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The Natural Resources Agency
Department of Water Resources

South Delta Temporary Barriers Project

2007 South Delta Temporary Barriers Monitoring Report

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Metric Conversions Table

Qua	*To convert from metric unit*	*To customary unit*	*Multiply*	*To*
Len	millimeters (mm)	inches (in)*	0.03937	25.4
	centimeters (cm) for snow	inches (in)	0.3937	2.54
	meters (m)	feet (ft)	3.2808	0.3048
	kilometers (km)	miles (mi)	0.62139	1.6093
Area	square millimeters (mm^2)	square inches (in^2)	0.00155	645.16
	square meters (m^2)	square feet (ft^2)	10.764	0.09290
	hectares (ha)	acres (ac)	2.4710	0.40469
	square kilometers (km^2)	square miles (mi^2)	0.3861	2.590
Volu	liters (L)	gallons (gal)	0.26417	3.7854
	megaliters	million gallons (10*)	0.26417	3.7854
	cubic meters (m^3)	cubic feet (ft^3)	35.315	0.02831
	cubic meters (m^3)	cubic yards (yd^3)	1.308	0.76455
	cubic dekameters (dam^3)	acre-feet (ac-ft)	0.8107	1.2335
Flow	cubic meters per second	cubic feet per second	35.315	0.02831
	liters per minute (L/mn)	gallons per minute	0.26417	3.7854
	liters per day (L/day)	gallons per day	0.26417	3.7854
	megaliters per day (ML/day)	million gallons per day	0.26417	3.7854
	cubic dekameters per day	acre-feet per day (ac-	0.8107	1.2335
Mas	kilograms (kg)	pounds (lbs)	2.2046	0.45359
	megagrams (Mg)	tons (short, 2,000 lb.)	1.1023	0.90718
Velo	meters per second (m/s)	feet per second (ft/s)	3.2808	0.3048
Pow	kilowatts (kW)	horsepower (hp)	1.3405	0.746
Pres	kilopascals (kPa)	pounds per square inch	0.14505	6.8948
	kilopascals (kPa)	feet head of water	0.33456	2.989
Spe	liters per minute per meter drawdown	gallons per minute per foot drawdown	0.08052	12.419
Con	milligrams per liter (mg/L)	parts per million (ppm)	1.0	1.0
Elec	microsiemens per centimeter (µS/cm)	micromhos per centimeter (µmhos/cm)	1.0	1.0
Tem	degrees Celsius (°C)	degrees Fahrenheit	(9/5 x	(°F - 32)

Abbreviations and Acronyms

BO	biological opinion
CD	DWR Central District
CDEC	California Data Exchange Center (http://cdec.water.ca.gov/)
CDRR	combined differential recovery rates
cfs	cubic feet per second
CPUE	Catch-Per-Unit-Effort
CVP	Central Valley Project
CWT	coded-wire tag
DFG	California Department of Fish and Game
DICU	Delta Island Consumptive Use
DO	dissolved oxygen
DRR	differential recovery rates
DSM2-Hydro	DWR Delta Simulation Model
DWR	California Department of Water Resources
GLC	Grant Line Canal
HORB	Head of Old River Barrier
HTI	Hydroacoustic Technology, Inc.
IEP	Interagency Ecological Program (www.iep.water.ca.gov)
ITP	Incidental Take Permit
km	kilometer
mg/L	milligrams per liter
MKT	Mossdale Kodiak Trawl
mL	milliliter
mm	millimeter
MR	Middle River
MRH	Merced River Hatchery
MSL	mean sea level
NGVD	National Geodatic Vertical Datum
NTU	Nephelometric Turbidity Unit
ORT	Old River at Tracy [barrier]
SAV	submerged aquatic vegetation
SJR	San Joaquin River
SWP	State Water Project
TBP	Temporary Barriers Project
TFCF	Tracy Fish Collection Facility
TPS	Tom Paine Slough
TWA	Tracy Wildlife Association
µm	micrometer
µmhos/cm	micromhos per centimeter
USGS	US Geological Survey
VAMP	Vernalis Adaptive Management Plan

Chapter 1. Introduction

The Department of Water Resources (DWR) issued the draft environmental impact report and environmental impact statement for the South Delta Water Management Program in 1990. Objectives of the program are to achieve the following:

1. Increase water levels, circulation patterns and water quality in the southern Delta area for local agricultural diversions.
2. Improve operational flexibility of the State Water Project to help reduce fishery impacts and improve fishery conditions.

Because of concerns related to both agriculture and the fisheries, the Temporary Barriers Project (TBP) was initiated to better determine effects of installing permanent barriers in the southern Delta. A 5-year program began in 1991 to test a facsimile of the proposed barriers. In 1996, this test was extended for another 5 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 (DFG) Streambed Alteration Agreement and various Temporary Entry Permits required from landowners and local reclamation districts. Table 1-1 shows installation and removal dates for the various years of the project.

Although the South Delta TBP has been in place since 1991, the Middle River barrier and the fall Head of Old River barrier have been installed in earlier years under different programs. The Grant Line Canal barrier was installed for the first time in 1996, at a site about 4.5 miles east of the originally proposed location. In 1997, the spring Head of Old River barrier was installed with two 48-inch culverts. In 1998, none of the barriers were installed due to high river flows throughout the spring and summer. In 1999, the Head of Old River barrier was not installed in the spring or the fall but the other barriers were installed. In 2000 through 2004, all the barriers were installed (see Table 1-1). In 2005 and 2006, the spring Head of Old River Barrier was not installed due to excessively high flows in the San Joaquin River. The fall Head of Old River Barrier was not installed in 2006 due to favorable dissolved oxygen conditions.

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, 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 Biological Opinion, (4) the March 30, 2001, US Fish and Wildlife Service Biological Opinion for the DWR TBP 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 and /or CALFED funds. The elements of the monitoring plan came from permit conditions required by DFG, National Marine Fisheries Service, and US Fish and Wildlife Service. The monitoring plan covers fish species including salmon, steelhead, delta smelt and splittail. Also included are

terrestrial species such as Swainson's Hawks, pond turtles, and sensitive plants. The following are brief descriptions of each chapter.

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

In 2001, a pilot study was developed to provide an experimental approach to determining the behavioral response of fish with the installation of the temporary barriers in the south Delta. However, this project was canceled due to insufficient data collection and recapture capabilities. A revised program was planned for 2003; however, funding and personnel shortages precluded implementation. Therefore, the fish monitoring study has not been conducted since 2002. Future studies are planned, but implementation will be dependent on the availability of necessary staff.

In 2007, a 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. These results are included in this chapter.

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

This chapter presents the results of fish entrainment monitoring at the Head od Old River barrier for spring 2007. The monitoring plan was designed and implemented by 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 Head of Old River Barrier.
- Determine the percentage of coded-wire tagged 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. In years 2004 and 2005, the spring Head of Old River Barrier was not installed due to high flows in the San Joaquin River; Kodiak Trawls were conducted instead.

Chapter 4. Salmon Smolt Survival Investigations (Prepared by Patricia Brandes, US Fish and Wildlife Service)

This section describes the methods used in conducting the 2007 Vernalis Adaptive Management Plan Chinook salmon smolt survival investigations, and presents results of the calculated survival indices and absolute survival estimates for juvenile Chinook salmon during the VAMP 2007 test period.

Chapter 5. Annual Summary Report of SWP and CVP Salvage (Prepared by Kimberly Gazzaniga and Katherine Marquez, DWR)

This chapter investigates the potential effect of the TBP on fish entrainment at the Skinner (State Water Project) and Tracy (Central Valley Project) fish facilities. Daily salvage densities for 2007 are analyzed and compared to TBP operations, Delta hydrodynamics, and project export flows.

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

This section describes Swainson's Hawk observations and the effects of the barriers construction activities in 2007 on nesting pairs within a half-mile radius of the sites.

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

This chapter presents results of the monitoring conducted in 2007 to determine the effects of the barriers on water surface elevations and circulations patterns in the southern Delta channels.

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

Monitoring was conducted in 2007 to evaluate the changes in various water quality parameters due to installation and operation of the barriers. The water quality parameters measured include 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*. This information is presented in chapter 8.

Chapter 9. Hydrologic Modeling (Prepared by Parviz Nader-Tehrani, DWR)

The DWR Delta Simulation Model, DSM2-Hydro, was used to conduct a hydrodynamic simulation of the effects the temporary barriers have on water levels in the south Delta for the year 2007. In this chapter, the DSM2-simulated stages and flows are compared to historical data in the south Delta.

Table 1-1. Schedule of installation and removal dates for South Delta Temporary Barriers from 1987 through 2007 (11 x 17 format. See separate pdf online)

	Middle River							Old River near Tracy (ORT)							Grant Line Canal			
	Installation				Removal			Installation				Removal			Installation			Flashboards
Year	Started	Closed	Completed	Notched	Started	Breached	Completed	Started	Closed	Completed	Notched	Started	Breached	Completed	Started	Closed	Completed	Adjusted
1987			15-May		End of Sep		End of Sep											
1988	26-May		28-May		23-Sep		23-Sep											
1989			12-Apr		26-Sep		26-Sep											
1990			16-Apr		29-Sep		29-Sep											
1991	4-Apr		5-Apr		27-Sep		27-Sep	14-Aug		30-Aug		28-Sep		13-Oct. (i)				
1992	8-Apr		10-Apr		28-Sep		29-Sep	15-April boat port on		01-May 09-May boat port on		30-Sep		Oct-09(ii)				
1993	14-Jun		17-Jun		23-Sep		24-Sep	12-May		1-Jun		27-Sep		6-Oct				
1994	23-Apr		25-Apr		29-Sep		5-Oct	22-April boat port on. All culverts tied open (5/18 to 6/1)		24-April 01-May		26-Sep		10-Oct				
1995	8-Aug		11-Aug		10-Oct		10-Oct	3-Aug		8-Aug		27-Sep		6-Oct				
1996	18-May		20-May		29-Sep		29-Sep	12-May		10-Jun (iii)		29-Sep		16-Oct	17-Jun		10-Jul	
1997	3-Apr		7-Apr		27-Sep		28-Sep	8-Apr		17-Apr		30-Sep		7-Oct	21-May		4-Jun	
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	
2000	4-Apr		6-Apr		1-Oct		7-Oct	4-Apr		16-Apr		1-Oct		7-Oct	19-May		1-Jun	
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	
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	
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 (Complete)	11-Jun	23-Apr. (Partial) 17-June (Complete)	16-Sept.
2004	9-Apr	12-Apr	13-Apr	23-Sept.	9-Nov.	10-Nov.	12-Nov	1-Apr	15-Apr	20-Apr	10-Sept.	8-Nov.	8-Nov.	1-Dec.	1-Apr. (Partial) 2-June (Complete)	9-Apr (partial) 5-June (complete)	28 Apr (partial) 9-June (complete)	9-Sept.
2005	10-May	12-May	17-May	15-Sept.	7-Nov	8-Nov	9-Nov.	9-May	31-May	6-Jun	15-Sept.	8-Nov.	10-Nov	30-Nov	2-May	14-Jul	18-Jul	14-July & 14-Sept.
2006	5-Jul	7-Jul	8-Jul	1-Oct	17-Nov	18-Nov	20-Nov	7-Jul	17-Jul	31-Jul	1-Oct	13-Nov	16-Nov	8-Dec	7-Jul	20-Jul	26-Jul	20-Jul & 1-Oct
2007	7-Apr	10-Apr	10-Apr	21-Sept.	19-Nov	20-Nov	29-Nov	2-Apr	18-Apr	23-Apr	21-Sep	5-Nov	7-Nov	18-Nov	9-Apr (Partial) 27-Apr (Completed)	17-Apr (Partial) 10-May (Completed)	17-Apr (Partial) 11-May (Completed)	17-Apr (Partial) 10-May (Completed)

	Spring Head of Old River						Fall Head of Old River (v)						
	Installation			Removal			Installation			Notched	Removal		
Year	Started	Closed	Completed	Started	Breached	Completed	Started	Closed	Completed		Started	Breached	Completed
1987							9-Sep		11-Sep				28-Nov
1988							22-Sep		28-Sep				2-Dec
1989							27-Sep		28-Sep		27-Nov		30-Nov
1990							10-Sep		11-Sep				27-Nov
1991							9-Sep		13-Sep		22-Nov		27-Nov
1992	15-April boat port on		23-April @ 4ft 26-April@6ft 01-May	2-Jun		8-Jun	8-Sep		11-Sep		30-Nov		4-Dec
1993							8-Nov (vii)		11-Nov		3-Dec		7-Dec
1994	21-April boat port on		23-April @10ft 01-May	18-May		20-May	6-Sep		8-Sep		28-Nov		30-Nov
1995	(vii)						(vii)						
1996	6-May		11-May	16-May		3-Sept (iv)	30-Sep		3-Oct		18-Nov		22-Nov
1997	9-Apr		16-Apr	15-May		19-May (viii)							
1998	(vii)						(vii)						
1999	(vii)						(viii)						
2000	5-Apr		16-Apr	19-May		2-Jun	27-Sep		7-Oct		27-Nov		8-Dec
2001	17-Apr		26-Apr	23-May		30-May	24-Sep		6-Oct		22-Nov	22-Nov	2-Dec
2002	2-Apr		18-Apr	22-May	24-May	7-Jun	24-Sep		4-Oct		11-Nov	12-Nov	21-Nov
2003	1-Apr	15-Apr	21-Apr	16-May	18-May	3-Jun	2-Sept.	15-Sept.	18-Sep	16-Sept.	3-Nov	4-Nov	13-Nov
2004	1-Apr	15-Apr	21-Apr	19-May	24-May	10-Jun	7-Sep	27-Sept.	29-Sept.	28-Sept.	1-Nov.	2-Nov.	12-Nov
2005	(vii)	(vii)	(vii)	(vii)	(vii)	(vii)	19-Sept.	28-Sept.	30-Sept.	29-Sep	7-Nov	8-Nov	15-Nov
2006	(vii)	(vii)	(vii)	(vii)	(vii)	(vii)	(ix)	(ix)	(ix)	(ix)	(ix)	(ix)	(ix)
2007	11-Apr	20-Apr	26-Apr	19-May	22-May	6-Jun	5-Oct	17-Oct	18-Oct	18-Oct	9-Nov	10-Nov	29-Nov

(i) Barrier notched on Sept. 28, 1991. Construction resumed o
(ii) Barrier notched on Sept. 30, 1992. Construction resumed c
(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, bu 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.
(ix) Not installed because existing flows and dissolved oxyge sufficient for Chinook Salmon.

Chapter 2. Fisheries Monitoring and Water Quality Analysis

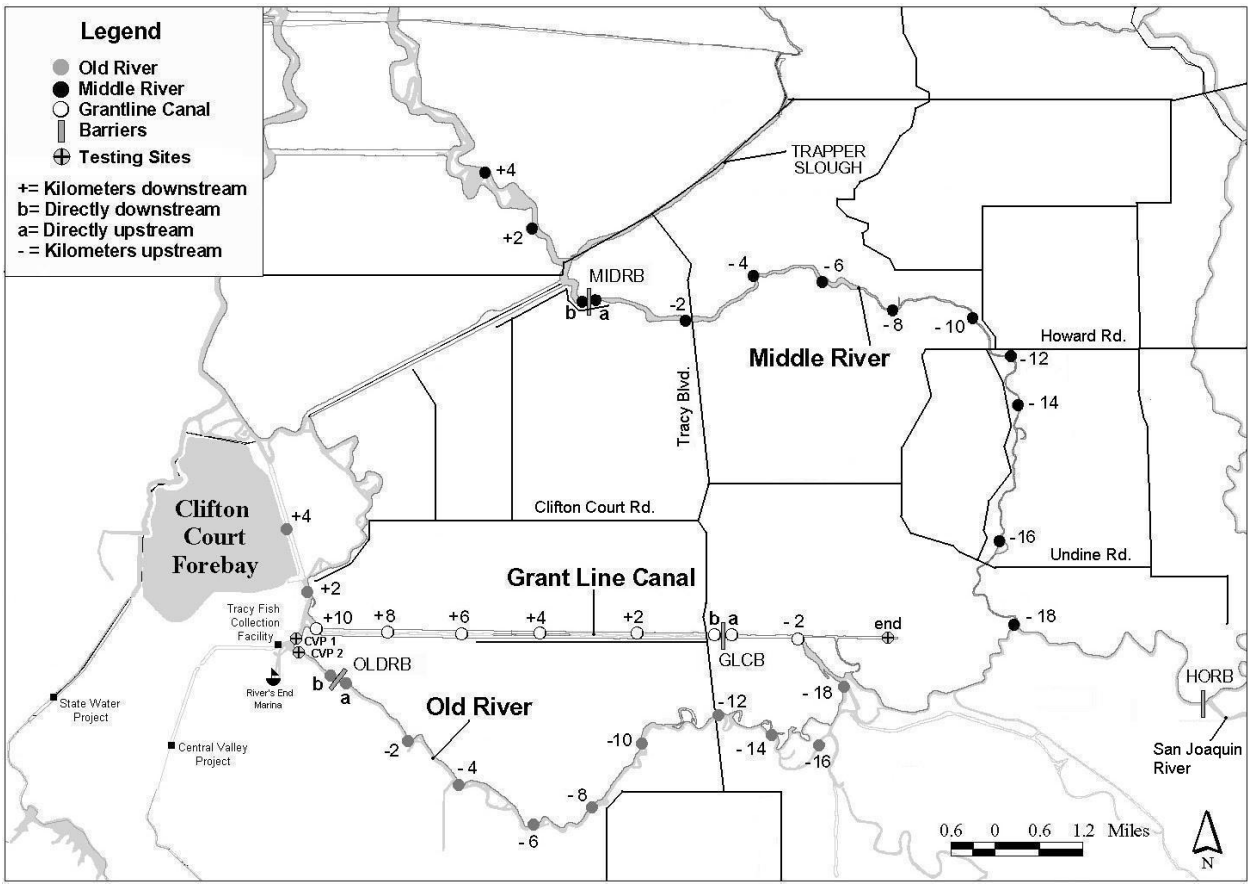
The South Delta Temporary Barriers Project consists of the construction, operation, and monitoring of 4 temporary rock fill barriers. Three of the barriers, located in 3 south Delta channels (Grant Line Canal, Old and Middle rivers), are constructed seasonally and operate during the agricultural season, usually April through October. The 4th barrier, located at the head of Old River, is designed in the spring as a fish barrier to prevent fall-run San Joaquin River Chinook salmon smolts, as well as Central Valley steelhead smolts from the San Joaquin River watershed from migrating down through Old River toward the Central Valley Project (CVP) and the State Water Project (SWP) export facilities. This barrier is also installed in the fall to improve water quality on the San Joaquin River downstream of the barrier. In addition to the program objectives, stated in Chapter 1 Introduction of this report, the Temporary Barriers Project objectives are to collect baseline data for use in the design of the permanent barriers and for its future use as a reference in permanent barrier operations.

Starting in 1992 and continuing through 1995, a seasonal (year round) fish sampling program monitored the fishery resources and water quality in the south Delta. From 1996 through 2000, this monitoring program was changed from a seasonal study to a study conducted March through October. Its objectives were to concentrate on the potential effects of the barriers on the various fish species inhabiting the channels and to find if the barriers could cause an increase in predatory fish by creating a more favorable habitat for them. In 2001, a pilot study was developed to provide an experimental approach to determining the behavioral response of fish to the installation of the temporary barriers. However, this project was canceled due to insufficient data collection and recapture capabilities. A revised program was planned for 2003, however, funding and personnel shortages precluded implementation. Therefore, the fish monitoring study has not been conducted since 2002. Future studies are planned, but implementation will be dependent on the availability of necessary staff.

Since 2002, physical water quality parameters have been monitored not only for their possible effects 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 study plan are:

- Determine water quality profiles of the channels affected by the temporary barriers.
- Determine if there are null zones within the south Delta, upstream of the 3 barriers.

Figure 2-1. Water quality sampling sites in the south Delta, 2007



Materials and Methods

Thirty-four permanent water quality sites were sampled on Grant Line Canal, Old and Middle rivers (Figure 2-1)[1]. Each channel's sites are set at approximately 2 kilometer (km) intervals. A hydrolab was used to determine water temperature in degrees Celsius (ºC), dissolved oxygen in milligrams per liter (mg/L), and specific conductance in micromhos per centimeter (µmhos/cm)—the water's ability to conduct an electric current and directly related to the total dissolved salts or ions normalized to 25 ºC. Turbidity was measured in NTUs (the degree to which light is scattered by suspended particles) using a portable turbidimeter. Two replicate water samples were collected at each site at depths equal to 40% and 60% of the total depth. Water samples were taken from downstream to upstream at the beginning of each tidal stage (ebb and flood tides). Tidal stage, location, and time were recorded at each permanent site. Monthly average air temperature for Stockton was collected from Western Underground Web site (www.wunderground.com) because both the California Data Exchange Center and the Western Regional Climate Center had incomplete data.

Each channel's water quality parameters were compared over time (months) and location (sampling sites). Three different water quality profiles were graphed for each

[1] For ease of reference, Figure 2-1 is placed on this page, but the remaining figures mentioned in Chapter 2 text appear at the back of the chapter.

channel and parameter: (1) the monthly data in relation to the barrier (Figures 2-2 through 2-13); (2) the yearly average in relation to the barrier (Figure 2-14); and (3) the monthly average (Figure 2-15). As in previous years, the data used for analysis was an average of the 4 samples taken at each location. Statistical analysis was not performed because of insufficient data collection due to various mechanical difficulties of equipment and other project requirements.

Results

The water quality results from 2007 are similar to results from previous years. However, there were some differences, and they are addressed in the following sections.

Grant Line Canal

The water temperature data for Grant Line Canal is shown in Figures 2-2, 2-14A, 2-15A, and 2-16A. The water temperature began low and increased over the summer, before decreasing again in the fall. There were no significant differences between sites. The average monthly water temperature seems to follow the average monthly air temperature. This suggests a relationship between water temperature and the time of year, a seasonal trend, and is supported by the fact that all 3 channels followed the same pattern.

Grant Line Canal's dissolved oxygen data are shown in Figures 2-3, 2-14B, 2-15B, and 2-16A. The dissolved oxygen values were initially elevated during the spring and decreased throughout the summer months, before improving again in the fall. This is the exact opposite of water temperature, an inverse relationship, and follows the principle that the ability of water to hold dissolved oxygen decreases as the water temperature increases (Munson et al. 2007). Furthermore, all 3 channels had similar monthly dissolved oxygen patterns that suggest a relationship between dissolved oxygen and the time of year. The lowest dissolved oxygen reading was directly above the barrier on July 16 and measured 3.08 mg/L. Of the 207 samples collected on Grant Line Canal, 19 were below 5 mg/L (9%), the minimum water quality objective stated in the California Regional Water Quality Control Board's Basin Plan (4th ed.).

Figures 2-4, 2-14C, and 2-15C depict the specific conductance data for Grant Line Canal. The monthly average profile shows that the specific conductance for Grant Line Canal follows the specific conductance of the water that enters the south Delta (San Joaquin River at Mossdale's specific conductance). However, the monthly profiles indicate a spike in specific conductance 6 km downstream of the barrier that continues upstream past the barrier. This spike apparently starts in July and continues through the year with the downstream sites gradually increasing in conductivity until they are as high as their upstream counterparts. Coincidentally, just after June 15, all culverts flap gates were closed, functioning tidally; and total exports went from about 1,000 cfs to 10,000 cfs in a 3-week period (Figure 2-17B). Furthermore, flow at the head of Old River Barrier, the south Delta's water supply, was only about 1,000 cfs (Figure 2-17C). The critical water year, depicted in Figure 2-18, resulted in a low flow of water through the south Delta. Add this to the total export increase, and the cumulative effect was most likely a reduced flushing effect of the incoming tidal water. Other factors that could possibly affect the specific conductance would be wastewater discharge, agricultural runoff from farming activities (return locations and amount of water used and returned), decomposition of detritus, and urban runoff from roads and developments. The highest specific conductance reading was directly below the barrier

on July 6 and measured 874 µmhos/cm. Of the 207 samples collected on Grant Line Canal, 115 were above 700 µmhos/cm.

Grant Line Canal's turbidity data are shown in Figures 2-5, 2-14D, and 2-15D. There were no significant differences between sites, and the turbidity was always below 50 NTUs. The yearly averages for all 3 channels were similar. This suggests a relationship between specific conductance and the time of year. The varying turbidity is most likely due to outside sources since the critical water year resulted in low flows. Some of these sources might be soil erosion, wastewater discharge, suspended solids from agricultural runoff, urban runoff from roads and developments, algae growth, water recreation (water agitation), and bottom feeders.

Old River

The water temperature data for Old River are shown in Figures 2-6, 2-14A, 2-15A, and 2-16B. The water temperature began low and increased over the summer, before decreasing again in the fall. There were no significant differences between sites. The average monthly water temperature tracked well with the average monthly air temperature. This suggests a relationship between water temperature and the time of year, a seasonal trend, and is supported by the fact that all 3 channels followed the same pattern.

Old River's dissolved oxygen data are shown in Figures 2-7, 2-14B, 2-15B, and 2-16B. The dissolved oxygen values were lowest in summer and highest in early spring and fall. As stated previously, this is the exact opposite of water temperature, an inverse relationship. Furthermore, all 3 channels had similar monthly dissolved oxygen patterns that suggest a relationship between dissolved oxygen and the time of year. However, when the monthly profiles are examined, an obvious sag in dissolved oxygen appears in June, after June 13 to be exact. This sag coincides with the closing of the culvert flap gates (operating tidally) and the increase in exports from the CVP and SWP. The trivial incoming flow from the San Joaquin River (~1,000 cfs) in combination with the high exports (~10,000 cfs) significantly decreases the naturally flushing effects of the incoming tides. To help improve circulation and water quality on Old River (Holderman 2007), the culvert flap-gates of the Old River near Tracy barrier were tied open in various configurations from July 13 until the barrier was removed. Another factor that can affect dissolved oxygen is algae. Algal biomass is indicated by the presence of chlorophyll *a*, and the degradation of chlorophyll *a* (decomposition of algae) is indicated by the presence of pheophytin *a* (Philippart 2006). Algae affects dissolved oxygen concentration by creating it through photosynthesis and using it after algae die during decomposition. Therefore, the sag in dissolved oxygen could also be contributed to the high chlorophyll *a* / pheophytin *a* content of the San Joaquin River water that enters into the south Delta. The Department of Water Resources (DWR) data for chlorophyll *a* and pheophytin *a* illustrate a marked increase in both parameters in the water entering the south Delta (Chapter 8). The decomposition of the algae, at potential null zones, decreases the dissolved oxygen concentration as seen in June. A small increase in dissolved oxygen in July's monthly average is evident and may have been caused by the high dissolved oxygen concentration of the San Joaquin River water that enters into the south Delta, flap gate operations, increased photosynthesis due to increased nutrient load (see specific conductance), and/or increased water agitation due to water recreation. The lowest dissolved oxygen reading was at 6 km upstream of the barrier on June 18 and measured 2.25 mg/L. Of the 376 samples collected on Grant Line Canal, 31 were below 5 mg/L, the

minimum water quality objective stated in the California Regional Water Quality Control Board's Basin Plan (4th ed.).

Figures 2-8, 2-14C, and 2-15C depict the specific conductance data for Old River. Old River's monthly average specific conductance follows the specific conductance of the water that enters the south Delta (San Joaquin River at Mossdale's specific conductance). However, the monthly profiles from March through October indicate spikes in specific conductance upstream of the barrier that continues through to the last site on Old River. Spikes that occur in early spring are most likely caused from agricultural runoff and occur 4 to 6 km upstream of the barrier. The June through October spikes tend to first appear at the barrier and are most likely the natural spikes that would occur in the channel; but these spikes are compounded due to the low flow and high exports and are moved farther downstream. The negated flushing effect of the tides traps the irrigation return water upstream of the barrier and increases the already high specific conductance. Also, the low flow and small tidal surge allows detritus to settle out of the water and be available for decomposition that will increase specific conductivity. Other factors that could affect the specific conductance are wastewater discharge and urban runoff from roads and developments. The highest specific conductance reading was 6 km upstream of the barrier on April 2 and measured 1,013 µmhos/cm. Of the 376 samples collected on Old River, 210 were above 700 µmhos/cm (56%).

Old River's turbidity data are shown in Figures 2-9, 2-14D, and 2-15D. Turbidity seemed to follow the same pattern as specific conductance, higher upstream of the barrier and lower downstream of the barrier. The yearly averages for all 3 channels were similar. This suggests a relationship between specific conductance and the time of year. Of the 376 samples collected on Old River, only 6 were above 50 NTUs. The varying turbidity is most likely due to outside sources since the critical water year resulted in low flows. Some of these sources might be soil erosion, wastewater discharge, suspended solids from agricultural runoff, urban runoff from roads and developments, algae growth, water recreation (water agitation), and bottom feeders.

Middle River

The water temperature data for Middle River are shown in Figures 2-10, 2-14A, 2-15A, and 2-16C. The water temperature began low and increased over the summer before decreasing again in the fall. There were no significant differences between sites. A seasonal trend is present because the average monthly water temperature follows the average monthly air temperature. All 3 channels followed the same pattern.

Middle River's dissolved oxygen data are shown in Figures 2-11, 2-14B, 2-15B, and 2-16C. The dissolved oxygen values were initially elevated during the spring and decreased throughout the summer months before improving again in the fall. As stated before, this is an inverse relationship. All 3 channels had similar monthly dissolved oxygen patterns that further suggest a relationship between dissolved oxygen and the time of year. A more in-depth look at the dissolved oxygen data through the monthly profiles and the yearly average shows an obvious sag in dissolved oxygen appearing at the site 14 km upstream of the barrier, especially in August. DWR's Middle River data for chlorophyll *a* and pheophytin *a* illustrate a marked increase in both of these parameters at DWR's "site 5" (see Figure 8-1 in Chapter 8). Site 5 is just upstream of this project's site "MIDRB -16" located 16 km upstream of the barrier, 2 km upstream of the sag. The algae growth in July, shown by the dramatic increase in chlorophyll *a*, creates higher dissolved oxygen readings. This is present

16 to 18 kms upstream of the barrier in July's monthly profile. As the algae dies and moves downstream in Middle River, bacteria decomposes the organic matter causing an increase in pheophytin *a* and hence a decrease in the dissolved oxygen concentration as seen at the site 14 km upstream of the barrier. The low flow in Middle River due to the critical water year and high exports most likely exacerbates this cycle by not allowing the system to flush and allowing organic matter to settle onto the river floor for decomposition. The lowest dissolved oxygen reading was 14 km upstream of the barrier on August 29 and measured 0.8 mg/L. Of the 371 samples collected on Middle River, 38 were below 5 mg/L, the minimum water quality objective stated in the California Regional Water Quality Control Board's Basin Plan (4th ed.).

Figures 2-12, 2-14C, and 2-15C depict the specific conductance data for Middle River. Unlike Grant Line Canal and Old River, the specific conductance of Middle River does not follow the changes in the water that enter the south Delta (San Joaquin River at Mossdale's specific conductance). This supports the theory that waterflow down Middle River was minimal at best. The monthly profiles for all months except May and June indicate spikes in specific conductance upstream of the barrier that continues through to the head of Middle River. Spikes that occur in early spring are most likely caused from agricultural runoff and occur at various sites upstream of the barrier. The July spikes first appear at 14 km upstream of the barrier. As time progressed, this spike moved closer to the barrier. The decreased flow down Middle River along with the negated flushing effect of the tides traps the water high in specific conductance behind the barrier. Also, the low flow and small tidal surge allows detritus to settle out of the water and be available for decomposition that will increase specific conductivity. Other factors that could possibly affect the specific conductance would be urban runoff from roads and developments. The highest specific conductance reading was 10 km upstream of the barrier on March 28. It measured 1,010 µmhos/cm. Of the 371 samples collected on Old River, 81 were above 700 µmhos/cm.

Middle River's turbidity data are shown in Figures 2-13, 2-14D, and 2-15D. Middle River had the lowest turbidity of all 3 channels, most likely due to the low flows and the settling out of particulate matter. The water clarity in Middle River 12 to 16 kms upstream of the barrier was so clear that, while navigating the waterways, the bottom of the channel was readily visible. This is the first time such clear conditions have occurred in the past 7 years. The clarity of the water allowed a surge in the growth of submerged aquatic vegetation and algae that gave the water a dark green/black appearance. Other parameters of Middle River support the turbidity findings because the higher turbidity at sites 16 to 18 km upstream of the barrier also had high specific conductance and cholorphyll *a* concentrations while the site located only 14 km upstream of the barrier had low turbidity and low dissolved oxygen concentrations. The lowest specific conductance reading was 12 km upstream of the barrier on October 11 and measured 1.3 NTUs. Of the 371 samples collected on Old River, none were over 50 NTUs and 55 were below 5 NTUs. Approximately one-half the readings at the site located at 14 km above the barrier were under 5 NTUs. The varying turbidity is most likely due to outside sources because the critical water year resulted in low flows. Some of these sources may be soil erosion, suspended solids from agricultural runoff, urban runoff from roads and developments, algae growth, and bottom feeders.

Conclusion

When data are examined from 2 different viewpoints, broad (monthly averages) and narrow (raw monthly data), different trends and causes can be found for changes in the water quality parameters. A broad viewpoint tends to hide random highs and lows and gives an overview of what is occurring to the water quality because averages tend to hide these outliers. The broad viewpoint for the south Delta indicates all 4 water quality parameters follow a seasonal trend. This is due to the influence of the San Joaquin River water that enters the Delta, the ambient air temperature, and the local weather. A narrow viewpoint highlights site-specific spikes and sags in the water quality chronologically. These high points and low points are due to various secondary influences. These secondary influences consist of agricultural runoff from farming activities (return locations and amount of water used and returned), wastewater discharge, urban runoff from roads and developments, soil erosion, water recreation (water agitation), bottom feeders, decomposition of detritus, algae growth, and high levels of algae (going through a natural boom and bust cycle) from the San Joaquin River water entering the south Delta. When river flows and tidal surges become inadequate, the water is not moved out of the system fast enough and/or becomes trapped upstream of the barriers exacerbating poor water quality factors such as high specific conductance or low dissolved oxygen. River flows and tidal surges become inadequate—as it did for this critical water year in mid-June for all 3 channels—when the culvert flap gates are closed and the exports from the CVP and SWP facilities are increased. Grant Line Canal is less likely to be affected by this due to the amount of water that enter the south Delta that is directed down Grant Line Canal as compared to Old and Middle rivers.

When yearly averages spike or sag in water quality profiles, it indicates possible null zones because this area is higher or lower, on average, than the rest of the sample sites. These zones tend to move with the local conditions. However, Old River's possible null zone tended to span from 2 to 6 km upstream of the barrier; and Grant Line Canal's, if present, seemed to be downstream of the barrier. Middle River had an unmistakable null zone located 14 km upstream of the barrier.

Efforts were made again this year to pinpoint the cause/area of water quality concerns on Old River (previous sags in dissolved oxygen located directly below the barrier). To determine if dissolved oxygen was low upstream as well as downstream of the Tracy Fish Collection Facility (TFCF), 2 dissolved oxygen testing sites were added to Old River in 2005 and were sampled again in 2007 (Figure 2-1). The water quality profiles with the testing sites included (Figure 2-19) suggest that, between the TFCF and the Old River near Tracy Barrier, dissolved oxygen decreases while temperature oddly increases and specific conductance increases. All 3 water profiles in Figure 2-19 are small in scale to point out slight changes in water quality and should not be compared to water quality profiles not of the same scale. These trends may indicate that tidal influence in this area of Old River is diminished because water quality parameters worsen directly after the TFCF. In addition to Old River, Grant Line Canal had a testing site added to the sampling (Figure 2-1). The water quality profiles, with the testing site included (Figure 2-20), suggest the dead-end slough on the east side of Grant Line Canal has low dissolved oxygen, high electroconductivity, and high turbidity. All 4 water profiles in Figure 2-20 are small in scale to point out slight changes in water quality and should not be compared to water quality profiles not of the same scale. These trends indicate that tidal influences in this area are diminished. Also, because the shallowness of this dead-end slough may worsen the situation due to agricultural

operators having less water to use exacerbated by the minimal water exchange of the area. All testing sites included this year will be included again in next year's sampling season to help monitor these potentially poor water quality locations.

At first glance it seems that the barriers impact the water quality on the south Delta by contributing to the reduced tidal flushing and trapping poor water quality upstream of the barriers, creating null zones. However, it is unknown what the water quality would be with a critical water year and high exports without the barriers. Without these conditions or baseline conditions to compare to current conditions, it is difficult to evaluate the impacts of the barriers on the south Delta water quality or decide which scenario (barriers with flap gates functioning, barriers with some flap gates functioning, barriers with flap gates tied open, or no barriers) impact water quality the least.

Recommendations

A similar study is planned for 2008. This is to further evaluate the effects of the temporary barriers on the south Delta water quality. Testing sites selected to monitor potential null zones/areas of concern in 2007 will remain a part of the water quality monitoring program in 2008.

References

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Philippart, Shaun. 2006 Dec. "Chapter 8. Weekly Water Quality Sampling". *In:* 2005 South Delta Temporary Barrier Monitoring Report. Temporary Barriers Program Home. California Department of Water Resources, South Delta Branch. 8-8 pp. 31 January 2008. Availability at http://baydeltaoffice.water.ca.gov/sdb

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Figure 2-2. Monthly water temperature in relation to the Grant Line Canal barrier

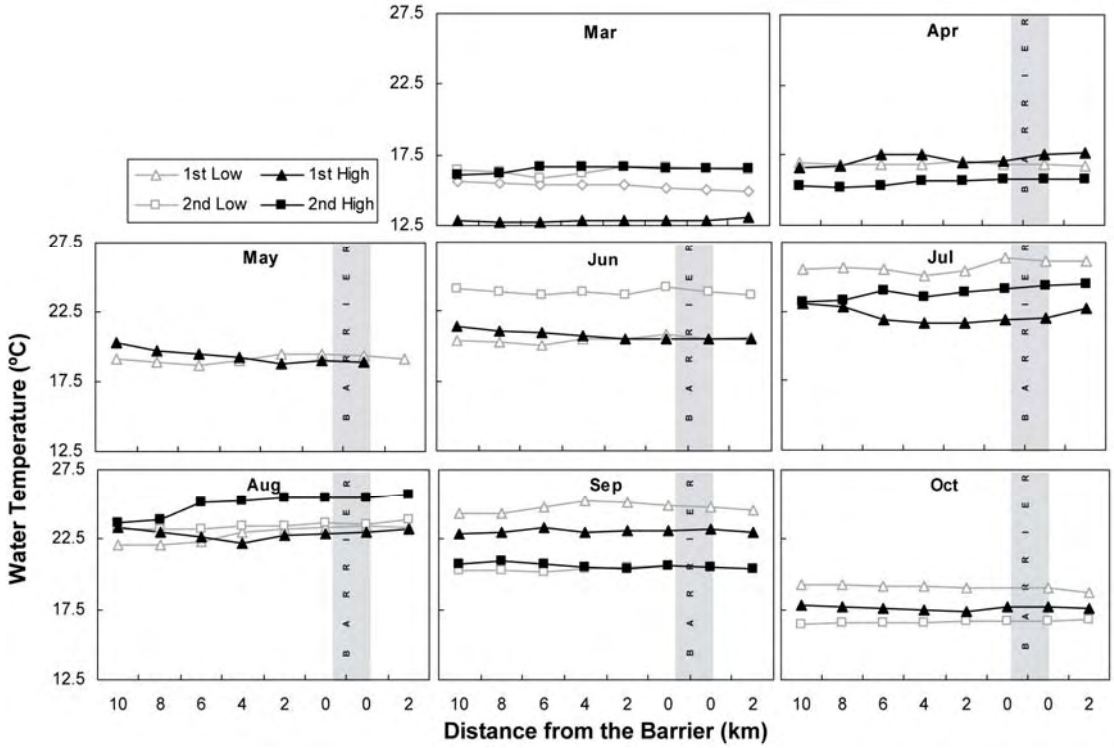


Figure 2-3. Monthly dissolved oxygen in relation to the Grant Line Canal barrier

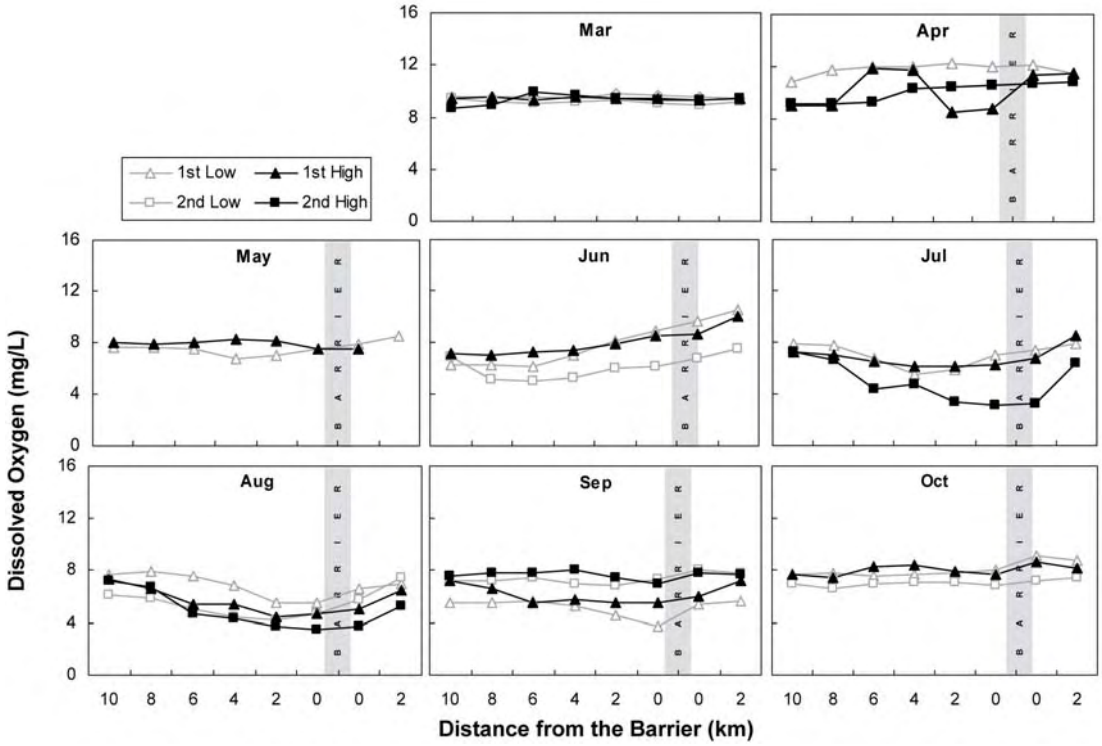


Figure 2-4. Monthly specific conductance in relation to the Grant Line Canal barrier

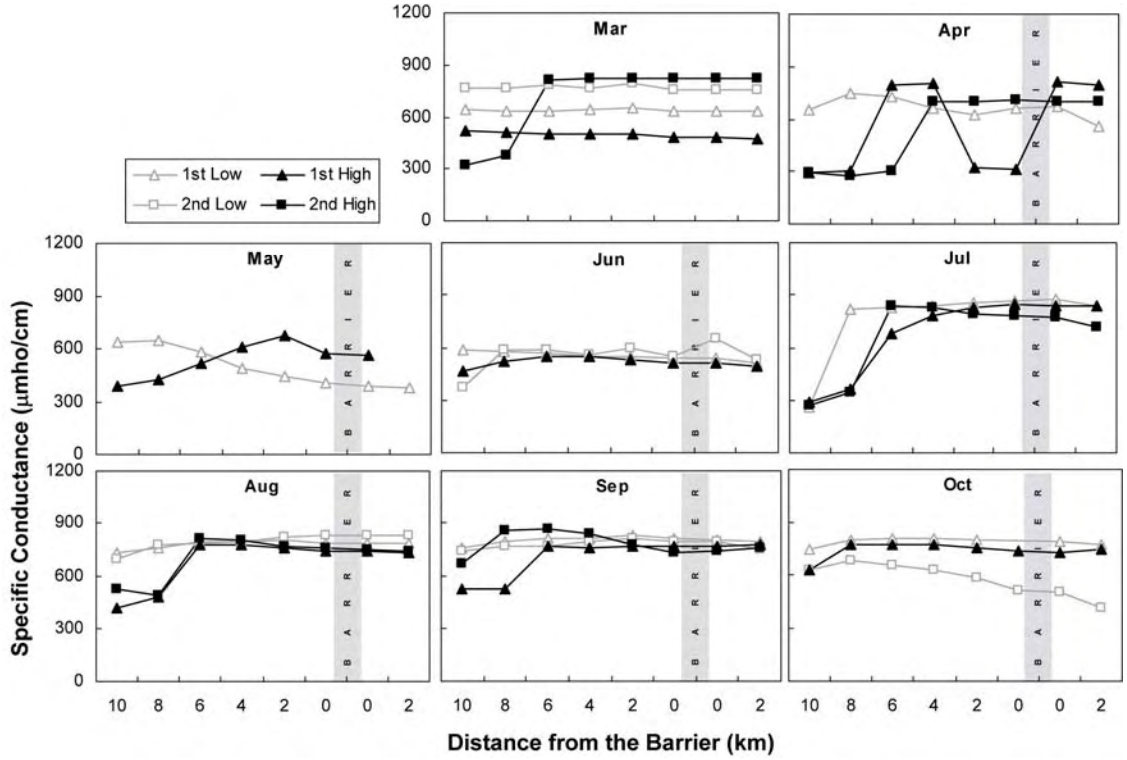


Figure 2-5. Monthly turbidity in relation to the Grant Line Canal barrier

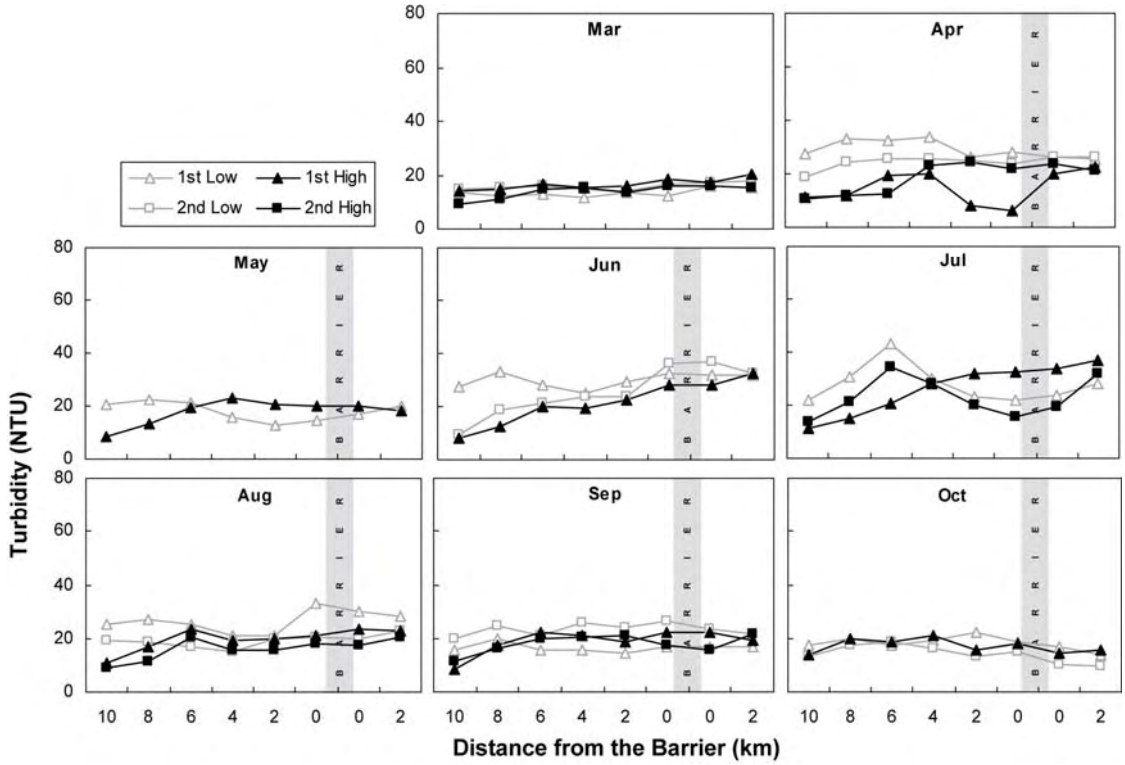


Figure 2-6. Monthly water temperature in relation to the Old River barrier

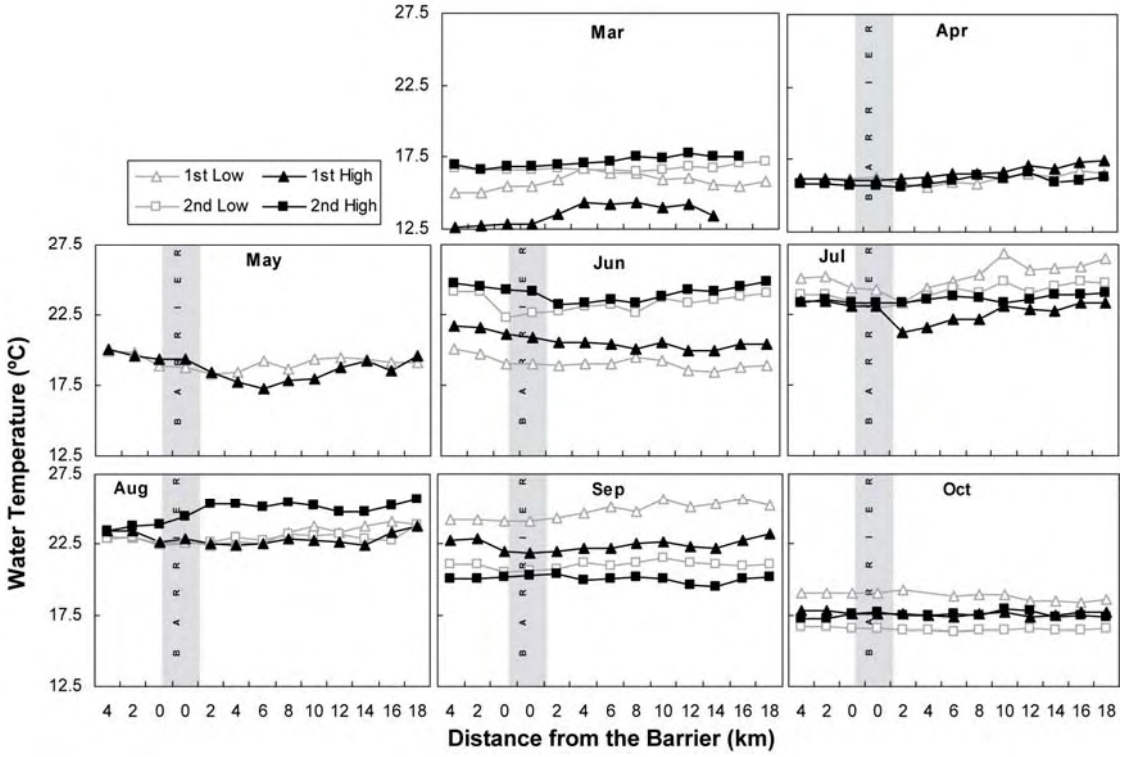


Figure 2-7. Monthly dissolved oxygen in relation to the Old River barrier

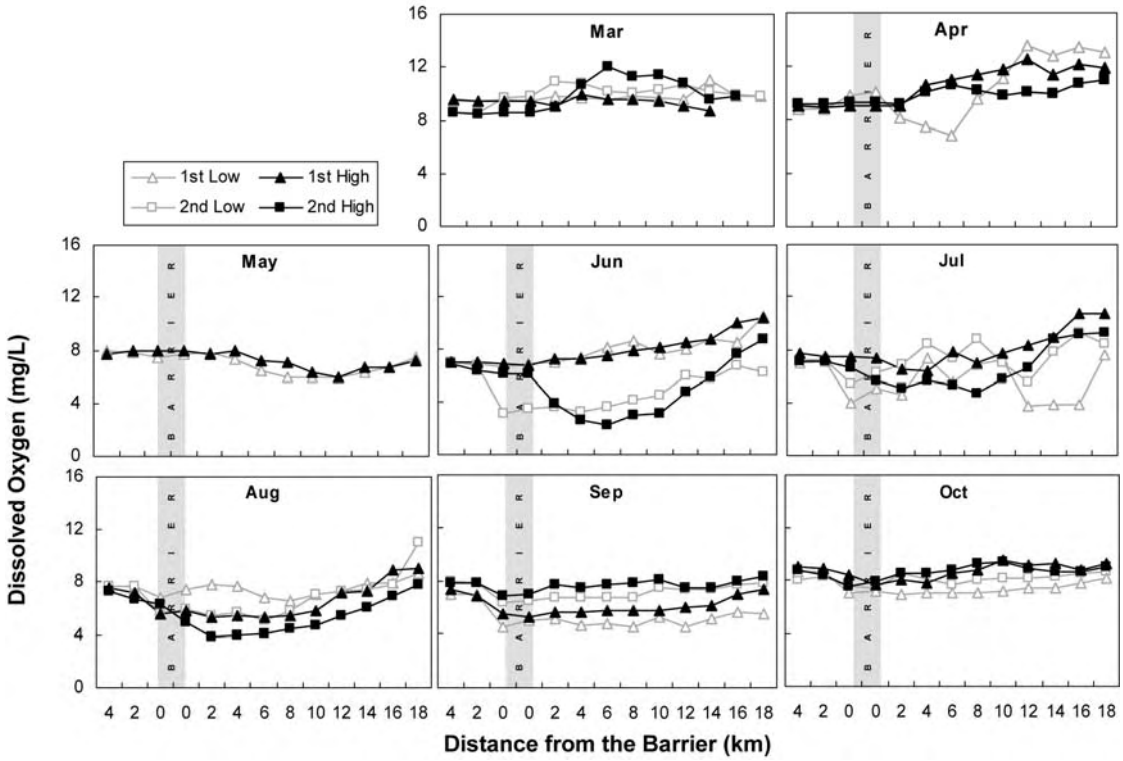


Figure 2-8. Monthly specific conductance in relation to the Old River barrier

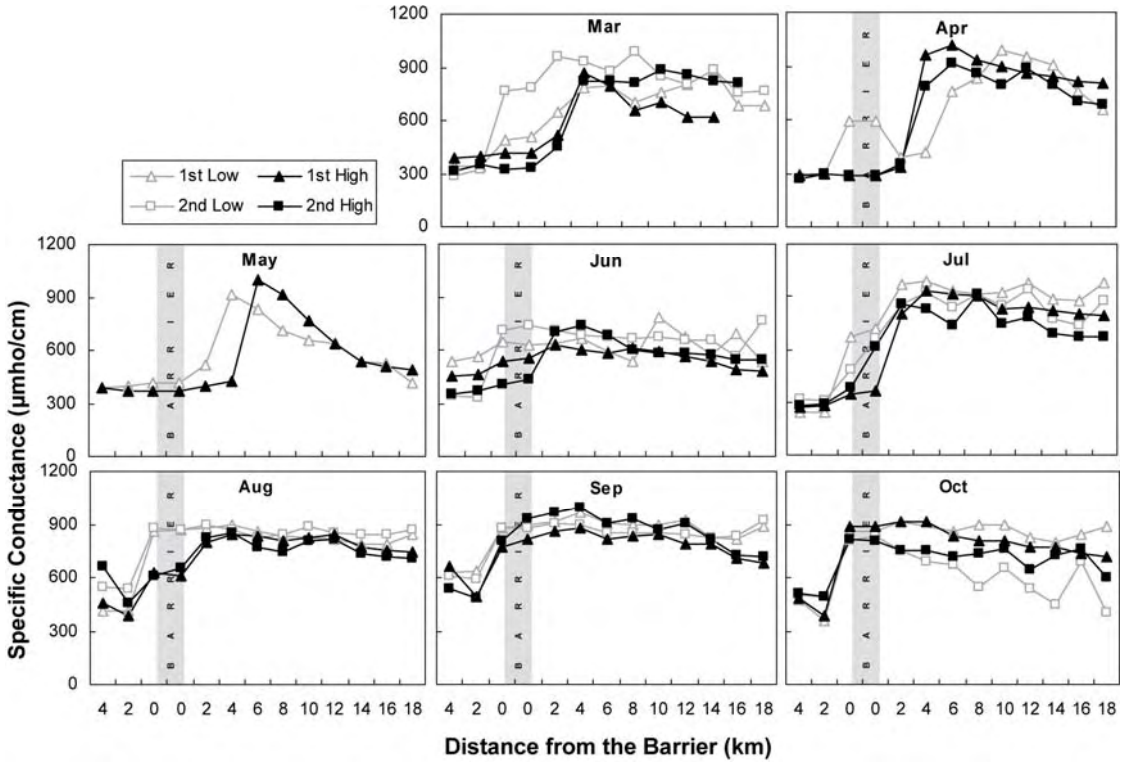


Figure 2-9. Monthly turbidity in relation to the Old River barrier

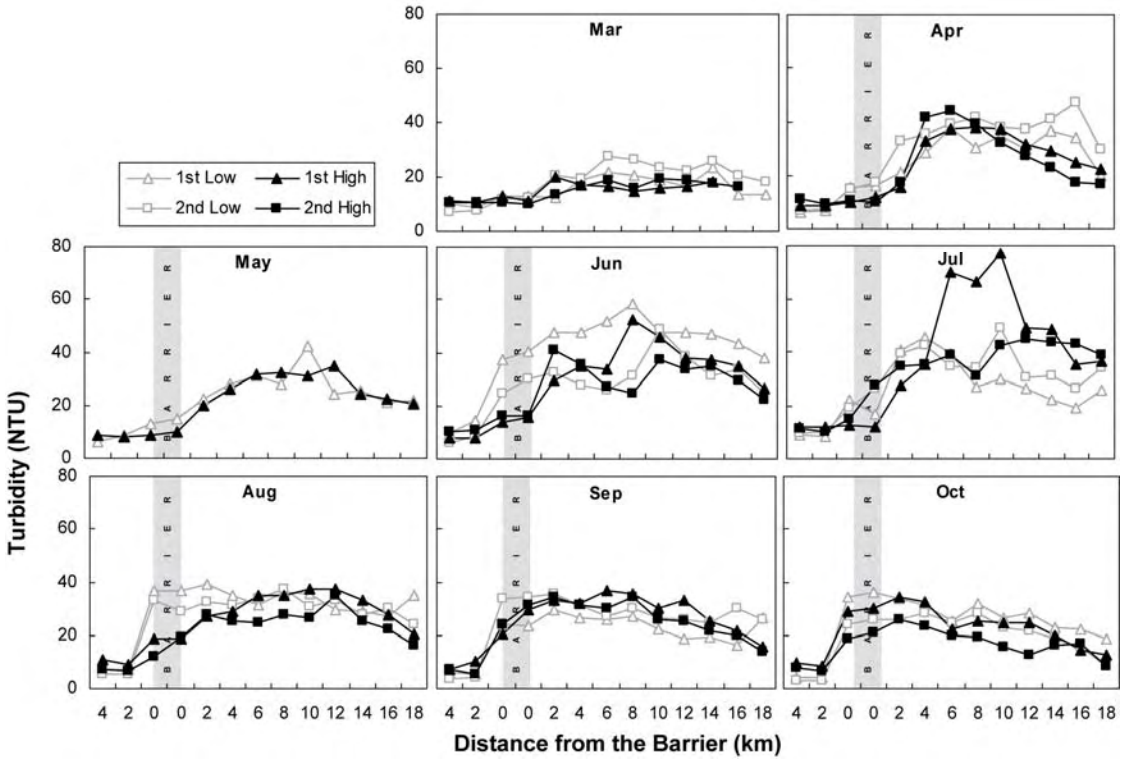


Figure 2-10. Monthly water temperature in relation to the Middle River barrier

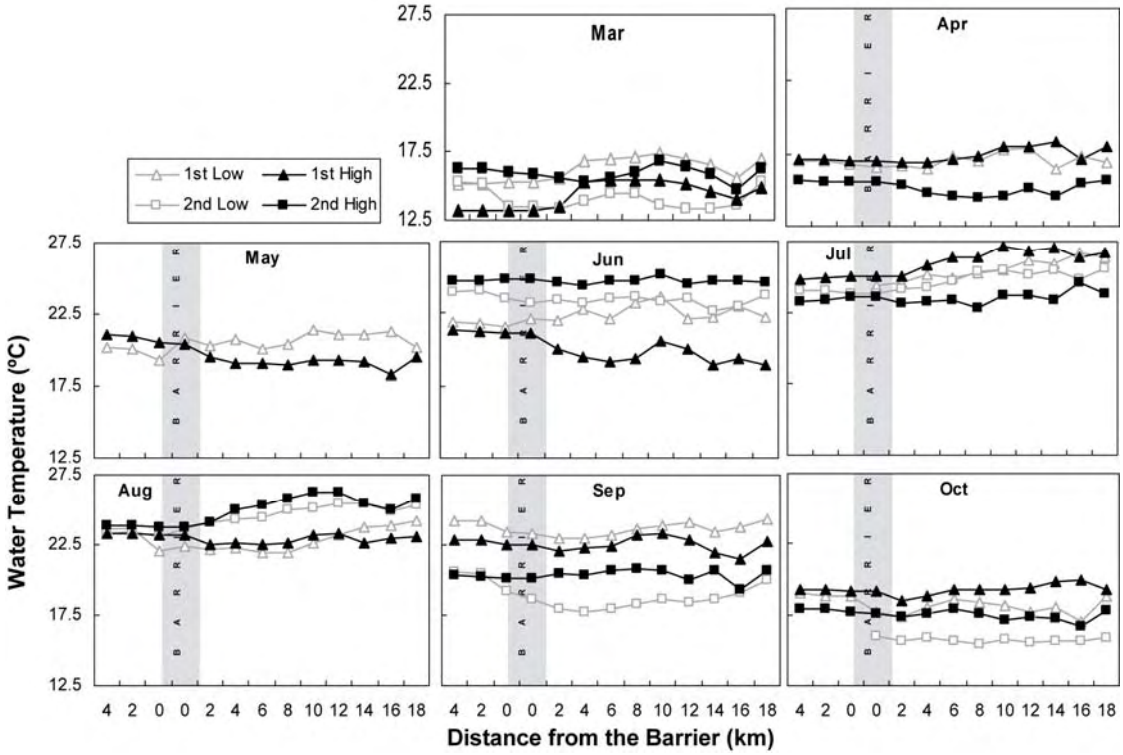


Figure 2-11. Monthly dissolved oxygen in relation to the Middle River barrier

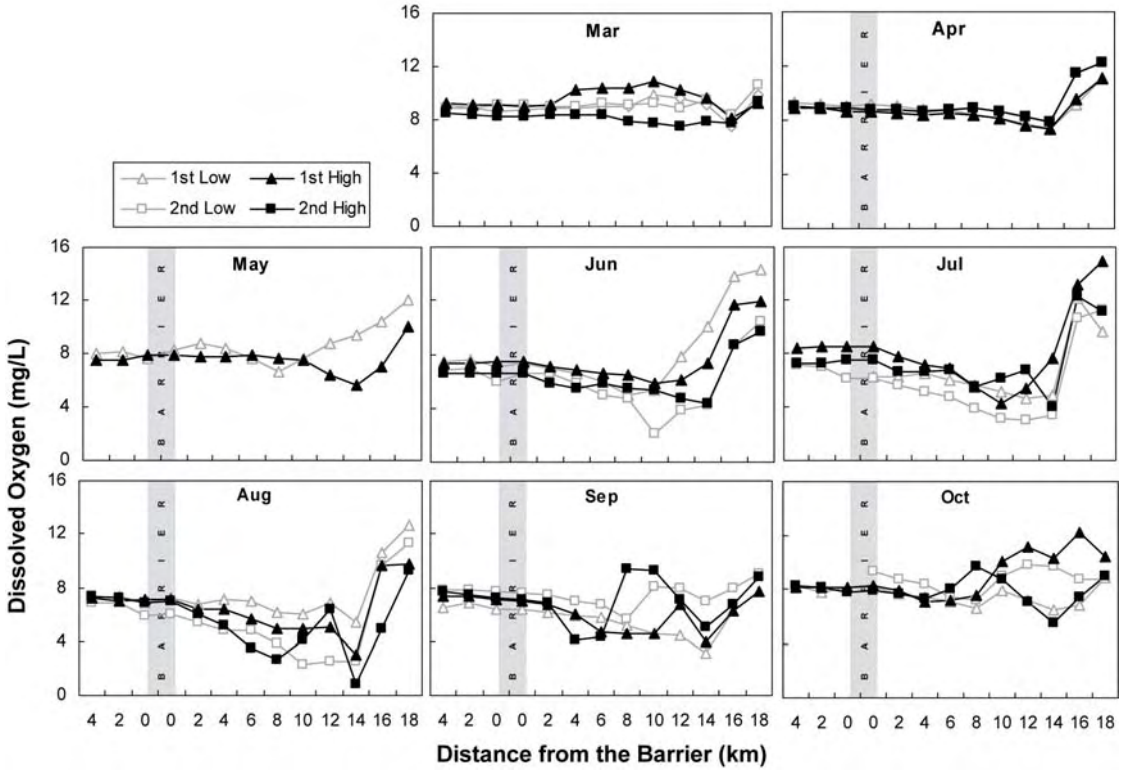


Figure 2-12. Monthly specific conductance in relation to the Middle River barrier

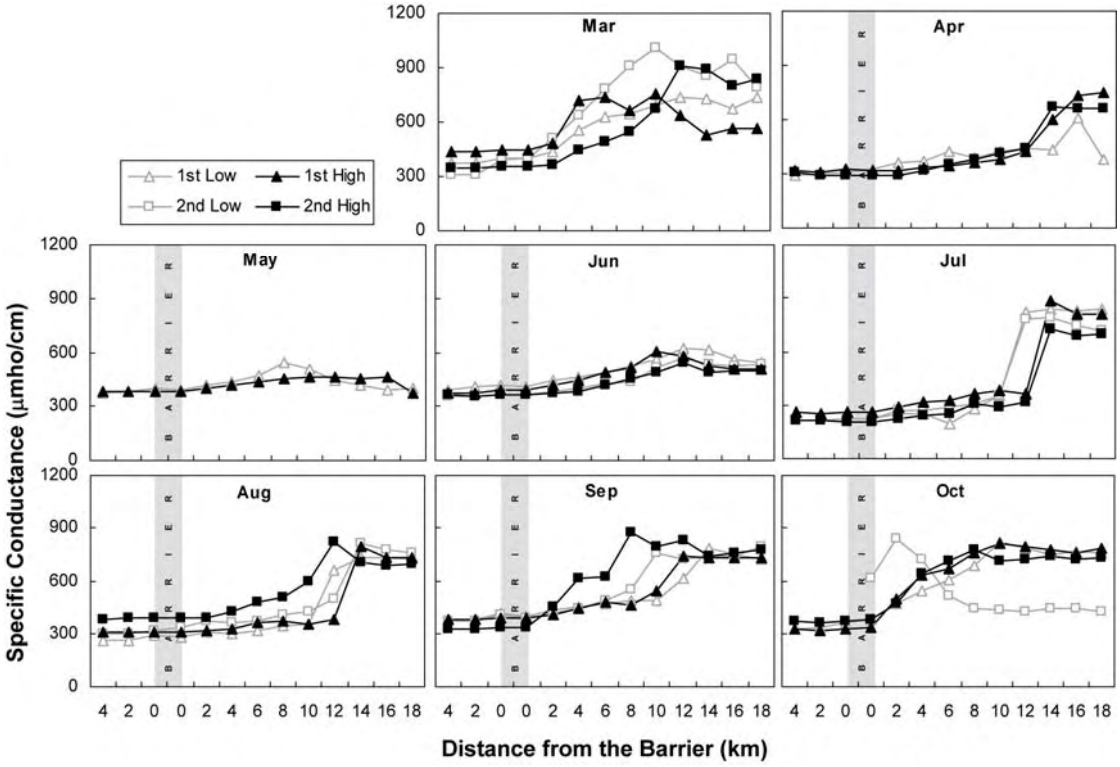


Figure 2-13. Monthly turbidity in relation to the Middle River barrier

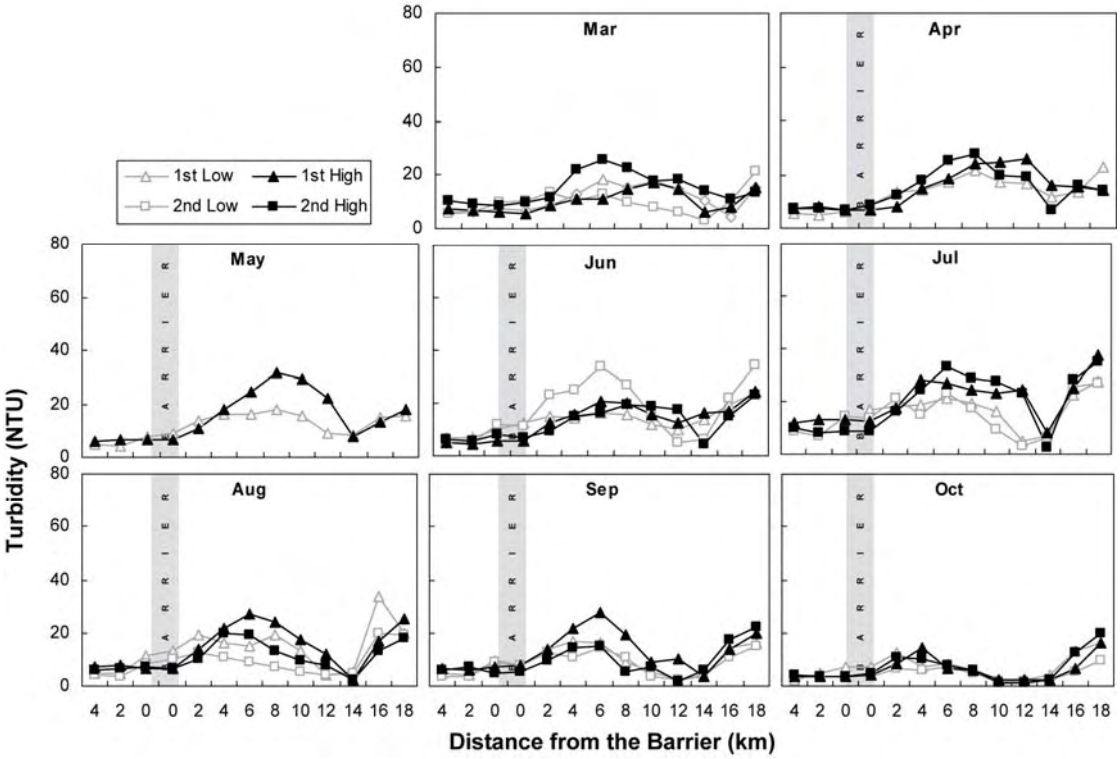
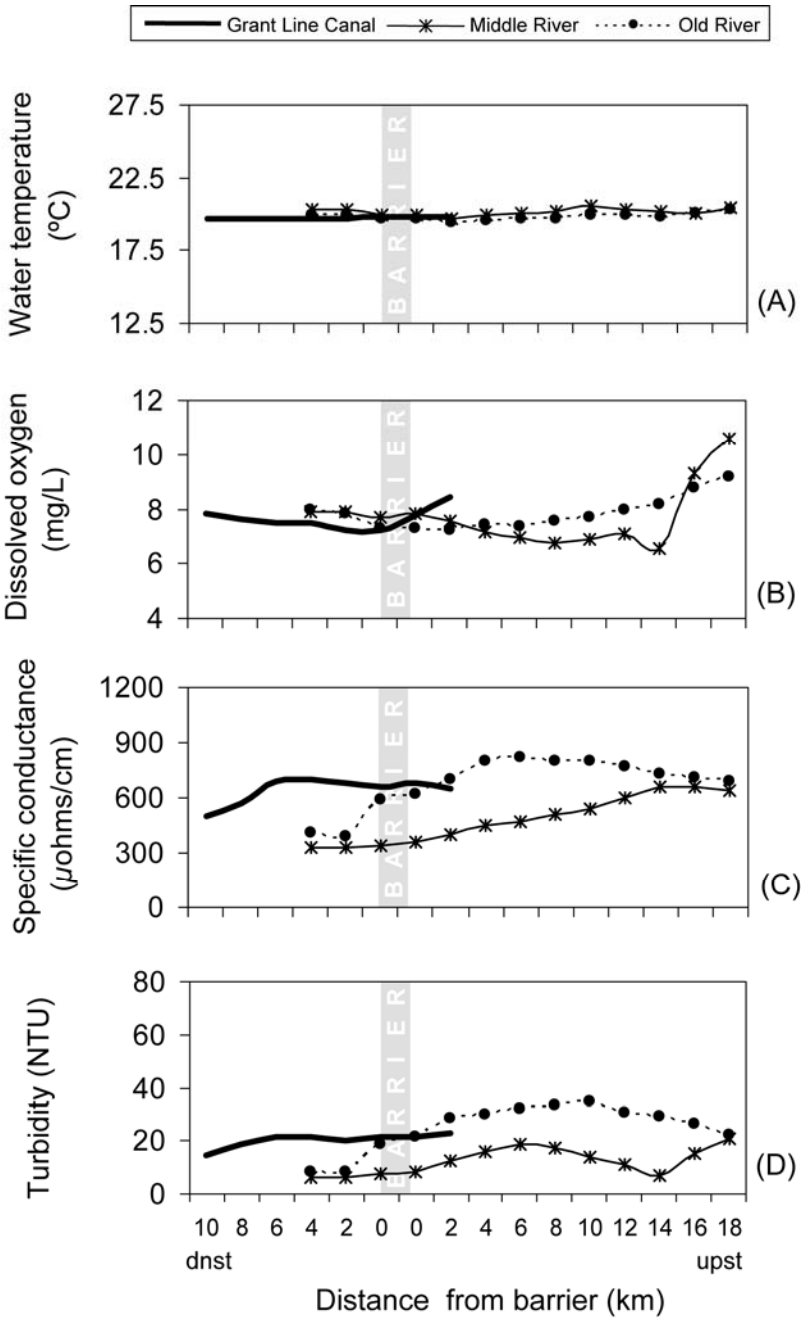


Figure 2-14. Yearly water quality parameters in relation to the barriers



Grant Line Canal was sampled 10km downstream to 2km upstream of the barrier. Old and Middle rivers were sampled 4km downstream to 18km upstream of the barriers.

