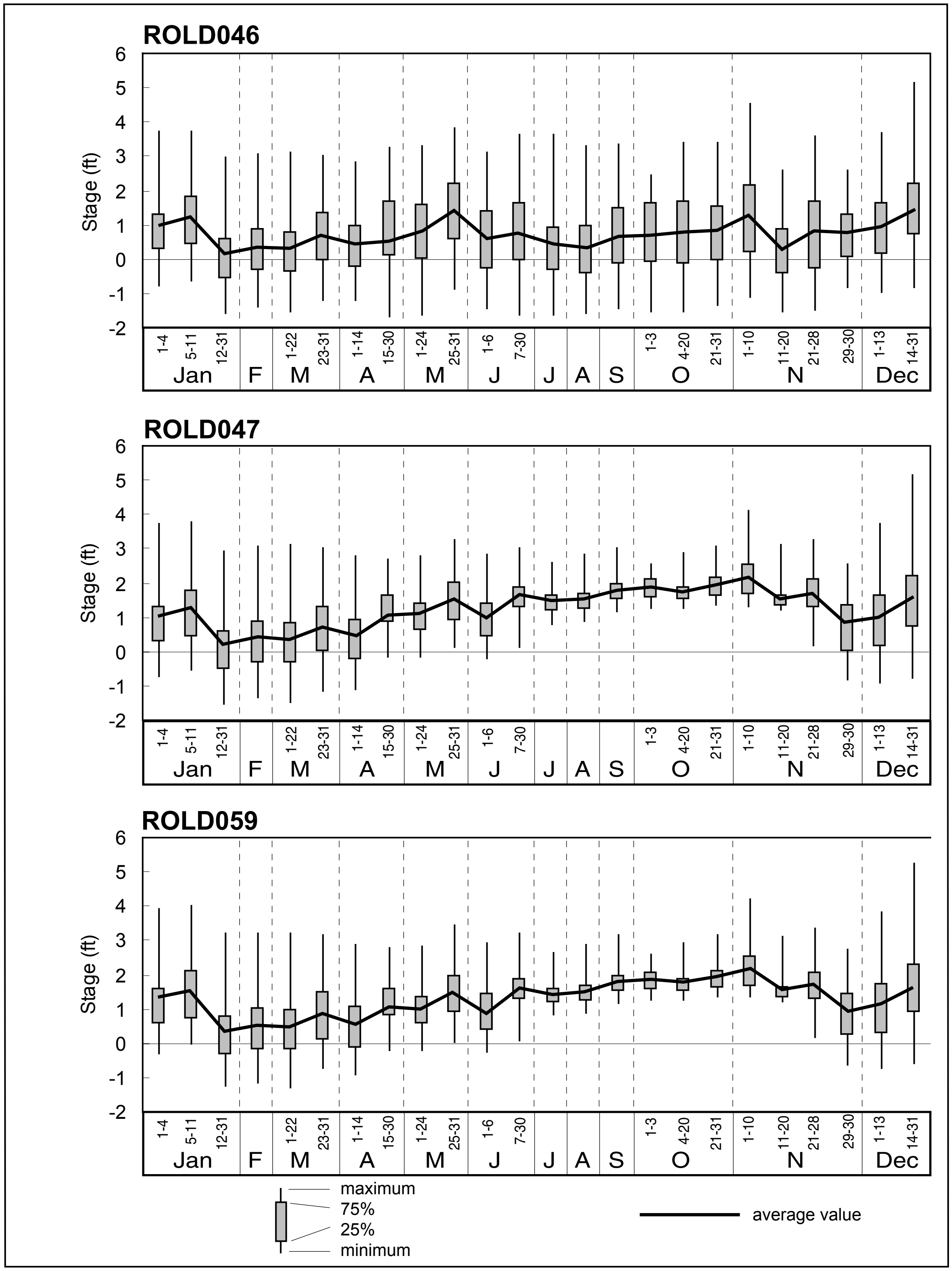


Figure 8-9 cont. Box Plots showing distribution of DSM2-simulated stages for various periods during 2002.

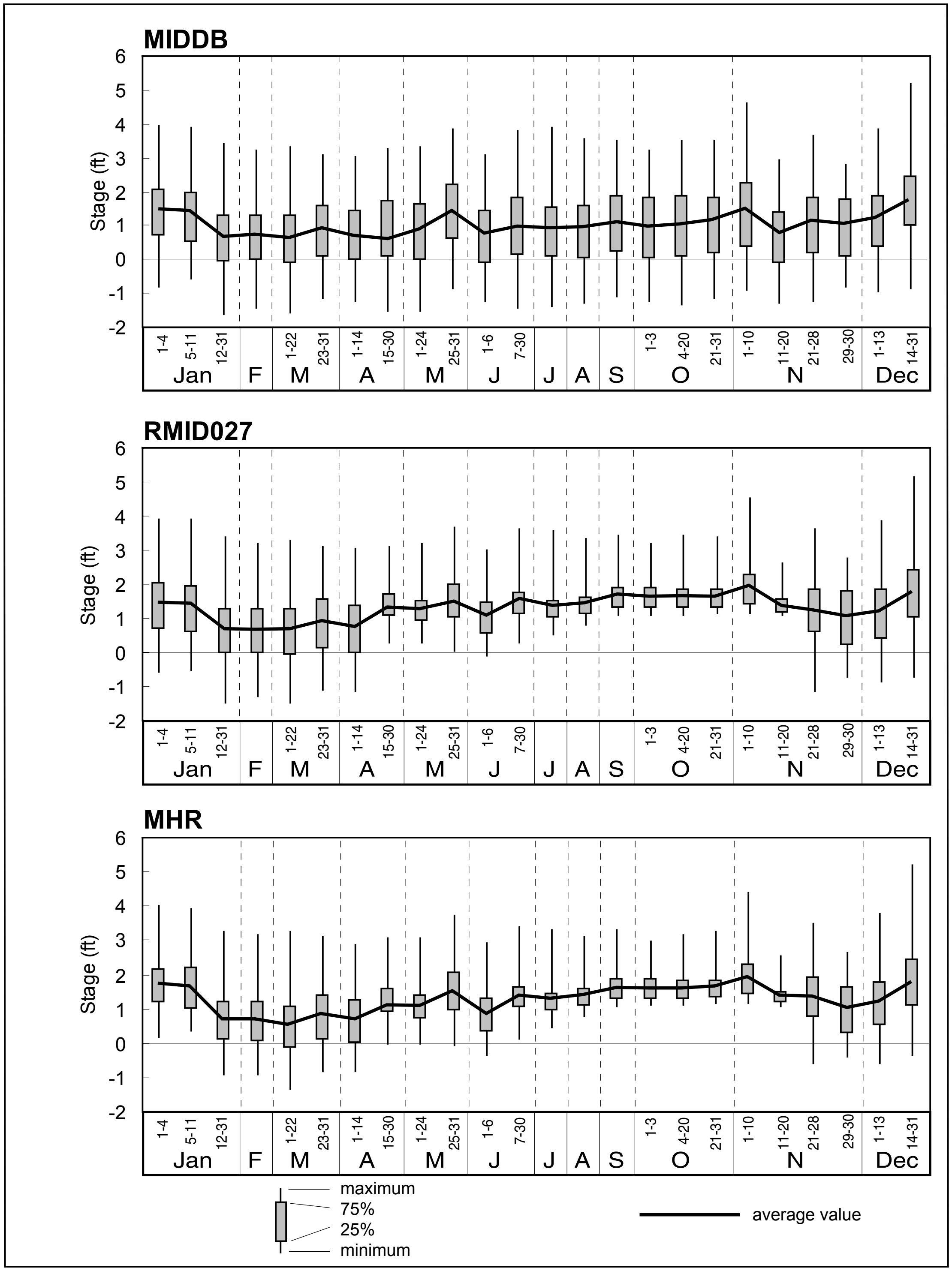


Figure 8-9 cont. Box Plots showing distribution of DSM2-simulated stages for various periods during 2002.

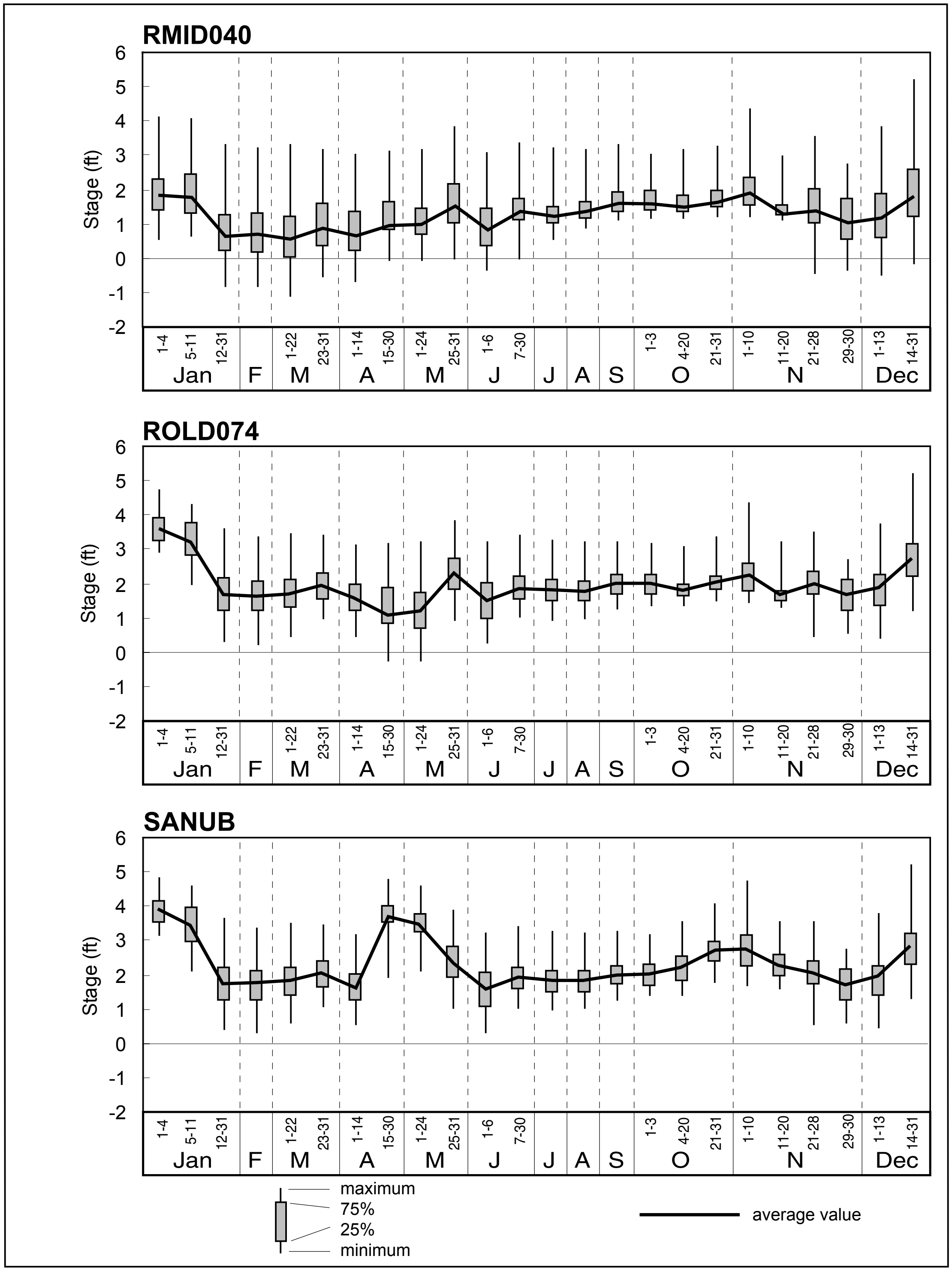


Figure 8-10. Box Plots showing distribution of DSM2-simulated flows for various periods during 2002.

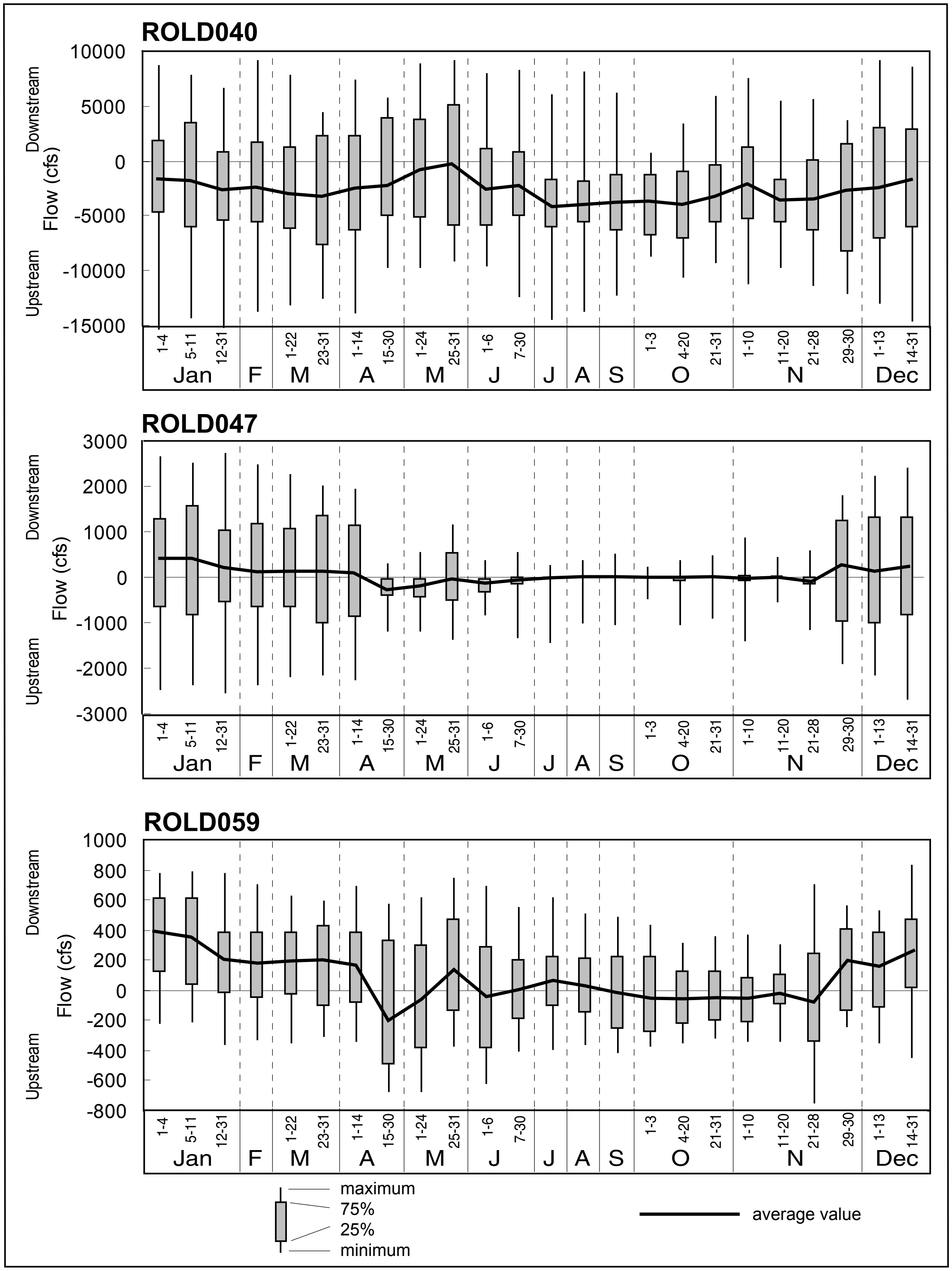


Figure 8-10 cont. Box Plots showing distribution of DSM2-simulated flows for various periods during 2002.

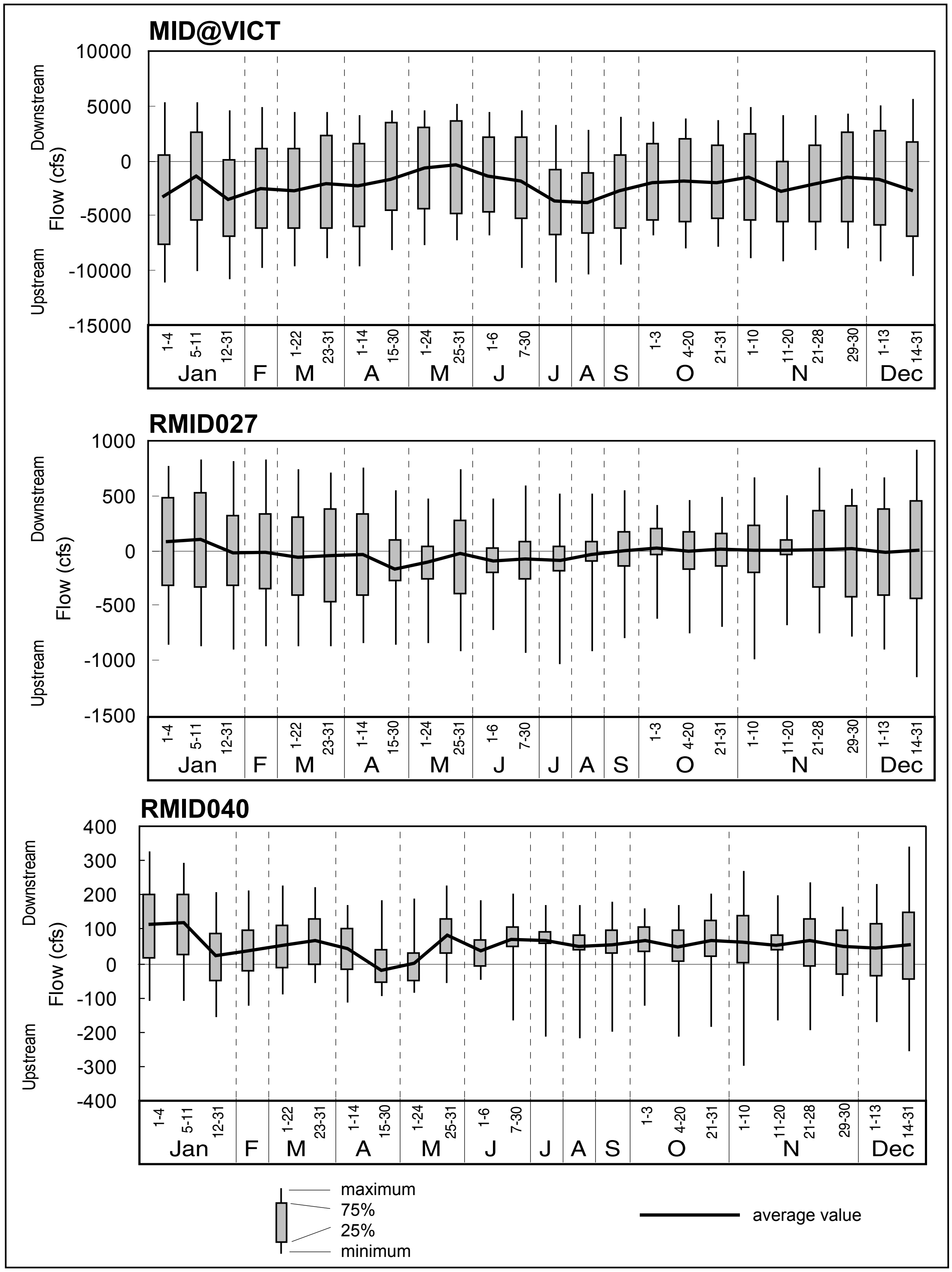


Figure 8-10 cont. Box Plots showing distribution of DSM2-simulated flows for various periods during 2002.

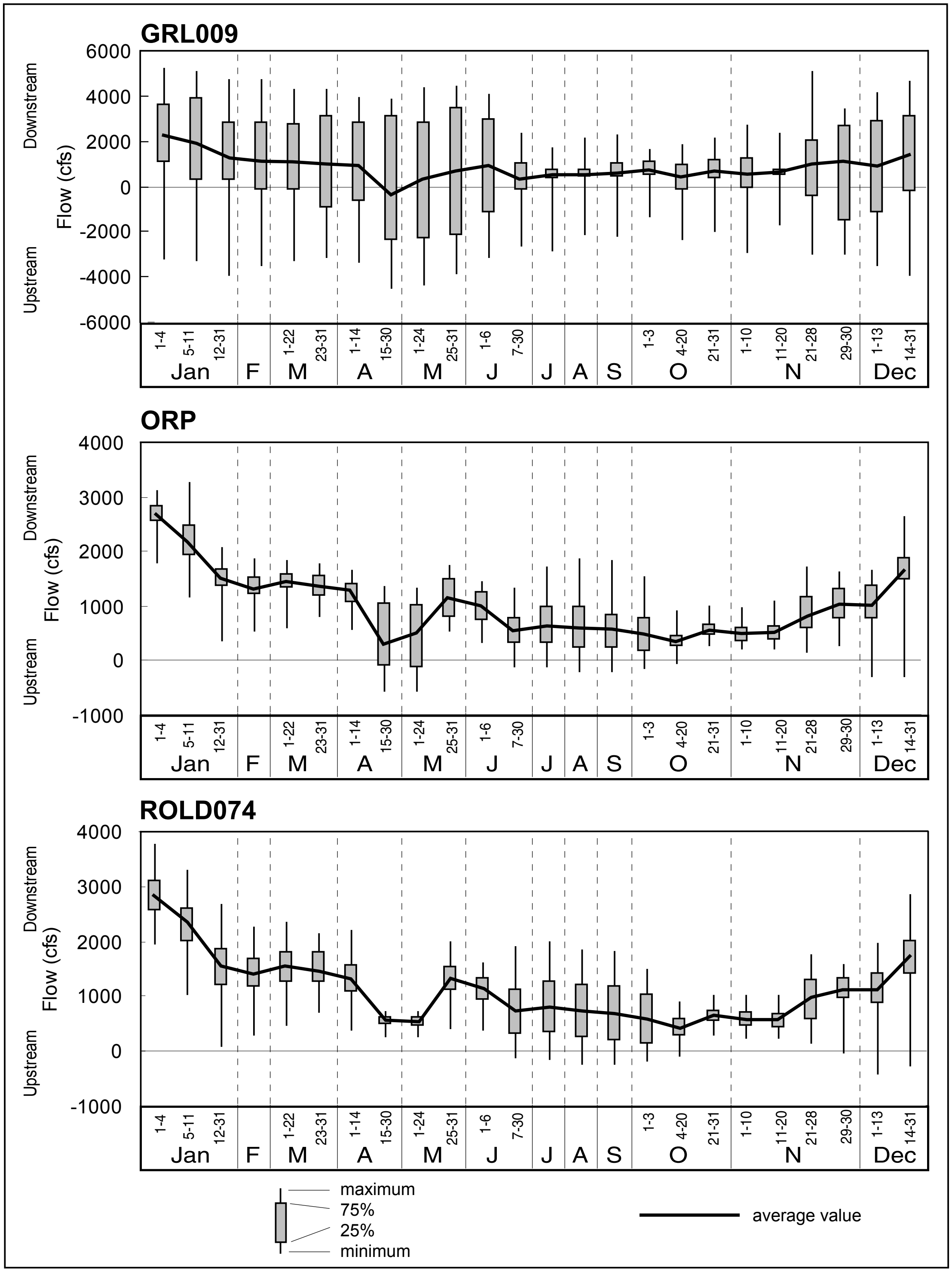


Figure 8-10 cont. Box Plots showing distribution of DSM2-simulated flows for various periods during 2002.