Figure 2-15. Monthly water quality parameters

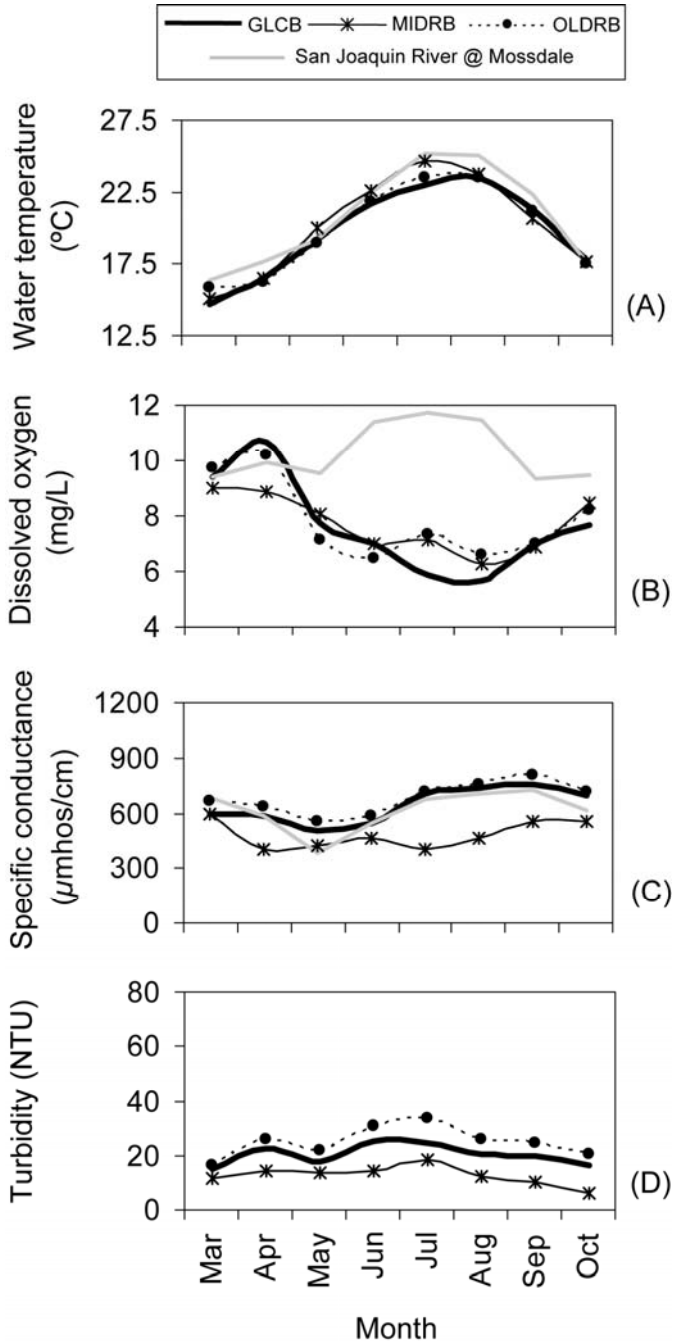


Figure 2-16. Monthly water temperature, air temperature, and dissolved oxygen for the south Delta

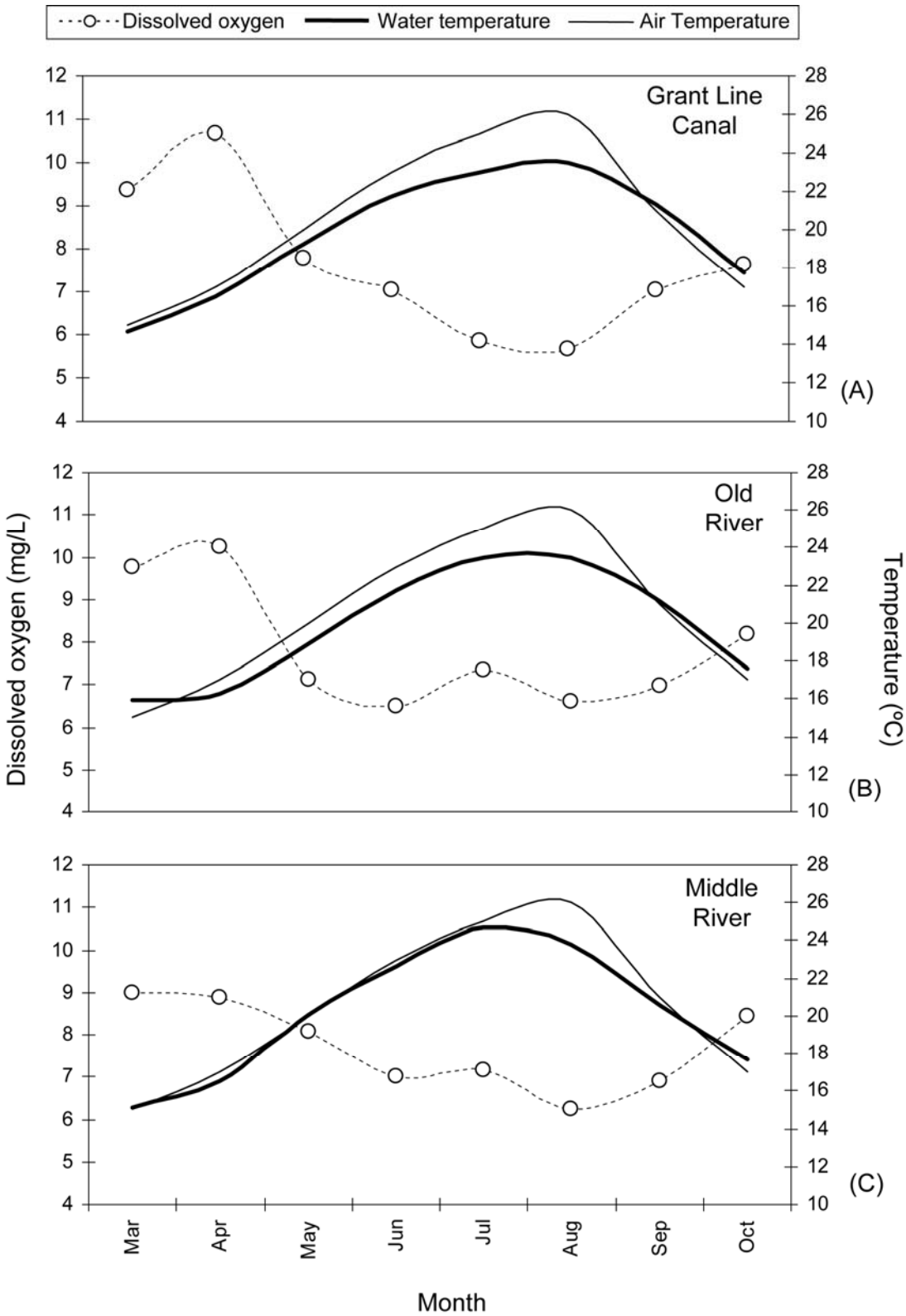


Figure 2-17. South Delta flows and daily exports

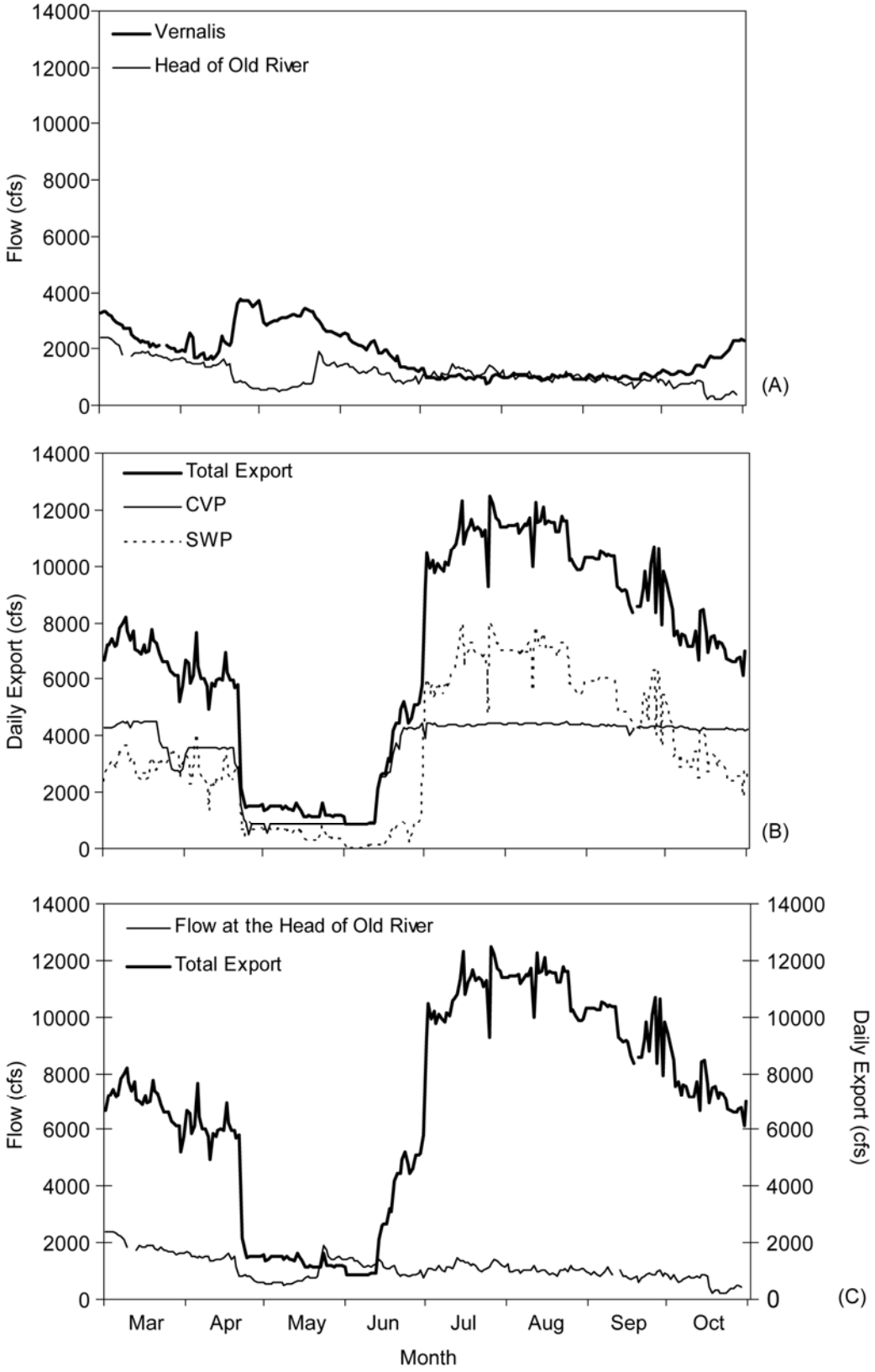


Figure 2-18. San Joaquin River mean daily flows at Vernalis

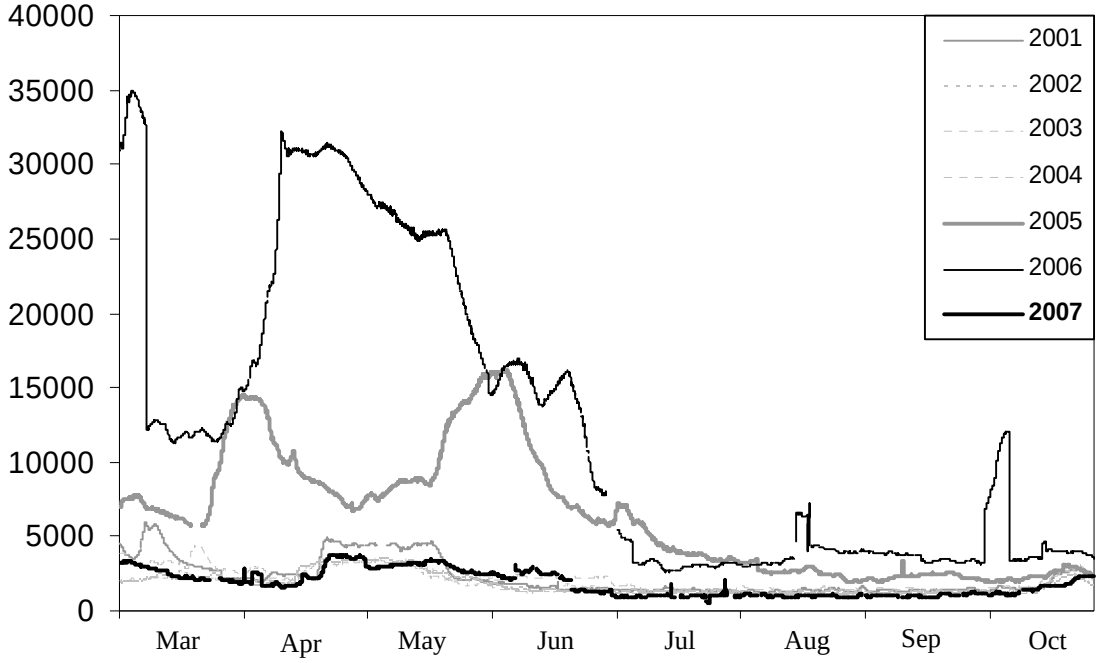


Figure 2-19. Yearly water quality parameters in relation to the Old River at Tracy Barrier, including testing sites

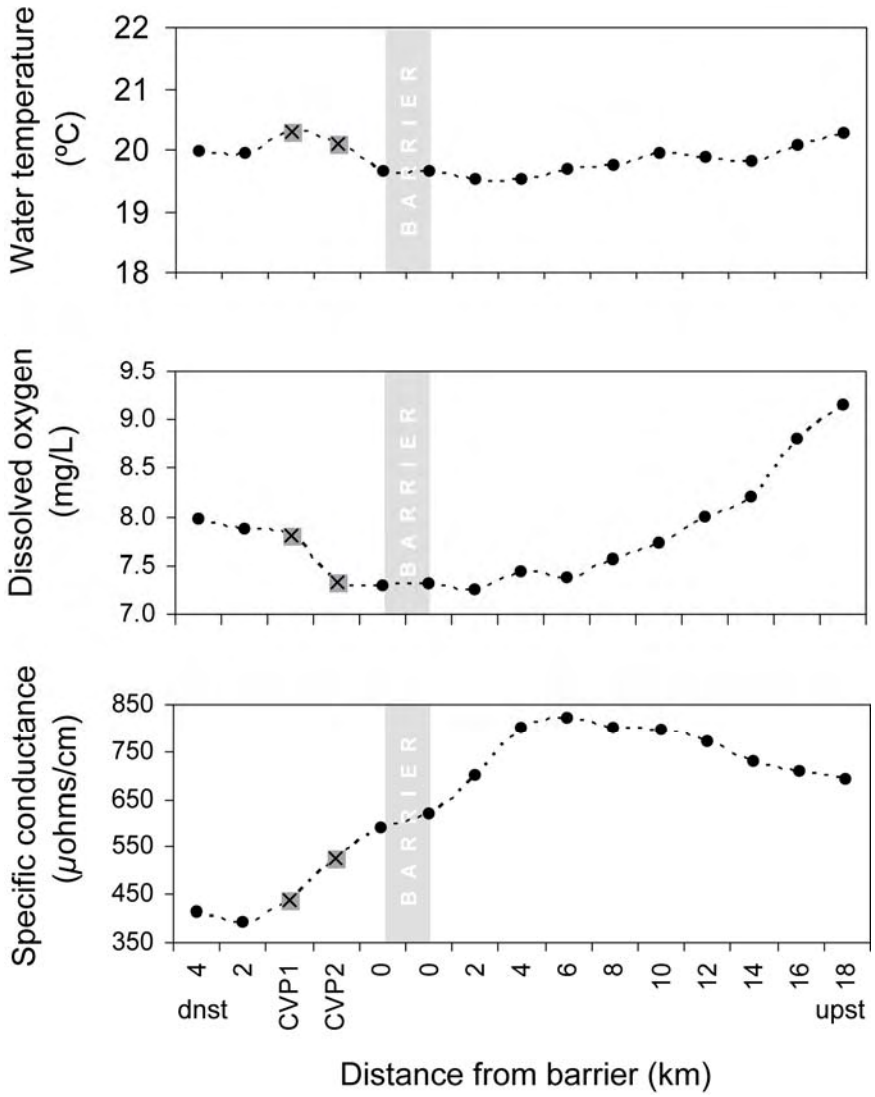
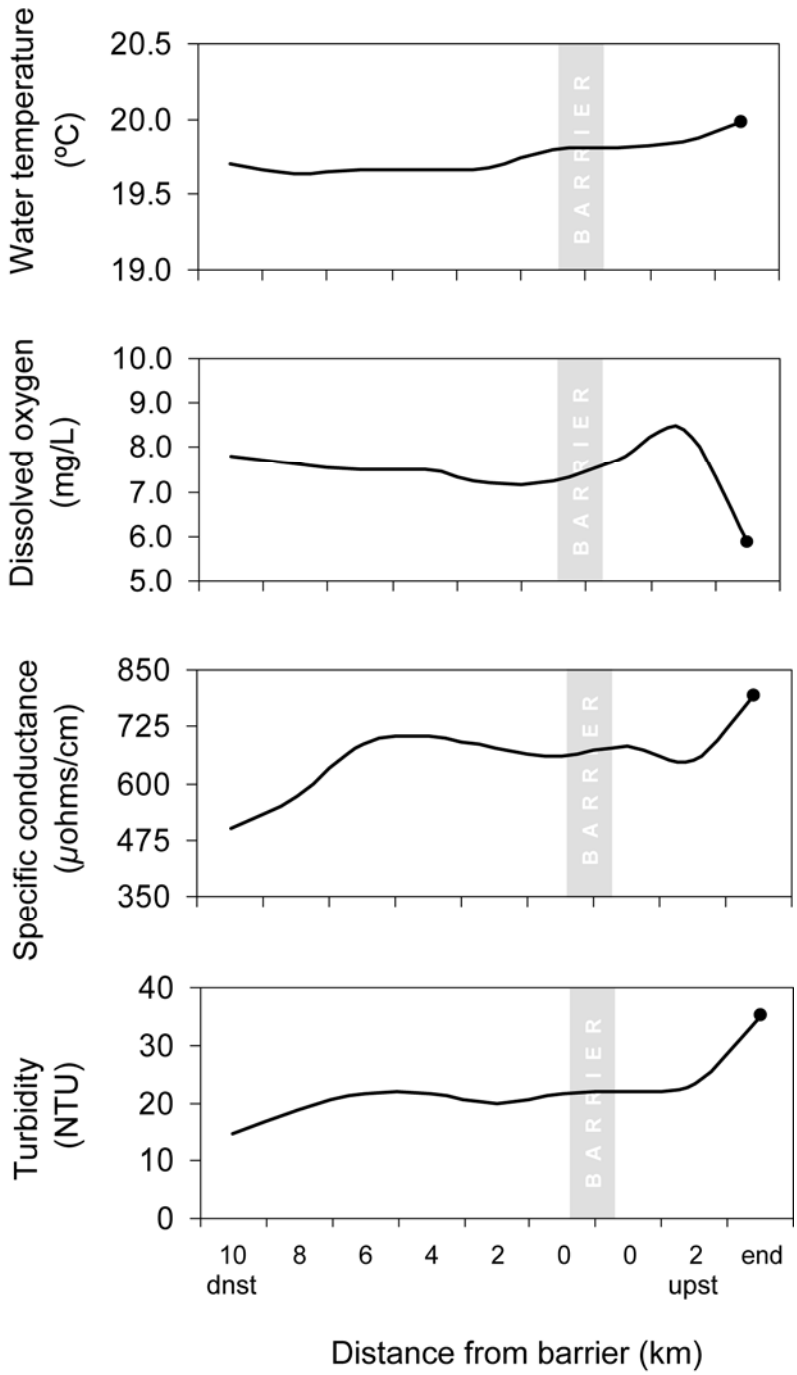


Figure 2-20. Yearly water quality parameters in relation to the Grant Line Canal Barrier, including testing site

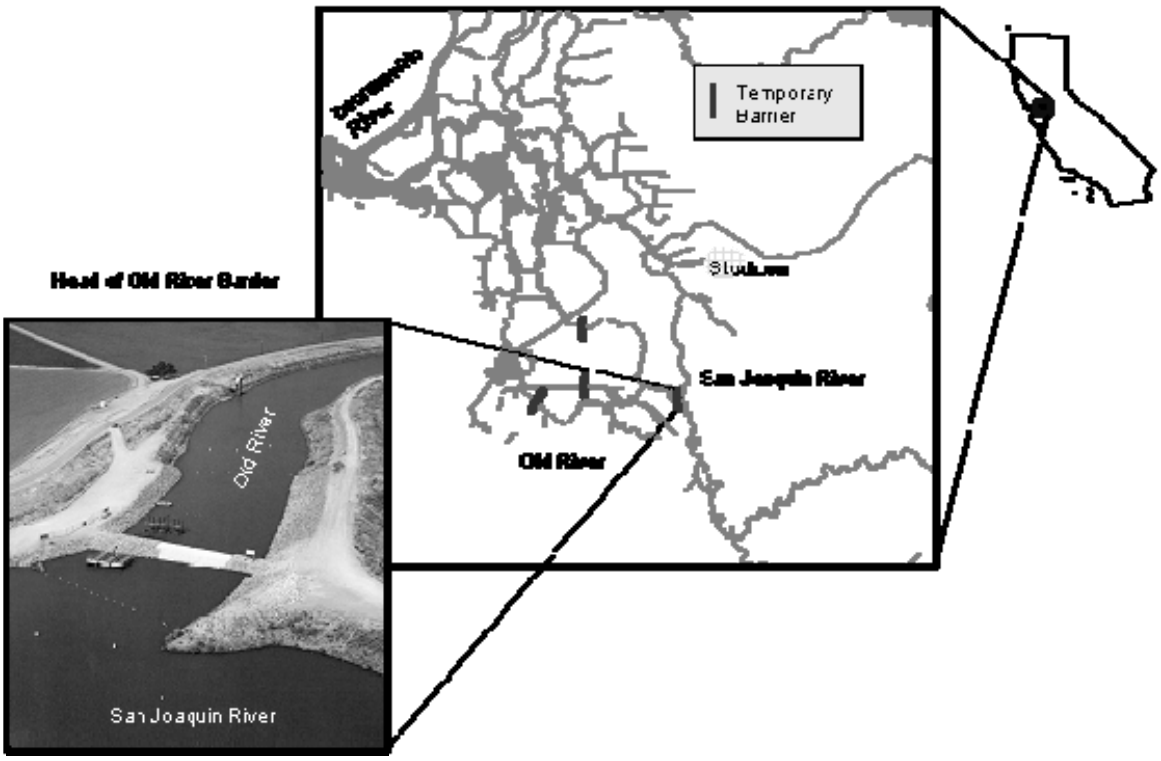


Chapter 3. Fish Entrainment Monitoring at the Spring Head of Old River Barrier

The Temporary Barriers Project was developed in 1990 to achieve two objectives. One objective was to increase water levels, improve circulation patterns and improve water quality for local agricultural diversions 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 south 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 temporary barrier was designed for the head of Old River to meet the fishery objectives. The barrier is constructed where Old River diverges from the San Joaquin River, just downstream of Mossdale (Figure 3-1). This barrier is built in the spring to block the passage of out-migrating San Joaquin River juvenile Chinook salmon (*Oncorhynchus tshawytscha*) into Old River, which leads to the SWP and Central Valley Project export facilities.

Figure 3-1. Locations of the south Delta temporary barriers with an enlargement of the head of Old River barrier



In 1997, the South Delta Water Agency (SDWA) expressed concern about water volume and quality in upper Old River due to the installation of the spring head of Old River barrier (HORB). To address this concern, the California 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 spring HORB design and install two 48-inch culverts at an average invert elevation of -4 feet mean sea level (top of the culverts are at mean sea level). DWR indicated that, at flows of 6,500 cfs in the San Joaquin River, the culverts allow approximately 300 cfs to flow through the barrier and down Old River. DFG, US Fish and Wildlife Service, and National Marine Fisheries Service agreed to DWR's modification with the provision that DFG would monitor fish entrainment through the newly installed culverts.

In 2000, DWR again modified the spring HORB to include six 48-inch gated culverts. The culverts allow approximately 1,000 cfs to flow through the barrier and down Old River. The culvert gates are operated to meet water level objectives of the SDWA. In 2001, the spring HORB was modified with trash racks to control the amount of debris flowing into the culverts. These racks were small enough to stop most debris from entering the culverts but large enough to allow the passage of Chinook salmon smolts. The design of the spring HORB has not changed since 2001. In 2005 and 2006, the spring HORB was not installed because of high river flows. The 2007 barrier was assembled with 6 culverts that were gated and operated to address water level concerns of the SDWA.

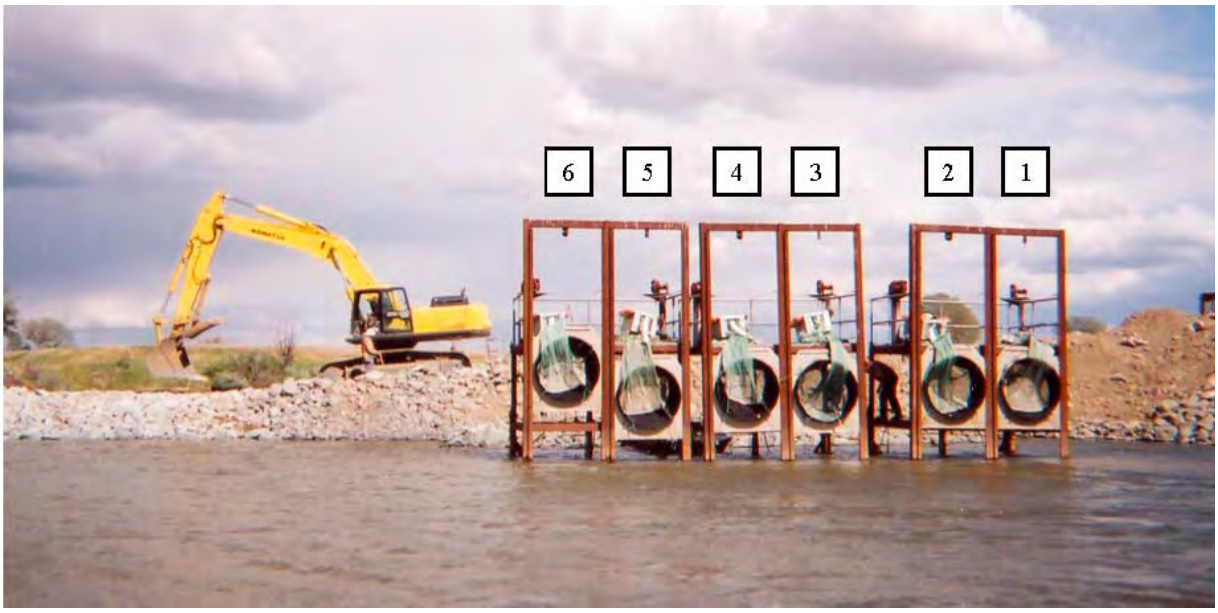
There is some uncertainty about how to operate a barrier (permanent or temporary) to effectively protect both out-migrating juvenile salmon on the San Joaquin River and young-of-the-year delta smelt in the central and south Delta, address agricultural water use concerns in Old River, and improve operational flexibility of the SWP and CVP. Entrainment monitoring will help assess the fishery impacts at the spring HORB. Specifically, it can help determine if the modified barrier with culverts is adequate protection for out-migrating juvenile salmon. The 2007 study was designed to increase our understanding of salmon entrainment at the spring HORB and help develop operational scenarios to minimize the impacts to out-migrating salmon and other species of concern.

All 6 culverts in the spring HORB were installed for the 2007 Vernalis Adaptive Management Plan (VAMP) test period, although the number of culverts open varied throughout the 30 day VAMP period. Since the culverts were not screened, juvenile Chinook salmon and other fish species that pass near the culverts were vulnerable to entrainment. DFG designed and implemented a fish monitoring program to evaluate and quantify fish entrainment at the spring HORB. The specific objectives of the 2007 entrainment monitoring investigations were to:

- Determine the total number of juvenile Chinook salmon and other fish species entrained through the culverts at the spring HORB, and
- Estimate the percentage of out-migrating salmon entrained into Old River relative to previous years with a spring HORB.

Figure 3-2. Culverts in the spring head of Old River barrier

The culverts are numbered from 1 to 6, with number 1 closest to shore. Culvert numbers 2, 3, and 5 were closed throughout the fish monitoring period.



Materials and Methods

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, and are made of 1/4-inch braided mesh. Five of the 6 nets are 60 feet long, and one net 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 culverts were numbered from 1 to 6 with number 1 located next to the shoreline (viewed from downstream) and number 6 located mid-channel (Figure 3-2). On April 27, fyke nets were attached to the downstream slide gate flanges of all six culverts. These gates were not lowered over the culverts at this time and thus, were not sampling. The slide gates on culvert numbers 1, 4, and 6, with attached nets and live-boxes, were lowered over the culvert outfalls at 1400 hours on Monday, April 29, to commence fish entrainment monitoring. Only culvert numbers 1, 4, and 6 were opened and remained opened throughout the monitoring period. On Friday, May 4, at 1300, the nets were raised, checked, and then piled onto the frames. The nets did not fish over the weekend. The following Monday, at 1300 hours, the nets for culvert numbers 1, 4, and 6 were lowered back into the water. All nets were removed at noon on Friday, May 11.

The fyke nets were checked at 0100, 0600, 1300, and 2000 hours Monday through Friday. The nets were checked by closing the culvert slides gate (upstream side) for about 20 minutes, enabling the live-boxes to be pulled onto a boat. Fish were removed from the live-boxes and placed into buckets. Once all the nets were checked and reset, the collected fish were processed. All the fish were identified and counted. 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 coded-wire-tag (CWT) processing. All

salmon were measured (fork-lengths) to the nearest millimeter. Culvert number, date, time, water temperature, and diel-period were recorded for each net check. Except for adipose fin-clipped salmon, all fish were released downstream of the spring HORB into Old River.

Unlike previous years, there were no VAMP salmon releases upstream of the spring HORB at Mossdale or Durham Ferry. Consequently, no entrainment loss indices were calculated for 2007. Instead, an unmarked salmon average daily entrainment index per culvert (Culvert Entrainment Index) was generated from the spring HORB fish entrainment results to track relative changes in entrainment among years. For each year of entrainment monitoring, a Culvert Entrainment Index was calculated by dividing the total number of unmarked salmon caught by the number of days sampled and the number of culverts open. The result was then multiplied by 5 for graphical scaling purposes.

To track relative changes in unmarked salmon abundance just upstream of the barrier, salmon catch from the Mossdale Kodiak Trawl (MKT) was used to calculate an average 5 hour daily abundance index (Abundance Index). The Abundance Index was calculated by summing the daily catch of unmarked salmon (standardized to fifteen 20-minute tows) and dividing by the number of days sampled. The Abundance Index was calculated for the same days in which there was entrainment monitoring. Abundance and Entrainment Indices are calculated for a 2- to 3-week period during the VAMP test period. No indices were calculated for 2005 and 2006 because the spring HORB was not installed due to high San Joaquin River flows.

Fish catch was calculated for each culvert. Catch-Per-Unit-Effort (CPUE) for salmon comparison among years was calculated as the number of fish collected per hour per culvert. Standard deviation is used to describe the variability round the mean. DWR installed flow meters in culverts number 1, 4, and 6. Unmarked salmon entrainment density (fish per acre-foot) was calculated per culvert sampling period by dividing the catch by the amount of water that flowed through the culvert (mean flow (cfs) * sampling duration (s) * 43,560 (af/cf)).

Results

The spring HORB was closed on April 22; however, construction on the barrier continued for another 4 days. As mentioned previously, only culvert numbers 1, 4, and 6 were open during the fish monitoring period. The remaining culverts were opened May 16 after fish monitoring was completed. DFG monitored the spring HORB culverts over 10 days, for approximately 167 hours of sampling per culvert, and collected 95 samples. Two samples from culvert number 4 were lost due to the process of clearing the net of gravel and resetting the net at the next net check.

Almost 500 fish were collected representing 17 species from 10 families of fish. No delta smelt (*Hypomesus transpacificus*), juvenile steelhead (*Oncorhynchus mykiss*), or splittail (*Pogonichthys macrolepidotus*) were collected in the fyke nets. The most abundant species was white catfish (*Ictalurus catus*), followed by common carp (*Cyprinus carpio*) (Table 3-1). Of the 51 salmon caught, 1 had a CWT; 46 were unmarked; and 2 were acoustically tagged. No color-marked salmon were caught this year. Overall, the number of salmon entrained per hour (0.1 ± 0.2) was lower than it was in previous years (0.7 in 2004, 3.4 in 2003, 2.5 in 2002, 1.4 in 2001). The mean fork length for unmarked salmon was 85 ± 7.6 mm, and the one CWT salmon was 93 mm.

Unmarked salmon were caught throughout the monitoring period (Figure 3-3). The average unmarked salmon CPUE over the entire monitoring period was 0.1 ± 0.2 fish/hour/culvert. The highest unmarked salmon CPUE (0.8 fish/hour/culvert) occurred on May 4 and May 8. The average CWT salmon CPUE over the entire monitoring period was 0.002 ± 0.020 fish/hour/culvert. The highest CWT salmon CPUE (0.2 fish/hour/culvert) occurred on May 10.

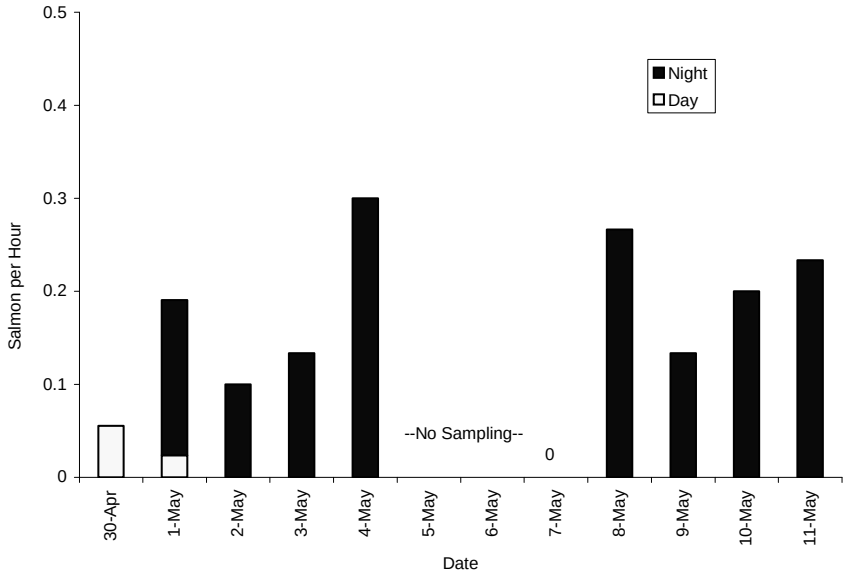
Table 3-1. Raw abundance and composition of fishes entrained at the HORB, 2007

Chinook salmon catch is divided into CWT salmon, unmarked salmon, color-marked salmon, and radio-tagged salmon.

Species	Catch
White Catfish	185
Common Carp	85
Sacramento Sucker	81
Channel Catfish	29
Bluegill	12
Tule Perch	11
Redear Sunfish	3
Lamprey Spp.	2
Striped Bass	2
Prickly Sculpin	2
Green Sunfish	2
Golden Shiner	2
Brown Bullhead	1
Goldfish	1
Largemouth Bass	1
Threadfin Shad	1
Inland Silverside	1
Total Chinook Salmon	**51**
CWT Salmon	1
Unmarked Salmon	48
Color-Marked Salmon	0
Acoustically tagged Salmon	2
Total	**472**

Figure 3-3. Daily average number of unmarked salmon entrained per culvert hour at the spring head of the Old River Barrier, 2007

The catch is separated by day and night. No sampling occurred on May 5 and 6.



In order to compare relative trends in unmarked salmon entrainment, a Culvert Entrainment Index and an Abundance Index was calculated for each of the previous years in which we conducted entrainment monitoring. The 2007 Abundance Index was similar to the 2001, 2003 and 2004 Abundance indices (Figure 3-4). For the most part, the Culvert Entrainment Index tracked the Abundance Index, except in 2003 and 2007. Although 2003 and 2007 had nearly identical Abundance Indices, the 2007 Culvert Entrainment Index was approximately 15 times lower. Both 2003 and 2007 had 3 open culverts. Although river flow can influence emigration patterns, San Joaquin River flow was similar among study years (2001–2004 and 2007) and flow probably had a negligible affect (Figure 3-4).

Unmarked salmon entrainment was highest in culvert number 6 and lowest in culvert number 1. Approximately half of the salmon entrained in 2007 were entrained through culvert number 6, which is similar to 2003 and 2004 (Table 3-2). Although 55 % of the entrained salmon went through culvert number 6, only 34 % of the water flowed through this culvert (Table 3-2). Salmon density for fish entrained through culvert number 6 was 0.03 fish/af, twice the density of culvert numbers 1 and 4.

Salmon entrainment differed greatly between diel periods. More unmarked salmon were entrained at night (47) than during the day (2). This year's nighttime entrainment is higher than in previous years when approximately 75% of the salmon were caught at night.

Figure 3-4. Mean unmarked salmon Abundance Index and Culvert Entrainment Index during annual VAMP period when both Mossdale Kodiak Trawl and HORB entrainment monitoring were sampling

Indices were not calculated for 2005 and 2006 because the HORB was not installed due to high San Joaquin River flows. Mean San Joaquin River flow during VAMP was measured at Vernalis.

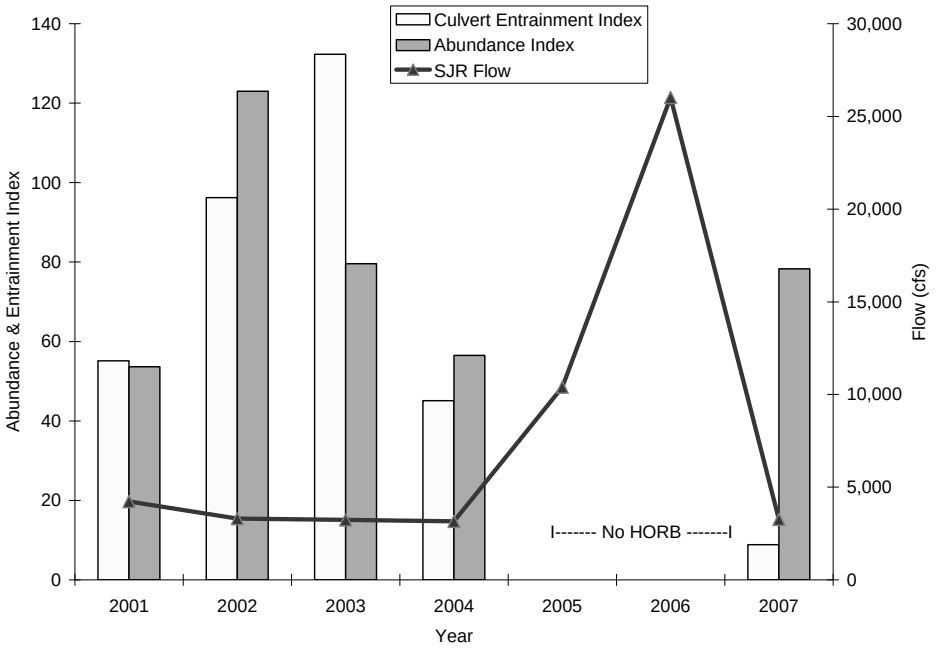


Table 3-2. Percentage of total number of unmarked salmon caught by culvert and year, and 2007 culvert flow and entrainment fish density

Catch comparisons made only for time periods when culverts were fully operational and fyke nets were fishing. An "X" indicates the culvert was closed. Days indicate the number of days the culverts were compared in the given culvert operational status.

				Culvert Number					
	Year	Days		1	2	3	4	5	6
Catch									
	2001	6.2	Percent	3%	7%	7%	18%	20%	44%
	2002	11.0	Percent	10%	12%	16%	33%	16%	12%
	2003	19.7	Percent	X	X	X	17%	39%	45%
	2004	2.0	Percent	X	X	X	15%	39%	46%
	2004	5.9	Percent	22%	X	11%	0%	5%	62%
	2007	7.3	Percent	21%	X	X	24%	X	55%
Flow (cfs)									
	2007	7.3	Percent	33%	X	X	32%	X	34%
			Avg ± SD	59 ± 8.8	X	X	58 ± 8.5	X	61 ± 8.9
Density (Fish/af)*100)									
	2007	7.3	Avg ± SD	1.2 ± 3.0			1.5 ± 2.9		3.0 ± 4.1

Discussion

Similar to previous years, white catfish made the top 2 most abundant species caught at the spring HORB. For the first time, Chinook salmon was not the most abundant or second most abundant species caught. In 2007, Chinook salmon was the fourth most abundant species caught after common carp and Sacramento sucker. Both carp and sucker catch was proportionally higher this year than in previous years. Carp and sucker each comprised around 17% of the total catch in 2007 compared to less than 2% from 2001 to 2004. Similar to previous years, large schools of common carp were observed swimming along the downstream edges of the spring HORB and nosing up against the barrier where water was seeping through the rocks.

The spring HORB is relatively effective in keeping salmon on the San Joaquin side of the barrier. Previous studies at the spring HORB (see 2001–2004 South Delta Temporary Barriers Project Monitoring Reports) indicate typically less than 1% of the VAMP CWT salmon released upstream of the spring HORB is entrained through the spring HORB culverts. Because there was no VAMP CWT salmon releases in 2007, we were unable to estimate the percentage of salmon entrained at the spring HORB. As an alternative to directly estimating entrainment using CWT salmon, culvert entrainment and abundance indices were generated for unmarked salmon to compare relative changes among years.

Total fish entrainment at the spring HORB was much lower this year than in previous years. Due to a staff shortage, the fyke nets were only fished over a period of 10 days. Although the number of days sampled was reduced, the proportional decrease in overall salmon entrainment was much greater than expected, even when we account for the number of operational culverts. There was an 86% decrease in CPUE compared to 2004, the previous low. A large contributing factor for the overall decline in salmon entrainment was the practically non-existent CWT salmon catch. In previous years, CWT salmon can account for more than half of all the salmon entrained. This year's single CWT salmon catch is by far the lowest on record. Due to the low returns at Merced River Hatchery in the fall of 2006, there were very few smolts raised and coded wire tagged at the hatchery for release in the spring of 2007.

Although CWT salmon typically accounts for a large percentage of the overall salmon entrainment, there was also a sharp decline in unmarked salmon entrainment. This decline in entrainment might be due to a decline in the number of out-migrating juvenile salmon. However, the unmarked salmon Abundance Index during the 2007 VAMP period was similar to previous years with a spring HORB, although it is likely that our abundance indices are not very precise or comparable given differences in relative efficiency were not estimated among years.

While we were sampling at the spring HORB in 2007, it appears there was no sharp decline in the number of unmarked salmon just upstream of the barrier. The decline in the 2007 Culvert Entrainment Index might be related to culvert gate operation. In previous years when only three culverts were opened (2003 and part of 2004), the three culverts closest to the channel were opened; and the three closest to shore were closed. This year, the culvert at the end, one in the middle, and the one closest to shore were open. The zone of entrainment might be higher with three adjacent open culverts. There is probably a larger draw of water at a fixed distance from an open culvert if the adjacent culverts are open. In contrast, when closed culverts are between the open culverts, the zone of entrainment might be lower.

Over the years, we have noticed the culvert closest to the shore (number 1) typically entrains the fewest number of salmon. It was thought that the lower entrainment might be

related to lower flows in culvert number 1. Visually, it appears less water flows through culvert number 1 compared to the other culverts. Theoretically, flows should be the same in all culverts since it is the head difference between upstream and downstream water levels that is responsible for flow. In 2002, a cursory check of flows among culverts using a handheld flowmeter suggested flow through culvert number 1 was about 10 cfs lower than flow through the other five culverts (2002 South Delta Temporary Barriers report). However, in 2007, flowmeters installed in culvert numbers 1, 4, and 7 indicate flow was similar among culverts.

The position of out-migrating salmon in the water column probably is the biggest factor affecting entrainment. The proximity of culvert number 1 to the shore and culvert number 6 to the center of the channel, may account for the large entrainment discrepancies between the 2 culverts. Salmon entrainment densities suggest salmon are more abundant in the center of the channel. Juvenile salmon may prefer to migrate down the middle of the channel rather than along the shoreline. Predation might also be higher along the shore which would reduce the number of salmon vulnerable to entrainment at culvert number 1.

The data collected over the spring HORB monitoring years strongly suggest salmon are more vulnerable to entrainment at night. Salmon entrainment at night was higher in 2007 than in previous years. In 2004, 80% of the unmarked salmon were entrained at night. In 2007, approximately 95% of the entrained unmarked salmon were caught at night. Although the MKT caught between 40 and 208 unmarked salmon per day (for a total of 678) just upstream of the barrier using surface tows, the spring HORB entrained between 0 and 1 salmon (for a total of 2) during that same daylight timeframe. This suggests salmon are more surface oriented during the day than at night. Since the culverts are placed on the bottom of the channel, salmon are less likely to be entrained if they remain near the surface.

Although overall salmon entrainment was lower this year, it appears the approximately 400 acoustically tagged salmon released upstream of the spring HORB were entrained at a similar rate as VAMP CWT salmon from previous studies. Acoustically tagged salmon were released at Durham Ferry and Mossdale as part of juvenile migration study in the south Delta (San Joaquin River Group Authority 2007 Annual Technical Report). No acoustically tagged juvenile salmon from the first set of releases and 2 acoustically tagged salmon from the second set of releases were entrained at the spring HORB. The overall entrainment loss for acoustically tagged salmon was 0.5 % which is similar to VAMP CWT entrainment losses at the spring HORB from 2001–2004.

As in previous years with a barrier, a large amount of gravel was caught in the nets which resulted in three lost samples. It is recommended that VAMP delay any future CWT salmon releases by at least 5 days beyond the closure of the spring HORB. The delay allows for completion of the barrier and minimizes the field crew’s exposure to heavy equipment operation. It also allows time for any loose material near the barrier to pass through the culverts before the nets are attached. If keeping out-migrating salmon out of Old River and in the San Joaquin River is beneficial to their survival, then it might be prudent to only open culvert numbers 1, 4, and 6 during peak salmon migration. It might be possible to further reduce salmon entrainment by opening the culverts closest to shore and only open culverts during daylight hours. A possible experiment to further test culvert gate operations on salmon entrainment is to only open culvert numbers 1, 2, and 3 for the first VAMP CWT salmon release and only open culvert numbers 4, 5, and 6 for the second VAMP release.

Chapter 4. Salmon Smolt Survival Investigations: Acoustic–Tagged Smolt Distribution Study[1]

One of the primary objectives of the Vernalis Adaptive Management Plan (VAMP) study, in addition to providing enhanced protection of juvenile Chinook salmon emigrating from the San Joaquin River system, is to determine the effects of San Joaquin River flows, State Water Project (SWP) and Central Valley Project (CVP) water exports, and Head of Old River Barrier (HORB) placement on survival of Chinook salmon smolts emigrating from the San Joaquin River through the Delta. Early in 2007, it was determined that Merced River Hatchery (MRH) would not meet its production needs. Thus production at the hatchery was not sufficient to provide study fish for a traditional VAMP coded-wire tag (CWT) experiment. A fully supported CWT VAMP experiment would require 400,000 juvenile Chinook salmon from MRH. As an alternative, an acoustic-tag experiment using only 1,000 salmon was planned to estimate survival from Durham Ferry to Jersey Point and Chipps Island and look at mortality and distribution by reach within the San Joaquin River with the HORB in place. However, due to logistical constraints, acoustic receivers were not actually installed at Chipps Island and Jersey Point and survival was not estimated.

Introduction

A pilot acoustic-tagging salmon study was conducted in the south Delta during the spring of 2006. A summary of the results is available in the 2006 VAMP annual report (SJRGA 2007). The 2006 study indicated that without the HORB in place and during high-flow conditions many (half or more) of the acoustic-tagged fish, released near Mossdale, migrated into Old River. Survival through the Delta could not be estimated in the spring of 2006 because receivers available were not effective in large channels (Chipps Island or Jersey Point). In 2007, we explored renting and deploying multi-hydrophone receivers in these large channels; however, logistical problems prevented their installation in 2007.

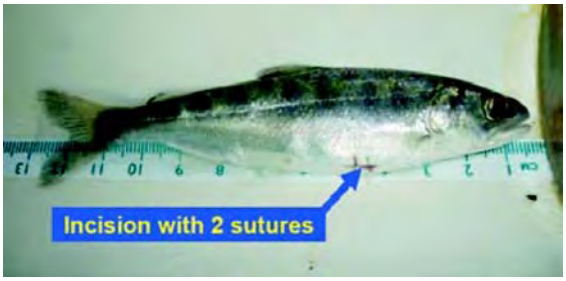
Fish Tagging

Fish used for the acoustic study were obtained from MRH. Originally, the plan was to tag and release 1,000 fish, but 30 fewer fish were released due to receipt of fewer tags for the experiments, tag failure, or fish mortality shortly after surgery. Ultimately, 970 juvenile Chinook salmon were surgically implanted (tagged) with Hydroacoustic Technology, Inc. (HTI) individually identifiable acoustic transmitters (tags) and released for the experiments (Figures 4-1 and 4-2). Prior to tagging the fish at MRH, an extensive training session was conducted at Mokelumne River Fish Hatchery.

[1] This chapter is a republication of Chapter 5 Salmon Smolt Survival Investigations: Acoustical-Tagged Smolt Distribution Study *in* 2007 Annual Technical Report on Implementation and Monitoring of the San Joaquin River Agreement and the Vernalis Adaptive Management Plan. Prepared by the San Joaquin River Group Authority for the California Water Resource Control Board in compliance with D-1641. January 2008.

Figure 4-1. Example acoustic transmitter, comparison to pen (Vogel 2006)

Figure 4-2. Chinook salmon smolt with implanted acoustic transmitter (Vogel 2006)



Because fish for training were unavailable at MRH, Mokelumne River Fish Hatchery provided 2,000 fish needed for training. Tagging personnel were trained by US Geological Survey (USGS) Cook, Washington, Lab. Procedures for tagging followed a strict standard operating procedure. Tagging consisted of surgically implanting an acoustic tag in the fish's body cavity. Size and weight of fish for training were similar to those later used at MRH for the VAMP experiments. Four individuals were trained to surgical implant the tags, and 8 others were trained to assist and to record data. Training was conducted between April 16 and April 26.

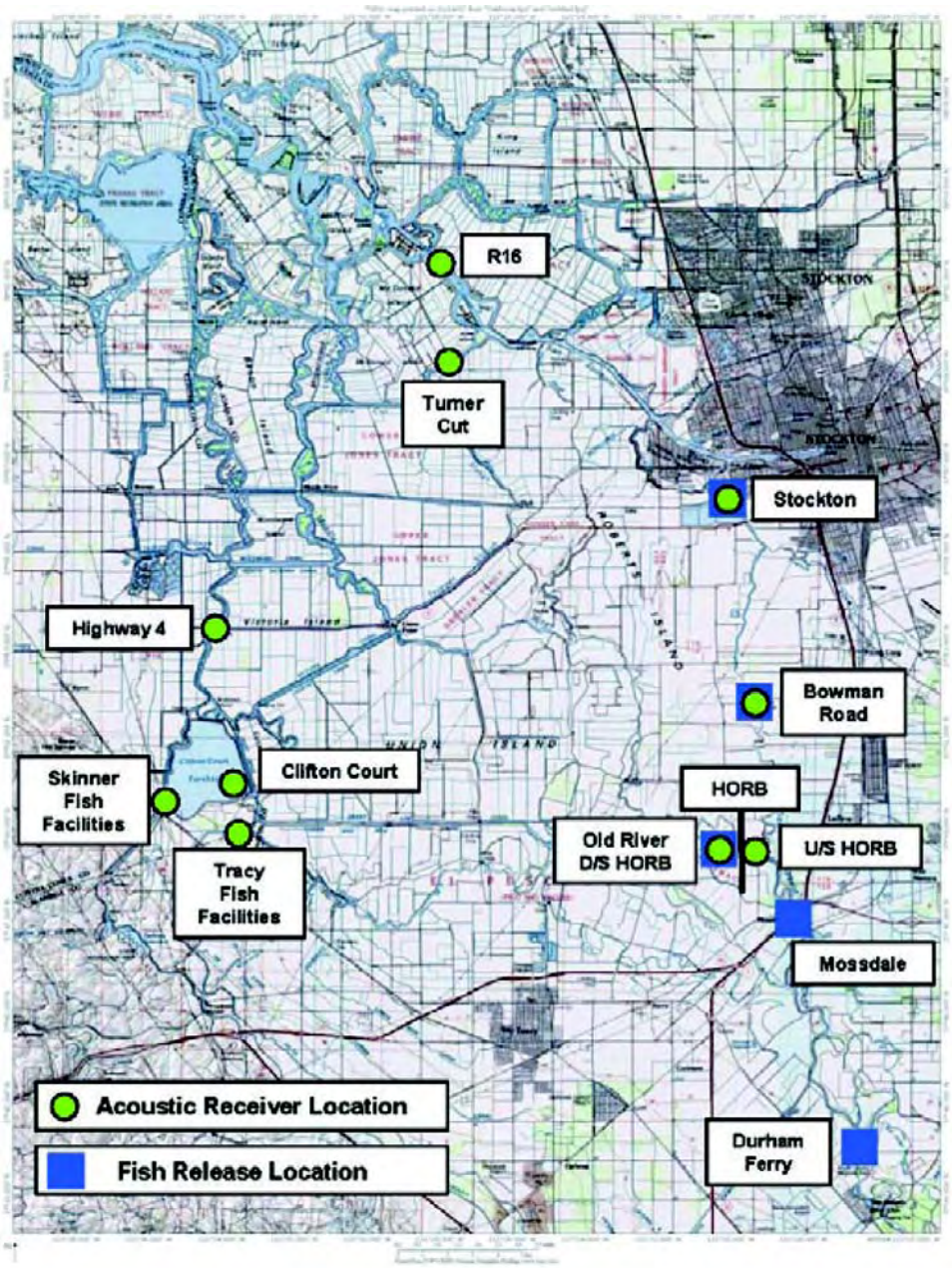
Prior to surgical implantation, acoustic tags were weighed and programmed, and fish were weighed and measured. The duration of surgical procedure was also recorded and was usually less than 4 minutes. Tagging and support personnel began conducting actual surgical operations at MRH on April 30 and May 7. The fish were held at MRH for 48 hours prior to release. The Durham Ferry and Mossdale groups were tagged on April 30 and May 7 with the 3 remaining groups (upper Old River, Bowman Road, and Stockton) tagged on May 1 and May 8. Throughout the tagging process, some fish were tagged with non-operational "dummy" tags that were of a similar size and weight as the functional tags.

Fish Releases

The acoustic-tagged MRH Chinook salmon were released at 4 sites on the San Joaquin River and 1 site in Old River. The intent was to release approximately 100 fish at each location during each of 3 weeks of experiments. Release locations were:

- Durham Ferry
- Mossdale
- Upper Old River (downstream of the HORB)
- San Joaquin River at Bowman Road
- San Joaquin River near the Stockton Waste Water Treatment Facility (SWWTF) (Figure 4-3).

Figure 4-3. Fish release locations and acoustic receiver locations during the 2007 VAMP experiments



The fish releases were made twice over a 2-week period for a total of 10 releases. The number of tagged fish released in the first week was 495. Releases were made at Durham Ferry and Mossdale on May 3 and in upper Old River, Bowman Road, and Stockton on May 4. The number of tagged fish for the second week of releases was 475. Releases were made at Durham Ferry and Mossdale on May 10 and in upper Old River, Bowman Road, and Stockton on May 11 (Table 4-1).

The tagged fish were acclimated for a short time prior to release. At each release location, 2 holding tubs, fitted with mesh covers, were filled with water from the hatchery vehicle. The groups of tagged fish were split approximately in half and transferred from the hatchery truck into the tubs. The temperature of the water from the hatchery was colder than that of the river; thus the fish were acclimated for approximately one hour prior to release. Once the fish were in the tubs and water temperatures measured, small amounts of river water were added to the tubs to slowly raise the temperature to the river temperature. Once the water temperature in the tubs was close to the river temperature (within a couple of degrees Fahrenheit), the fish were held for the balance of the hour prior to release. A GPS reading was taken at each of the 5 release sites.

Table 4-1. Release dates/times of acoustic-tagged juvenile Chinook salmon at each location during the first and second weeks of the 2007 VAMP experiments

	First release		Second release	
Release location	Date (in 2007)/Time	No. fish	Date (in 2007)/Time	No. fish
Durham Ferry	May 3, 1130 hours	98	May 10, 1140 hours	96
Mossdale	May 3, 1300 hours	99	May 10, 1230 hours	97
Old River (downstream of HORB)	May 4, 1017 hours	99	May 11, 1122 hours	95
Bowman Road	May 4, 1215 hours	99	May 11, 1205 hours	95
Stockton	May 4, 1250-1253 hours	100	May 11, 1243 hours	92

Water Temperature Monitoring

Water temperature was monitored during the VAMP 2007 study using individual computerized temperature recorders (e.g., Onset Stowaway Temperature Monitoring/Data Loggers). Water temperatures were measured at locations along the longitudinal gradient of the San Joaquin River and interior Delta channels between Durham Ferry and Chipps Island—locations along the migratory pathway for the juvenile Chinook salmon released as part of these tests (Appendix A-1). As part of the 2007 VAMP monitoring program, additional temperature recorders were deployed in the south and central Delta (Appendix A-1) to provide geographic coverage for characterizing water temperature conditions while juvenile salmon emigrate from the lower San Joaquin River through the Delta. Water temperature was recorded at 24-minute intervals throughout the period of the VAMP 2007 investigations. Water temperatures were also recorded within the hatchery raceways at the MRH coincident with the period when juvenile Chinook salmon were being tagged and held (Appendix A-1).

A number of temperature recorders deployed as part of this year's VAMP temperature monitoring could not be relocated and were probably lost to vandalism or removed by recreational boaters.

Results of water temperature monitoring within the MRH showed that juvenile Chinook salmon were reared in, and acclimated to, water temperatures of approximately 11- 16 °C (52 - 61 °F) prior to release into the lower San Joaquin River (Figures 4-4 and 4-5; Appendix A-2). Results of water temperature monitoring at Durham Ferry, Dos Reis, and Werner Cut, near Woodward Island, during the April-June fall-run Chinook salmon smolt emigration from the San Joaquin River through the Delta are shown in Figures 4-6, 4-7, and 4-8. Water temperature monitoring showed that water temperatures throughout the lower

San Joaquin River and Delta (Appendix A-2) were higher than those at the hatchery during the spring months, which is consistent with results of temperature monitoring in all previous years of the VAMP tests. Water temperatures measured within the lower San Joaquin River and Delta (Figures 4-6, 4-7, and 4-8 ; Appendix A-2) were within a range considered to be suitable (typically < 20 °C; 68 °F) during April and May in the mainstem San Joaquin River (e.g., Durham Ferry, Old River at HORB, and Dos Reis (Appendix A-2) but exceeded 20 °C (68 °F) farther downstream within the Delta (e.g., Old River/Indian Slough Confluence, Werner Cut – Channel above Woodward Isle; Appendix A-2). Results of the 2007 water temperature monitoring showed a longitudinal gradient of temperatures that generally increased as a function of distance downstream within the mainstem river and Delta. Water temperatures measured in the river during April-May would not be expected to result in adverse effects or reduced survival of emigrating juvenile Chinook salmon released as part of the VAMP 2007 investigations. Water temperatures measured downstream within the Delta during April and early May were within the general range considered to be suitable for juvenile fall-run Chinook salmon migration; however, temperatures during the late May and June were within the range considered to be stressful for juvenile Chinook salmon.

Figure 4-4. Water temperature in holding tank,Hatchery 1

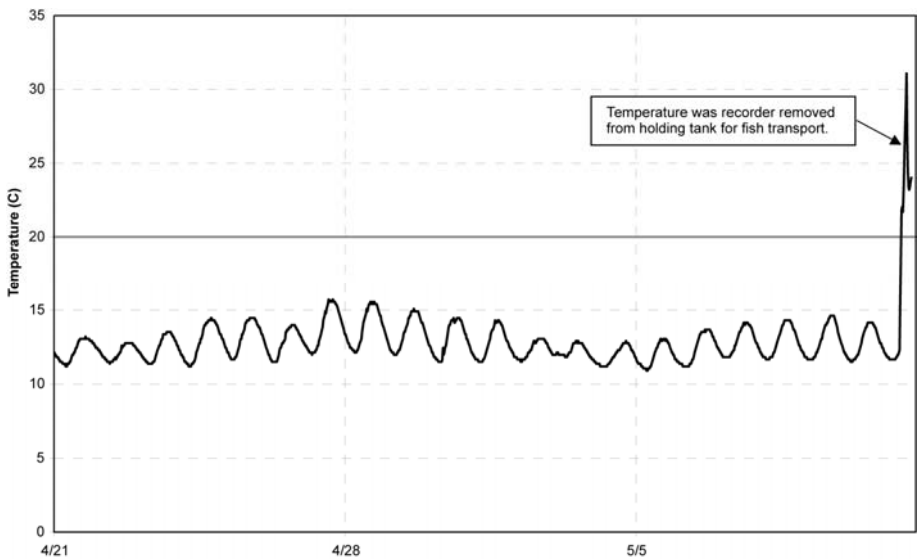


Figure 4-5. Water temperature in holding tank, Hatchery 2

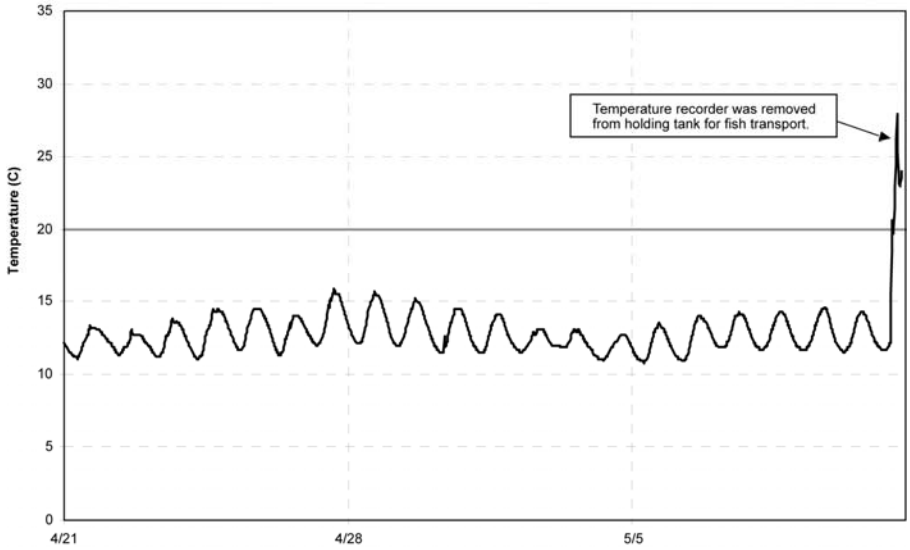


Figure 4-6. Water temperature monitoring at Durham Ferry

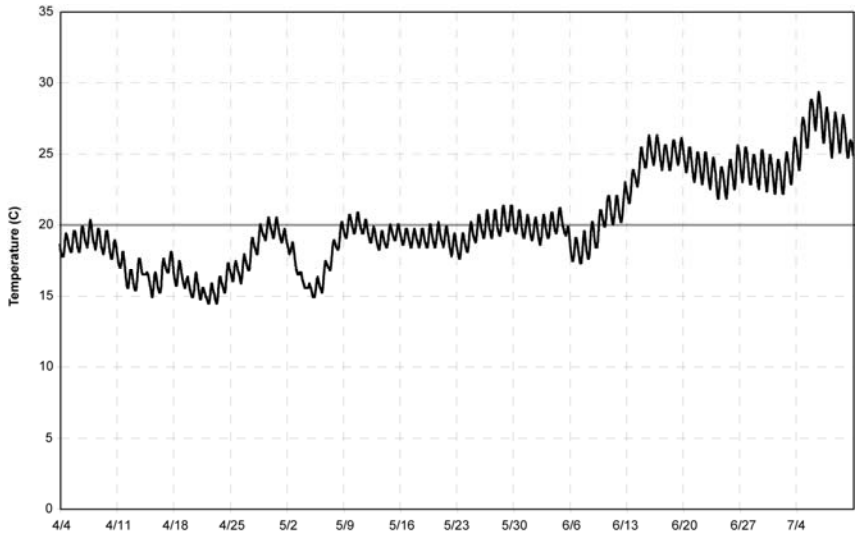


Figure 4-7. Water temperature monitoring at Dos Reis

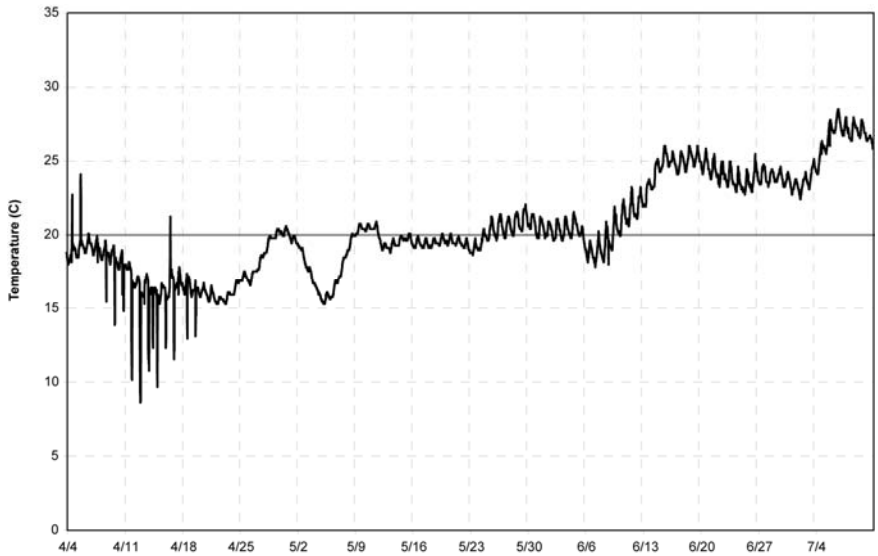
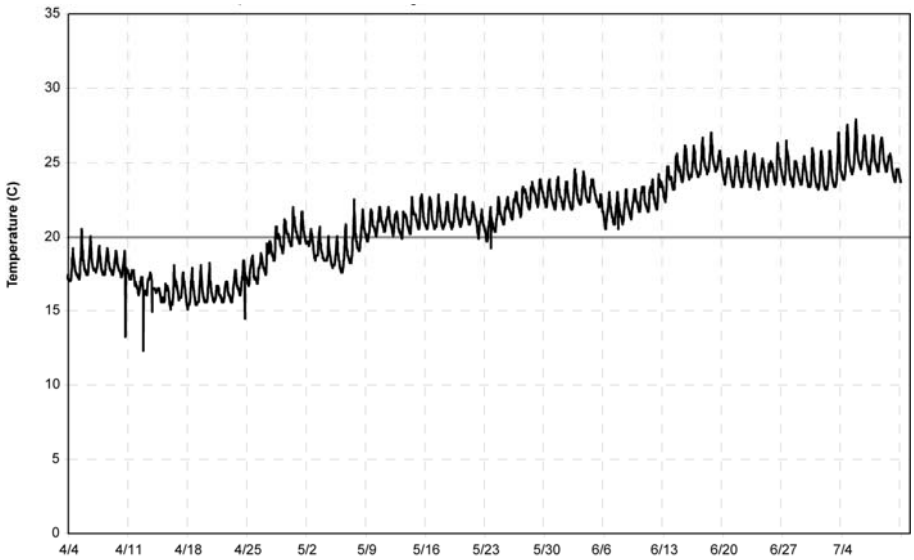


Figure 4-8. Water temperature monitoring at Werner Cut - Channel above Woodward Isle



Net Pen and Health Assessments

A fish health assessment was conducted to determine if delayed mortality would occur in the acoustically tagged fish. For the first set of releases, 10 fish tagged with “dummy” tags were held in net pens at both Mossdale and Durham Ferry. For the second release, 20 tagged fish were held at each of the same locations. Fish were transported similarly to the other tagged fish; but instead of being released, they were placed into a net pen, held for 48 hours, and then assessed for condition. After 48 hours, fish were removed from the net pens, euthanized, and examined. Each fish was measured (fork length in millimeters) and examined for scale loss, color, fin hemorrhaging, eye condition, and gill color. One fish from the first Mossdale release died during the 48-hour period. One other, from the second

Mossdale release had caudal fin hemorrhaging. All other characteristics examined were normal (Appendix A-3).

Dummy-tagged fish were also held at the hatchery. One set of 10 fish were tagged during the first week of tagging, on 4/30 and a second set of 10 fish were tagged during the second week of tagging on 5/7. Both sets of fish were euthanized on May 14 and examined for the same parameters as above. No mortalities were observed from either of the 2 groups, and the condition characteristics assessed were normal.

Health and Physiological Tests

Ten fish from the first Durham Ferry and Mossdale releases (5 from each location) and the 20 fish from the hatchery were used to obtain kidney samples for histological examination by the US Fish and Wildlife Service California/ Nevada Fish Health Center. Prior VAMP studies using CWT fish from MRH has regularly found infection by the parasite (*T. bryosalmonae*) that causes proliferative kidney disease. Findings for the samples in 2007 indicated that all 30 fish examined were infected with *T. bryosalmonae* (Table 4-2). Kidney lesions were observed in 5 of the 30 infected kidney sections. Short-term survival (<2 weeks) was not likely influenced by these infections; however, proliferative kidney disease is progressive and can continue after fish enter the ocean.

Table 4-2. Incidence and severity of *Tetracapsuloides bryosalmonae* in VAMP dummy-tagged acoustic groups released in 2007

Group	Infected	Clinical
MRH1	10-Oct	10-Feb
MRH2	10-Oct	10-Mar
Durham Ferry	5-May	0/5
Mossdale	5-May	0/5

Detection of Acoustic-Tagged Fish

Ten HTI acoustic receivers were distributed at various locations in the south and central Delta to detect acoustic-tagged fish as they migrated through the Delta (Figure 4-3). The fixed-station receivers electronically logged a time stamp when each individually identifiable tag passed the sites. Figure 4-9 shows an example deployment of a receiver in the Delta. The receivers were positioned in the channel to provide coverage across the channel to detect acoustic-tagged salmon (Figure 4-10). As previously mentioned, additional receiver sites were planned for Chipps Island and Jersey Point although logistical constraints prevented equipment being deployed. The USGS's Acoustic Doppler Current Profiler (ADCP) created frequency interference at Jersey Point, and debris at the bottom of the channel at Chipps Island created logistical obstacles of laying miles of cable that could not be overcome in the timeframe available.

The 10 locations where receivers were deployed in 2007 were:

1. San Joaquin River near the head of the HORB (U/S HORB),
2. Old River just downstream of the HORB (D/S HORB),
3. San Joaquin River near Bowman Road,
4. San Joaquin River near the Stockton Waste Water Treatment Plant,
5. Turner Cut,
6. San Joaquin River downstream of Turner Cut (R16),
7. Old River north of Clifton Court Forebay (Highway 4),
8. Inlet to Clifton Court Forebay (CCF),
9. Skinner Fish Facility (FF), and
10. Tracy Fish Facility (FF) (Figure 4-3).

Fish releases at Old River, Bowman Road, and Stockton were made near the acoustic receivers (Figure 4-3) to verify that tags were functioning at the time of release. A mobile receiver was used at the Durham Ferry and Mossdale release sites to confirm that transmitters were functioning just prior to the fish release.

Figure 4-9. Typical deployment of acoustic receiver (Vogel 2006)

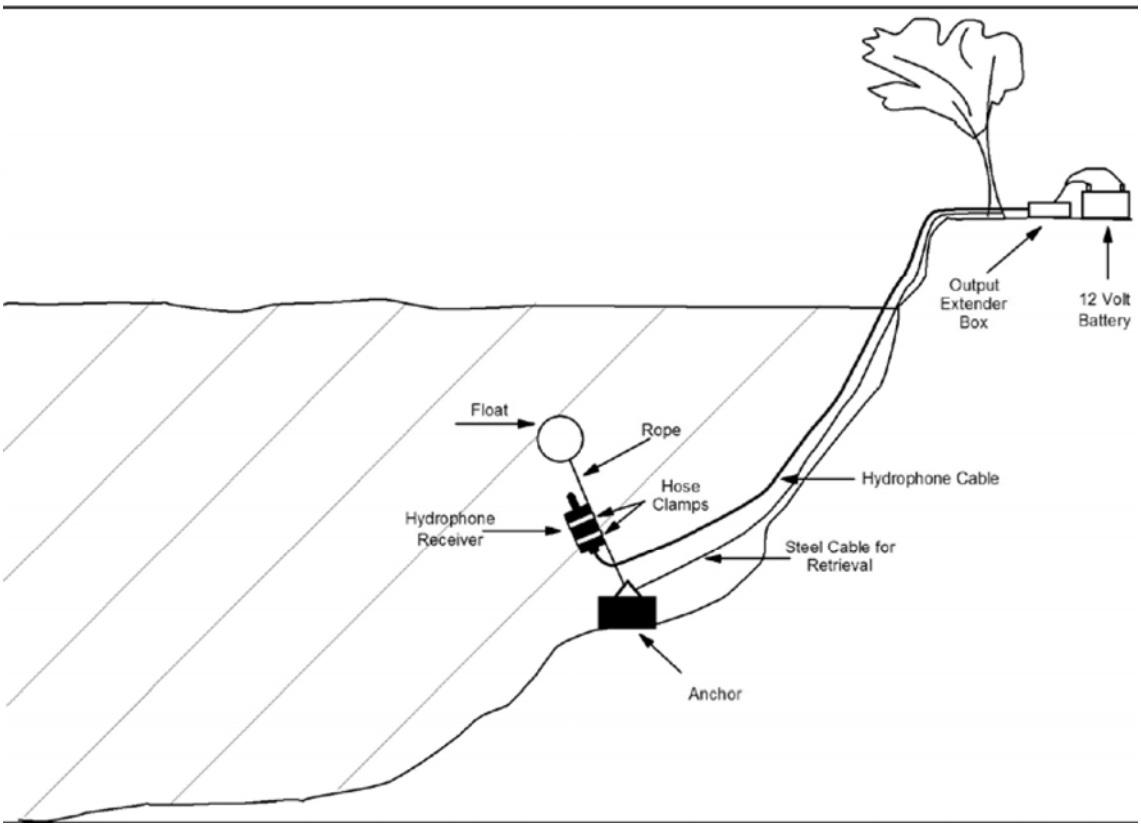
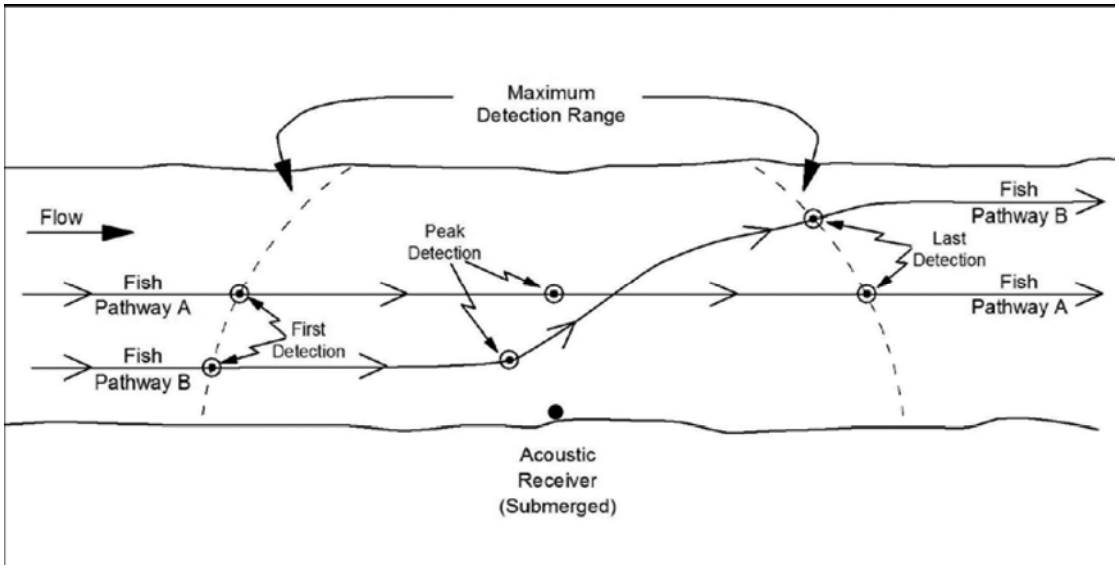


Figure 4-10. Typical acoustic receiver detection range (Vogel 2006)



Fish Transit Time

Because each acoustic receiver recorded the detection time of acoustic-tagged salmon within reception range (Figure 4-10) and each acoustic transmitter was individually identifiable, transit times and migration rates from release locations to each receiver site could be calculated. These calculations used the time of first detection by a receiver and the estimated in-channel distances between sites. Actual average speed of fish in the water would likely be faster because fish may not take the most-direct route between locations. Net fish migration rates in the San Joaquin River were more rapid in upstream reaches as compared to downstream reaches (Tables 4-3 and 4-4), a phenomenon attributed to tidal influence farther downstream. Fish released at Durham Ferry generally took about 1 day to reach the Old River flow split, whereas fish released at Mossdale took only about 4 hours. Fish released at Mossdale and Durham Ferry took about 1 to 2 days to reach Stockton, respectively. Although the sample sizes were small in the downstream-most areas, fish released at Durham Ferry and Mossdale took about 3 to 6 days to reach the San Joaquin River near R16 or Turner Cut. Fish released at Bowman Road took about a day and a half to reach Stockton. Fish released at Stockton exhibited the slowest overall net migration rates due to the large tidal seiching effects on fish migration in the lower San Joaquin River. Fish released in Old River just downstream of the HORB exhibited much slower migration rates than fish released in the San Joaquin River, undoubtedly because of the lower flows and slower water in Old River, Grant Line Canal, and Fabian and Bell Canal. It took about 3-1/2 to 4-1/2 days for fish released in Old River to reach the Tracy FF, CCF, Skinner FF, and Highway 4 (Tables 4-5 and 4-6).

Table 4-3. Average transit time, standard deviation, range, and average migration rate from fish release location to fish detection location during the first week of fish releases, May 3–4, 2007

	Detection location				
Release site	**U/S HORB**	**Bowman Road**	**Stockton**	**Turner Cut**	**R16**
Durham Ferry N = 98 fish	N = 69 fish 29.3 h (23.1 h) 12.2 h – 162.5 h 0.50 mph	N = 66 fish 35.6 h (18.0 h) 17.8 h – 98.9 h 0.58 mph	N = 25 fish 50.9 h (23.8 h) 26.2 h – 101.9 h 0.52 mph	N = 6 fish 78.9 h (20.5 h) 64.5 h – 115.0 h 0.47 mph	N = 9 fish 161.5 h (56.1 h) 123.4 h – 302.7 h 0.23 mph
Mossdale N = 99 fish	N = 97 fish 3.6 h (1.8 h) 1.8 h – 10.6 h 0.78 mph	N = 83 fish 14.5 h (7.9 h) 6.7 h – 44.9 h 0.60 mph	N = 33 fish 24.6 h (8.5 h) 19.4 h – 52.6 h 0.58 mph	N = 4 fish 72.4 h (32.4 h) 42.3 h – 105.8 h 0.35 mph	N = 9 fish 154.6 h (31.6 h) 122.6 h – 212.4 h 0.17 mph
Bowman Road N = 99 fish			N = 31 fish 34.4 h (14.4 h) 27.3 h – 81.1 h 0.16 mph	N = 2 fish 84.0 h (23.9) 67.1 h – 100.9 h 0.20 mph	N = 4 fish 136.8 h (13.2 h) 123.4 h – 151.0 h 0.12 mph
Stockton N = 100 fish				N = 3 fish 50.7 h (10.3 h) 43.5 h – 62.5 h 0.21 mph	N = 9 fish 112.9 h (15.9 h) 98.7 h – 149.8 h 0.10 mph

Table note: Transit time in hours (h); standard deviation in parentheses; range in times (h); average migration rate in miles per hour (mph)

Table 4-4. Average transit time, standard deviation, range, and average migration rate from fish release location to fish detection location during the second week of fish releases, May 10–11, 2007

	Detection location				
Release site	**U/S HORB**	**Bowman Road**	**Stockton**	**Turner Cut**	**R16**
Durham Ferry N = 96 fish	N = 56 fish1 17.7 h (4.5 h) 9.8 h – 27.4 h 0.83 mph	N = 36 fish 25.7 h (4.8 h) 15.4 h – 34.9 h 0.80 mph	N = 9 fish 41.2 h (10.8 h) 27.0 h – 60.4 h 0.64 mph	N = 1 fish 68.4 h (N.A.) N.a. 0.54 mph	N = 8 fish 75.3 h (11.4 h) 55.4 h – 95.4 h 0.50 mph
Mossdale N = 97 fish	N = 95 fish 4.0 h (1.1 h) 2.5 h – 8.1 h 0.70 mph	N = 76 fish 12.2 h (13.0 h) 6.5 h – 103.3 h 0.72 mph	N = 32 fish 22.8 h (11.7 h) 14.4 h – 60.8 h 0.63 mph	N = 7 fish 71.4 h (28.4 h) 37.2 h – 124.9 h 0.35 mph	N = 13 fish 75.6 h (26.8 h) 29.8 h – 143.3 h 0.34 mph
Bowman Road N = 95 fish			N = 25 fish 34.0 h (49.2 h) 3.7 h – 201.7 h 0.17 mph	N = 2 fish 63.9 h (17.0) 51.9 h – 76.0 h 0.26 mph	N = 11 fish 48.7 h (14.6 h) 29.0 h – 80.3 h 0.35 mph
Stockton N = 92 fish				N = 2 fish 32.1 h (13.7 h) 22.4 h – 41.7 h 0.34 mph	N = 9 fish 44.1 h (15.5 h) 19.6 h – 69.7 h 0.26 mph

1. The acoustic receiver U/S HORB was not operational from 1800 May 11 to 1400 May 14, 2007, so some of the Durham Ferry fish likely passed the site during that period. Therefore, the data shown is probably biased toward a rapid migration rate and average travel time and migration rate would likely be slower than shown here.