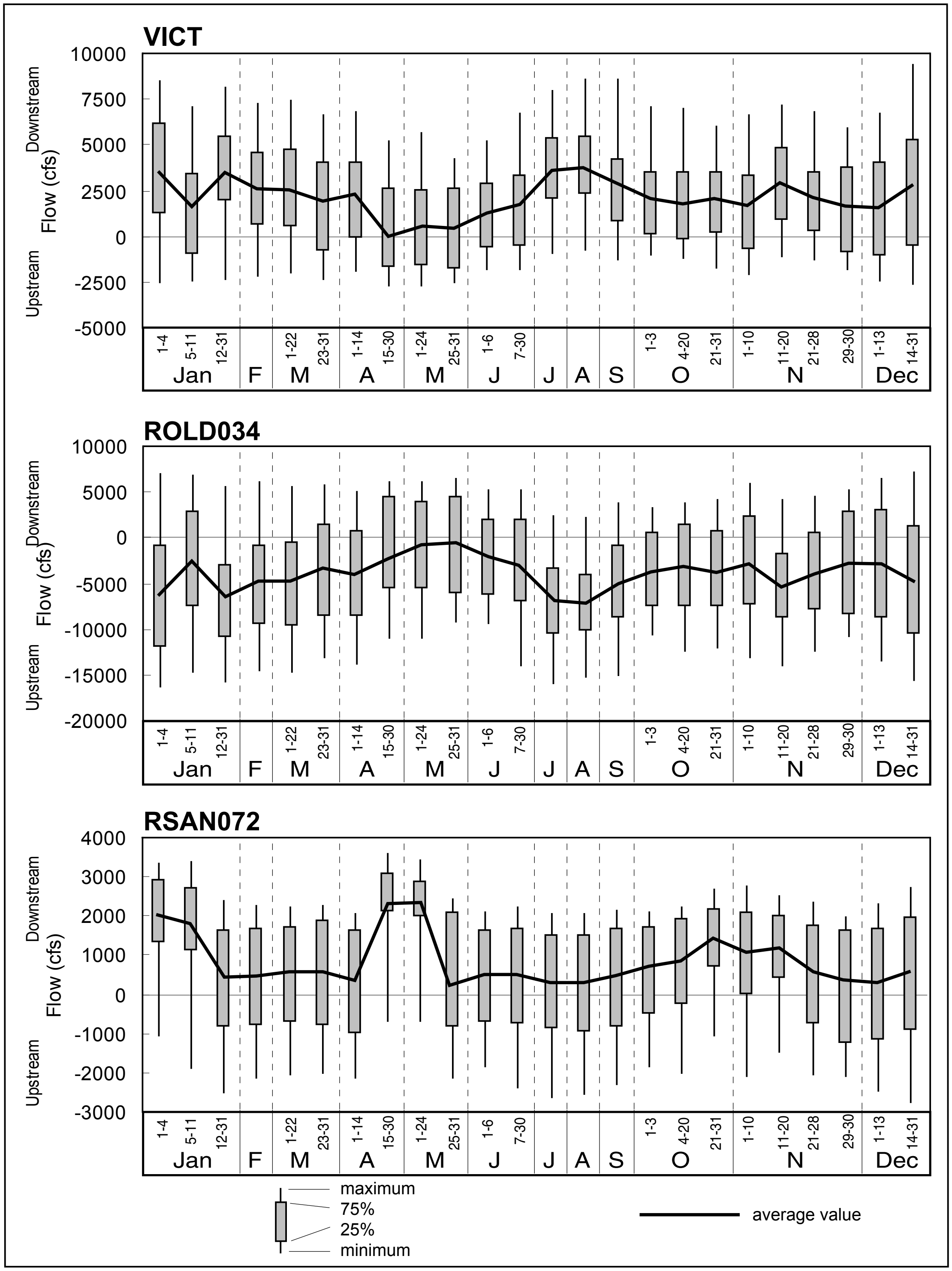


Figure 8-11. DSM2-simulated average flow patterns and minimum stages for 2002.

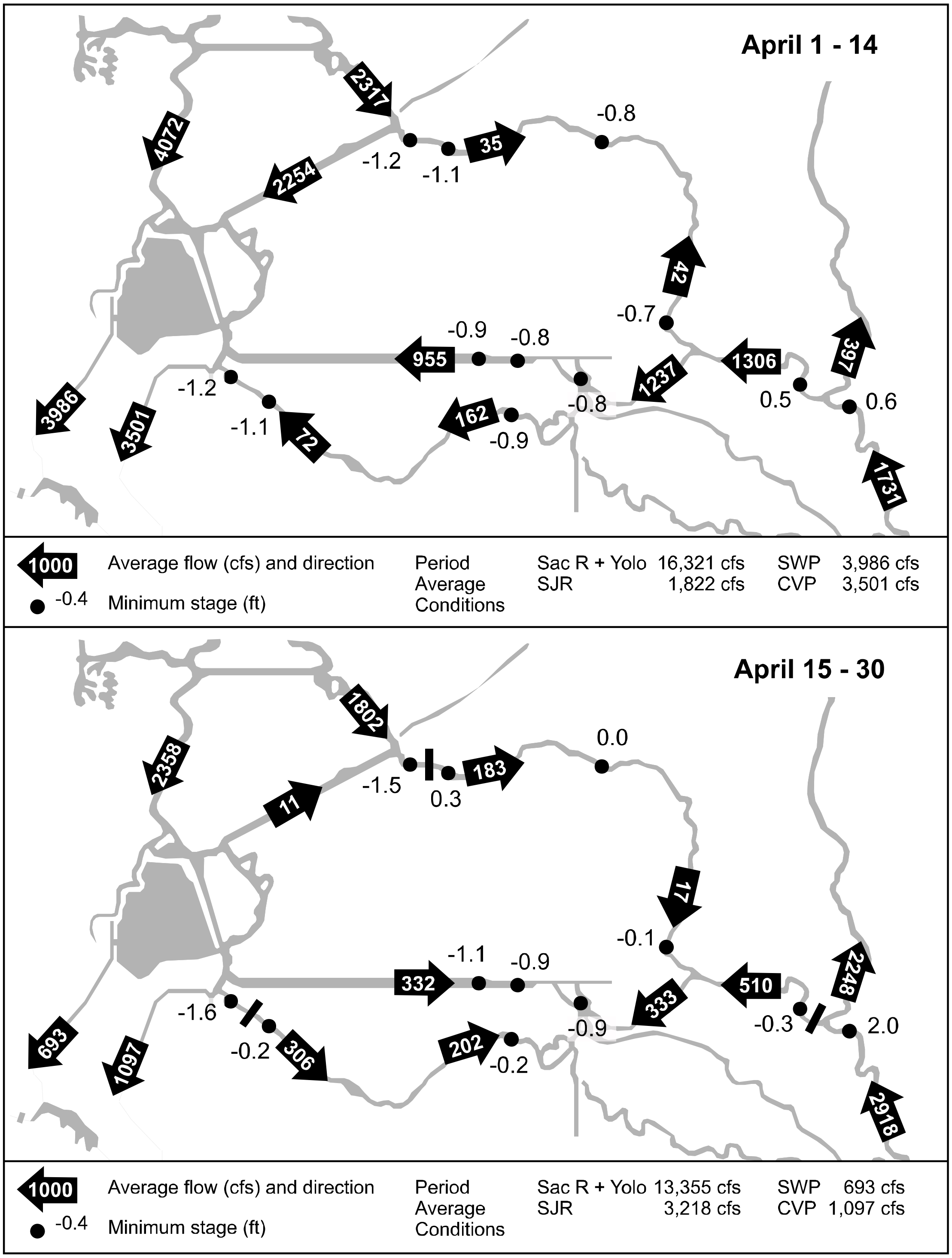
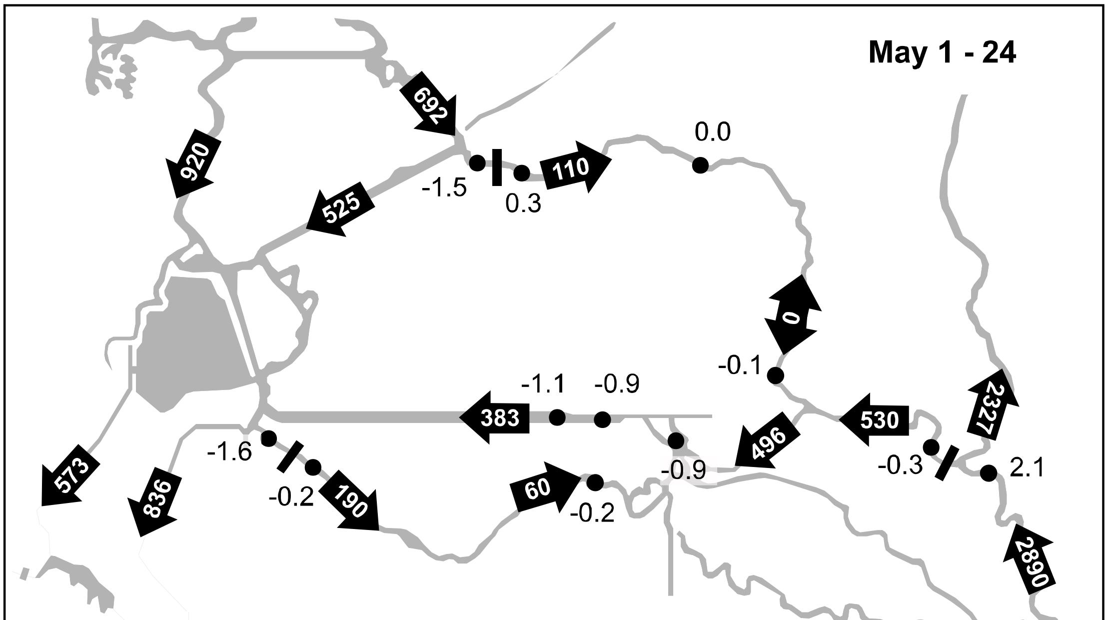
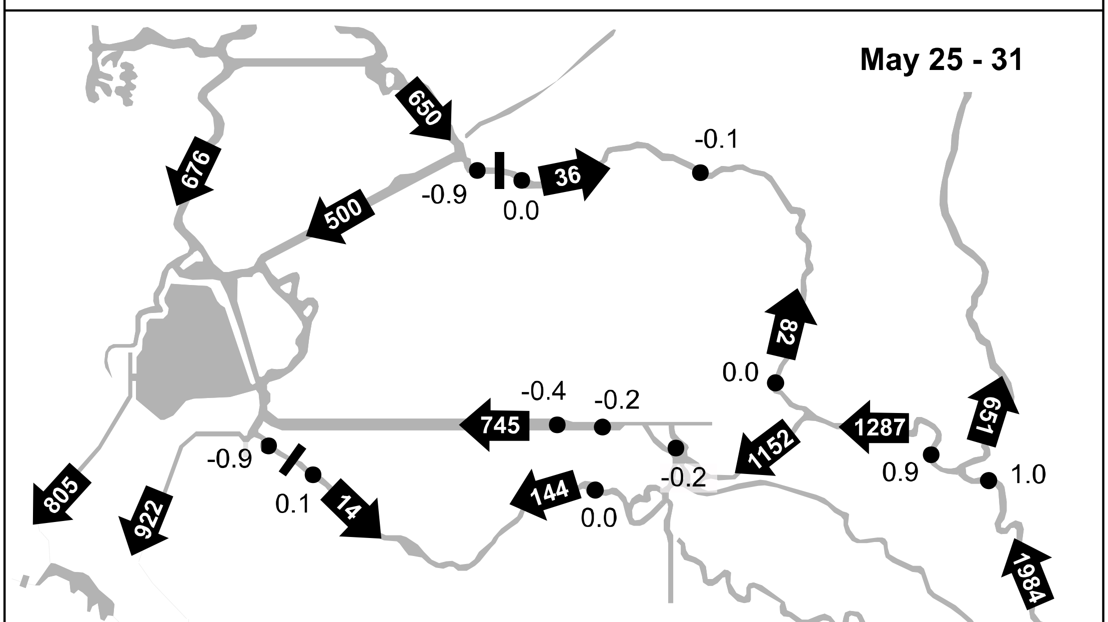


Figure 8-11 cont. DSM2-simulated average flow patterns and minimum stages for 2002.



1000 Average flow (cfs) and direction
● -0.4 Minimum stage (ft)

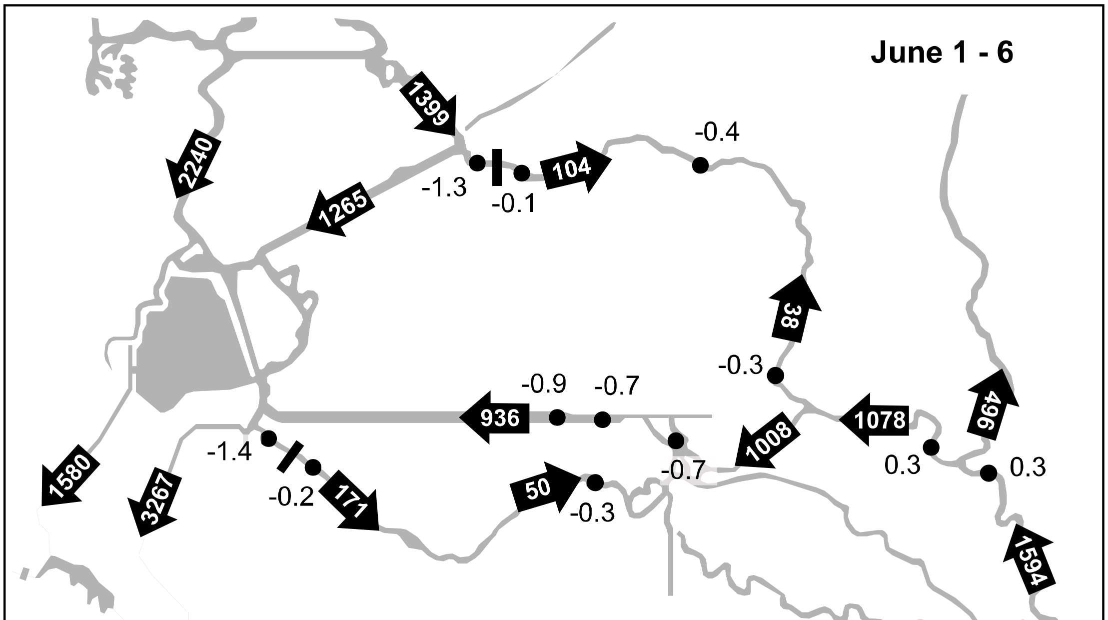
Period Average Conditions	Sac R + Yolo	12,694 cfs	SWP	573 cfs
	SJR	3,000 cfs	CVP	836 cfs



1000 Average flow (cfs) and direction
● -0.4 Minimum stage (ft)

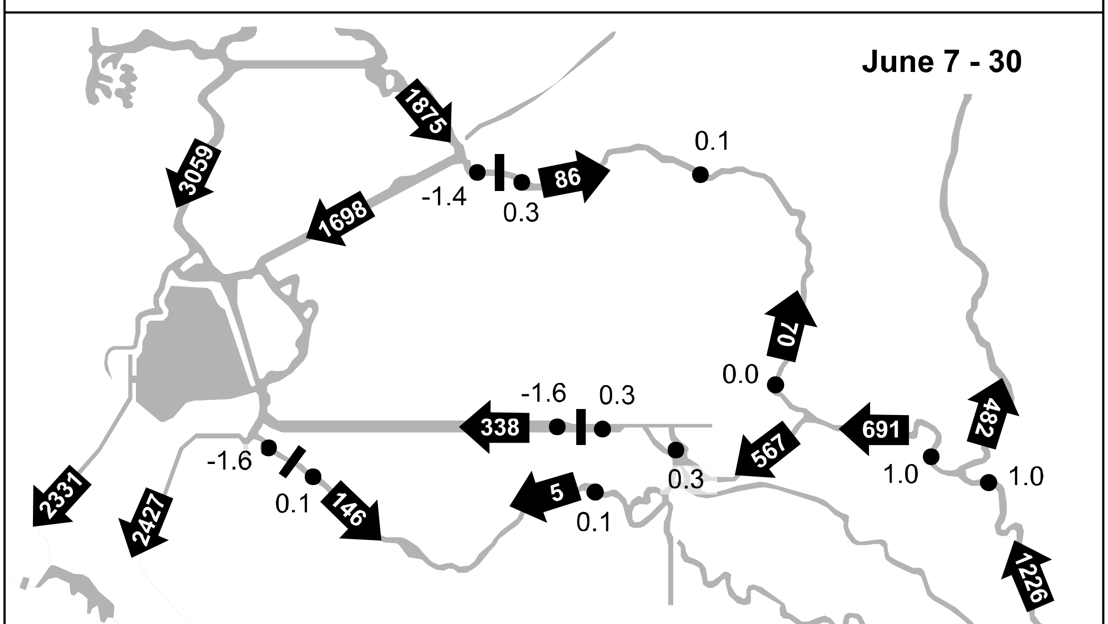
Period Average Conditions	Sac R + Yolo	15,098 cfs	SWP	805 cfs
	SJR	2,107 cfs	CVP	922 cfs

Figure 8-11 cont. DSM2-simulated average flow patterns and minimum stages for 2002.



1000 Average flow (cfs) and direction
● -0.4 Minimum stage (ft)

Period Average Conditions: Sac R + Yolo 12,653 cfs; SJR 1,676 cfs; SWP 1,580 cfs; CVP 3,267 cfs



1000 Average flow (cfs) and direction
● -0.4 Minimum stage (ft)

Period Average Conditions: Sac R + Yolo 14,105 cfs; SJR 1,368 cfs; SWP 2,331 cfs; CVP 2,427 cfs

Figure 8-11 cont. DSM2-simulated average flow patterns and minimum stages for 2002.

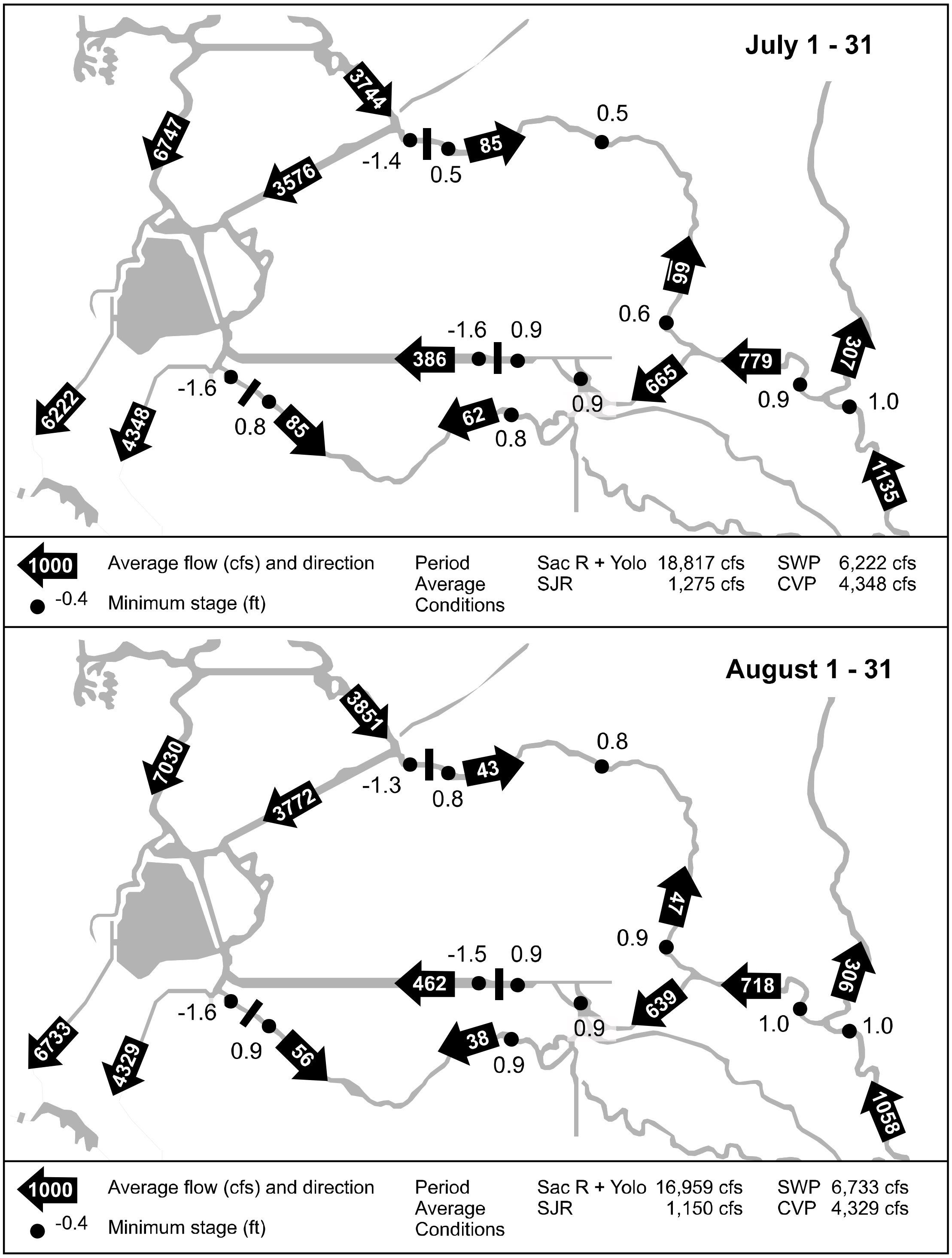


Figure 8-11 cont. DSM2-simulated average flow patterns and minimum stages for 2002