Table note: Transit time in hours (h); standard deviation in parentheses; range in times (h); average migration rate in miles per hour (mph)

Table 4-5. Average transit time, standard deviation, range, and average migration rate from fish release location downstream of the HORB to fish detection location during the first week of fish releases, May 3–4, 2007

	Detection location			
Release site	**Tracy FF**	**Clifton Court**	**Skinner FF**	**Highway 4**
Downstream HORB N = 99 fish	N = 22 fish 101.8 h (62.2 h) 33.7 h – 294.5 h 0.15 mph	N = 19 fish 69.0 h (25.3 h) 40.2 h – 115.6 h 0.23 mph	N = 4 fish 96.5 h (31.8 h) 68.0 h – 129.9 h 0.19 mph	N = 23 fish 85.4 h (44.0 h) 50.1 h – 242.2 h 0.24 mph

Table note: Transit time in hours (h); standard deviation in parentheses; range in times (h); average migration rate in miles per hour (mph)

Table 4-6. Average transit time, standard deviation, range, and average migration rate from fish release location downstream of the HORB to fish detection location during the first week of fish releases, May 10–11, 2007

	Detection location		
Release site	**Tracy FF**	**Skinner FF1**	**Highway 4**
Downstream HORB N = 95 fish	N = 31 fish 69.4 h (31.2 h) 31.8 h – 174.2 h 0.23 mph	N = 3 fish 96.9 h (66.0 h) 52.6 h – 172.7 h 0.19 mph	N = 10 fish 64.6 h (10.3 h) 54.2 h – 82.3 h 0.32 mph

1 The acoustic receiver at the entrance to CCF was not operational for part of the time during the second fish release; therefore, transit times from HORB to CCF could not be determined. However, 3 fish were detected at Skinner FF which undoubtedly entered CCF during the down time of the CCF receiver.

Table note: Transit time in hours (h); standard deviation in parentheses; range in times (h); average migration rate in miles per hour (mph)

Chinook Salmon Distribution and Survival

Tables 4-7 and 4-8 provide the numbers of acoustic-tagged salmon detected at each acoustic receiver site. During the course of the study, there were receivers that either did not work properly during a specific period or were not placed in the river until after some of the tagged fish may have passed by. For instance, the acoustic receiver at U/S HORB was not operational between May 11, 1800 hrs and May 14, 1400 hours. In addition, the acoustic receiver in Clifton Court Forebay did not record data from May 11, 2100 hrs to May 14, 1000 hours. The acoustic receiver placed at the Stockton site had only partial channel coverage during the study and an operational acoustic receiver was not positioned at Channel Marker R16 until May 8 at 1500 hours due to USGS boat problems. Although the probability of detecting an individual fish does not have to be 100% to estimate survival, it is necessary to have downstream receivers to determine the detection probability for an individual receiver.

The probability of detection of each receiver for each release was estimated using the formula:

$$\hat{p}_i = \frac{r_i}{r_i + z_i} \quad (1)$$

where i = estimated probability of detection at site i,
conditional on the fish being alive at site i.

r_i = the total number of fish detected downstream of site i
of those detected at site i and

z_i = the total number of fish that were not detected at site i,
but were detected downstream of the site i.

Although detection probabilities were estimated to be 100% or close to 100% for the acoustic receivers positioned just upstream of the HORB and at Bowman Road (Tables 4-9 and 4-10), we know this is incorrect, based on mobile monitoring conducted near Stockton (see later section of this report and Table 4-11). During mobile monitoring near Stockton on May 17 and 18, some tags from both Durham Ferry releases were detected that had not been detected previously at any of the stationary monitors upstream (U/S HORB, Bowman Road, or Stockton). But because this mobile monitoring was not conducted systematically throughout the study period, we could not use these detections to help estimate detection efficiency. We can understand how some of the Durham Ferry fish from the second release likely missed detection at the U/S HORB receiver because it was not operational for 3 days after release (May 11, 1800 hours to May 14, 1400 hours). However, it is not clear how they would have been missed at the Bowman Road receiver or why 2 tags from the first Durham Ferry release were also not detected at any of the stationary receivers upstream. Given the questionable issues surrounding the Durham Ferry releases, survival estimates obtained using the Durham Ferry release groups are likely more uncertain that those using the Mossdale and Bowman Road release groups to estimate survival to Stockton. Even though the Stockton receiver only had partial coverage of the channel (and low probability of detection), we have tried to account for this limitation when estimating survival.

Table 4-7. Number of acoustic-tagged salmon released at 5 locations on May 3 and 4, 2007, and detected passing acoustic receiver sites[1]

Release location	Location of acoustic receivers									
	U/S HORB	D/S HORB	Bowman road	Stockton[2]	Turner Cut	r16[3]	Tracy FF	Clifton Court	Skinner FF	Hwy 4
Durham Ferry N = 98 fish	69	0	66	25	6	9	0	1	0	1
Mossdale N = 99 fish	97	0	83	33	4	9	1	0	0	1
Bowman Road N = 99 fish	0	0		31	2	4	0	0	0	0
Stockton N = 100 fish	0	0	0		3	9	0	0	0	0
D/S HORB N = 99 fish	1		0	0	0	0	22	19	4	23

Note: For locations, see Figure 4-3.

1, 2-The acoustic receiver placed at the Stockton site had only partial channel coverage during the study.

3-An operational acoustic receiver was not positioned at Channel Marker R16 until May 8 at 1500 hrs due to boat problems.

Table 4-8. Number of acoustic-tagged salmon released at 5 locations on May 10 and 11, 2007, detected at acoustic receiver sites

Release Location	Location of acoustic receivers									
	U/S HORB[1]	D/S HORB	Bowman road	Stockton	Turner Cut	R16	Tracy FF	Clifton Court[2]	Skinner FF	Hwy 4
Durham Ferry N = 96 fish	56	2	36	9	1	8	1	0	0	0
Mossdale N = 97 fish	95	0	76	32	7	13	1	0	0	1
Bowman road N = 95 fish	0	0		25	2	11	0	0	0	0
Stockton N = 92 fish	0	0	0		2	9	1	0	0	0
D/S HOrB N = 95 fish	0		0	0	0	0	31	6	3	10

Note: For locations, see Figure 4-3.

1 The acoustic receiver at Old River was not operational from 1800 hrs. May 11 to 1400 hrs. May 14, 2007. Based on travel times, some of the Durham Ferry fish likely passed the site during that period whereas all fish released at Mossdale and passing the Old River flow split were assumed to have been detected.

2 Acoustic receiver did not record data from 2100 hrs. May 11 to 1000 hrs. May 14; fish entering CCF during this period would not have been detected.

Table 4-9. Detection probability for receivers during the first week of releases, May 3 and 4, 2007

Release locations	Receiver locations		
	U/S HORB	Bowman Road	Stockton
Durham Ferry N = 98 fish	1	1	0.46
Mossdale N = 99 fish	1	1	0.38
Bowman Road N = 99 fish	--		0.5

Table 4-10. Detection probabilities for receivers during the second week of releases, May 10 and 11, 2007

	Receiver locations		
Release location	U/S HORB	Bowman Road	Stockton
Durham Ferry N = 96 fish	0.947	0.875	0.125
Mossdale N = 97 fish	1	0.976	0.35
Bowman Road N = 95 fish	--		0.18

Table 4-11. Number of acoustic transmitters detected in the San Joaquin River near the railroad bridge at Stockton on May 17 and 18, 2007

Fish release location	Release date	Number of acoustic tags detected
Durham Ferry	3-May-07	12 (2)
Mossdale	3-May-07	1 (0)
Bowman Road	4-May-07	5 (2)
Stockton	4-May-07	6 (6)
Durham Ferry	10-May-07	21 (7)
Mossdale	10-May-07	14 (0)
Bowman Road	11-May-07	26 (14)
Stockton	11-May-07	31 (31)

The number never detected elsewhere is included in parentheses.

Estimates of Survival

Survival in a reach is based on the number of tags detected and the probability of detection, and is calculated as shown in the following formula:

$$S = \frac{\text{\# detected}}{(\text{\# released or observed upstream})}.$$

Detection probability

Where possible, the survival of the acoustic fish by reach was estimated. Survival by reach is estimated using the proportion detected at the receiver at the end of the reach and the probability of detection by that receiver. Standard errors can also be generated.

The longest reach where survival could be estimated was between Durham Ferry and Stockton. Reaches within this larger reach could also be estimated—Durham Ferry and Mossdale to Upstream HORB, Bowman Road, and Stockton. Stockton is the end point to where survival can be estimated because the most downstream receivers were at Turner Cut and R16 and were used to estimate the probability of detection of the Stockton receiver.

Survival down the San Joaquin River for 3 release groups (Durham Ferry, Mossdale, and Bowman Road) was estimated and shown in Figures 4-11 through 4-16. Survival estimates for all reaches between Mossdale and Stockton were relatively high. Survival seemed lower between Durham Ferry and Mossdale. A survival estimate of greater than 1.0, was estimated for the reach between Bowman Road and Stockton for the second Bowman Road release and is likely due to the combination of high survival but low detection probability calculated for the Stockton receiver. Although to confidently make assessments of differences in survival between reaches, standard errors would need to be generated to determine if significant differences exist. For our purposes, it is useful to understand how

survival can be generated to help plan where to place receivers in 2008 for maximum coverage and for estimating survival by reach.

Most fish released at Durham Ferry and Mossdale migrated downstream via the San Joaquin River, although some were found to arrive at the fish facilities using multiple pathways. For instance, 2 individuals (3374, 3381) from the second Durham Ferry release presumably migrated into Old River through the HORB culverts, as they were detected at the receiver in Old River downstream of the HORB (Appendix A-6). One of these individuals (3374) was later detected at the Tracy FF. One additional individual from the first Durham Ferry release (3294) was detected at the U/S HORB, D/S Bowman Road, and at Highway 4 receivers prior to being detected at the CCF receiver, indicating that it had migrated down the San Joaquin River but turned south at one of the junctions downstream of Bowman Road. In addition, 2 fish released from Mossdale (3910 from the first release and 3801 from the second release) were detected at the Tracy FF, with both being detected at the receivers at U/S HORB, Bowman Road, Stockton and Turner Cut, (Appendices A-4 and A-6) One individual (3801) was observed at Highway 4 after being observed at Tracy FF, while another (3910) was observed at Hwy 4 prior to being detected at the CVP facility.

In at least one case, a fish released at Stockton also migrated to the Tracy FF. One individual from the second Stockton release (5978) was detected at the Tracy FF after being detected at R16 (Appendix A-6). These cases seem to show that not only do juvenile salmon migrate through the culverts of the HORB to arrive at the fish facilities, they also get there through Turner Cut or from other areas farther downstream in the San Joaquin River.

Figure 4-11. Survival by reach for fish released at Durham Ferry during the first week of releases

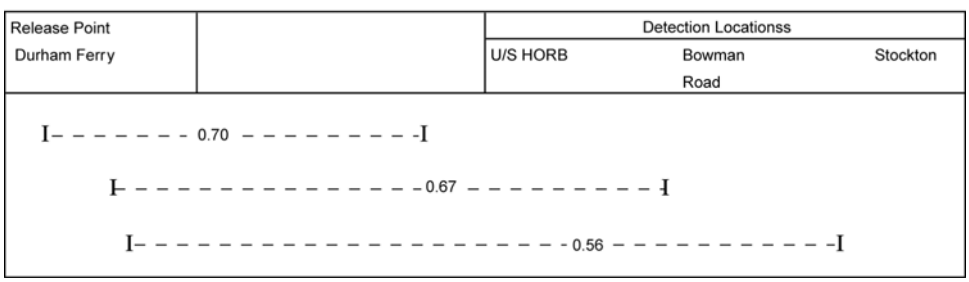


Figure 4-12. Survival by reach for fish released at Mossdale during the first week of releases

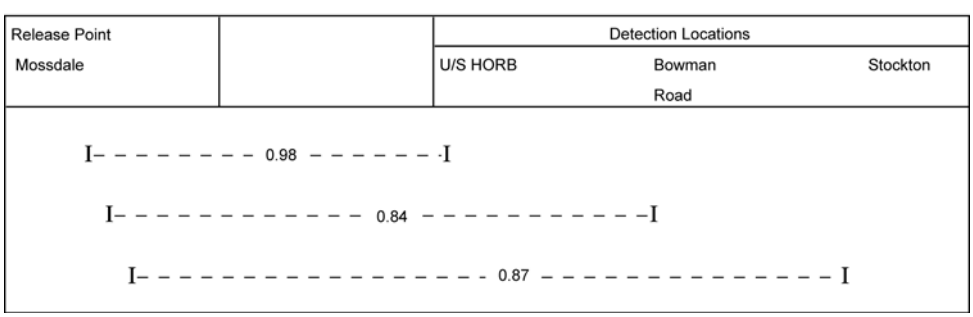


Figure 4-13. Survival by reach for fish released at Bowman Road during the first week of releases

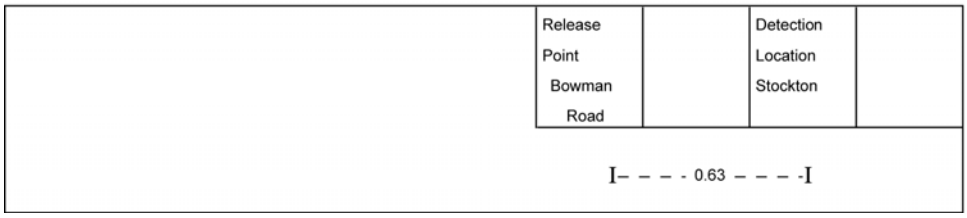


Figure 4-14. Survival by reach for fish released at Durham Ferry during the second week of releases

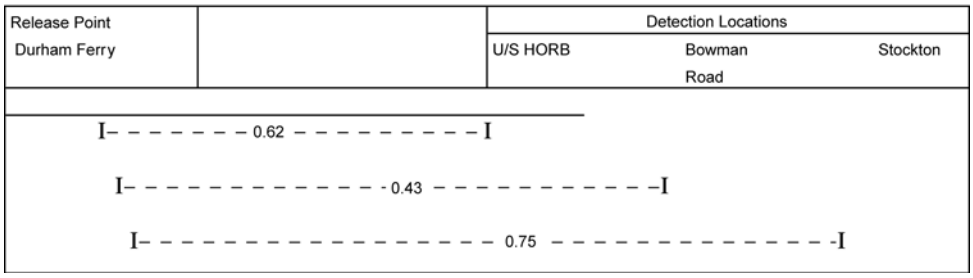


Figure 4-15. Survival by reach for fish released at Mossdale during the second week of releases

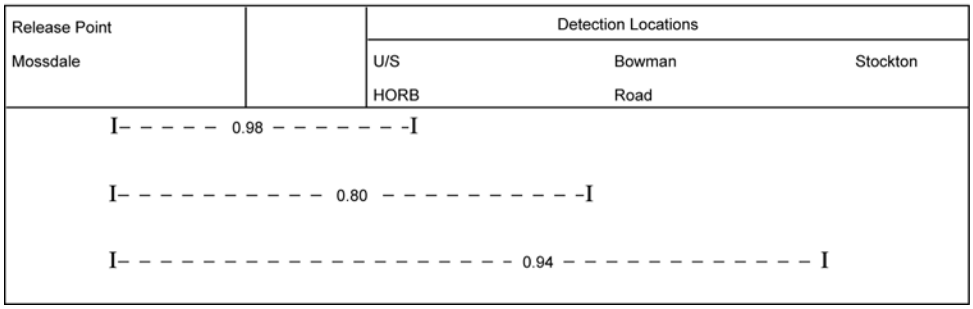
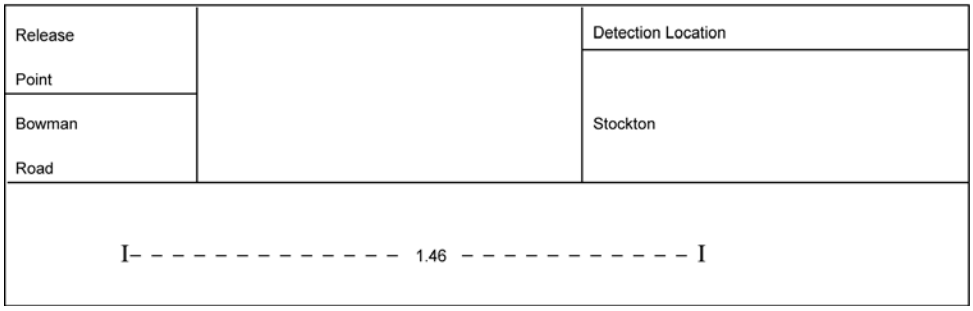


Figure 4-16. Survival by reach for fish released at Bowman Road during the second week of releases



Head of Old River Barrier Releases

Survival was not estimated for the group of tagged fish released in Old River, downstream of HORB, because there were insufficient acoustic receivers to provide coverage in all channels where fish could subsequently migrate (e.g., Middle River, Victoria Canal). However, these fish were detected downstream at the Tracy FF near Tracy, at the entrance to CCF, at the Skinner FF, and in Old River at the Highway 4 Bridge. Of the 99 fish released for the first release, 22 were detected at the Tracy FF, 19 at CCF, and 23 at Highway 4. Some of the fish were detected at more than one of the locations, with fish being detected at CCF or Highway 4 after being detected at Tracy or being detected at Tracy or CCF after being detected at Highway 4 (Appendix A-5). In one case, an individual (4673) was detected at Tracy after it had been detected in CCF (perhaps inside a predator). If we assume the remaining 18 salmon detected in CCF were live salmon and stayed in CCF, we can estimate survival through the forebay. With 4 individuals detected at the Skinner FF, we estimate survival across CCF to be 22% assuming 100% detection probability at both locations.

In addition, one of the individuals (4799) from the first release in Old River was detected at the U/S HORB receiver indicating that it had moved through the HORB culverts to the San Joaquin River. This tag was likely in a predator as it would seem unusual for a salmon to move against the flow through a HORB culvert.

During the second week of fish releases in Old River, the CCF receiver did not record data a portion of the time when fish could have entered the forebay. This was empirically documented when 3 fish detected at the Skinner FF were not detected by the CCF receiver (Appendix A-7). Of the 95 salmon released in Old River during the second week, 31 were detected at the Tracy FF and 10 at Highway 4. Again, some of these individuals were detected at more than one location (Appendix A-7). For instance, 3 fish detected at Tracy were also later detected at Skinner (4424) and at Highway 4 (4515, 4760). One of these (4424) had also been detected previously at Highway 4. One of the 3 fish detected in CCF (5096) had previously been detected at Tracy. For both weeks of fish releases in Old River, the numbers detected at the receivers in the south Delta were higher than we assumed. Our assumption was that the numbers would have been very low because of slow water, longer exposure time to predators and unscreened diversions, and routes where fish could have migrated without detection.

Mobile Monitoring

A week after the last fish releases, a mobile acoustic receiver was used in several Delta channels in an attempt to locate non-moving transmitters. During mobile monitoring in the San Joaquin River from Mossdale to the Stockton Deep Water Ship Channel, a high number of acoustic transmitters were detected at a very small, localized site at Stockton. The area was approximately 0.75 miles downstream of the Highway 4 Bridge, 1.7 miles upstream of the Stockton Deep Water Ship Channel, and adjacent to a railroad bridge and the Stockton wastewater treatment facilities (Figure 4-17). This site was just downstream of our stationary receiver and release site near the Stockton waste water treatment facility. A total of 116 tags were found at this site which included some fish from all of the releases made on the San Joaquin River during the 2 weeks of releases (see Table 4-11). This may be a minimum number lost at that location as the mobile monitoring was done on May 17 and 18 after the battery life of some of the tags from the first week fish releases may have ended. These tags

were motionless, indicating the tags were either in dead fish or had been defecated by a predator. An investigation by the Regional Water Quality Control Board found that the wastewater treatment facility was in compliance with discharge permit requirements. The cause of this high mortality remains unknown, but this area was apparently a hostile place for juvenile salmon in May.

The history of some of these individual tags was odd in that some had moved downstream past this site earlier and many of the others had never been detected upstream. For instance, 3 tags observed at this site from the first Durham Ferry release had been detected at R16, 9 to 10 days earlier. In addition, a total of 10 individuals detected in the mobile monitoring from the releases at Durham Ferry (3441, 3042, 3140, 3017, 3031, 3094, 3115, 3150, 3157, 3185) had never been detected at any of the receivers upstream (see Table 4-11). Because the receiver at the HORB was not operating between May 11 and May 14, it is likely that some of the fish released on May 10 at Durham Ferry may have passed that receiver without being detected because it took about a day for the Durham Ferry fish to reach the HORB. However, it is unclear why they would not have been detected at Bowman Road. It is also understandable that they were not detected at receivers at Stockton, in Turner Cut and at R16 as the receivers were not very efficient because they were not covering the entire channel. In addition, 2 of the 8 fish detected at R16 from the second release at Durham Ferry were also never detected upstream (Appendix A-6). It is noteworthy that these odd cases were restricted to fish released at Durham Ferry. All of the fish detected in the mobile monitoring at Stockton from the Mossdale releases had been detected at the upstream receivers (Appendices A4 and A-6).

There were indications of piscivorous predation on some of the acoustic-tagged salmon during the study. Uncharacteristic behavior of an acoustic-tagged salmon compared to the majority of observed behavior patterns suggested some tagged fish were consumed by a predator and the transmitter inside the predator was subsequently detected passing a receiver. For example, there were instances where a transmitter was detected in a sequential downstream direction then eventually moved back upstream. Although predation could not be empirically confirmed in these cases, this behavior was considered unlikely for a salmon smolt. There were some instances where predation could be confirmed because of multiple predation events on acoustic-tagged salmon by a single predator (e.g., a predator eating 2 acoustic-tagged salmon). In one instance, 1 predator ate 4 acoustic tagged salmon. This phenomenon can be observed during data processing that shows identical detailed movements of transmitters. Lastly, the acoustic receivers can determine if a transmitter remains motionless. In these latter cases, fish mortality was certain but the reason for the mortality could not be determined.

An additional site of relatively high fish mortality was located at the head of Old River flow split downstream of Mossdale. In 2006, five acoustic transmitters among 100 fish released at Mossdale were located at the same site. Based on observations of striped bass feeding activity in this area during the 2006 VAMP study, it was hypothesized that acoustic-tagged salmon were consumed by predatory fish and the transmitters were subsequently defecated and deposited on the bottom of the channel. A description of the unusual scour hole near the Old River flow split is provided in the 2006 VAMP Annual Report (SJRGA 2007). In 2007, it appeared that 19 acoustic tagged salmon from both weeks of fish releases may have been preyed on in the same vicinity.

Numerous acoustic transmitters were also located in front of the trashracks just upstream of the Tracy FF. As with other sites where motionless transmitters were found or the transmitters exhibited unusual movements, it could not be determined where the

acoustic-tagged salmon were preyed upon, only where the transmitters were found. For example, an acoustic tagged salmon could have been eaten by a predator at another location and the predator subsequently swam to the Tracy FF trashracks where the tag was detected for long periods (anomalous behavior for a smolt at this location) or was defecated (motionless transmitter). Alternatively, the acoustic-tagged salmon may have followed the flow toward the Tracy FF but were eaten by predators residing in front of the trashracks. A total of 57 transmitters were detected just upstream of the Tracy FF trashracks and potentially had been consumed by predators. Fifty-three acoustic tagged fish were detected at the stationary receiver at the Tracy FF from the downstream of HORB release. Four of these were later detected at other locations (Skinner, CCF or Highway 4). Determining which acoustic tagged fish have been eaten with certainty is problematic.

A limitation of the acoustic tag methodology is the ability to determine whether a tag is still inside a live juvenile salmon. Without this assurance, it is possible that survival is biased. Although some types of behavior do indicate the tagged fish has been eaten, or that the fish has died, there are probably some cases where fish are assumed to be live and they are not. Thus it is likely survival would be overestimated using these methods. Traditional coded-wire tag VAMP studies did not have this limitation, although they had other technical challenges.

Figure 4-17. Lower San Joaquin River near Stockton

Comparison with Past Years

Ocean Recovery Information

Ocean recovery data of CWT salmon groups can provide an additional source of recoveries for estimating survival through the Delta. The ocean harvest data may be more reliable due to the greater number of CWT recoveries and the extended recovery period.

Adult ocean recovery data are gathered from commercial and sport ocean harvest checked at various ports by the California Department of Fish and Game. The Pacific States Marine Fisheries Commission database of ocean harvest CWT data was the source of recoveries through 2006. The ocean CWT recovery data accumulate over a 1- to 4-year period after the year a study release is made as nearly all of a given year-class of salmon have been either harvested or spawned by age 5. Consequently, these data are essentially complete for releases made through 2002 and partially available for CWT releases made from 2003 to 2005; no ocean recovery data are available yet for the 2006 releases. Differential recovery rates (DRR) based on Chipps Island or ocean recoveries and combined differential recovery rates (CDRR) based on both Antioch and Chipps Island recoveries for salmon produced at the MRH are shown in Table 4-12. Absolute survival estimates based on Chipps Island and Antioch survival indices are also included. The earlier releases were made as part of south Delta survival evaluations (1996–1999) with the later releases associated with VAMP (2000–2006). Releases have been made at several locations: Dos Reis, Mossdale, Durham Ferry, and Jersey Point. The Chipps Island and Antioch survival estimates and combined differential (Antioch and Chipps Island recoveries summed) or differential recovery rates (Chipps Island recoveries only) are graphed in relation to the differential recovery rate using the ocean recovery information in Figure 4-18.

Results of this comparative analysis of survival estimates and differential recovery rates for Chinook salmon produced in the MRH show (1) there is general agreement between survival estimates and differential recovery rates based on juvenile CWT salmon recoveries at Chipps Island and adult recoveries from the ocean fishery (r^2=0.76); (2) there is less agreement with Antioch trawling, which has fewer years of data; and (3) additional comparisons need to be made, as more data become available from VAMP releases for recoveries at Antioch, Chipps Island, and the ocean fishery.

Table 4-12. Absolute survival estimates and differential recovery rates based on Chipps Island, Antioch, or ocean recoveries of Merced River Hatchery salmon released as part of South Delta studies between 1996 and 2006

Release Year	San Joaquin River (Merced River origin) Tag Number	Release Number	Release Site	Release Date	Chipps Island Recovs.	Antioch Recovs.	Expanded Adult Ocean Recovs. (Age 1+ to 4+) Total	Chipps Island	Antioch	DRR or CDRR	Ocean DRR
		CWT Smolt Releases						Absolute Survival Estimates		Differential Recovery Rates	
1996	61110412	22,198	Dos Reis	1-May-96	2		3				
	61110413	25,414	Dos Reis	1-May-96	2		37				
	61110414	16,050	Dos Reis	1-May-96	1		8				
	61110415	31,208	Dos Reis	1-May-96	5		10				
	61110501	46,190	Jersey Point	3-May-96	39		186				
	Effective Release	94,870	Dos Reis		10		58	0.120		0.125	0.152
	Effective Release	46,190	Jersey Point		39		186				
1997	62545	48,973	Dos Reis	29-Apr-97	9		180				
	62546	53,483	Dos Reis	29-Apr-97	7		168				
	62547	51,576	Jersey Point	2-May-97	27		356				
	Effective Release	102,456	Dos Reis		16		348	0.290		0.298	0.492
	Effective Release	51,576	Jersey Point		27		356				
	62548	46,674	Dos Reis	8-May-97	5		90	0.3		0.283	0.477
	62549	47,534	Jersey Point	12-May-97	18		192				
1998	61110809	26,465	Mossdale	16-Apr-98	25		60				
	61110810	25,264	Mossdale	16-Apr-98	31		39				
	61110811	25,926	Mossdale	16-Apr-98	32		58				
	61110806	26,215	Dos Reis	17-Apr-98	34		48				
	61110807	26,366	Dos Reis	17-Apr-98	25		35				
	61110808	24,792	Dos Reis	17-Apr-98	34		62				
	61110812	24,598	Jersey Point	20-Apr-98	87		110				
	61110813	25,673	Jersey Point	20-Apr-98	100		91				
	Effective Release	77,655	Mossdale		88		157	0.300		0.305	0.506
	Effective Release	77,373	Dos Reis		93		145	0.320		0.323	0.469
	Effective Release	50,271	Jersey Point		187		201				
1999	62642	24,765	Mossdale	19-Apr-99	8		128				
	62643	24,773	Mossdale	19-Apr-99	15		135				
	62644	25,279	Mossdale	19-Apr-99	13		132				
	62645	25,014	Dos Reis	19-Apr-99	20		151				
	62646	24,841	Dos Reis	19-Apr-99	19		225				
	6.01E+08	25,101	Jersey Point	21-Apr-99	34		334				
	62647	24,359	Jersey Point	21-Apr-99	25		387				
	Effective Release	74,817	Mossdale		36		395	0.380		0.403	0.362
	Effective Release	49,855	Dos Reis		39		376	0.600		0.656	0.517
	Effective Release	49,460	Jersey Point		59		721				
2000	06-45-63	24,457	Durham Ferry	17-Apr-00	11	11	296				
	6/4/2001	23,529	Durham Ferry	17-Apr-00	7	6	215				
	6/4/2002	24,177	Durham Ferry	17-Apr-00	10	10	232				
	06-44-01	23,465	Mossdale	18-Apr-00	9	14	207				
	06-44-02	22,784	Mossdale	18-Apr-00	9	16	174				
	06-44-03	25,527	Jersey Point	20-Apr-00	24	50	649				
	06-44-04	25,824	Jersey Point	20-Apr-00	41	47	704				
	Effective Release	72,163	Durham Ferry		28	27	743	0.310	0.190	0.242	0.391
	Effective Release	46,249	Mossdale		18	30	381	0.310	0.330	0.329	0.313
	Effective Release	51,351	Jersey Point		65	97	1353				
	6.01E+08	23,698	Durham Ferry	28-Apr-00	7	8	46				
	6.01E+08	26,805	Durham Ferry	28-Apr-00	5	15	45				
	6.01E+08	23,889	Durham Ferry	28-Apr-00	10	8	70				
	6.01E+08	25,572	Durham Ferry	1-May-00	48	76	358				
	0601061002	24,661	Jersey Point	1-May-00	30	76	230				
	Effective Release	74,392	Durham Ferry		22	31	161	0.190	0.140	0.156	0.185
	Effective Release	50,233	Jersey Point		78	152	588				

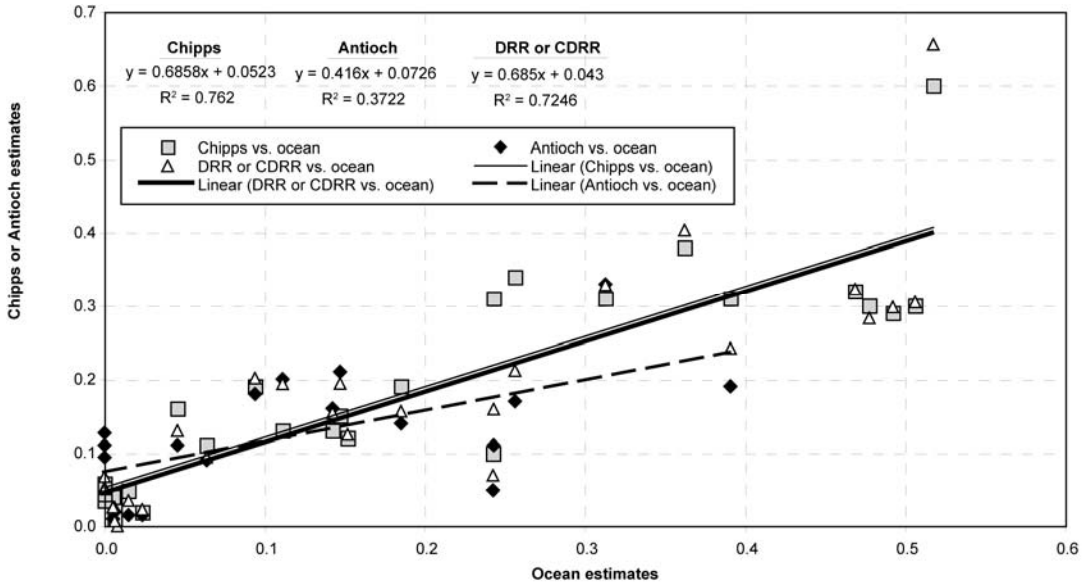
Table 4-12 (cont.). Absolute survival estimates and differential recovery rates based on Chipps Island, Antioch, or ocean recoveries of Merced River Hatchery salmon released as part of South Delta studies between 1996 and 2006

Release Year	San Joaquin River (Merced River origin) Tag Number	Release Number	Release Site	Release Date	Chipps Island Recovs.	Antioch Recovs.	Expanded Adult Ocean Recovs. (Age 1+ to 4+) Total	Chipps Island	Antioch	DRR or CDRR	Ocean DRR
		CWT Smolt Releases						Absolute Survival Estimates		Differential Recovery Rates	
2001	06-44-29	23,351	Durham Ferry	30-Apr-01	14	28	95				
	06-44-30	22,720	Durham Ferry	30-Apr-01	22	30	158				
	06-44-31	22,376	Durham Ferry	30-Apr-01	17	18	111				
	06-44-32	23,022	Mossdale	1-May-01	17	18	122				
	06-44-33	22,191	Mossdale	1-May-01	14	15	106				
	06-44-34	24,444	Jersey Point	4-May-01	50	156	470				
	06-44-35	24,993	Jersey Point	4-May-01	61	173	556				
	Effective Release	68,447	Durham Ferry		53	76	364	0.340	0.170	0.212	0.256
	Effective Release	45,213	Mossdale		31	33	228	0.310	0.110	0.159	0.243
	Effective Release	49,437	Jersey Point		111	329	1026				
	06-44-36	24,029	Durham Ferry	7-May-01	2	8	17				
	06-44-37	23,907	Durham Ferry	7-May-01	5	11	45				
	06-44-38	24,054	Durham Ferry	7-May-01	2	10	28				
	06-44-39	23,882	Mossdale	8-May-01	4	8	25				
	06-44-40	25,310	Mossdale	8-May-01	4	11	27				
	06-44-41	25,910	Jersey Point	11-May-01	17	43	243				
	06-44-42	25,466	Jersey Point	11-May-01	27	53	335				
	Effective Release	71,990	Durham Ferry		9	29	90	0.130	0.200	0.194	0.111
	Effective Release	49,192	Mossdale		8	19	52	0.19	0.18	0.201	0.094
	Effective Release	51,376	Jersey Point		44	96	578				
2002	06-44-71	23,920	Durham Ferry	18-Apr-02	4	11	33				
	06-44-72	25,176	Durham Ferry	18-Apr-02	9	20	96				
	06-44-73	23,872	Durham Ferry	18-Apr-02	4	12	74				
	06-44-74	24,747	Durham Ferry	18-Apr-02	4	20	67				
	06-44-57	25,515	Mossdale	19-Apr-02	6	13	76				
	06-44-58	25,272	Mossdale	19-Apr-02	7	29	69				
	06-44-59	24,802	Jersey Point	22-Apr-02	46	101	494				
	06-44-60	24,128	Jersey Point	22-Apr-02	37	89	456				
	Effective Release	97,715	Durham Ferry		21	63	270	0.13	0.16	0.154	0.142
	Effective Release	50,787	Mossdale		13	42	145	0.15	0.21	0.194	0.147
	Effective Release	48,930	Jersey Point		83	190	950				
	06-44-70	24,680	Durham Ferry	25-Apr-02	3	6	23				
	06-44-75	24,659	Durham Ferry	25-Apr-02	5	2	21				
	06-44-76	24,783	Durham Ferry	25-Apr-02	3	4	7				
	06-44-77	24,381	Durham Ferry	25-Apr-02	4	6	6				
	06-44-78	24,519	Mossdale	26-Apr-02	2	3	26				
	06-44-79	24,820	Mossdale	26-Apr-02	3	4	14				
	06-44-80	24,032	Jersey Point	30-Apr-02	18	43	307				
	06-44-81	22,880	Jersey Point	30-Apr-02	28	32	290				
	Effective Release	98,503	Durham Ferry		15	18	57	0.16	0.11	0.13	0.045
	Effective Release	49,339	Mossdale		5	7	40	0.11	0.09	0.094	0.064
	Effective Release	46,912	Jersey Point		46	75	597				
2003	6/2/1982	24,453	Durham Ferry	21-Apr-03	0	1	9				
	6/2/1983	25,927	Durham Ferry	21-Apr-03	2	4	0				
	6/27/1942	24,069	Durham Ferry	21-Apr-03	1	1	10				
	6/27/1948	24,471	Mossdale	22-Apr-03	2	2	3				
	6/27/1943	25,212	Mossdale	22-Apr-03	3	2	5				
	6/27/1944	24,414	Jersey Point	25-Apr-03	57	71	265				
	Effective Release	74,449	Durham Ferry		3	6	19	0.019	0.015	0.023	0.024
	Effective Release	49,683	Mossdale		5	4	8	0.048	0.015	0.035	0.015
	Effective Release	24,414	Jersey Point		57	71	265				
	6/27/1945	24,685	Durham Ferry	28-Apr-03	0	0	6				
	6/27/1946	25,189	Durham Ferry	28-Apr-03	0	0	0				
	6/27/1947	24,628	Durham Ferry	28-Apr-03	0	0	4				
	6/27/1949	24,180	Mossdale	29-Apr-03	0	0	5				

Table 4-12 (cont.). Absolute survival estimates and differential recovery rates based on Chipps Island, Antioch, or ocean recoveries of Merced River Hatchery salmon released as part of South Delta studies between 1996 and 2006

Release Year	San Joaquin River (Merced River origin) Tag Number	Release Number	Release Site	Release Date	Chipps Island Recovs.	Antioch Recovs.	Expanded Adult Ocean Recovs. (Age 1+ to 4+) Total	Chipps Island	Antioch	DRR or CDRR	Ocean DRR
		CWT Smolt Releases						Absolute Survival Estimates		Differential Recovery Rates	
2003	6/27/1950	24,346	Mossdale	29-Apr-03	1	0	0				
(cont.)	6/27/1951	25,692	Jersey Point	2-May-03	39	35	426				
	Effective Release	74,502	Durham Ferry		0	0	10			0	0.008
	Effective Release	48,526	Mossdale		1	0	5	0.01		0.007	0.006
	Effective Release	25,692	Jersey Point		39	35	426				
2004	6/27/1952	23,440	Durham Ferry	22-Apr-04	0	1	3				
	6/27/1953	21,714	Durham Ferry	22-Apr-04	1	1	0				
	6/27/1954	23,328	Durham Ferry	22-Apr-04	1	0	0				
	6/27/1955	23,783	Durham Ferry	22-Apr-04	1	0	0				
	06-46-70	25,319	Mossdale	23-Apr-04	0	1	0				
	06-45-82	23,586	Mossdale	23-Apr-04	1	0	0				
	06-45-83	24,803	Mossdale	23-Apr-04	2	0	2				
	06-45-80	22,911	Jersey Point	26-Apr-04	25	22	117				
	Effective Release	92,265	Durham Ferry		3	2	3	0.03	0.02	0.026	0.006
	Effective Release	73,708	Mossdale		3	1	2	0.04	0.01	0.026	0.005
	Effective Release	22,911	Jersey Point		25	22	117				
2005	06-46-72	23,414	Durham Ferry	2-May-05	5	0	0				
	06-46-73	23,193	Durham Ferry	2-May-05	2	2	0				
	06-46-74	23,660	Durham Ferry	2-May-05	4	3	3				
	06-46-75	23,567	Durham Ferry	2-May-05	1	1	0				
	06-46-97	22,302	Dos Reis	3-May-05	1	1	0				
	06-46-98	24,149	Dos Reis	3-May-05	1	3	0				
	06-45-91	22,675	Dos Reis	3-May-05	1	3	0				
	06-45-88	22,767	Jersey Point	6-May-05	32	31	3				
	Effective Release	93,834	Durham Ferry		12	6	3	0.099	0.049	0.069	0.243
	Effective Release	69,126	Dos Reis		3	7	0	0.035	0.11	0.052	0
	Effective Release	22,767	Jersey Point		32	31	3				
	06-45-84	22,777	Durham Ferry	9-May-05	2	1	0				
	06-45-85	22,968	Durham Ferry	9-May-05	1	1	0				
	06-45-86	23,012	Durham Ferry	9-May-05	3	3	0				
	06-45-87	22,806	Durham Ferry	9-May-05	0	2	0				
	06-45-89	21,443	Dos Reis	10-May-05	3	5	0				
	06-45-90	23,755	Dos Reis	10-May-05	2	2	0				
	06-46-99	23,448	Dos Reis	10-May-05	1	0	0				
	06-47-00	23,231	Jersey Point	13-May-05	38	27	14				
	Effective Release	91,563	Durham Ferry		6	7	0	0.044	0.094	0.051	0
	Effective Release	68,646	Dos Reis		6	7	0	0.058	0.127	0.068	0
	Effective Release	23,231	Jersey Point		38	27	14				
2006	06-47-13	24,703	Mossdale	4-May-06	7	5	0				
	06-47-14	24,315	Mossdale	4-May-06	2	4	0				
	06-47-16	25,602	Dos Reis	5-May-06	7	3	0				
	06-47-15	26,192	Jersey Point	8-May-06	58	26	0				
	Effective Release	49,018	Mossdale		9	9	0	0.08	0.18	0.115	
	Effective Release	25,602	Dos Reis		7	3	0	0.12	0.11	0.122	
	Effective Release	26,192	Jersey Point		58	26	0				
	06-47-21	25,105	Mossdale	19-May-06	2	0	0				
	06-47-22	24,008	Mossdale	19-May-06	0	0	0				
	06-47-24	23,980	Jersey Point	22-May-06	44	14	0				
	Effective Release	49,113	Mossdale		2	0	0	0.03	0	0.017	
	Effective Release	23,980	Jersey Point		44	14	0				

Figure 4-18. Comparison of Antioch and Chipps Island survival estimates and differential or combined differential recovery rates compared to differential ocean recovery rates for 1996-2006 CWT releases



San Joaquin River Salmon Protection

One of the VAMP objectives is to provide improved conditions to increase the survival of juvenile Chinook salmon smolts produced in the San Joaquin River tributaries during their downstream migration through the lower river and Delta. It is hypothesized that these actions to improve conditions for the juveniles will translate into greater adult abundance and escapement in future years than would otherwise occur without the actions.

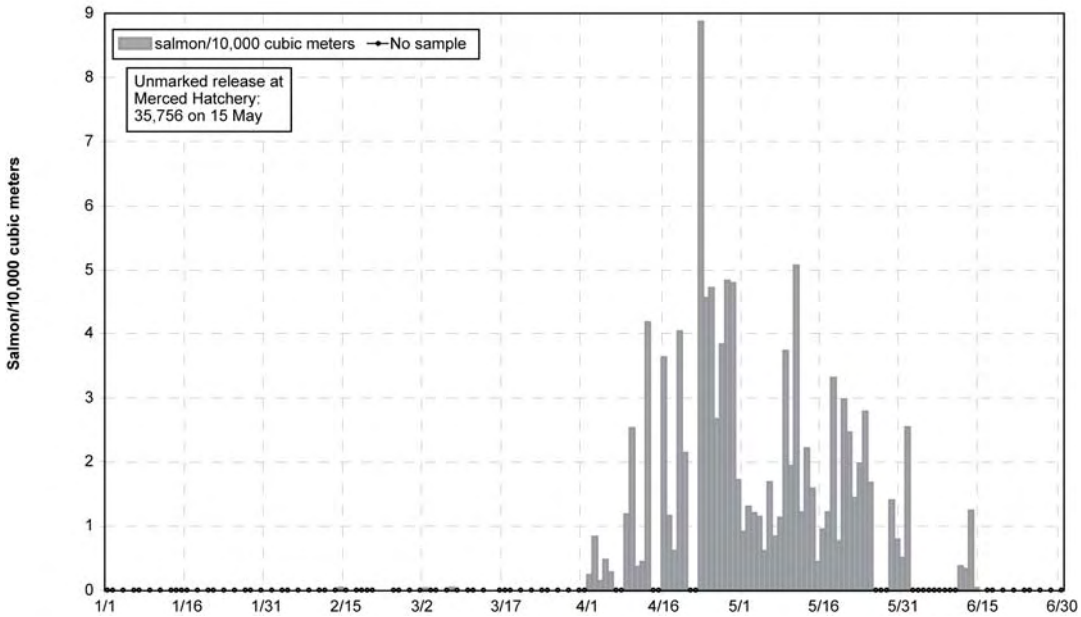
To determine if VAMP has been successful in targeting the migration period of naturally produced juvenile salmon, catches of unmarked salmon at Mossdale and in salvage at the CVP and SWP facilities were compared prior to and during the VAMP period.

Unmarked and Marked Salmon Captured at Mossdale

The typical time period for VAMP (April 15 to May 15) was chosen based on historical data that indicated a high percentage of the juvenile salmon emigrating from the San Joaquin tributaries passed into the Delta at Mossdale during that time. The peak average catch per 10,000 cubic meters per day of unmarked juvenile salmon captured at Mossdale occurred on April 23—densities may have been as high or higher on April 21 and 22 when no sampling was conducted at Mossdale and river flows were increasing. In 2007, the VAMP period was April 22 to May 22. The average daily density of unmarked juvenile salmon caught in Kodiak trawling at Mossdale during January through June is shown in Figure 4-19. Unmarked salmon do not have an adipose clip and can be juveniles from natural spawning or unmarked hatchery fish from the MRH. On May 15 a total of 35,756 unmarked smolts were released at MRH and this was the only release of unmarked hatchery smolts from MRH conducted during 2007. Peak density of unmarked juvenile salmon at Mossdale was observed on April 23 and immediately followed the leading edge of the VAMP pulse flow. (Figure 4-19). The size of the juvenile salmon captured in the Mossdale trawl during January through June is shown in Figure 4-20. Recaptures of adipose finclipped CWT salmon released at Merced River Hatchery on April 20 and May 4 and at Hatfield on

April 24–26 and May 8–9 were prominent in the catch at Mossdale during April 27–30 and May 9–13. The adipose fin-clipped juvenile salmon captured at Mossdale on April 4 was a wild migrant captured and tagged on the Stanislaus River at Caswell.

Figure 4-19. Average daily densities of unmarked salmon caught in the Mossdale Kodiak



Salmon Salvage and Losses at Delta Export Pumps

Fish salvage operations at the CVP and SWP export facilities capture juvenile salmon and transport them by tanker truck to release sites in the western Sacramento-San Joaquin Delta. The untagged salmon are potentially from any source in the Central Valley. It is not certain which unmarked salmon recovered are of San Joaquin basin origin, although the timing of salvage and fish size can be compared with Mossdale trawl data and CWT recovery data for MRH smolts at the salvage facilities to provide indications to the unmarked fish's origin.

The estimated salmon losses at the CVP and SWP facilities are based on expanded salvage and an estimate of screen efficiency and survival through the facility and salvage process. The CVP pumps divert directly from the Old River channel and direct losses are estimated to range from about 50 to 80% of the number salvaged. Four to 5 salmon are estimated to be lost per salvaged salmon at the SWP because of high predation rates in Clifton Court Forebay. The SWP loss estimates are therefore about 6 to 8 times higher, per salvaged salmon, than for the CVP. The loss estimates do not include any indirect mortality in the Delta due to water export operations or additional mortality associated with post-release predation.

Density of salmon encountering both of the export and fish salvage facilities off Old River is represented by the combined salvage and loss estimated per acre-foot of water pumped. The Department of Fish and Game and DWR maintain a database of daily, weekly, and monthly salvage data. The number and density of juvenile salmon that migrated through the system, the placement of the HORB, and the amount of water pumped by each facility are some of the factors that influence the number of juvenile salmon salvaged and lost.

Density is an indicator of when concentrations of juvenile salmon may be more susceptible to the export facilities and salvage system. Additionally, salvage efficiency is lower for smaller-sized salmon (fry and presmolts) so their salvage numbers and estimated losses are underrepresented.

The weekly data covering the period of April 23 to May 20 approximated the 2007 VAMP period. A review of weekly data for January through June indicates that the highest CVP salvage and losses occurred during the 2 weeks preceding the VAMP period, with lesser peaks during early March, (Figure 4-21). Highest SWP salvage and losses occurred during the week immediately preceding the VAMP period, with lesser peaks during early March and early April (Figure 4-22). Salmon densities based on combined salvage and loss estimates were highest at the CVP during the 2 weeks immediately preceding the VAMP period and during the 3 weeks immediately following the VAMP period, with a smaller peak during early March (Figure 4-23). At the SWP, salmon densities were highly variable with peak densities occurring immediately preceding the VAMP period, during the VAMP period, and late May into early June (Figure 4-23); lesser peaks were observed during early March and early April. The peak at both facilities during April preceding VAMP occurred when exports greatly exceeded Vernalis flow; the peaks observed after VAMP occurred during decreasing flow and export (Figure 4-24).

The size distribution of unmarked salmon during January through June in the Mossdale trawl (Figure 4- 20) generally overlaps with the size distribution of those salvaged at the fish facilities (Figure 4-25, Source E. Chappell, DWR). Based on comparisons with Mossdale data, some salmon salvaged before, during, and after the VAMP period could have been from the San Joaquin basin (Figure 4-19).

The 2007 VAMP test period coincided with part of the peak period of San Joaquin River salmon smolt emigration. The highest daily density observed at Mossdale was on the second day of the VAMP period (April 23), and it is unfortunate that sampling was not conducted during the 2 days preceding the observed peak when flows were increasing. Smolt abundance and production estimates at Mossdale could be improved by ensuring that sampling is conducted daily when salmon smolts are emigrating. The most concentrated period of estimated losses in 2007 occurred in April prior to VAMP export reduction, as has been recorded in other years. Export curtailments may be more protective if based on real-time migration activity observed at Mossdale or observed salvage/density at the export facilities.

References Cited

California Department of Water Resources. 2006. Figure 4-25 Observed Chinook Salvage at the SWP and CVP Delta Fish Facilities, Aug 1, 2006 through July 31, 2007 from Erin Chappell, Division of Environmental Services.

San Joaquin River Group Authority. 2007. 2006 Annual Technical Report on the Implementation and Monitirong of the San Joaquin River Agreement and the Vernalis Adaptive Management Plan. January 2007. 137 pgs.

Vogel, D.A. 2006. Evaluation of acoustic telemetry equipment for monitoring juvenile Chinook salmon. Natural Resource Scientists, Inc. Report prepared for the California Department of Water Resources. March 2006. 56 pgs.

Figure 4-20. Mossdale Kodiak trawl individual daily forklengths of juvenile Chinook salmon, January through June 2007

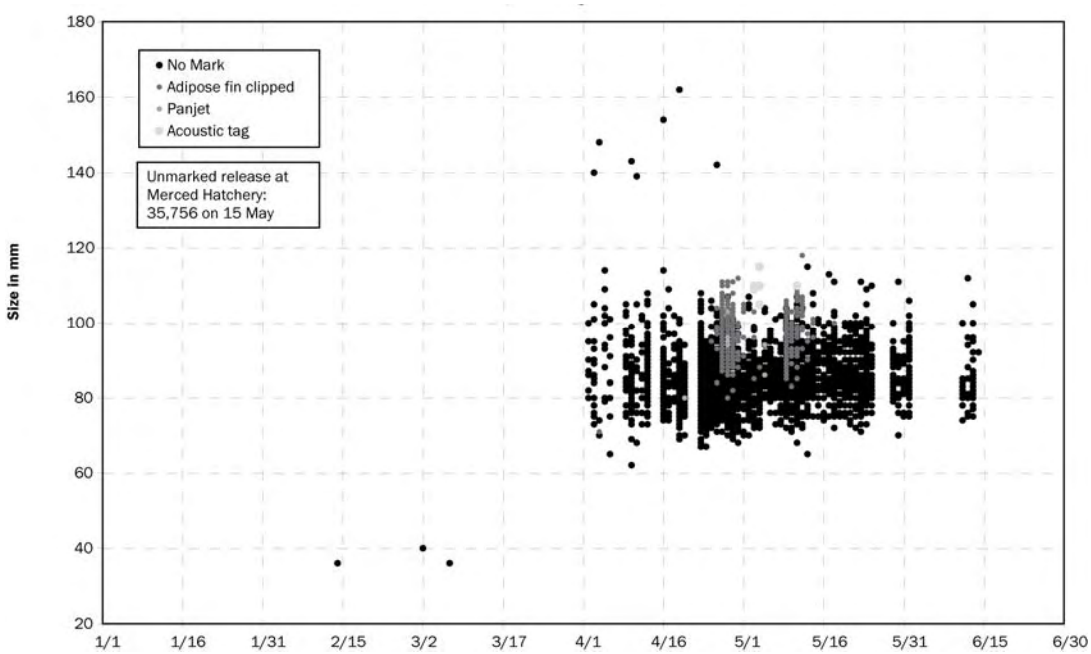


Figure 4-21. CVP estimated salmon salvage and loss, 2007

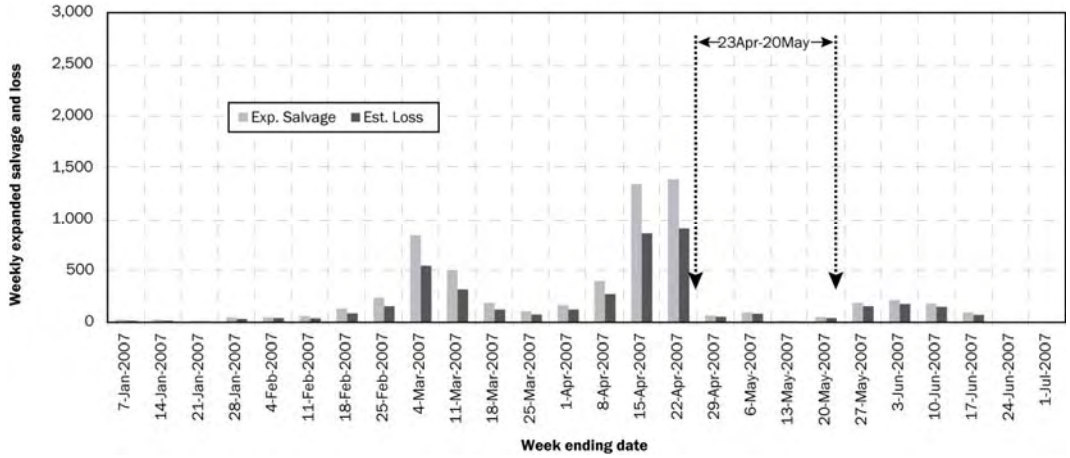


Figure 4-22. SWP estimated salmon salvage and loss, 2007

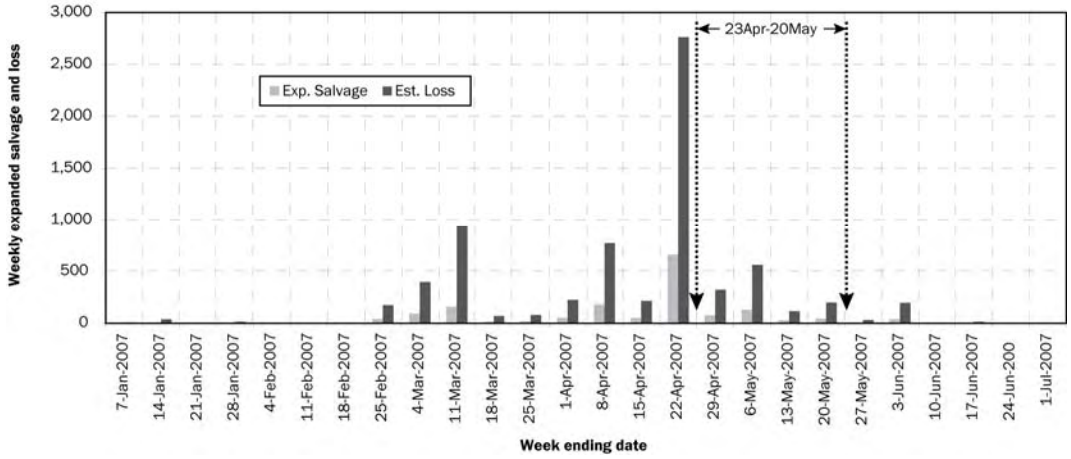


Figure 4-23. SWP and CVP combined salvage and loss density, 2007

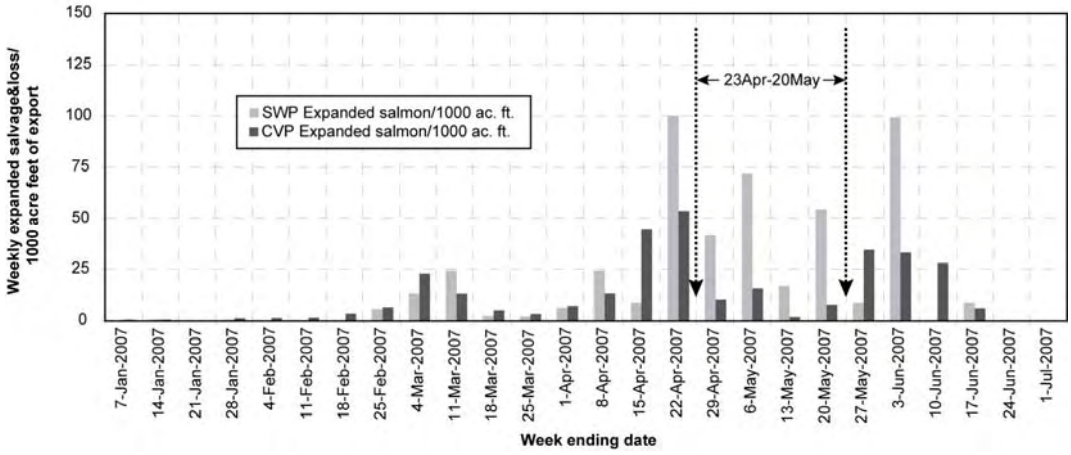


Figure 4-24. Weekly export rates and Vernalis flow, 2007

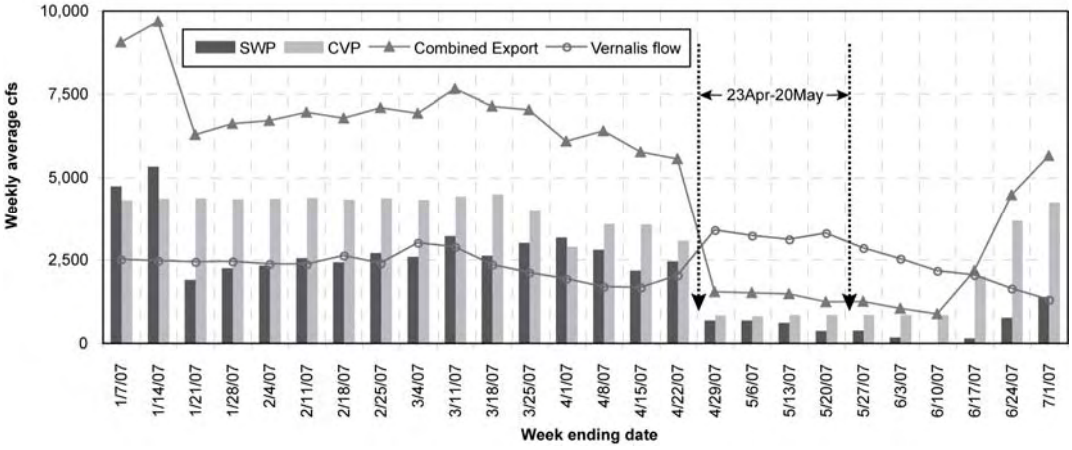
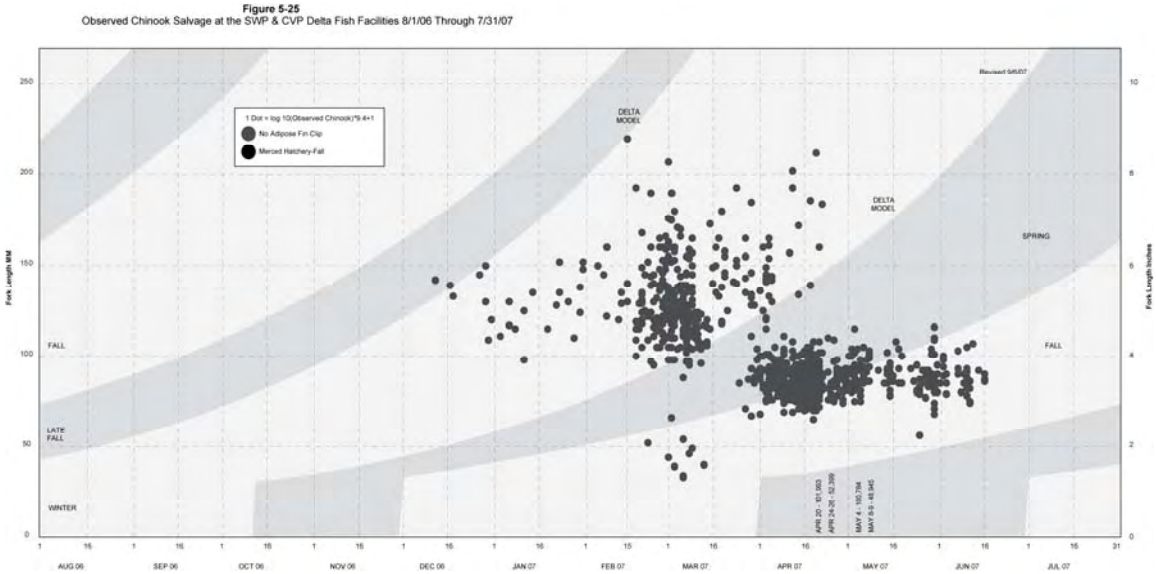


Figure 4-25. Observed Chinook Salvage at the SWP and CVP Delta Fish Facilities, Aug 1, 2006 through July 31, 2007 (large format 11x17)



(11X 17 figure in separate document online)

Chapter 5. Annual Summary Report of SWP and CVP Salvage

This Annual Summary Report of State Water Project (SWP) and Central Valley Project (CVP) Salvage is being included in the Temporary Barriers Project (TPB) annual report with the intention of evaluating whether or not seasonal temporary fish barriers reduce fishery impacts by reducing entrainment of fish at the Skinner (SWP) and Tracy (CVP) fish facilities. Due to the complexities involved with analyzing a multitude of variables including export rates, local population dynamics of fishes in the south Delta and Clifton Court Forebay, Delta hydrodynamics, barrier influences of the south Delta flow, etc., an appropriate methodology has proven difficult to ascertain. As a result of these complexities, this section focuses solely on presenting the available data regarding changes in temporary barrier operations, project exports, and listed species salvaged at both the SWP and CVP facilities during 2007.

Data Collection

Skinner and Tracy salvage data were downloaded from the Department of Fish and Game's Bay-Delta Office ftp Web site (ftp://ftp.delta.dfg.ca.gov). Project water exports were provided by the Department of Water Resources from the Division of Operations and Maintenance, SWP Operations Control Branch, Operations Scheduling Section. Barrier operations were obtained from the Temporary Barriers Project "Weekly Updates" and "Schedule of Operations," which are posted on the DWR South Delta Branch Web site (http://sdelta.water.ca.gov).

Methods

Daily water export data (expressed as percent relative exports) and fish salvage data were graphed for each listed fish species entrained at either the SWP or the CVP facility. Listed fish species include: Chinook salmon, steelhead, splittail, longfin smelt, and Delta smelt (Figures 5-1 through 5-10[1]).

Each figure illustrates the operations of the spring Head of Old River barrier (spring HORB), shown as vertical dotted lines, identifying when the barrier was put into operation (closed) and sufficiently removed (breached) to allow the return of pre-barrier flow. Incomplete installations and barrier-specific operational adjustments, such as culvert configuration changes and the notching of weirs may have altered flow, and are noted in Table 5-1.

[1] These figures appear at the back of this chapter.

Table 5-1. Location and barrier-specific operational adjustments

Location	Installation (2007)			Notched (2007)	Removed (2007)		
	Started	Closed	Completed		Started	Breached	Completed
Old River nr Tracy	2-Apr	18-Apr	23-Apr	21-Sep	5-Nov	7-Nov	18-Nov
Spring HORB	11-Apr	20-Apr	26-Apr	n/a	19-May	22-May	6-Jun
Fall HORB	5-Oct	17-Oct	18-Oct	18-Oct	9-Nov	10-Nov	29-Nov
Middle River	7-Apr	10-Apr	21-Sep	21-Sep	19-Nov	20-Nov	29-Nov
Grant Line Canal (Partial)	9-Apr	17-Apr	17-Apr	17-Apr	n/a	n/a	n/a
Grant Line Canal (Completed)	27-Apr	10-May	11-May	10-May (flashboards adjusted)	6-Nov	8-Nov	29-Nov

Although all the temporary barriers are noted in Table 5-1, the spring HORB is the only barrier included in the figures due to its intended purpose as a fish barrier (the remaining barriers serve as agricultural barriers). According to the 2008 Biological Opinion created by NOAA, "The Head of Old River Barrier is designed to improve migration conditions for Central Valley fall-run Chinook salmon originating in the San Joaquin River watershed during adult and juvenile migrations (i.e., fall and spring) by 'blocking' migratory movements into the Old River channel from the mainstem San Joaquin River."

Fish Salvage Concerns

An examination of fish salvage as a sample of entrained fishes is complicated due to differences in how fish species and age groups respond to environmental conditions. The SWP and CVP fish facilities are not designed to effectively sample all fish equally. Salvage efficiency is related to the size of the fish, species and age groups. In addition, due to the inherent variability in sizes of fish populations from year to year, significantly large proportions of stocks may be entrained because of their inability to escape the pumps' zone of influence. Larval fishes are especially susceptible to entrainment.

Differences in SWP and CVP fish collection configurations complicate a comparison of the daily project salvage data relative to position of species in the south Delta. The simple presence of Clifton Court Forebay prior to entry into the SWP fish facility may directly or indirectly alter salvage estimates at this facility.

Salvage Observations

Daily water export and fish salvage data are presented in graphical form (Figures 5-1 through 5-10) using percent relative exports and listed fish species for both the SWP and the CVP. These figures are summarized in Table 5-2.

Table 5-2. Summary of chapter figures

Figure	Location	Dates	Species
5-1	SWP	1/1/07-12/23/07	Chinook salmon
5-2	CVP	1/1/07-12/23/07	Chinook salmon
5-3	SWP	1/24-07-6/8/07	Steelhead
5-4	CVP	1/24-07-6/8/07	Steelhead
5-5	SWP	2/10/07-11/30/07	Splittail
5-6	CVP	2/10/07-11/30/07	Splittail
5-7	SWP	1/20/07-12/20/07	Longfin smelt
5-8	CVP	1/20/07-12/20/07	Longfin smelt
5-9	SWP	2/15/07-7/20/07	Delta smelt
5-10	CVP	2/15/07-7/20/07	Delta smelt

As mentioned in the Fish Salvage Concerns section, there are complications in drawing specific conclusions regarding the effect of the temporary barriers on fish populations using the available data. Water export fluctuation (both natural and human-induced) and the inherent variability in fish population dynamics from year to year, regardless of temporary barriers, make it difficult to accurately assess the data and make correlations. Therefore, export and salvage data are presented for documentation purposes only.

Recommendations

It appears that significant correlations between fish species densities and changes in water project hydrodynamics are complicated by variability of fish sampling and yearly water fluctuations. Due to this uncontrolled variability, the data collected for this monitoring report does not provide the ability to draw accurate conclusions. The use of this data for analysis would be aided by the inclusion of ecological data on fish populations in the Delta. This type of data may be available from additional research activities including DWR's Interagency Ecological Program (IEP) studies and the Operating Criteria and Plan (OCAP) for the Central Valley Project (CVP) and the State Water Project (SWP) studies. It is recommended that future monitoring reports incorporate additional ongoing research data (i.e. IEP and OCAP data) to gain a more focused understanding of the baseline conditions of fish populations by year and compare that to salvage data and the use of the Temporary Barriers.

References

DWR, 2002. 2002 South Delta Temporary Barriers Monitoring Report.

DWR, 2005. 2003 South Delta Temporary Barriers Monitoring Report.

DWR, 2006. 2004 South Delta Temporary Barriers Monitoring Report.

DWR, 2006. 2005 South Delta Temporary Barriers Monitoring Report.

DWR, 2008. 2006 South Delta Temporary Barriers Monitoring Report.

National Oceanic and Atmospheric Administration, 2008. Biological Opinion for the "Reinitiation of formal consultation for the South Delta Temporary Barriers Project and extension of the Project until 2010".