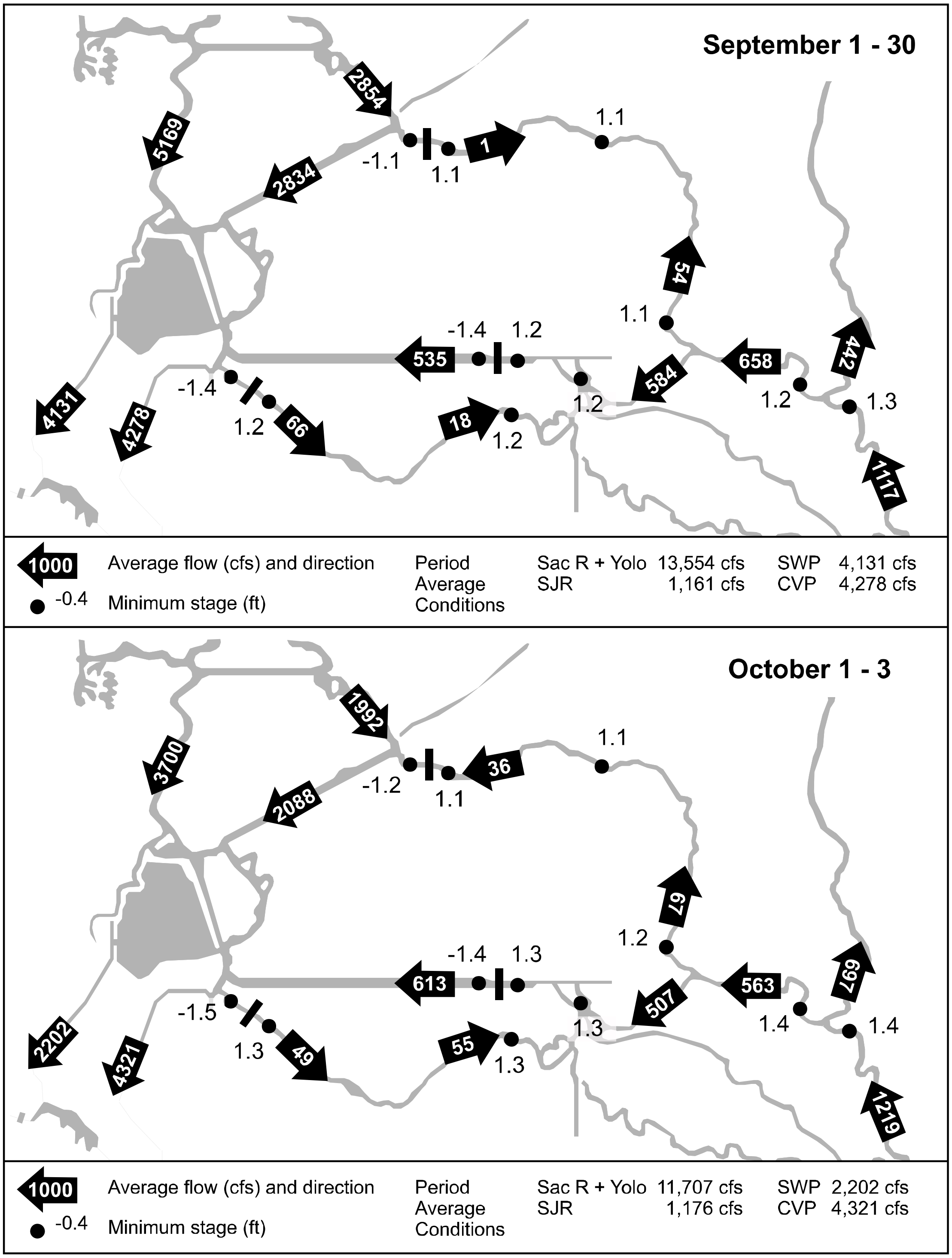


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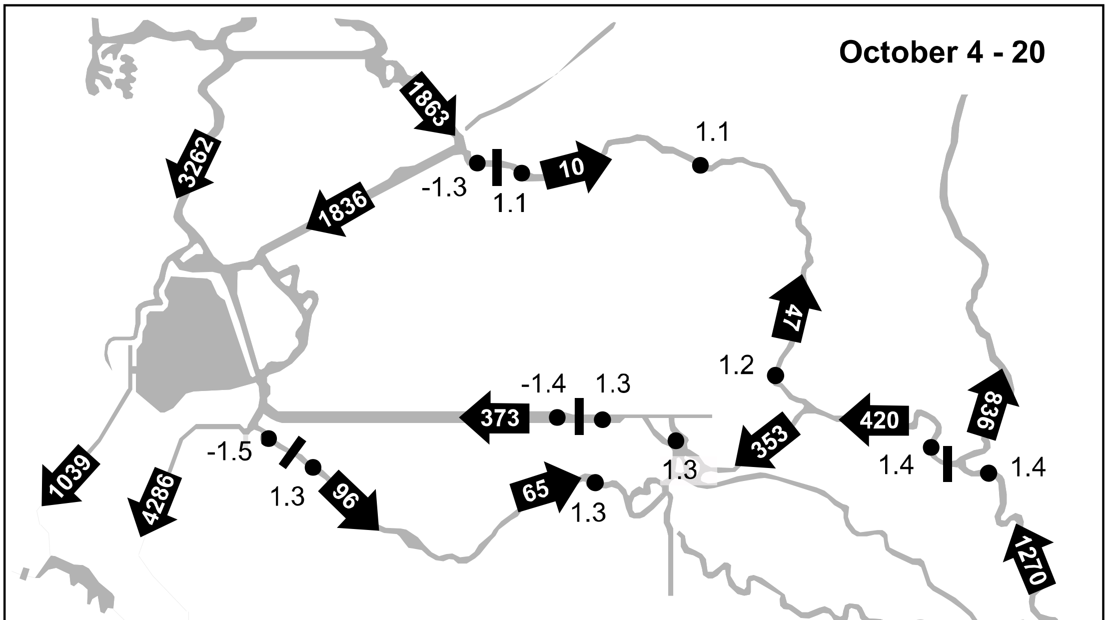
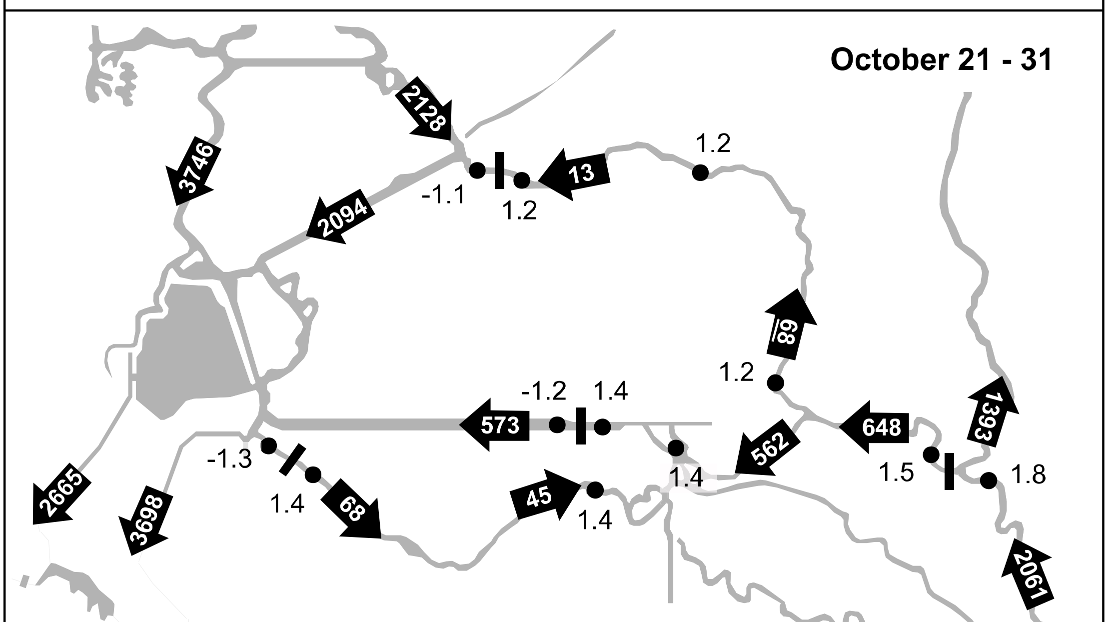
Figure 8-11 cont. DSM2-simulated average flow patterns and minimum stages for 2002.



1000 Average flow (cfs) and direction
-0.4 Minimum stage (ft)

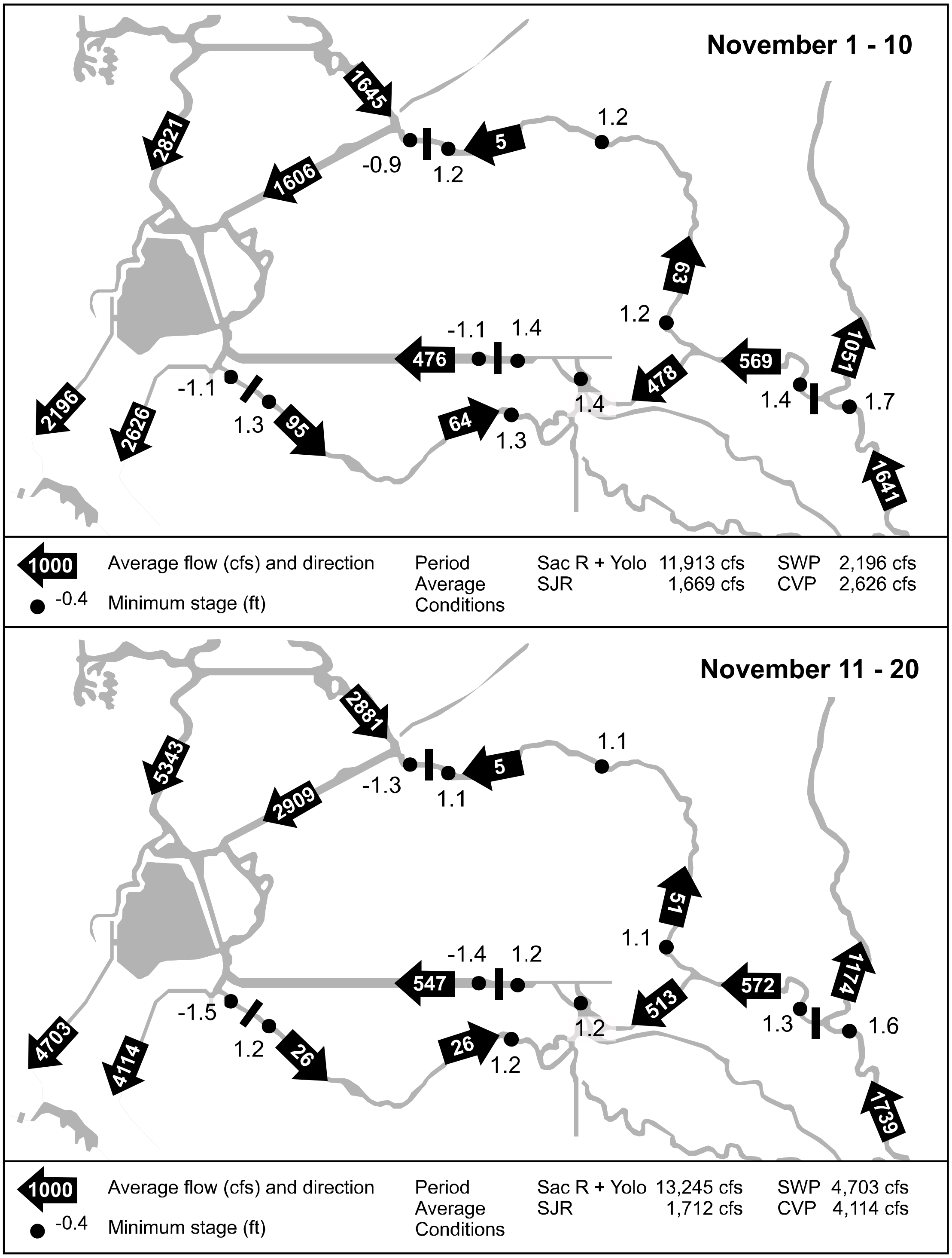
Period Average Conditions				
Sac R + Yolo	9,772 cfs		SWP	1,039 cfs
SJR	1,306 cfs		CVP	4,286 cfs



1000 Average flow (cfs) and direction
-0.4 Minimum stage (ft)

Period Average Conditions				
Sac R + Yolo	9,709 cfs		SWP	2,665 cfs
SJR	2,069 cfs		CVP	3,698 cfs

Figure 8-11 cont. DSM2-simulated average flow patterns and minimum stages for 2002.



Appendix A. Chinook Salmon Survival Investigations

Figure A-1. Sacramento-San Joaquin Estuary: Water Temperature Monitoring Locations During the VAMP 2002 Experiment.

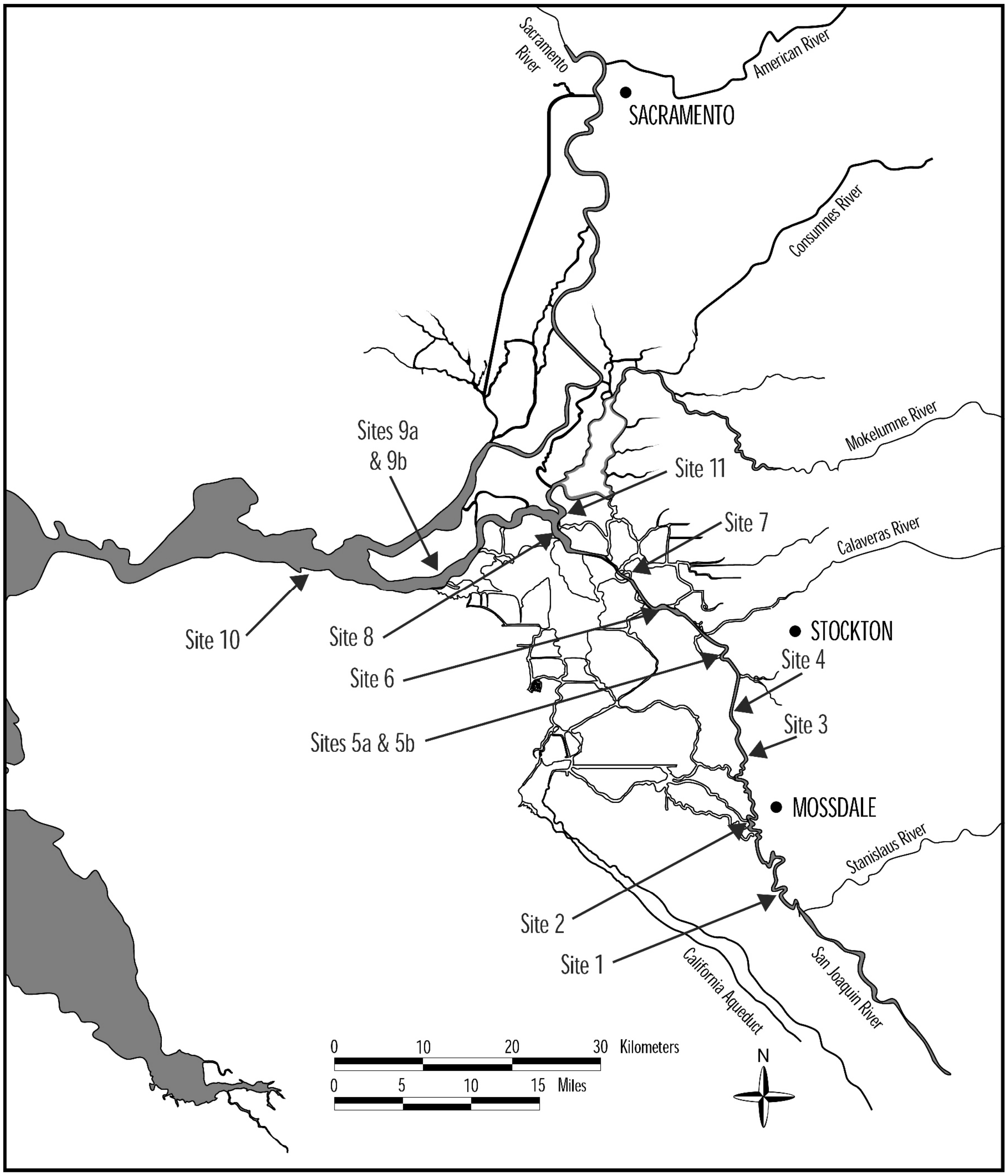


Table A-1. VAMP 2002 Water Temperature Monitoring Locations

Site No.	Temperature Monitoring Location	Latitude	Longitude	Distance from Durham Ferry (mi)	Date Deployed	Date Retrieved	Notes
	Merced River Hatchery - 1			n/a	March 15	April 26	In river April 18
	Merced River Hatchery - 2			n/a	March 15	April 30	In river April 25
1	Durham Ferry	N 37 41.381	W 121 15.657	n/a	April 4	June 15	In 3 feet of water
2	Mossdale	N 37 47.180	W 121 18.425	11.2	April 1	June 15	In 3 feet of water
3	Dos Reis	N 37 49.808	W 121 18.665	16.4	April 1	June 15	In 3 feet of water
4	DWR Monitoring Station	N 37 51.869	W 121 19.376	19.4	April 1	June 15	In 3 feet of water
5a	Confluence – Top	N 37 56.818	W 121 20.285	26.5	April 1	June 15	2 feet below surface
5b	Confluence- Bottom	N 37 56.818	W 121 20.285	26.5	April 1	June 15	On river bottom
6	Downstream of Channel Marker 30	N 37 59.776	W 121 25.569	33.3	April 1	June 15	In 3 feet of water
7	½ mile Upstream of Channel Marker 13	N 38 01.940	W 121 28.769	37.3	April 1	June 15	In 3 feet of water
8	Downstream of Channel Marker 36	N 38 04.522	W 121 34.413	44.7	April 1	June 15	In 3 feet of water
9a	Jersey Point USGS Gauging Station - top	N 38 03.172	W121 41.637	56	April 1	June 15	2 feet below surface
9b	Jersey Point USGS Gauging Station – bottom	N 38 03.172	W121 41.637	56	April 1		Logger lost
10	Chipps Island	N 38 03.084	W 121 55.463	71.5	April 1	June 15	In 3 feet of water
11	Mokelumne River	N 38 06.334	W 121 34.213	40	April 1	June 15	In 3 feet of water

Figure A-2. Water Temperature Monitoring: Site 1, Durham Ferry

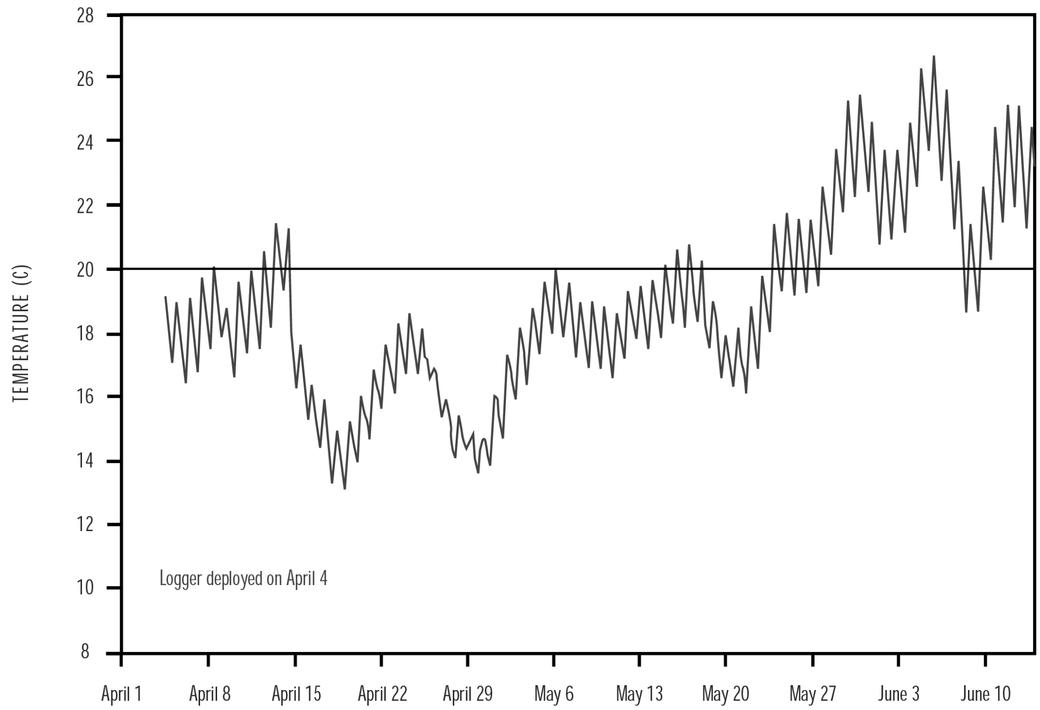


Figure A-3. Water Temperature Monitoring: Site 2, Mossdale

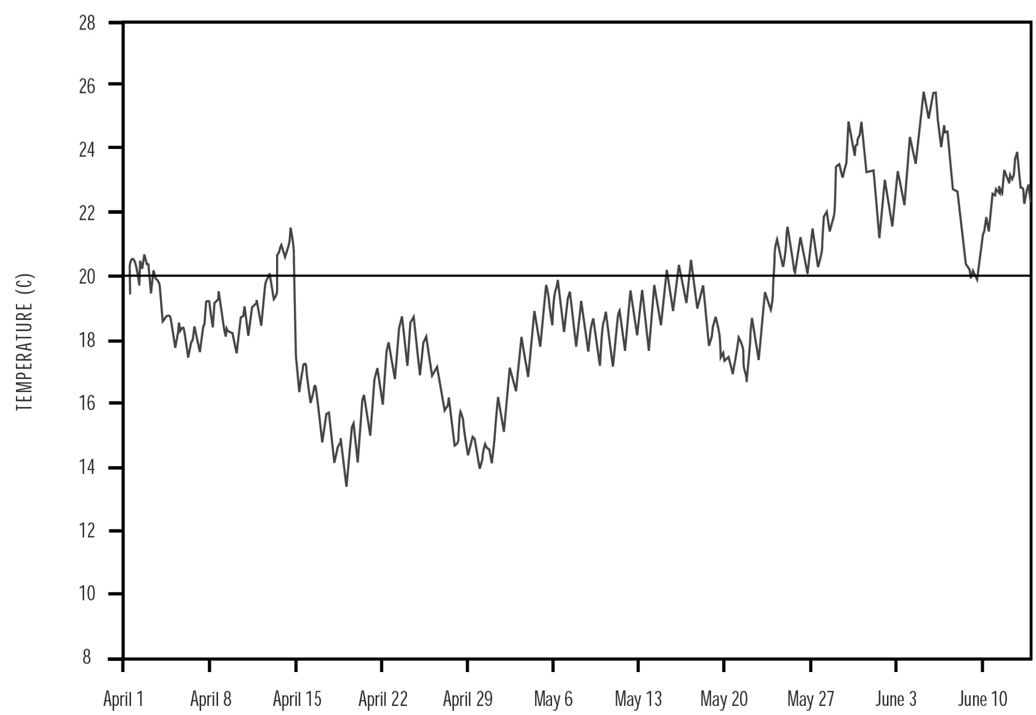


Figure A-4. Water Temperature Monitoring: Site 3, Dos Reis

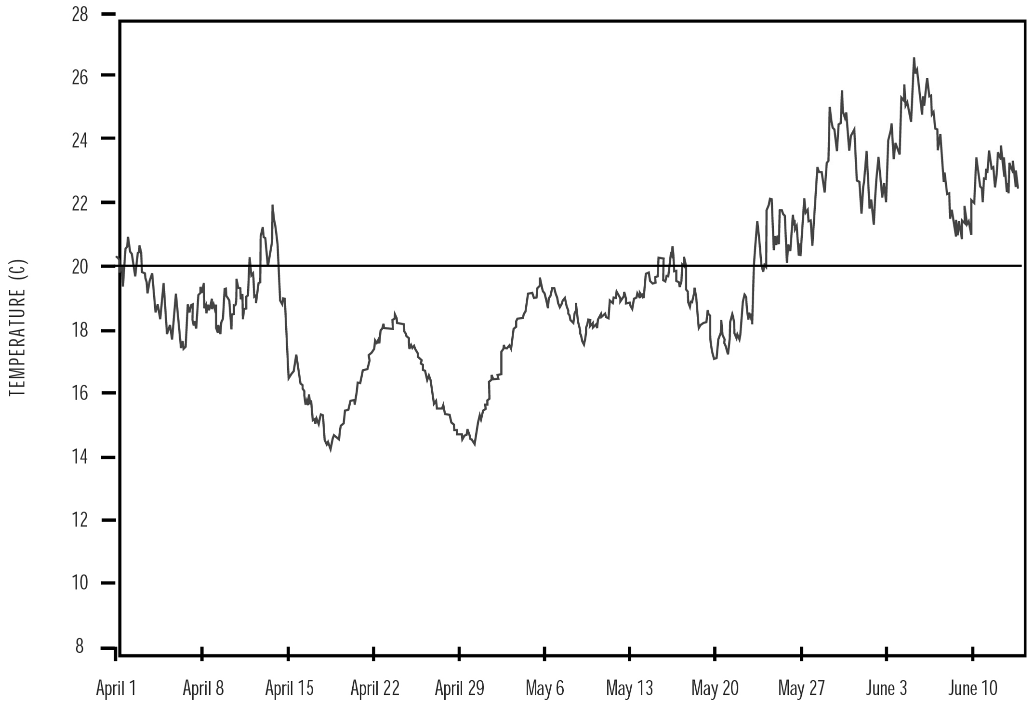


Figure A-5. Water Temperature Monitoring: Site 4, DWR Monitoring Station

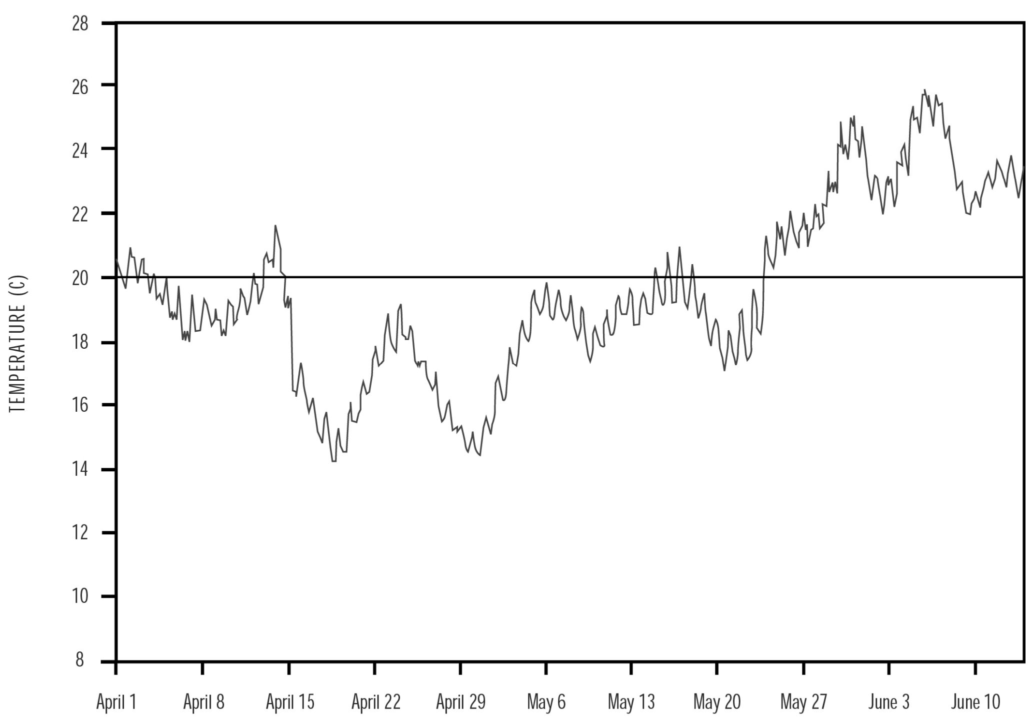


Figure A-6. Water Temperature Monitoring: Site 5a, Confluence-Top

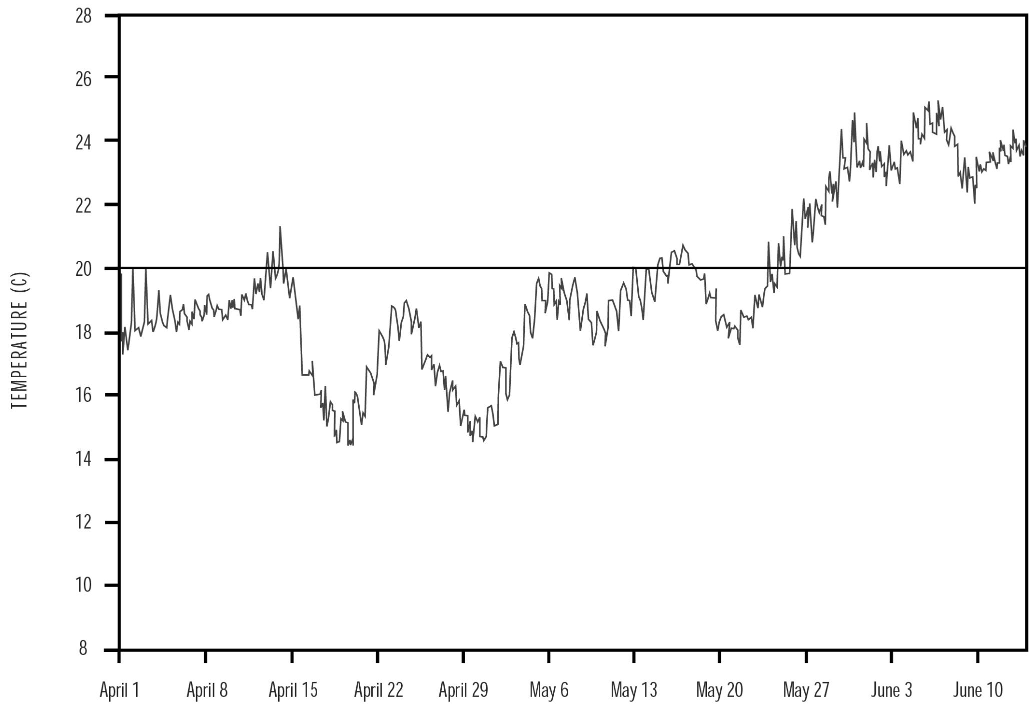


Figure A-7. Water Temperature Monitoring: Site 5b, Confluence-Bottom

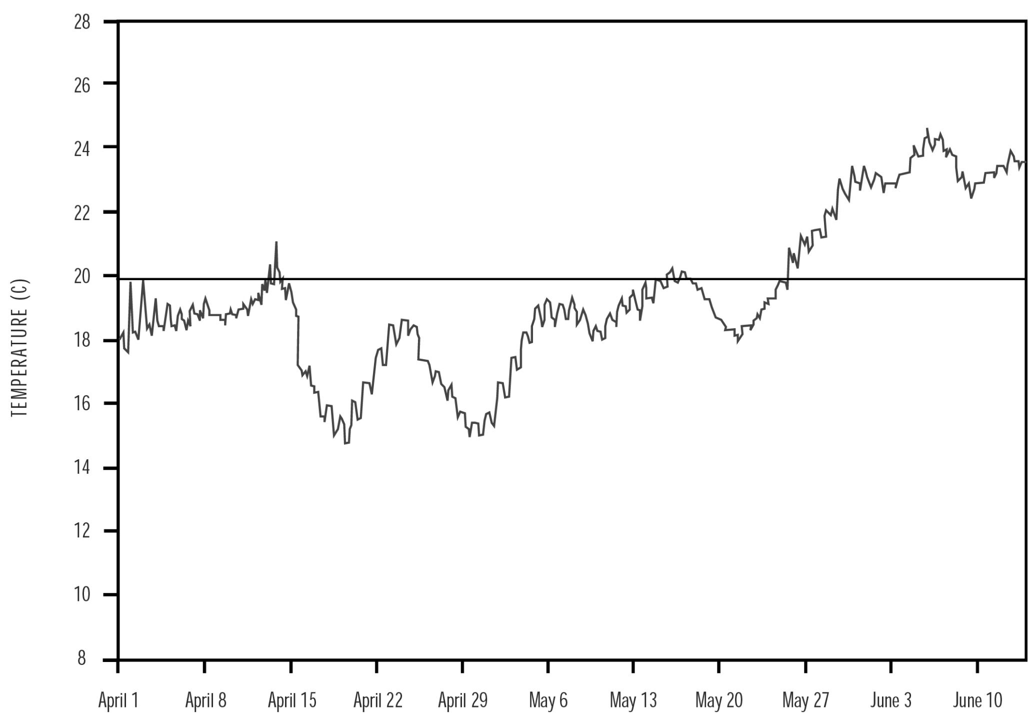


Figure A-8. Water Temperature Monitoring: Site 6, Downstream of Channel Marker 30

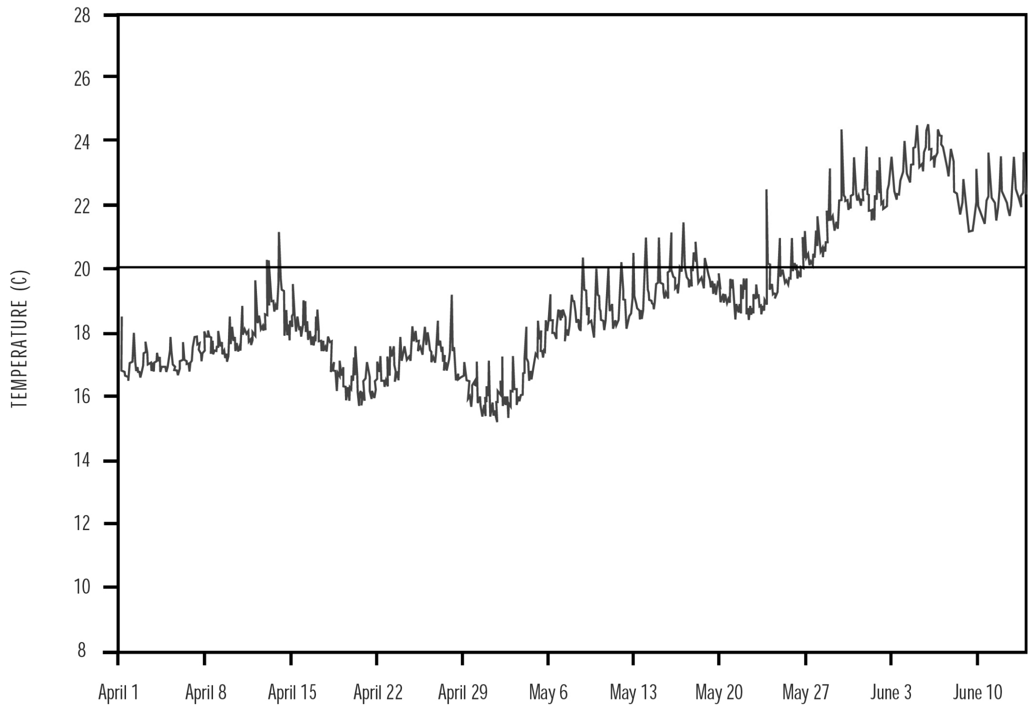


Figure A-9. Water Temperature Monitoring: Site 7, 1/2 Mile Upstream of Channel Marker 13

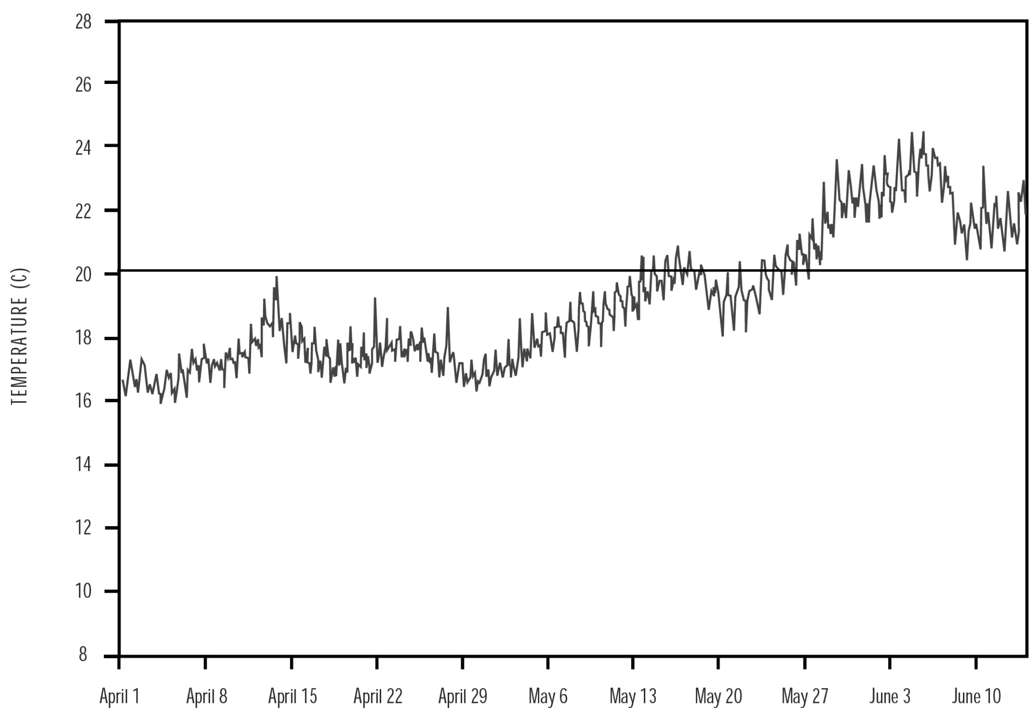


Figure A-10. Water Temperature Monitoring: Site 8, Downstream of Channel Marker 36