Figure 5-1. Percent relative exports and Chinook salmon salvage for the State Water Project, Jan 1 to Dec 23, 2007

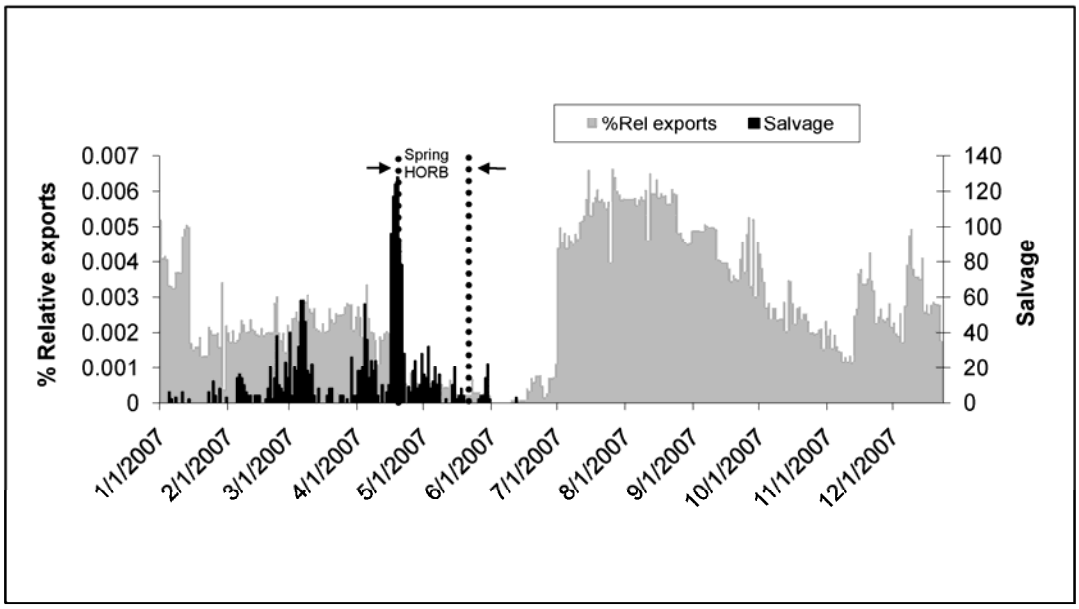


Figure 5-2. Percent relative exports and Chinook salmon salvage for the Central Valley Project, Jan 2 to Dec 23, 2007

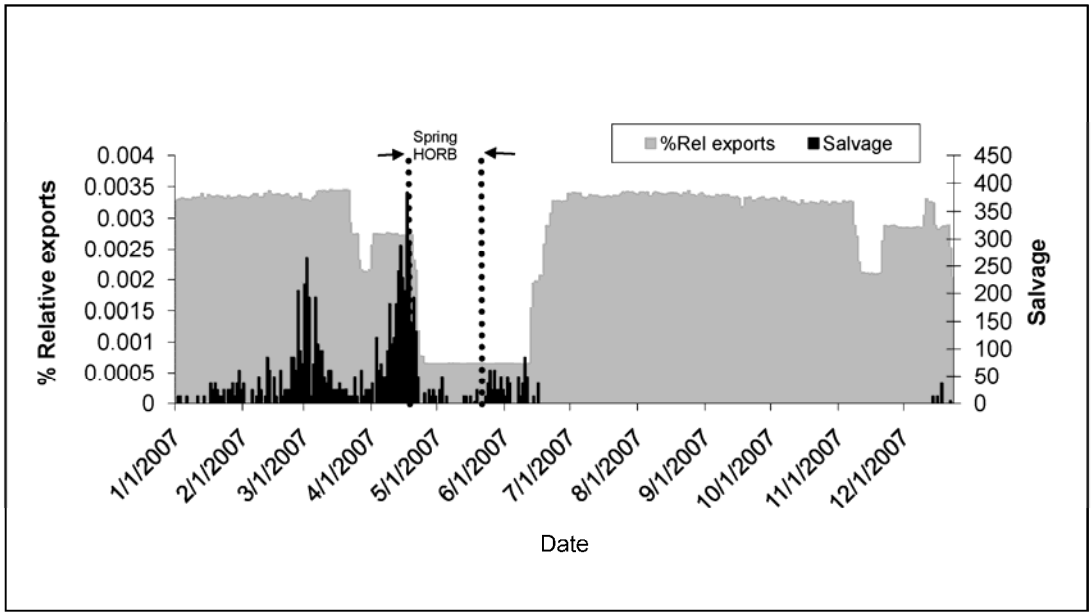


Figure 5-3. Percent relative exports and steelhead salvage for the State Water Project, Jan 24 to June 8, 2007

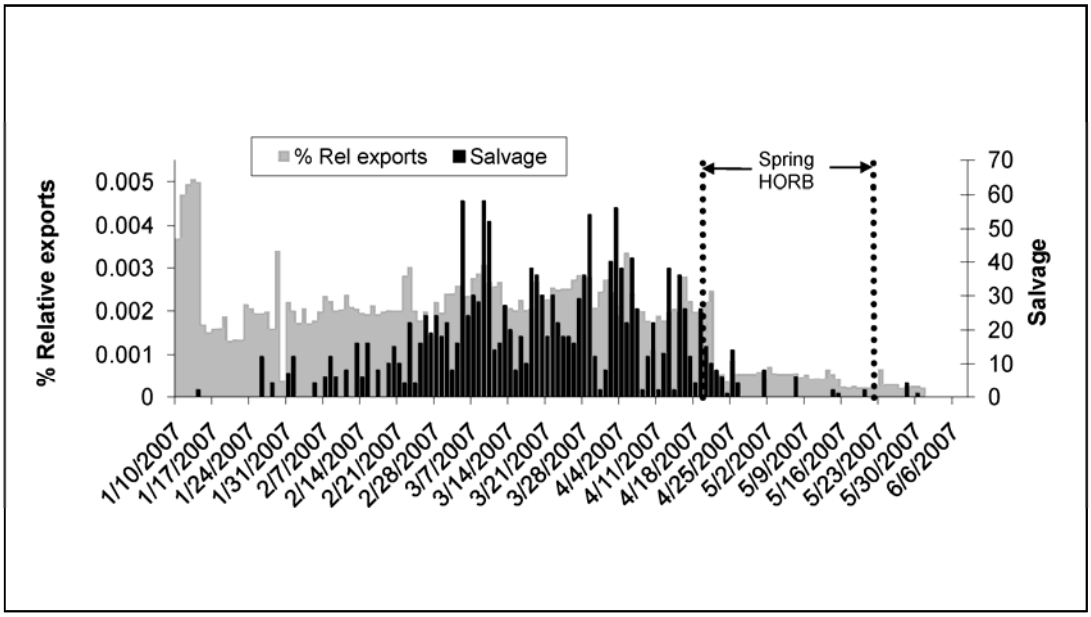


Figure 5-4. Percent relative exports and steelhead salvage for the Central Valley Project, Jan 24 to June 8, 2007

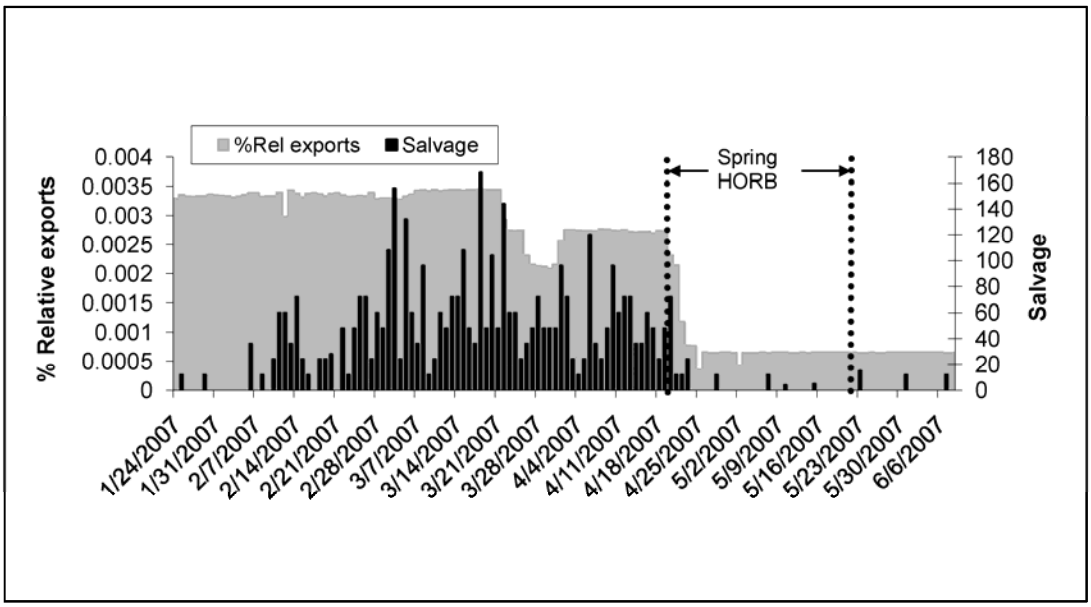


Figure 5-5. Percent relative exports and splittail salvage for the State Water Project, Feb 10 to Nov 30, 2007

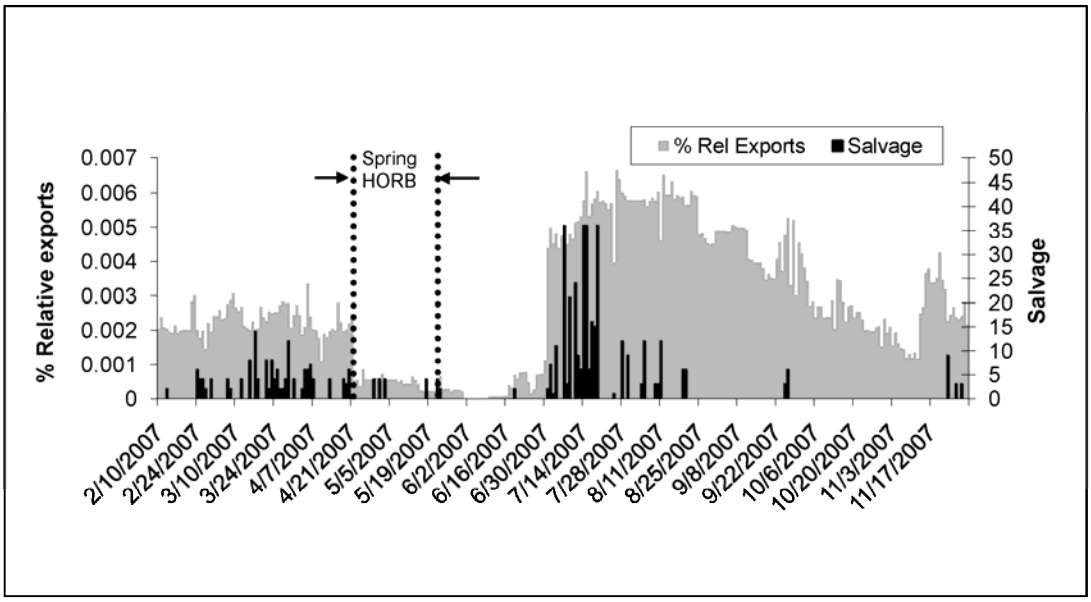


Figure 5-6. Percent relative exports and splittail salvage for the Central Valley Project, Feb 10 to Nov 30, 2007

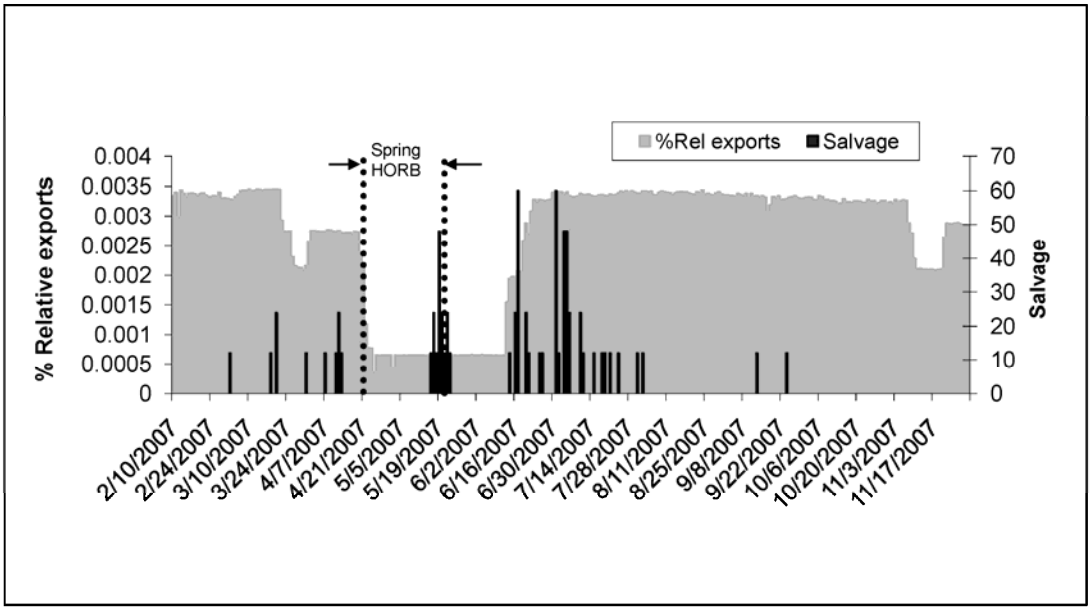


Figure 5-7. Percent relative exports and longfin smelt salvage for the State Water Project, Jan 20 to Dec 20, 2007

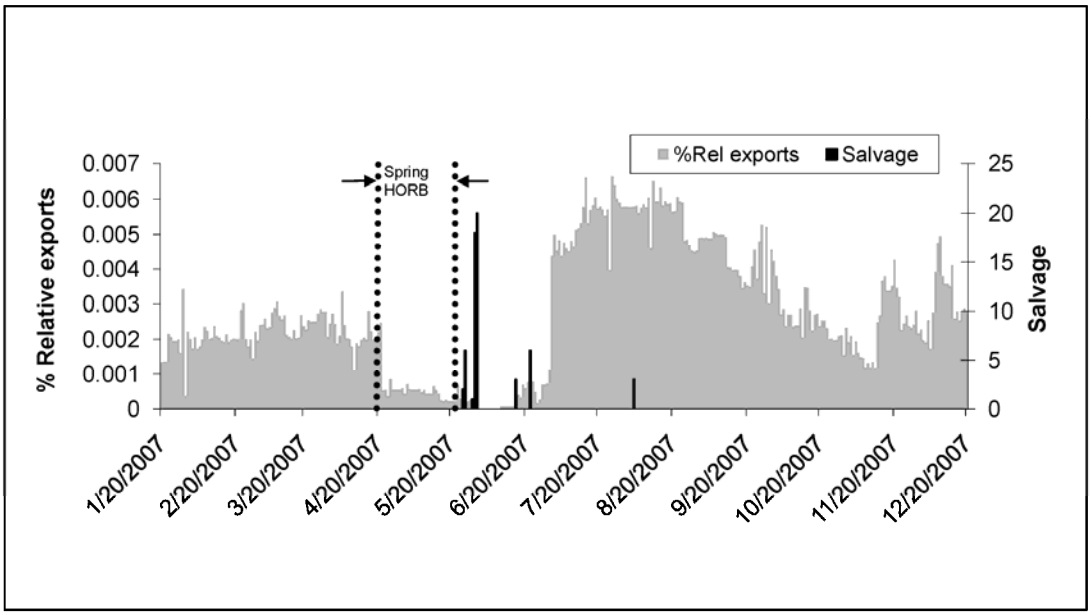


Figure 5-8. Percent relative exports and longfin smelt salvage for the Central Valley Project, Jan 20 to Dec 20, 2007

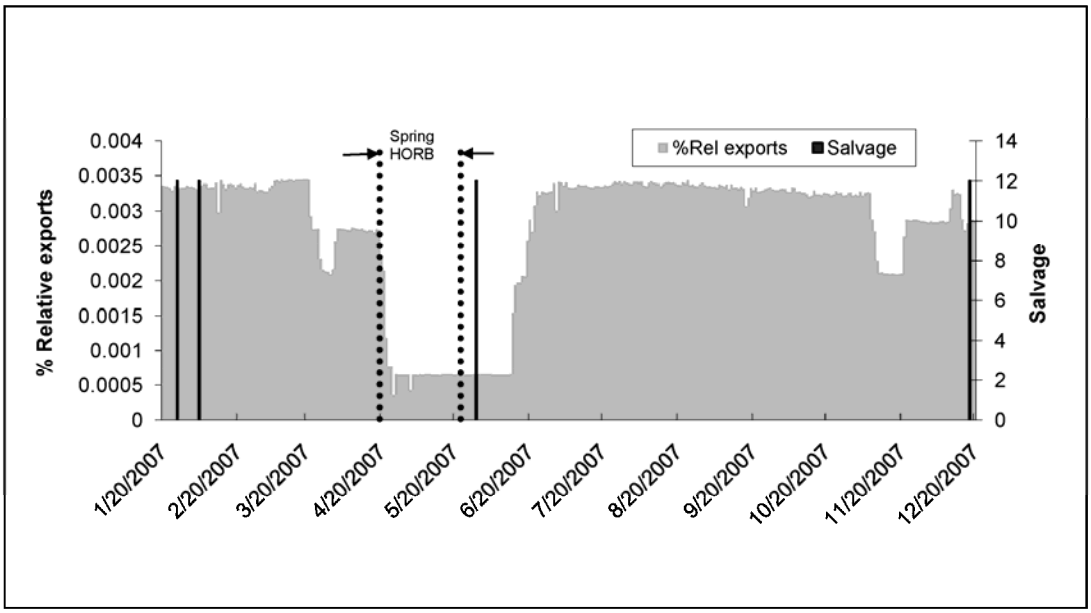


Figure 5-9. Percent relative exports and Delta smelt salvage for the State Water Project, Feb 15 to July 20, 2007

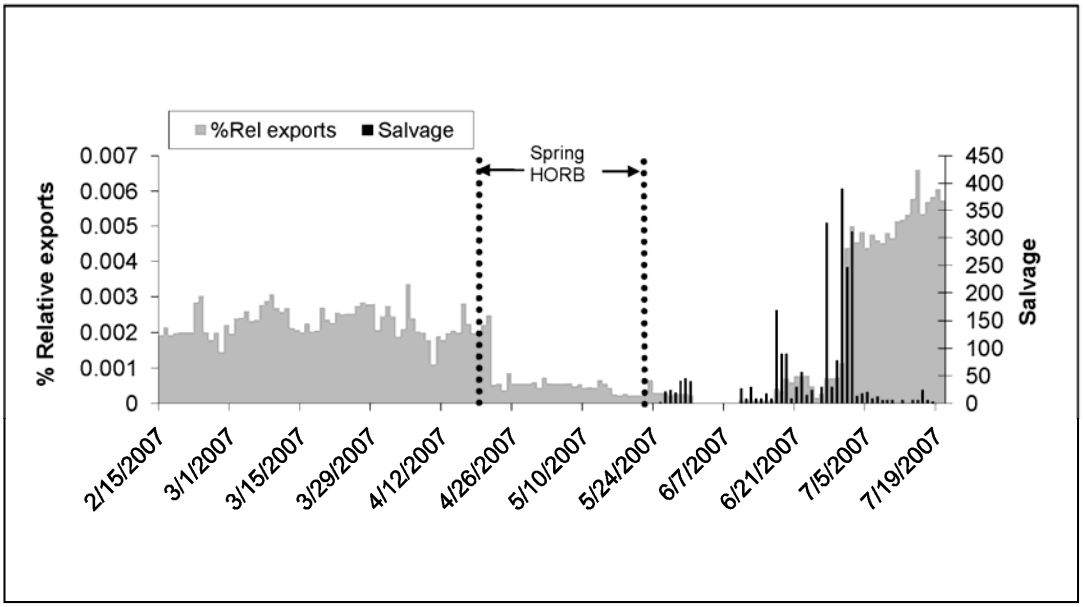
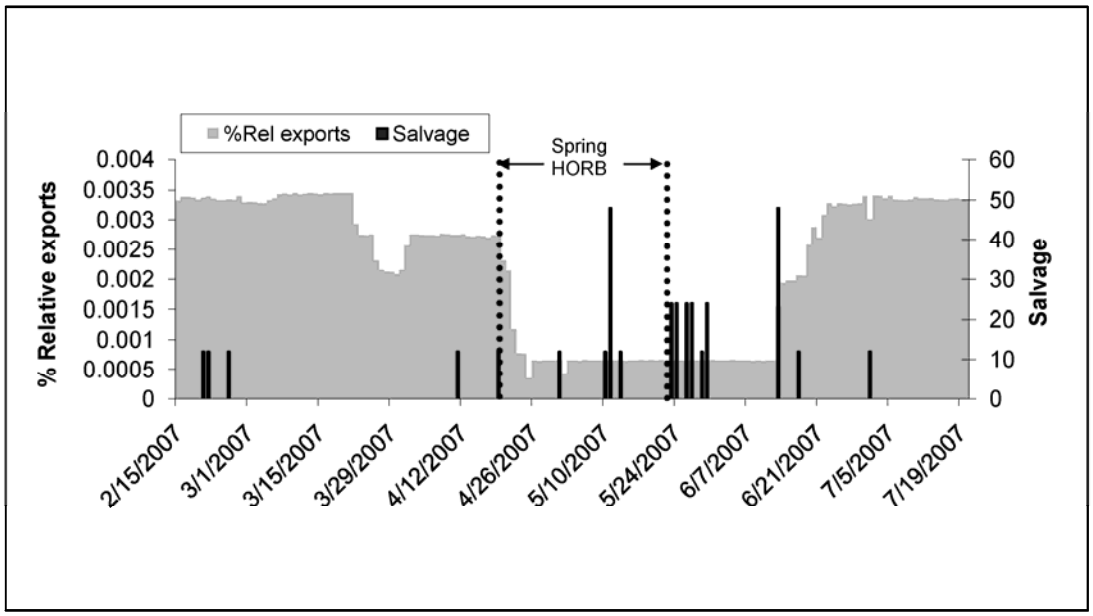


Figure 5-10. Percent relative exports and Delta smelt salvage for the Central Valley Project, Feb 15 to July 20, 2007



Chapter 6. Swainson's Hawk Survey and Monitoring Report for the Temporary Barriers Project, 2007 Construction Season

Swainson's Hawk surveys were initiated at the Temporary Barriers Project (TBP) construction and storage sites on April 2, 2007, the date construction was initiated at the Old River near Tracy barrier. Because of the late notice to begin construction, the Department of Fish and Game Incidental Take Permit (ITP) requirement of 5- and 3-day preconstruction surveys for Swainson's hawks (and other nesting raptors) was not met. A waiver was received from DFG to forgo the preconstruction surveys other than the day-of survey, in part because Swainson's Hawks do not typically begin nesting until mid-April. One Swainson's Hawk was building a nest upstream of the barrier and rock storage site, but it was well beyond the half-mile buffer afforded to nesting Swainson's Hawks. Swainson's Hawk pairs were observed at previously used nest sites, already defining and defending territories.

Additionally, Great-horned Owl nests and Red-tailed Hawk nests were observed close to construction sites. Those species have been somewhat ignored in the past, but Best Management Practices should be implemented to provide them with at least minimal protections during nesting, which is recommended for the 2008 construction season.

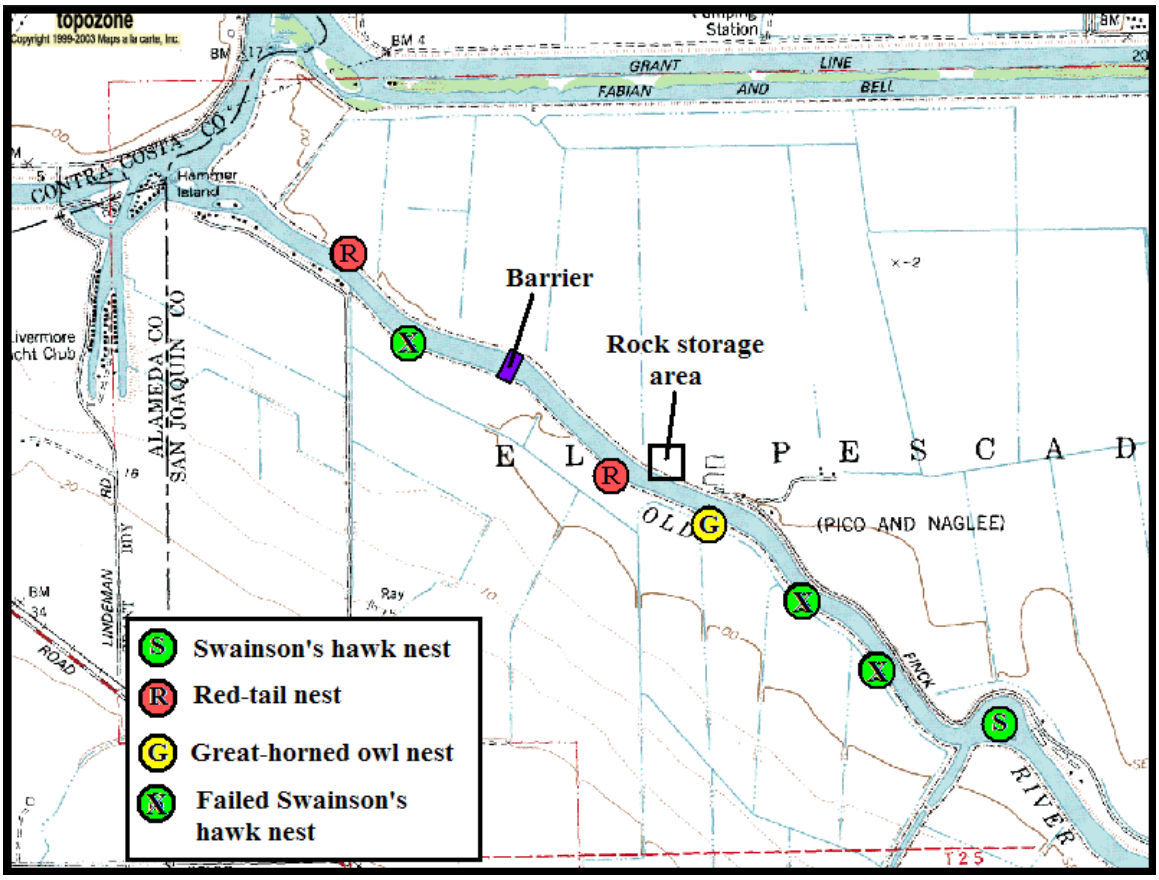
Old River at ORT Barrier

Barrier construction and Swainson's Hawk surveys were initiated on April 2. A Swainson's Hawk was constructing a nest in the pine tree on the in-stream island well upstream of the barrier site (Figure 6-1). Red-tailed Hawks were on nests in an alder on the south levee between the barrier location and rock storage site and in the pine tree on the north levee well down stream of the barrier. Great-horned Owls were on a nest in an alder on the south levee directly south of the packing sheds next to the rock storage area.

Between April 2 and May 24 all nests were monitored at time intervals required in the ITP. During that time Swainson's Hawks constructed nests and laid eggs (evidenced by female in nest in brood position) at 4 locations along Old River. The Red-tailed Hawk nest was observed with 3 chicks, which were presumed to have fledged the first week of June. The Great-horned Owl nest was observed with 1 chick, which likely fledged by the end of April or first week of May.

Swainson's Hawks were last observed at the 3 nest sites closest to the barrier on May 24, still in brood position. By June 21, all 3 nests were abandoned. In June, large-scale grading at the Mountain House development adjacent to the south levee was initiated, which included removing vegetation from the south levee immediately adjacent to the 3 nest sites. That disturbance likely caused the abandonment of the 3 nest sites, which were particularly vulnerable to disturbance because of the relatively short trees used by the hawks. In contrast, the Swainson's Hawks that nested on the in-stream island away from the Mountain House construction activities raised 1 chick which likely fledged around the last week of June.

Figure 6-1. Location of nests on Old River near the ORT barrier



Grant Line Canal Barrier and Accessory Areas

Barrier Site

Surveys were initiated on April 2, and 3 pairs of Swainson's Hawks were observed: one pair was observed in its traditional territory upstream of the barrier site; the second pair was observed at the large cottonwood next to the barrier location; the third pair established a territory in the walnuts along the haul road, just north of the barrier site (Figure 6-2). The pair closest to the barrier was not observed again, even prior to the initiation of construction of the barrier's boat ramps the week of April 13. The pair that looked like it would nest in the walnut along the haul road never constructed a nest. The (a) pair that typically nests upstream of the barrier nested there again, in a large cottonwood; that pair hatched one chick, observed in late June, and presumed to have fledged.

Howard Road Storage Site

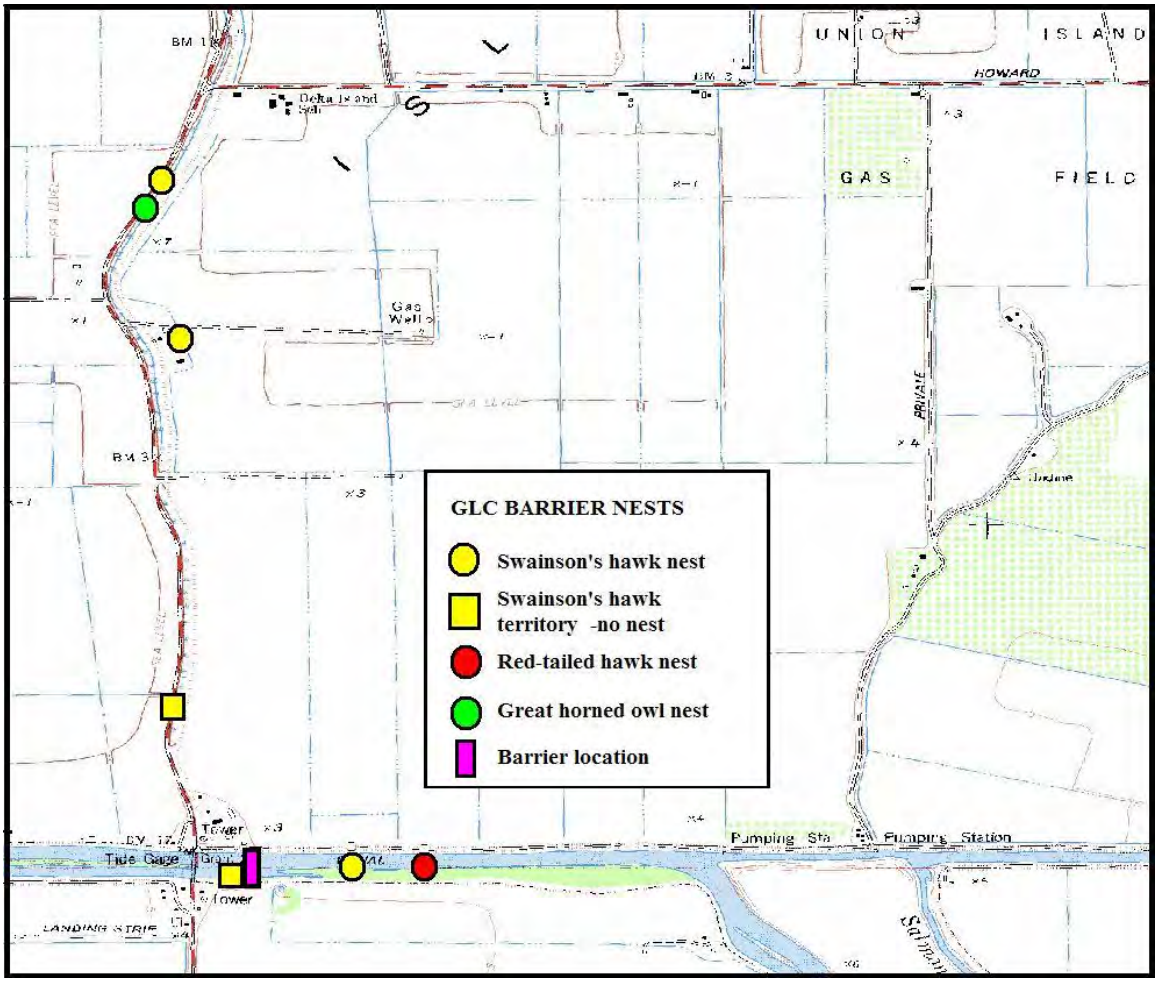
Two pairs of Swainson's Hawks were observed establishing territories near the rock storage site: one along Tracy Boulevard in a willow tree, and one northwest of the storage area in a eucalyptus tree. The pair that was observed along Tracy Boulevard nested in the willow; two young were observed on June 21 and were presumed to have fledged. The pair that was noted northwest of the storage area (likely the same pair that nested in the eucalyptus tree in previous years) apparently moved farther north to a willow tree in the riparian corridor along Tracy Boulevard, a nest site that has also been used in previous years

by Swainson's Hawks. That site is beyond half mile of the Howard Road storage area so monitoring of the pair was discontinued.

Haul Road between Rock Storage Site and Barrier Site

Three pairs of Swainson's Hawks were observed initiating nesting activities along the haul road. The Tracy Boulevard pair and walnut tree pair are discussed above. A third pair nested in the large walnut trees adjacent to the active farmyard near the intersection of Clifton Court Road and Tracy Boulevard. A pair(s) of Swainson's Hawks has nested at that site fairly consistently for 12 years. Other than to note their ongoing presence, no monitoring was done for the pair due to an inability to see the nest without trespassing on private property. Additionally, other than trucks passing 100 yards from the nest, no other TBP construction activities take place near the nest. TBP truck traffic blends well with the traffic on Tracy Boulevard and activity in the farmyard, and there has been no indication that the pair has been affected by the use of the haul road.

Figure 6-2. Raptor nests and territories at the Grant Line Canal barrier site and accessory areas

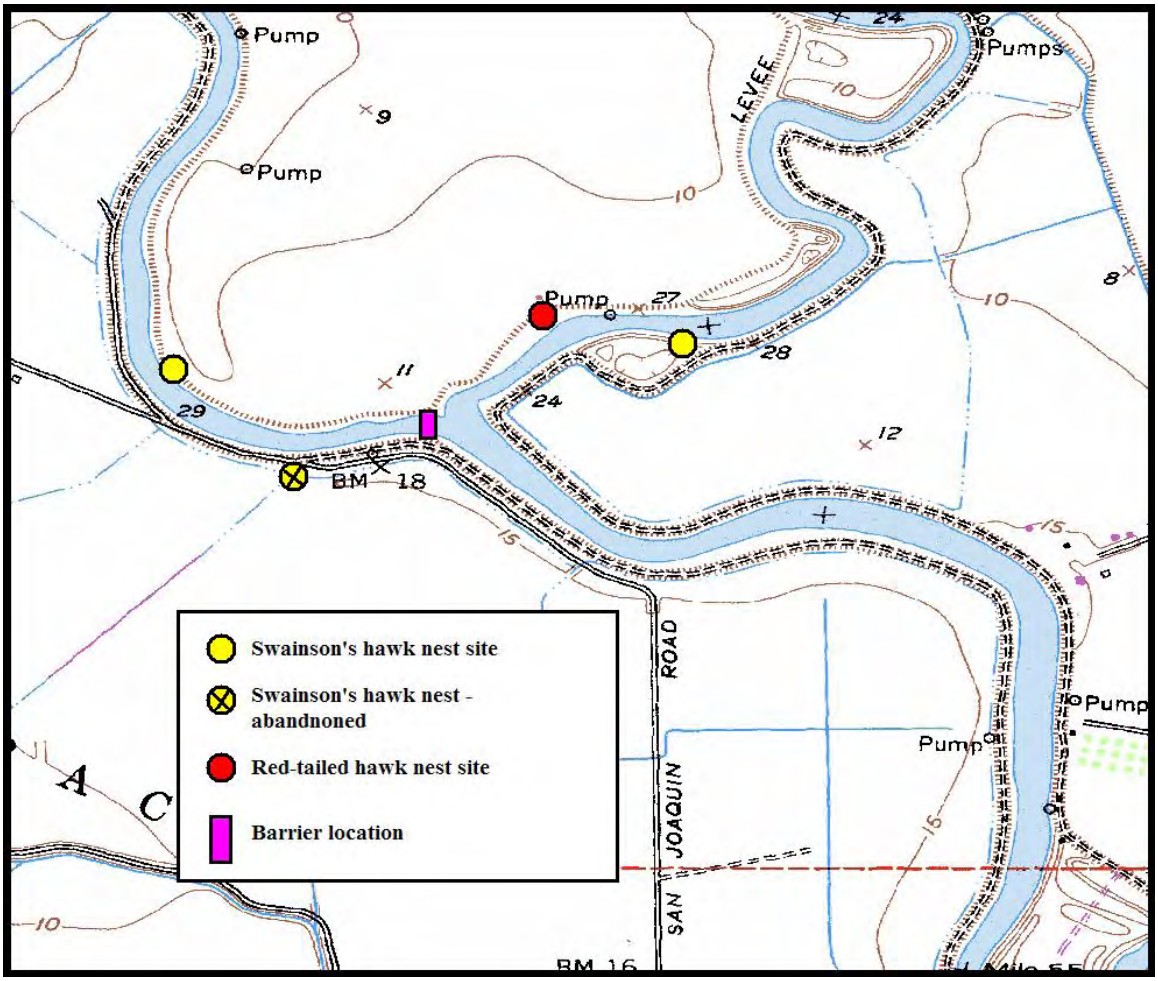


Head of Old River Barrier

Swainson's Hawk nest surveys were initiated on April 2. Most of the construction of the barrier was completed prior to the initiation of egg laying for the species. A pair of Swainson's Hawks was observed constructing a nest downstream of the barrier site on Old River, north bank, in an oak tree, one of a few that have been used for nesting in the past (Figure 6-3). The nest was never observed, but normal nesting activities were observed through the nesting season, so the pair was presumed to have successfully raised young. Additionally, the nest was almost 600 meters from the barrier site, outside the influence of construction activities.

A single Swainson's Hawk, probably male, constructed a nest in a haggard walnut tree off the south levee (land-side) immediately adjacent to the construction site. A mate was never observed. Although the bird was observed at the nest on a few occasions, it never appeared to lay eggs and finally abandoned the site sometime in May after construction of the barrier was completed. Given the observations, the conclusion was that it was an unmated male with an urge to construct a nest.

Figure 6-3. Raptor nest sites near the Head of Old River Barrier site



A pair of Swainson's Hawks was observed defending its territory 700+ yards north and downstream of the barrier site on the east bank of the San Joaquin River. Other than general observations of the pair, no nest monitoring was done as the nest site is well outside the influence of construction activities. A Red-tailed Hawk nest was observed downstream of the barrier on the San Joaquin River in the same cottonwood it has used in previous years, but the nest had apparently failed prior to the initiation of construction.

Middle River Barrier

Swainson's Hawk surveys were initiated on April 2, and construction of the barrier began on April 4. On April 2, a pair of Swainson's Hawks was observed mating in the willows on the in-stream island just downstream of the barrier site. They were observed again on April 5, but only one of the pair was observed in those trees after that date. On April 18, the single Swainson's Hawk (probably male) made contact with another Swainson's Hawk; they moved to a set of trees well north of Middle River. It's possible that the pair moved to a different nest location, or that the original female died and the male picked up a new mate and new territory. It is unlikely that the construction activities were a factor in the nest site change given the number of years this pair has nested next to the barrier site.

Effects of the Mountain House Development

The initiation of urban construction activities of the Mountain House development immediately adjacent to the Old River Barrier site at Delta-Mendota Canal likely resulted in the abandonment of all Swainson's Hawk nests along the south levee of Old River from the western riverside houses west of the barrier, upstream to the first in-stream island. All 3 pairs returned to their nest sites in 2008 and, as of the end of April, appear to be nesting again. There is currently no activity at the Mountain House development site, possibly an effect of the decline in housing sales; the three pairs may successfully nest at those sites in 2008.

Additional Comments

The ITP for the TBP requires that Swainson's Hawk surveys be initiated 5 and 3 days prior to the initiation of any construction at the barrier sites, rock storage sites and haul routes (if they are not paved, county roads). This is often difficult as the construction schedule sometimes "floats" and initiation dates often move. It is believed that these problems do not override the requirement to fulfill the ITP's conditions. Accurate and timely communication between DWR's Division of Engineering and Division of Environmental Services over the years has been the primary hurdle in meeting the conditions of the ITP. Although DWR's construction supervisor has taken steps to insure that the responsible environmental scientist is notified as soon as possible when schedules are created and modified, the supervisor is often left with no schedule buffer to inform the ES in a timely manner. The following procedures would greatly increase the timely notification of the responsible ES, and thus meet DWR's obligations under the ITP.

- Notify both the ES and construction supervisor of expected construction dates as soon as that information becomes available; a March notification of tentative schedule would be reasonable.
- Do not expect the construction supervisor to notify the ES; that information should come from the project or program manager.

- Notify the ES as construction schedules change; this is especially important with 2 weeks of construction initiation so that the pre-construction surveys can be done as required and not delay construction activities.
- Construction activities that are of concern include the heavy equipment work at the rock storage sites as early as February 15. Although Swainson's Hawks do not typically begin laying eggs until mid- to late-April, they may start as early as April 1, and other raptor species not covered by the ITP are protected by other laws. Great-horned Owls begin nesting in mid-February, and Red-tailed and Red-shouldered Hawks begin nesting in mid-March. Both Red-tailed Hawks and Great-horned Owls nest very close to both rock storage sites, and some precautions need to be implemented to insure no direct take of those species.

Chapter 7. Water Elevations

The 2007 water elevation monitoring program included operation and maintenance of 16 tide gauging stations near the barriers as shown in Figure 7-1. The 2007 monitoring program covers the period from January 2007 through December 2007, where stage is monitored at various stations with remote sensors.

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

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

Figure 7-1. Tide stations in the southern Delta

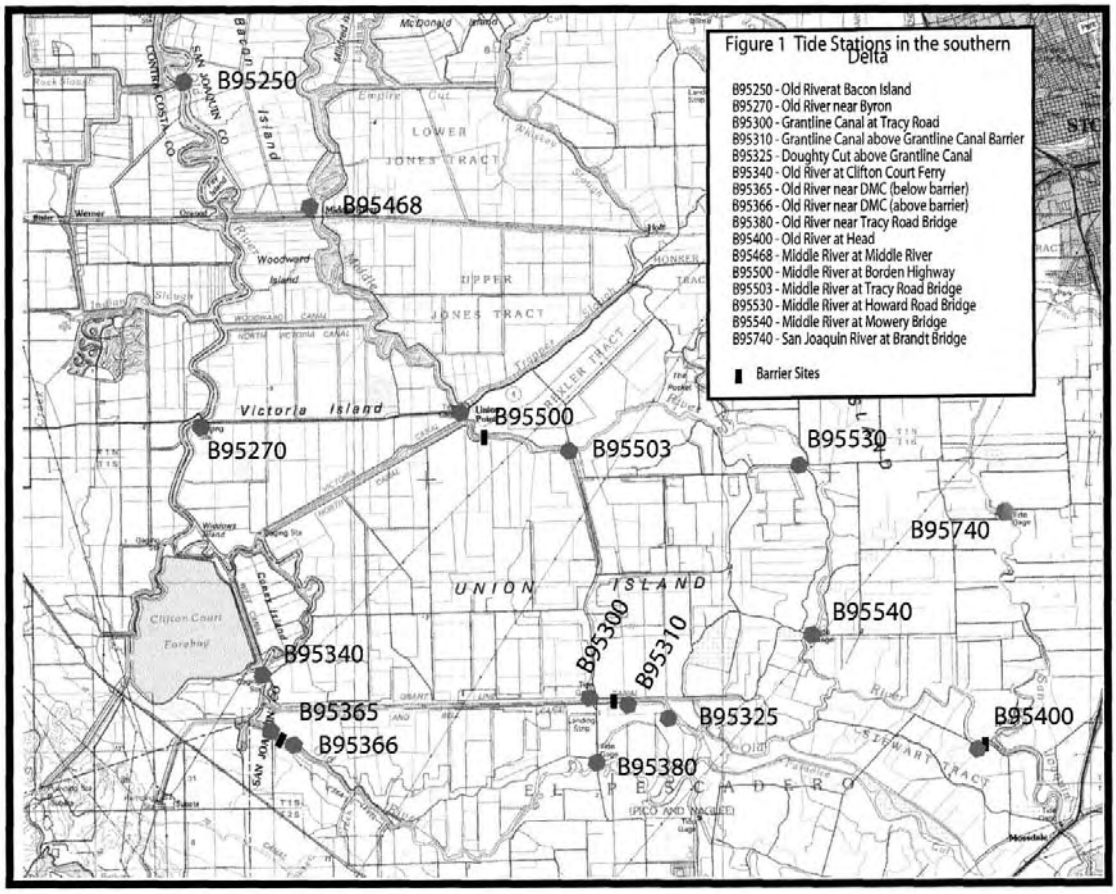
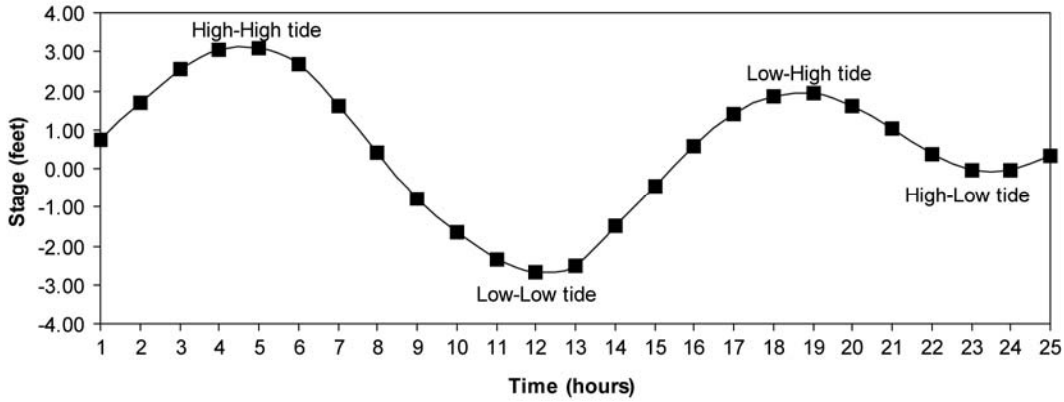


Figure 7-2. Tide stage variation over a 25-hour cycle



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

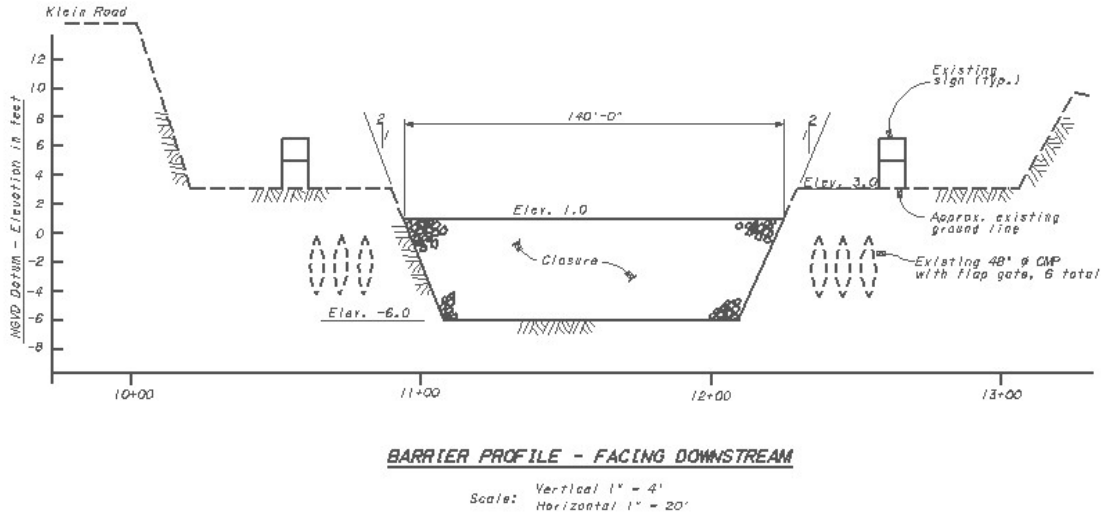
Typically, farmers in the south Delta encounter pumping difficulties due to low water elevations during the irrigation season. One objective of the Old River at Tracy, Middle River, and Grant Line Canal barriers is to improve water elevations for agricultural diversions. This goal is achieved by installing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

The agricultural barriers are constructed from 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 barriers operations 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.

Figure 7-3. Middle River barrier profile



Middle River Barrier

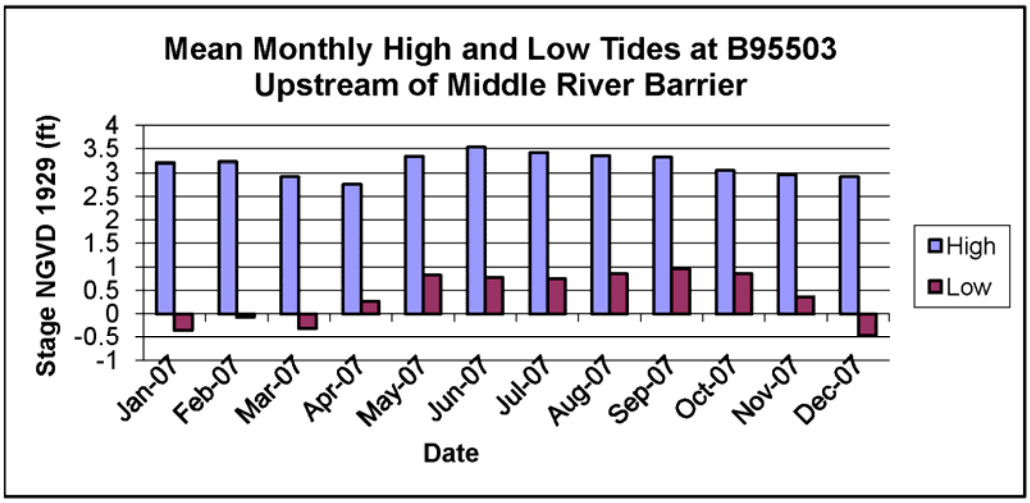
The Middle River Barrier is constructed to an elevation of +3.0 feet National Geodetic Vertical Datum (NGVD) and has six 48-inch diameter culverts. The center weir is 140 feet wide and constructed to an elevation of +1.0 foot NGVD (Figure 7-3). The center portion of the barrier is removed seasonally,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

The installation of Middle River (MR) barrier started on April 7, the closure and the complete installation was accomplished by April 10, 2007. The flap gates were tidally operational from April through November except for the period between May 23 and June 15, 2007, where 4 out of 6 flap gates were tied open (the 2 remaining flap gates had the cables broken and could not be tied open until they were repaired) to help improve the downstream flows to facilitate the movement of delta smelt out of the south and central Delta. Normal tidal operation of the flap gates resumed thereafter. For the 2007 operation, the MR agricultural barrier was operational until November 20, 2007. The MR barrier removal work began on November 19, breached by November 20, and was fully removed on November 29, 2007.

Water level monitoring was conducted at 2 nearby tide recording stations, B95500 downstream of this barrier at Borden Highway (Highway 4) and at B95503 just upstream of the barrier.

Figure 7-4 shows the mean monthly high tides and mean monthly low tides upstream and downstream of the MR barrier from January 2007 to December 2007. The barrier was in operation between April and November 2007. Figure 7-4 shows an increase in mean monthly low water levels upstream of the barrier of 3/4 of a foot or more between May through October and about 1/3 of a foot in November. This is a positive effect for agricultural diverters.

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



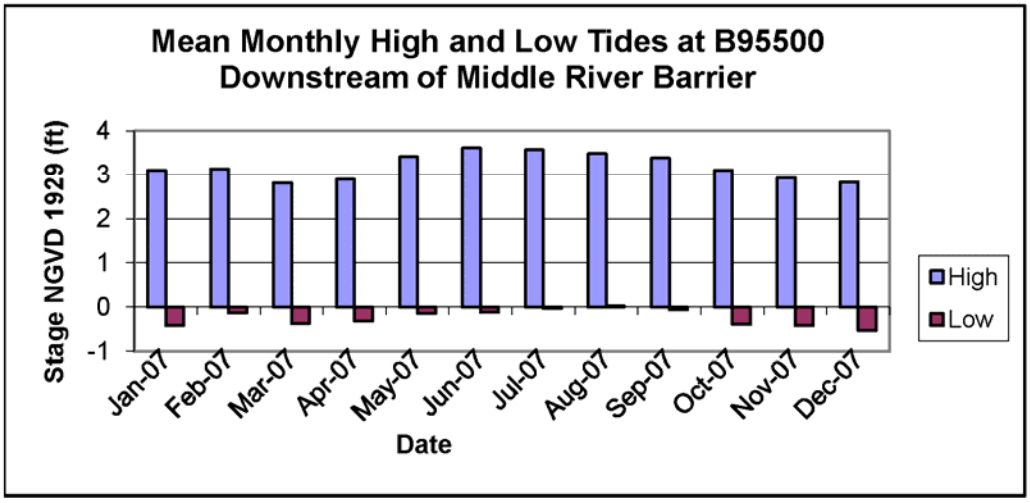
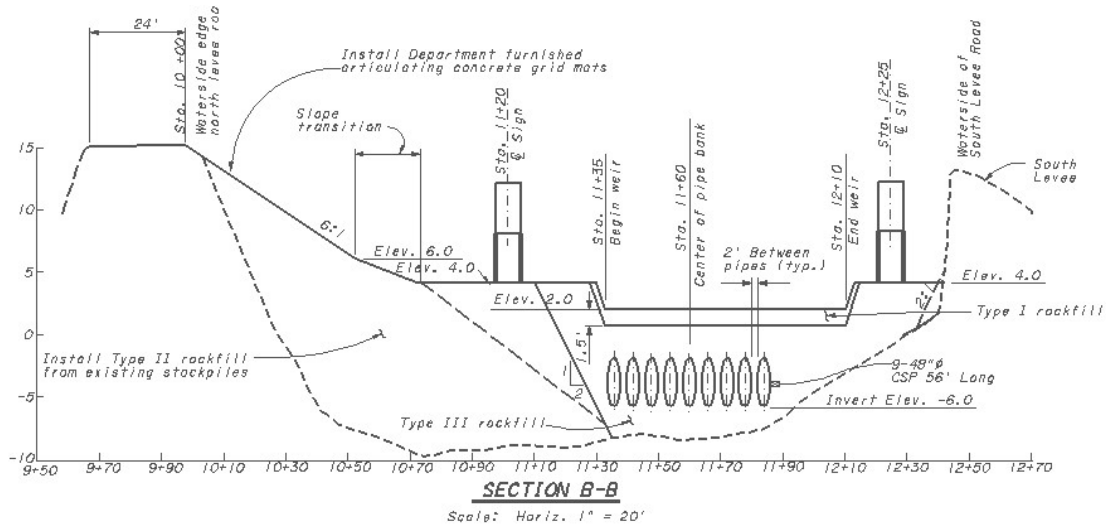


Figure 7-5. Old River at Tracy barrier profile



Old River at Tracy

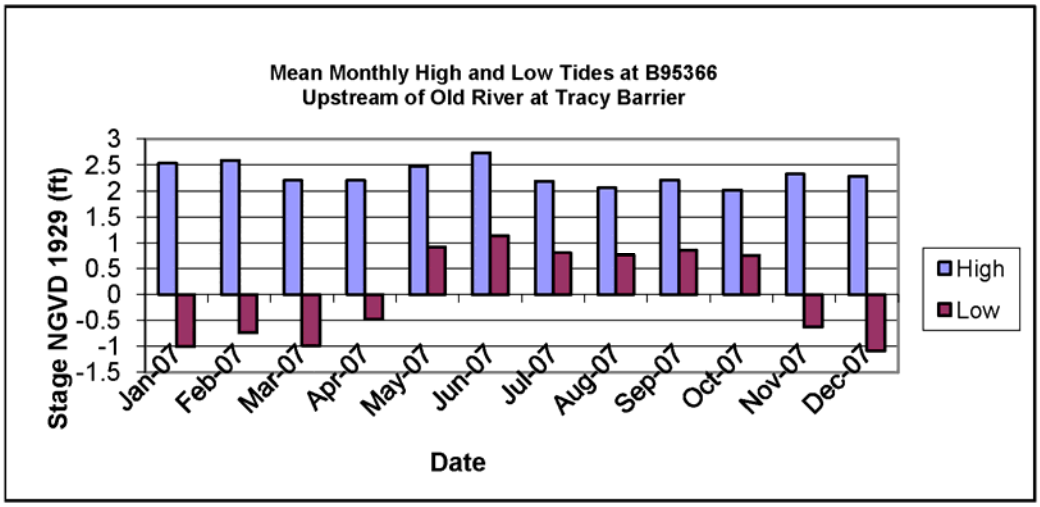
The Old River at Tracy (ORT) barrier is constructed to an elevation of +4.0 feet NGVD and has nine 48-inch diameter culverts. The center weir is 75 feet wide and constructed to an elevation of +2.0 feet NGVD (Figure 7-5). The whole barrier structure is removed seasonally.

The installation of the ORT barrier started on April 2; it was closed by April 18; and the installation was completed by April 23, 2007. The flap gates were operational tidally through July 13, 2007, except for the period of May 23 through June 15, 2007 when the flap gates had to be tied open to aid the survivability of the delta smelt. From July 13 through September 6, 2007, the flap gate operations were varied to reduce elevated salinity in Old River without compromising water elevations. Six culverts were tied open from September 6 until November 5, 2007, when the removal of the barrier started. The barrier was fully removed by November 18, 2007.

Water level monitoring is conducted at 2 nearby tide stations: (1) B95365, downstream of the ORT barrier and (2) B95366 upstream of the barrier. In 2007, the station on the upstream side of the barrier performed well and reported good data; the downstream data recorder below the barrier had missing data half the month of April. Mean low and high water surface elevation for this station depicted in Figure 7-6 during the month of April is based only on 15 days of data.

Figure 7-6 shows stages upstream and downstream of the ORT barrier from January 2007 to December 2007. Figure 7-6 shows an increase in mean monthly low water levels on the upstream end of more than a foot in June and approximately 3/4 of a foot for the period stretching from July through October. This is a positive effect for irrigators.

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



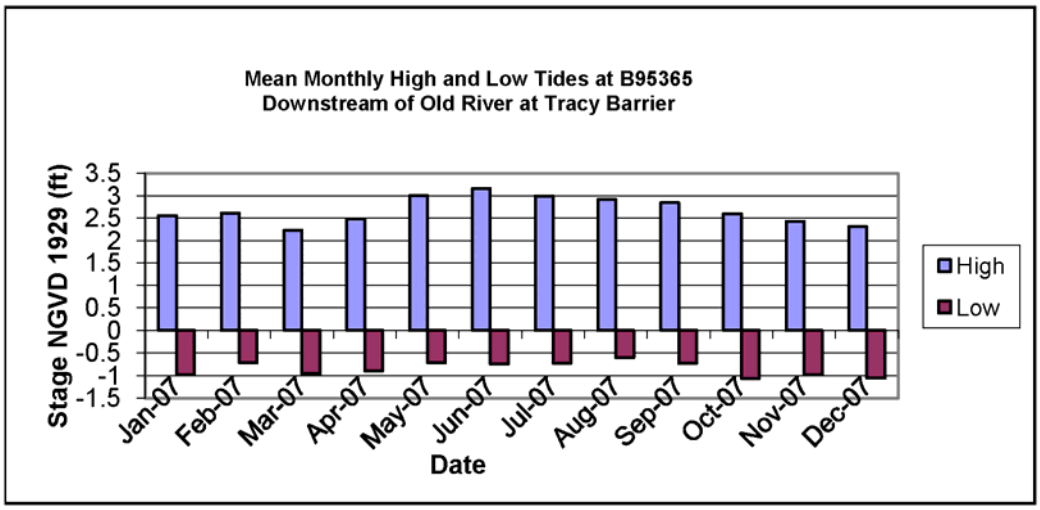
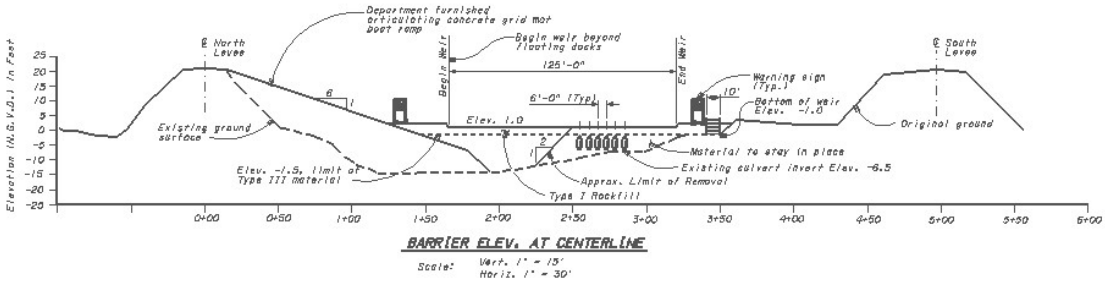


Figure 7-7. Grant Line Canal barrier profile



Grant Line Canal Barrier

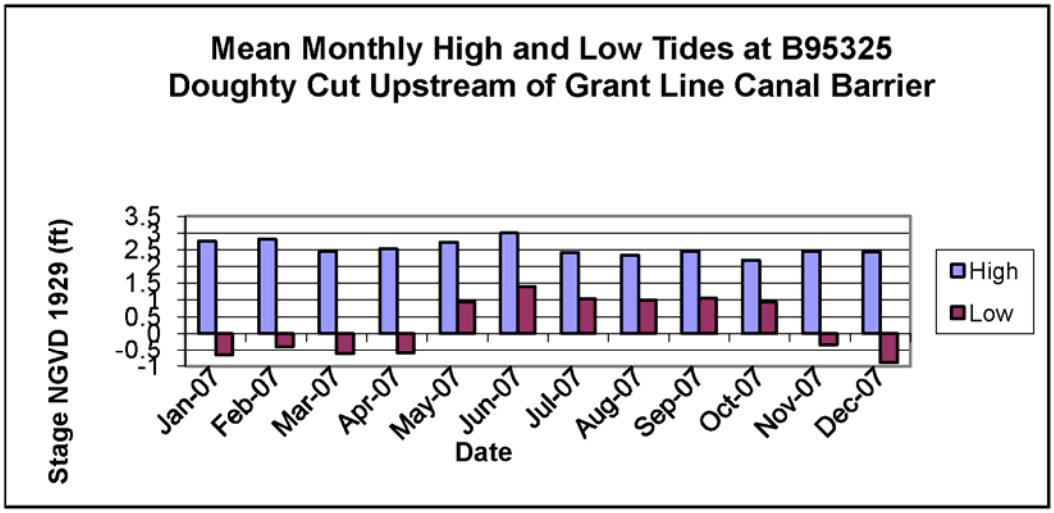
The Grant Line Canal (GLC) barrier is constructed to an elevation of +4.0 NGVD and has six 48-inch diameter culverts at the southern abutment of the barrier. The center weir is 140 feet wide and constructed to an elevation of +1.0 foot NGVD. Figure 7-7 shows the culverts, fish passage weir and the southern abutment of the GLC barrier, which 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.

In 2007, the construction of the northern abutment of the rock barrier started on April 8 and was completed on April 27, 2007. Work on closing the middle portion of the barrier started on April 17, 2007, and it was completed by May 11, 2007. The flashboards were adjusted twice in 2007: once on April 17 and a second time on May 11, 2007. The flashboards were adjusted to allow delta smelt passage.

The barrier removal work began on November 6. The breach was accomplished by November 8, and the barrier was fully removed by November 29, 2007. Water level monitoring is conducted at 2 nearby tide recording stations: (1) B95300 just downstream of the barrier, and (2) B95325 Doughty Cut upstream of the barrier.

Figure 7-8 shows stages upstream and downstream of the GLC barrier from January 2007 to December 2007. Figure 7-8 shows an increase in mean monthly low water levels on the upstream end of more than a foot in June; moreover, the mean monthly low water levels on the upstream end of the GLC barrier increased by an average of one foot in May and for the period August through October.

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



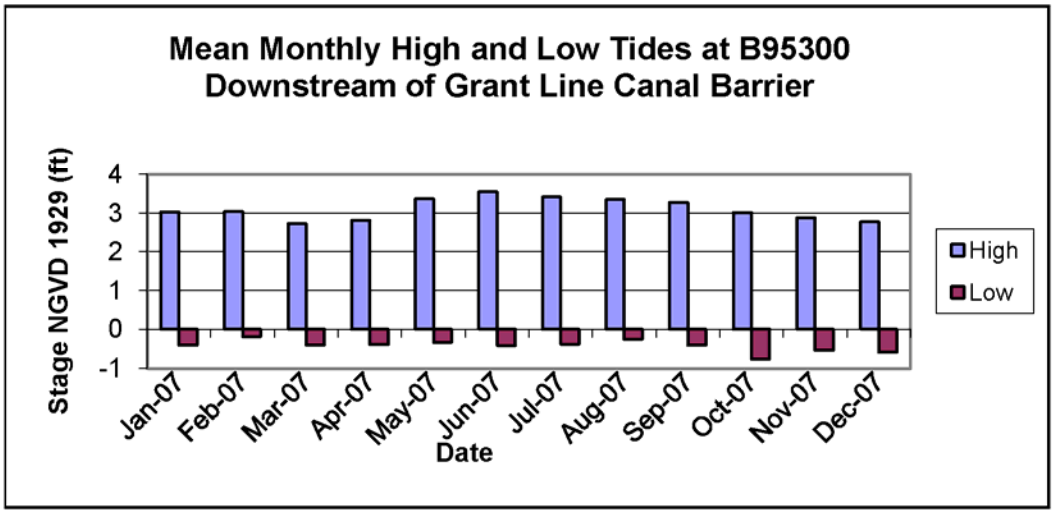
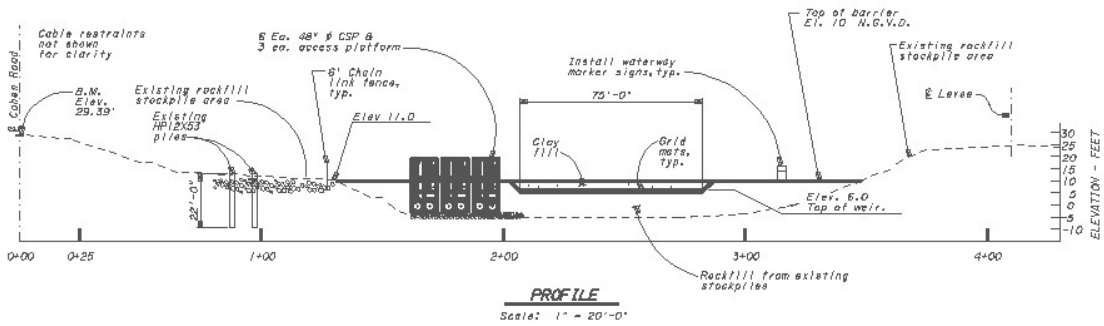


Figure 7-9. Spring head of Old River barrier profile



Old River at Head Barrier

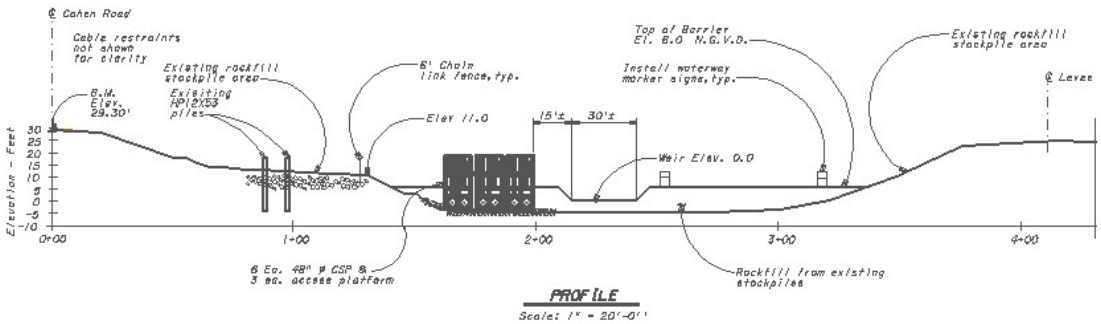
The head of Old River barrier (HORB) is designed as a fish barrier to prevent San Joaquin River Chinook salmon smolt from migrating down through Old River toward the Central Valley Project and State Water Project export facilities. The spring HORB was originally designed to withstand a San Joaquin River 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 2007 and future years, the barrier design includes 2 versions. A “low-flow” barrier would be built to a height of 10 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 2007, the low-flow version was installed (Figure 7-9).

The dimensions of the 2007 HORB were similar to the dimensions of the barrier installed back in 2004. The base width of the HORB was 100 feet and the crest elevation was 10 feet MSL. The top of the 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, 6 operable culverts were installed in the barrier. During 2007, three culverts were open during the barrier operation to allow some downstream flow into Old River to help with circulation. On May 16, 2007, however, the remaining 3 culverts were also opened in response to fishery agency concern over the distribution and abundance of delta smelt.

The spring barrier was installed between April 11 and April 26, 2007, with barrier closure achieved on April 20, 2007. Barrier removal began on May 19; the breach was accomplished by May 22, 2007 and the barrier removal was completed by June 6, 2007.

Figure 7-10. Fall head of Old River barrier profile



The fall HORB barrier was installed between October 5, 2007, with closure on October 17, and it was notched and completed on October 18, 2007. Barrier removal started on November 9, and it was breached by November 10. The complete removal was done by November 29, 2007. The fall HORB was constructed to an elevation of +4.0 feet NGVD and had six 48-inch diameter culverts (Figure 7-10).

Figure 7-11 shows water levels in Old River at head approximately 1,000 yards below the barrier. The mean monthly low level was the lowest during the month of April, an elevation of approximately 1/3 of a foot NGVD and a bit over one foot during the spring installation in the month of May. For the fall installation, the maximum mean monthly low water surface elevation of a little over one foot NGVD was also recorded during the month of October.

Figure 7-12 shows water level at Tom Paine Slough (TPS) above mouth, above the intake structure, and at Pump Plant #6.

Station B95420 TPS above mouth reported a mean monthly low level dipped below zero for the months of January through April and was above one foot during the period May through September. This station encountered problems during the period from October through December; consequently, no data was collected for this period.

Station B95421, TPS above the intake structure reported unreliable or missing data during the entire year and therefore there is no graph for this station. Some of the problems reported were float sinking, recorder malfunctioning, and tape was off the pulley.

Station B95425, at Pescadero Pump Plant #6 (upper reach of TPS) showed a mean monthly low of a little over a foot during the month of April and the highest was observed in October a value of more than 1-1/2 foot NGVD.

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

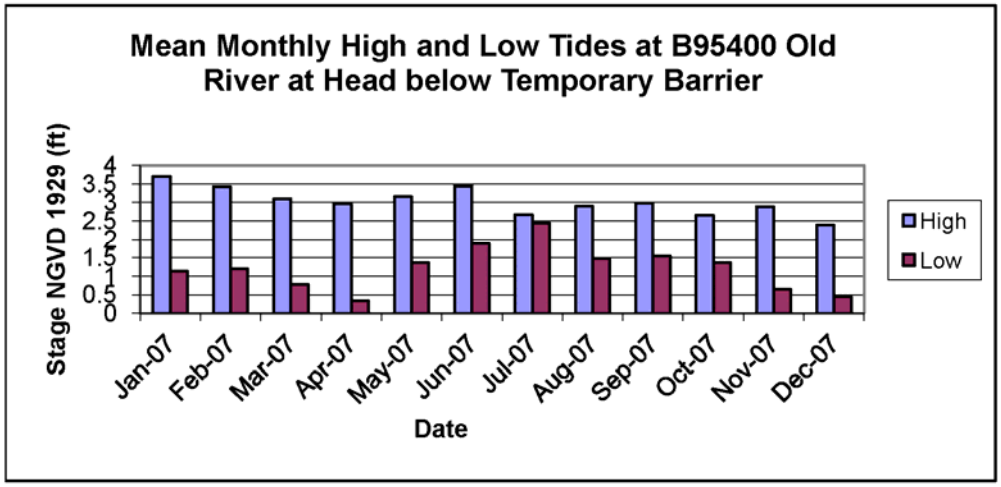
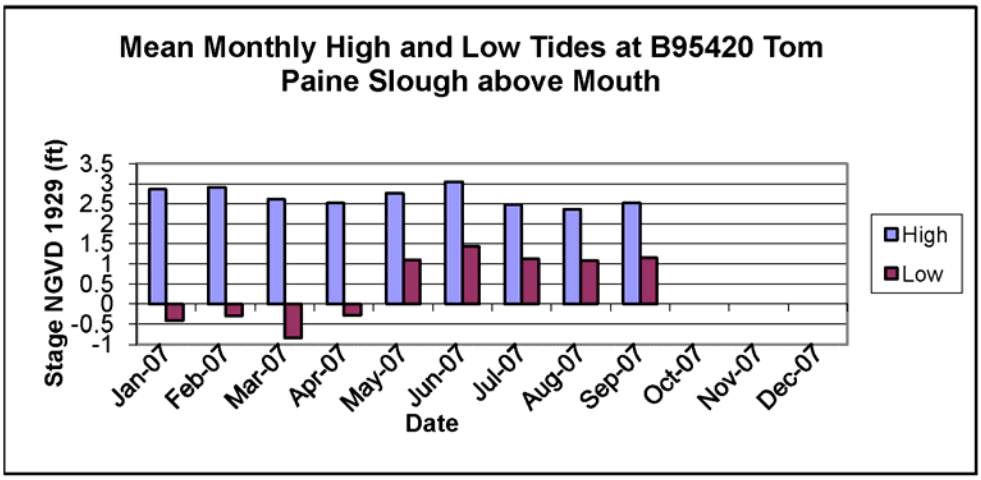
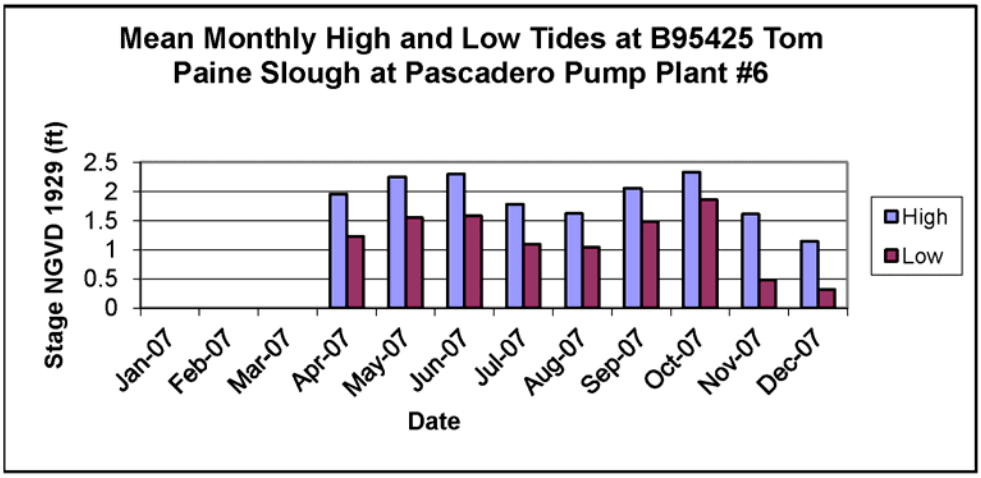


Figure 7-12. Water Levels at Tom Paine Slough above Mouth and above the Intake Structure and at Pump Plant #6





Chapter 8. South Delta Water Quality

Introduction

The Department of Water Resources (DWR) has been monitoring water quality as part of the South Delta Temporary Barriers project since 1991 to elucidate water quality conditions in the South Delta that may be affected by temporary barrier installations and operations. In 2007, DWR continued its South Delta water quality sampling program, which consists of 2 components: (1) bimonthly discrete sampling at 10 sites; and (2) continuous sampling at 13 sites. For detailed information on the South Delta Improvements Program and the Temporary Barriers Project please visit DWR's Bay-Delta Office Web site at http://baydeltaoffice.water.ca.gov/sdb/.

Historically, discrete sampling was conducted on a weekly basis at 10 locations to monitor physical and biological constituents, as well as nutrients. The objective of the discrete program is to monitor the effects of barrier installations/removals and operations on water quality. To meet this objective, discrete sampling commenced 2 weeks before the barriers were installed and did not conclude until 2 weeks after all the barriers were removed. Sampling was conducted every Tuesday morning in an effort to sample at a time when dissolved oxygen (DO) concentrations tend to be lowest.

In 2006, the weekly DO sampling was terminated and the biological constituents and nutrients were changed from weekly to bimonthly because of the expansion of the continuous monitoring program. Multi-parameter water quality instruments were installed at all 10 discrete sampling sites by the summer of 2006.

In 1998, Central District (CD) initiated a pilot program to test the viability of establishing continuous permanent multi-parameter water quality stations in the South Delta. This program was established to better understand barrier installations in accordance with the following: (1) to determine the feasibility of collecting reliable time-series water quality data; (2) to develop an understanding of dynamic water quality conditions in a tidally influenced system; and (3) to establish and maintain long-term continuous data records in the South Delta for analysis. This continuous water quality monitoring program began with 2 stations: Old River at Tracy Wildlife Association and Middle River at Howard Road. The time-series data generated from these 2 sites was found to be reliable, accurate, and precise when compared to calibration standards and field data. The success of the pilot program resulted in the decision to expand the continuous monitoring program. The expansion was designed to complement the existing discrete stations and resulted in employing a multi-parameter instrument at each of the 10 discrete stations. CD staff installed 4 stations between 2000 and 2003 and 5 stations in 2006 to meet this objective.

In 2005, a Permanent Barriers Project monitoring proposal included the implementation of 3 new continuous multi-parameter water quality stations. The proposed station locations were Grant Line Canal near Old River, Victoria Canal, and Doughty Cut above Grant Line Canal. The water quality instruments at Grant Line Canal near Old River and Victoria Canal were to be co-located with an acoustic doppler current profiler instruments. The establishment and operation of both instruments at these stations were to provide time-series water quality data that could be correlated with flow time-series data. The establishment of a multi-parameter station at Doughty Cut was proposed to document possible improvements to water quality based on permanent barrier operation. All 3 stations would also provide water quality information for the calibration and validation of the DSM2 model for the South Delta.

CD staff installed multi-parameter water quality stations at Doughty Cut above Grant Line Canal in 2006, and at Victoria Canal and Grant Line Canal near Old River in 2007. The data collected at these 3 sites is included in this chapter for data evaluation and analysis purposes. Therefore 13 permanent continuous multi-parameter water quality stations are now operated by CD in the South Delta.

Materials and Methods

Discrete Monitoring

The discrete monitoring program consists of 10 permanent sampling sites shown in Figure 8-1. The locations include one on the downstream side of each barrier, one on the upstream side of each barrier, excluding the Old River at Head barrier. Also, additional sites are located farther upstream on each of the main river channels (Old River, Middle River, and Grant Line Canal). Sampling of chlorophyll *a*, pheophytin *a*, dissolved ammonia, dissolved nitrite+nitrate, dissolved organic nitrogen, dissolved orthophosphate was conducted bimonthly from April 10 through November 27, 2007 on Tuesday mornings between 5 a.m. and 9 a.m. each of these stations.

Figure 8-1. Map of Department of Water Resources discrete water quality sites in the South Delta

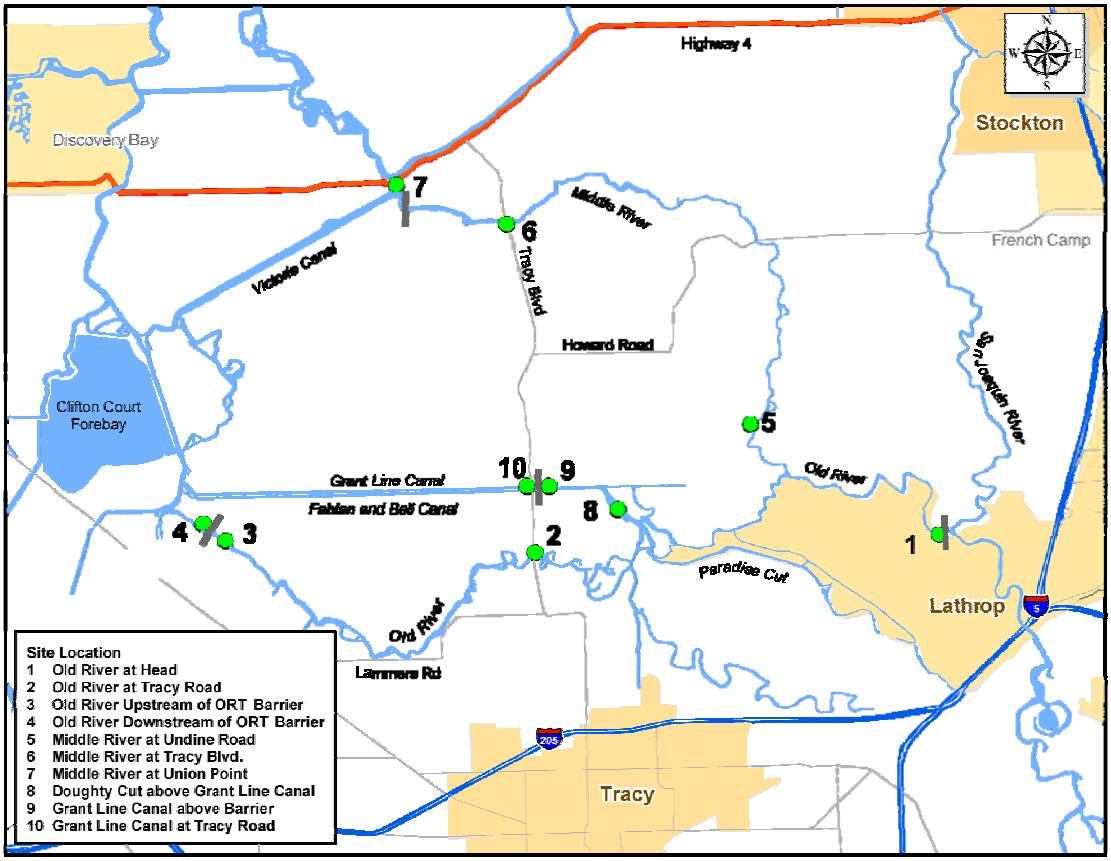


Table 8-1. Summary of lab methods for the water quality constituents measured at each of the 10 discrete water quality sampling sites

Constituent	Lab method[1]
Dissolved Ammonia	EPA 350.1
Dissolved Nitrite+Nitrite	Modified Standard Method 4500-NO3-F
Dissolved Organic Nitrogen	EPA 351.2
Dissolved Orthophosphate	Modified EPA 365.1
Chlorophyll *a*	Standard Method 10200 H, Spectrometric Determination of Chlorophyll
Pheophytin *a*	Standard Method 10200 H, Spectrometric Determination of Chlorophyll

[1]Dissolved Nitrite + Nitrate and Dissolved Orthophosphate Lab Methods Modified by DWR-Bryte Lab

Chlorophyll *a* and pheophytin *a* samples are collected from the top of the water column using a metal container. Water from the container is used to fill a plastic quart bottle at each site. All sample bottles collected are stored in a cooler containing ice packs to preserve the samples at 4 ºC and to keep them out of the sunlight. Immediately after the samples are collected, they are taken to a site in Stockton for filtration. For each sample approximately 500 mL of water is passed through a 47 mm diameter glass fiber filter with a 1.0 µm pore size at a pressure of 10 inches of mercury. The filters are immediately frozen and transported to DWR's Bryte Laboratory for analysis according to Standard Methods for the Examination of Water and Wastewater (APHA 1992).

Ammonia, nitrite+nitrate, organic nitrogen, and orthophosphate surface water samples are collected in the field using a metal container. Water from the container is used to fill a plastic quart bottle at each site. All sample bottles collected are stored in a cooler containing ice packs to preserve the samples at 4 ºC. Immediately after the samples are collected, they are taken to a site in Stockton for filtration. The samples are filtered through a 0.45 µm pore size membrane filter into a half-pint polyethylene bottle. The samples are then immediately transported to Bryte Laboratory for analysis. A summary of the lab methods for the nutrients measured are shown in Table 8-1.

Data Analysis. The use of summary statistics, such as mean, maximum, and minimum are used to compare the data for each constituent shown in Table 8-1 at all 10 discrete stations. Data for each constituent measured is also presented graphically by waterway (Old River, Middle River, and Grant Line Canal).

Continuous Monitoring

DWR collects water temperature (ºC), DO (mg/L), pH, specific conductance (µS/cm), turbidity (NTU), and chlorophyll (µg/L) data in 15-minute intervals. This data is collected at a 1-meter depth by deploying Yellow Spring Instrument (YSI) 6600 sondes. Continuous data are collected at 13 multi-parameter monitoring stations in the South Delta: 4 in Middle River, 4 in Old River, 4 in Grant Line Canal and one in Victoria Canal. (See Figure 8-2 for site locations.) Station coordinates and the date the station was established are shown in Table 8-2. In 2007, 2 new continuous monitoring sites were installed: Grant Line Canal near Old River and Victoria Canal. The new stations are operated in conjunction with USGS flow stations and provide real-time data on CDEC http://cdec4gov.water.ca.gov/. To access data from these stations select "real-time data" from the menu and then enter in the 3-digit station identification code. The code for Victoria Canal is "VCU" and the code for Grant Line Canal is "GLC."

Figure 8-2. Map of Department of Water Resources continuous water quality monitoring sites in the South Delta

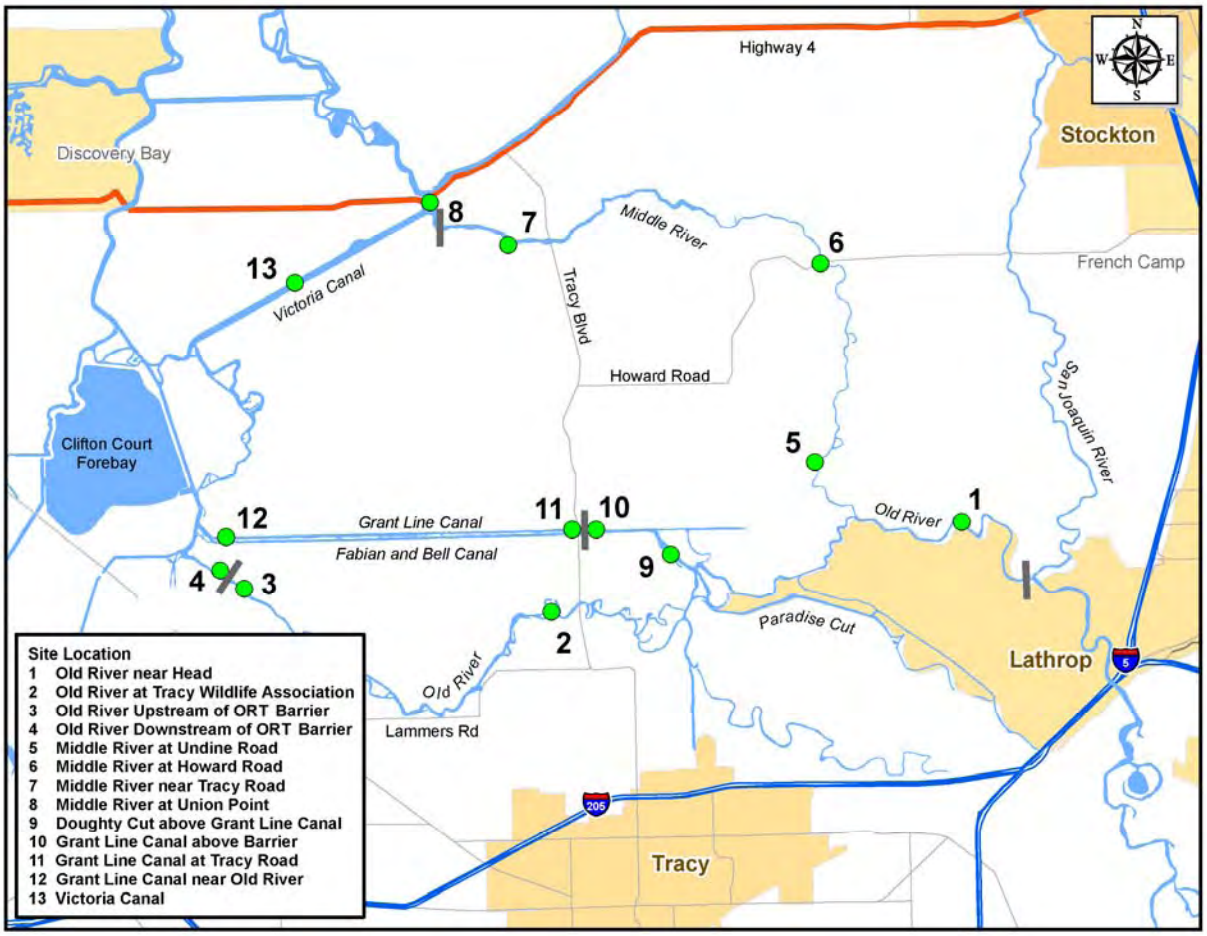


Table 8-2. Continuous monitoring station coordinates and date of establishment

Station name	Latitude	Longitude	Date established
Old River near Head	37º 49' 09.8"	121º 21' 36.4"	January 1, 2001
Old River at Tracy Wildlife Association	37º 48' 10.1"	121º 27' 26.7"	July 14, 1999
Old River upstream ORT Barrier	37º 48' 36.9"	121º 32' 31.9"	January 1, 2000
Old River downstream ORT Barrier	37º 48' 39.5"	121º 32' 39.9"	January 18, 2006
Middle River at Undine Road	37º 50' 02.2"	121º 23' 08.6"	June 4, 2002
Middle River at Howard Road	37º 52' 34.4"	121º 22' 59.9"	October 1, 1999
Middle River near Tracy Road	37º 52' 53.2"	121º 28' 02.5"	January 1, 2003
Middle River at Union Point	37º 53' 26.8"	121º 29' 18.1"	February 23, 2006
Doughty Cut above Grant Line Canal	37º 48' 53.0"	121º 25' 30.8"	June 19, 2006
Grant Line Canal above Barrier	37º 49' 12.7"	121º 26' 42.1"	March 24, 2006
Grant Line Canal at Tracy Road	37º 49' 12.4"	121º 26' 59.4"	March 6, 2006
Grant Line Canal near Old River	37º 49' 12.4"	121º 32' 40.6"	February 2, 2007
Victoria Canal	37º 52' 15.5"	121º 31' 47.9"	March 30, 2007

YSI 6600 sondes are approximately 2 feet long and 3½ 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. Deployment data are logged in each sonde's internal memory. Sondes are capable of sampling at many different user-specified frequencies. During 2000, an hourly sampling frequency was used for all stations, approximately 732 samples per month. In 2001, the sampling frequency was changed to a 15-minute interval, approximately 2,920 samples per month. The change to 15 minute intervals allows for a more in depth review of tidal factors that will influence water quality. For detailed information on YSI instrumentation visit www.ysi.com.

At each monitoring site, a sonde is vertically housed within a 4 inch diameter PVC pipe in the water column and suspended at a depth of approximately 1 meter. To adjust for changing tides floats are used to maintain the 1 meter depth. To discourage vandalism the pipes are covered at the top with an end-cap and locked shut with masterlocks through two 0.5-inch diameter bolts. Installation pipes are drilled with 2.25 inch diameter holes along the length of the pipe and spaced approximately 8 inches to 10 inches on center. Four sets of holes are drilled longitudinally at 90º angles from each other. These holes allow ambient water to adequately contact the sonde sensors to ensure accurate data collection. At each site, the sonde installation pipe is either lag-bolted into an existing float structure (wooden boat dock), steel-banded to a pump platform durable enough to withstand long-term usage, or bracketed to a USGS pile.

Each sonde is cleaned and calibrated at CD's water quality lab to ensure each probe is operating correctly before being deployed. Calibration methods for each constituent are based on YSI's principles of operations. A 3-week rotational period is used year-round as the standard time frame for exchanging out sondes in the South Delta (i.e., a newly calibrated sonde replaces a sonde that had been recording data in ambient conditions for 3 weeks). Field data are collected at each station when a sonde is exchanged during the rotational period for data comparison purposes.

A component of the quality assurance/quality control process involves comprehensive data checking by utilizing separate instrumentation. This instrumentation includes an YSI-63 handheld unit that measures water temperature, pH, and specific conductance, a HACH Luminescent Dissolved Oxygen (LDO) handheld unit to check DO concentrations, and a HACH 2100P turbidimeter to measure turbidity. Discrete chlorophyll *a* and pheophytin *a* samples are also collected during each site visit and are processed according to the method described in the discrete monitoring section. A spreadsheet is compiled throughout the year to compare separate field and sonde data for each constituent at every site.

The quality assurance/quality control process continues after each sonde is removed from the field. Each instrument is taken to CD's water quality lab where the data is downloaded and the instrument is post-deployed. Post-deployments are performed by checking individual probe readings against calibration standards to determine if errors from probe drift and/or fouling affected probe accuracy. All readings are taken the day the sonde is removed and before the instrument is cleaned. The data for each constituent is then rated as excellent, good, fair, or poor based on its deviation from the calibration standard according to the USGS technical report "Guidelines and Standard Procedures for Continuous Water Quality Monitors-Station Operation, Record Computation, and Data Reporting." Data files are then imported into the CD database Hydstra where quality assurance and quality control checks are performed. The data in Hydstra are used to populate the Water Data Library where the data for all the continuous sites are available online at http://wdl.water.ca.gov/.

Chlorophyll Estimation. Due to the lack of an accuracy specification for the 6026 chlorophyll probe, the data is estimated to more accurately reflect "real" chlorophyll *a* concentrations in the South Delta. The YSI chlorophyll probe provides an estimate of total chlorophyll concentrations by measuring fluorescence. Discrete samples for chlorophyll *a* are taken monthly at each site for analysis at Bryte lab. The discrete data provide a more accurate representation of ambient chlorophyll *a* concentrations in the South Delta at a specific point in time. Simple linear regression analysis is performed to predict continuous chlorophyll *a* concentrations based on the relationship between the response variable (continuous chlorophyll data) and the independent variable (lab analyzed chlorophyll *a* values). The assumption of normality built into the linear regression model is met by transforming the discrete and continuous chlorophyll data sets into natural logs. Since the regression equation based on the transformed data predicts the geometric mean, which is an estimate of the median, a bias correction method is used to get a more accurate prediction of the mean. This is achieved by using the Maximum Likelihood Estimator method that is valid only for log transformed data. The correction factor is calculated by taking the exponent of 0.5 multiplied by the mean squared error of the regression model.

Data Analysis. Summary statistics such as maximum, mean, minimum, and standard deviation (a measure of variation within a group) are used to compare data for each constituent at all 13 continuous stations. Data for each constituent measured are also presented graphically by waterway (Old River, Middle River, Grant Line Canal, and Victoria Canal).

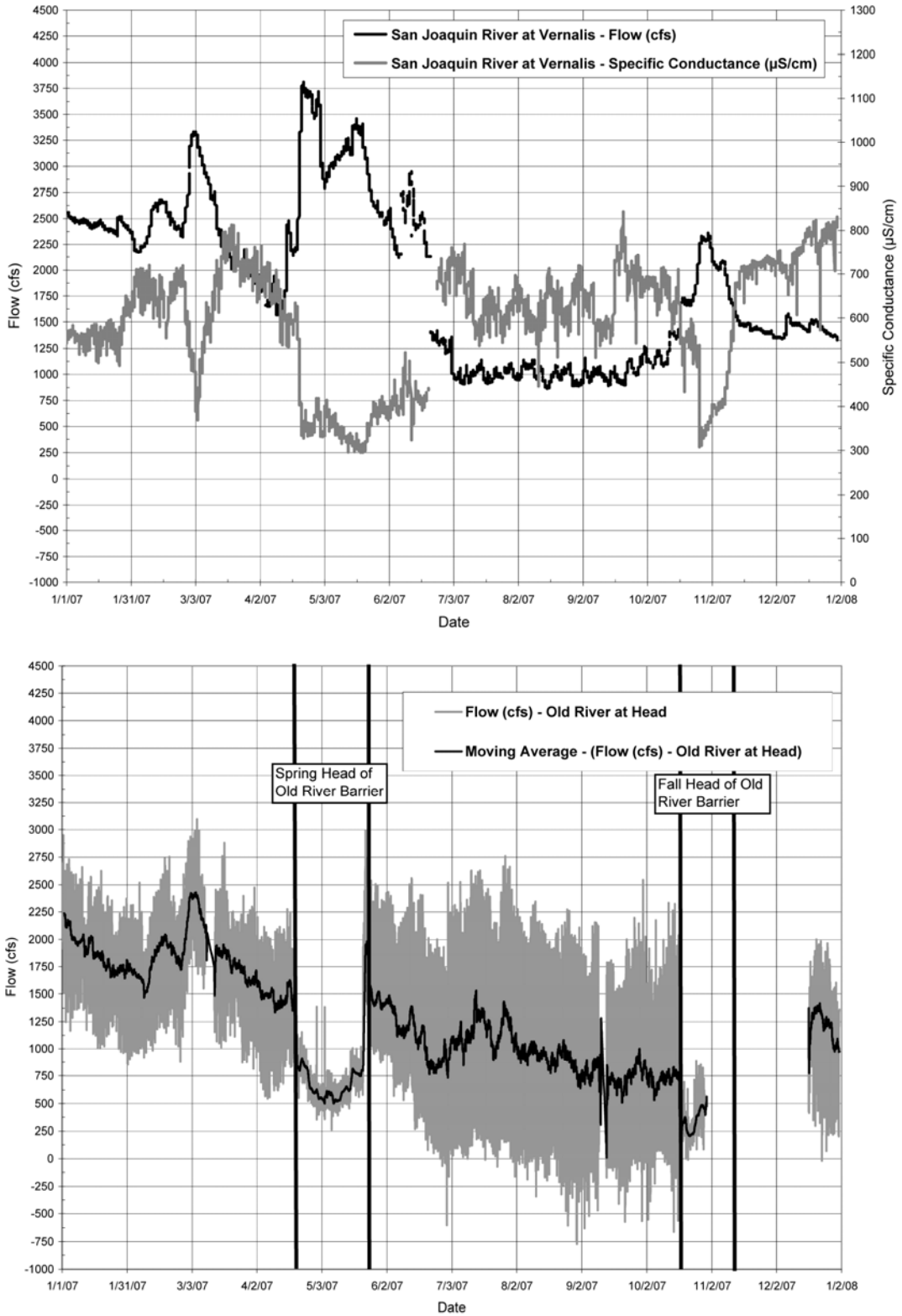
One-way analysis of variance (ANOVA) was used to test for differences among sites in a specific waterway (Old River, Middle River, and Grant Line Canal). An assumption of normality was used based on the number of samples. For every 24-hour period there are 96 samples recorded at each site, and every month approximately 2,920 samples are recorded at each site. To look at the data in a more meaningful way, daily averages were calculated for both DO and specific conductance, so the approximate monthly sample size at each site was 30. ANOVA was used to test for mean differences in DO in the months of June, July, and August in Old River, Middle River, and Grant Line Canal (when DO concentrations were the lowest during the year). ANOVA was also used to test for mean differences in specific conductance in each month from April through August in Old River. Tukey's HSD test was then performed to determine which pairs of means within a group were significantly different from each other.

Hydrology

Water year 2007 (October 1, 2006 – September 30, 2007) was classified as a critically dry year for the San Joaquin Valley. Unimpaired runoff was 2.46 million acre-feet, and runoff was greatest from April though July. For the Sacramento Valley water year 2007 was classified as a dry year with unimpaired runoff totaling 10.25 million acre-feet.

San Joaquin River flow past Vernalis was highest from March to May averaging 2,694 cfs. (See Figure 8-3 for San Joaquin River at Vernalis and Old River at Head flow.) Average flow during the same period in 2006 was 24,700 cfs. Flow was lowest from July through September averaging about 1,014 cfs. Flow at Old River at Head ranged from -769 cfs to 3,095 cfs, with the highest flow observed from January through mid-April and the lowest while the spring Head of Old River Barrier was installed (April 20 through May 2). No flow data are available for this site while the fall Head of Old River Barrier was in place from October 17 to November 10.

Figure 8-3. San Joaquin River at Vernalis flow and specific conductance (hourly intervals) and Old River at Head flow (15-minute intervals)



Flow data at Grant Line Canal near Old River were generally more positive (more downstream flow) from January through April and after the Grant Line Canal barrier was removed in early November (Figure 8-4). Flow ranged from -9,028 cfs to 13,300 cfs during this time period. While the Grant Line Canal barrier was operating (May 10–November 9) flow ranged from -6,456 cfs to 7,070 cfs; and there was no real distinct flow trend (positive or negative). Flow data at Victoria Canal were generally more negative (reverse flow) throughout the year, especially from late July through mid-September (Figure 8-4). Flow values ranged from -11,070 cfs to 5,140 cfs at Victoria Canal in 2007.

Total daily exports for the Central Valley Project (CVP) and State Water Project (SWP) averaged 7,229 cfs from January to March. In May and June, exports were the lowest during the year averaging 2,084 cfs and 3,704 cfs. (See Figure 8-5 for SWP and CVP total daily exports (cfs)). From July through December, daily exports averaged 8,650 cfs. (Note: All CVP and SWP pumping data is preliminary and has not been checked for accuracy.)

Figure 8-4. Grant Line Canal near Old River flow (15-minute intervals) and Victoria Canal flow (15-minute intervals)

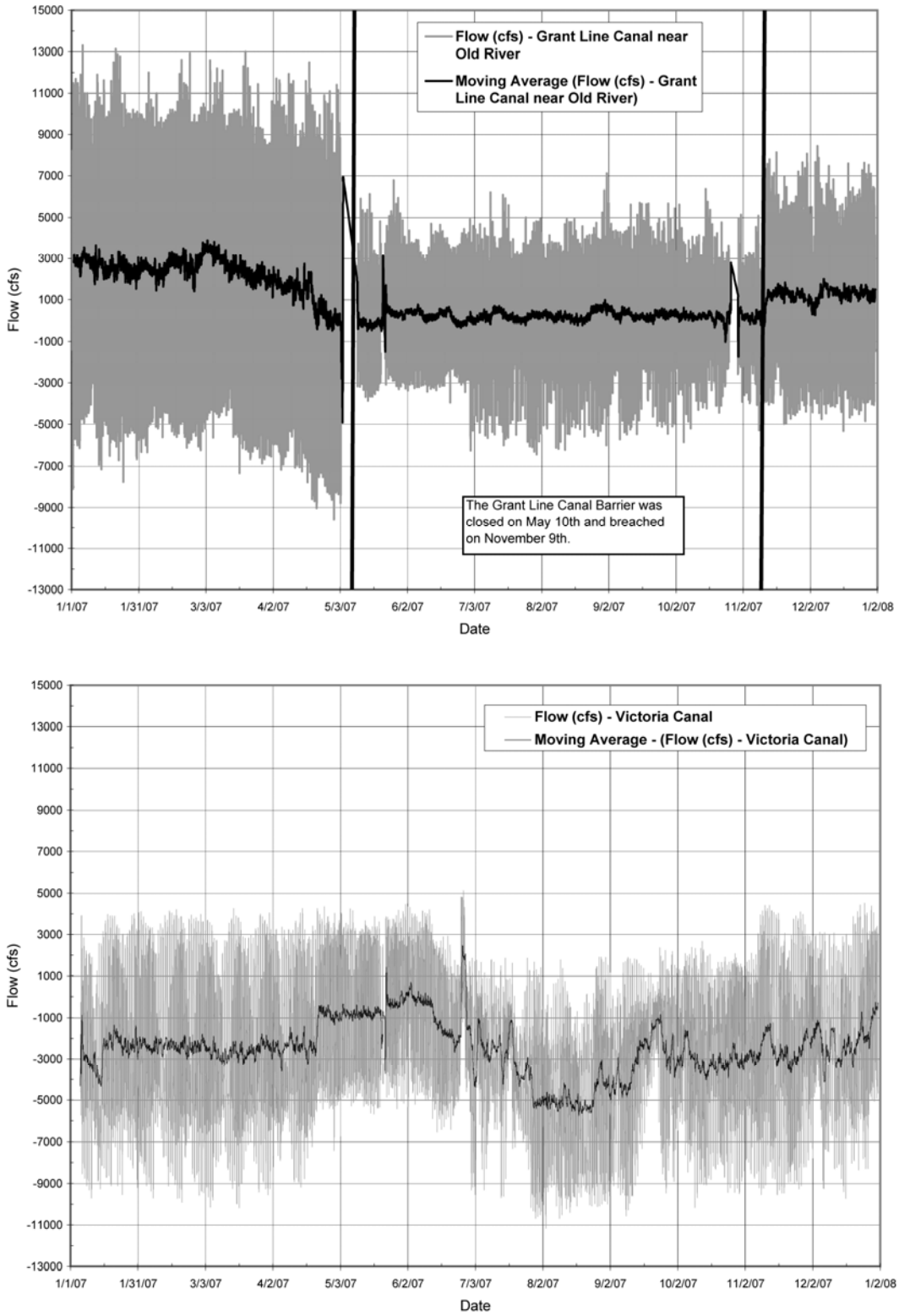
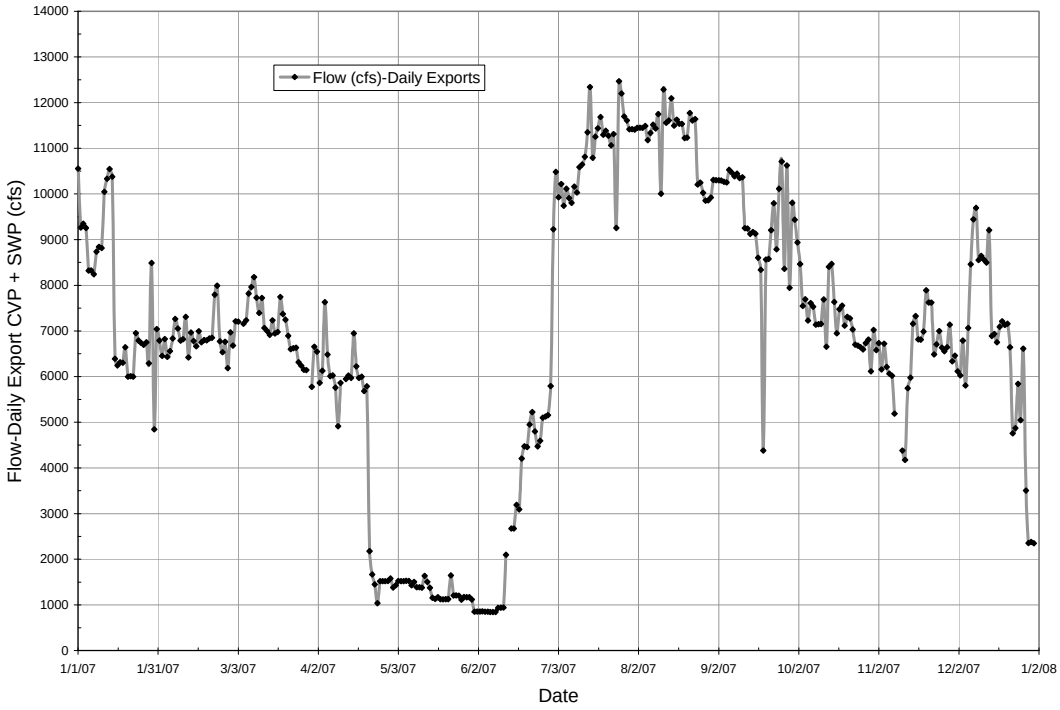


Figure 8-5. Daily combined State Water Project and Central Valley Project exports



Results

Water Temperature

Temperature affects pH, conductance, the solubility of constituents such as DO, the rate of chemical reactions, and biological activity in water (Radtke et al., 2004). It is also probably the single most important factor affecting fish distribution both between and within estuaries seasonally, although temperature effects are closely tied to the effects of other variables (Moyle and Cech, Jr. 2000).

A maximum water temperature of 31.02 °C (87.8 ºF) was recorded on July 5 at Middle River (MR) near Tracy Road and a minimum of 2.48 °C (36.5 ºF) was recorded on January 16 at MR at Howard Road. (Figures 8-6 to 8-9). Tables 8-3 to 8-6 provide a statistical summary of the 2007 water quality data collected in the South Delta. Temperature patterns followed seasonal trends, with the highest temperatures occurring in summer and the lowest in winter. Monthly mean temperatures in the summer ranged from 22.02 ºC
(71.6 ºF) in June at Old River (OR) upstream of the ORT barrier to 25.66 ºC (78.2 ºF) at MR at Howard Road. In the winter, monthly mean temperatures ranged from 6.68 ºC (44.0 ºF) in January at MR at Howard Road to 12.18 ºC (53.9 ºF) in February at Grant Line Canal (GLC) at Tracy Road. Water temperatures in spring and fall exhibited the steepest increases and decreases in temperature in accordance with seasonal temperature changes. Mean temperatures for the monitoring period at stations with a full data set ranged from 17.09 °C (62.8 ºF) at OR upstream the ORT barrier to 17.67 °C (63.8 ºF) at Doughty Cut above GLC.

In 2006 water temperatures ranged from a minimum of 5.52 °C (41.9 ºF) in December to a maximum of 33.27 °C (91.9 ºF) in July. Mean temperatures for the monitoring period ranged from 16.13 °C (61 ºF) to 17.16 °C (62.9 ºF).

Field Data

Field data collected throughout the year showed a strong correlation with the sonde data (R2 = .99). The mean water temperature of the sonde data was 17.79 ºC (64.0 ºF) and mean of the field data was 17.98 ºC (64.4 ºF), (n=206). (See Figure 8-10.)

Figure 8-6. Old River water temperature data (15-minute intervals)

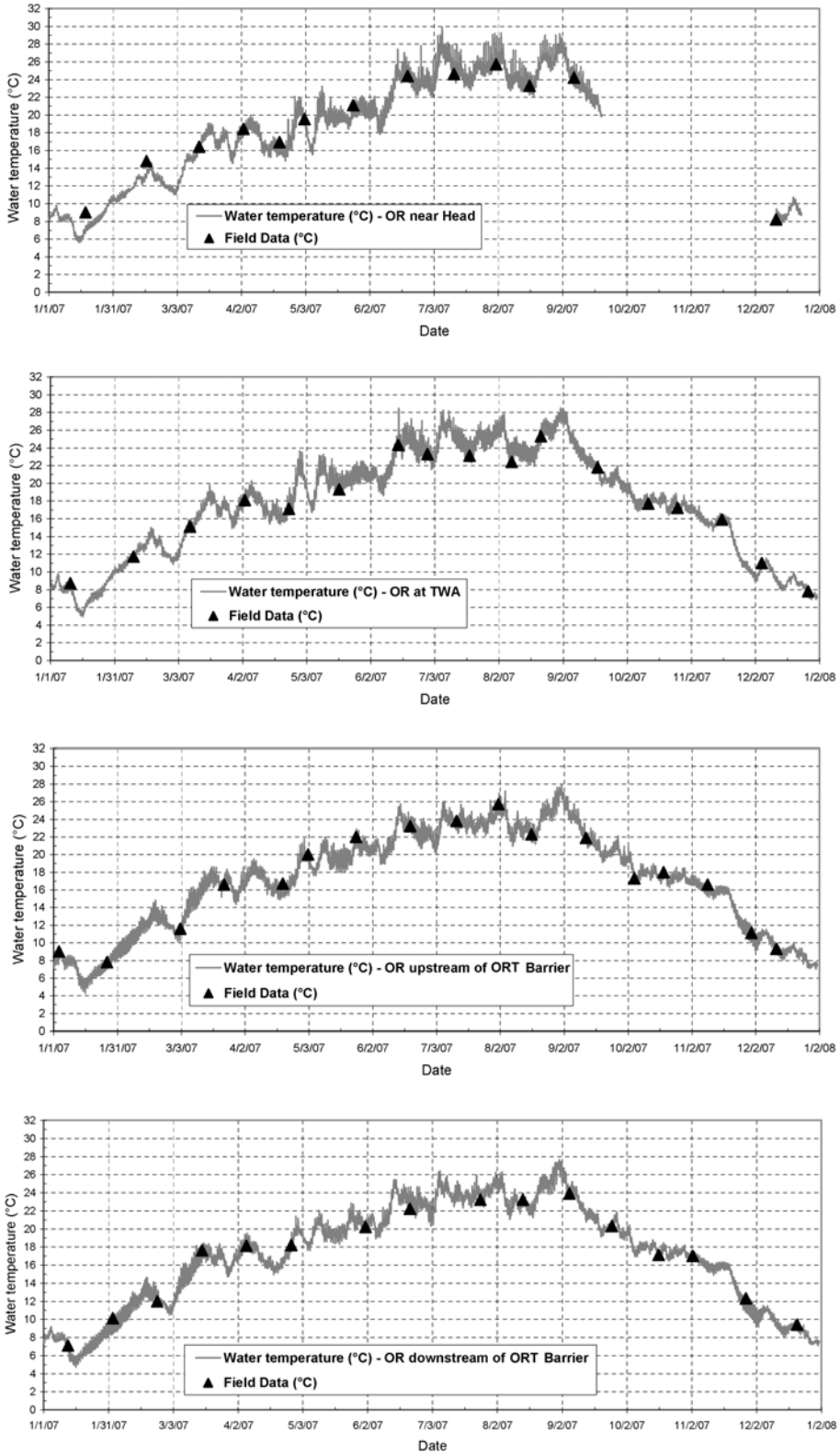


Figure 8-7. Middle River water temperature data (15-minute intervals)

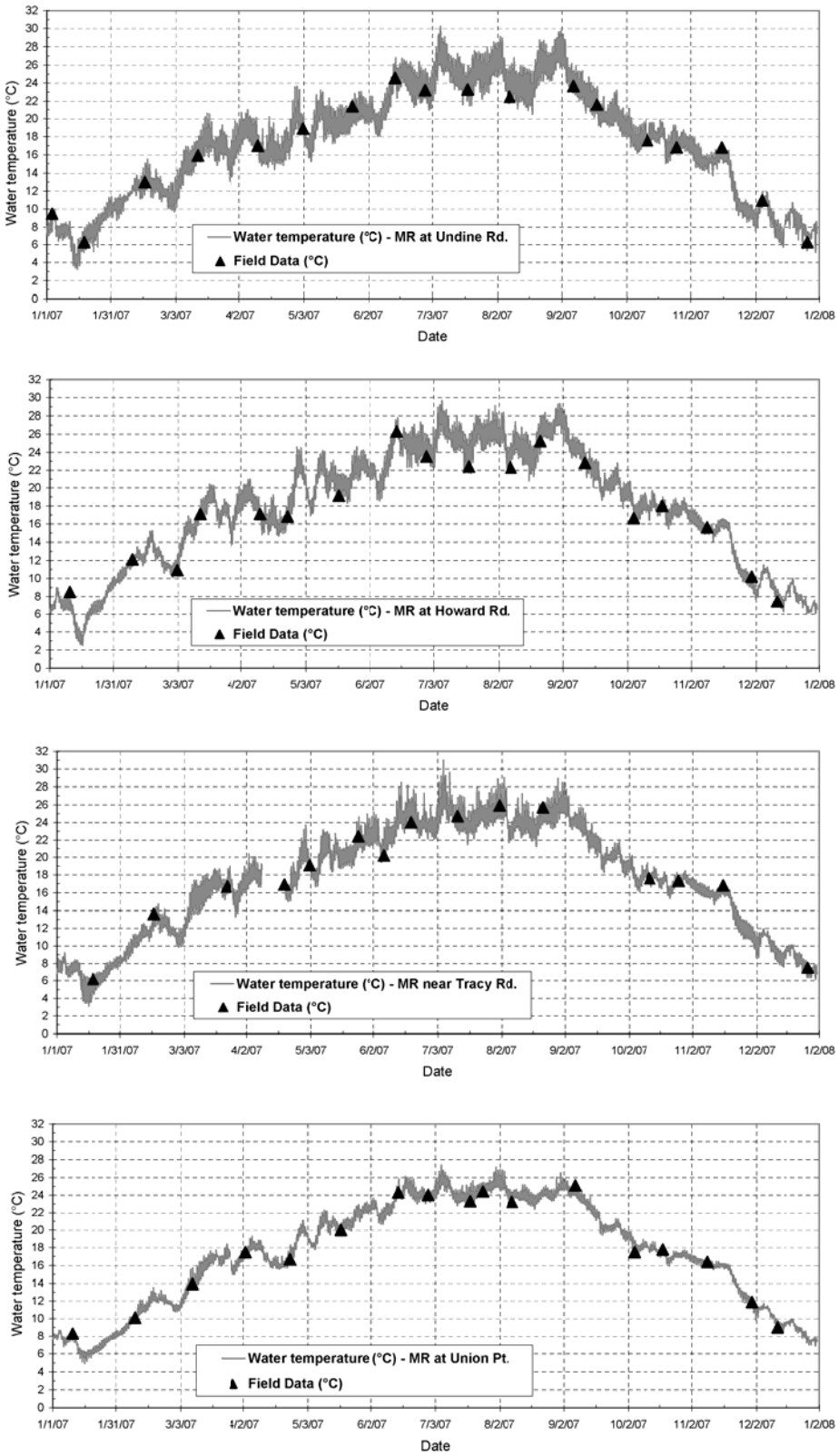


Figure 8-8. Grant Line Canal water temperature data (15-minute intervals)

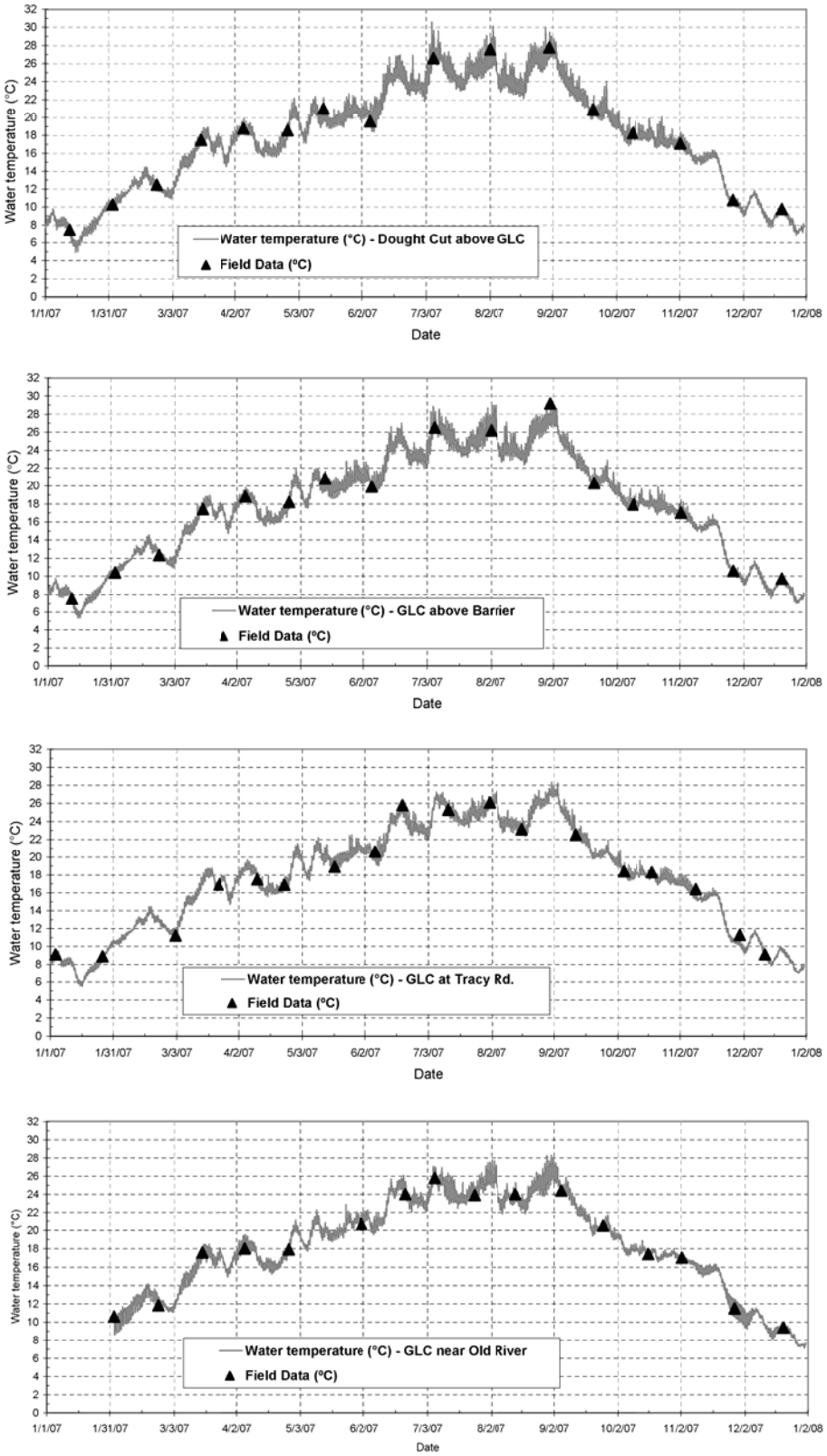


Figure 8-9. Victoria Canal water temperature, dissolved oxygen, pH, and specific conductance data (15-minute intervals)

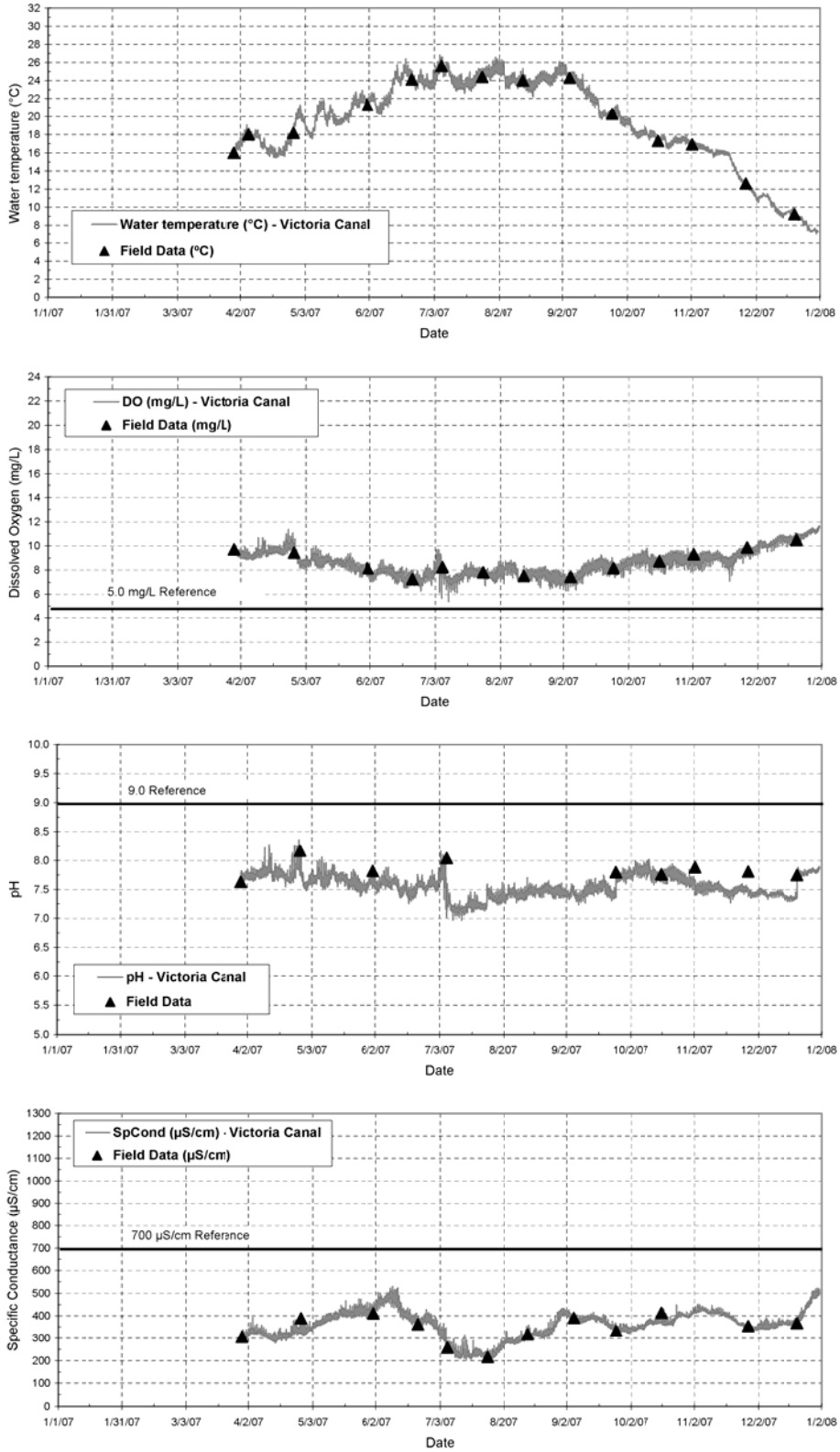


Table 8-3. Statistical summary of 2007 Old River continuous water temperature, dissolved oxygen, and pH data

Month	Water Temperature (°C)			
Maximums	Head	TWA	Abv ORT	Below ORT
Jan.	10.99	10.55	9.78	9.87
Feb.	14.56	14.96	14.81	14.64
Mar	19.05	19.80	18.62	18.40
Apr	22.06	23.67	21.79	21.38
May	23.22	23.24	22.89	22.80
Jun	27.80	28.44	25.72	25.45
Jul	29.93	28.24	26.13	26.42
Aug	29.25	28.50	27.83	27.62
Sep	28.70	28.36	26.99	27.40
Oct	-	20.08	20.91	20.43
Nov	-	17.55	17.61	17.51
Dec	10.69	11.55	11.54	11.54
Averages	**Head**	**TWA**	**Abv ORT**	**Below ORT**
Jan.	8.15	7.73	7.29	7.32
Feb.	12.13	12.15	11.60	11.57
Mar	15.83	16.10	15.54	15.56
Apr	17.50	17.96	17.20	17.27
May	19.55	20.31	19.83	19.89
Jun	22.55	22.84	22.02	22.22
Jul	25.20	24.89	23.50	23.73
Aug	25.06	24.95	23.93	24.01
Sep	23.54	22.67	21.96	22.00
Oct	-	17.99	17.75	17.80
Nov	-	14.49	14.87	14.85
Dec	9.09	9.03	9.26	9.26

Month	Dissolved Oxygen (mg/L)			
Maximums	Head	TWA	Abv ORT	Below ORT
Jan.	13.90	13.96	15.66	15.53
Feb.	12.96	13.35	16.18	15.54
Mar	14.07	16.47	16.57	16.72
Apr	16.62	20.34	15.10	15.18
May	14.96	14.51	9.60	10.12
Jun	21.76	14.45	9.19	10.62
Jul	23.16	14.65	15.83	11.80
Aug	20.12	13.28	15.25	10.58
Sep	14.79	11.43	11.48	9.82
Oct	-	12.65	12.12	11.20
Nov	-	10.66	10.39	10.56
Dec	11.64	12.06	11.61	11.63
Averages	**Head**	**TWA**	**Abv ORT**	**Below ORT**
Jan.	12.14	11.77	12.56	12.52
Feb.	10.29	9.61	11.94	10.62
Mar	10.38	11.06	10.38	10.42
Apr	12.42	12.21	10.20	10.17
May	11.04	7.76	7.89	7.95
Jun	12.19	8.70	6.15	6.74
Jul	12.29	7.63	6.15	6.72
Aug	11.54	7.53	6.22	6.37
Sep	9.45	8.23	6.81	7.01
Oct	-	9.43	8.06	8.50
Nov	-	8.64	8.19	8.46
Dec	11.19	10.22	10.04	10.49

Month	pH			
Maximums	Head	TWA	Abv ORT	Below ORT
Jan.	8.09	8.18	8.55	8.73
Feb.	8.16	8.15	8.69	8.66
Mar	8.71	8.91	9.15	9.15
Apr	9.24	9.28	9.02	8.99
May	9.17	8.82	8.21	8.09
Jun	9.65	9.08	8.32	8.47
Jul	9.70	9.17	9.15	8.80
Aug	9.47	9.00	9.21	8.83
Sep	8.95	8.46	8.48	8.21
Oct	-	8.61	8.49	8.36
Nov	-	8.03	7.96	8.23
Dec	7.79	8.11	8.07	8.13
Averages	**Head**	**TWA**	**Abv ORT**	**Below ORT**
Jan.	7.75	7.83	7.81	7.94
Feb.	7.73	7.77	7.74	7.58
Mar	7.89	8.03	7.92	7.71
Apr	8.60	8.59	8.13	8.00
May	8.37	7.78	7.57	7.51
Jun	8.95	7.92	7.63	7.60
Jul	9.15	8.57	7.88	7.89
Aug	8.85	8.42	7.93	7.93
Sep	8.46	8.12	7.80	7.75
Oct	-	8.10	7.87	7.83
Nov	-	7.59	7.69	7.94
Dec	7.71	7.68	7.80	7.95

Table 8-3 (cont.). Statistical summary of 2007 Old River continuous water temperature, dissolved oxygen, and pH data

Month	Water Temperature (°C)			
Minimums	**Head**	**TWA**	**Abv ORT**	**Below ORT**
Jan.	5.60	4.94	4.28	4.70
Feb.	10.08	9.92	8.29	8.29
Mar	11.00	11.25	10.18	10.47
Apr	14.81	15.37	14.90	14.91
May	15.53	16.71	17.61	17.61
Jun	17.83	18.60	18.90	18.89
Jul	22.03	21.56	20.25	20.29
Aug	22.07	21.94	20.95	21.07
Sep	19.81	18.98	18.73	18.91
Oct	-	16.40	16.26	16.45
Nov	-	9.77	10.08	10.10
Dec	7.84	6.89	7.01	7.09
Std. Devs.	**Head**	**TWA**	**Abv ORT**	**Below ORT**
Jan.	1.20	1.27	1.12	1.09
Feb.	1.00	1.20	1.35	1.37
Mar	1.96	1.92	1.90	1.90
Apr	1.51	1.66	1.30	1.25
May	1.40	1.31	1.06	0.98
Jun	2.10	1.95	1.48	1.53
Jul	1.37	1.29	1.08	1.02
Aug	1.54	1.56	1.55	1.53
Sep	2.06	2.38	2.06	2.07
Oct	-	0.76	0.73	0.74
Nov	-	2.24	1.94	1.92
Dec	0.68	1.14	1.16	1.16
2007 - Max.	29.93	28.50	27.83	27.62
2007 - Avg.	18.27	17.62	17.09	17.15
2007 - Min.	5.60	4.94	4.28	4.70
2007 - S.D.	6.09	5.87	5.52	5.57

Month	Dissolved Oxygen (mg/L)			
Minimums	**Head**	**TWA**	**Abv ORT**	**Below ORT**
Jan.	11.20	9.08	10.62	10.68
Feb.	9.02	6.56	8.50	8.29
Mar	9.04	7.94	8.30	8.23
Apr	9.96	4.05	6.39	7.13
May	8.60	2.15	6.12	6.04
Jun	8.30	3.73	1.22	2.21
Jul	6.86	0.62	0.72	3.02
Aug	6.91	4.62	2.55	3.07
Sep	6.30	4.34	3.57	3.46
Oct	-	7.17	5.73	6.16
Nov	-	7.00	4.93	7.60
Dec	10.55	8.62	7.80	8.66
Std. Devs.	**Head**	**TWA**	**Abv ORT**	**Below ORT**
Jan.	0.56	0.87	1.05	1.10
Feb.	0.94	1.45	1.24	1.51
Mar	0.89	1.68	1.29	1.25
Apr	1.20	2.36	1.40	1.38
May	1.12	1.88	0.67	0.66
Jun	1.66	2.39	1.59	1.41
Jul	2.28	2.43	1.72	1.22
Aug	2.01	1.39	1.63	1.41
Sep	1.23	1.56	1.34	1.39
Oct	-	1.14	0.89	0.99
Nov	-	0.82	1.17	1.19
Dec	0.25	0.71	0.76	0.66
2007 - Max.	23.16	20.34	16.57	16.72
2007 - Avg.	11.38	9.40	8.70	8.82
2007 - Min.	6.30	0.62	0.72	2.21
2007 - S.D.	1.68	2.27	2.51	2.25

Month	pH			
Minimums	**Head**	**TWA**	**Abv ORT**	**Below ORT**
Jan.	7.44	7.53	7.42	7.55
Feb.	7.58	7.52	7.44	7.12
Mar	7.55	7.47	7.58	7.23
Apr	8.02	7.73	7.37	7.42
May	7.71	7.21	7.27	7.25
Jun	8.30	7.23	7.24	7.24
Jul	8.89	7.88	7.15	7.40
Aug	8.29	7.85	7.36	7.22
Sep	7.95	7.78	7.47	7.40
Oct	-	7.64	7.57	7.50
Nov	-	7.30	7.48	7.60
Dec	7.56	7.48	7.49	7.71
Std. Devs.	**Head**	**TWA**	**Abv ORT**	**Below ORT**
Jan.	0.12	0.10	0.31	0.32
Feb.	0.12	0.11	0.29	0.32
Mar	0.27	0.34	0.37	0.44
Apr	0.23	0.28	0.39	0.42
May	0.33	0.29	0.16	0.13
Jun	0.23	0.50	0.21	0.23
Jul	0.14	0.23	0.37	0.35
Aug	0.19	0.21	0.37	0.33
Sep	0.14	0.14	0.16	0.16
Oct	-	0.20	0.18	0.17
Nov	-	0.19	0.08	0.10
Dec	0.03	0.14	0.08	0.08
2007 - Max.	9.70	9.28	9.21	9.15
2007 - Avg.	8.12	7.93	7.79	7.77
2007 - Min.	7.44	7.21	7.15	7.12
2007 - S.D.	0.56	0.43	0.33	0.34

Table 8-4. Statistical summary of 2007 Middle River continuous water temperature, dissolved oxygen, and pH data

Month	Water Temperature (°C)			
Maximums	Head	TWA	Abv ORT	Below ORT
Jan.	10.99	10.55	9.78	9.87
Feb.	14.56	14.96	14.81	14.64
Mar	19.05	19.80	18.62	18.40
Apr	22.06	23.67	21.79	21.38
May	23.22	23.24	22.89	22.80
Jun	27.80	28.44	25.72	25.45
Jul	29.93	28.24	26.13	26.42
Aug	29.25	28.50	27.83	27.62
Sep	28.70	28.36	26.99	27.40
Oct	-	20.08	20.91	20.43
Nov	-	17.55	17.61	17.51
Dec	10.69	11.55	11.54	11.54

Month	Dissolved Oxygen (mg/L)			
Maximums	Head	TWA	Abv ORT	Below ORT
Jan.	13.90	13.96	15.66	15.53
Feb.	12.96	13.35	16.18	15.54
Mar	14.07	16.47	16.57	16.72
Apr	16.62	20.34	15.10	15.18
May	14.96	14.51	9.60	10.12
Jun	21.76	14.45	9.19	10.62
Jul	23.16	14.65	15.83	11.80
Aug	20.12	13.28	15.25	10.58
Sep	14.79	11.43	11.48	9.82
Oct	-	12.65	12.12	11.20
Nov	-	10.66	10.39	10.56
Dec	11.64	12.06	11.61	11.63

Month	pH			
Maximums	Head	TWA	Abv ORT	Below ORT
Jan.	8.09	8.18	8.55	8.73
Feb.	8.16	8.15	8.69	8.66
Mar	8.71	8.91	9.15	9.15
Apr	9.24	9.28	9.02	8.99
May	9.17	8.82	8.21	8.09
Jun	9.65	9.08	8.32	8.47
Jul	9.70	9.17	9.15	8.80
Aug	9.47	9.00	9.21	8.83
Sep	8.95	8.46	8.48	8.21
Oct	-	8.61	8.49	8.36
Nov	-	8.03	7.96	8.23
Dec	7.79	8.11	8.07	8.13

	Head	TWA	Abv ORT	Below ORT
Jan.	8.15	7.73	7.29	7.32
Feb.	12.13	12.15	11.60	11.57
Mar	15.83	16.10	15.54	15.56
Apr	17.50	17.96	17.20	17.27
May	19.55	20.31	19.83	19.89
Jun	22.55	22.84	22.02	22.22
Jul	25.20	24.89	23.50	23.73
Aug	25.06	24.95	23.93	24.01
Sep	23.54	22.67	21.96	22.00
Oct	-	17.99	17.75	17.80
Nov	-	14.49	14.87	14.85
Dec	9.09	9.03	9.26	9.26

Averages	Head	TWA	Abv ORT	Below ORT
Jan.	12.14	11.77	12.56	12.52
Feb.	10.29	9.61	11.94	10.62
Mar	10.38	11.06	10.38	10.42
Apr	12.42	12.21	10.20	10.17
May	11.04	7.76	7.89	7.95
Jun	12.19	8.70	6.15	6.74
Jul	12.29	7.63	6.15	6.72
Aug	11.54	7.53	6.22	6.37
Sep	9.45	8.23	6.81	7.01
Oct	-	9.43	8.06	8.50
Nov	-	8.64	8.19	8.46
Dec	11.19	10.22	10.04	10.49

Averages	Head	TWA	Abv ORT	Below ORT
Jan.	7.75	7.83	7.81	7.94
Feb.	7.73	7.77	7.74	7.58
Mar	7.89	8.03	7.92	7.71
Apr	8.60	8.59	8.13	8.00
May	8.37	7.78	7.57	7.51
Jun	8.95	7.92	7.63	7.60
Jul	9.15	8.57	7.88	7.89
Aug	8.85	8.42	7.93	7.93
Sep	8.46	8.12	7.80	7.75
Oct	-	8.10	7.87	7.83
Nov	-	7.59	7.69	7.94
Dec	7.71	7.68	7.80	7.95

Table 8-4 (cont.). Statistical summary of 2007 Middle River continuous water temperature, dissolved oxygen, and pH data

Month	Water Temperature (°C)			
Minimums	**Head**	**TWA**	**Abv ORT**	**Below ORT**
Jan.	5.60	4.94	4.28	4.70
Feb.	10.08	9.92	8.29	8.29
Mar	11.00	11.25	10.18	10.47
Apr	14.81	15.37	14.90	14.91
May	15.53	16.71	17.61	17.61
Jun	17.83	18.60	18.90	18.89
Jul	22.03	21.56	20.25	20.29
Aug	22.07	21.94	20.95	21.07
Sep	19.81	18.98	18.73	18.91
Oct	-	16.40	16.26	16.45
Nov	-	9.77	10.08	10.10
Dec	7.84	6.89	7.01	7.09
Std. Devs.	**Head**	**TWA**	**Abv ORT**	**Below ORT**
Jan.	1.20	1.27	1.12	1.09
Feb.	1.00	1.20	1.35	1.37
Mar	1.96	1.92	1.90	1.90
Apr	1.51	1.66	1.30	1.25
May	1.40	1.31	1.06	0.98
Jun	2.10	1.95	1.48	1.53
Jul	1.37	1.29	1.08	1.02
Aug	1.54	1.56	1.55	1.53
Sep	2.06	2.38	2.06	2.07
Oct	-	0.76	0.73	0.74
Nov	-	2.24	1.94	1.92
Dec	0.68	1.14	1.16	1.16
2007 - Max.	29.93	28.50	27.83	27.62
2007 - Avg.	18.27	17.62	17.09	17.15
2007 - Min.	5.60	4.94	4.28	4.70
2007 - S.D.	6.09	5.87	5.52	5.57

Month	Dissolved Oxygen (mg/L)			
Minimums	**Head**	**TWA**	**Abv ORT**	**Below ORT**
Jan.	11.20	9.08	10.62	10.68
Feb.	9.02	6.56	8.50	8.29
Mar	9.04	7.94	8.30	8.23
Apr	9.96	4.05	6.39	7.13
May	8.60	2.15	6.12	6.04
Jun	8.30	3.73	1.22	2.21
Jul	6.86	0.62	0.72	3.02
Aug	6.91	4.62	2.55	3.07
Sep	6.30	4.34	3.57	3.46
Oct	-	7.17	5.73	6.16
Nov	-	7.00	4.93	7.60
Dec	10.55	8.62	7.80	8.66
Std. Devs.	**Head**	**TWA**	**Abv ORT**	**Below ORT**
Jan.	0.56	0.87	1.05	1.10
Feb.	0.94	1.45	1.24	1.51
Mar	0.89	1.68	1.29	1.25
Apr	1.20	2.36	1.40	1.38
May	1.12	1.88	0.67	0.66
Jun	1.66	2.39	1.59	1.41
Jul	2.28	2.43	1.72	1.22
Aug	2.01	1.39	1.63	1.41
Sep	1.23	1.56	1.34	1.39
Oct	-	1.14	0.89	0.99
Nov	-	0.82	1.17	1.19
Dec	0.25	0.71	0.76	0.66
2007 - Max.	23.16	20.34	16.57	16.72
2007 - Avg.	11.38	9.40	8.70	8.82
2007 - Min.	6.30	0.62	0.72	2.21
2007 - S.D.	1.68	2.27	2.51	2.25

Month	pH			
Minimums	**Head**	**TWA**	**Abv ORT**	**Below ORT**
Jan.	7.44	7.53	7.42	7.55
Feb.	7.58	7.52	7.44	7.12
Mar	7.55	7.47	7.58	7.23
Apr	8.02	7.73	7.37	7.42
May	7.71	7.21	7.27	7.25
Jun	8.30	7.23	7.24	7.24
Jul	8.89	7.88	7.15	7.40
Aug	8.29	7.85	7.36	7.22
Sep	7.95	7.78	7.47	7.40
Oct	-	7.64	7.57	7.50
Nov	-	7.30	7.48	7.60
Dec	7.56	7.48	7.49	7.71
Std. Devs.	**Head**	**TWA**	**Abv ORT**	**Below ORT**
Jan.	0.12	0.10	0.31	0.32
Feb.	0.12	0.11	0.29	0.32
Mar	0.27	0.34	0.37	0.44
Apr	0.23	0.28	0.39	0.42
May	0.33	0.29	0.16	0.13
Jun	0.23	0.50	0.21	0.23
Jul	0.14	0.23	0.37	0.35
Aug	0.19	0.21	0.37	0.33
Sep	0.14	0.14	0.16	0.16
Oct	-	0.20	0.18	0.17
Nov	-	0.19	0.08	0.10
Dec	0.03	0.14	0.08	0.08
2007 - Max.	9.70	9.28	9.21	9.15
2007 - Avg.	8.12	7.93	7.79	7.77
2007 - Min.	7.44	7.21	7.15	7.12
2007 - S.D.	0.56	0.43	0.33	0.34

Table 8-5. Statistical summary of 2007 Grant Line Canal continuous water temperature, dissolved oxygen, and pH data

Month	Water Temperature (°C)			
Maximums	Doughty Cut	GLC abv Bar	Tracy Rd.	GLC n OR
Jan.	10.83	10.63	10.67	-
Feb.	14.47	14.56	14.45	14.18
Mar	18.95	18.94	18.77	18.48
Apr	22.15	21.83	21.52	21.13
May	22.65	22.86	22.50	22.87
Jun	26.98	27.01	25.91	26.08
Jul	30.58	28.84	27.24	27.42
Aug	30.17	29.04	28.35	28.30
Sep	29.00	29.23	28.21	28.05
Oct	20.74	20.30	20.75	19.71
Nov	18.36	18.38	18.12	17.28
Dec	11.83	11.69	11.82	11.55

Averages	Doughty Cut	GLC abv Bar.	Tracy Rd.	GLC n OR
Jan.	8.02	8.05	8.03	-
Feb.	12.11	12.17	12.18	11.92
Mar	15.82	15.89	15.77	15.65
Apr	17.65	17.71	18.86	17.41
May	19.98	20.12	20.00	20.04
Jun	22.70	22.77	22.56	22.76
Jul	25.25	25.21	24.93	24.50
Aug	25.25	25.19	24.87	24.38
Sep	22.75	22.75	22.57	22.30
Oct	17.97	18.01	18.02	17.75
Nov	14.43	14.49	14.54	14.81
Dec	9.21	9.12	9.14	9.31

Month	Dissolved Oxygen (mg/L)			
Maximums	Doughty Cut	GLC abv Bar.	Tracy Rd.	GLC n OR
Jan.	13.11	13.40	14.37	-
Feb.	13.51	12.60	15.27	12.56
Mar	12.40	14.07	14.43	13.63
Apr	16.08	16.13	16.61	14.46
May	14.31	14.16	13.66	10.01
Jun	18.52	14.76	13.31	8.17
Jul	20.03	17.03	11.55	12.04
Aug	16.88	14.83	8.87	12.79
Sep	13.82	13.31	10.89	10.64
Oct	14.54	13.69	13.90	9.85
Nov	10.87	11.45	11.05	11.51
Dec	12.12	12.21	12.58	11.42

Averages	Doughty Cut	GLC abv Bar.	Tracy Rd.	GLC n OR
Jan.	12.04	12.36	12.27	-
Feb.	10.58	10.04	11.28	9.95
Mar	10.24	10.98	10.55	10.28
Apr	12.05	12.72	12.69	10.74
May	8.49	8.50	8.48	7.90
Jun	10.34	8.48	8.40	6.79
Jul	9.71	6.62	5.77	6.74
Aug	9.74	6.42	5.89	7.11
Sep	8.69	7.48	7.34	7.40
Oct	9.50	8.52	8.25	8.45
Nov	9.16	9.48	9.12	9.25
Dec	10.66	10.96	11.10	10.39

Month	pH			
Maximums	Doughty Cut	GLC abv Bar.	Tracy Rd.	GLC n Old Riv
Jan.	8.26	8.13	8.15	-
Feb.	8.27	8.23	8.10	8.15
Mar	8.63	8.53	8.60	8.62
Apr	9.19	9.08	9.09	8.93
May	8.96	8.98	8.85	8.45
Jun	9.27	9.02	9.10	7.91
Jul	9.56	9.41	9.12	8.87
Aug	9.33	9.24	8.73	8.77
Sep	8.96	8.90	8.49	8.25
Oct	8.81	8.82	8.65	8.09
Nov	8.38	8.76	8.00	8.02
Dec	7.95	8.26	8.06	7.85

Averages	Doughty Cut	GLC abv Bar.	Tracy Rd.	GLC n Old Riv
Jan.	7.97	7.85	7.93	-
Feb.	7.81	7.78	7.77	7.69
Mar	7.86	7.95	7.92	7.88
Apr	8.09	8.56	8.52	7.98
May	7.72	7.77	7.68	7.69
Jun	8.48	8.06	8.12	7.50
Jul	9.03	8.62	8.46	7.39
Aug	8.62	8.46	8.28	7.76
Sep	8.44	8.19	7.97	7.75
Oct	8.18	8.27	7.68	7.71
Nov	8.01	7.98	7.60	7.76
Dec	7.68	8.05	7.76	7.68

Table 8-5 (cont.). Statistical summary of 2007 Grant Line Canal continuous water temperature, dissolved oxygen, and pH data

Month	Water Temperature (°C)			
Minimums	Doughty Cut	GLC abv Bar.	Tracy Rd.	GLC n OR
Jan.	4.95	5.34	5.48	-
Feb.	9.96	10.08	10.18	8.59
Mar	10.96	10.91	11.00	11.07
Apr	15.57	15.52	16.51	15.22
May	17.15	17.50	17.39	17.73
Jun	18.39	19.35	18.97	19.56
Jul	21.85	22.13	21.88	22.09
Aug	22.18	22.37	22.38	21.86
Sep	19.09	19.48	19.44	18.99
Oct	16.55	16.76	16.85	16.55
Nov	9.87	9.84	10.03	10.03
Dec	6.91	7.04	6.95	7.14
Std.Devs.	Doughty Cut	GLC abv Bar.	Tracy Rd.	GLC n OR
Jan.	1.24	1.21	1.20	-
Feb.	1.02	1.03	1.02	1.13
Mar	1.93	1.95	2.16	1.90
Apr	1.39	1.38	1.52	1.26
May	0.98	1.02	0.96	0.94
Jun	2.01	1.85	1.81	1.65
Jul	1.38	1.25	1.08	1.01
Aug	1.64	1.53	1.41	1.28
Sep	2.37	2.33	2.37	2.21
Oct	0.85	0.68	0.65	0.65
Nov	2.29	2.30	2.28	2.06
Dec	1.17	1.12	1.22	1.18
2007 - Max.	30.58	29.23	28.35	28.30
2007 - Avg.	17.67	17.65	17.56	18.33
2007 - Min.	4.95	5.34	5.48	7.14
2007 - S.D.	5.85	5.86	5.75	5.03

Month	Dissolved Oxygen (mg/L)			
Minimums	Doughty Cut	GLC abv Bar.	Tracy Rd.	GLC n OR
Jan.	10.71	11.49	10.83	-
Feb.	7.87	8.12	9.73	8.82
Mar	8.14	9.08	8.59	8.63
Apr	8.87	10.28	9.78	7.94
May	5.92	5.60	5.27	5.42
Jun	6.10	2.93	3.97	3.94
Jul	2.72	0.77	1.64	3.17
Aug	4.85	1.34	3.71	3.28
Sep	4.23	3.22	3.84	3.50
Oct	7.08	5.59	6.24	5.86
Nov	7.46	7.18	6.93	5.92
Dec	9.49	9.38	9.40	8.84
Std.Devs.	Doughty Cut	GLC abv Bar.	Tracy Rd.	GLC n OR
Jan.	0.34	0.36	0.73	-
Feb.	0.88	1.10	1.26	0.90
Mar	0.74	0.84	1.29	0.87
Apr	1.34	1.13	1.14	1.49
May	1.24	1.45	1.51	0.55
Jun	2.15	2.20	2.32	0.78
Jul	2.74	2.78	2.16	1.15
Aug	2.03	1.91	0.88	1.11
Sep	1.64	1.85	1.47	1.18
Oct	1.19	1.19	1.10	0.71
Nov	0.75	0.89	1.00	1.06
Dec	0.57	0.52	0.75	0.51
2007 - Max.	20.03	17.03	16.61	14.46
2007 - Avg.	10.06	9.34	9.19	8.62
2007 - Min.	2.72	0.77	1.64	3.17
2007 - S.D.	1.82	2.58	2.65	1.77

Month	pH			
Minimums	Doughty Cut	GLC abv Bar.	Tracy Rd.	GLC n Old Riv
Jan.	7.66	7.57	7.69	-
Feb.	7.56	7.61	7.61	7.42
Mar	7.18	7.71	7.59	7.54
Apr	7.37	8.11	7.96	7.36
May	7.36	7.43	7.29	7.39
Jun	7.53	7.31	7.43	7.23
Jul	8.57	7.90	7.85	6.91
Aug	7.82	7.68	7.76	7.23
Sep	7.91	7.58	7.53	7.46
Oct	7.83	7.91	7.29	7.38
Nov	7.65	7.71	7.33	7.39
Dec	7.52	7.82	7.55	7.38
Std.Devs.	Doughty Cut	GLC abv Bar.	Tracy Rd.	GLC n Old Riv
Jan.	0.07	0.09	0.06	-
Feb.	0.14	0.13	0.11	0.15
Mar	0.35	0.18	0.25	0.27
Apr	0.43	0.22	0.22	0.43
May	0.35	0.33	0.40	0.11
Jun	0.34	0.40	0.45	0.11
Jul	0.14	0.27	0.25	0.36
Aug	0.23	0.25	0.19	0.26
Sep	0.17	0.22	0.18	0.12
Oct	0.21	0.12	0.26	0.15
Nov	0.13	0.13	0.16	0.12
Dec	0.07	0.06	0.15	0.60
2007 - Max.	9.56	9.41	9.12	8.93
2007 - Avg.	8.04	8.05	7.89	7.68
2007 - Min.	7.18	7.31	7.29	6.91
2007 - S.D.	0.47	0.37	0.40	0.29

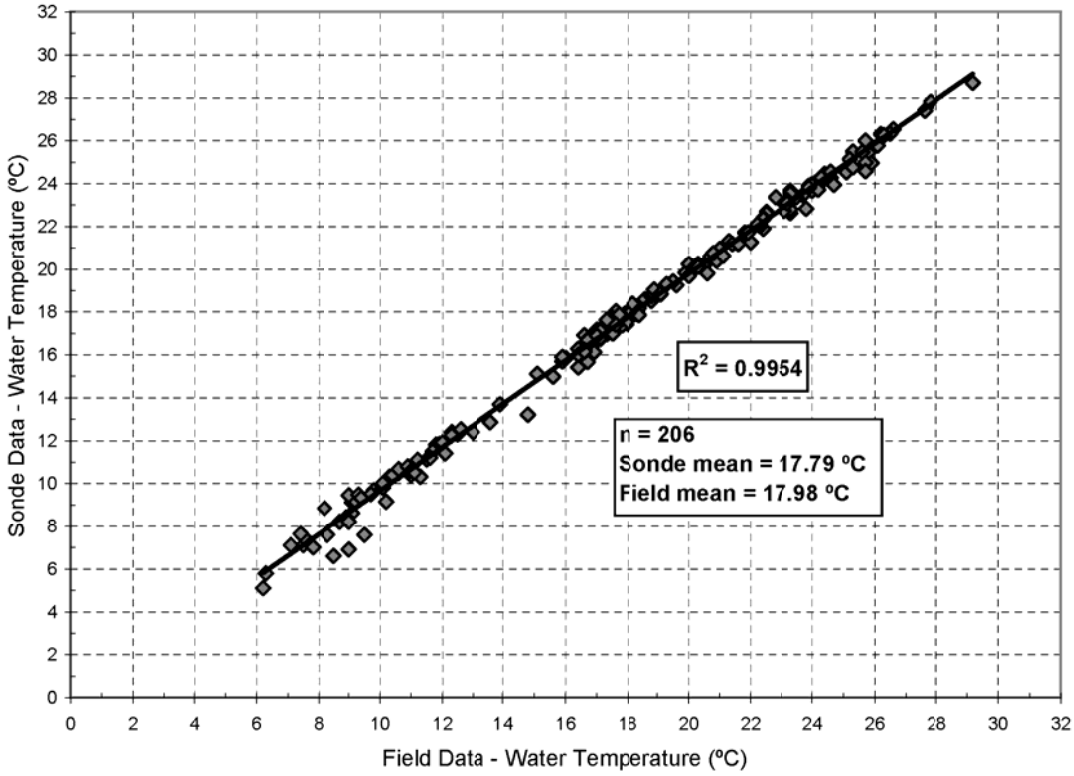
Table 8-6. Statistical summary of 2007 Victoria Canal continuous water temperature, dissolved oxygen, pH, specific conductance, turbidity, and chlorophyll *a* data

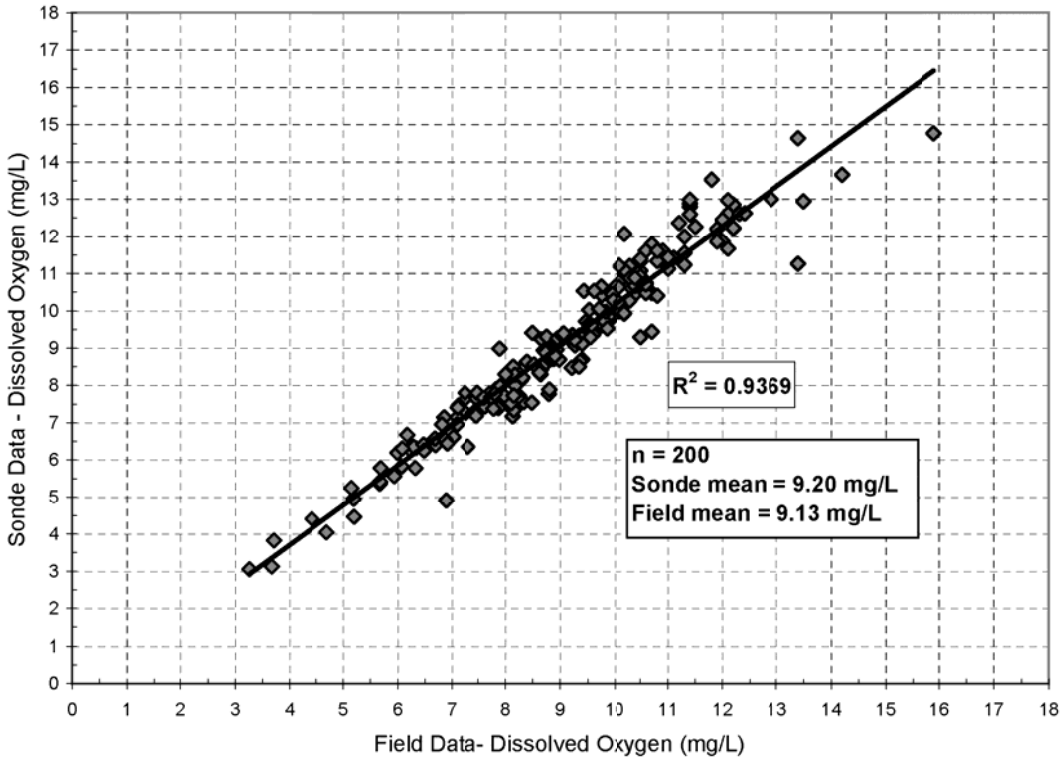
Month	Water Temperature (ºC)	Month	Dissolved Oxygen (mg/L)	Month	pH	Month	Specific Conductance (µS/cm)	Month	Turbidity (NTU)	Month	Chlorophyll a (µg/L)
Maximums	**Victoria Canal**	**Maximums**	**Victoria Canal**	**Maximums**	**Victoria Canal**	**Maximums**	**Victoria Canal**	**Maximums**	**Victoria Canal**	**Maximums**	**Victoria Canal**
Jan.	-	Jan.	-	Jan.	-	Jan.	-	Jan.	-	Jan.	-
Feb.	-	Feb.	-	Feb.	-	Feb.	-	Feb.	-	Feb.	-
Mar	-	Mar	-	Mar	-	Mar	-	Mar	-	Mar	-
Apr	21.30	Apr	11.36	Apr	8.36	Apr	390.8	Apr	27.8	Apr	12.22
May	22.94	May	10.00	May	8.06	May	474.3	May	12.5	May	26.98
Jun	26.41	Jun	8.86	Jun	7.88	Jun	529.8	Jun	33.0	Jun	4.89
Jul	26.82	Jul	9.71	Jul	8.16	Jul	389.2	Jul	54.2	Jul	23.33
Aug	26.39	Aug	8.80	Aug	7.70	Aug	431.8	Aug	30.6	Aug	10.12
Sep	25.86	Sep	9.26	Sep	7.87	Sep	427.2	Sep	17.5	Sep	8.47
Oct	19.89	Oct	9.80	Oct	8.02	Oct	446.8	Oct	8.8	Oct	5.34
Nov	17.39	Nov	10.02	Nov	7.72	Nov	449.1	Nov	10.0	Nov	4.11
Dec	11.77	Dec	11.67	Dec	7.89	Dec	521.5	Dec	18.2	Dec	3.47
Averages	**Victoria Canal**	**Averages**	**Victoria Canal**	**Averages**	**Victoria Canal**	**Averages**	**Victoria Canal**	**Averages**	**Victoria Canal**	**Averages**	**Victoria Canal**
Jan.	-	Jan.	-	Jan.	-	Jan.	-	Jan.	-	Jan.	-
Feb.	-	Feb.	-	Feb.	-	Feb.	-	Feb.	-	Feb.	-
Mar	-	Mar	-	Mar	-	Mar	-	Mar	-	Mar	-
Apr	17.35	Apr	9.50	Apr	7.76	Apr	318.6	Apr	7.5	Apr	2.12
May	20.19	May	8.56	May	7.64	May	395.2	May	5.6	May	5.42
Jun	23.15	Jun	7.59	Jun	7.55	Jun	419.4	Jun	7.60	Jun	2.22
Jul	24.39	Jul	7.68	Jul	7.29	Jul	247.4	Jul	12.1	Jul	4.32
Aug	24.19	Aug	7.74	Aug	7.44	Aug	316.4	Aug	7.5	Aug	3.67
Sep	22.23	Sep	8.01	Sep	7.50	Sep	371.2	Sep	4.9	Sep	2.46
Oct	17.87	Oct	8.90	Oct	7.76	Oct	368.1	Oct	2.4	Oct	2.33
Nov	15.23	Nov	9.16	Nov	7.51	Nov	392.7	Nov	2.0	Nov	1.10
Dec	9.49	Dec	10.61	Dec	7.50	Dec	386.9	Dec	3.2	Dec	1.29

Table 8-6 (cont.). Statistical summary of 2007 Victoria Canal continuous water temperature, dissolved oxygen, pH, specific conductance, turbidity, and chlorophyll *a* data

Month	Water Temperature (ºC)	Month	Dissolved Oxygen (mg/L)	Month	pH	Month	Specific Conductance (µS/cm)	Month	Turbidity (NTU)	Month	Chlorophyll *a* (µg/L)
Minimums	**Victoria Canal**	**Minimums**	**Victoria Canal**	**Minimums**	**Victoria Canal**	**Minimums**	**Victoria Canal**	**Minimums**	**Victoria Canal**	**Minimums**	**Victoria Canal**
Jan.	-	Jan.	-	Jan.	-	Jan.	-	Jan.	-	Jan.	-
Feb.	-	Feb.	-	Feb.	-	Feb.	-	Feb.	-	Feb.	-
Mar	-	Mar	-	Mar	-	Mar	-	Mar	-	Mar	-
Apr	15.43	Apr	8.16	Apr	7.48	Apr	277.4	Apr	3.5	Apr	0.64
May	17.56	May	7.43	May	7.38	May	331.7	May	2.6	May	2.54
Jun	20.21	Jun	6.27	Jun	7.26	Jun	341.0	Jun	2.9	Jun	0.96
Jul	22.61	Jul	5.39	Jul	6.97	Jul	205.7	Jul	4.7	Jul	1.13
Aug	22.21	Aug	6.46	Aug	7.26	Aug	248.5	Aug	2.8	Aug	1.58
Sep	18.97	Sep	6.29	Sep	7.24	Sep	323.9	Sep	1.5	Sep	0.48
Oct	16.40	Oct	7.53	Oct	7.53	Oct	319.7	Oct	0.5	Oct	0.27
Nov	11.64	Nov	7.10	Nov	7.27	Nov	335.5	Nov	0.4	Nov	0.04
Dec	7.01	Dec	9.23	Dec	7.29	Dec	336.7	Dec	0.9	Dec	0.21
Std. Devs.	**Victoria Canal**	**Std. Devs.**	**Victoria Canal**	**Std. Devs.**	**Victoria Canal**	**Std. Devs.**	**Victoria Canal**	**Std. Devs.**	**Victoria Canal**	**Std. Devs.**	**Victoria Canal**
Jan.	-	Jan.	-	Jan.	-	Jan.	-	Jan.	-	Jan.	-
Feb.	-	Feb.	-	Feb.	-	Feb.	-	Feb.	-	Feb.	-
Mar	-	Mar	-	Mar	-	Mar	-	Mar	-	Mar	-
Apr	1.26	Apr	0.45	Apr	0.12	Apr	16.9	Apr	2.6	Apr	1.27
May	1.19	May	0.39	May	0.10	May	27.9	May	1.4	May	2.98
Jun	1.43	Jun	0.41	Jun	0.10	Jun	45.8	Jun	2.2	Jun	0.59
Jul	0.86	Jul	0.50	Jul	0.21	Jul	36.6	Jul	5.3	Jul	2.07
Aug	0.74	Aug	0.41	Aug	0.07	Aug	38.7	Aug	2.4	Aug	0.77
Sep	1.90	Sep	0.58	Sep	0.13	Sep	23.5	Sep	1.9	Sep	0.65
Oct	0.72	Oct	0.33	Oct	0.08	Oct	23.3	Oct	1.1	Oct	0.56
Nov	1.66	Nov	0.37	Nov	0.06	Nov	28.9	Nov	1.1	Nov	0.40
Dec	1.28	Dec	0.43	Dec	0.19	Dec	48.8	Dec	1.1	Dec	0.33
2007 - Max.	26.82	2007 - Max.	11.67	2007 - Max.	8.36	2007 - Max.	529.8	2007 - Max.	54.2	2007 - Max.	26.98
2007 - Avg.	19.33	2007 - Avg.	8.66	2007 - Avg.	7.53	2007 - Avg.	356.8	2007 - Avg.	5.9	2007 - Avg.	2.77
2007 - Min.	7.01	2007 - Min.	5.39	2007 - Min.	6.97	2007 - Min.	205.7	2007 - Min.	0.4	2007 - Min.	0.04
2007 - S.D.	4.81	2007 - S.D.	1.05	2007 - S.D.	0.19	2007 - S.D.	60.9	2007 - S.D.	3.9	2007 - S.D.	1.92

Figure 8-10. Water temperature and dissolved oxygen linear regression plots for field data versus sonde data





Dissolved Oxygen

One of the most important measures of water quality is the amount of DO (Masters 1998). The US Environmental Protection Agency has established National Ambient Water Quality Criteria for inorganic constituents, such as DO to protect freshwater aquatic life. However, there is considerable variability in DO tolerances among fish and other aquatic life. For a warm water system like the Delta, DO criteria for early aquatic life stages (embryos, larvae, and less than 30-day-old juveniles) was set at 5 mg/L, and 3 mg/L for other life stages (older juveniles and adults). (Marshack 2000). Sources of DO in surface waters are primarily atmospheric reaeration and photosynthetic activity of aquatic plants (Lewis, 2005). DO saturation is inversely related to water temperature (i.e. as water temperature increases, DO saturation decreases). Super saturated DO conditions can occur as a result of excess photosynthetic production of oxygen by phytoplankton and/or aquatic plants. The depletion of DO can occur by inorganic oxidation reactions or by biological or chemical processes that consume dissolved, suspended, or precipitated organic matter (Hem, 1989).