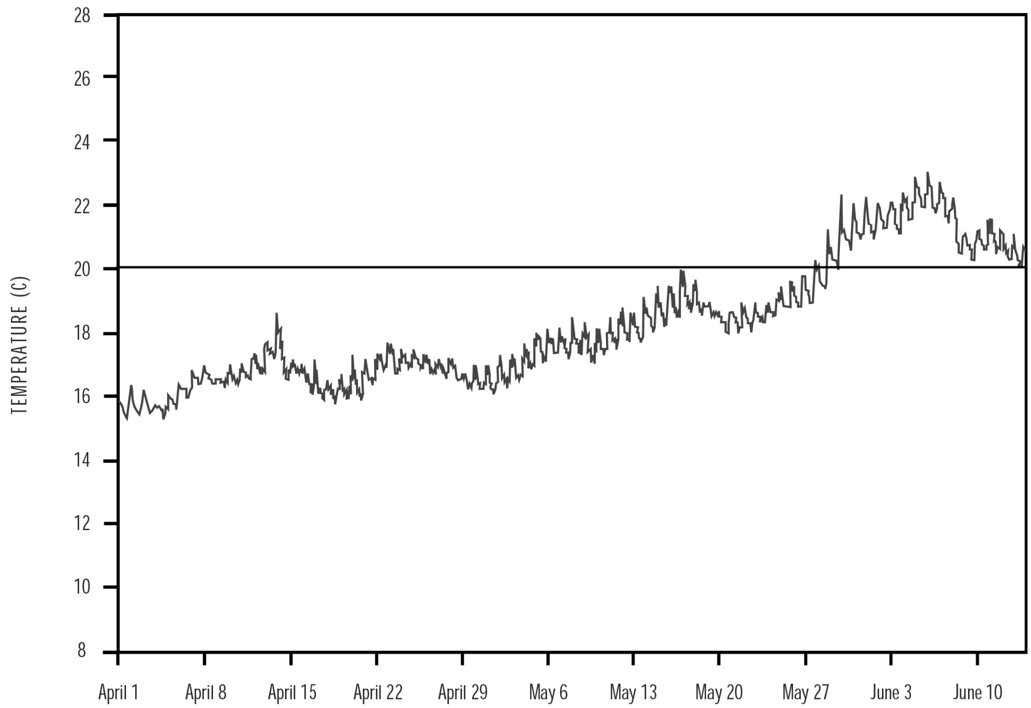


Figure A-11. Water Temperature Monitoring: Site 9a, Jersey Point-Top

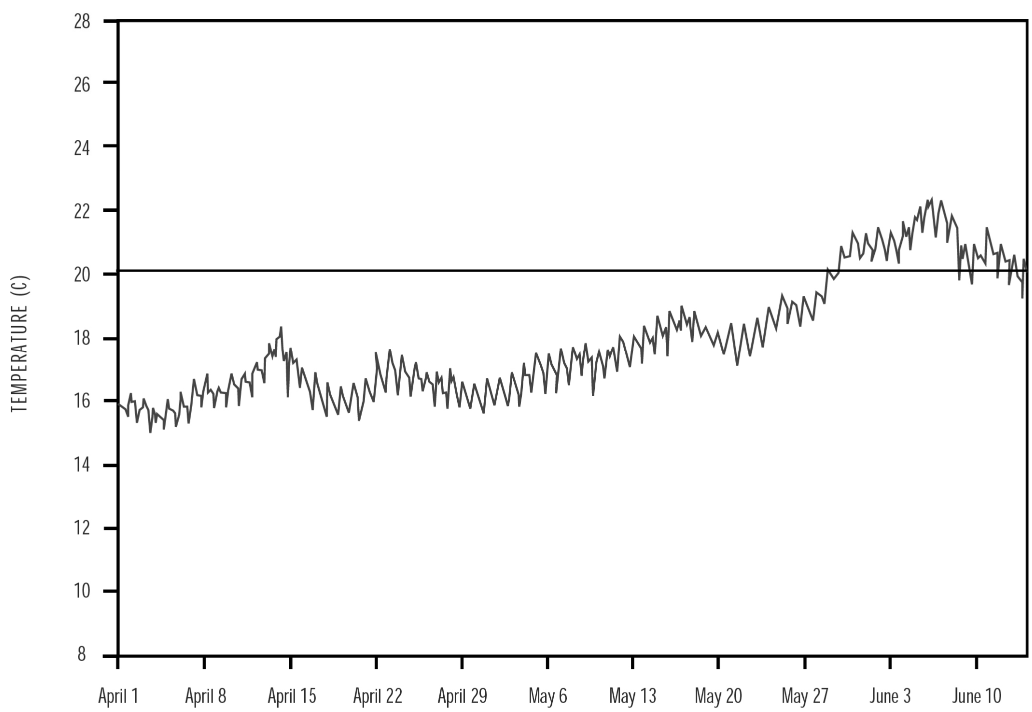


Figure A-12. Water Temperature Monitoring: Site 10, Chipps Island

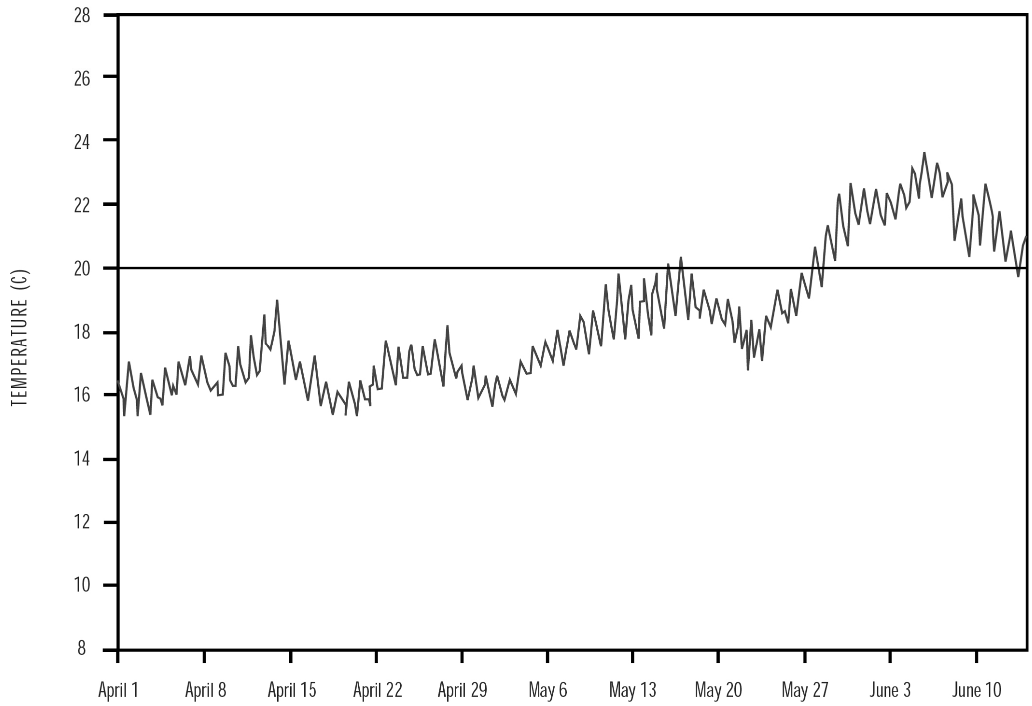


Figure A-13. Water Temperature Monitoring: Site 11, Mokelumne River

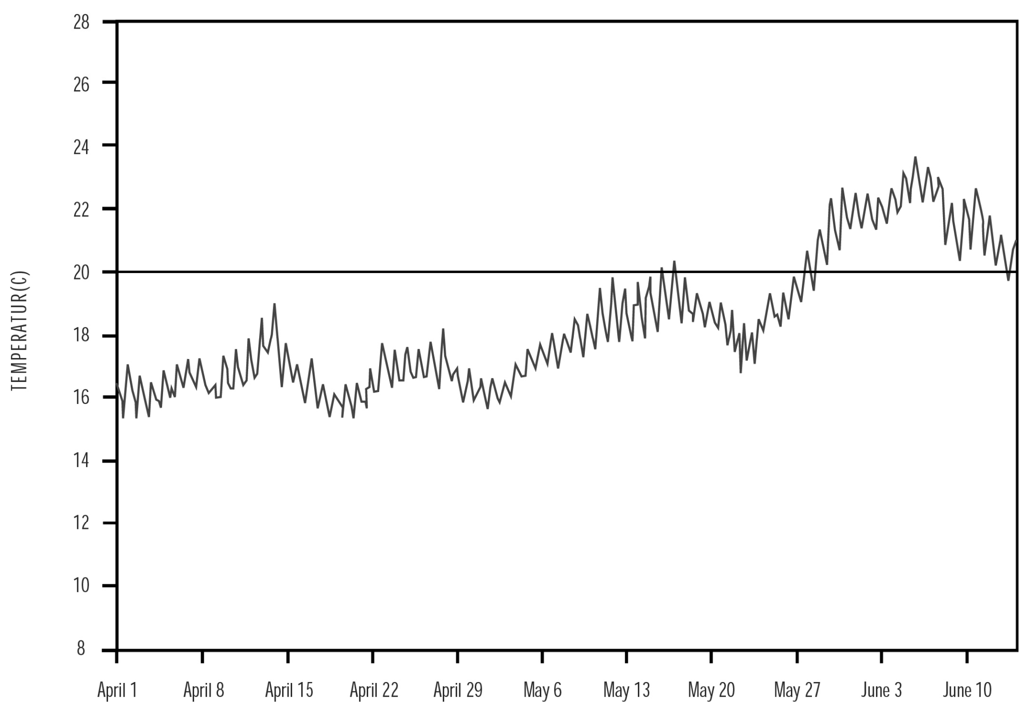


Figure A-14. Water Temperature Monitoring: Merced River Fish Hatchery—1

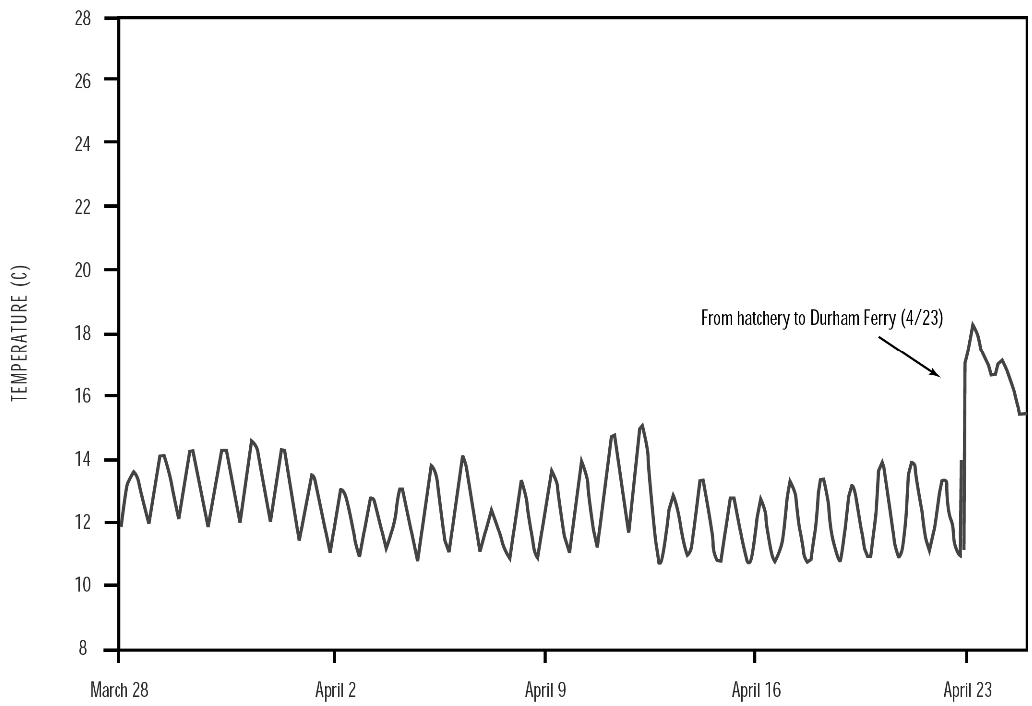


Figure A-15. Water Temperature Monitoring: Merced River Fish Hatchery—2

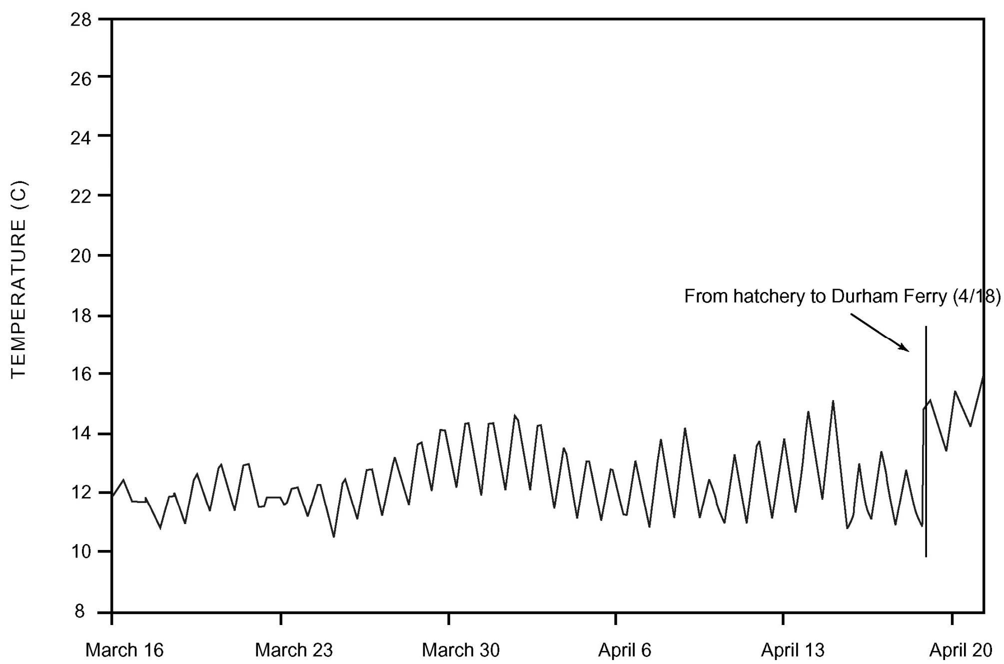


Table A-2. Results of Net Pen Sampling Conducted Immediately After Release, VAMP 2002

LOCATION	FORK LENGTH MEAN (RANGE) (millimeters)	WEIGHT MEAN(RANGE) (grams)	SCALE LOSS MEAN(RANGE) (percent)	COLOR	FIN HEMORRHAGING	EYES	GILL COLOR	AD CLIPS COMMENTS
Durham Ferry I Pen #1	80.96(64-87)	5.82(2.7-7)	3.8(1-11)	Normal	None	Normal	Normal	0.04(1 deformed pectoral fin)
Durham Ferry I Pen #2	82.00(74-90)	6.09(4.4-7.7)	3.6(2-7)	Normal	None	Normal	Normal	
Mossdale I Pen #2	84.5(77-92)	6.7(4.9-8.9)	4.9(1-15)	Normal	None	Normal	Normal	0.04(1 poor ad clips)
Mossdale I Pen #3	81.9(68-90)	5.9(3.5-8)	3.4(1-15)	Normal	None	Normal	Normal	0.04(1 deformed pectoral fin)
Jersey Point I Pen #2	85.0(70-95)	6.7(3.6-9.4)	3.6(1-7)	Normal	None	Normal	Normal	0.08(2 half ad clips) 0.04(1 deformed pectoral fins)
Jersey Point I Pen #3	82.0(61-92)	6.1(2.4-8.2)	3.3(1-6)	Normal	None	Normal	Normal	0.04(1 half ad clip) 0.04(1 deformed pectoral fin)
Group I	82.76(61-95)	6.24(2.4-9.4)	3.77(1-15)					
Durham Ferry II Pen #1	80.1(67-93)	5.8(4.1-8.1)	5.9(2-20)	Normal	None	Normal	Normal	0.04(1 half adipose fin clip)
Durham Ferry II Pen #2	79.24(67-93)	5.24(3.1-8.4)	12.32(1-25)	Normal	None	Normal	Normal	0.04(1 caudal fin damage)
Mossdale II Pen #1	82.4(75-104)	6.1(4.4-12.4)	7.3(3-15)	Normal	None	Normal	Normal	0.08(2 caudal fin damage)
Mossdale II Pen#2	80.2(70-90)	5.43(3.7-7.7)	8.08(2-25)	Normal	None	Normal	Normal	0.04(caudal/dorsal clip?) 0.08(2 no adipose fin clip)
Jersey Point II Pen #2	85.2(77-96)	6.77(4.8-9)	2.44(1-5)	Normal	None	Normal	Normal	
Jersey Point II Pen #3	83.8(75-90)	6.62(4.3-9)	2.32(1-6)	Normal	None	Normal	Normal	0.08(2 half adiose fin clip) 0.08(2 deformed pectoral fin)
Group II	81.83(67-104)	5.99(3.1-12.4)	6.39(1-25)					

Table A-3. Results of Net Pen Sampling Conducted 48 Hours After Release, VAMP 200

LOCATION	FORK LENGTH MEAN(RANGE) millimeters	WEIGHT MEAN(RANGE) grams	SCALE LOSS MEAN(RANGE) percent	COLOR	FIN HEMORRHAGING	EYES	GILL COLOR	AD. CLIPS COMMENTS
Durham Ferry I Pen #1	83(69-102)	6.0(3.2-11.5)	4(2-7)	Normal	None	Normal	Normal	
Durham Ferry I Pen #2	84.4(76-90)	6.2(4.5-7.7)	2.9(1.0-5.0)	Normal	None	Normal	Normal	
Mossdale I Pen #2	82.92(75-91)	6.0(7.5-7.8)	3(1-12)	Normal	None	Normal	Normal	
Mossdale I Pen #3	82.4(66-92)	5.8(4-8.2)	3(1-7)	Normal	None	Normal	Normal	0.04(scoliosis-spine)
Jersey Point I Pen #2	85.5(76-94)	6.6(4.3-8.1)	13(1-40)	Normal	None	Normal	Normal	0.08(half adipose clip)
Jersey Point I Pen #3	83.6(72-95)	5.9(3.8-9.1)	9.1(4.0-15.0)	Normal	None	Normal	Normal	0.04(hemmoraged eye)
Group II	83.6(66-102)	6.1(3.2-11.5)	6(1-40)					
Durham Ferry II Pen #1	80(71-94)	5.4(3.6-9.3)	12.3(2.0-30.0)	Normal	None	Normal	Normal	
Durham Ferry II Pen #2	80.64(71-93)	5.3(3.6-9.3)	6(1-21)	Normal	None	Normal	Normal	
Mossdale II Pen#1	80.6(70-89)	5.4(3.6-7.4)	5.2(2.0-10.0)	Normal	None	Normal	Normal	0.04(hemmoraged eye) 0.04(no adipose fin clip)
Mossdale II Pen#2	79.9(67-88)	5.6(3.2-7.0)	6.5(2.0-12.0)	Normal	None	Normal	Normal	
Jersey Point II Pen #2	82.0(71-94)	5.8(3.7-9.2)	4.3(2.0-10.0)	Normal	None	Normal	Normal	0.20(half adipose fin clip) 0.04(deformed pectoral fin)
Jersey Point II Pen #3	82.9(75-93)	6.3(4.4-8.6)	4.9(2.0-9.0)	Normal	None	Normal	Normal	0.16(half adipose fin clip) 0.04(no adipose fin clip)
Group II	80.48(67-82.9)	5.5(9.3-7.9)	6.6(1.0-30.0)					

(note: averages are for first 25 fish worked up in each pen)