Winter (December-February)

A maximum DO concentration of 22.51 mg/L was measured on February 5 at MR near Tracy Road and a minimum of 6.49 mg/L was recorded on December 8 at MR at Undine Road (Figures 8-11 to 8-13, 8-9 and Tables 8-3 to 8-6). Monthly mean DO concentrations during this period ranged from 9.94 mg/L in February at MR at Undine Road to 13.38 mg/L in January at MR at Howard Road. The expected range of DO values in the winter (assuming 100% saturation) based on water temperature, salinity, and local barometric was between 10.0 mg/L and 13.76 mg/L. Actual DO percent saturation values ranged from 76% to 205% (6.49–22.51 mg/L).

Figure 8-11. Old River dissolved oxygen data (15-minute intervals)

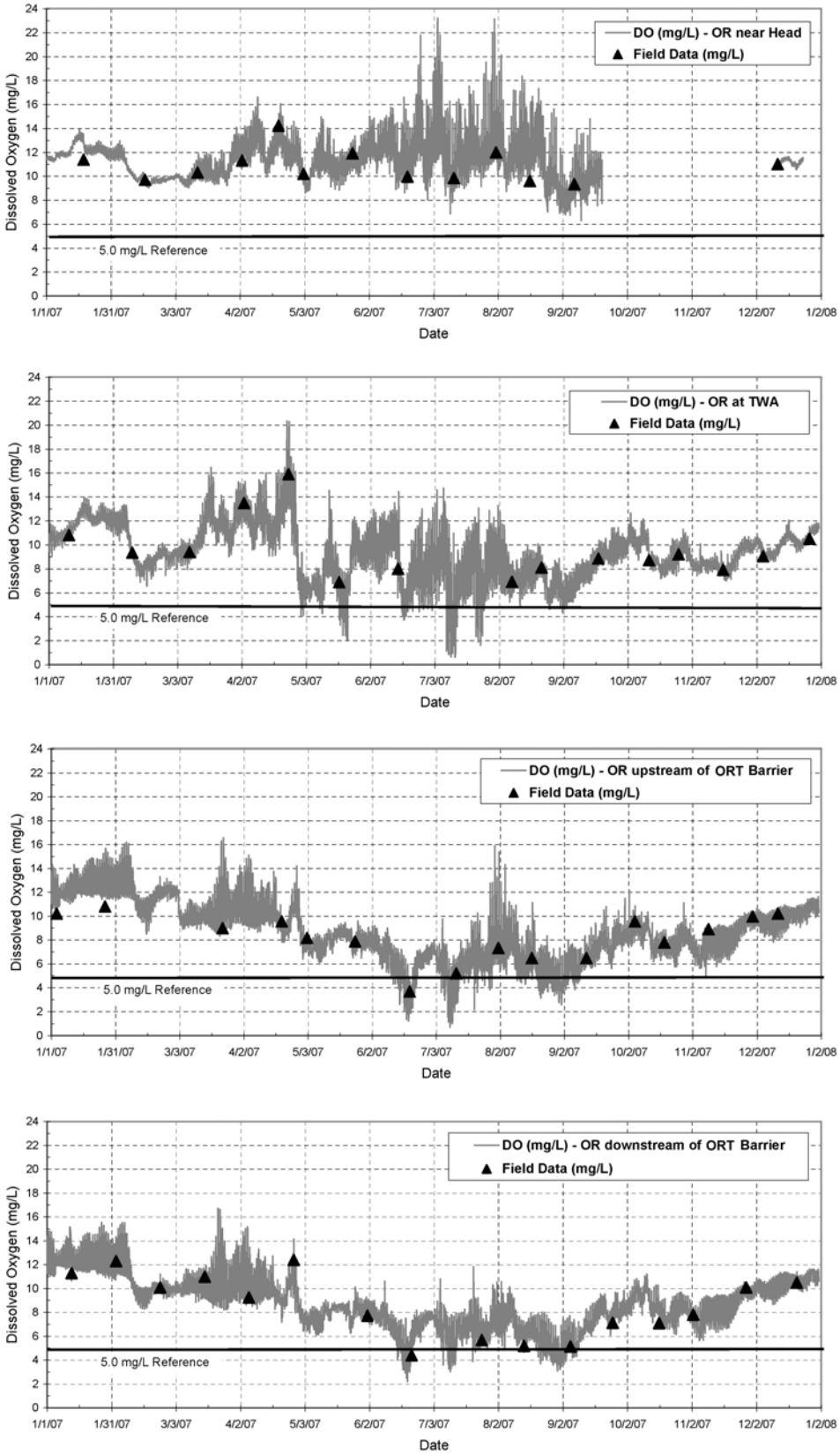


Figure 8-12. Middle River dissolved oxygen data (15-minute intervals)

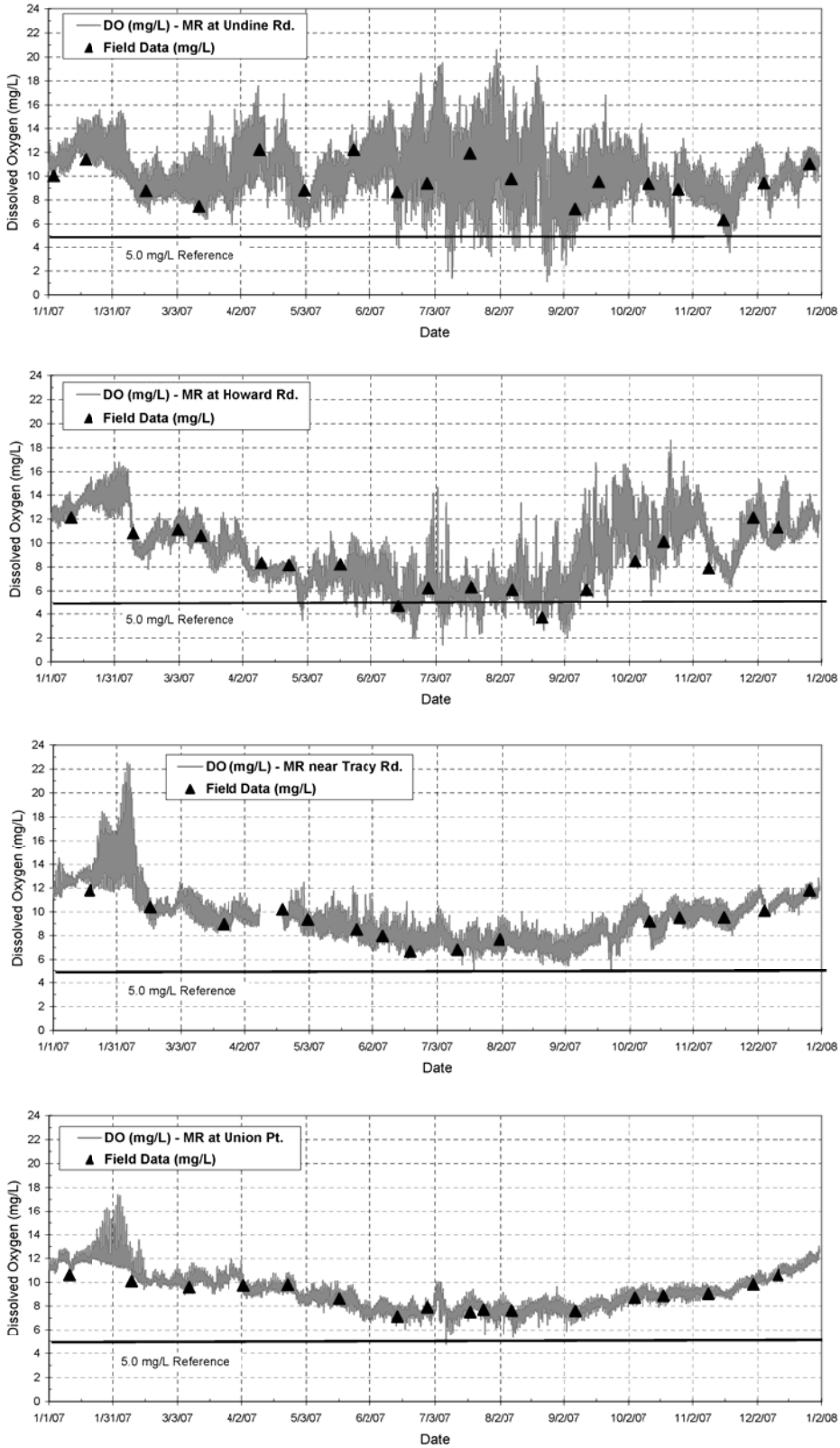
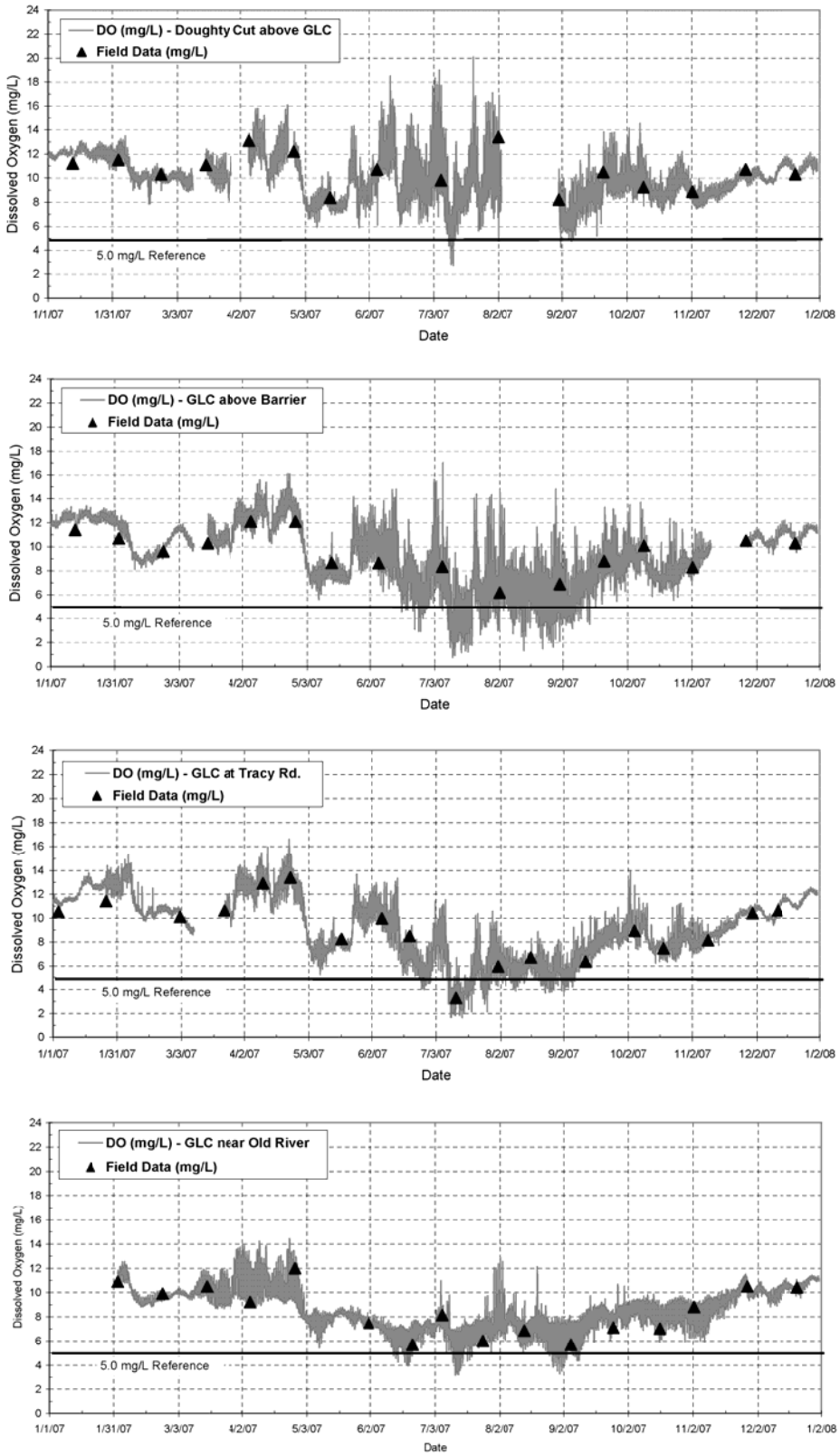


Figure 8-13. Grant Line Canal dissolved oxygen data (15-minute intervals)



Spring (March-May)

A maximum DO concentration of 22.34 mg/L was measured on April 23 and a minimum of 2.15 mg/L was recorded on May 22 both at OR at Tracy Wildlife Association (TWA). Monthly mean DO concentrations during this period ranged from 7.27 mg/L in May at MR at Howard Road to 12.72 mg/L in April at GLC above barrier. The expected range of DO values in the spring (assuming 100% saturation) based on water temperature, salinity, and local barometric was between 8.98 mg/L and 10.1 mg/L. Actual DO percent saturation values ranged from 24% to 220% (2.15–22.34 mg/L). There were 2 stations that recorded DO concentrations below 5.0 mg/L: MR at Howard Road and OR at TWA.

Summer (June-August)

A maximum DO concentration of 23.16 mg/L was measured on July 4 at OR near Head and a minimum of 0.62 mg/L was recorded on July 12 at OR at TWA. Monthly mean DO concentrations during this period ranged from 5.77 mg/L in July at GLC at Tracy Road to 12.29 mg/L in July at OR near Head. The expected range of DO values in the summer (assuming 100% saturation) based on water temperature, salinity, and local barometric was between 7.51 mg/L and 9.56 mg/L. Actual DO percent saturation values ranged from 7.5% to 301% (0.62–23.16 mg/L). Eleven of the 13 stations recorded DO concentrations below 5.0 mg/L, with the exceptions being OR near Head and Victoria Canal.

Fall (September-November)

A maximum DO concentration of 18.61 mg/L was measured on October 22 and a minimum of 2.09 mg/L was recorded on September 3, both at MR at Howard Road. Monthly mean DO concentrations during this period ranged from 6.81 mg/L in September at OR above the ORT barrier to 11.45 mg/L in October at MR at Howard Road. The expected range of DO values in the fall (assuming 100% saturation) based on water temperature, salinity, and local barometric was between 7.63 mg/L and 11.69 mg/L. Actual DO percent saturation values ranged from 26% to 195% (2.09–18.61 mg/L). Ten of the 13 stations recorded DO concentrations below 5.0 mg/L, with the exceptions being OR near Head, Victoria Canal, and MR at Union Point.

ANOVA Analysis

Old River

ANOVA was performed on average daily DO concentrations data to determine whether monthly mean concentrations in June, July, and August differed among 4 Old River monitoring locations (near Head, TWA, upstream of the ORT barrier, downstream of the ORT barrier). Test results showed that at least one mean was significantly different in June [$F(3,112)=107$, $p <.001$), July ($F(3,120)=159$, $p < .001$), and August ($F(3,116)=128$, $p<.001$]. [Explanation of $F(3,112)=107$, $p <.001$: $F(3,112)$ refers to the between-groups degrees of freedom (3) and the within-groups degrees of freedom (112). The F-statistic (107) and p-value (<.001) were calculated from the ANOVA test. Statistical significance was based on having a p-value of less than .01.] Tukey's HSD test was then performed to determine which mean site concentrations differed. The results showed that DO concentrations were significantly less ($p<.01$) at OR upstream of the ORT barrier and at OR downstream of the ORT barrier in comparison to the 2 upstream sites in June and August. In July DO concentrations at the sites near the barrier were significantly less than at Old River near Head ($p<.01$), but there was not a significant difference ($p>.05$) between OR at TWA and the sites upstream/downstream of the barrier. DO concentrations measured at OR near Head were significantly higher ($p<.01$) than at the other 3 sites during each of the months analyzed. There were no significant differences ($p>.05$) in DO concentrations between the sites upstream and downstream of the ORT barrier.

In 2007, there were 2,239 (upstream of the ORT barrier), 1,489 (downstream of the ORT barrier), and 710 (OR at TWA) DO readings below 5 mg/L (Figure 8-14). There were no recorded DO concentrations below 5 mg/L at OR near Head. There were 19 days (OR upstream of the ORT barrier), 11 days (OR downstream of the ORT barrier), 4 days (OR at TWA) where daily average DO concentrations were less than 5 mg/L (Figure 8-15). Average daily DO concentrations below 5 mg/L were observed in 3 distinct periods; from June 17 to June 22, July 7 to July 13, and August 28 to September 2. Daily average DO concentrations below 5 mg/L were only recorded from June through early September. In 2005 and 2006, the majority of the DO concentrations below 5 mg/L in Old River were recorded near the ORT barrier.

Figure 8-14. Number of dissolved oxygen readings less than 5.0 mg/L at each Old River, Middle River, and Grant Line Canal continuous monitoring site

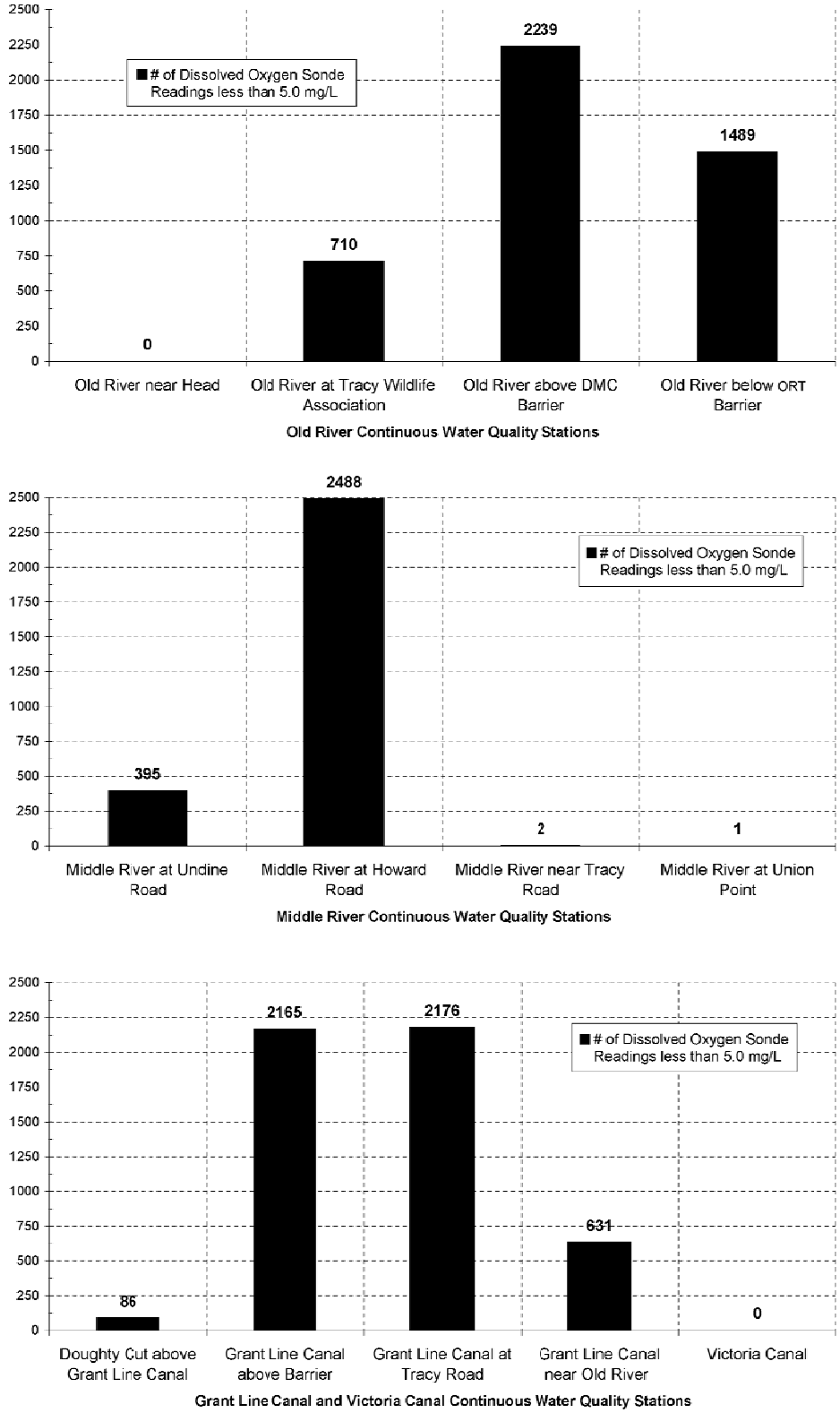
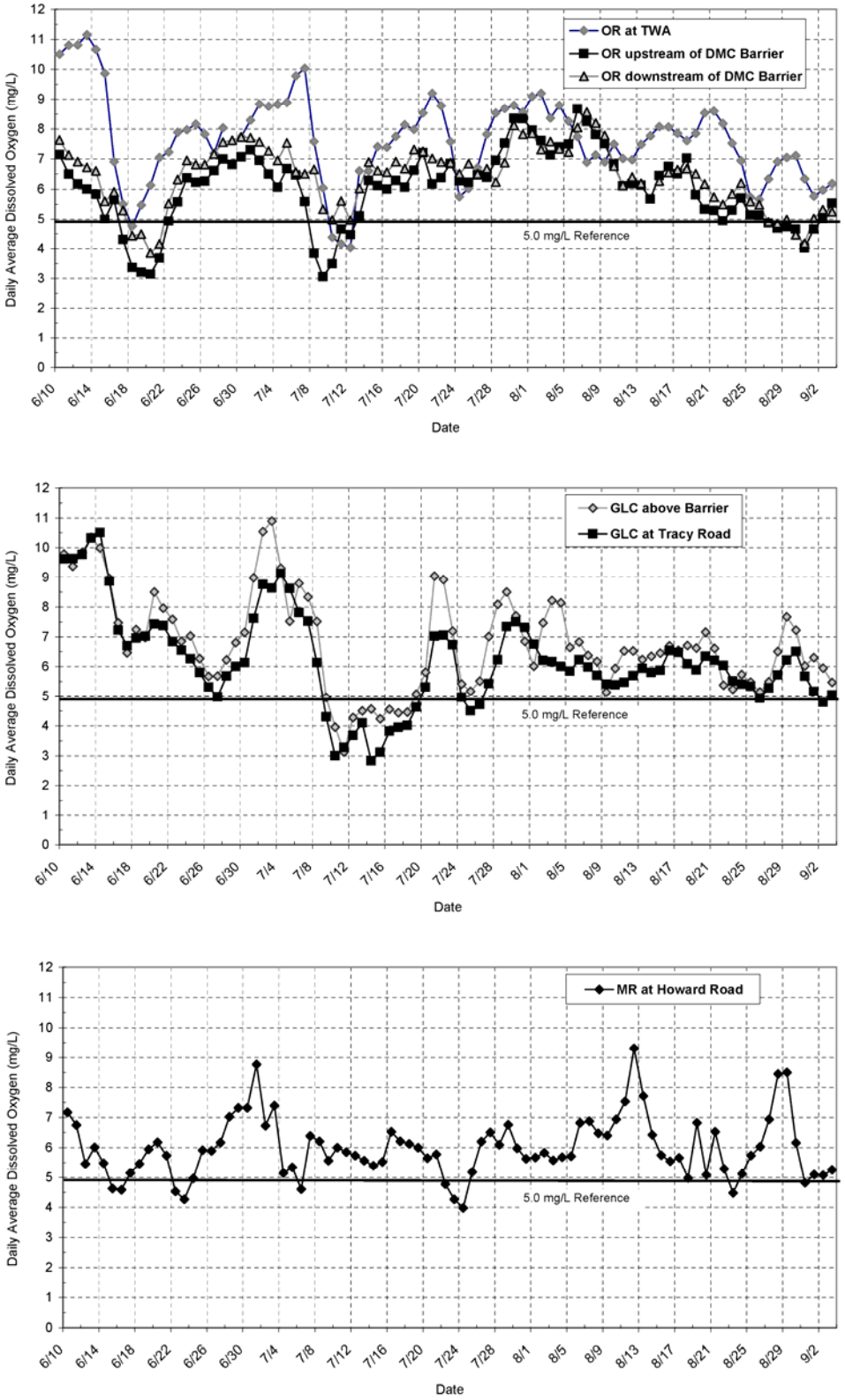


Figure 8-15. Daily average dissolved oxygen concentrations at selected Old River, Middle River, and Grant Line Canal continuous monitoring sites from June 10 through September 4, 2007



Middle River

ANOVA was performed on average daily DO concentrations data to determine whether monthly mean concentrations in June, July, and August differed among 4 Middle River monitoring locations (Undine Road, Howard Road, near Tracy Road, Union Point). Test results showed that at least one mean was significantly different in June [$F(3,116)=211$, $p <.001$), July ($F(3,120)=180$, $p < .001$], and August ($F(3,120)=78$, $p<.001$). Tukey's HSD test was then performed to determine which mean site concentrations differed. The results showed that DO concentrations were significantly less ($p<.01$) at MR at Howard Road in comparison to each of the other 3 sites in June, July and August, while MR at Undine Road had significantly higher concentrations ($p<.01$) than the other MR sites during the same time period. There were no significant differences ($p>.05$) in DO concentrations between MR near Tracy Road and MR at Union Point.

In 2007 there were 2,488 DO readings below 5 mg/L recorded at MR at Howard Road (Figure 8-14). There were a combined 398 readings below 5.0 mg/L at the other 3 MR sites, with the majority of those readings at MR at Undine Road (395). There were 12 days at MR at Howard Road where the average daily DO concentration was below 5 mg/L (Figure 8-15). Daily average DO concentrations below 5 mg/L were only recorded from June through late August. This is a shift from the 2005 and 2006 data where the majority of the DO concentrations below 5 mg/L were recorded at MR at Tracy Road.

Grant Line Canal

ANOVA was performed on average daily DO concentrations data to determine whether monthly mean concentrations in June, July, and August differed among 4 Grant Line Canal monitoring locations (Doughty Cut, above barrier, Tracy Road, near Old River). Test results showed that at least one mean was significantly different in June ($F(3,116)=25$, $p <.001$), July ($F(3,119)=28$, $p < .001$), and August ($F(2,90)=28$, $p<.001$). Tukey's HSD test was then performed to determine which mean site concentrations differed. The results showed that DO concentrations were significantly higher ($p<.01$) at Doughty Cut above GLC in June and July in comparison to each of the downstream sites. (Note: There was no Doughty Cut above GLC DO data in August due to a punctured DO membrane.) GLC above barrier and GLC at Tracy Road had significantly lower ($p>.01$) DO concentrations than the other 2 GLC sites in July and August and were not significantly different ($p>.05$) from each other in June and July.

In 2007, there were 86 (Doughty Cut above GLC), 2,165 (GLC above barrier), 2,176 (GLC at Tracy Rd.), and 631 (GLC near OR) DO readings below 5 mg/L (see Figure 8-14). There were 10 days (GLC above Barrier) and 17 days (GLC at Tracy Road) where daily average DO concentrations were below 5 mg/L (Figure 8-15). Daily average DO concentrations below 5 mg/L were only recorded from June through early September. In 2006, there were no DO concentrations less than 5.0 mg/L recorded near the barrier.

Field Data

Field data collected throughout the year showed a strong correlation with the sonde data ($R^2 = .94$). The mean DO concentration of the sonde data was 9.20 mg/L and mean of the field data was 9.13 mg/L, (n=200). (See Figure 8-10.)

pH

pH is a measure of the hydrogen ion concentration [H^+] of a solution. pH values range from 1 to 14 with values less than 7 considered acidic and values greater than 7 considered basic. Since the pH scale is logarithmic, a pH value of 7 is 10 times greater than a pH value of 6 and 100 times greater than a value of 5. Natural waters usually have pH values in the range of 4 to 9, and most are slightly basic (APHA 1992).

The US Environmental Protection Agency-recommended criterion for pH is an instantaneous maximum between 6.5 and 9.0 (Marshack, 2000).

A maximum pH of 9.70 was recorded on July 4 at OR near Head and a minimum of 6.76 was recorded on July 17 at MR at Howard Road (Figures 8-16 to 8-18, 8-9 and Tables 8-3 to 8-6). pH values were highest from April through August, especially in July where 3 stations (OR near Head, MR at Undine Road, and Doughty Cut above GLC) had pH averages of 9.0 or higher. Recorded pH values of 9.0 or greater were more prevalent at the upstream sites on OR, MR, and GLC. In 2007, there were 5,667 (OR near Head), 4,518 (MR at Undine Road) and 2,412 (Doughty Cut above GLC) readings where the sonde(s) recorded pH values of 9.0 or greater, while the other 10 stations had a combined total of 1,896 readings (Figure 8-19). The downstream monitoring sites had the fewest occurrences of pH values of 9.0 or higher: OR below ORT Barrier (40), MR at Union Point (9), GLC near Old River (0), and Victoria Canal (0). In 2005 and 2006, there were a combined 517 pH readings where values were 9.0 or greater.

Field Data

Field data collected throughout the year showed a fairly strong correlation with the sonde data (R^2 = .76). The correlation between the field and sonde data for pH is affected by the relatively narrow range of values in comparison to the other constituents monitored. The mean pH value of the sonde data was 7.49, and mean of the field data was 7.51, (n=146). (Figure 8-20)

Figure 8-16. Old River pH data (15-minute intervals)

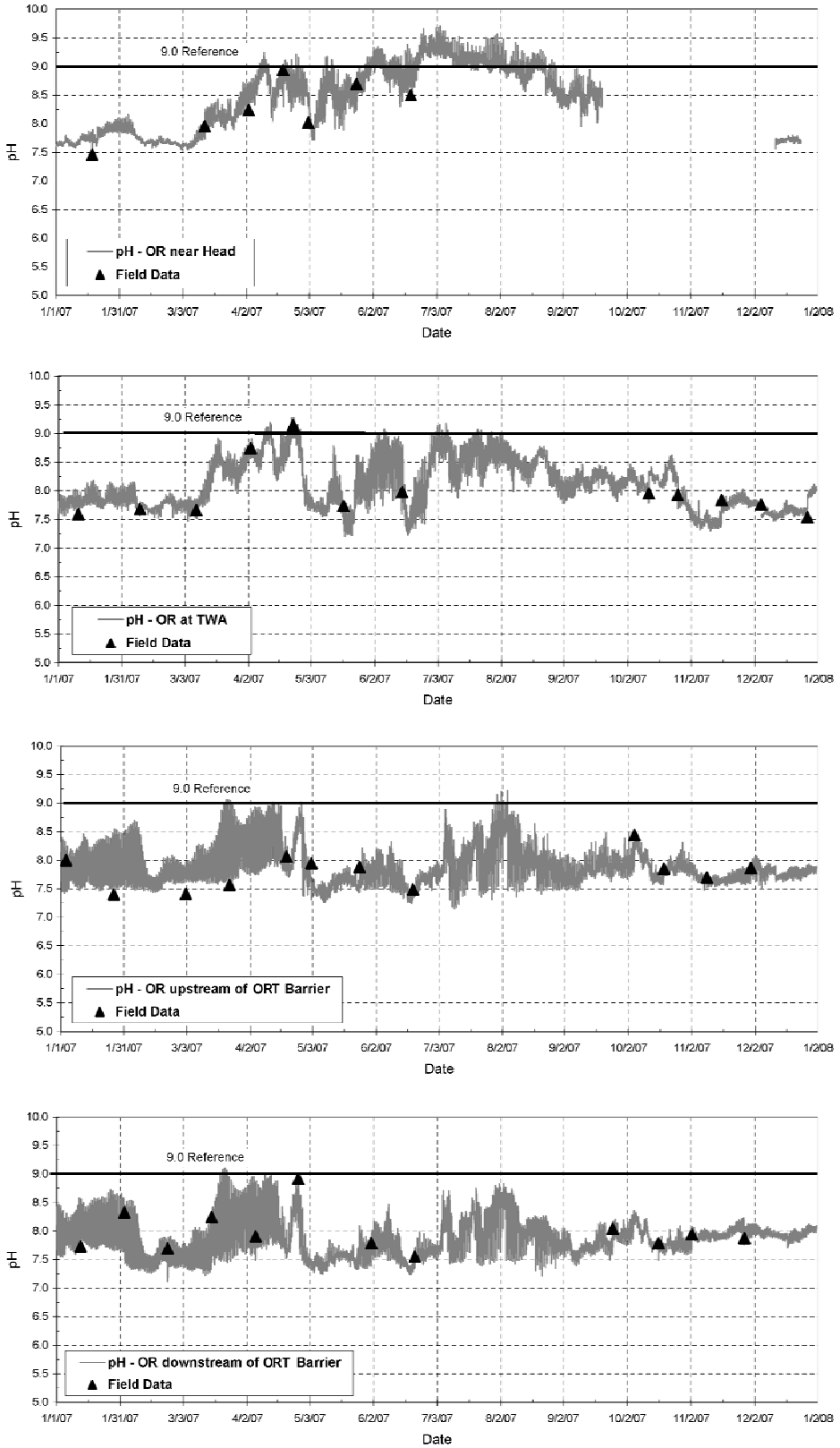


Figure 8-17. Middle River pH data (15-minute intervals)

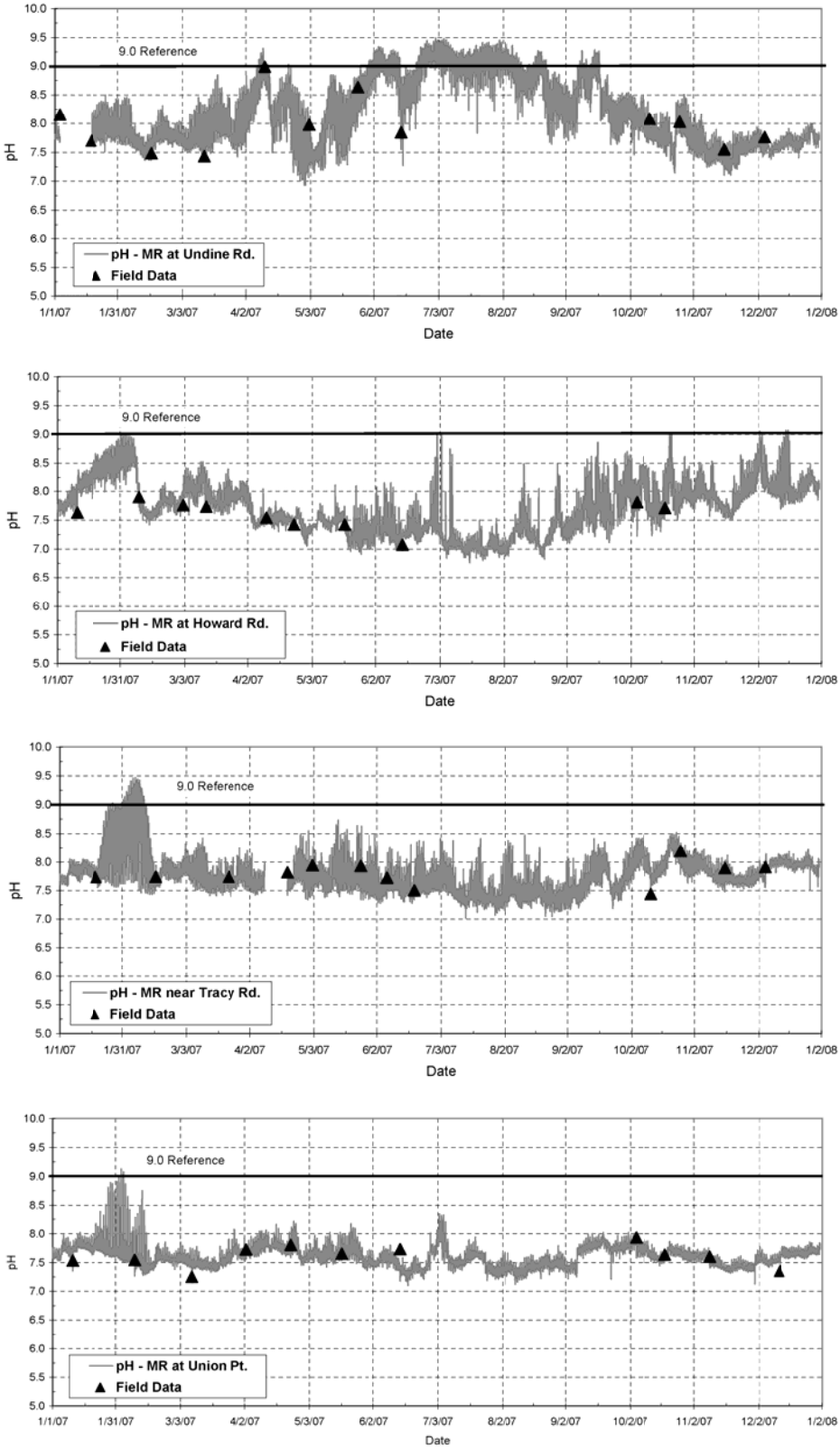


Figure 8-18. Grant Line Canal pH data (15-minute intervals)

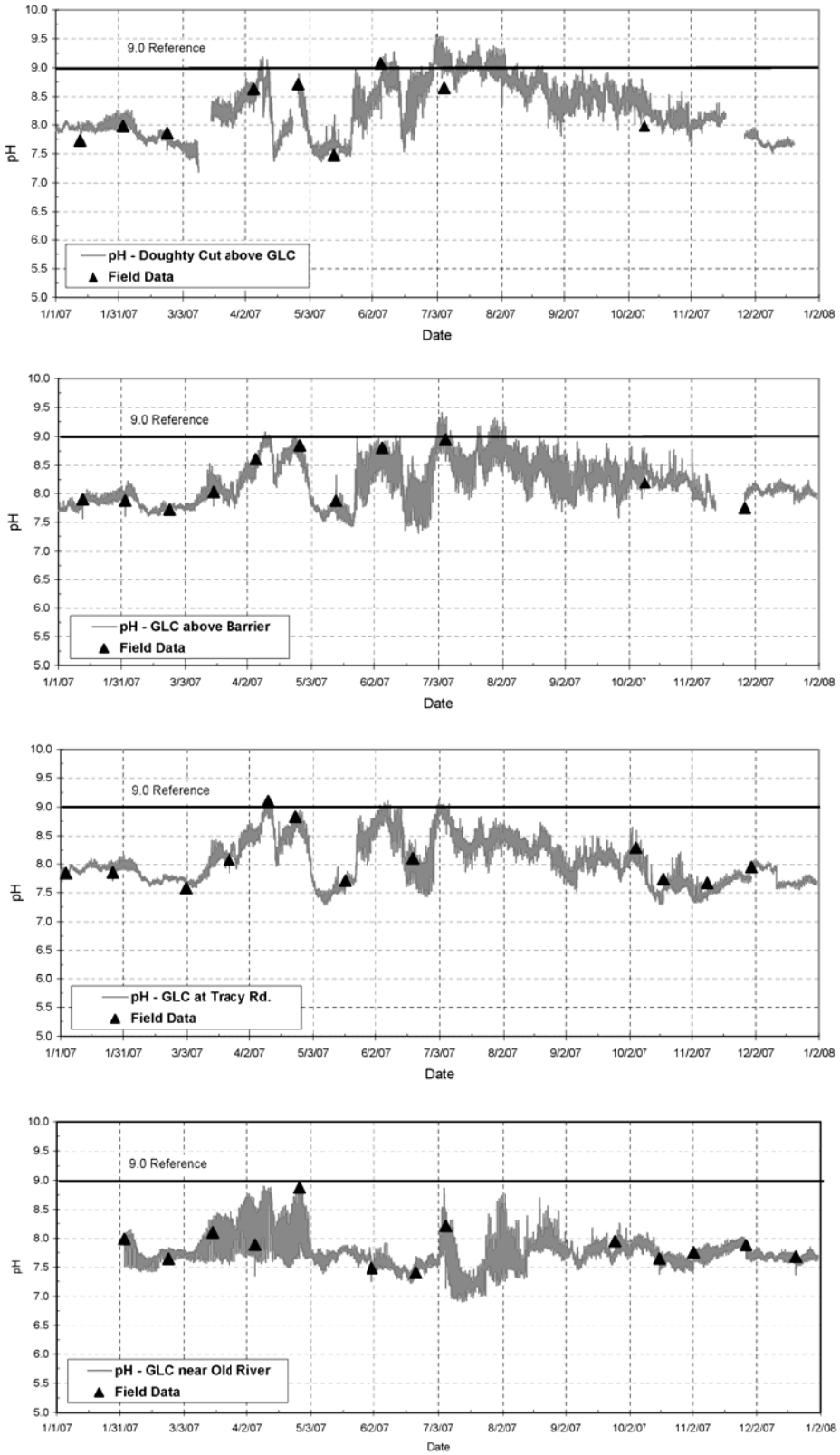


Figure 8-19. Number of pH readings greater than 9.0 at each Old River, Middle River, and Grant Line Canal continuous monitoring site

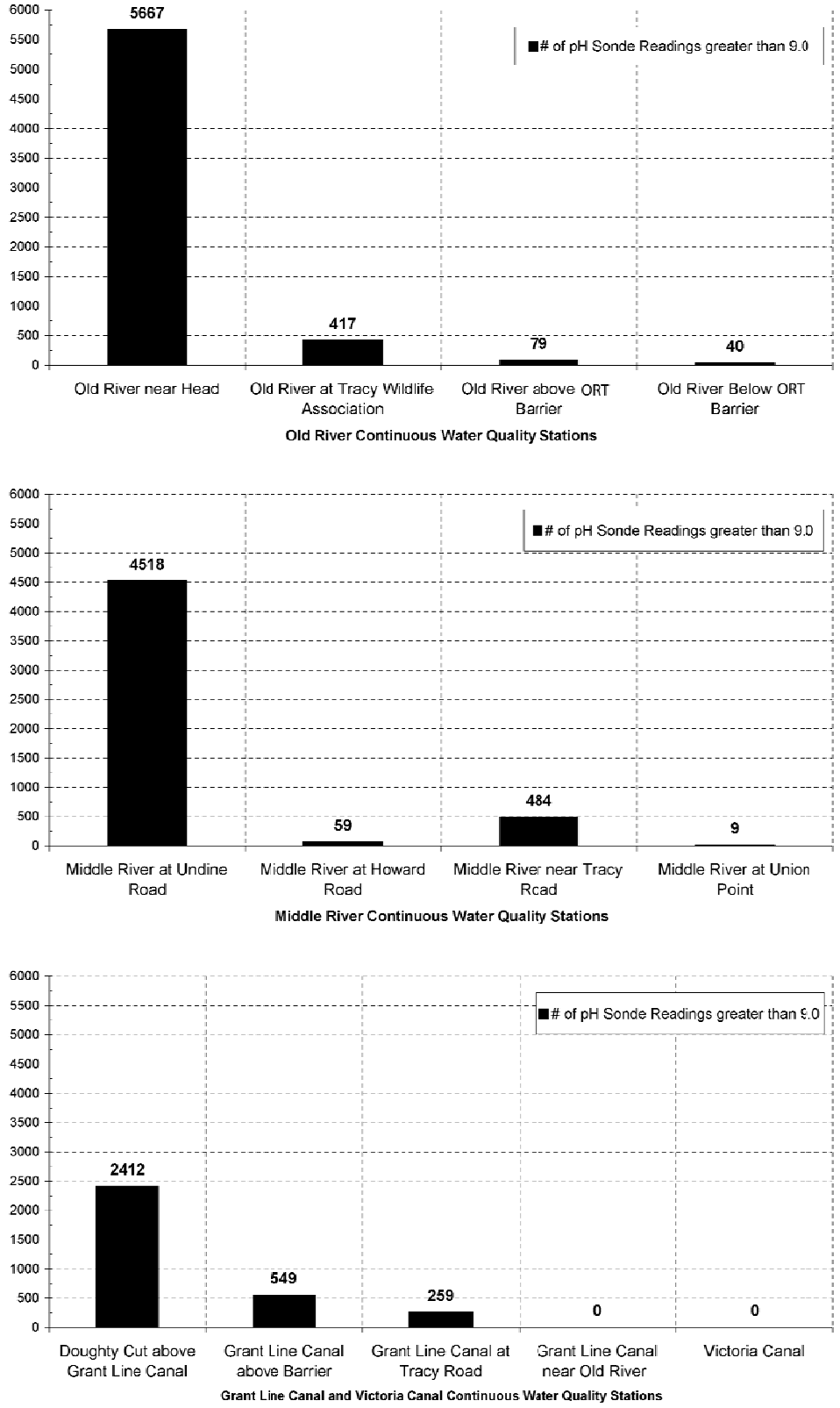
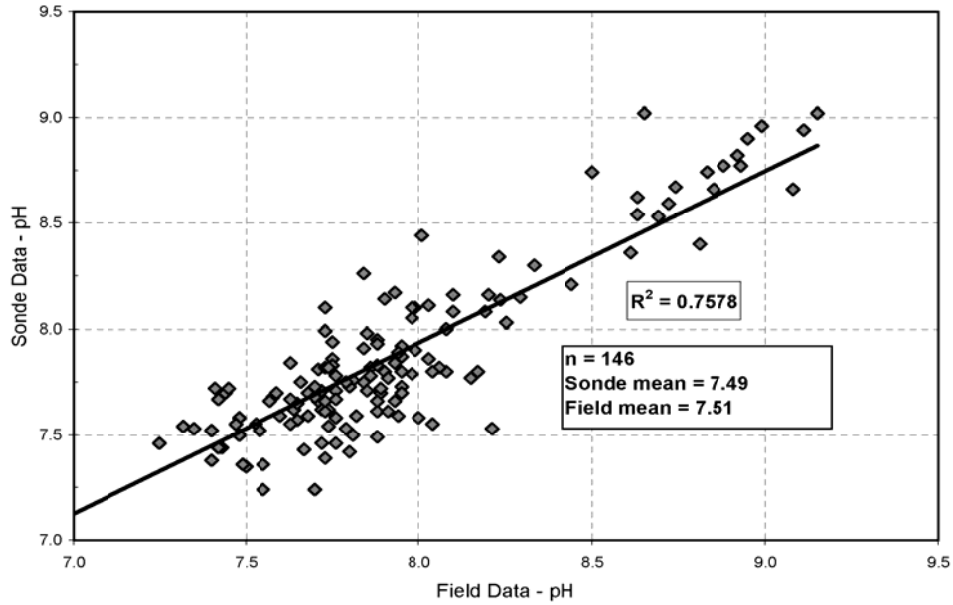
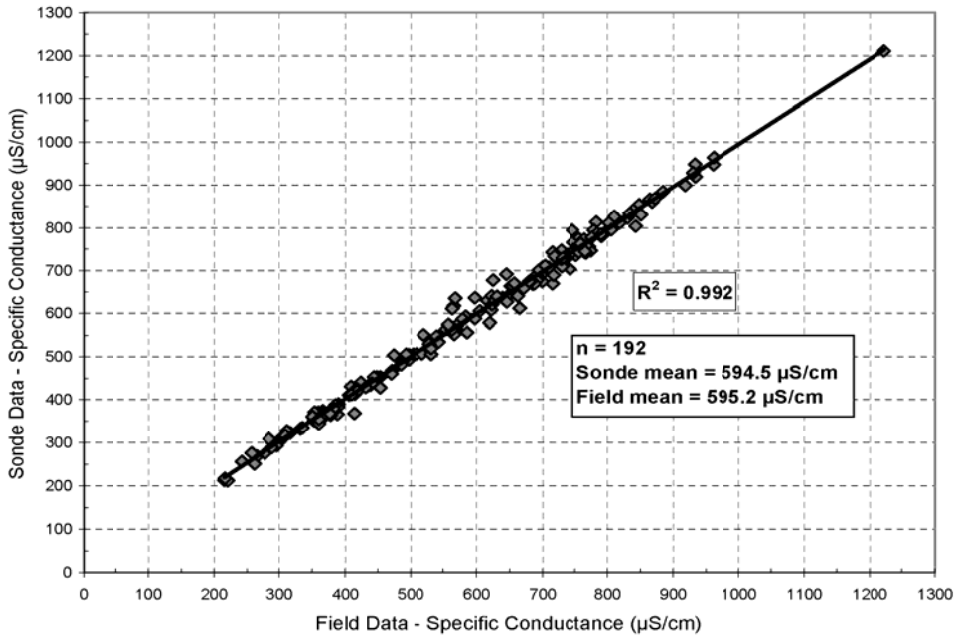


Figure 8-20. pH and specific conductance linear regression plots for field data versus sonde data





Specific Conductance

Conductivity is a measure of the ability of an aqueous solution to carry an electrical current (APHA 1992). Specific conductance values are temperature compensated to 25 ºC and can be used to estimate salinity and total dissolved solids. (Wagner et al., 2006) Specific conductance is of vital importance in the South Delta because the water is used for irrigation. High amounts of dissolved salts in irrigation water can result in crop damage and reduced yield. The USEPA recommended that the agricultural water limit for specific conductance not exceed 700 µS/cm (Marshack 2000).

April through August

A maximum of 1259.3 µS/cm was recorded on July 15 at MR at Howard Road. (Figures 8-21 to 8-23, 8-9, and Tables 8-6 to 8-9) The minimum recorded specific conductance was 195.4 µS/cm on July 14 at MR at Union Point. Monthly mean values for this time period ranged from 233.3 µS/cm in July at MR at Union Point to 861.3 µS/cm in April at OR at TWA. Eight of the 13 monitoring sites had at least one month where specific conductance averaged 700 µS/cm or higher. Mean conductance values were highest at these 8 stations in July and August. OR at TWA had the highest monthly average conductance values in every month during this period, with June being the only month where the average was less than 700 µS/cm. In April, the average conductance at TWA was approximately 157 µS/cm higher than at any of the other monitoring sites. The 5 stations that did not have a month where conductance values averaged more than 700 uS/cm were MR at Howard Road, MR at Tracy Road, MR at Union Point, Victoria Canal, and GLC near OR. It is important to note that MR at Howard Road had the highest maximum specific conductance values in the South Delta from April through August. Spikes in electrical conductivity at MR at Howard Road ranged from 377 µS/cm to 906 µS/cm higher than the upstream and downstream monitoring sites on MR.

Figure 8-21. Old River specific conductance data (15-minute intervals)

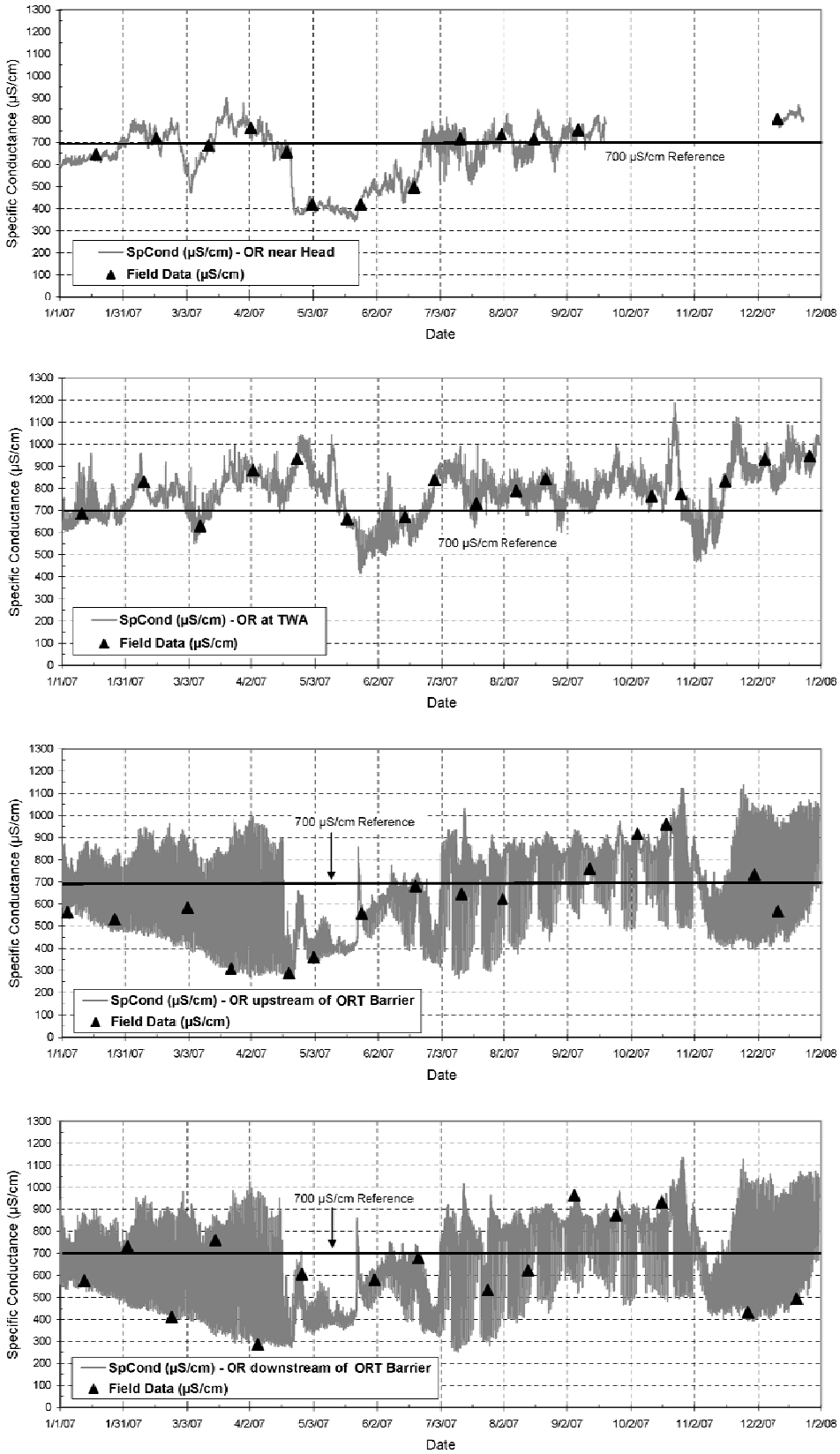


Figure 8-22. Middle River specific conductance data (15-minute intervals)

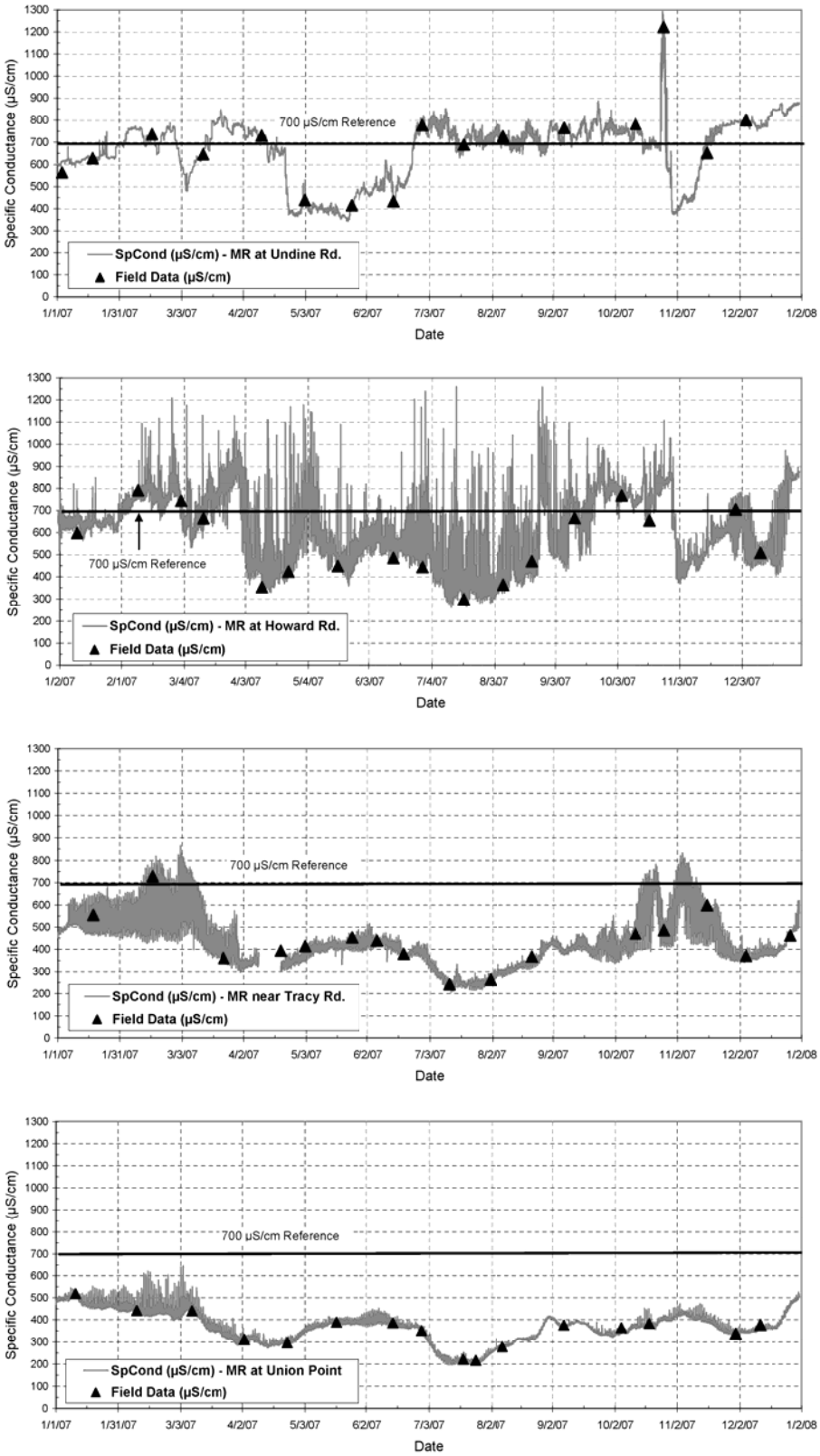


Figure 8-23. Grant Line Canal specific conductance data (15-minute intervals)

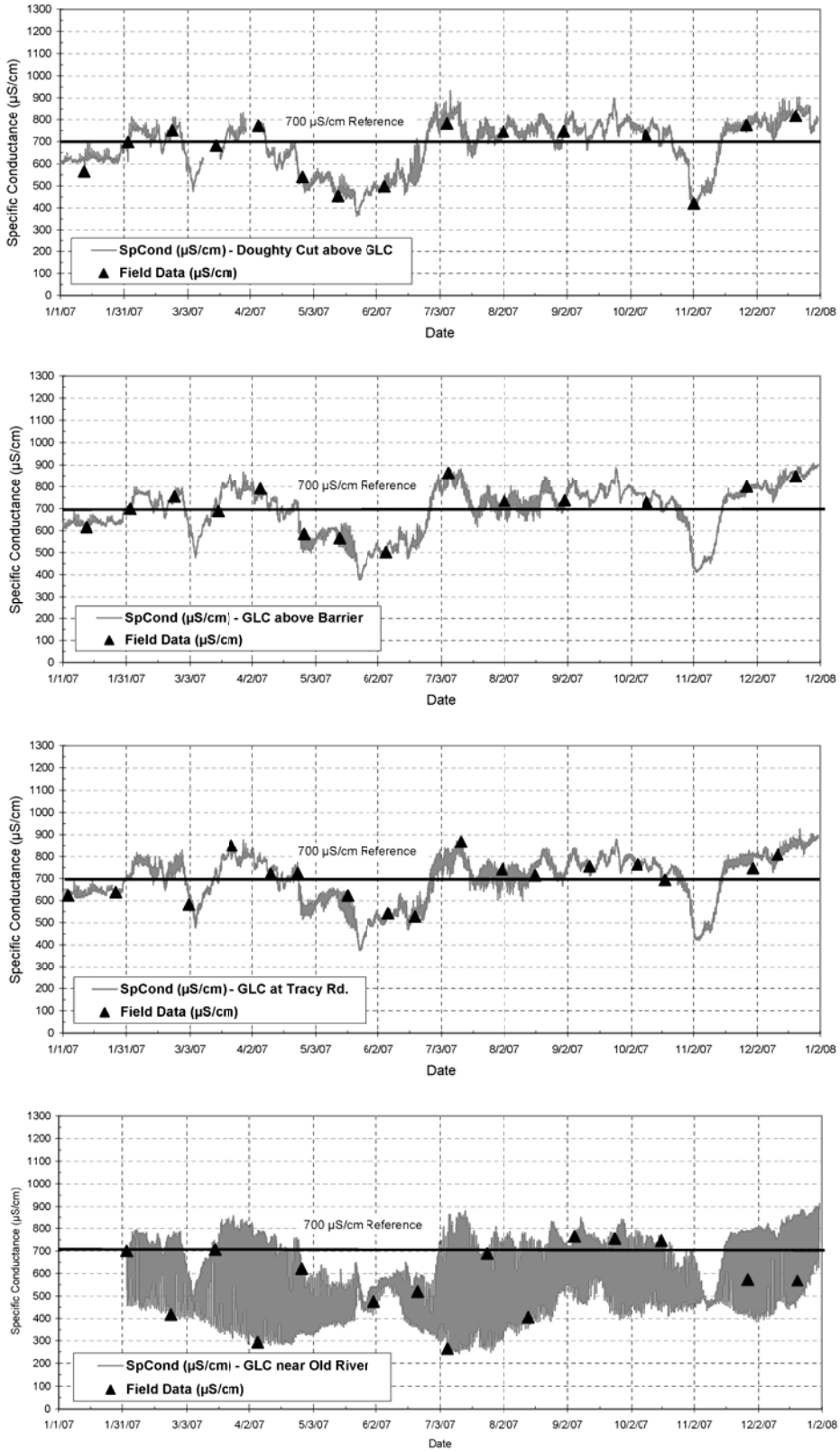


Table 8-7. Statistical summary of 2007 Old River continuous specific conductance, turbidity, and chlorophyll *a* data

Month	Specific Conductance (µS/cm)			
Maximums	**Head**	**TWA**	**Abv ORT**	**Below ORT**
Jan.	725.4	958.0	882.3	938.5
Feb.	807.2	959.7	961.4	979.5
Mar	902.4	995.3	984.6	982.6
Apr	822.7	1041.3	994.2	1024.8
May	530.4	1041.3	857.7	858.9
Jun	793.6	887.1	773.2	749.4
Jul	812.5	993.9	1032.3	1013.6
Aug	848.9	896.9	925.8	923.7
Sep	823.8	996.2	976.5	983.5
Oct	-	1186.0	1121.9	1133.3
Nov	-	1124.6	1137.0	1126.5
Dec	870.4	1086.7	1071.9	1072.2
Averages	**Head**	**TWA**	**Abv ORT**	**Below ORT**
Jan.	628.4	691.4	665.1	664.3
Feb.	732.4	782.4	687.6	664.6
Mar	700.9	767.7	620.8	615.3
Apr	624.0	861.3	520.6	500.1
May	412.3	703.0	457.6	455.7
Jun	557.7	648.2	589.9	573.5
Jul	681.9	810.1	699.4	674.6
Aug	705.2	779.3	774.6	774.0
Sep	747.8	802.5	815.6	812.5
Oct	-	809.8	828.6	824.0
Nov	-	770.7	650.1	632.0
Dec	815.3	913.6	758.9	740.6

Month	Turbidity (NTU)			
Maximums	**Head**	**TWA**	**Abv ORT**	**Below ORT**
Jan.	67.9	68.0	179.2	27.7
Feb.	81.4	29.9	93.8	50.8
Mar	105.7	43.5	96.3	42.7
Apr	105.9	57.8	187.3	132.0
May	129.1	130.7	98.0	115.8
Jun	172.0	129.3	111.3	173.4
Jul	133.3	118.4	289.0	79.4
Aug	185.9	86.3	109.8	90.8
Sep	60.0	69.8	64.2	121.4
Oct	-	43.5	112.0	59.2
Nov	-	60.3	128.6	103.6
Dec	42.1	45.3	165.0	33.6
Averages	**Head**	**TWA**	**Abv ORT**	**Below ORT**
Jan.	10.1	10.6	9.1	8.6
Feb.	18.5	13.1	14.0	10.8
Mar	26.0	15.9	15.3	12.5
Apr	21.4	31.8	17.5	21.1
May	19.2	31.6	16.5	14.5
Jun	35.7	40.4	28.6	31.6
Jul	35.2	41.5	29.4	27.1
Aug	25.3	33.0	28.6	26.8
Sep	20.4	24.5	23.6	27.3
Oct	-	20.4	22.6	24.7
Nov	-	17.2	22.9	18.5
Dec	10.7	12.6	9.5	10.2

Month	Chlorophyll *a* (µg/L)			
Maximums	**Head**	**TWA**	**Abv ORT**	**Below ORT**
Jan.	66.1	91.2	124.4	92.9
Feb.	64.7	129.2	107.5	238.4
Mar	241.1	271.4	207.2	417.1
Apr	307.3	498.3	269.7	495.5
May	127.2	124.4	32.4	29.8
Jun	389.1	143.4	45.9	74.2
Jul	474.3	273.8	226.5	123.8
Aug	243.1	269.6	191.2	95.2
Sep	106.7	101.8	70.9	52.5
Oct	-	137.0	62.5	81.5
Nov	-	61.3	52.0	40.5
Dec	16.5	47.2	28.1	19.4
Averages	**Head**	**TWA**	**Abv ORT**	**Below ORT**
Jan.	12.4	29.7	31.6	23.5
Feb.	16.2	31.4	22.0	32.8
Mar	46.5	54.9	30.6	48.6
Apr	112.8	199.6	57.5	68.2
May	53.7	30.5	6.3	4.6
Jun	174.6	54.7	10.5	14.6
Jul	234.9	107.3	54.6	31.1
Aug	84.6	78.3	47.2	27.8
Sep	47.4	49.8	12.8	15.8
Oct	-	47.6	20.5	25.6
Nov	-	24.3	10.3	7.4
Dec	6.5	17.4	5.6	4.0

Table 8-7 (cont.). Statistical summary of 2007 Old River continuous specific conductance, turbidity, and chlorophyll *a* data

Month	Specific Conductance (µS/cm)			
Minimums	**Head**	**TWA**	**Abv ORT**	**Below ORT**
Jan.	585.5	607.3	475.4	469.7
Feb.	634.0	702.7	412.5	398.0
Mar	471.4	551.0	287.4	292.5
Apr	370.4	690.2	271.9	271.3
May	341.6	418.5	331.0	333.2
Jun	425.1	496.9	335.3	335.5
Jul	509.9	624.0	265.6	249.9
Aug	567.2	602.4	375.6	384.5
Sep	667.1	685.2	482.0	465.9
Oct	-	583.0	487.3	464.2
Nov	-	467.6	395.8	393.2
Dec	766.7	773.3	408.6	402.8
Std. Devs.	**Head**	**TWA**	**Abv ORT**	**Below ORT**
Jan.	24.9	54.5	117.8	115.5
Feb.	34.7	42.2	161.9	171.7
Mar	104.1	94.7	203.6	197.4
Apr	144.7	71.9	208.8	199.8
May	38.5	145.3	88.9	88.1
Jun	90.4	84.8	102.6	281.6
Jul	55.2	67.0	177.6	192.8
Aug	59.1	47.8	119.8	134.2
Sep	29.5	55.0	96.4	107.7
Oct	-	104.7	135.5	143.7
Nov	-	168.8	181.4	174.3
Dec	21.6	65.0	214.7	215.8
2007 - Max.	902.4	1186.0	1137.0	1133.3
2007 - Avg.	646.0	778.4	672.6	661.2
2007 - Min.	341.6	418.5	265.6	249.9
2007 - S.D.	127.8	115.3	191.5	194.4

Month	Turbidity (NTU)			
Minimums	**Head**	**TWA**	**Abv ORT**	**Below ORT**
Jan.	4.8	4.7	4.3	4.3
Feb.	8.8	5.6	4.0	3.6
Mar	11.1	6.8	5.7	4.7
Apr	11.0	17.7	4.7	6.1
May	8.9	14.9	5.8	6.9
Jun	12.9	16.0	7.0	9.1
Jul	14.8	12.4	11.7	10.1
Aug	8.6	18.4	11.2	7.1
Sep	7.8	15.6	9.0	5.7
Oct	-	10.1	6.0	6.0
Nov	-	8.6	3.4	2.8
Dec	6.6	4.8	0.9	2.5
Std. Devs.	**Head**	**TWA**	**Abv ORT**	**Below ORT**
Jan.	3.8	4.3	7.7	2.9
Feb.	10.5	2.5	9.5	3.9
Mar	9.8	3.1	7.6	4.2
Apr	7.3	4.8	9.7	11.2
May	7.2	10.5	6.3	7.0
Jun	13.8	9.8	13.5	14.6
Jul	10.6	11.0	11.0	8.7
Aug	10.7	6.6	9.6	7.8
Sep	4.7	3.6	5.5	10.0
Oct	-	4.3	7.0	7.1
Nov	-	3.5	14.2	10.8
Dec	3.2	5.4	9.0	5.3
2007 - Max.	185.9	130.7	187.3	173.4
2007 - Avg.	22.9	24.4	19.8	19.4
2007 - Min.	4.8	4.7	0.9	2.5
2007 - S.D.	12.1	12.4	11.7	11.4

Month	Chlorophyll *a* (µg/L)			
Minimums	**Head**	**TWA**	**Abv ORT**	**Below ORT**
Jan.	3.1	5.6	2.8	1.6
Feb.	3.9	3.5	2.4	3.5
Mar	8.9	4.0	1.7	3.4
Apr	40.7	13.2	2.0	1.2
May	11.6	3.7	0.8	0.2
Jun	48.9	10.4	1.6	1.1
Jul	79.0	15.9	1.8	1.2
Aug	13.2	18.6	3.5	0.8
Sep	8.9	1.0	0.6	0.9
Oct	-	13.2	1.0	1.6
Nov	-	10.2	1.2	0.9
Dec	2.9	5.3	0.7	0.3
Std. Devs.	**Head**	**TWA**	**Abv ORT**	**Below ORT**
Jan.	7.7	17.4	26.6	22.5
Feb.	9.0	26.9	25.4	45.0
Mar	34.8	44.7	41.6	75.6
Apr	50.6	93.4	67.5	95.6
May	127.2	15.8	5.7	4.8
Jun	80.2	24.9	9.6	14.7
Jul	76.8	55.3	50.5	28.1
Aug	40.8	43.4	40.5	23.5
Sep	18.5	20.6	7.8	11.3
Oct	-	25.4	12.8	14.5
Nov	-	9.7	6.0	6.1
Dec	1.8	7.3	3.7	3.1
2007 - Max.	474.3	498.3	269.7	495.5
2007 - Avg.	84.7	60.1	25.9	25.3
2007 - Min.	2.9	1.0	0.6	0.2
2007 - S.D.	85.0	63.0	36.6	43.9

Table 8-8. Statistical summary of 2007 Middle River continuous specific conductance, turbidity, and chlorophyll *a* data

Month	Specific conductance (µS/cm)			
Maximums	**Undine**	**Howard**	**Tracy**	**Union Pt.**
Jan.	747.5	848.8	678.6	551.8
Feb.	789.5	1208.4	818.8	619.3
Mar	849.3	1175.3	864.6	644.4
Apr	789.6	1166.3	403.9	361.9
May	529.7	1176.7	486.5	423.8
Jun	820.5	1240.1	514.3	452.7
Jul	851.4	1259.3	423.4	353.2
Aug	805.0	1256.9	440.4	417.1
Sep	887.4	1099.1	524.5	413.1
Oct	1291.9	1100.8	782.1	453.2
Nov	801.2	774.1	833.7	473.1
Dec	880.4	972.2	618.6	525.0
Averages	**Undine**	**Howard**	**Tracy**	**Union Pt.**
Jan.	628.7	642.6	533.0	480.8
Feb.	730.3	765.9	570.8	449.6
Mar	694.4	752.6	494.2	387.3
Apr	623.8	525.3	342.0	304.5
May	408.3	557.5	412.4	379.5
Jun	563.3	562.8	412.0	383.5
Jul	736.5	430.5	265.3	233.3
Aug	717.1	512.9	329.7	310.4
Sep	757.7	688.2	414.4	368.6
Oct	722.3	776.2	518.7	371.1
Nov	623.5	531.1	538.6	391.6
Dec	818.0	631.9	403.8	388.0

Month	Turbidity (NTU)			
Maximums	**Undine**	**Howard**	**Tracy**	**Union Pt.**
Jan.	52.7	28.1	89.0	29.5
Feb.	39.0	43.8	58.4	46.0
Mar	136.5	79.6	105.1	42.7
Apr	195.3	64.6	31.8	41.1
May	80.3	70.3	171.6	39.4
Jun	113.2	99.9	139.3	32.2
Jul	89.9	158.8	34.1	56.1
Aug	153.3	115.6	31.0	27.8
Sep	70.3	77.5	108.9	25.8
Oct	53.5	38.4	32.2	23.0
Nov	42.2	33.1	28.9	12.8
Dec	72.4	17.2	29.1	19.8
Averages	**Undine**	**Howard**	**Tracy**	**Union Pt.**
Jan.	5.7	5.5	7.0	6.7
Feb.	5.6	4.4	11.8	10.2
Mar	11.4	10.7	11.1	7.4
Apr	27.8	18.9	12.2	6.8
May	24.9	17.5	21.2	5.8
Jun	36.1	16.1	18.5	7.1
Jul	39.0	28.7	16.1	10.1
Aug	35.9	13.6	12.2	7.6
Sep	21.4	8.5	11.0	5.1
Oct	13.6	2.2	6.1	3.2
Nov	6.9	2.6	4.2	2.9
Dec	6.2	3.6	5.4	3.5

Month	Chlorophyll *a* (µg/L)			
Maximums	**Undine**	**Howard**	**Tracy**	**Union Pt.**
Jan.	65.5	156.9	165.4	30.6
Feb.	88.0	179.1	485.4	42.7
Mar	143.9	328.1	35.5	17.0
Apr	485.8	315.0	46.6	7.3
May	114.9	38.3	41.0	5.0
Jun	498.2	98.3	20.6	10.4
Jul	499.8	245.5	34.4	13.9
Aug	254.9	69.5	27.7	19.5
Sep	178.7	130.8	20.6	8.9
Oct	79.0	19.7	20.6	14.0
Nov	23.6	11.5	16.6	23.4
Dec	23.9	9.8	6.9	5.9
Averages	**Undine**	**Howard**	**Tracy**	**Union Pt.**
Jan.	11.2	16.2	21.0	3.2
Feb.	9.9	12.5	73.1	6.6
Mar	19.7	18.4	5.8	2.7
Apr	121.1	23.8	5.3	2.4
May	26.0	7.4	6.8	1.7
Jun	183.3	8.4	7.3	2.4
Jul	230.2	18.1	5.1	2.7
Aug	91.7	6.4	4.8	2.1
Sep	45.9	8.1	3.7	2.1
Oct	21.7	2.6	3.2	2.5
Nov	7.8	1.7	2.7	2.4
Dec	5.9	2.4	2.3	2.9

Table 8-8 (cont.). Statistical summary of 2007 Middle River continuous specific conductance, turbidity, and chlorophyll a data

Month	Specific conductance (µS/cm)			
Minimums	**Undine**	**Howard**	**Tracy**	**Union Pt.**
Jan.	587.4	518.2	451.8	436.6
Feb.	644.9	656.2	424.9	395.5
Mar	480.8	533.9	296.8	286.2
Apr	365.4	330.2	302.3	272.0
May	343.4	359.6	333.0	325.1
Jun	421.3	435.2	345.2	326.6
Jul	629.5	264.8	206.7	195.4
Aug	636.8	281.9	248.0	245.1
Sep	678.4	427.5	342.2	321.6
Oct	374.9	573.2	336.9	320.8
Nov	376.7	371.5	344.9	332.3
Dec	751.7	408.3	341.3	338.8
Std. Devs.	**Undine**	**Howard**	**Tracy**	**Union Pt.**
Jan.	22.5	26.6	53.4	21.5
Feb.	33.2	66.2	94.4	34.1
Mar	98.9	107.0	134.0	58.5
Apr	142.9	157.9	19.2	14.4
May	35.9	117.0	22.8	16.6
Jun	107.3	80.7	29.0	22.6
Jul	42.8	141.1	38.0	31.3
Aug	32.1	177.3	44.6	41.8
Sep	35.5	132.7	29.7	24.0
Oct	143.5	62.3	113.9	25.3
Nov	150.3	85.6	129.4	32.1
Dec	35.5	156.6	49.4	50.8
2007 - Max.	1291.9	1259.3	864.6	644.4
2007 - Avg.	668.4	614.0	438.1	370.1
2007 - Min.	343.4	264.8	206.7	195.4
2007 - S.D.	136.4	159.8	118.7	70.9

Month	Turbidity (NTU)			
Minimums	**Undine**	**Howard**	**Tracy**	**Union Pt.**
Jan.	2.8	2.7	2.7	2.4
Feb.	1.7	1.4	2.6	3.4
Mar	3.2	2.7	4.2	3.4
Apr	6.6	5.7	5.7	3.4
May	6.0	7.3	5.9	2.4
Jun	12.8	3.7	7.0	2.5
Jul	12.7	4.7	8.3	3.9
Aug	9.5	0.1	4.2	2.2
Sep	4.7	1.0	4.1	2.3
Oct	1.0	0.1	1.5	1.2
Nov	1.1	0.4	1.2	1.0
Dec	1.5	0.8	1.7	1.4
Std. Devs.	**Undine**	**Howard**	**Tracy**	**Union Pt.**
Jan.	2.7	1.5	4.3	2.1
Feb.	2.1	1.9	5.2	6.2
Mar	7.5	6.0	6.2	2.2
Apr	17.5	6.6	3.3	2.4
May	10.2	7.0	22.2	2.0
Jun	11.3	10.0	14.2	2.4
Jul	10.9	18.1	3.6	3.2
Aug	18.0	14.1	3.9	4.4
Sep	9.7	8.2	7.8	1.5
Oct	8.0	2.4	2.7	1.0
Nov	2.6	2.1	2.2	1.1
Dec	5.5	1.6	2.2	1.4
2007 - Max.	195.3	158.8	171.6	56.1
2007 - Avg.	19.3	11.0	11.3	6.3
2007 - Min.	1.0	0.1	1.2	1.0
2007 - S.D.	16.0	11.5	10.1	3.7

Month	Chlorophyll *a* (µg/L)			
Minimums	**Undine**	**Howard**	**Tracy**	**Union Pt.**
Jan.	1.9	0.9	0.1	0.5
Feb.	1.9	0.3	4.2	2.1
Mar	3.1	0.5	0.9	0.1
Apr	2.8	2.9	2.2	0.5
May	0.5	0.4	1.6	0.1
Jun	22.3	0.1	0.1	0.9
Jul	46.3	0.1	1.0	0.1
Aug	10.1	1.0	0.8	0.1
Sep	8.2	0.5	0.9	0.2
Oct	0.4	0.3	1.0	0.6
Nov	2.2	0.2	0.3	0.8
Dec	1.30	0.1	0.2	0.7
Std. Devs.	**Undine**	**Howard**	**Tracy**	**Union Pt.**
Jan.	7.2	19.5	33.6	2.9
Feb.	9.9	23.5	101.9	5.8
Mar	19.0	26.1	3.1	1.2
Apr	99.9	38.1	1.8	0.6
May	27.2	3.9	4.9	0.5
Jun	105.8	7.9	2.2	0.5
Jul	89.4	30.1	2.9	1.6
Aug	52.2	5.0	2.7	1.3
Sep	16.4	10.4	2.5	0.5
Oct	17.4	1.6	1.5	0.6
Nov	4.1	0.9	1.4	0.9
Dec	2.5	0.9	0.7	1.1
2007 - Max.	499.8	328.1	485.4	42.7
2007 - Avg.	64.6	10.4	11.8	2.8
2007 - Min.	0.4	0.1	0.1	0.1
2007 - S.D.	90.2	19.7	36.6	2.4

Table 8-9. Statistical summary of 2007 Grant Line Canal continuous specific conductance, turbidity, and chlorophyll *a* data

Month	Specific Conductance (µS/cm)			
Maximums	Doughty Cut	GLC abv Bar.	Tracy Rd.	GLC n OR
Jan.	690.4	711.6	715.4	-
Feb.	812.3	796.7	828.9	793.7
Mar	835.5	869.3	876.7	858.0
Apr	790.1	821.2	836.6	832.4
May	579.2	635.5	658.0	649.8
Jun	882.0	827.6	810.2	650.7
Jul	933.7	882.2	874.2	883.0
Aug	831.2	846.7	838.8	831.9
Sep	901.1	887.3	879.8	849.9
Oct	815.3	808.8	811.8	791.1
Nov	817.2	809.3	828.0	796.0
Dec	905.5	906.3	926.8	914.8
Averages	**Doughty Cut**	**GLC abv Bar.**	**Tracy Rd.**	**GLC n OR**
Jan.	625.2	640.4	641.5	-
Feb.	733.2	740.4	745.9	666.4
Mar	658.4	708.5	710.4	612.8
Apr	629.2	690.5	704.0	534.7
May	485.2	531.3	546.2	460.0
Jun	576.8	574.3	568.8	494.9
Jul	758.4	765.0	752.3	536.2
Aug	749.6	731.5	735.0	594.8
Sep	775.5	781.2	781.0	651.0
Oct	717.8	726.1	735.0	575.3
Nov	635.7	634.5	642.3	588.2
Dec	800.7	832.6	831.1	709.3

Month	Turbidity (NTU)			
Maximums	Doughty Cut	GLC abv Bar.	Tracy Rd.	GLC n OR
Jan.	153.9	90.2	21.5	-
Feb.	96.3	118.2	31.5	20.9
Mar	83.9	105.9	38.4	28.2
Apr	70.7	190.7	57.4	38.8
May	124.5	104.3	50.2	37.6
Jun	171.1	132.9	166.5	43.0
Jul	177.5	179.8	188.5	45.2
Aug	77.2	64.2	121.2	41.2
Sep	48.5	59.5	63.6	33.9
Oct	112.6	69.7	52.1	28.0
Nov	60.3	54.9	62.3	35.0
Dec	146.0	54.5	24.9	45.7
Averages	**Doughty Cut**	**GLC abv Bar.**	**Tracy Rd.**	**GLC n OR**
Jan.	11.0	8.0	8.5	-
Feb.	14.2	9.6	9.1	9.1
Mar	12.4	15.1	13.8	12.3
Apr	27.5	25.1	23.3	17.9
May	27.4	19.4	20.3	16.0
Jun	36.5	29.9	30.7	16.2
Jul	33.8	27.7	31.5	21.1
Aug	26.9	18.9	23.8	16.1
Sep	16.4	13.5	15.9	12.5
Oct	13.7	11.5	12.8	9.1
Nov	11.7	10.9	13.6	8.7
Dec	10.9	8.7	9.1	7.9

Month	Chlorophyll a (µg/L)			
Maximums	Doughty Cut	GLC abv Bar.	Tracy Rd.	GLC n OR
Jan.	73.8	81.1	46.5	-
Feb.	96.0	66.1	47.1	45.1
Mar	170.7	260.0	147.6	106.1
Apr	399.3	360.3	275.6	207.5
May	156.3	125.0	80.3	60.2
Jun	365.6	254.2	251.4	18.6
Jul	496.4	244.7	429.4	132.7
Aug	156.7	148.0	92.8	87.4
Sep	169.9	88.7	60.7	34.0
Oct	130.0	73.3	95.8	20.1
Nov	60.5	108.3	43.3	14.2
Dec	34.6	35.6	17.3	12.6
Averages	**Doughty Cut**	**GLC abv Bar.**	**Tracy Rd.**	**GLC n OR**
Jan.	14.6	16.8	11.7	-
Feb.	17.7	17.8	9.9	10.5
Mar	62.6	53.9	44.8	20.7
Apr	131.6	135.7	121.8	51.9
May	40.0	21.9	19.2	7.8
Jun	110.5	62.7	64.3	5.0
Jul	138.2	94.6	107.6	20.9
Aug	49.1	33.3	31.8	14.4
Sep	45.7	25.9	24.2	5.9
Oct	27.6	20.7	20.0	3.7
Nov	14.8	15.7	18.1	3.7
Dec	11.0	6.8	9.1	4.2

Table 8-9 (cont.). Statistical summary of 2007 Grant Line Canal continuous specific conductance, turbidity, and chlorophyll *a* data

Month	Specific Conductance (µS/cm)			
Minimums	**Doughty Cut**	**GLC abv Bar.**	**Tracy Rd.**	**GLC n OR**
Jan.	567.3	610.6	599.4	-
Feb.	611.1	655.9	644.9	398.2
Mar	474.6	477.8	477.7	309.7
Apr	469.4	500.2	516.1	280.0
May	363.2	377.9	374.5	325.4
Jun	460.3	474.5	469.2	322.4
Jul	626.6	618.9	602.7	243.4
Aug	663.1	641.7	598.1	303.1
Sep	661.8	708.8	711.4	395.8
Oct	438.7	501.8	536.0	407.3
Nov	412.1	412.5	419.9	395.9
Dec	707.0	729.2	728.1	385.7
Std. Devs.	**Doughty Cut**	**GLC abv Bar.**	**Tracy Rd.**	**GLC n OR**
Jan.	19.1	18.8	20.6	-
Feb.	34.8	33.0	33.3	122.8
Mar	87.3	101.3	100.5	154.0
Apr	76.5	82.5	80.0	190.6
May	46.5	66.2	74.7	73.7
Jun	100.7	83.6	67.8	83.6
Jul	56.6	61.0	50.8	188.2
Aug	34.2	39.2	40.0	139.5
Sep	39.0	34.1	33.6	113.6
Oct	70.8	56.5	50.7	108.9
Nov	140.2	145.2	143.5	131.4
Dec	38.5	39.6	36.3	158.1
2007 - Max.	933.7	906.3	926.8	914.8
2007 - Avg.	680.4	696.2	699.3	583.0
2007 - Min.	363.2	377.9	374.5	243.4
2007 - S.D.	114.9	110.5	106.9	155.5

Month	Turbidity (NTU)			
Minimums	**Doughty Cut**	**GLC abv Bar.**	**Tracy Rd.**	**GLC n OR**
Jan.	4.5	3.7	4.2	-
Feb.	5.5	4.7	4.0	3.2
Mar	3.7	7.0	5.9	4.8
Apr	10.1	11.7	12.2	5.3
May	11.7	6.1	10.1	5.7
Jun	14.8	12.3	15.3	5.7
Jul	11.4	10.6	14.0	7.6
Aug	7.2	4.7	9.4	4.2
Sep	4.4	3.3	7.8	3.2
Oct	3.9	4.2	6.9	2.4
Nov	5.2	4.8	6.3	2.3
Dec	4.7	3.9	5.2	2.3
Std. Devs.	**Doughty Cut**	**GLC abv Bar.**	**Tracy Rd.**	**GLC n OR**
Jan.	9.4	4.0	2.2	-
Feb.	8.7	4.7	2.8	2.9
Mar	7.7	7.8	3.3	3.9
Apr	7.8	10.2	4.9	7.3
May	13.4	9.3	5.1	5.6
Jun	14.1	10.6	10.4	6.2
Jul	11.2	13.0	13.0	7.1
Aug	8.2	6.7	10.6	6.3
Sep	4.3	5.4	4.0	4.4
Oct	7.4	4.7	2.9	3.9
Nov	5.1	5.0	5.1	4.6
Dec	6.8	4.5	10.0	4.3
2007 - Max.	177.5	190.7	188.5	45.7
2007 - Avg.	20.1	16.5	17.4	13.4
2007 - Min.	3.7	3.3	4.0	2.3
2007 - S.D.	13.3	10.6	9.9	6.8

Month	Chlorophyll a (µg/L)			
Minimums	**Doughty Cut**	**GLC abv Bar.**	**Tracy Rd.**	**GLC n OR**
Jan.	3.1	4.1	0.1	-
Feb.	5.3	5.3	0.5	2.6
Mar	8.0	5.3	2.9	3.8
Apr	8.8	37.4	37.2	0.7
May	7.1	2.3	4.5	2.7
Jun	19.6	8.3	7.8	1.5
Jul	34.3	23.6	18.9	1.1
Aug	5.9	6.4	10.9	0.8
Sep	11.7	4.9	8.6	0.7
Oct	8.8	5.8	6.1	0.2
Nov	6.9	1.3	6.1	0.1
Dec	0.50	0.9	3.4	0.8
Std. Devs.	**Doughty Cut**	**GLC abv Bar.**	**Tracy Rd.**	**GLC n OR**
Jan.	8.1	9.3	4.7	-
Feb.	10.7	11.1	9.7	9.7
Mar	24.2	47.1	31.7	18.5
Apr	58.7	51.8	44.6	51.0
May	27.1	17.3	15.5	5.3
Jun	61.1	35.9	34.8	2.2
Jul	69.1	54.6	94.2	21.5
Aug	23.0	19.9	16.4	15.6
Sep	13.7	10.7	8.1	4.0
Oct	13.5	9.3	9.5	2.6
Nov	4.1	6.3	7.1	2.2
Dec	2.9	3.0	2.1	2.2
2007 - Max.	496.4	360.3	429.4	207.5
2007 - Avg.	52.7	42.1	39.8	13.5
2007 - Min.	0.5	0.9	0.1	0.1
2007 - S.D.	55.2	47.2	49.5	23.0

September through March

A maximum of 1291.9 µS/cm was recorded on October 25 at MR at Undine Road. The minimum recorded specific conductance was 286.2 µS/cm on March 31st at MR at Union Point. Monthly mean values for this period ranged from 319.7 µS/cm in October at Victoria Canal to 913.6 µS/cm in December at OR at TWA. In December, the average conductance at OR at TWA was approximately 85.0 µS/cm higher than at any of the other monitoring sites. The lowest monthly mean conductance values were recorded at MR at Tracy Road, MR at Union Point, and Victoria Canal, where values did not exceed 600 µS/cm.

ANOVA Analysis

Old River

ANOVA was performed on average daily specific concentrations data to determine whether monthly mean concentrations from April through August differed among 4 Old River monitoring locations (near Head, TWA, upstream of the ORT barrier, downstream of the ORT barrier). Test results showed that at least one mean was significantly different in April ($F(3,115)=73$, $p <.001$), May ($F(3,120)=64$, $p <.001$), June ($F(3,115)=6$, $p <.001$), July ($F(3,120)=20$, $p < .001$), and August ($F(3,119)=19$, $p<.001$). [Explanation of $F(3,115)=73$, $p <.001$: $F(3,115)$ refers to the between-groups degrees of freedom (3) and the within-groups degrees of freedom (115). The F-statistic (73) and p-value (<.001) were calculated from the ANOVA test. Statistical significance was based on having a p-value of less than .01.] Tukey's HSD test was then performed to determine which mean site conductance values differed. The results showed that specific conductance values were significantly higher ($p<.01$) at OR at TWA in comparison to each of the other 3 sites in April, May, June (except upstream of the ORT barrier; $p >.05$), and July. There were no significant ($p>.05$) differences in specific conductance values between the sites upstream and downstream of the ORT barrier. There were also no significant differences ($P>.05$) between OR near Head and either of the barrier sites in May, June, and July.

Field Data

Field data collected throughout the year showed a strong correlation with the sonde data ($R^2 = .99$). The mean specific conductance of the sonde data was 594.5 µS/cm and mean of the field data was 595.2 µS/cm, (n=192) (Figure 8-20).

Turbidity

Turbidity in water is caused by suspended matter, such as clay, silt, organic and inorganic matter, plankton, and other microscopic organisms (APHA 1992). Turbidity is an expression of the optical property that causes light to be scattered and absorbed rather than transmitted in straight lines through the sample (APHA 1992). In surface waters with reduced water clarity, phytoplankton and aquatic plant growth may be adversely affected because of reduced light penetration in the water column. Water clarity (turbid vs. clear) may affect predator-prey interactions of some aquatic species, and highly turbid water may be harmful to aquatic life.

Turbidity values ranged from a high of 195.3 NTU on April 4 at MR at Undine Road to a low of 0.1 NTU on August 12 at MR at Howard Road (Figures 8-24 to 8-27, and see Tables 8-6 to 8-9). 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 if a single value is greater than 200 NTU; however, there are moments during the year where several continuous readings reveal a true event. Summer turbidity readings were the highest, with mean values ranging from 7.1 NTU in June at MR at Union Point to 41.5 NTU in July at OR at TWA. Late fall and winter turbidity reading were the lowest, with the MR at Howard Road, MR at Tracy Road, MR at Union Point, and Victoria Canal being the least turbid sites. Monthly average turbidity values at these sites were less than 12.0 NTU in the fall and winter. In 2007 mean turbidity values ranged from 5.9 NTU at Victoria Canal to 24.4 NTU at OR at TWA.

Figure 8-24. Old River turbidity data (15-minute intervals)

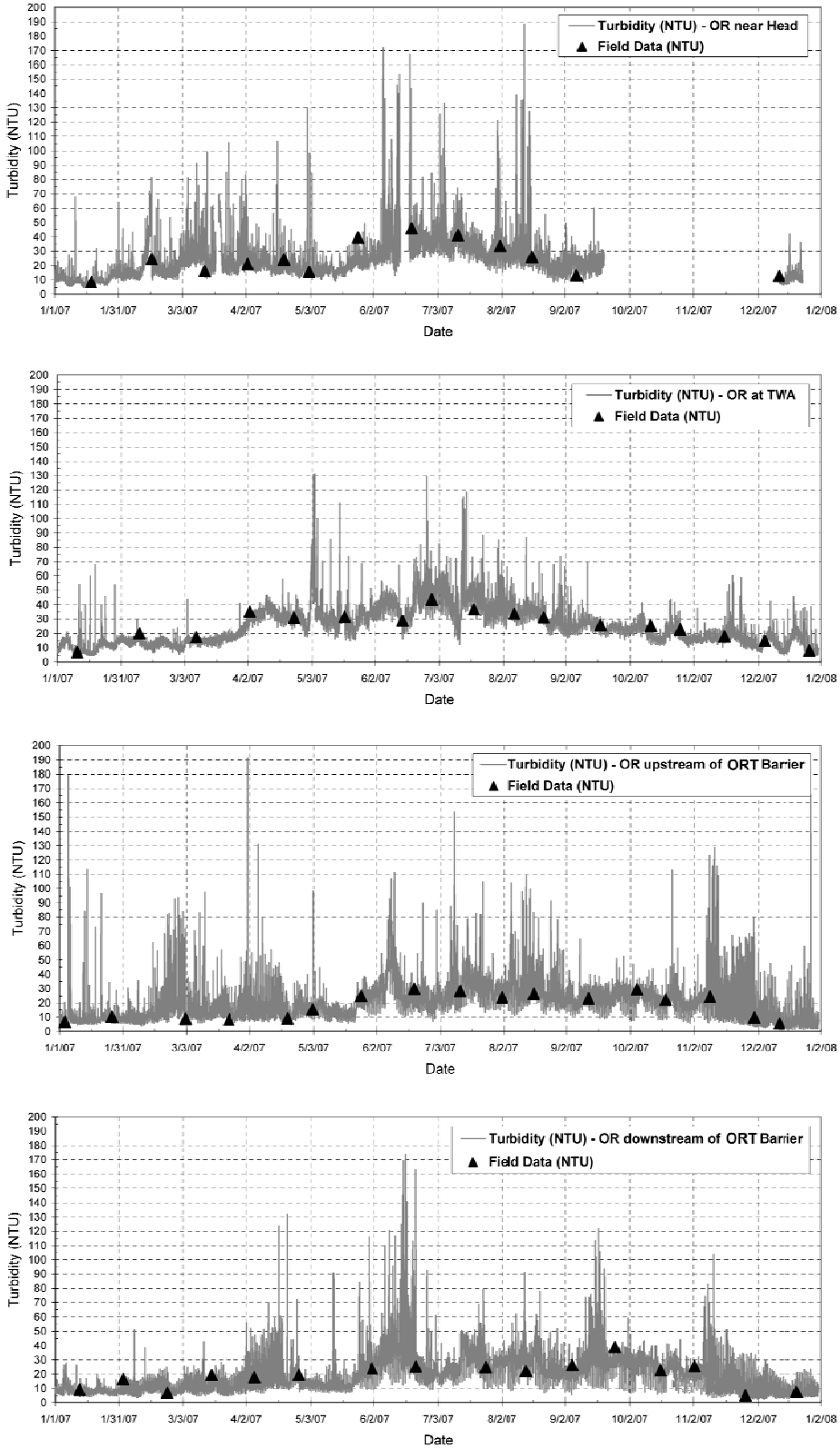


Figure 8-25. Middle River turbidity data (15-minute intervals)

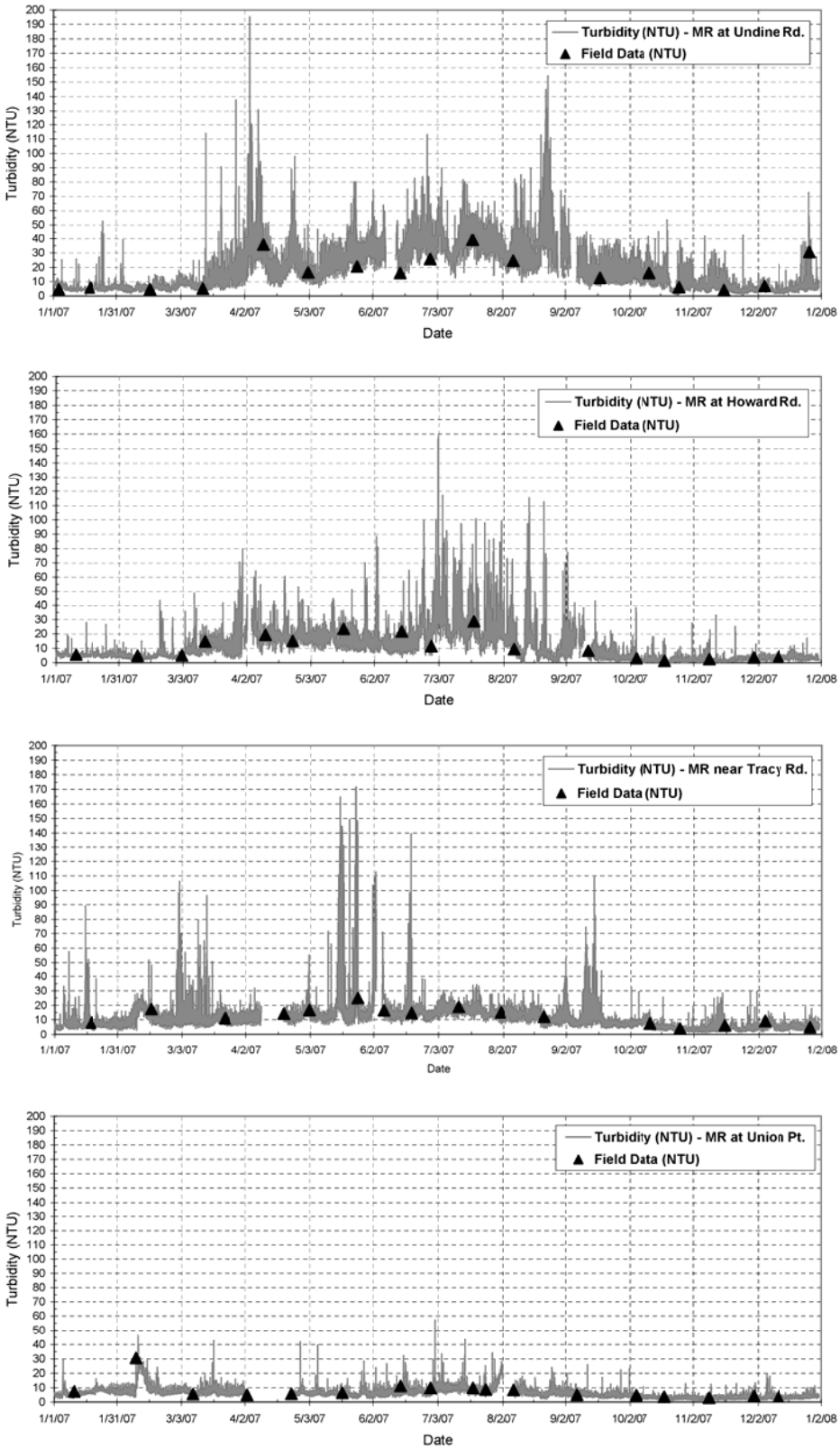


Figure 8-26. Grant Line Canal turbidity data (15-minute intervals)

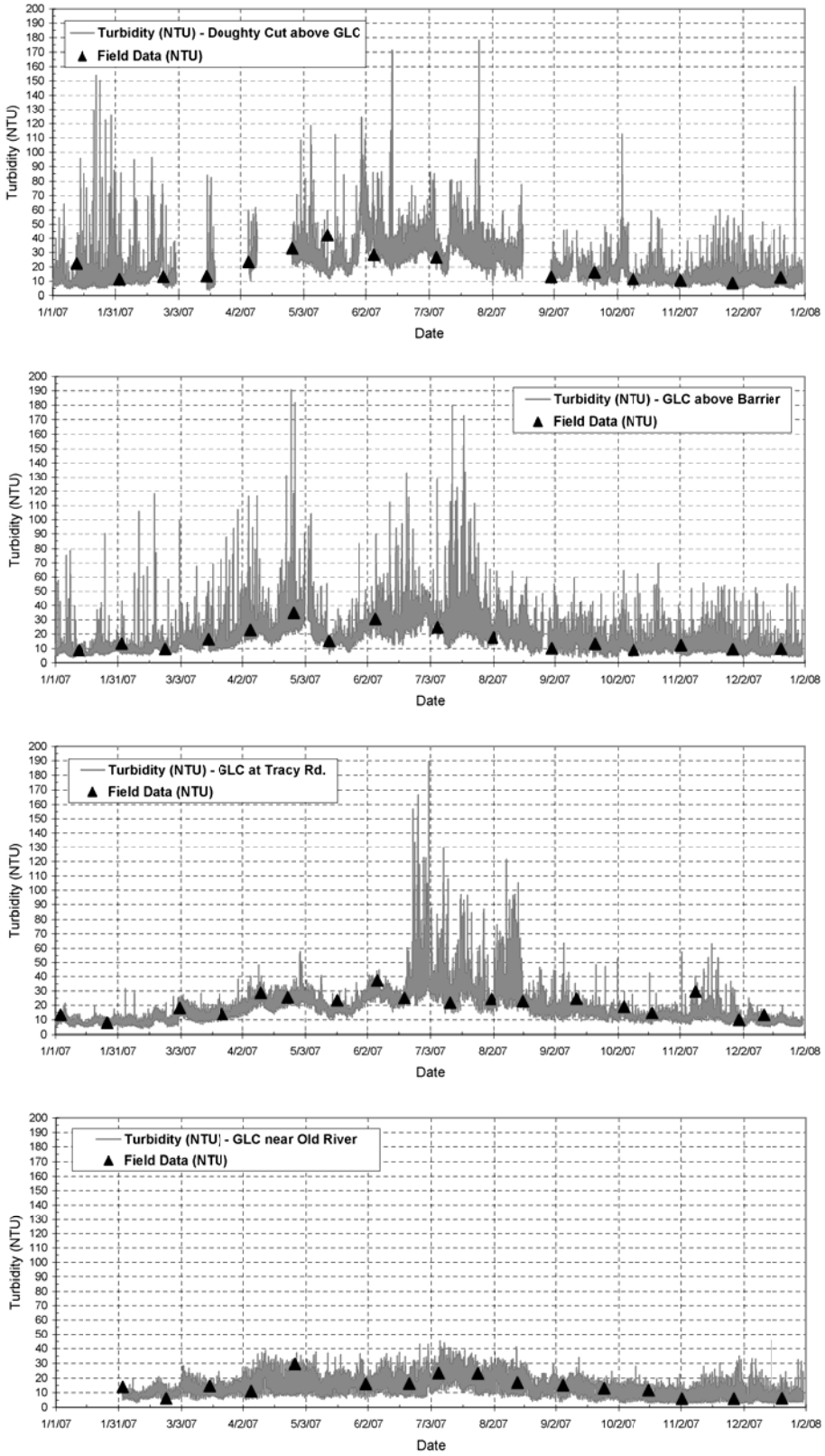
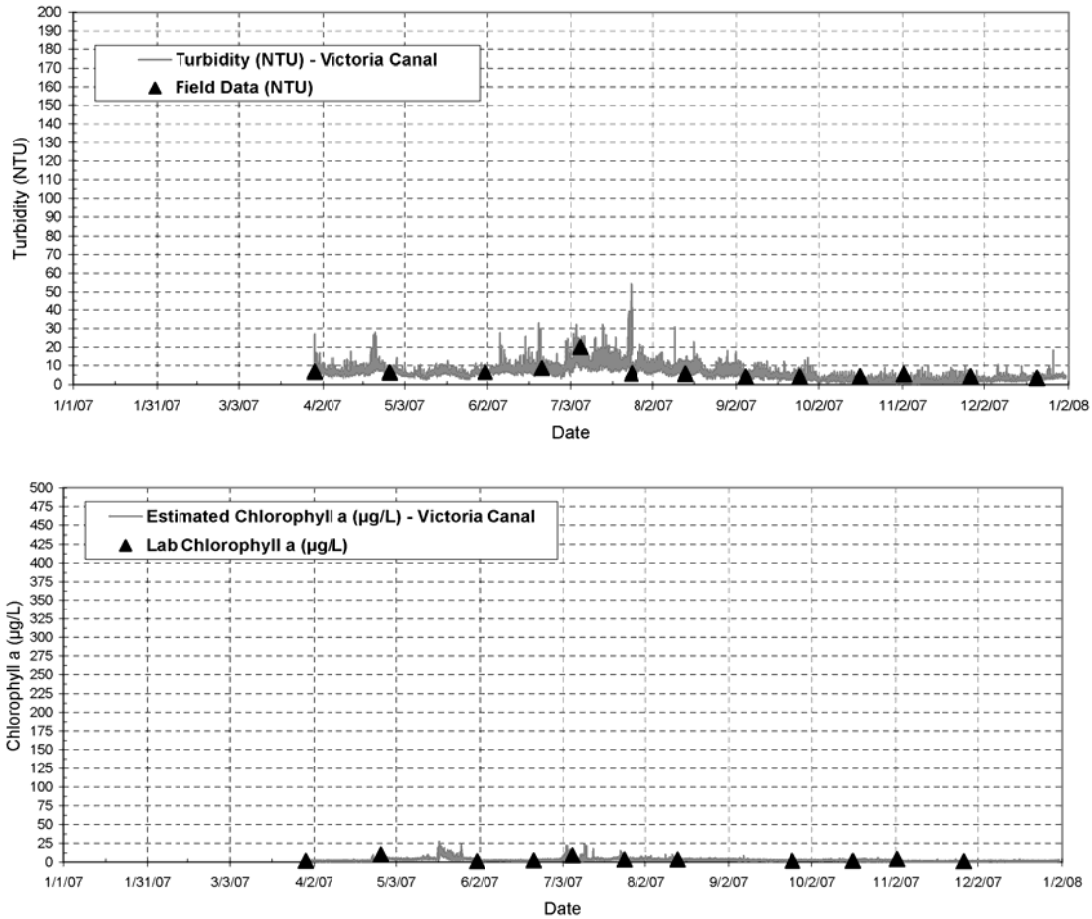


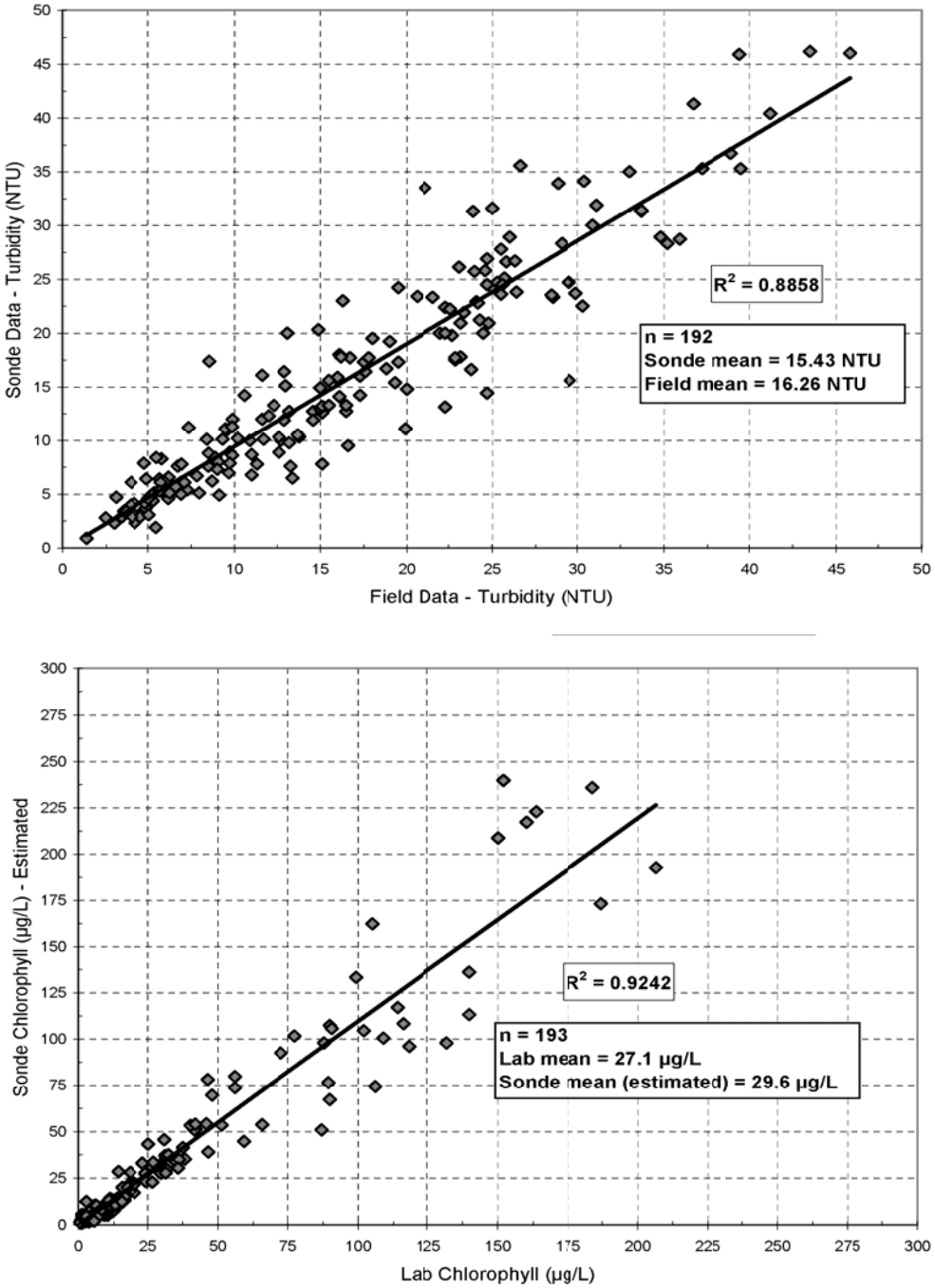
Figure 8-27. Victoria Canal turbidity and estimated chlorophyll *a* data (15-minute intervals)



Field Data

Field data collected throughout the year showed a fairly strong correlation with the sonde data (R^2 = .89). The correlation between the field and sonde data for turbidity is affected, in part, by sampling depth. A metal container is used to collect surface water samples, which are tested using field instruments, while the sonde measures turbidity at a depth of one-meter. The mean of the turbidity sonde data was 15.43 NTU and mean of the field data was 16.26 NTU, (n=192) (Figure 8-28).

Figure 8-28. Turbidity and chlorophyll linear regression plots for field/lab data versus sonde data



Chlorophyll *a*

Chlorophyll *a* concentrations can be used as an indicator of phytoplankton biomass in water body (APHA 1992). Phytoplankton (microscopic algae) occur as unicellular, colonial, or filamentous forms and are primarily grazed upon by zooplankton and other aquatic organisms (APHA 1992). The species composition and/or biomass of phytoplankton may be a useful tool in assessing water quality (APHA 1992). Algae can influence water quality by affecting pH, DO, turbidity, the color, taste and odor of water; under certain conditions, some species can develop noxious blooms.

Winter (December-February)

A maximum chlorophyll *a* concentration of 458.4 µg/L was measured on February 8 at MR near Tracy Road and a minimum of 0.10 µg/L was recorded on December 26 at Middle River at Howard Road (Figures 8-29 to 8-31, Figure 8-26, and see Tables 8-6 to 8-9). Monthly mean chlorophyll *a* concentrations during this time period ranged from 1.29 µg/L in December at Victoria Canal to 73.1 µg/L in January at MR near Tracy Road. MR at Tracy Road, OR at TWA, OR upstream of the ORT barrier, and OR downstream of the ORT barrier were the only sites to have monthly concentrations of greater than 20.0 µg/L in January and February. Winter chlorophyll *a* concentrations were the lowest of the 4 seasons.

Figure 8-29. Old River estimated chlorophyll *a* data (15-minute intervals)

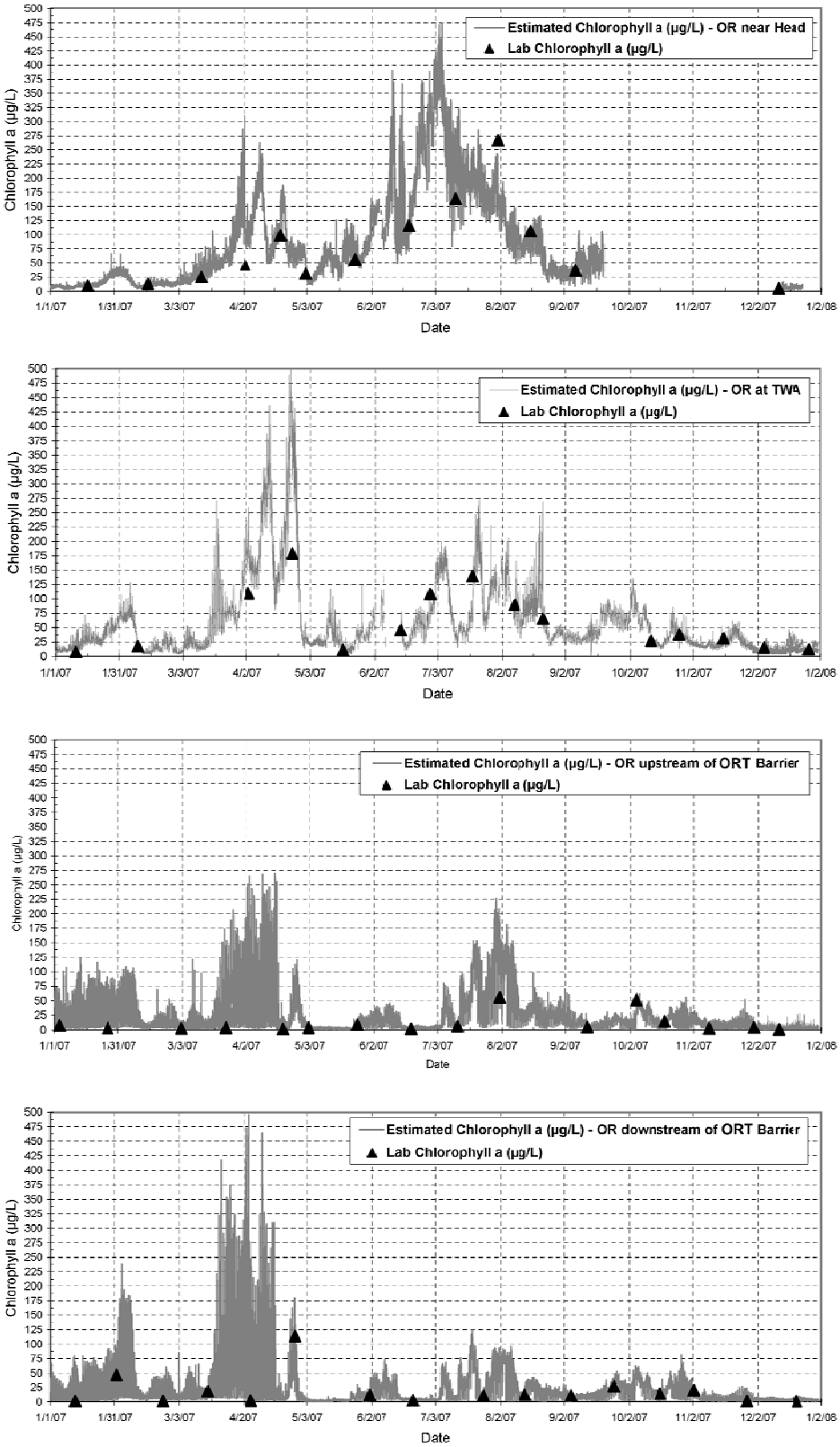


Figure 8-30. Middle River estimated chlorophyll *a* data (15-minute intervals)

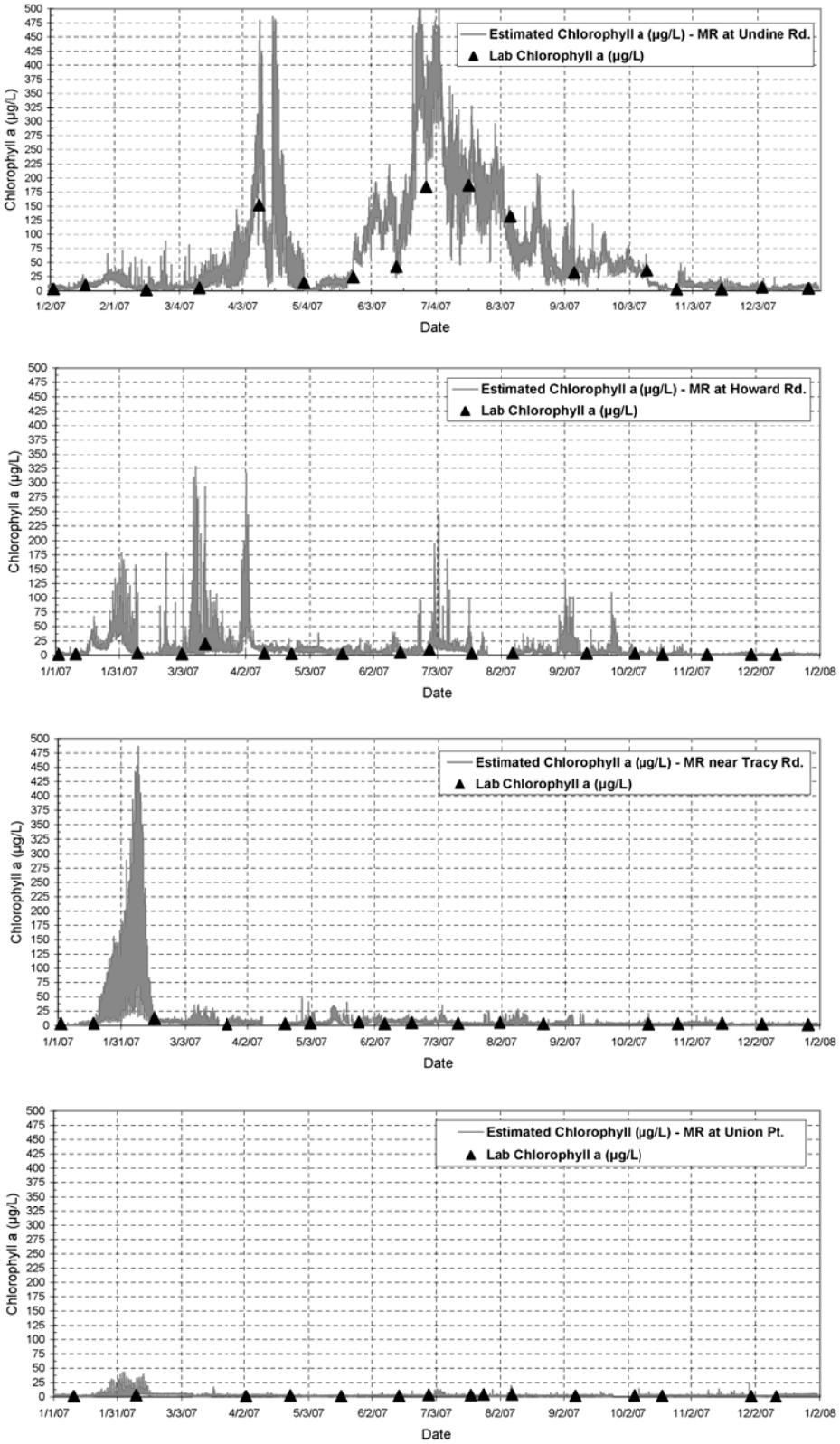
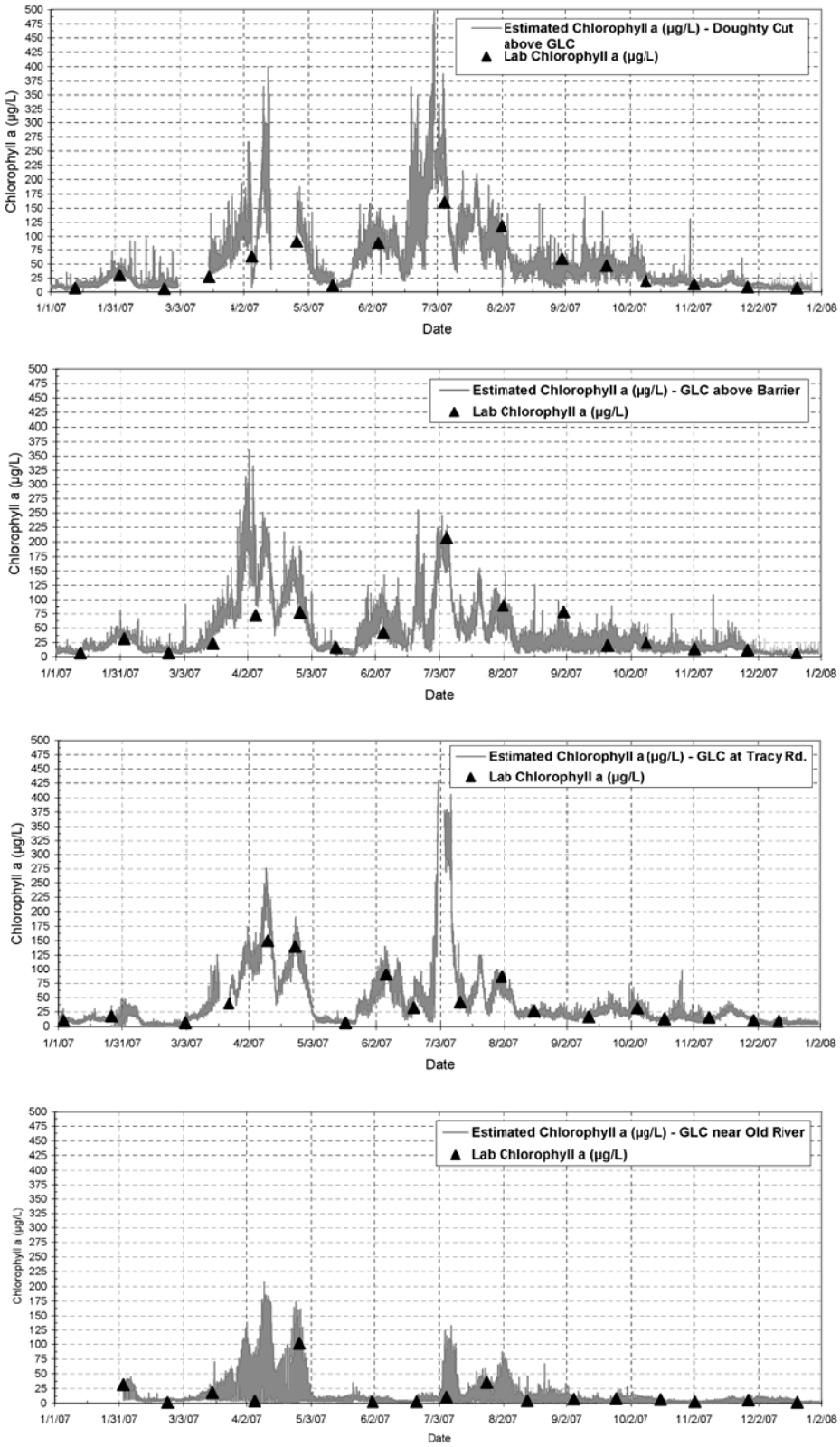


Figure 8-31. Grant Line Canal estimated chlorophyll *a* data (15-minute intervals)



Spring (March-May)

A maximum chlorophyll *a* concentration of 498.3 µg/L was measured on April 23 at OR at TWA and a minimum of 0.1 µg/L was recorded on March 8 at MR at Union Point. Monthly mean chlorophyll *a* concentrations during this period ranged from 1.7 µg/L in May at MR at Union Point to 199.6 µg/L mg/L in April at OR at TWA. Six of the 13 stations had monthly average chlorophyll concentrations in April of over 100 µg/L (OR near Head, OR at TWA, MR at Undine Road, Doughty Cut above GLC, GLC above barrier, and GLV at Tracy Road). OR upstream of the ORT barrier, OR downstream of the ORT barrier, and GLC near Old River had average chlorophyll concentrations in April of between 50 and 60 µg/L. The lowest chlorophyll *a* concentrations were observed at MR at Howard Road, MR near Tracy Road, MR at Union Point, and Victoria Canal where average monthly concentrations did not exceed 25 µg/L.

Summer (June-August)

A maximum chlorophyll *a* concentration of 499.8 µg/L was measured on July 5 at MR at Undine Road and a minimum of 0.1 µg/L was recorded on July 26 at MR at Union Point. Monthly mean chlorophyll *a* concentrations during this period ranged from 2.1 µg/L in August at MR at Union Point to 234.9 µg/L in July at OR near Head. Chlorophyll *a* concentrations were highest during the year in the month of July, with the highest concentrations measured at OR near Head and MR at Undine Road (230.2 µg/L). Doughty Cut above GLC, GLC above barrier, GLC at Tracy Road, and OR at TWA had average chlorophyll concentrations ranging from 94.6 µg/L to 138.2 µg/L. Concentrations near the ORT barrier averaged from 31.1 µg/L to 54.6 µg/L in July. The lowest chlorophyll *a* concentrations were observed at MR at Howard Road, MR near Tracy Road, MR at Union Point, and Victoria Canal where average monthly concentrations did not exceed 25 µg/L. Summer chlorophyll *a* concentrations were the highest of the 4 seasons.

Fall (September-November)

A maximum chlorophyll *a* concentration of 178.7 µg/L was measured on September 6 at MR at Undine Road, and a minimum of 0.04 µg/L was recorded on November 5 at MR at Victoria Canal. Monthly mean chlorophyll *a* concentrations during this period ranged from 1.10 µg/L in November at Victoria Canal to 49.8 mg/L in September at OR at TWA. Monthly chlorophyll *a* concentrations were highest during September and lowest in November, with all of the stations averaging less than 25.0 µg/L in November. OR near Head, OR at TWA, MR at Undine Road, and Doughty Cut above GLC had the highest chlorophyll *a* concentrations in September with values ranging from 45.7 µg/L to 49.8 µg/L. Concentrations near the ORT barrier averaged from 12.8 µg/L to 15.8 µg/L in September. The lowest chlorophyll *a* concentrations were observed at MR at Howard Road, MR near Tracy Road, MR at Union Point, Victoria Canal, and GLC near OR where average monthly concentrations did not exceed 10 µg/L.

Field Data

Field data collected throughout the year showed a strong correlation with the sonde data (R^2 = .92). The mean chlorophyll *a* concentration of the estimated data was 29.6 µg/L, and mean of the lab data was 27.1 µg/L, (n=193) (Figure 8-27). The estimated chlorophyll *a* data and the seasonal patterns seen in the continuous data are further corroborated by additional chlorophyll *a* samples collected by DWR's Surface Water Data Section (Figures 8-32 to 8-34).

Figure 8-32. Old River: chlorophyll *a*, pheophytin *a*, and ammonia discrete water quality data

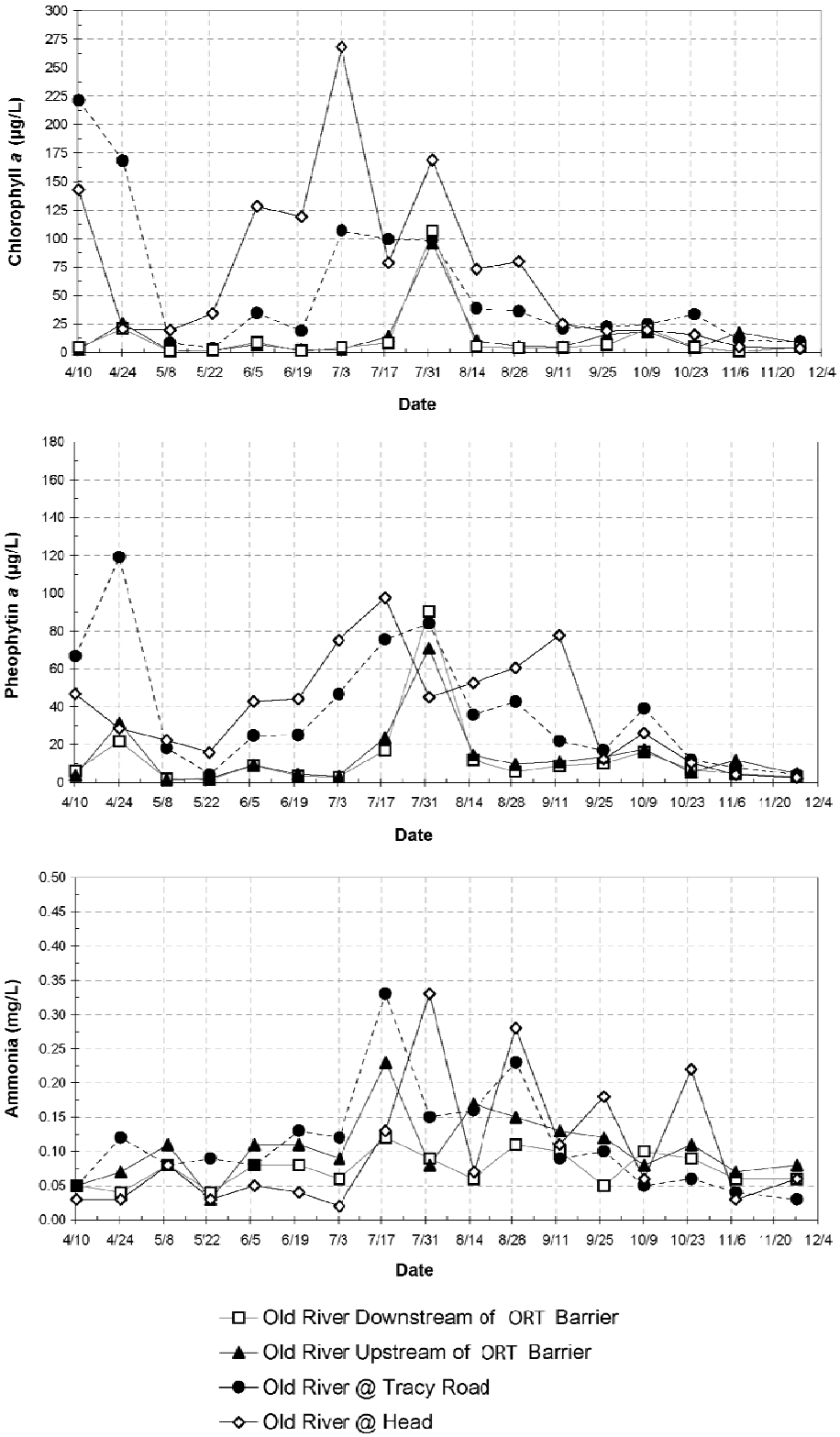


Figure 8-33. Middle River chlorophyll *a*, pheophytin *a*, and ammonia discrete water quality data

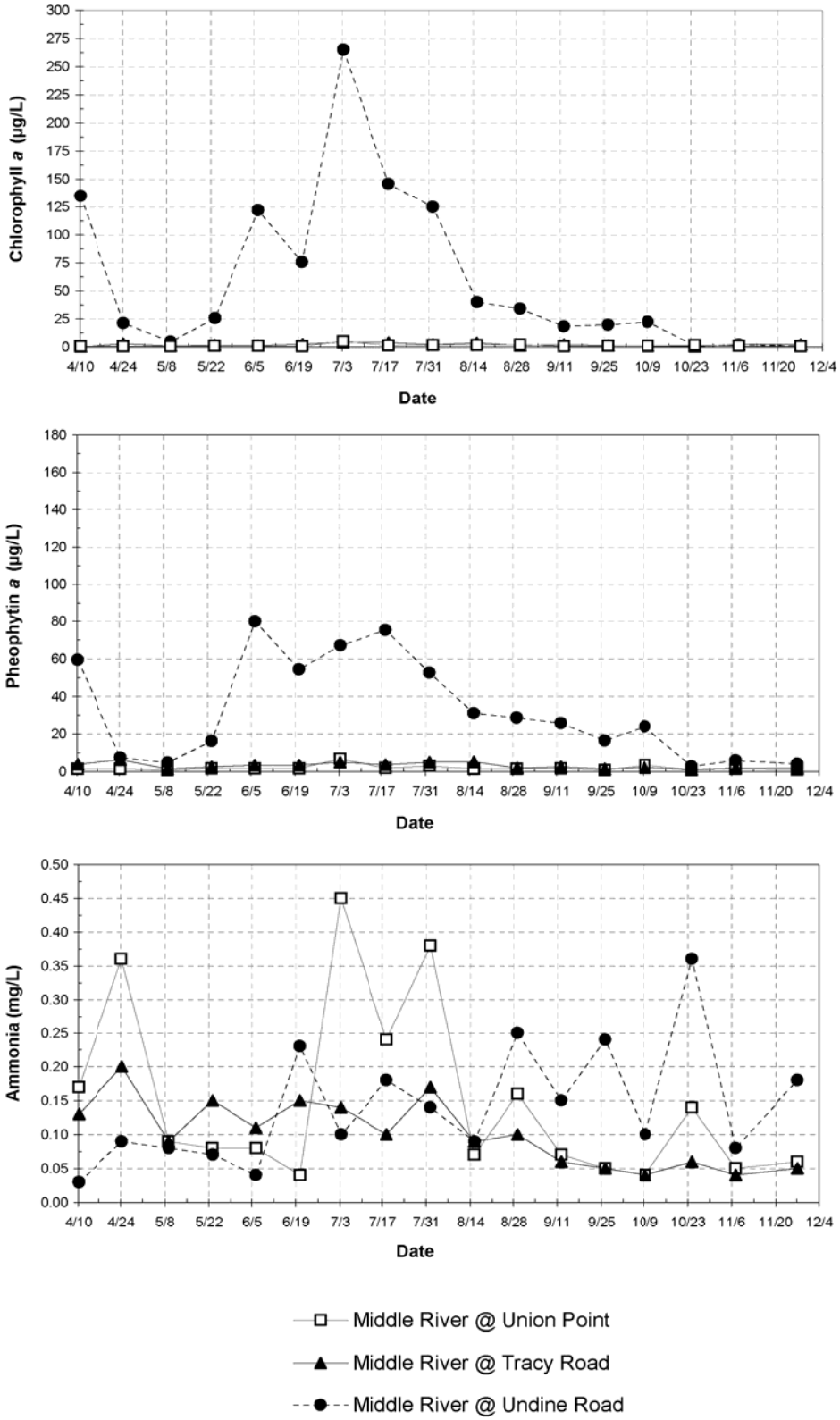
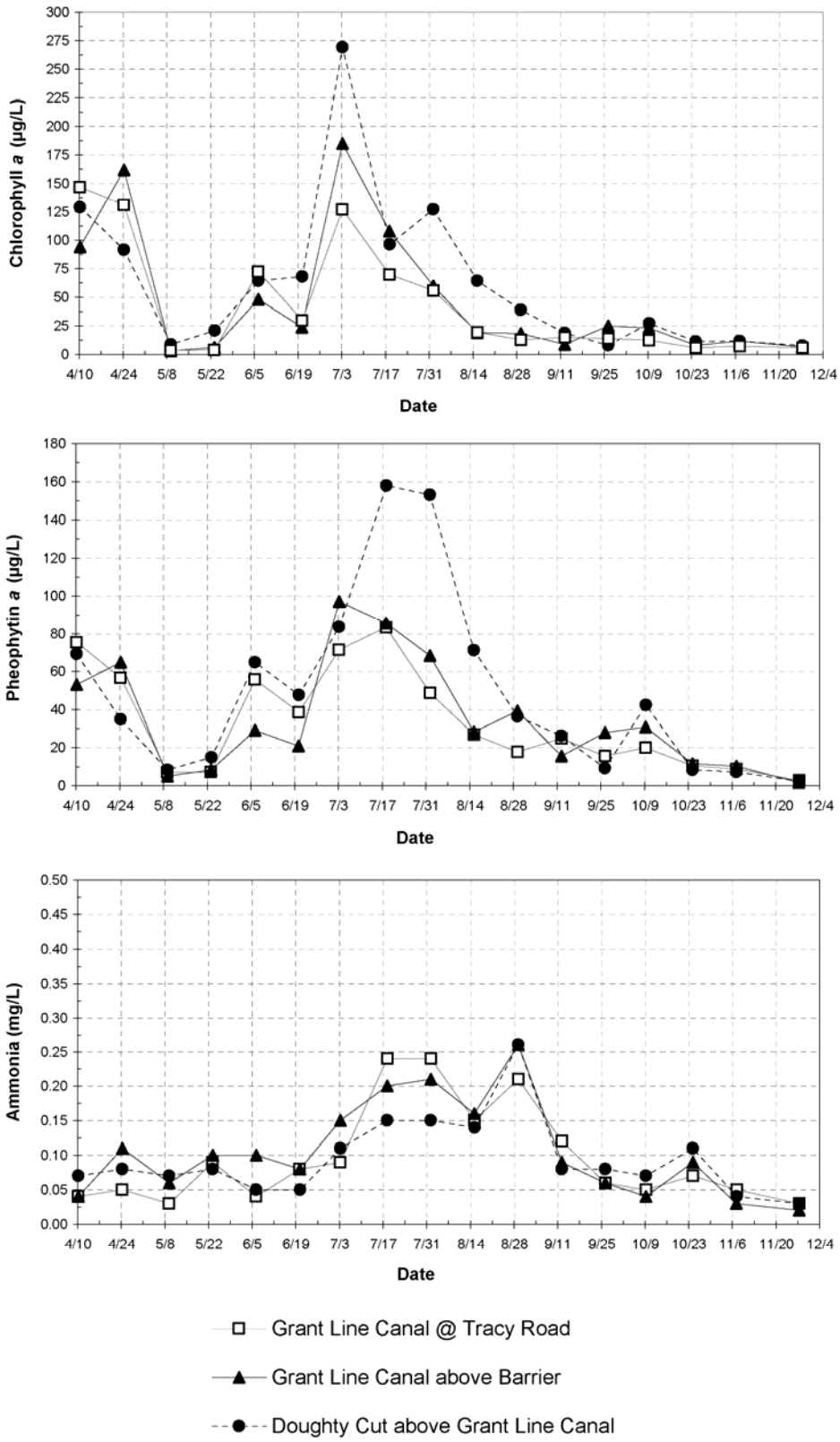


Figure 8-34. Grant Line Canal chlorophyll *a*, pheophytin *a*, and ammonia discrete water quality data



Pheophytin *a*

As phytoplankton populations decline, chlorophyll *a* degrades into byproducts. Pheophytin *a* is a degradation product of chlorophyll *a*. When phytoplankton are actively growing, the concentrations of pheophytin *a* are normally expected to be low in relation to chlorophyll *a*.

Pheophytin *a* concentrations were highest during the summer and lowest in November, mirroring chlorophyll *a* concentrations (Figures 8-32 to 8-34). A maximum pheophytin *a* concentration of 158 µg/L was recorded on July 18 at Doughty Cut above GLC, and a minimum of 0.61 µg/L was recorded on September 26 at MR at Union Point. Average pheophytin *a* concentrations were highest during the monitoring period at OR at Head (42.8 µg/L), OR at Tracy Road (24.9 µg/L), MR at Undine Road (32.6 µg/L), Doughty Cut above GLC (49.3 µg/L), GLC above barrier (35.2 µg/L), and GLC at Tracy Road (33.7 µg/L) where the largest chlorophyll *a* concentrations were observed. The remaining sites (MR at Tracy Road, MR at Union Point, OR upstream and downstream of the ORT barrier) had average pheophytin *a* concentrations of less than 10.0 µg/L paralleling average chlorophyll *a* concentrations.

Ammonia

Ammonia is present naturally in surface water and wastewater (APHA 1992). It is produced largely by deamination of organic nitrogen containing compounds and is sometimes used by wastewater treatment plants to react with chlorine (APHA 1992). High ammonia concentrations in natural surface water may indicate contamination from effluent.

Measured ammonia concentrations in the South Delta ranged from a minimum of 0.2 mg/L to a maximum of 0.45 mg/L (Figures 8-32 to 8-34). Average concentrations during the monitoring period ranged from a low of .07 mg/L at OR downstream of the ORT barrier to a high of 0.15 mg/L at MR at Union Point. South Delta ammonia concentrations were elevated in July and August averaging 0.17 mg/L. Every monitoring site, except MR at Undine Road and MR at Tracy Road, had peak ammonia values recorded in either July or August.

Nitrite + Nitrate

Total oxidized nitrogen is the sum of nitrate and nitrite nitrogen (APHA 1992). Nitrate is an essential nutrient for many photosynthetic autotrophs and can be a growth-limiting nutrient (APHA 1992). Nitrite is an intermediate oxidation state of nitrogen, both in the oxidation of ammonia to nitrate and in the reduction of nitrate (APHA 1992).

Nitrite+Nitrate concentrations in the South Delta ranged from a minimum of 0.15 mg/L to a maximum of 5.90 mg/L (Figures 8-35 to 8-37). Average concentrations during the monitoring period ranged from a low of .56 mg/L at MR at Tracy Road to a high of 1.88 mg/L at MR at Undine Road. South Delta nitrite+nitrate concentrations were elevated in October averaging 1.76 mg/L. Old River and Grant Line Canal showed little variation between sites in comparison to Middle River. In Middle River the Undine Road monitoring site had consistently higher nitrite-nitrate concentrations from June through November.

Figure 8-35. Old River nitrite + nitrate, organic nitrogen, and orthophosphate discrete water quality data

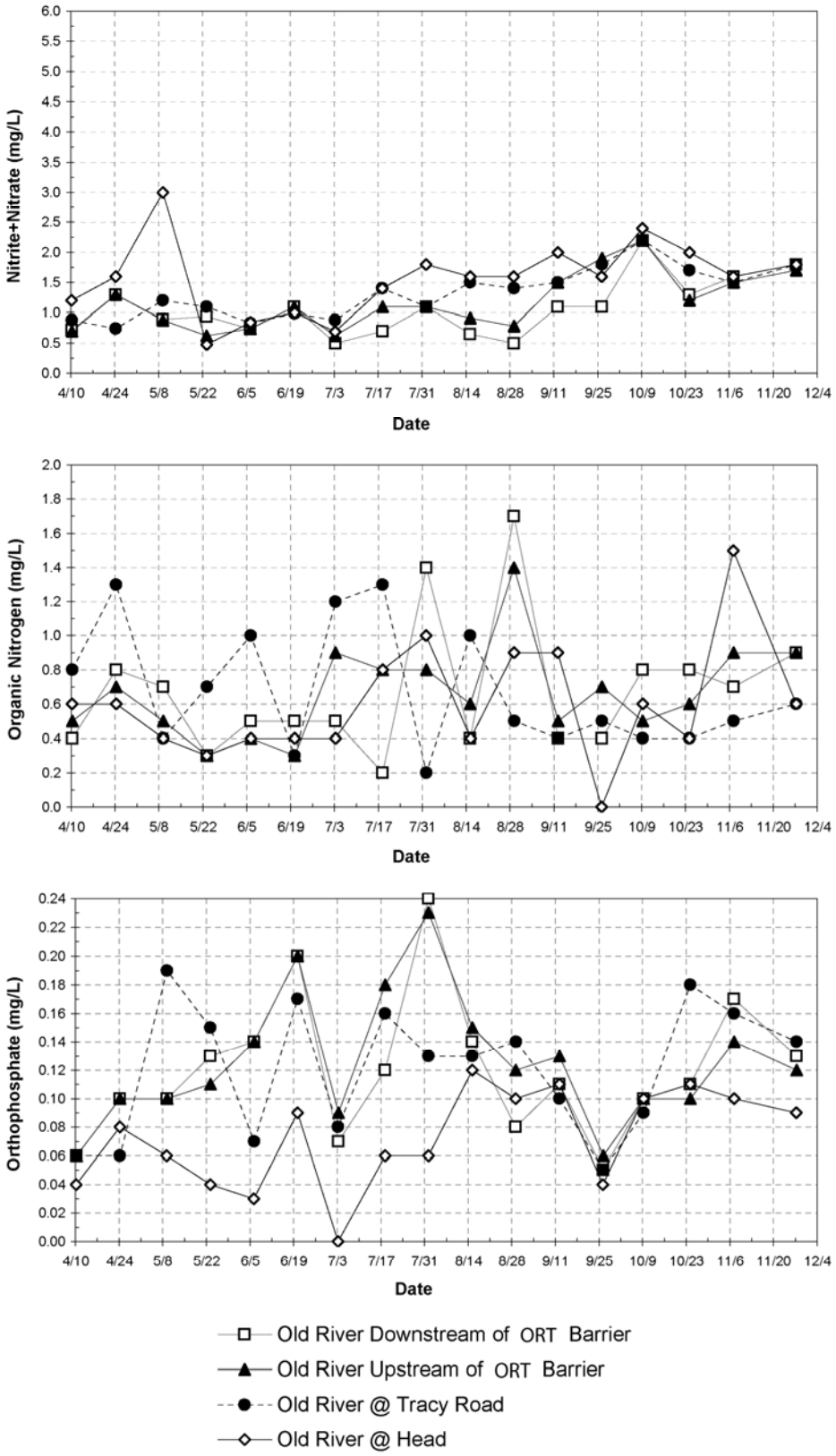


Figure 8-36. Middle River nitrite + nitrate, organic nitrogen, and orthophosphate discrete water quality data

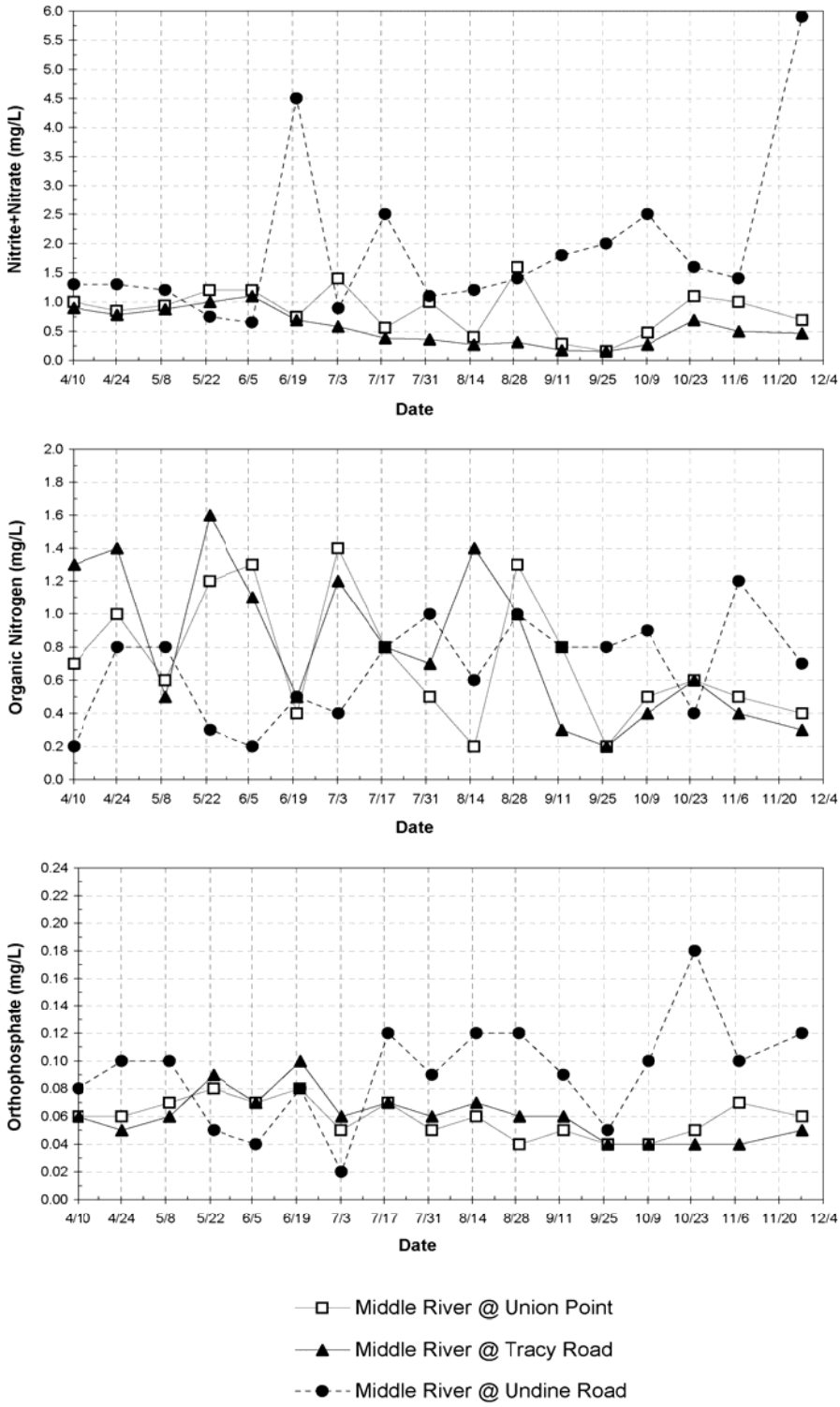
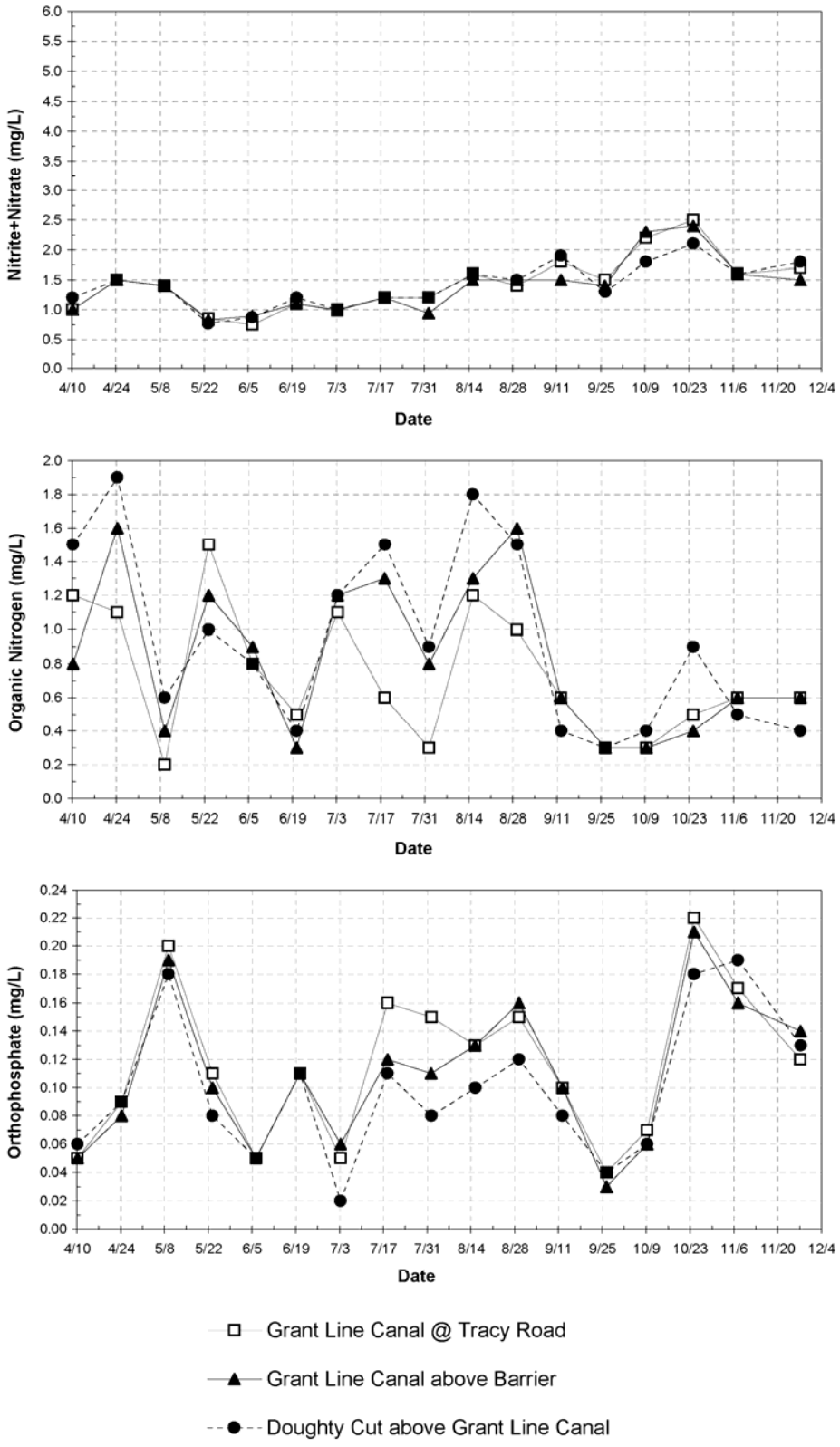


Figure 8-37. Grant Line Canal nitrite + nitrate, organic nitrogen, and orthophosphate discrete water quality data



Organic Nitrogen

Organic nitrogen is a component in the nitrogen cycle along with nitrite, nitrate, ammonia, and nitrogen gas and is defined functionally as organically bound nitrogen in the trinegative oxidation state (APHA 1992). Organic nitrogen includes such materials as proteins and peptides, nucleic acids and urea, and numerous synthetic organic materials (APHA 1992). Organic nitrogen concentrations can range from a few hundred micrograms per liter in some lakes to more than 20 mg/L in raw sewage (APHA 1992).

Organic nitrogen concentrations in the South Delta ranged from a minimum of 0 mg/L (below 0.1 mg/L reporting limit) to a maximum of 1.90 mg/L (Figures 8-35 to 8-37). Average concentrations during the monitoring period ranged from a low of .60 mg/L at OR at Head to a high of 0.94 mg/L at Doughty Cut above GLC. South Delta organic nitrogen concentrations in Old River and Middle River fluctuated throughout the monitoring period with no discernible trends. Concentrations of organic nitrogen in GLC were visibly lower from September through November.

Orthophosphate

Phosphorus is essential to phytoplankton growth and can be a limiting nutrient for primary productivity. In cases where phosphate is a limiting factor, the discharge of raw or treated wastewater, agricultural drainage, and/or certain industrial wastes may stimulate the growth of photosynthetic micro- and macro-organisms in nuisance quantities (APHA 1992). Orthophosphates applied to agricultural or residential cultivated land, as fertilizers, are carried into surface water with storm runoff (APHA 1992).

Orthophosphate concentrations in the South Delta ranged from a minimum of 0 mg/L (below 0.01 mg/L reporting limit) to a maximum of 0.24 mg/L (Figures 8-35 to 8-37). Average concentrations during the monitoring period ranged from a low of .06 mg/L at MR at Tracy Road to a high of 0.13 mg/L at OR upstream of the ORT barrier. South Delta orthophosphate concentrations fluctuated throughout the monitoring period with no discernible trends and tended to show little variation between sites in Old River, Middle River, and Grant Line Canal, except for at OR near Head and MR at Undine Road. Concentrations of organic nitrogen recorded at OR at Head were markedly lower in OR from April through August, while concentrations in MR at Howard Road were consistently higher from mid-July through November.

Discussion

A visual comparison of the 2007 water temperature plots for the South Delta monitoring sites revealed similar trends. This would seem reasonable because all of the sites are located within 10 miles of each other and thus are subject to relatively similar meteorological conditions throughout the year. Figure 8-38 shows the linear correlation between water temperature (MR at Undine Road) and air temperature (Tracy, CA) in the South Delta. Temperature variation between the 13 continuous sites is likely due to site-specific localized differences and tidal influences.

Variation observed in specific conductance was due in part to differences in source water, flow dynamics, and agricultural pumping and return flows. Specific conductance values at OR near Head, MR at Undine Road, Doughty Cut above GLC, GLC above barrier, GLC at Tracy Road showed similar trends in 2007, with the exception of one conductance spike at MR at Undine Road in late October. The specific conductance patterns observed at the aforementioned sites are similar to those observed upstream in the San Joaquin River at Vernalis (see Figure 8-3). Specific conductance values decreased in late February through early March, possibly as the result of increased flow in the San Joaquin River during the same period. Values were typically lowest during the year at these locations from late April through late June when flow was highest and specific conductance was lowest in San Joaquin River at Vernalis. Electrical conductivity values also decreased from late October through early November when flow increased and specific conductance decreased in the San Joaquin River at Vernalis.