Figure A-16. Net Pen Sampling Results: Chipps Island/Durham Ferry I

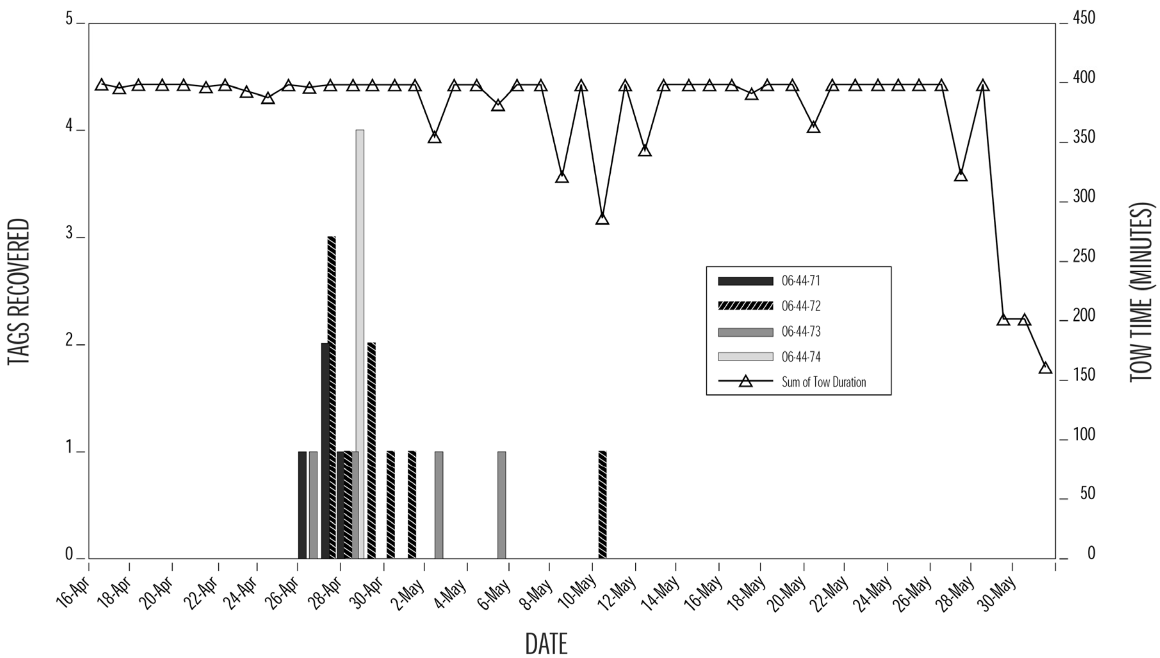


Figure A-17. Net Pen Sampling Results: Chipps Island/Mossdale I

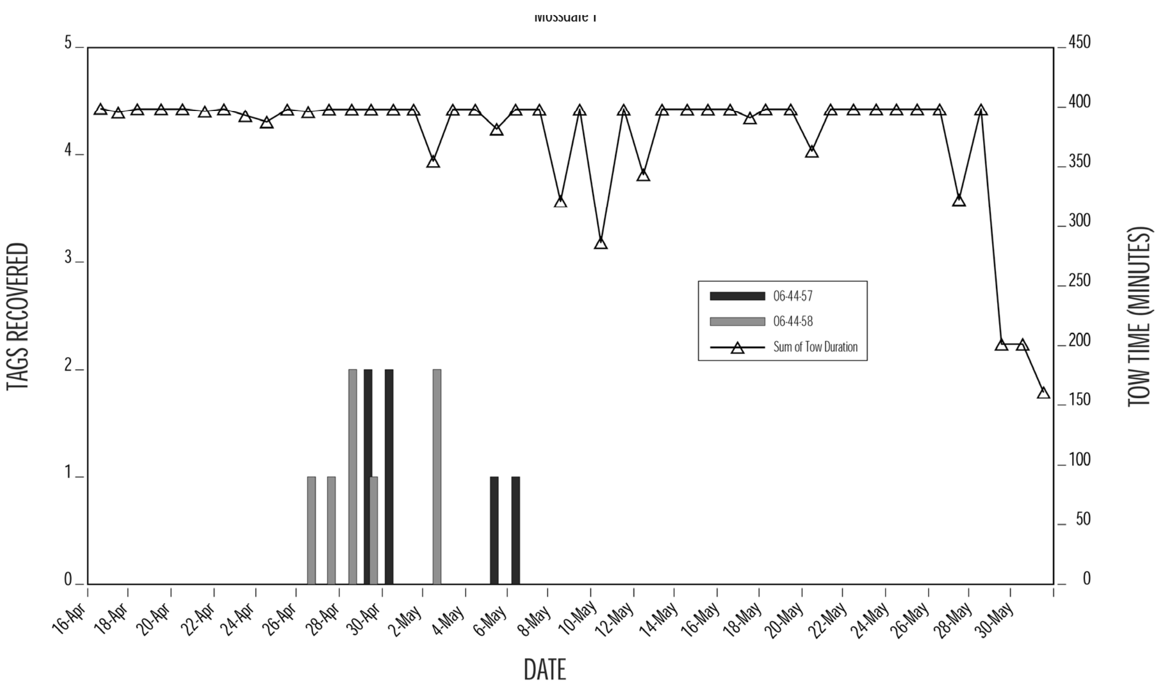


Figure A-18. Net Pen Sampling Results: Chipps Island/Jersey Point I

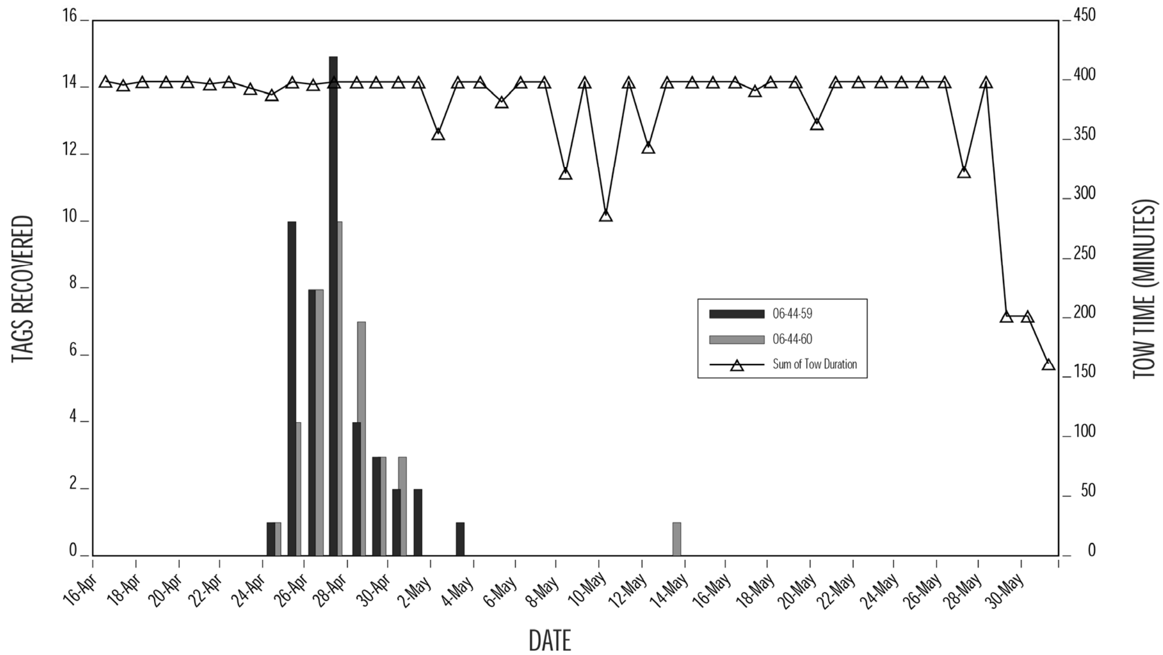


Figure A-19. Net Pen Sampling Results: Chipps Island/Durham Ferry II

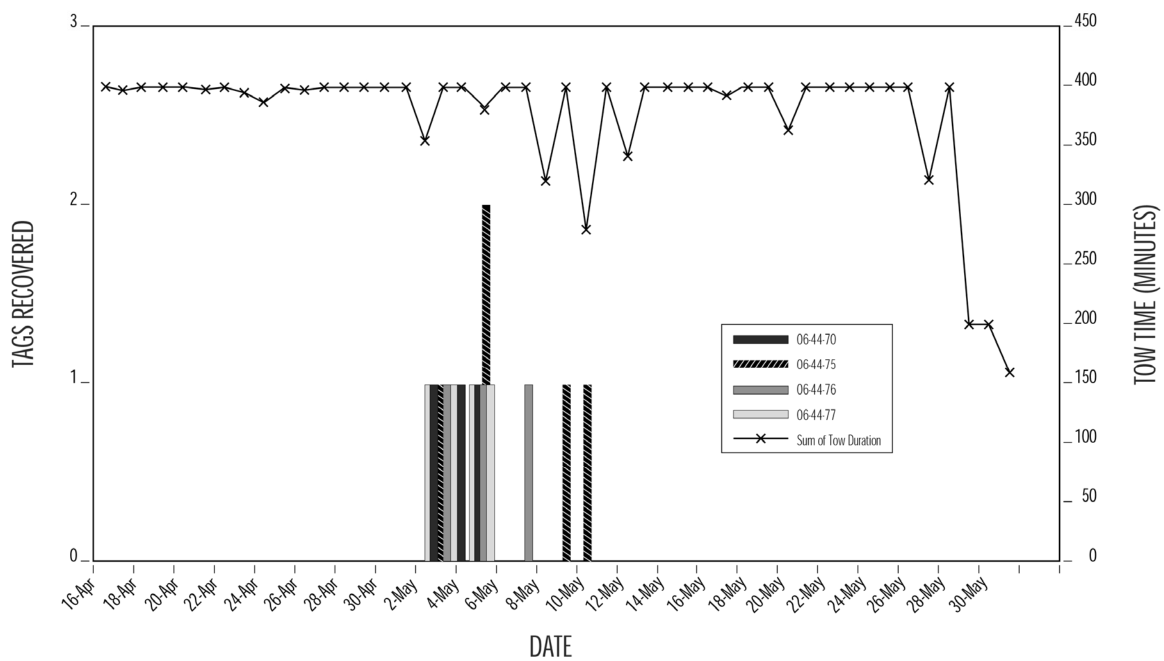


Figure A-20. Net Pen Sampling Results: Chipps Island/Mossdale II

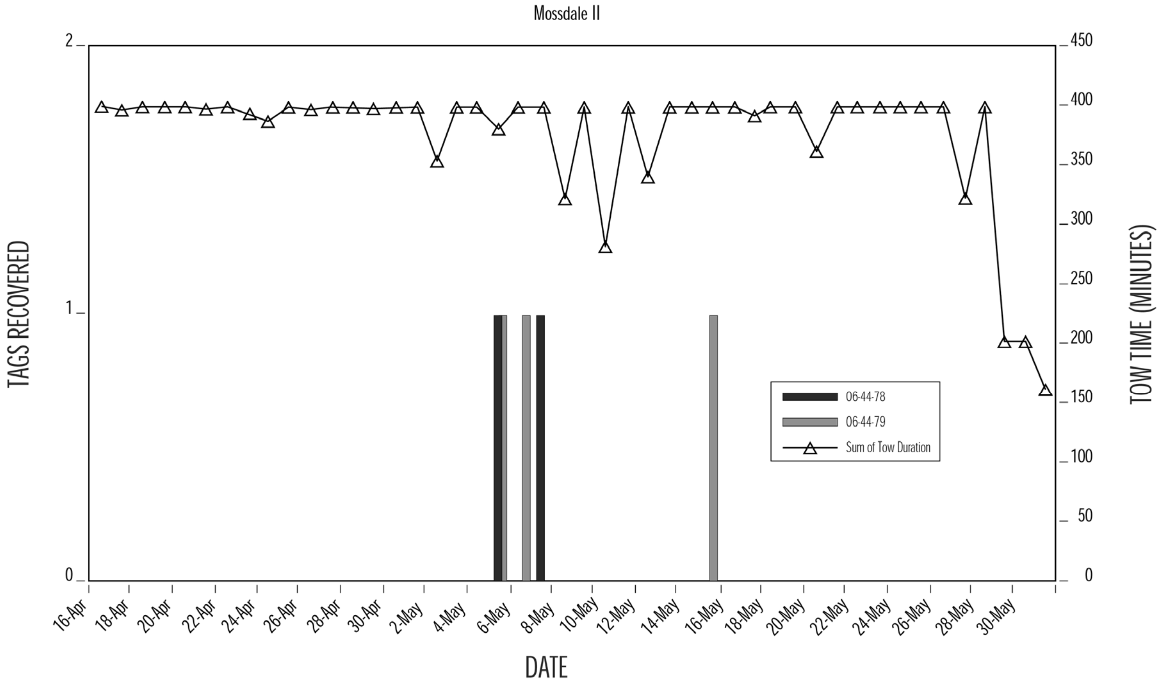


Figure A-21. Net Pen Sampling Results: Chipps Island/Jersey Point II

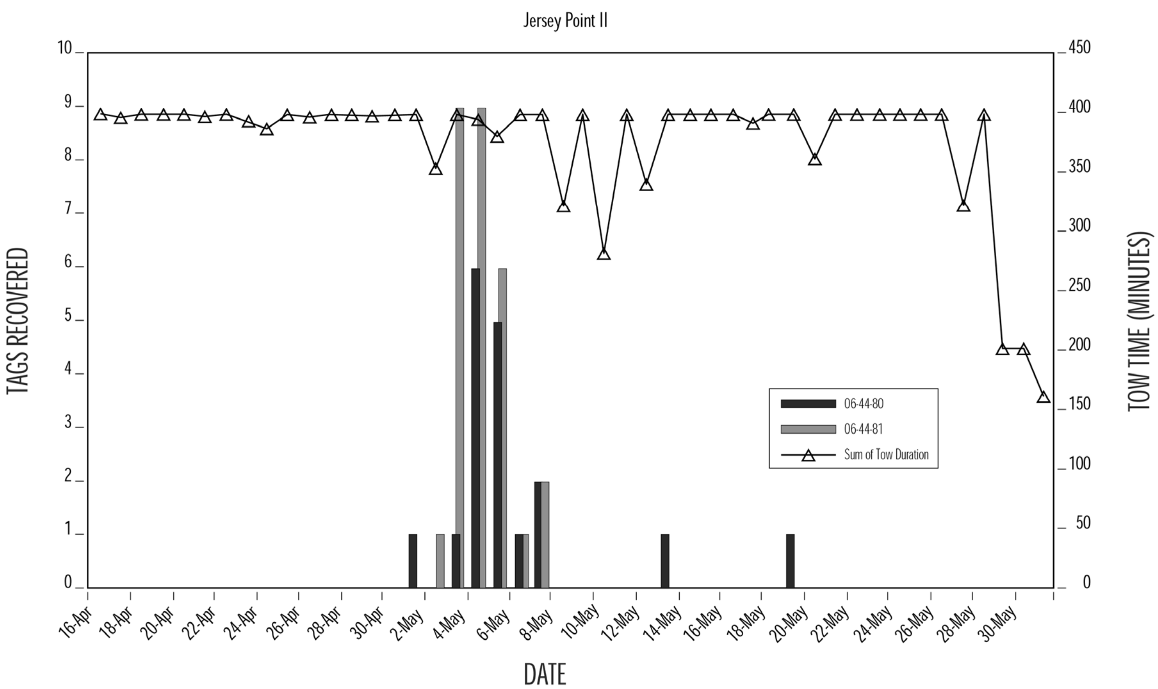


Figure A-22. Net Pen Sampling Results: Antioch/Durham Ferry I

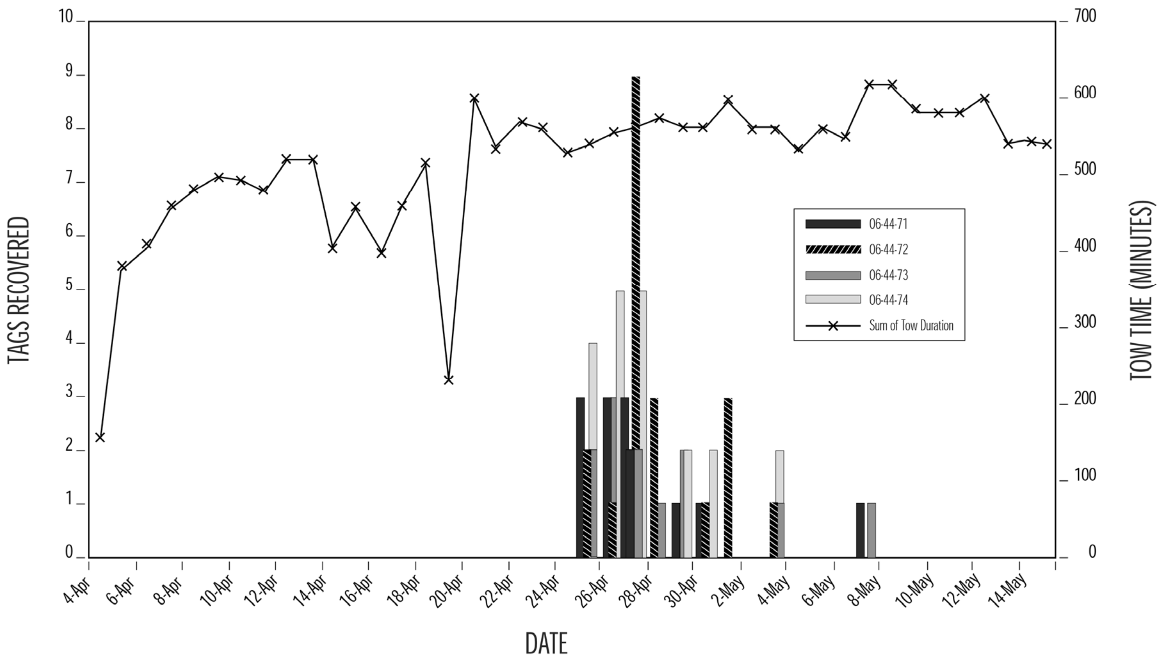


Figure A-23. Net Pen Sampling Results: Antioch/Mossdale I

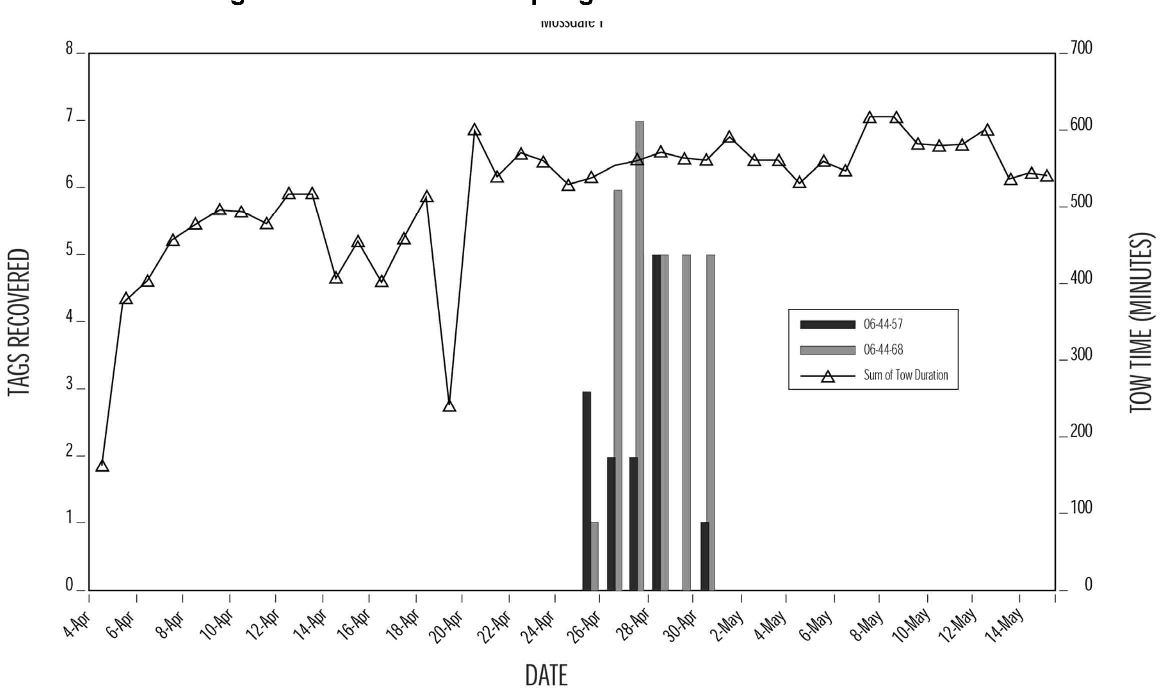


Figure A-24. Net Pen Sampling Results: Antioch/Jersey Point I

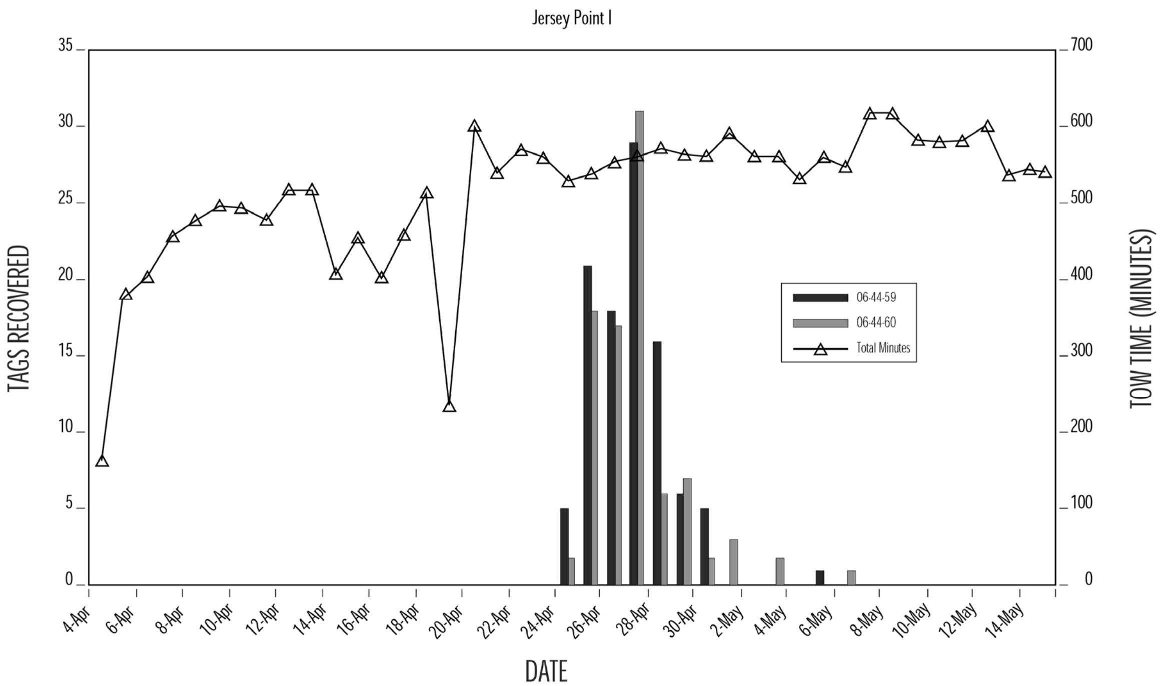


Figure A-25. Net Pen Sampling Results: Antioch/Durham Ferry II

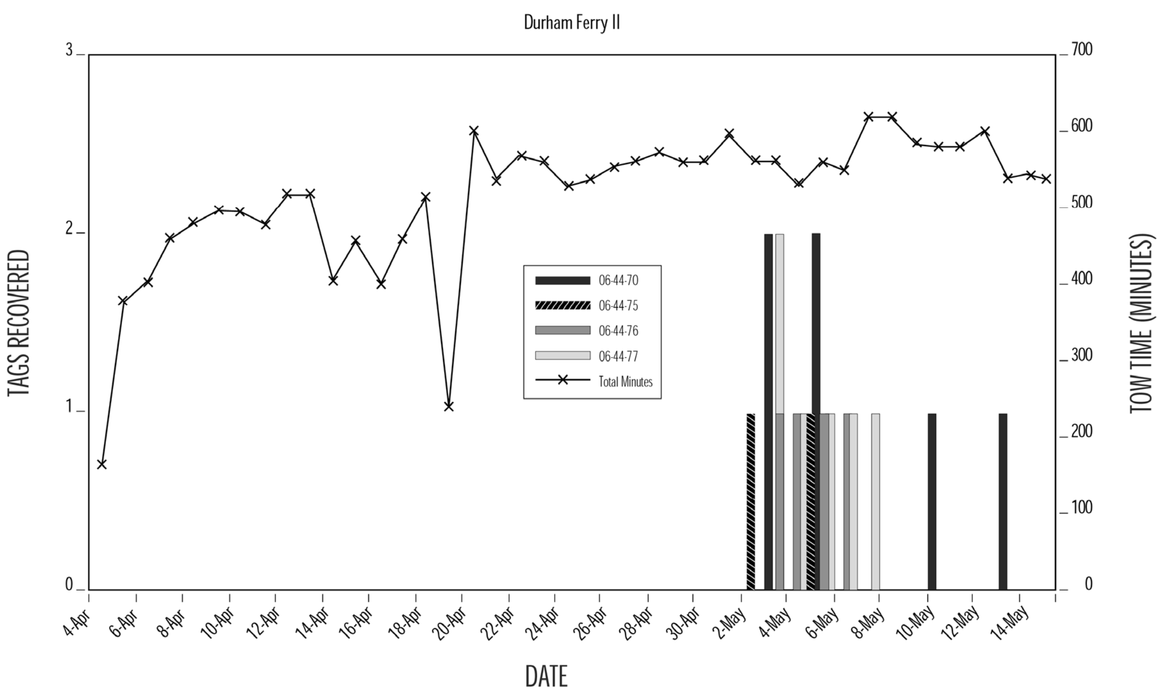


Figure A-26. Net Pen Sampling Results: Antioch/Mossdale II

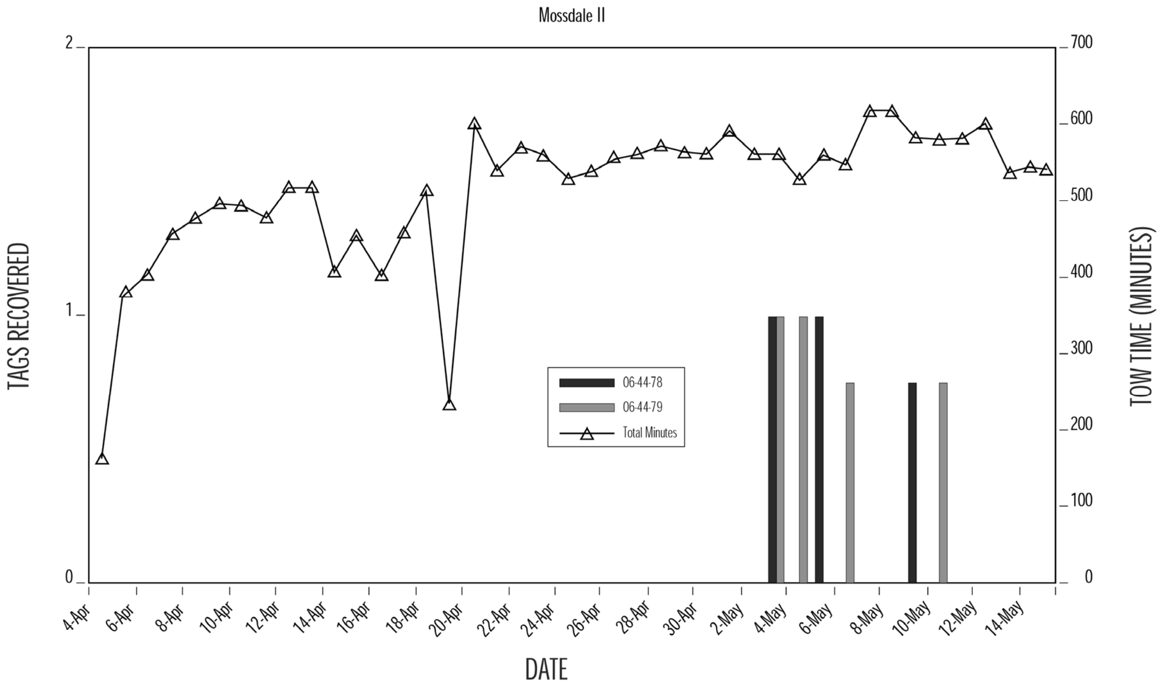


Figure A-27. Net Pen Sampling Results: Antioch/Jersey Point II

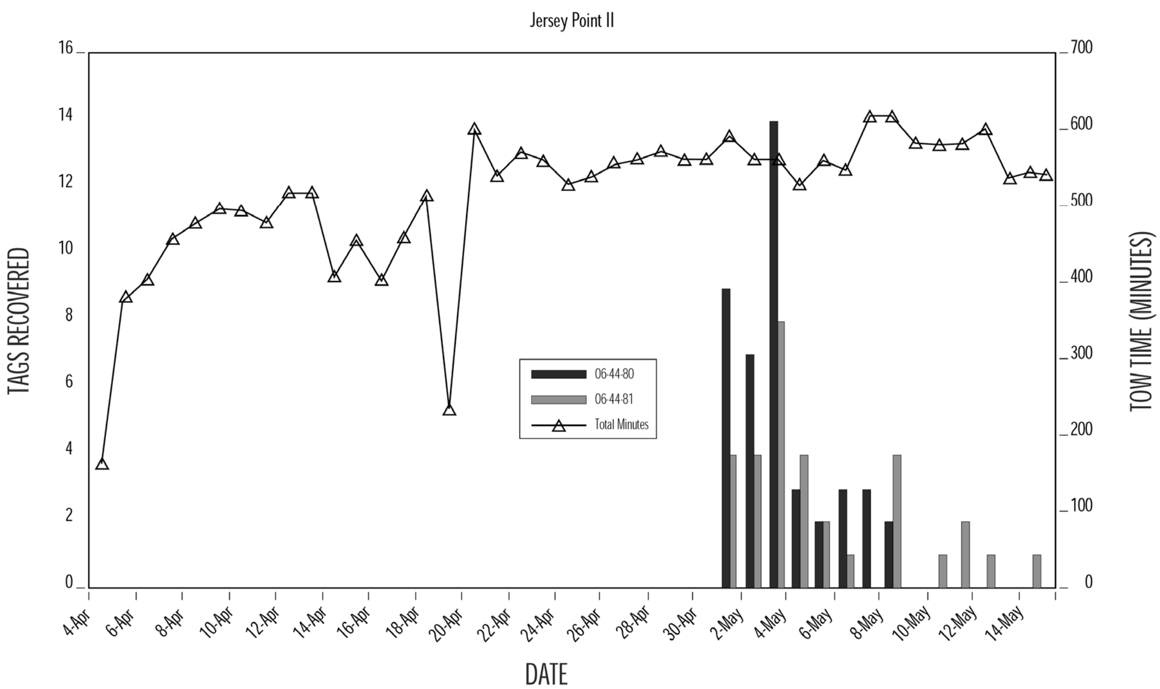


Table A-4. Release and Recovery Information for Coded Wire Tagged Smolts Released in the San Joaquin River and Tributaries in the Spring of 2002

							Antioch				Chipps Island				Salvage		Trib. Sur	
TagCode	Release Site/Stock	Date	Truck Temp (F)	River Temp (F)	Number Released	Average Size (mm)	Number Recovered	Percent Sampled	Survival Index	Group Index	Number Recovered	Percent Sampled	Survival Index	Group Index	Expanded CVP	Expanded SWP	Antioch	Chipps Island
06-44-63	Upper Merced @ MRFF		N/P	N/P	23188	74	1	0.316	0.010		1	0.278	0.020		12	6		
06-44-64	Upper Merced @ MRFF		N/P	N/P	23915	74	0	--	--		0	--	--		0	0		
06-44-65	Upper Merced @ MRFF		N/P	N/P	23775	74	0	--	--		0	--	--		0	0		
06-44-66	Upper Merced @ MRFF		N/P	N/P	23185	74	0	--	--		0	--	--		0	0		
	Total	31-Mar-02			94063		1	0.316		0.002	1	0.278		0.005			0.05	0.11
06-44-51	Hatfield State Park (MRFF)		53.6	62.6	24380	77	10	0.345	0.086		2	0.272	0.039		480	47		
06-44-52	Hatfield State Park (MRFF)		53.6	62.6	24228	77	1	0.389	0.008		1	0.222	0.024		492	34		
06-45-48	Hatfield State Park (MRFF)		53.6	62.6	24890	77	3	0.361	0.024		3	0.180	0.087		528	55		
	Total	3-Apr-02			73498		14	0.345		0.040	6	0.238		0.045				
06-44-62	Grayson	3-Apr-02	N/P	N/P	15434	90	3	0.398	0.035		1	0.278	0.030		12	0		
06-44-82	Upper Merced @ MRFF		N/P	N/P	22522	71	0	--	--		0	--	--		0	0		
06-44-83	Upper Merced @ MRFF		N/P	N/P	23086	71	1	0.375	0.008		0	--	--		0	0		
06-44-84	Upper Merced @ MRFF		N/P	N/P	23140	71	0	--	--		0	--	--		0	0		
06-44-85	Upper Merced @ MRFF		N/P	N/P	22183	71	0	--	--		0	--	--		0	0		
	Total	21-Apr-02			90931		1	0.375		0.002	0	--		--			0.08	0
06-44-86	Hatfield State Park (MRFF)		53.6	60.8	23349	73	2	0.410	0.015		2	0.250	0.045		12	6		
06-44-87	Hatfield State Park (MRFF)		53.6	60.8	23363	73	5	0.405	0.038		0	--	--		0	12		
06-44-88	Hatfield State Park (MRFF)		53.6	60.8	23639	73	2	0.404	0.015		1	0.278	0.020		0	0		
	Total	26-Apr-02			70351		9	0.402		0.023	3	0.250		0.022				
06-44-06	La Grange (MRFF)		57.2	53.6	24976	86	3	0.423	0.020		1	0.264	0.020		12	12		
06-44-67	La Grange (MRFF)		57.2	53.6	24813	86	5	0.392	0.037		7	0.261	0.141		0	12		
06-44-68	La Grange (MRFF)		57.2	53.6	25220	86	3	0.378	0.023		0	--	--		12	18		
	Total	24-Apr-02			75009		11	0.399		0.026	8	0.261		0.053				
06-44-61	Old Fisherman's Club (MRFF)	26-Apr-02	55.4	62	25701	85	1	0.389	0.007		6	0.273	0.111		0	6	3.7	0.47
06-44-69	Old Fisherman's Club (MRFF)	29-Apr-02	55.4	60.8	23870	86	2	0.408	0.015		3	0.260	0.063		12	15	1.7	0.84
06-44-46	Knight's Ferry (MRFF)		56.3	53.6	23745	82	1	0.403	0.008		2	0.257	0.043		12	0	1.04	2.09
06-44-47	Knight's Ferry (MRFF)		53.6	52.7	24236	83	5	0.397	0.037		2	0.194	0.055		0	6		
	Total	1-May-02			47981		6	0.397		0.023	4	0.236		0.046				
06-44-48	Two Rivers (MRFF)	4-May-02	59	64.4	24646	84	3	0.398	0.022		1	0.236	0.022		0	0		

Table A-5. Timing of Recovery at Antioch and Chipps Island for Coded Wire Tagged Smolts Released in San Joaquin River and Tributaries in the Spring of 2002

							Antioch						Chipps Island						
TagCode	Release Site/Stock	Date	Truck Temp (F)	River Temp (F)	Number Released	Average Size (mm)	First Day Recovered	Last Day Recovered	Number Recovered	Minutes Fished	Survival Index	Group Index	First Day Recovered	Last Day Recovered	Number Recovered	Minutes Fished	Percent Sampled	Survival Index	Group Index
06-44-63	Upper Merced @ MRFF		N/P	N/P	23188	74	15-Apr-02	15-Apr-02	1	455	0.010		11-Apr-02	11-Apr-02	1	400	0.278	0.020	
06-44-64	Upper Merced @ MRFF		N/P	N/P	23915	74	--	--	0	--	--		--	--	0	--	--	--	
06-44-65	Upper Merced @ MRFF		N/P	N/P	23775	74	--	--	0	--	--		--	--	0	--	--	--	
06-44-66	Upper Merced @ MRFF		N/P	N/P	23185	74	--	--	0	--	--		--	--	0	--	--	--	
	Total	31-Mar-02			94063		15-Apr-02	15-Apr-02	1	455		0.002	11-Apr-02	11-Apr-02	1	400	0.278		0.005
06-44-51	Hatfield State Park (MRFF)		53.6	62.6	24380	77	10-Apr-02	27-Apr-02	10	8937	0.086		7-Apr-02	11-Apr-02	2	1960	0.272	0.039	
06-44-52	Hatfield State Park (MRFF)		53.6	62.6	24228	77	27-Apr-02	27-Apr-02	1	560	0.008		12-Apr-02	12-Apr-02	1	320	0.222	0.024	
06-45-48	Hatfield State Park (MRFF)		53.6	62.6	24890	77	12-Apr-02	12-Apr-02	3	520	0.024		12-Apr-02	14-Apr-02	3	777	0.180	0.087	
	Total	3-Apr-02			73498		10-Apr-02	27-Apr-02	14	8937		0.040	7-Apr-02	14-Apr-02	6	2737	0.238		0.045
06-44-62	Grayson	3-Apr-02	N/P	N/P	15434	90	27-Apr-02	10-May-02	3	8014	0.035		11-May-02	11-May-02	1	400	0.278	0.030	
06-44-82	Upper Merced @ MRFF		N/P	N/P	22522	71	--	--	0	--	--		--	--	0	--	--	--	
06-44-83	Upper Merced @ MRFF		N/P	N/P	23086	71	13-May-02	13-May-02	1	540	0.008		--	--	0	--	--	--	
06-44-84	Upper Merced @ MRFF		N/P	N/P	23140	71	--	--	0	--	--		--	--	0	--	--	--	
06-44-85	Upper Merced @ MRFF		N/P	N/P	22183	71	--	--	0	--	--		--	--	0	--	--	--	
	Total	21-Apr-02			90931		13-May-02	13-May-02	1	540		0.002	--	--	0	--	--		--
06-44-86	Hatfield State Park (MRFF)		53.6	60.8	23349	73	6-May-02	12-May-02	2	4136	0.015		9-May-02	11-May-02	2	1080	0.250	0.045	
06-44-87	Hatfield State Park (MRFF)		53.6	60.8	23363	73	7-May-02	14-May-02	5	4671	0.038		--	--	0	--	--	--	
06-44-88	Hatfield State Park (MRFF)		53.6	60.8	23639	73	9-May-02	11-May-02	2	1746	0.015		9-May-02	9-May-02	1	400	0.278	0.020	
	Total	26-Apr-02			70351		6-May-02	14-May-02	9	5221		0.023	9-May-02	11-May-02	3	1080	0.250		0.022
06-44-06	La Grange (MRFF)		57.2	53.6	24976	86	7-May-02	9-May-02	3	1826	0.020		5-May-02	5-May-02	1	380	0.264	0.020	
06-44-67	La Grange (MRFF)		57.2	53.6	24813	86	3-May-02	7-May-02	5	2820	0.037		3-May-02	11-May-02	7	3379	0.261	0.141	
06-44-68	La Grange (MRFF)		57.2	53.6	25220	86	3-May-02	4-May-02	3	1090	0.023		--	--	0	--	--	--	
	Total	24-Apr-02			75009		3-May-02	9-May-02	11	4026		0.026	3-May-02	11-May-02	8	3379	0.261		0.053
06-44-61	Old Fisherman's Club (MRFF)	26-Apr-02	55.4	62	25701	85	5-May-02	5-May-02	1	560	0.007		3-May-02	5-May-02	6	1179	0.273	0.111	
06-44-69	Old Fisherman's Club (MRFF)	29-Apr-02	55.4	60.8	23870	86	5-May-02	8-May-02	2	2350	0.015		5-May-02	8-May-02	3	1500	0.260	0.063	
06-44-46	Knight's Ferry (MRFF)		56.3	53.6	23745	82	11-May-02	11-May-02	1	580	0.008		11-May-02	12-May-02	2	740	0.257	0.043	
06-44-47	Knight's Ferry (MRFF)		53.6	52.7	24236	83	9-May-02	14-May-02	5	3431	0.037		10-May-02	10-May-02	2	280	0.194	0.055	
	Total	1-May-02			47981		9-May-02	14-May-02	6	3431		0.023	10-May-02	12-May-02	4	1020	0.236		0.046
06-44-48	Two Rivers (MRFF)	4-May-02	59	64.4	24646	84	11-May-02	13-May-02	3	1720	0.022		12-May-02	12-May-02	1	340	0.236	0.022	

Appendix B

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 24 time periods.

Figure B-1. Locations stage and flow data presented.

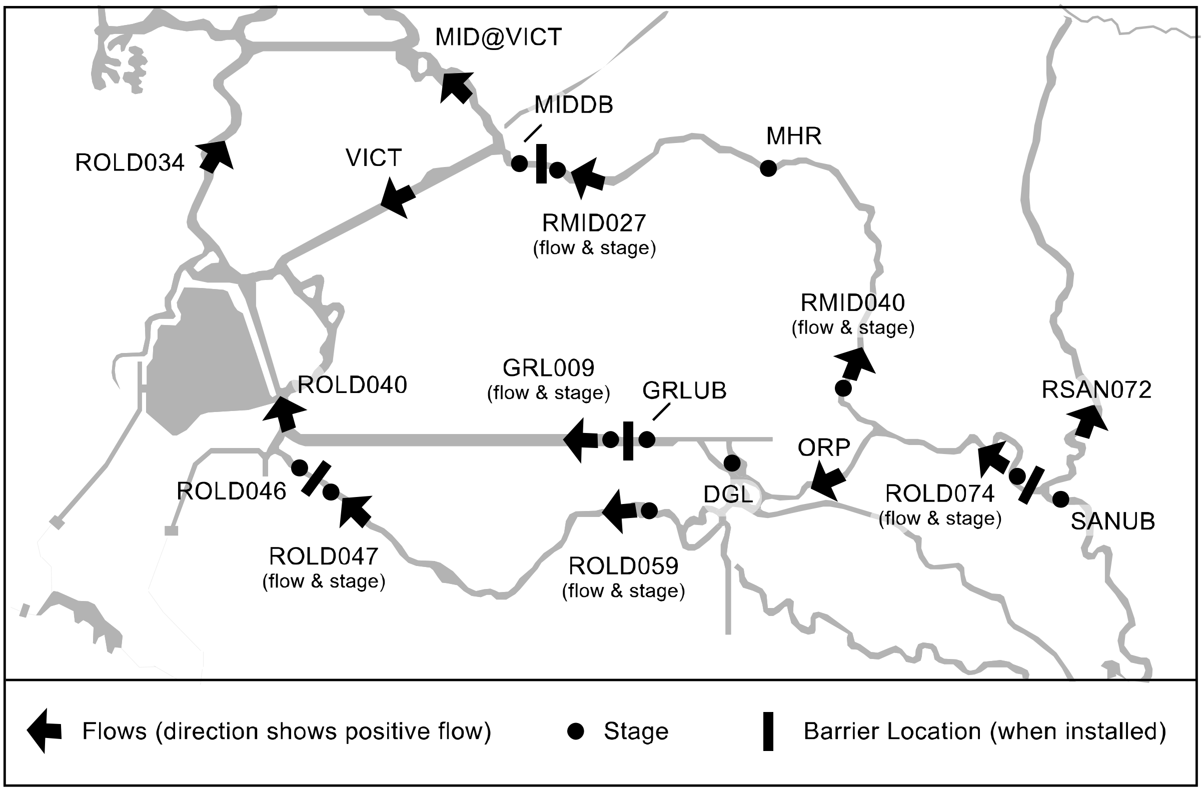


Table B-1. Distribution of stages (feet) by study period.

		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 - 4	0.2	1.2	1.8	2.2	4.0	0.6	1.4	2.0	2.3	4.1	-0.1	0.7	1.4	1.7	4.0
	5 - 10	0.4	1.0	1.7	2.2	3.9	0.7	1.3	1.9	2.4	4.1	0.2	0.8	1.6	2.2	4.0
	11 - 31	-0.9	0.1	0.7	1.2	3.3	-0.8	0.2	0.8	1.3	3.3	-1.1	-0.3	0.4	0.9	3.2
Feb	1 - 28	-0.9	0.0	0.7	1.2	3.2	-0.8	0.2	0.8	1.3	3.2	-1.0	-0.1	0.6	1.2	3.1
Mar	1 - 22	-1.4	-0.2	0.5	1.1	3.3	-1.1	0.0	0.7	1.2	3.3	-1.1	-0.1	0.6	1.1	3.3
	23 - 31	-0.8	0.1	0.9	1.4	3.1	-0.5	0.3	1.0	1.6	3.1	-0.7	0.2	1.0	1.6	3.1
Apr	1 - 14	-0.8	0.0	0.7	1.3	2.9	-0.7	0.2	0.8	1.3	3.0	-0.8	0.0	0.7	1.2	2.8
	15 - 30	0.0	0.9	1.1	1.6	3.1	-0.1	0.8	1.1	1.7	3.1	-0.9	0.5	0.8	1.7	3.0
May	1 - 24	0.0	0.7	1.1	1.4	3.1	-0.1	0.6	1.1	1.5	3.2	-0.9	0.3	1.0	1.6	3.1
	25 - 31	-0.1	0.9	1.5	2.1	3.7	0.0	1.0	1.6	2.2	3.8	-0.2	0.9	1.6	2.2	3.8
Jun	1 - 6	-0.4	0.3	0.9	1.3	2.9	-0.3	0.3	0.9	1.4	3.0	-0.7	0.2	0.9	1.6	3.1
	7 - 30	0.1	1.0	1.4	1.7	3.4	0.0	1.1	1.5	1.7	3.4	0.3	1.3	1.7	1.9	3.2
Jul	1 - 31	0.5	0.9	1.3	1.5	3.3	0.6	1.0	1.3	1.5	3.2	0.9	1.2	1.5	1.7	2.9
Aug	1 - 31	0.8	1.1	1.4	1.6	3.1	0.9	1.1	1.5	1.7	3.2	0.9	1.3	1.5	1.8	3.0
Sep	1 - 30	1.1	1.3	1.6	1.9	3.3	1.1	1.3	1.7	1.9	3.3	1.2	1.5	1.8	2.0	3.2
Oct	1 - 3	1.1	1.3	1.6	1.9	3.0	1.2	1.4	1.7	2.0	3.0	1.3	1.5	1.8	2.1	2.7
	4 - 20	1.1	1.3	1.6	1.8	3.2	1.2	1.3	1.6	1.9	3.2	1.3	1.5	1.7	1.9	3.0
	21 - 31	1.2	1.3	1.7	1.9	3.3	1.2	1.4	1.8	2.0	3.2	1.4	1.6	1.9	2.1	3.2
Nov	1 - 10	1.2	1.4	1.9	2.3	4.4	1.2	1.5	2.0	2.4	4.4	1.4	1.6	2.1	2.5	4.2
	11 - 20	1.1	1.2	1.4	1.5	2.6	1.1	1.2	1.4	1.6	3.0	1.2	1.3	1.5	1.6	3.1
	21 - 28	-0.6	0.8	1.3	1.9	3.5	-0.5	1.0	1.5	2.0	3.5	-0.5	1.0	1.5	2.1	3.4
	29 - 30	-0.4	0.3	1.0	1.7	2.7	-0.4	0.5	1.2	1.7	2.7	-0.5	0.3	1.0	1.6	2.7
Dec	1 - 13	-0.6	0.5	1.2	1.8	3.8	-0.5	0.6	1.3	1.9	3.8	-0.6	0.4	1.2	1.8	3.8
	14 - 31	-0.3	1.1	1.8	2.5	5.2	-0.1	1.2	1.9	2.6	5.2	-0.4	0.9	1.7	2.4	5.2

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

		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 - 4	-0.1	0.7	1.4	1.7	4.0	-0.8	0.3	1.0	1.3	3.7	-0.7	0.3	1.0	1.3	3.7
	5 - 10	0.2	0.8	1.6	2.2	4.0	-0.6	0.4	1.2	1.8	3.7	-0.5	0.4	1.2	1.8	3.8
	11 - 31	-1.1	-0.3	0.4	0.9	3.2	-1.6	-0.6	0.2	0.6	3.0	-1.5	-0.5	0.2	0.6	2.9
Feb	1 - 28	-1.0	-0.1	0.6	1.2	3.1	-1.4	-0.4	0.3	0.9	3.1	-1.3	-0.3	0.4	0.9	3.1
Mar	1 - 22	-1.1	-0.1	0.6	1.1	3.3	-1.5	-0.4	0.3	0.8	3.1	-1.5	-0.4	0.3	0.8	3.1
	23 - 31	-0.7	0.2	1.0	1.6	3.1	-1.2	0.0	0.7	1.3	3.0	-1.1	0.0	0.7	1.3	3.0
Apr	1 - 14	-0.8	0.0	0.7	1.2	2.8	-1.2	-0.3	0.4	1.0	2.8	-1.1	-0.3	0.4	0.9	2.8
	15 - 30	-0.9	0.5	0.8	1.7	3.0	-1.6	0.1	0.5	1.7	3.3	-0.2	0.8	1.0	1.7	2.7
May	1 - 24	-0.9	0.3	1.0	1.6	3.1	-1.6	0.0	0.8	1.6	3.3	-0.2	0.6	1.0	1.4	2.8
	25 - 31	-0.2	0.9	1.6	2.2	3.8	-0.9	0.6	1.4	2.2	3.8	0.1	0.9	1.5	2.0	3.3
Jun	1 - 6	-0.7	0.2	0.9	1.6	3.1	-1.4	-0.3	0.6	1.4	3.1	-0.2	0.4	0.9	1.4	2.8
	7 - 30	0.3	1.3	1.7	1.9	3.2	-1.6	-0.1	0.8	1.6	3.6	0.1	1.3	1.6	1.9	3.0
Jul	1 - 31	0.9	1.2	1.5	1.7	2.9	-1.6	-0.4	0.4	0.9	3.6	0.8	1.2	1.4	1.6	2.6
Aug	1 - 31	0.9	1.3	1.5	1.8	3.0	-1.6	-0.4	0.4	1.0	3.3	0.9	1.2	1.5	1.7	2.8
Sep	1 - 30	1.2	1.5	1.8	2.0	3.2	-1.4	-0.2	0.7	1.5	3.4	1.2	1.5	1.8	2.0	3.0
Oct	1 - 3	1.3	1.5	1.8	2.1	2.7	-1.5	-0.1	0.7	1.6	2.5	1.3	1.6	1.8	2.1	2.6
	4 - 20	1.3	1.5	1.7	1.9	3.0	-1.5	-0.1	0.8	1.7	3.4	1.3	1.5	1.7	1.9	2.9
	21 - 31	1.4	1.6	1.9	2.1	3.2	-1.3	-0.1	0.8	1.6	3.4	1.4	1.6	1.9	2.2	3.1
Nov	1 - 10	1.4	1.6	2.1	2.5	4.2	-1.1	0.2	1.2	2.2	4.5	1.3	1.7	2.1	2.6	4.1
	11 - 20	1.2	1.3	1.5	1.6	3.1	-1.5	-0.4	0.3	0.9	2.6	1.2	1.3	1.5	1.6	3.1
	21 - 28	-0.5	1.0	1.5	2.1	3.4	-1.5	-0.3	0.8	1.7	3.6	0.2	1.3	1.7	2.1	3.2
	29 - 30	-0.5	0.3	1.0	1.6	2.7	-0.8	0.0	0.8	1.3	2.6	-0.8	0.0	0.8	1.4	2.6
Dec	1 - 13	-0.6	0.4	1.2	1.8	3.8	-1.0	0.1	1.0	1.7	3.7	-0.9	0.1	1.0	1.6	3.7
	14 - 31	-0.4	0.9	1.7	2.4	5.2	-0.8	0.7	1.4	2.2	5.1	-0.8	0.7	1.5	2.2	5.1

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

		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 - 4	-0.8	0.7	1.4	2.1	3.9	-0.3	0.6	1.3	1.6	3.9	-0.6	0.7	1.4	2.1	3.9
	5 - 10	-0.6	0.5	1.3	2.0	3.9	0.0	0.7	1.5	2.1	3.9	-0.5	0.6	1.4	2.0	3.9
	11 - 31	-1.6	-0.1	0.6	1.3	3.4	-1.2	-0.3	0.4	0.8	3.1	-1.5	0.0	0.7	1.3	3.4
Feb	1 - 28	-1.4	-0.1	0.6	1.3	3.2	-1.0	-0.2	0.5	1.0	3.2	-1.3	0.0	0.7	1.3	3.2
Mar	1 - 22	-1.6	-0.2	0.6	1.3	3.3	-1.2	-0.2	0.5	1.0	3.2	-1.5	-0.1	0.6	1.3	3.3
	23 - 31	-1.1	0.1	0.9	1.6	3.1	-0.7	0.2	0.9	1.5	3.1	-1.1	0.1	0.9	1.6	3.1
Apr	1 - 14	-1.2	0.0	0.7	1.4	3.1	-0.9	0.0	0.6	1.1	2.9	-1.1	0.0	0.7	1.4	3.1
	15 - 30	-1.5	0.1	0.6	1.7	3.3	-1.1	0.3	0.7	1.7	3.1	0.3	1.0	1.2	1.7	3.1
May	1 - 24	-1.5	0.0	0.8	1.7	3.3	-1.1	0.2	0.9	1.6	3.2	0.3	0.9	1.3	1.5	3.2
	25 - 31	-0.9	0.6	1.4	2.2	3.8	-0.4	0.8	1.5	2.2	3.8	0.0	1.0	1.6	2.0	3.7
Jun	1 - 6	-1.3	-0.1	0.7	1.5	3.1	-0.9	0.0	0.8	1.4	3.1	-0.1	0.5	1.0	1.5	3.0
	7 - 30	-1.4	0.1	1.0	1.8	3.8	-1.6	0.0	0.9	1.7	3.7	0.3	1.1	1.5	1.8	3.6
Jul	1 - 31	-1.4	0.1	0.9	1.6	3.9	-1.6	-0.2	0.5	1.0	3.6	0.5	1.0	1.4	1.5	3.6
Aug	1 - 31	-1.3	0.0	0.9	1.6	3.6	-1.5	-0.3	0.5	1.1	3.4	0.8	1.1	1.5	1.6	3.4
Sep	1 - 30	-1.1	0.2	1.1	1.9	3.5	-1.4	0.0	0.8	1.6	3.4	1.1	1.3	1.7	1.9	3.4
Oct	1 - 3	-1.2	0.0	1.0	1.8	3.2	-1.4	0.0	0.8	1.8	2.7	1.1	1.3	1.7	1.9	3.2
	4 - 20	-1.3	0.0	1.0	1.9	3.5	-1.4	0.0	0.9	1.7	3.5	1.1	1.3	1.6	1.9	3.4
	21 - 31	-1.1	0.2	1.1	1.8	3.5	-1.2	0.2	1.0	1.7	3.5	1.2	1.3	1.7	1.8	3.4
Nov	1 - 10	-0.9	0.4	1.4	2.3	4.6	-1.1	0.3	1.3	2.3	4.5	1.2	1.4	1.9	2.3	4.5
	11 - 20	-1.3	-0.1	0.7	1.4	2.9	-1.4	-0.3	0.4	1.1	2.6	1.1	1.2	1.4	1.5	2.6
	21 - 28	-1.2	0.2	1.0	1.8	3.7	-1.2	0.1	1.0	1.8	3.7	-1.1	0.6	1.2	1.8	3.6
	29 - 30	-0.8	0.1	1.0	1.8	2.8	-0.6	0.2	1.0	1.6	2.7	-0.7	0.2	1.0	1.8	2.8
Dec	1 - 13	-1.0	0.4	1.2	1.9	3.9	-0.7	0.3	1.1	1.8	3.8	-0.8	0.4	1.2	1.9	3.8
	14 - 31	-0.8	1.0	1.7	2.5	5.2	-0.5	0.9	1.6	2.3	5.2	-0.7	1.0	1.7	2.4	5.2

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

		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 - 4	3.2	3.5	3.9	4.2	4.8	-0.3	0.6	1.3	1.6	3.9	2.9	3.2	3.6	3.9	4.7
	5 - 10	2.1	2.9	3.4	4.0	4.6	0.0	0.7	1.5	2.1	4.0	2.0	2.8	3.2	3.8	4.3
	11 - 31	0.4	1.2	1.8	2.2	3.6	-1.3	-0.4	0.3	0.8	3.2	0.3	1.2	1.7	2.1	3.6
Feb	1 - 28	0.3	1.2	1.7	2.1	3.3	-1.1	-0.2	0.5	1.0	3.2	0.2	1.2	1.6	2.1	3.3
Mar	1 - 22	0.6	1.4	1.8	2.2	3.5	-1.3	-0.2	0.4	1.0	3.2	0.5	1.3	1.7	2.1	3.4
	23 - 31	1.1	1.6	2.0	2.4	3.4	-0.7	0.1	0.8	1.5	3.2	1.0	1.5	2.0	2.3	3.4
Apr	1 - 14	0.6	1.2	1.6	2.0	3.2	-0.9	-0.1	0.5	1.1	2.9	0.5	1.2	1.6	2.0	3.1
	15 - 30	2.0	3.5	3.5	4.0	4.8	-0.2	0.8	1.0	1.6	2.8	-0.3	0.8	1.1	1.9	3.2
May	1 - 24	2.1	3.2	3.4	3.8	4.6	-0.2	0.5	1.0	1.4	2.8	-0.3	0.6	1.2	1.7	3.2
	25 - 31	1.0	1.9	2.4	2.8	3.9	0.0	0.9	1.5	2.0	3.5	0.9	1.8	2.3	2.7	3.8
Jun	1 - 6	0.3	1.0	1.6	2.1	3.2	-0.3	0.4	0.9	1.4	2.9	0.3	1.0	1.5	2.0	3.2
	7 - 30	1.0	1.5	1.9	2.2	3.4	0.1	1.3	1.6	1.9	3.2	1.0	1.5	1.9	2.2	3.4
Jul	1 - 31	1.0	1.5	1.8	2.1	3.3	0.8	1.2	1.4	1.6	2.6	0.9	1.4	1.8	2.1	3.2
Aug	1 - 31	1.0	1.5	1.8	2.1	3.2	0.9	1.2	1.5	1.7	2.9	1.0	1.4	1.8	2.1	3.2
Sep	1 - 30	1.3	1.7	2.0	2.3	3.3	1.2	1.5	1.8	2.0	3.1	1.2	1.6	2.0	2.2	3.2
Oct	1 - 3	1.4	1.7	2.0	2.3	3.2	1.3	1.6	1.8	2.1	2.6	1.4	1.6	2.0	2.2	3.1
	4 - 20	1.4	1.8	2.2	2.5	3.5	1.3	1.5	1.7	1.9	2.9	1.4	1.6	1.8	2.0	3.0
	21 - 31	1.8	2.4	2.7	3.0	4.1	1.4	1.6	1.9	2.1	3.2	1.5	1.8	2.0	2.2	3.4
Nov	1 - 10	1.7	2.2	2.8	3.2	4.7	1.3	1.7	2.1	2.5	4.2	1.4	1.8	2.2	2.6	4.3
	11 - 20	1.6	1.9	2.3	2.6	3.5	1.2	1.3	1.5	1.6	3.1	1.3	1.4	1.7	1.8	3.2
	21 - 28	0.6	1.7	2.0	2.4	3.5	0.2	1.3	1.7	2.1	3.4	0.5	1.6	2.0	2.4	3.5
	29 - 30	0.6	1.2	1.7	2.2	2.7	-0.6	0.2	0.9	1.5	2.8	0.6	1.2	1.7	2.1	2.7
Dec	1 - 13	0.5	1.4	1.9	2.3	3.8	-0.7	0.3	1.1	1.7	3.8	0.4	1.3	1.8	2.3	3.7
	14 - 31	1.3	2.3	2.8	3.2	5.2	-0.6	0.9	1.6	2.3	5.2	1.2	2.1	2.7	3.2	5.2

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

		ROLD059					ROLD047					RMID040				
		Min	25%	Avg	75%	Max	Min	25%	Avg	75%	Max	Min	25%	Avg	75%	Max
Jan	1 - 4	-221	112	389	615	769	-2461	-670	367	1276	2646	-107	12	114	200	326
	5 - 10	-206	30	358	617	784	-2370	-845	401	1554	2515	-107	20	119	201	290
	11 - 31	-357	-19	204	386	769	-2551	-561	193	1051	2732	-153	-54	22	87	205
Feb	1 - 28	-331	-52	173	383	695	-2346	-683	141	1175	2472	-121	-28	40	98	211
Mar	1 - 22	-345	-34	185	388	626	-2184	-693	116	1084	2256	-86	-15	52	109	223
	23 - 31	-309	-113	195	429	588	-2135	-1047	114	1361	1991	-54	-9	67	129	222
Apr	1 - 14	-333	-86	162	383	682	-2235	-882	72	1154	1931	-112	-21	42	101	166
	15 - 30	-670	-495	-202	333	568	-1191	-440	-306	-36	298	-91	-59	-17	39	183
May	1 - 24	-670	-394	-60	304	608	-1191	-453	-190	-33	532	-82	-54	0	30	185
	25 - 31	-373	-147	144	474	737	-1340	-533	-14	540	1132	-55	28	82	132	223
Jun	1 - 6	-614	-389	-50	294	692	-826	-348	-171	-32	356	-47	-11	38	69	183
	7 - 30	-406	-198	5	204	549	-1335	-194	-146	-10	547	-166	43	70	107	200
Jul	1 - 31	-387	-112	62	219	613	-1432	-23	-85	5	260	-209	56	66	92	169
Aug	1 - 31	-353	-157	38	216	507	-983	-22	-56	8	358	-216	33	47	81	169
Sep	1 - 30	-415	-256	-18	228	477	-1040	-24	-66	11	513	-196	24	54	98	179
Oct	1 - 3	-364	-279	-55	227	433	-470	-22	-49	10	208	-119	30	67	104	158
	4 - 20	-347	-225	-65	122	309	-1022	-98	-96	-10	352	-210	1	47	99	170
	21 - 31	-312	-206	-45	123	357	-895	-18	-68	6	480	-183	15	68	124	201
Nov	1 - 10	-335	-221	-64	81	366	-1396	-114	-95	42	868	-297	-4	63	137	265
	11 - 20	-333	-102	-26	101	294	-539	-12	-26	2	427	-164	34	51	81	198
	21 - 28	-747	-345	-85	249	703	-1139	-170	-95	3	580	-191	-11	68	128	234
	29 - 30	-236	-144	195	408	563	-1906	-1013	255	1240	1773	-92	-34	45	99	165
Dec	1 - 13	-348	-122	151	387	528	-2152	-1020	131	1310	2202	-167	-41	42	114	231
	14 - 31	-448	6	259	475	832	-2676	-852	247	1336	2396	-252	-48	54	150	338

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

		VICT					GRL009					ROLD034				
		Min	25%	Avg	75%	Max	Min	25%	Avg	75%	Max	Min	25%	Avg	75%	Max
Jan	1 - 4	-2501	1198	3459	6225	8481	-3189	1048	2263	3651	5195	-16337	-11975	-6164	-831	6980
	5 - 10	-2469	-1008	1597	3415	7098	-3282	247	1945	3921	5086	-14672	-7494	-2596	2950	6808
	11 - 31	-2309	1891	3473	5515	8133	-3923	238	1303	2805	4741	-15723	-10979	-6432	-2996	5484
Feb	1 - 28	-2172	609	2547	4586	7223	-3477	-163	1111	2845	4712	-14408	-9544	-4741	-798	6168
Mar	1 - 22	-1946	506	2613	4784	7428	-3250	-190	1150	2777	4269	-14631	-9672	-4902	-451	5631
	23 - 31	-2298	-862	1922	4055	6634	-3142	-942	1066	3118	4284	-13089	-8654	-3423	1405	5719
Apr	1 - 14	-1855	-80	2254	4037	6826	-3306	-696	955	2848	3938	-13864	-8640	-4072	777	5104
	15 - 30	-2672	-1750	-11	2610	5243	-4523	-2406	-332	3152	3874	-11002	-5656	-2358	4496	6139
May	1 - 24	-2672	-1640	525	2508	5687	-4379	-2333	383	2825	4345	-10925	-5583	-920	3977	6100
	25 - 31	-2486	-1773	500	2645	4248	-3859	-2192	745	3516	4414	-9127	-6117	-676	4520	6364
Jun	1 - 6	-1818	-642	1265	2919	5235	-3107	-1216	936	2958	4084	-9364	-6255	-2240	2021	5126
	7 - 30	-1829	-522	1698	3317	6698	-2634	-162	338	1047	2327	-13906	-7066	-3059	1959	5221
Jul	1 - 31	-940	1989	3576	5387	7936	-2808	337	386	739	1711	-15864	-10544	-6747	-3372	2334
Aug	1 - 31	-765	2238	3772	5512	8564	-2128	391	462	757	2147	-15231	-10274	-7030	-4051	2205
Sep	1 - 30	-1253	745	2834	4236	8589	-2176	430	535	1023	2237	-15064	-8747	-5169	-847	3830
Oct	1 - 3	-1006	86	2088	3500	7087	-1305	456	613	1130	1583	-10680	-7544	-3700	623	3228
	4 - 20	-1159	-163	1836	3497	7015	-2314	-195	373	980	1807	-12405	-7574	-3262	1423	3738
	21 - 31	-1698	104	2094	3525	5993	-1970	342	573	1158	2141	-11985	-7598	-3746	836	4217
Nov	1 - 10	-2041	-703	1606	3335	6660	-2883	-73	476	1281	2670	-13135	-7458	-2821	2339	5978
	11 - 20	-1138	865	2909	4886	7179	-1655	472	547	738	2342	-13921	-8767	-5343	-1747	4140
	21 - 28	-1261	241	2158	3545	6772	-2986	-440	938	2018	5056	-12314	-7917	-3900	554	4451
	29 - 30	-1779	-874	1683	3787	5934	-3007	-1525	1007	2725	3393	-10792	-8495	-2875	2923	5169
Dec	1 - 13	-2389	-1074	1651	4030	6751	-3457	-1167	816	2918	4110	-13365	-8802	-2874	3038	6531
	14 - 31	-2580	-547	2740	5293	9335	-3893	-262	1341	3093	4624	-15590	-10504	-4857	1225	7190

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

		ORP					ROLD074					MID at VICT				
		Min	25%	Avg	75%	Max	Min	25%	Avg	75%	Max	Min	25%	Avg	75%	Max
Jan	1 - 4	1790	2541	2676	2838	3107	1965	2550	2804	3114	3762	-11018	-7688	-3430	460	5319
	5 - 10	1170	1928	2207	2470	3242	1031	1996	2313	2616	3296	-9979	-5541	-1417	2598	5303
	11 - 31	369	1356	1505	1683	2079	106	1202	1537	1859	2661	-10764	-6968	-3488	22	4493
Feb	1 - 28	545	1199	1326	1520	1843	293	1155	1389	1688	2266	-9740	-6215	-2600	1164	4807
Mar	1 - 22	618	1333	1418	1580	1836	468	1250	1504	1810	2337	-9572	-6312	-2700	1079	4438
	23 - 31	824	1177	1368	1556	1765	716	1236	1481	1800	2142	-8716	-6226	-2003	2262	4452
Apr	1 - 14	580	1067	1237	1424	1655	379	1063	1306	1584	2186	-9570	-6149	-2317	1511	4014
	15 - 30	-565	-115	333	1062	1356	275	466	510	637	718	-8019	-4600	-1802	3457	4528
May	1 - 24	-565	-137	496	1027	1328	275	450	530	622	715	-7547	-4501	-692	3118	4514
	25 - 31	533	790	1152	1496	1743	406	1095	1287	1544	1976	-7207	-4957	-650	3616	5050
Jun	1 - 6	352	729	1008	1250	1436	376	923	1078	1326	1617	-6759	-4839	-1399	2123	4316
	7 - 30	-95	323	567	790	1332	-103	301	691	1140	1888	-9653	-5428	-1875	2197	4569
Jul	1 - 31	-109	298	665	1003	1708	-127	328	779	1264	1978	-10948	-6790	-3744	-725	3258
Aug	1 - 31	-184	231	639	989	1861	-231	229	718	1232	1854	-10254	-6718	-3851	-1159	2738
Sep	1 - 30	-185	220	584	853	1828	-229	182	658	1192	1824	-9422	-6312	-2854	576	3912
Oct	1 - 3	-123	154	507	784	1543	-160	115	563	1036	1475	-6688	-5518	-1992	1611	3438
	4 - 20	-52	245	353	447	901	-90	263	420	589	887	-7972	-5716	-1863	1954	3845
	21 - 31	285	453	562	665	1001	299	540	648	753	1013	-7821	-5446	-2128	1387	3700
Nov	1 - 10	225	340	478	601	971	235	449	569	705	1011	-8803	-5569	-1645	2429	4800
	11 - 20	215	372	513	623	1071	232	422	572	684	1019	-9009	-5734	-2881	-10	4059
	21 - 28	148	591	867	1174	1721	162	560	950	1320	1745	-8023	-5732	-2195	1418	4080
	29 - 30	265	762	1055	1320	1607	-18	965	1082	1339	1583	-7919	-5651	-1561	2620	4159
Dec	1 - 13	-289	758	1017	1375	1660	-394	878	1082	1427	1971	-9049	-6022	-1706	2804	5026
	14 - 31	-278	1465	1637	1873	2623	-265	1410	1714	2025	2857	-10465	-6947	-2770	1769	5515

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

		RMID027					RSAN072					ROLDO40				
		Min	25%	Avg	75%	Max	Min	25%	Avg	75%	Max	Min	25%	Avg	75%	Max
Jan	1 - 4	-850	-326	83	478	762	-1049	1312	1986	2908	3322	-15255	-4813	-1557	1874	8709
	5 - 10	-858	-353	106	525	823	-1902	1084	1758	2715	3387	-14208	-6110	-1701	3448	7763
	11 - 31	-895	-329	-8	318	809	-2490	-826	448	1643	2372	-15141	-5570	-2691	815	6549
Feb	1 - 28	-859	-357	-21	341	825	-2111	-819	464	1695	2247	-13732	-5696	-2396	1778	9068
Mar	1 - 22	-861	-414	-58	305	731	-2049	-718	540	1716	2235	-13084	-6213	-2921	1271	7766
	23 - 31	-859	-474	-50	372	706	-1992	-791	586	1890	2243	-12524	-7778	-3114	2337	4405
Apr	1 - 14	-837	-418	-35	337	742	-2146	-1005	397	1655	2056	-13789	-6446	-2495	2255	7385
	15 - 30	-842	-291	-183	97	541	-701	2104	2248	3085	3566	-9635	-5118	-2138	3957	5767
May	1 - 24	-839	-265	-110	42	471	-701	1950	2327	2901	3409	-9635	-5168	-686	3740	8802
	25 - 31	-909	-402	-36	280	730	-2136	-860	651	2074	2408	-9053	-6000	-344	5091	9178
Jun	1 - 6	-712	-220	-104	18	469	-1825	-720	496	1635	2077	-9594	-5926	-2282	1103	7983
	7 - 30	-920	-268	-86	89	581	-2384	-755	482	1687	2221	-12368	-5135	-2314	901	8194
Jul	1 - 31	-1023	-196	-85	44	518	-2634	-908	307	1506	2058	-14346	-6074	-4133	-1656	5952
Aug	1 - 31	-903	-111	-43	83	517	-2538	-980	306	1522	2069	-13660	-5696	-3993	-1767	8076
Sep	1 - 30	-784	-148	-1	174	544	-2281	-834	442	1664	2136	-12243	-6412	-3862	-1195	6117
Oct	1 - 3	-614	-49	36	196	406	-1840	-528	697	1738	2076	-8638	-6929	-3661	-1210	647
	4 - 20	-753	-182	-10	167	455	-2014	-275	836	1931	2228	-10551	-7114	-4032	-894	3408
	21 - 31	-684	-149	13	161	485	-1052	675	1393	2172	2686	-9289	-5648	-3239	-309	5909
Nov	1 - 10	-977	-218	5	228	661	-2109	-33	1051	2107	2745	-11089	-5341	-2255	1248	7491
	11 - 20	-665	-45	5	100	495	-1486	389	1174	2016	2526	-9720	-5657	-3566	-1739	5367
	21 - 28	-747	-348	15	366	744	-2068	-749	547	1780	2339	-11312	-6485	-3533	79	5563
	29 - 30	-777	-435	20	404	554	-2093	-1240	386	1638	1954	-12046	-8380	-2819	1632	3627
Dec	1 - 13	-892	-424	-17	381	656	-2479	-1170	305	1682	2299	-12866	-7109	-2439	2975	9121
	14 - 31	-1151	-447	-5	450	913	-2747	-941	582	1972	2697	-14530	-6118	-1775	2847	8542

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

Year	Middle River							Old River near Tracy (DMC)							Grant Line Canal						
	Installation			Notched	Removal			Installation			Notched	Removal			Installation			Flashboards	Removal		
	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					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					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

Year	Spring Head of Old River						Fall Head of Old River (v)						
	Installation			Removal			Installation			Notched	Removal		
	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				2-Jun		8-Jun	8-Sep		11-Sep		30-Nov		4-Dec
1993							8-Nov (vii)		11-Nov		3-Dec		7-Dec
1994				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		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.

Table 3-2. Release and Recovery Information for Coded Wire Tag Groups Released for VAMP 2002

TagCode	Release Site	Date	Truck Temp (F)	River Temp (F)	Number Released	Average Size (mm)	Number Recovered At Antioch	Percent Sampled At Antioch	Survival Index At Antioch	Group Index At Antioch	Number Recovered At Chipps	Percent Sampled At Chipps	Survival Index At Chipps	Group Index At Chipps	Expanded Salvage CVP	Expanded Salvage SWP	Absolute Survival Antioch	Absolute Survival Chipps	Absolute DF-MD Survival Antioch	Absolute DF-MD Survival Chipps
06-44-71	Durham Ferry		54.5	59	23920	83	11	0.391	0.085		4	0.277	0.078		12	12				
06-44-72	Durham Ferry		54.5	59	25176	83	20	0.391	0.146		9	0.264	0.176		60	36				
06-44-73	Durham Ferry		54.5	59	23872	83	12	0.391	0.093		4	0.273	0.080		0	27				
06-44-74	Durham Ferry		54.5	59	24747	83	20	0.391	0.149		4	0.278	0.076		24	36				
	Total	**18-Apr-02**			**97715**		**63**	**0.391**		**0.119**	**21**	**0.265**		**0.105**			**0.16**	**0.13**	**0.77**	**0.86**
06-44-57	Mossdale		55.4	57.2	25515	84	13	0.388	0.095		6	0.272	0.112		24	90				
06-44-58	Mossdale		55.4	51.8	25272	82	29	0.388	0.213		7	0.273	0.132		72	48				
	Total	**19-Apr-02**			**50787**		**42**	**0.388**		**0.153**	**13**	**0.273**		**0.122**			**0.21**	**0.15**		
06-44-59	Jersey Point		59	64.4	24802	85	101	0.387	0.758		46	0.273	0.882		0	12				
06-44-60	Jersey Point		59	64.4	24128	83	89	0.386	0.688		37	0.266	0.750		24	12				
	Total	**22-Apr-02**			**48930**		**190**	**0.386**		**0.724**	**83**	**0.266**		**0.830**						
06-44-70	Durham Ferry		60.8	62.6	24680	80	6	0.399	0.044		3	0.273	0.058		36	6				
06-44-75	Durham Ferry		60.8	62.6	24659	80	2	0.384	0.015		5	0.259	0.102		0	24				
06-44-76	Durham Ferry		60.8	62.6	24783	80	4	0.382	0.030		3	0.275	0.057		24	25				
06-44-77	Durham Ferry		60.8	62.6	24381	80	6	0.392	0.045		4	0.266	0.080		24	36				
	Total	**25-Apr-02**			**98503**		**18**	**0.398**		**0.033**	**15**	**0.257**		**0.077**			**0.11**	**0.16**	**1.2**	**1.5**
06-44-78	Mossdale		55.4	63.5	24519	79	3	0.399	0.022		2	0.273	0.039		12	93				
06-44-79	Mossdale		55.4	63.5	24820	81	4	0.400	0.029		3	0.260	0.060		0	24				
	Total	**26-Apr-02**			**49339**		**7**	**0.400**		**0.026**	**5**	**0.260**		**0.051**			**0.09**	**0.11**		
06-44-80	Jersey Point		52.7	63.5	24032	82	43	0.399	0.323		18	0.265	0.367		0	0				
06-44-81	Jersey Point		52.7	63.5	22880	82	32	0.398	0.253		28	0.270	0.589		0	0				
	Total	**30-Apr-02**			**46912**		**75**	**0.398**		**0.289**	**46**	**0.265**		**0.480**						

Table 3-4 2002 Smolt Survival Differential Recovery Rates

	REC. AT ANTIOCH	REC. AT CL	# RELEASED	A+C	A+C/R	S DF TO MD	S MD TO JP	S DF TO JP	S DF/MD-JP	S-2SE	S+2SE	S-1SE	S+1SE
Durham Ferry (DF) 1	11	4	23,920	15	0.00062								
	20	9	25,176	29	0.00115								
	12	4	23,872	16	0.00067								
	20	4	24,747	24	0.00096								
Total	**63**	**21**	**97,715**	**84**	**0.00085**	**0.793**				**0.518**	**1.069**	**0.656**	**0.931**
Mossdale	13	6	25,515	19	0.00074			0.154		0.115	0.192	0.134	0.173
(MD) 1	29	7	25,272	36	0.00142								
Total	**42**	**13**	**50,787**	**55**	**0.00108**		**0.194**			**0.136**	**0.251**	**0.165**	**0.222**
Jersey Point (JP) 1	101	46	24,802	147	0.00592								
	89	37	24,128	126	0.00522								
Total	**190**	**83**	**48,930**	**273**	**0.00557**								
Durham Ferry (DF) 2	6	3	24,680	9	0.00036								
	2	5	24,659	7	0.00028								
	4	3	24,783	7	0.00028								
	6	4	24,381	10	0.00041								
Total	**18**	**15**	**98,503**	**33**	**0.00033**	**1.377**				**0.448**	**2.305**	**0.913**	**1.841**
Mossdale (MD) 2	3	2	24,519	5	0.00020			0.129		0.078	0.180	0.104	0.155
	4	3	24,820	7	0.00028								
Total	**7**	**5**	**9,339**	**12**	**0.00024**		**0.094**			**0.037**	**0.151**	**0.065**	**0.122**
Jersey Point (JP) 2	43	18	24,032	61	0.00253								
	32	28	22,880	60	0.00262								
Total	**75**	**46**	**46,912**	**121**	**0.00257**								
Combined													
DF (1&2)	81	36	196,218	117	0.00059	0.891				0.618	1.164	0.754	1.027
MD (1&2)	49	18	100,126	67	0.00066		0.162			0.119	0.205	0.141	0.184
JP (1&2)	265	129	95,842	394	0.00411			0.145		0.114	0.175	0.129	0.160
DF/MD (1&2)	130	54	296,344	184	0.00062				0.151	0.124	0.177	0.137	0.164

S – Differential Recovery Rate • 1SE – One Standard Error • 2SE – Two Standard Errors

Table 3-5 2000 Smolt Survival Differential Recovery Rates

	REC AT ANT.	REC AT CI	# RELEASED	A+C	A+C/R	S DF TO MD	S MD TO JP	S DF-JP	S DF/MD-JP	S-2SE	S+2SE	S-1SE	S+1SE
Durham 1	6	7	23629	13	0.00055								
	10	10	24177	20	0.00082								
	11	11	24457	22	0.00089								
	27	28	72263	55	0.00076	0.733				0.443	1.022	0.588	0.878
MD 1	14	9	23465	23	0.00098								
	16	9	22784	25	0.00109								
	30	18	46249	48	0.00103		0.328			0.220	0.437	0.274	0.383
JP 1	50	24	25527	74	0.00289								
	47	41	25824	88	0.00340								
	97	65	51351	162	0.00315			0.241		0.166	0.316	0.203	0.278
Durham 2	8	7	23698	15	0.0006								
	15	5	26805	20	0.00074								
	8	10	23889	18	0.00075								
	31	22	74392	53	0.00071	1.036				0.445	1.628	0.741	1.332
MD 2	9	7	23288	16	0.0006		0.150			0.072	0.227	0.111	0.188
JP 2	76	48	25572	124	0.00484								
	76	30	24661	106	0.00429								
	152	78	50233	230	0.00457			0.155		0.108	0.202	0.131	0.179
<u>**Combined**</u>													
DF (1&2)	58	50	146655	108	0.00073	1.066				0.814	1.319	0.940	1.193
MD (1&2)	39	25	69537	48	0.00069		0.178			0.114	0.243	0.146	0.211
JP (1&2)	249	143	101584	392	0.00385			0.190		0.149	0.232	0.170	0.211
DF/MD(1&2)	97	75	216192	156	0.00072				0.186	0.149	0.224	0.168	0.205

S – Differential Recovery Rate ; 1SE – One Standard Error ; 2SE – Two Standard Errors

Table 3-6 2001 Smolt Survival Differential Recovery Rates

	REC AT ANT`	REC AT CI	# RELEASED	A+C	A+C/R	S DF TO MD	S MD TO JP	S DF-JP	S DF/MD-JP	S-2SE	S+2SE	S-1SE	S+1SE
Durham 1	28	14	23354	42	0.00179								
	30	22	22837	52	0.00227								
	18	17	22491	35	0.00155								
	76	53	68682	129	0.00187	1.325				0.920	1.730	1.123	1.528
MD 1	18	17	23000	35	0.00152								
	15	14	22177	29	0.00130								
	33	31	45177	64	0.00141		0.159			0.116	0.201	0.137	0.180
JP 1	156	50	24443	206	0.00842								
	173	61	24992	234	0.00936								
	329	111	49435	440	0.00890			0.211		0.168	0.253	0.189	0.232
Durham 2	8	2	24025	10	0.00041								
	11	5	24029	16	0.00066								
	10	2	24177	12	0.00049								
	29	9	72231	38	0.00052	0.958				0.476	1.440	0.717	1.199
MD 2	8	4	23878	12	0.00050								
	11	4	25308	15	0.00059								
	19	8	49186	27	0.00054		0.201			0.116	0.286	0.159	0.243
JP 2	43	17	25909	60	0.00231								
	53	27	25465	80	0.00314								
	96	44	51374	140	0.00272			0.193		0.122	0.263	0.157	0.228
Combined													
DF (1&2)	105	62	140913	167	0.00118	1.228				0.908	1.549	1.068	1.388
MD (1&2)	52	39	94363	91	0.00096		0.167			0.129	0.205	0.148	0.186
JP (1&2)	425	155	100809	580	0.00575			0.205		0.169	0.242	0.187	0.224
DF/MD(1&2)	157	101	235276	258	0.00109				0.190	0.162	0.219	0.176	0.204

S – Differential Recovery Rate ; 1SE – One Standard Error ; 2SE – Two Standard Errors