The OR at TWA monitoring site is less than a quarter-mile downstream from OR at Tracy Road, which is a compliance location for specific conductance during April through August (30-day running average not to exceed 700 µS/cm) and from September through March (30-day running average not to exceed 1,000 µS/cm). In April, May, July, and August monthly average specific conductance values at OR at TWA exceeded 700 µS/cm. Data analysis showed that OR at TWA had significantly higher daily average specific conductance values in comparison to the other 3 OR monitoring sites in April, May, and July. One possible explanation as to why specific conductance values are higher in the vicinity of OR at Tracy Road is the influence of Sugar Cut and Paradise Cut. CD's Surface Water Section established a station in Paradise Cut to discern if water in the area was higher in specific conductance than OR at Tracy Road and OR at TWA. Figure 8-39 shows a plot of Paradise Cut and OR at TWA. The preliminary data indicates that Paradise Cut is a possible source of high conductivity water (values as high as 2,000 µS/cm) and under certain flow conditions may be contributing to the higher specific conductance values recorded downstream.

Figure 8-38. Linear regression plot of air temperature (Tracy, CA) versus water temperature (Middle River at Undine Road)

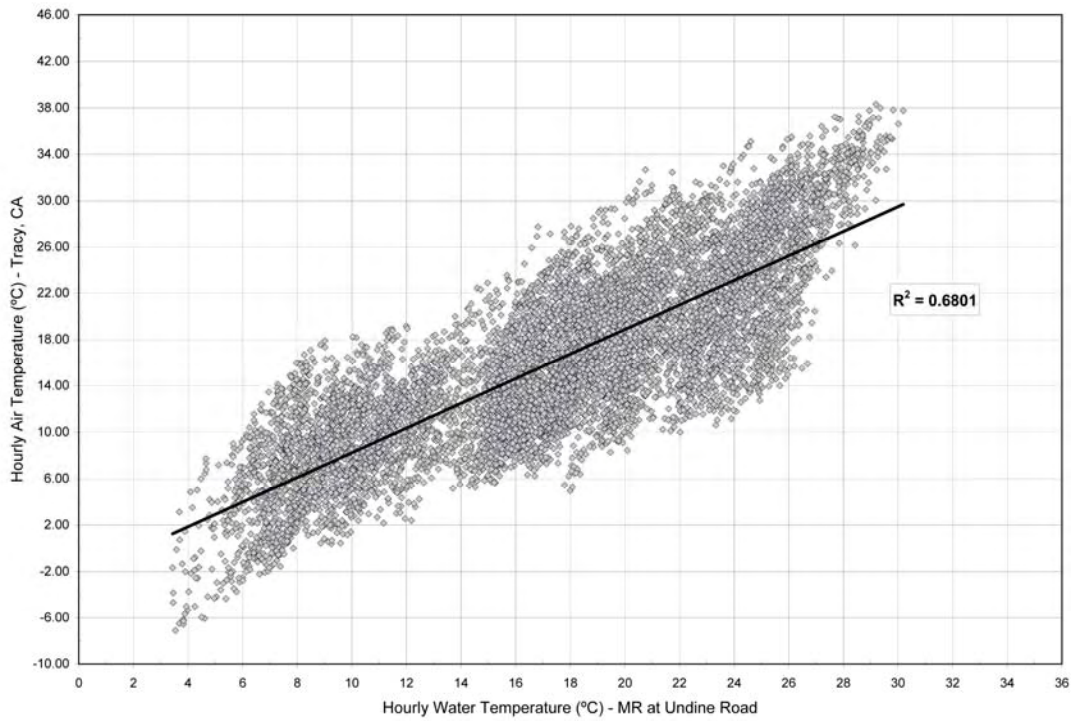
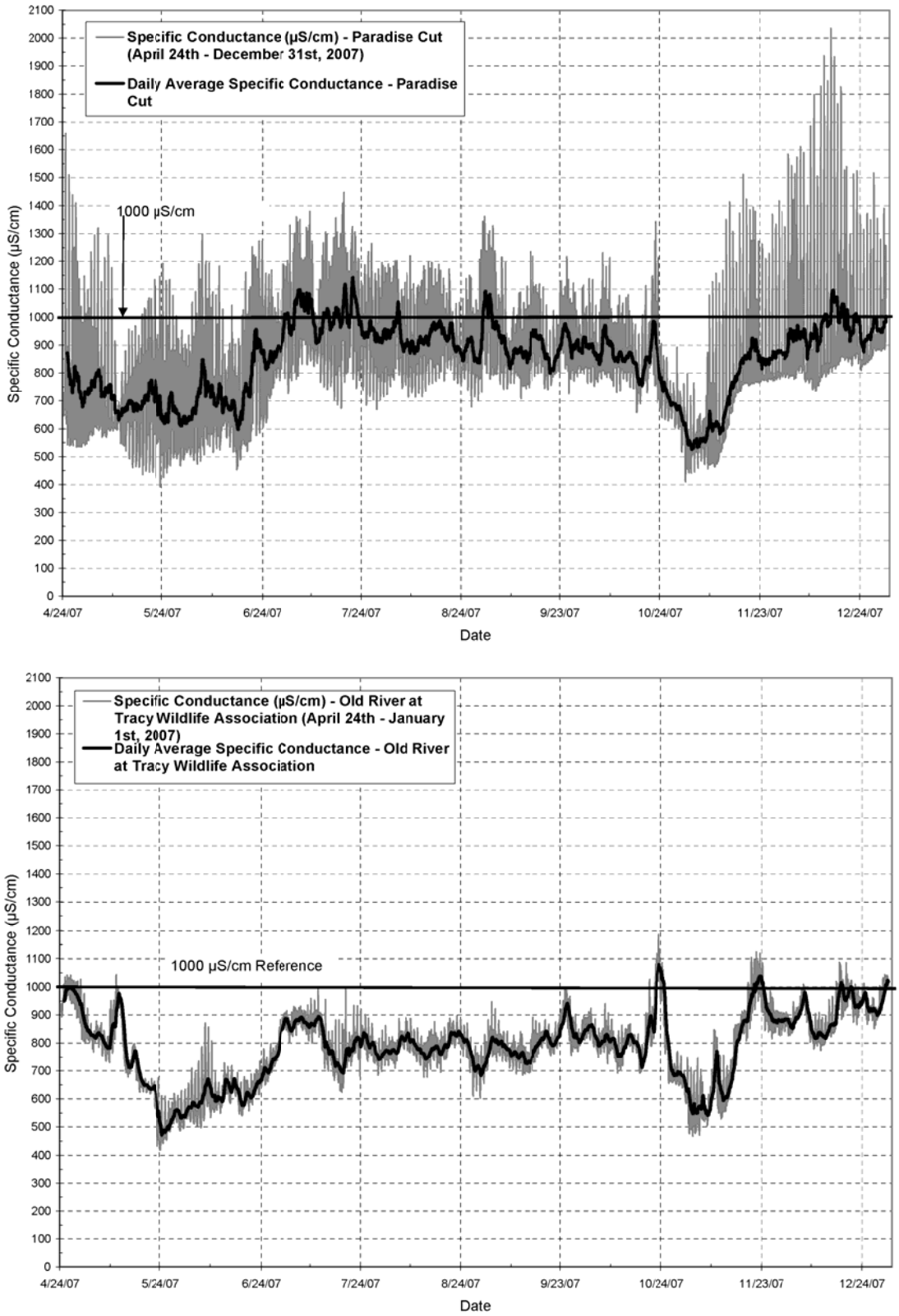


Figure 8-39. Paradise Cut and Old River at Tracy Wildlife Association specific conductance data from April 24 through December 31st, 2007



Variation in specific conductance values was most pronounced at the stations upstream and downstream of the ORT Barrier and at GLC near OR. These stations locations represent areas where there was a marked difference between upstream and downstream specific conductance values. The higher conductivity water measured on the ebb tide is likely from the San Joaquin River as well as other sources, and the lower conductivity water measured on the flood tide is likely from the Sacramento River as well as other sources. Stations (Victoria Canal, MR at Union Point, and MR near Tracy Road) where the source of water is likely from the Sacramento River had the lowest specific conductance values throughout the year, especially in July. Conductivity values at these sites were lowest in July when there was increased CVP and SWP exports in comparison to May and June. It is likely that specific conductance values at Victoria Canal, MR at Union Point, and MR near Tracy Road increase when there is more net downstream flow in OR, MR, and GLC since the upstream water is higher in conductivity.

Specific conductance spikes were observed throughout most of the year at MR at Howard Road and are likely the result of agricultural pumping and returns flows, and flow dynamics. The fact that the observed conductivity spikes are greater in magnitude than the values recorded either upstream or downstream indicate salts are introduced into the system in this area, though salt accumulation could also occur if there was little or no net downstream flow in the area.

There were 2 extensive algae blooms (as indicated by chlorophyll *a* concentrations) in the South Delta in 2007, one in the spring (pre-barrier) and one in the summer, likely the result of warm water temperatures, low flow conditions, and the availability of nutrients. The spring bloom (late March through early May) was observed at all the Old River and Grant Line Canal monitoring stations and at MR at Howard Road. The spring bloom dissipated in May when the spring Head of Old River barrier was installed, which dramatically reduced flow from the San Joaquin River down OR (see Figure 8-3). When the spring Head of Old River Barrier was removed in early June, chlorophyll *a* concentrations began to increase. The summer bloom (early June through late August) was observed at OR near Head, OR at TWA, MR at Undine Road and at all the GLC monitoring stations except GLC near OR. The bloom was seen to a smaller extent in July and August at the stations upstream and downstream of the ORT barrier. The sites with source water likely from the Sacramento River (Victoria Canal, MR at Union Point, MR at Tracy Road, and MR at Howard Road) had low chlorophyll *a* concentrations throughout most of the year. (A winter bloom was observed at MR near at Tracy Road.)

During the late spring through early fall, there was distinct diurnal variation in DO concentrations at stations with high chlorophyll *a* (algae) concentrations such as OR near Head and MR at Undine Road. Diurnal variation in DO concentrations occurs via algae photosynthesis and respiration. During a typical summer day, DO concentrations reached a maximum in the late afternoon and a minimum during the early morning.

The majority of the DO concentrations below 5.0 mg/L were recorded during the summer (June-August) when water temperatures and chlorophyll *a* concentrations were highest. The stations that had the most sonde readings and daily average DO concentrations below 5 mg/L were OR at TWA, OR upstream of the ORT barrier, OR downstream of the ORT barrier, GLC above Barrier, GLC at Tracy Road, and MR at Undine Road. The primary causes of low DO concentrations at these stations during the summer are likely high biological oxygen demand (oxygen consumption by microorganisms) due to organic waste (algae biomass, detritus, etc.) and high summer water temperatures (decreased DO saturation). Most of the DO reading recorded in OR and GLC occurred during specific periods when water temperatures were highest and algae biomass was declining, possibly indicating an algae die-off (also indicted by high pheophytin *a* concentrations). DO concentrations at MR at Howard Road were also likely influenced by algae die-offs upstream. The possible reason why there were not many observed DO readings below 5.0 mg/L during the spring bloom was that average water temperature in the spring is about 5 ºC to 10 ºC cooler (increased DO saturation).

The upstream monitoring sites (OR near Head, MR at Undine Road, and Doughty Cut above GLC) did not have as many DO reading below 5 mg/L because these locations had the highest estimated algae biomass. The supersaturated conditions observed at these sites kept DO concentrations well above 5 mg/L. DO concentrations at the downstream sites (Victoria Canal, MR at Union Point, MR near Tracy Road) were likely influenced predominantly by water temperature. These sites had lower DO concentrations in the summer when water temperatures were warm, but had only 3 combined readings below 5 mg/L.

Most of the observed pH concentrations greater than 9.0 were recorded at 3 locations: OR near Head, MR at Undine Road, and Doughty Cut above GLC. pH values were highest during the summer when water temperatures were warm and there was an algae bloom observed at these sites. The high pH values observed at these locations are likely a direct function of algal photosynthesis; as algae consume CO_2 from water they produce DO as a byproduct of photosynthesis. Less CO_2 in the water drives the pH higher (decrease in carbonic acid), which results in the water becoming more alkaline. Downstream stations with the least algae biomass, such as Victoria Canal and MR at Union Point, had the fewest number of measured pH concentrations greater than 9.0.

In general, turbidity at all 13 sites was lower from mid-winter through early spring and in fall, and higher during mid-spring through summer. Turbidity readings during the summer were higher partly because of increased primary productivity (algae biomass), low San Joaquin River flows, and agricultural pumping and return flows. The farthest sites downstream (Victoria Canal, MR at Union Point, and GLC near OR) had the lowest turbidity readings during most of the year. High water clarity at these sites during the late spring through early fall may be attributed in part to lower algae biomass.

Data collected in 2007 elucidated trends in water temperature, DO, pH, specific conductance, turbidity, and chlorophyll *a* in the South Delta. Further research on the dynamic conditions and variables influencing these constituents will need to be studied before any definitive conclusions can be made; however, some trends are readily apparent. The areas near the OR and GLC barriers and at MR at Howard Road had the lowest DO concentrations in 2007, with numerous values in the summer below 5.0 mg/L. Additional monitoring and analysis is imperative to determining the relationships between DO concentrations and factors such as algae biomass, biological oxygen demand, and flow. Specific conductivity at OR at TWA was the highest throughout most of the year in the South Delta. A monitoring station should be added to Sugar Cut to discern if this area along with Paradise Cut is influencing downstream specific conductance values at OR at Tracy Road and OR at TWA. Monitoring will continue in 2008 at all 13 stations to supplement the existing time-series record and provide historical data for the South Delta.

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Chapter 9. Hydrologic Modeling

This chapter describes the details of the simulation of historical 2007 Delta hydrodynamic conditions as requested by the Temporary Barriers and Lower San Joaquin Section in California Department of Water Resources's Bay-Delta Office. The period of simulation is from January 1, 2007, to December 31, 2007.

To simulate the hydrodynamics, the Delta Modeling Section used DSM2-Hydro which is a one-dimensional open channel unsteady flow model based on a 4-point finite difference solution of equations of momentum and continuity. The solution scheme has proven to be stable. The model network extends north to Sacramento River at I street, south to San Joaquin River at Vernalis, and west to Martinez where a 15-minute time history of stage input governs how the tide signal propagates into the Delta.

Boundary Conditions

Flow and stage information required at model boundaries were downloaded from the Interagency Ecological Program Web site (www.water.ca.gov) and from the California Data Exchange Center Web site (http://cdec.water.ca.gov/). The IEP database includes data collected by various agencies, including DWR and US Geological Survey. When duplicate data from more than one agency was available, they were assigned a priority order. As the first option, DSM2 uses data ranked at the highest priority, and then proceeds to those of lower priority if necessary. Priority was assigned based on data availability, quality of the data, and past experience. Input data, visually examined using plotting routines, was occasionally missing. In most cases, alternate sources of data filled any gaps.

Resulting key boundary conditions for 2007 are shown in Figures 9-1 through 9-4.

Figure 9-1. Daily average historical inflow from the Sacramento River, 2007

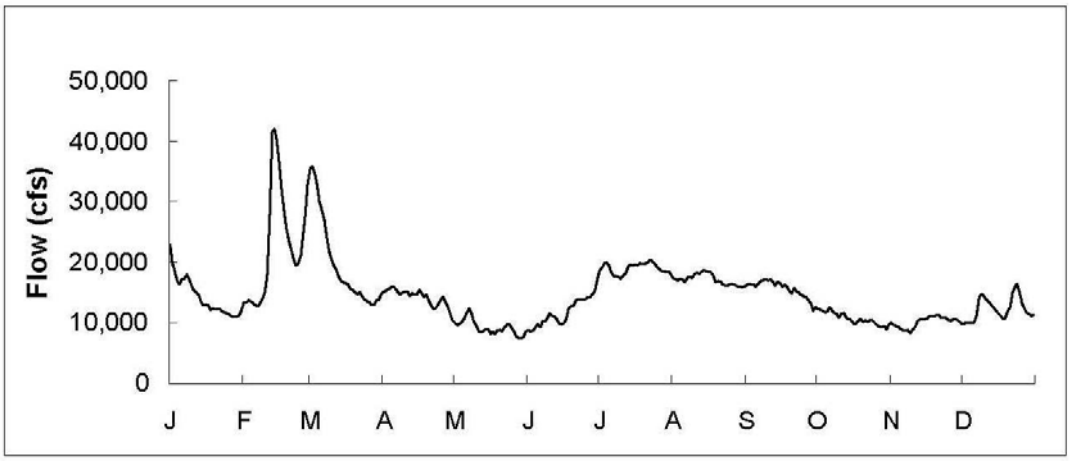


Figure 9-2. Daily average historical inflow from the Yolo Bypass, 2007

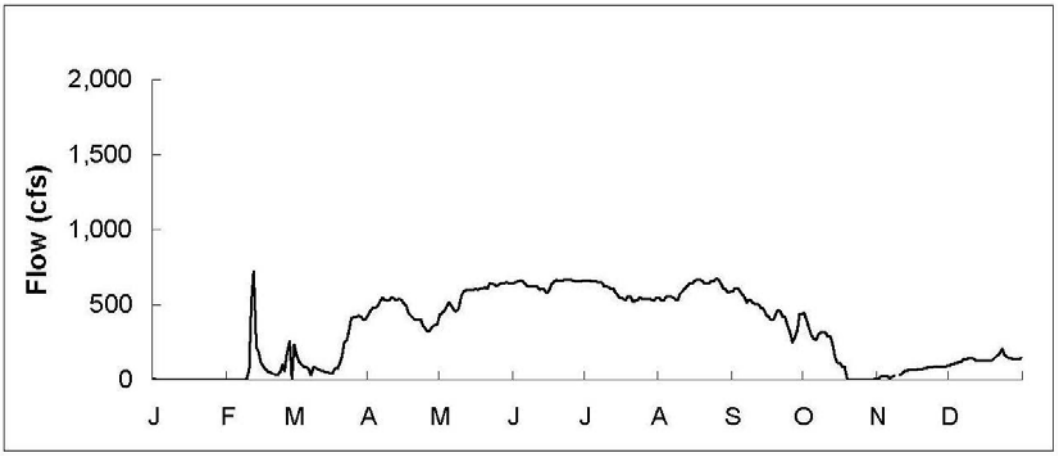


Figure 9-3. Daily average historical inflow from the San Joaquin River, 2007

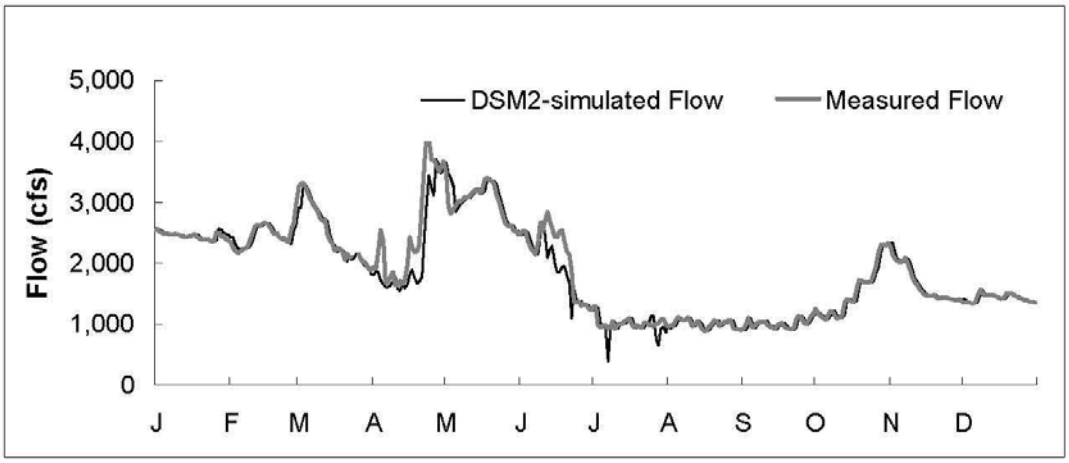
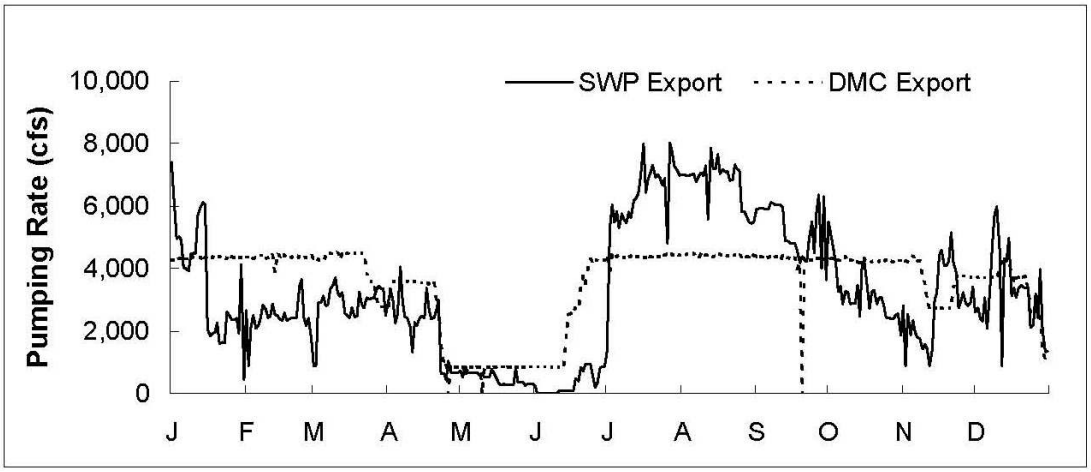


Figure 9-4. Daily average historical pumping at Banks and Delta Pumping plants, 2007



Consumptive use

The Delta Island Consumptive Use (DICU) model provided an estimate of the amount of water diverted from and returned to Delta channels due to agricultural activities. Input to DICU model includes precipitation, pan evaporation data, and water year types. The water year type determines which of 2 possible cropping patterns in the Delta is assumed, which in turn contributes to the estimation of agricultural water needs.

Delta Structures

All three temporary agricultural barriers and the spring and fall head of Old River barriers were installed in 2007. The fall barrier at the head of Old River varied from the spring barrier by being notched at 0.0 mean sea level. Although 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 and times, as inferred from 15-minute observed water levels. Table 9-1 describes the historical operation of all the South Delta Barriers.

The Delta Cross Channel gates were operated in 2007 as shown on Table 9-2.

Table 9-1. Historical south Delta barriers installation and removal, 2007

Barrier	Installation		Removal	
	Started*	Ended*	Started*	Ended*
Middle River	4/10/07	4/10/07	11/20/07	11/20/07
Old River near Delta Mendota Canal	4/18/07	4/18/07	11/7/07	11/7/07
Grant Line Canal	5/10/07	5/10/07	11/8/07	11/8/07
Old River @ Head (spring)	4/20/07	4/20/07	5/22/07	5/22/07
Old River @ Head (fall)	10/17/07	10/17/07	11/10/07	11/10/07

* As reported by Temporary Barriers Program, DWR

Table 9-2. Historical Delta Cross Channel operation for 2007

	Time interval			
Date	Time	Date	Time	Status
5/25/2007	0949	5/30/2007	1240	open
5/30/2007	1240	6/2/2007	0825	closed
6/2/2007	0825	6/5/2007	1045	open
6/5/2007	1045	6/9/2007	0830	closed
6/9/2007	0830	6/11/2007	0830	open
6/11/2007	0830	6/16/2007	0855	closed
6/16/2007	0855	12/14/2007	1138	open
12/14/2007	1138	12/31/2007	2400	closed

Discussion

Figure 9-5 shows the south delta locations where flow and stage are simulated. Figure 9-6 shows daily maximum and minimum stage model output along with those measured in the field at locations throughout the south Delta. Results for SJL (San Joaquin River below the head of Old River) clearly show the effect of the head of Old River barrier during the VAMP period. With the head of Old River, the values drop somewhat, but remain at elevated levels until the temporary agriculture barriers are removed. Results for the interior South Delta locations (those upstream of the temporary barriers) clearly show the effect of the barriers through the higher water levels. Results for the remaining locations downstream of the temporary barriers show that barriers seem to have little effect (as expected) on the water levels.

Figure 9-7 shows daily maximum, average and minimum flow output for DSM2 along with those measured in the field at locations throughout South Delta. Once again the effect of the head of Old River barrier at the SJL (San Joaquin River downstream of the head of Old River) during the VAMP period is very obvious as shown with higher flows during this period. In fact, during the VAMP period is the only time the flow at this location, is unidirectional (i.e. no reverse flow). At all other times, the flow at this location shows the sign of reversal. Interestingly, the flow output for the head of Old River (ROLD074) indicates that the model is underestimating the flow during the VAMP period. At this period, the flow can either go through the culverts or through the rocks. Perhaps in the future, the flow coefficient corresponding the weir flow can be adjusted to represent the leaky nature of the rock barriers. The flow output for the Old River near the barrier (ROLD047), clearly illustrates the strong dampening effect of the agricultural barriers. At all the remaining locations (RSAN063, ROLD024, ROLD34, MDM), there is a very good agreement between the model results at field data.

Figure 9-5. Locations where simulated Delta stages and flows for 2007 are presented

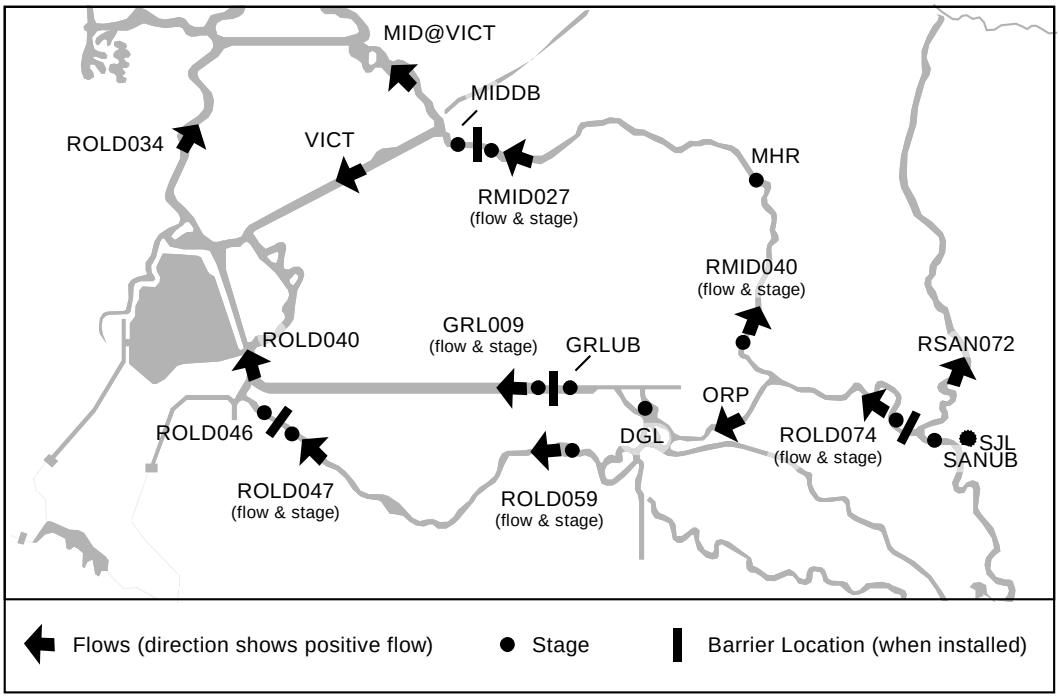


Figure 9-6. Comparison of stage between model results and measured Data during 2007

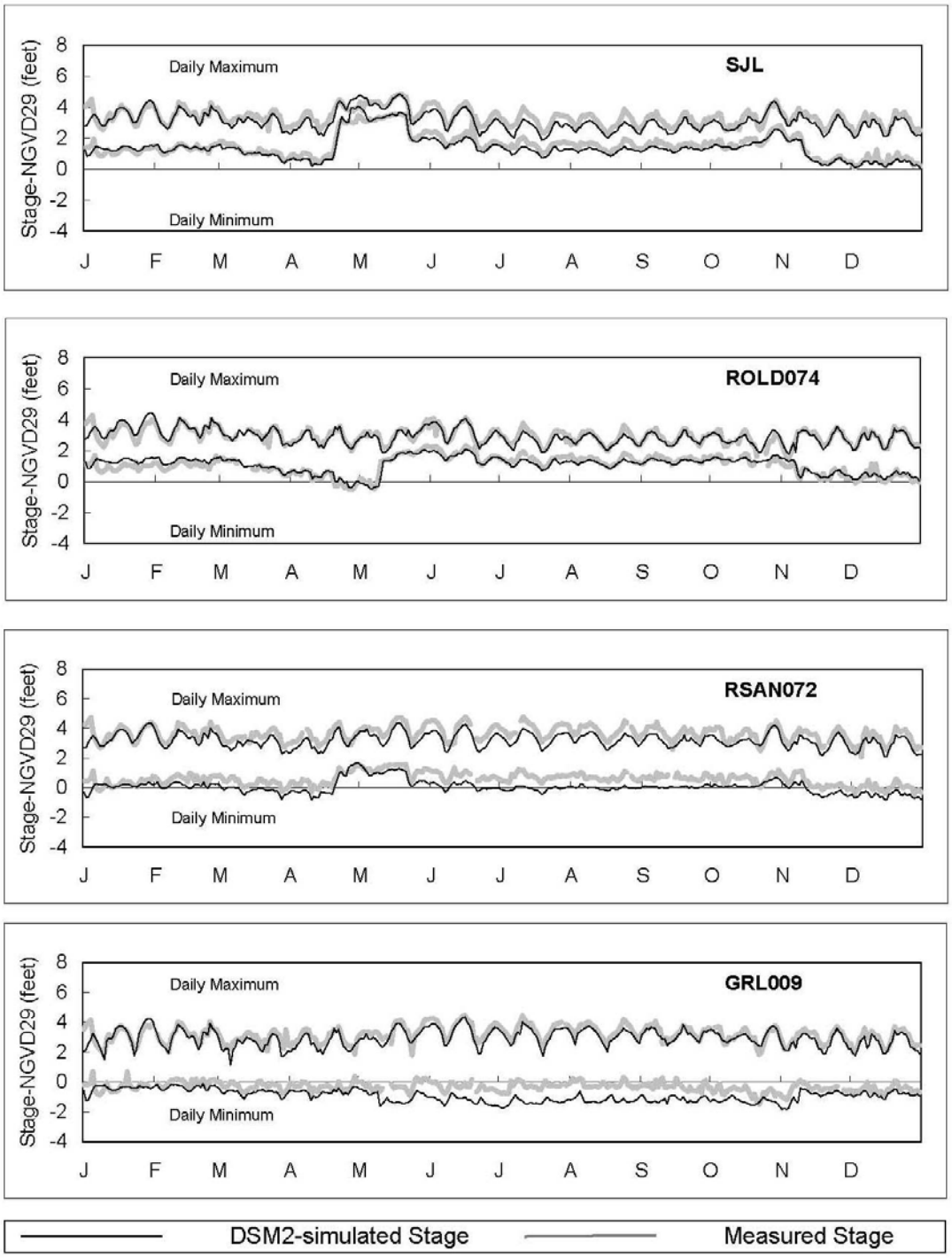


Figure 9-6 (cont.). Comparison of stage between model results and measured data during 2007

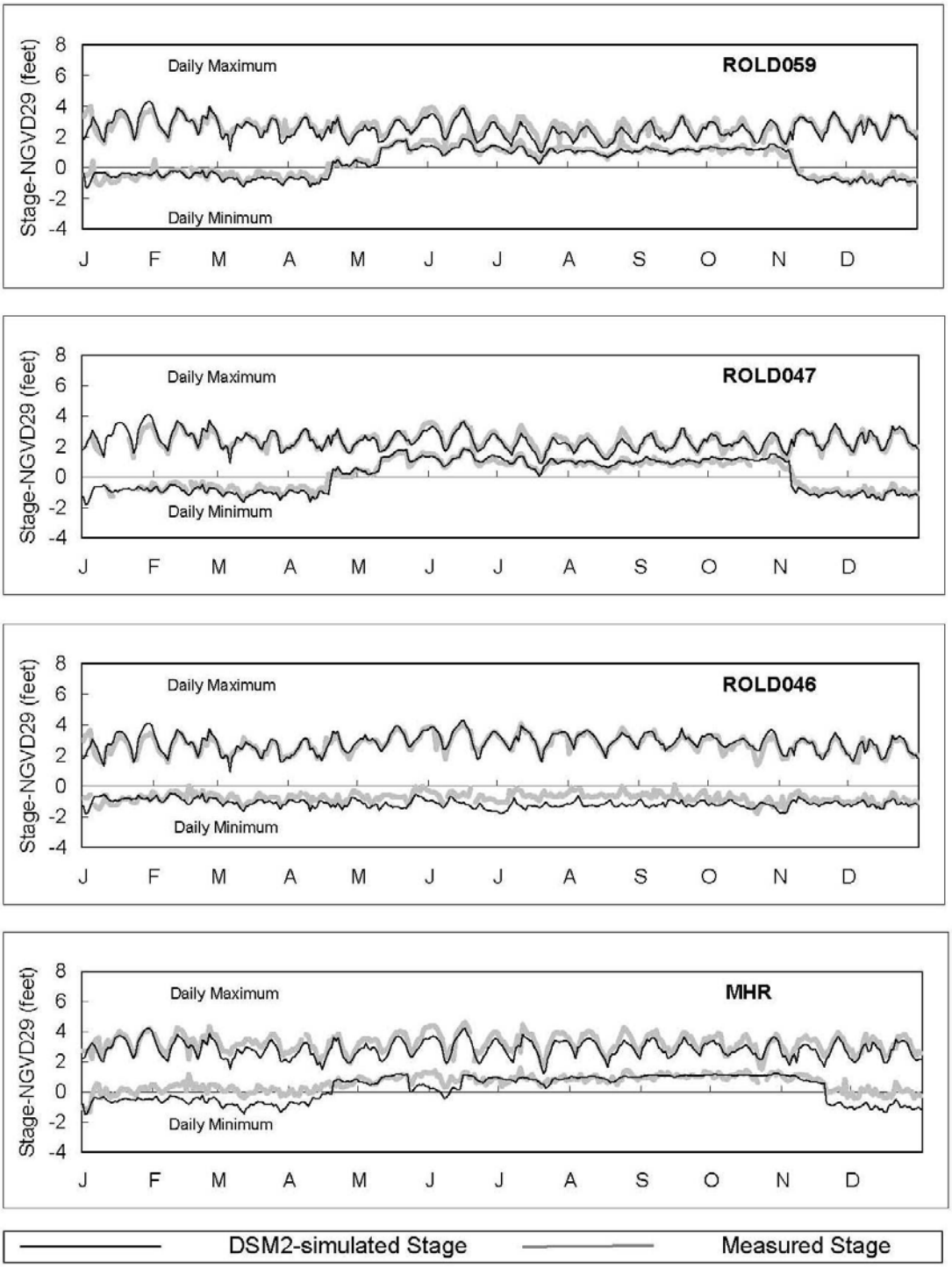


Figure 9-6 (cont.). Comparison of stage between model results and measured data during 2007

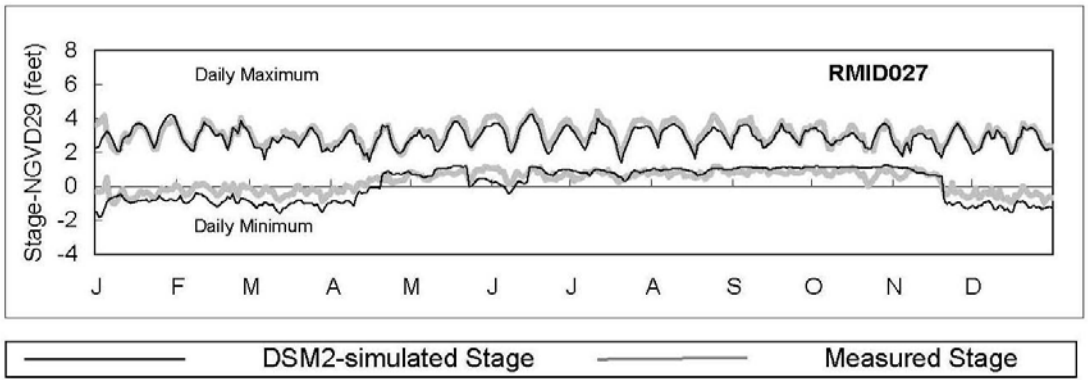


Figure 9-7. Comparison of flow between model results and measured data during 2007

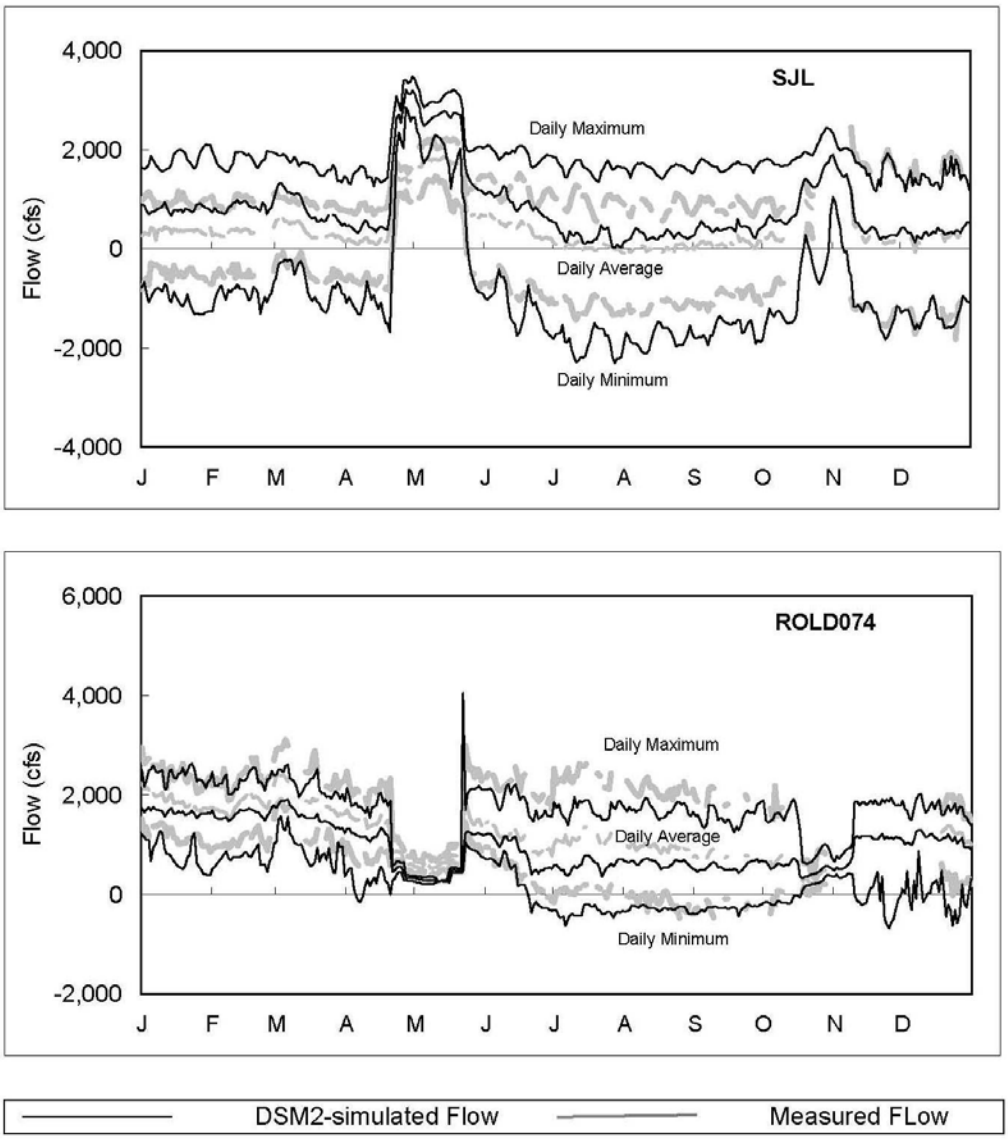


Figure 9-7 (cont.). Comparison of flow between model results and measured data during 2007

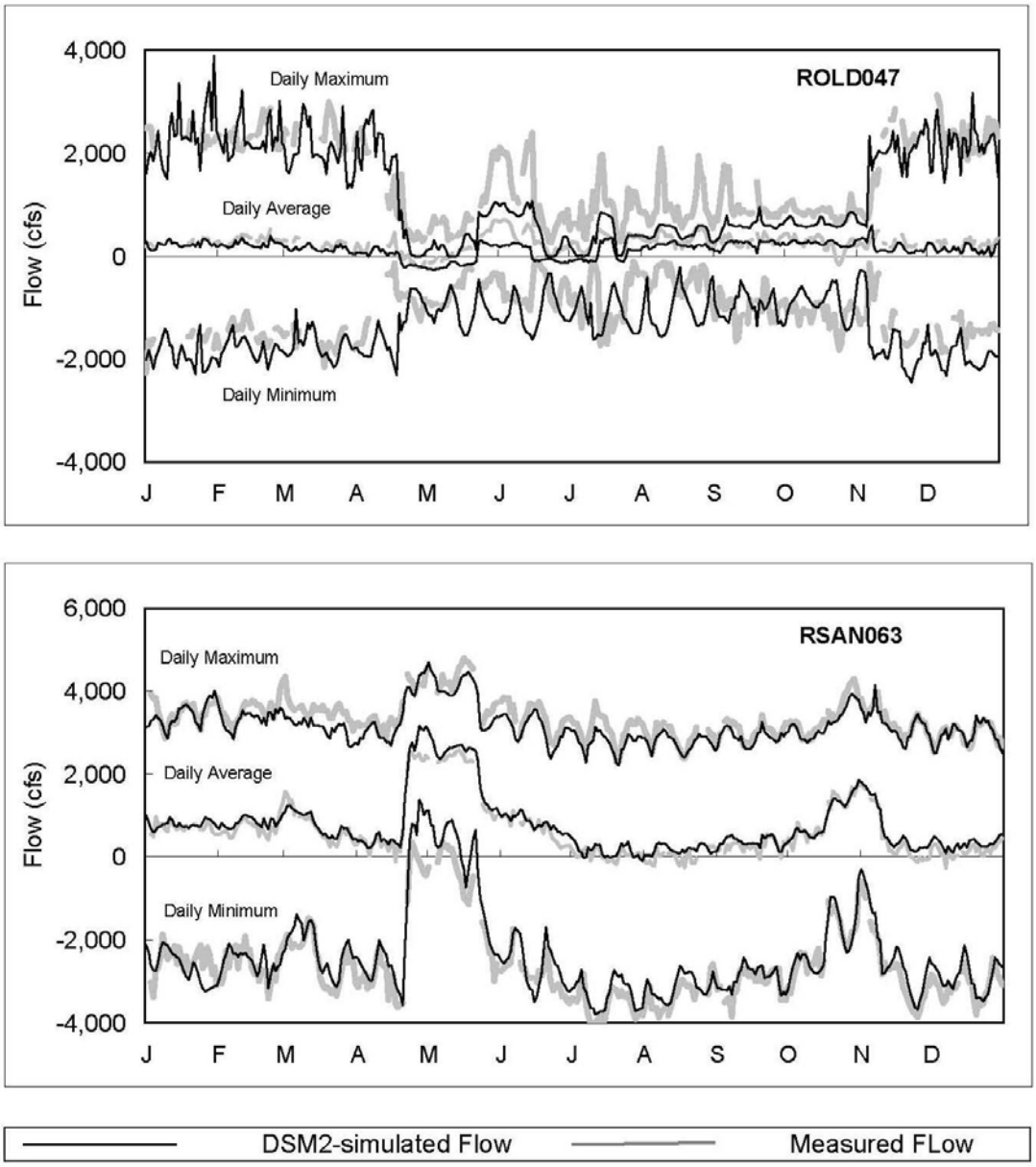


Figure 9-7 (cont.). Comparison of flow between model results and measured data during 2007

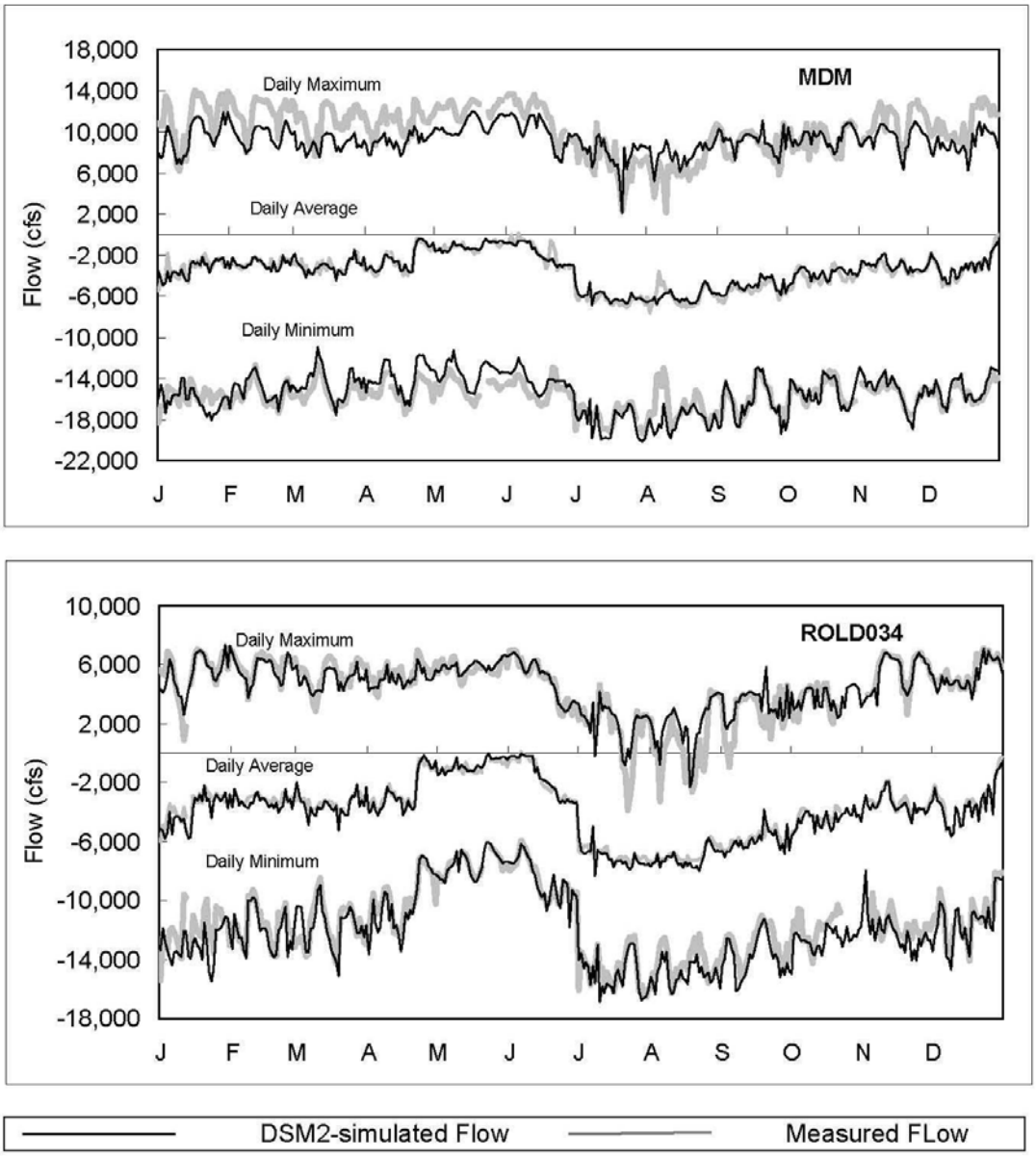
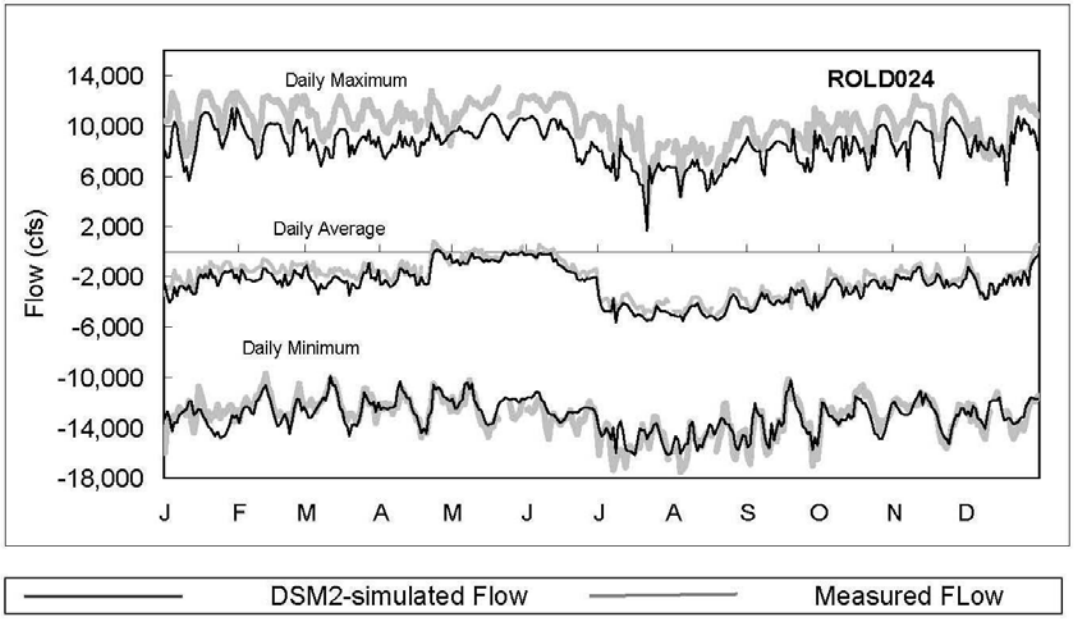
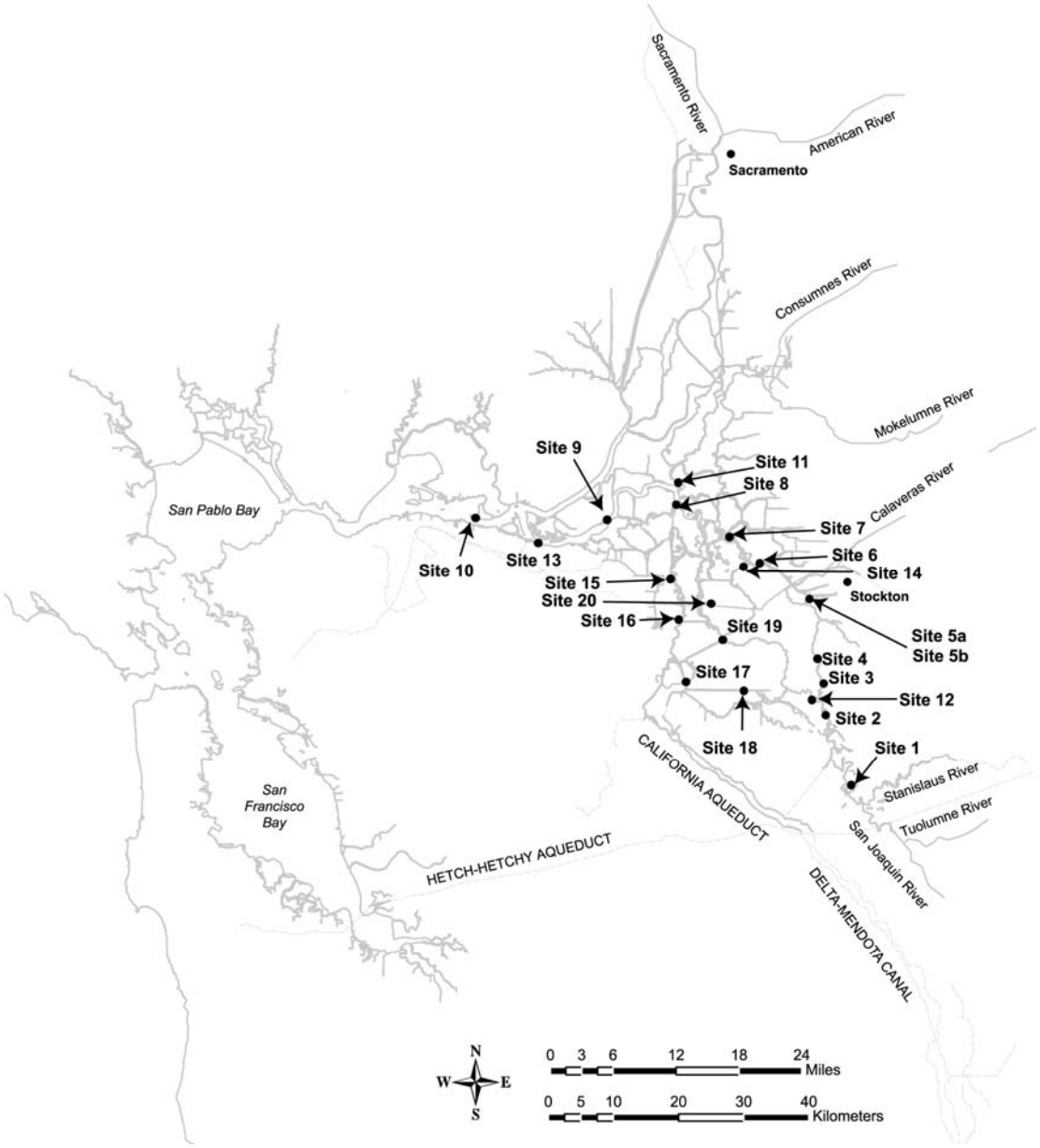


Figure 9-7 (cont.). Comparison of flow between model results and measured data during 2007



Appendix A. Chinook Salmon Survival Investigations

Appendix A-1. Water temperature monitoring locations (map)

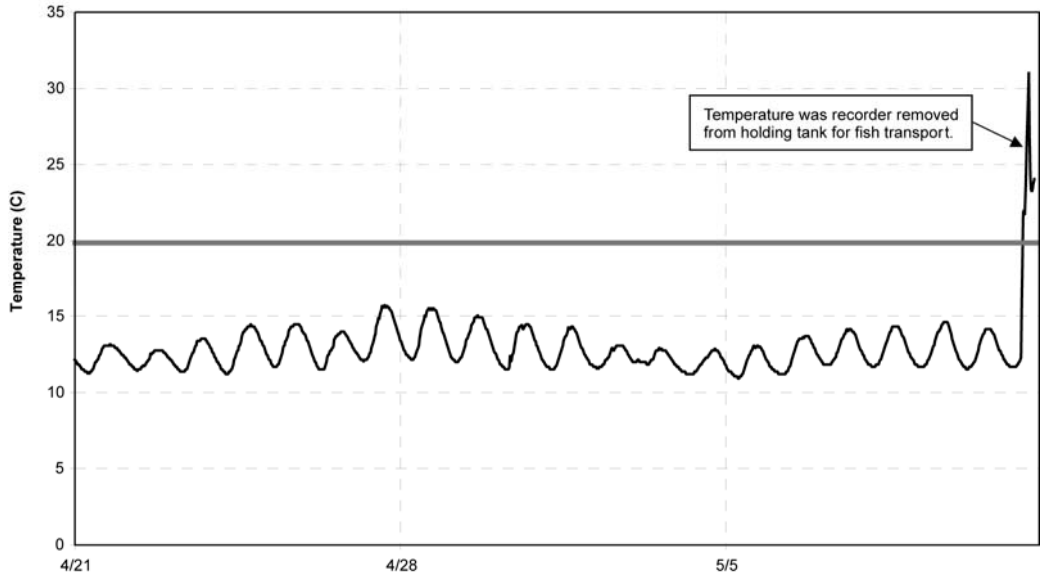


Appendix A-1. VAMP 2007 water temperature monitoring (table)

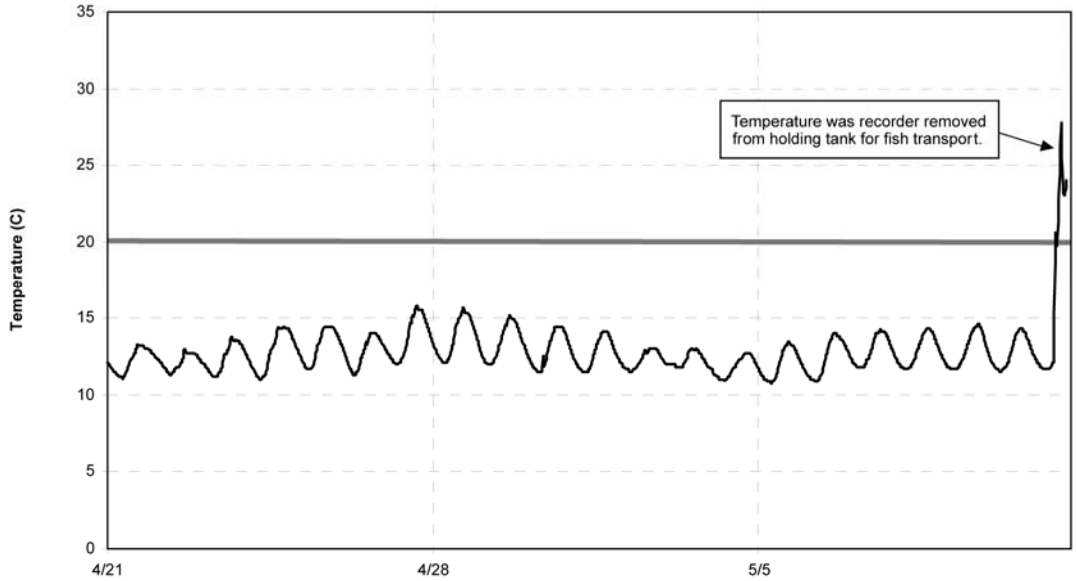
Site #	Logger number	Temperature Monitoring Location	Lat	Long	Distance from Durham Ferry	Date Deployed	Date Retrieved	Notes
n/a	900618	Hatchery 1	n/a	n/a	n/a	4/6/07		
n/a	877664	Hatchery 2	n/a	n/a	n/a	4/6/07		
n/a	900619	Hatchery 3	n/a	n/a	n/a	4/6/07		
n/a	900620	Hatchery 4	n/a	n/a	n/a	4/6/07		
1	900616	Durham Ferry	N 37 41.381	W 121 15.657	0	4/3/07	7/19/07	Near intake pump on tree at water line
2	877665	Mossdale	N 37 47.180	W 121 18.425	11	4/3/07	Missing	Under bridge on cable
3	900625	Old River at HORB	N 37 48.457	W 121 19.872	14	4/3/07	7/19/07	On tree near flagging across from intake pump
4	900617	Dos Reis	N 37 49.808	W 121 18.665	16	4/3/07	7/19/07	On tree normally used across from launch ramp
5	877669	DWR Monitoring Station	N 37 51.869	W 121 19.376	19	4/3/07	Missing	As normal
6a	900615	Confluence – Top	N 37 56.818	W 121 20.285	27	4/3/07	Missing	As normal
6b	626431	Confluence- bottom	N 37 56.818	W 121 20.285	27	4/3/07	Missing	As normal
7	626437	Downstream of Channel Marker 30	N 37 59.776	W 121 25.569	33	4/3/07	Missing	As normal
8	877666	Turner Cut	N 37 59.468	w121 27.267	35	4/3/07	Missing	On USGS gaging station
9	900622	“Q” Piling 1/2 mile upstream of channel marker 13	N 38 01.940	W 121 28.769	37	4/3/07	Missing	As normal
10	900624	All Pro abandoned boat	N 38 04.522	W 121 34.413	45	4/3/07	Missing	As normal
11	551654	Jersey Point USGS Gauging Station	N 38 03.172	W 121 41.637	56	4/3/07	Missing	As normal
12	562570	Antioch Marina	N 38 01.147	W 121 48.829	64	4/3/07	Missing	On pilings across channel from marina upstream
13	551657	Chipps Island	N 38 03.084	W 121 55.463	72	4/3/07	Missing	As normal
14	562563	Holland Riverside Marina	N 37 58.323	W 121 34.887	South Delta	4/2/07	Missing	On “No Wake” sign
15	900623	Old River / Indian Slough Confluence	N 37 54.954	W 121 33.949	South Delta	4/2/07	7/13/07	On “Indian Slough” sign
16	877663	CCF Radial Gates	N 37 49.773	W 121 33.096	South Delta	4/2/07	Missing	On DWR gaging station near intake gates
17	900626	Grant Line Canal at Travy Blvd Bridge	N 37 49.143	W 121 27.026	South Delta	4/2/07	Missing	Under bridge near repairs
18	540810	Middle River at Victoria Canal Confluence	N37 53.323	W 121 29.334	South Delta	4/2/07	Missing	On Staff gage
19	877668	Werner Cut: Channel above Woodward Isle	N 37 56.319	W 121 30.584	South Delta	4/2/07	7/13/07	On old pilings

Total Loggers: 24 - Set to record every 24 mins (132 days)

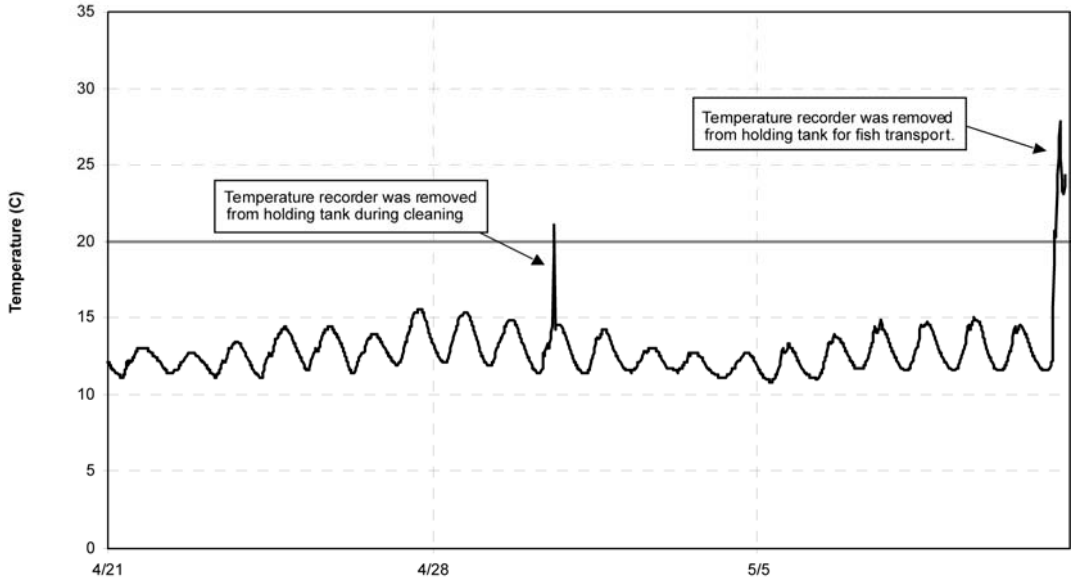
Appendix A-2. Water temperature in holding tank, Hatchery 1 (figure)



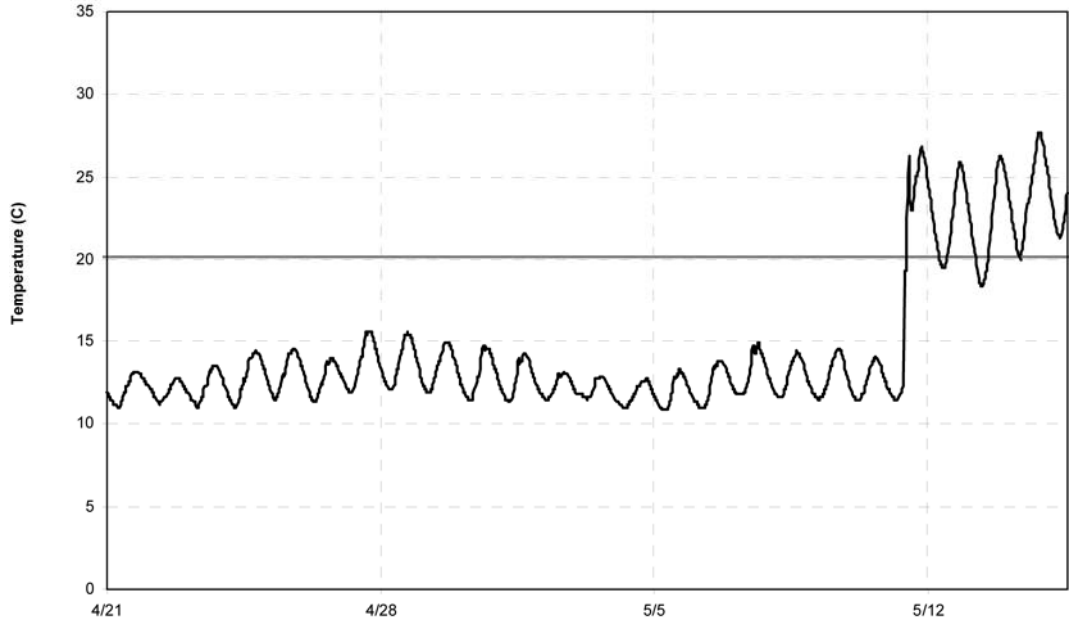
Appendix A-2. Water temperature in holding tank, Hatchery 2 (figure)



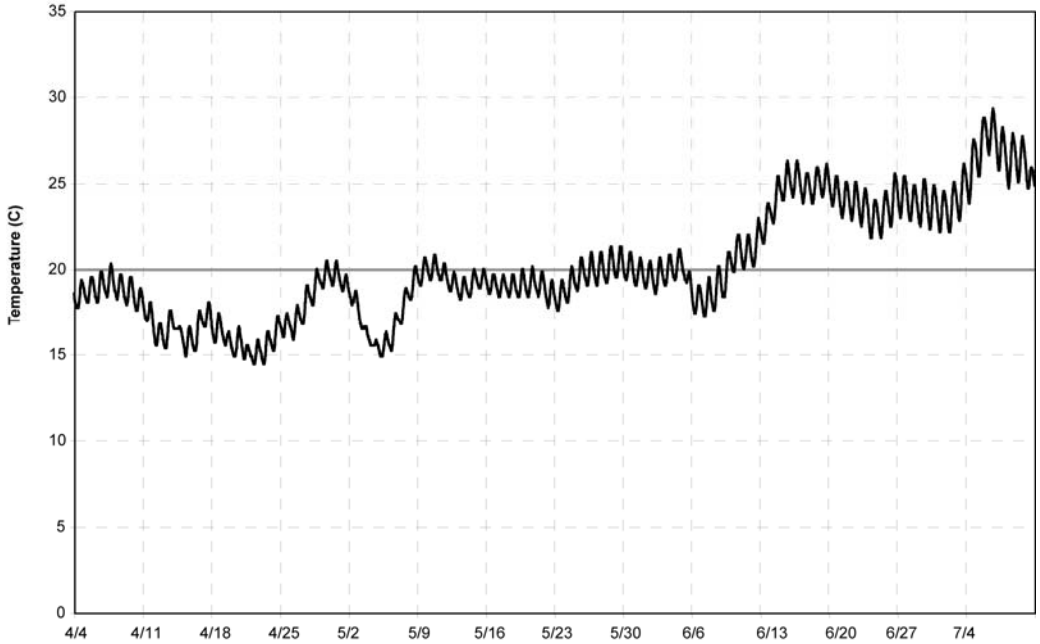
Appendix A-2. Water temperature in holding tank, Hatchery 3 (figure)



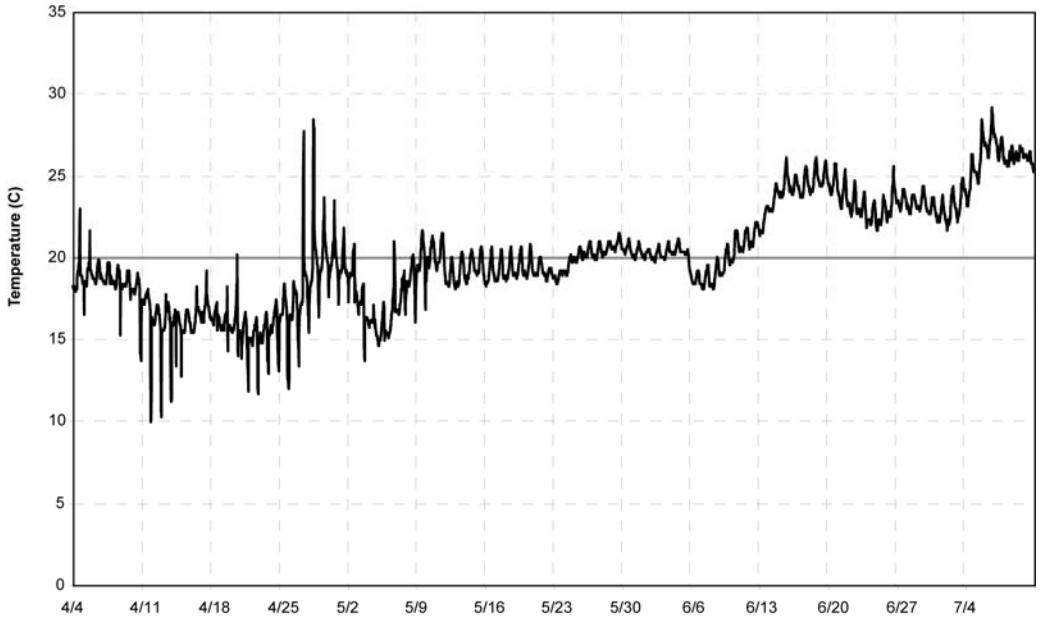
Appendix A-2. Water temperature in holding tank, Hatchery 4 (figure)



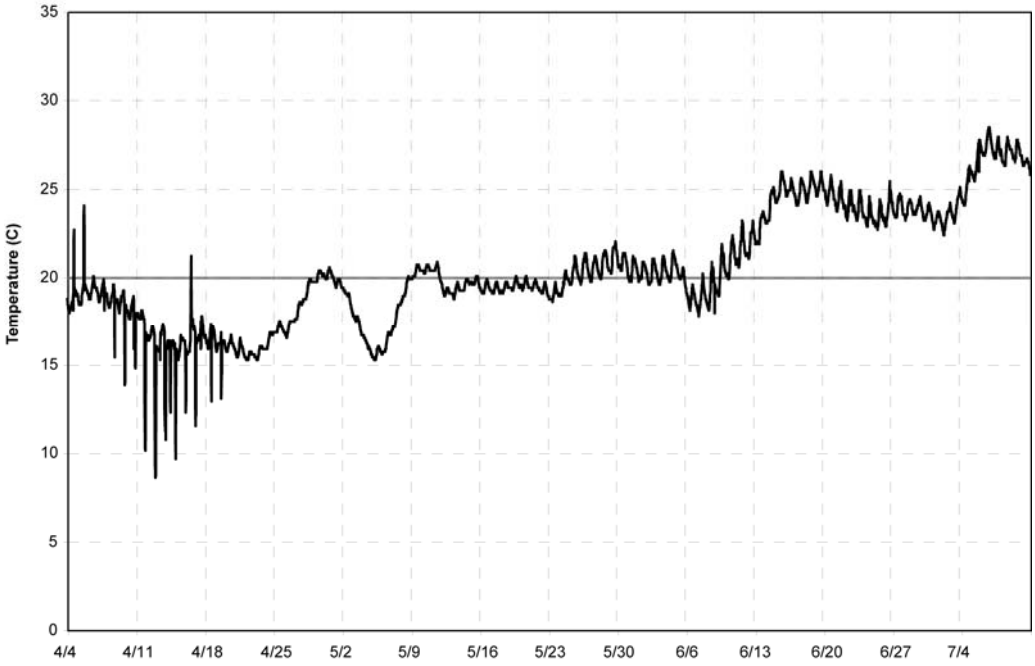
Appendix A-2. Water temperature, Durham Ferry (figure)



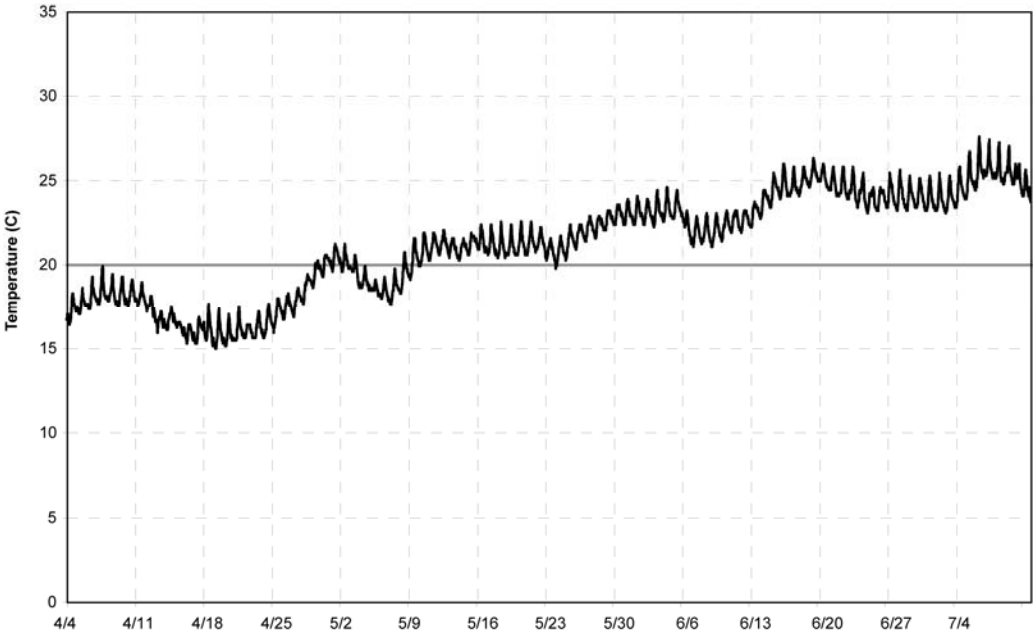
Appendix A-2. Water temperature, Old River at HORB (figure)



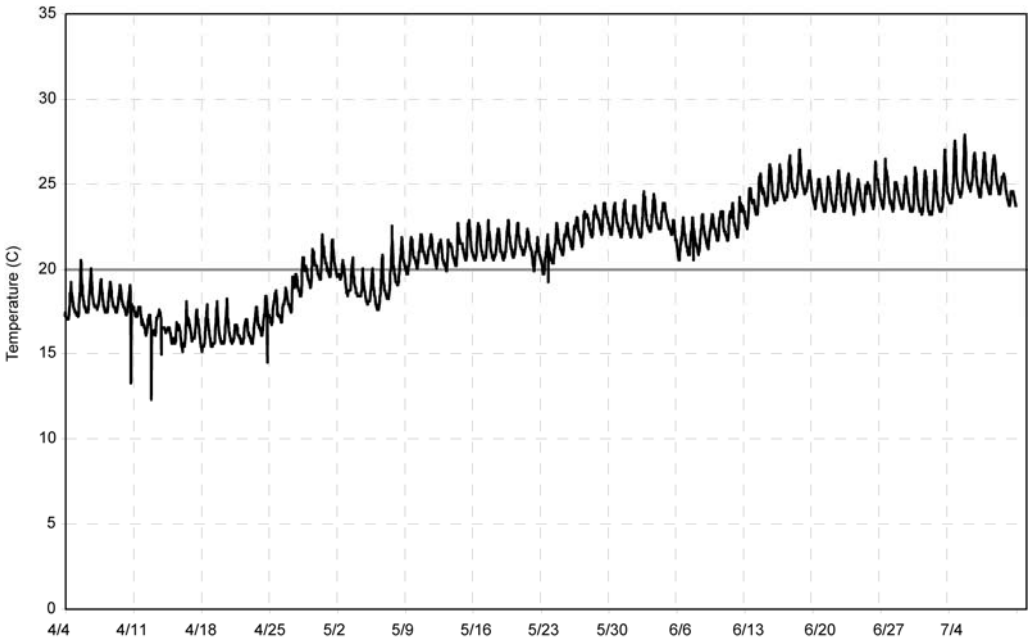
Appendix A-2. Water temperature, Dos Reis (figure)



Appendix A-2. Water temperature, Old River/Indian Slough confluence (figure)



Appendix A-2. Water temperature, Werner Cut-Channel above Woodward Isle (figure)



Appendix A-3. Chinook salmon smolt condition 48-hours post-release (table)

CWT codes	Exam. Date	n	Min FL	Max FL	Mean FL	River Temp C	Truck Temp C	Delivery Time	Fish released	Min Scale Loss	Max Scale Loss	Mean Scale Loss	Color (% norm.)	Fin hemor-rhaging (% none)	Eyes (% norm.)	Gill color (% norm.)	Partial ad clips (number)	Missing ad clips (number)	Mortalities	comments or other abnormal-ities
acoustic tagged	5/5/07	10	104	113	109	11.0	17.0	10:30	11:30	1.0	3.0	2.2	100	100	100	100	0	0	0	
acoustic tagged	5/5/07	10	105	111	109.0	13.0	17.0	12:00	13:00	1.0	4.0	2.0	100	100	100	100	0	0	0	
acoustic tagged	5/14/07	10	103	113	110.0			11:15		1.0	6.0	2.7	100	100	100	96	0	0	0	mortality; scale loss
acoustic tagged	5/12/07	20	103	126	113.0	11.0	19.0	10:45	11:40	1.0	6.0	3.3	100	100.0	100.0	100.0	0.0	0.0	0	
acoustic tagged	5/12/07	20	107	122	112.8	11.5	21.0	11:30	12:30	1.0	7.0	2.1	100	100.0	100.0	100.0	0.0	0.0	0	
acoustic tagged	5/14/07	10	109	119	113.8			12:15		1.0	5.0	2.6	100	100.0	100.0	100.0	0.0	0.0	0	

Appendix A-4. Detections of acoustic-tagged salmon from May 3 & 4 releases upstream of the Head of Old River Barrier (table)

Release Dates: May 3 and May 4, 2007 Relase Locations: Durham Ferry, Mossdale, Bowman Road, Stockton

Release Date	Release Time	Release Site	Tag Code	Upstream of HORB Date/Time	Bowman Road Date/Time	Stockton Date/Time	Turner cut Date/Time	R16 Date/Time	Mobile Monitoring Near Stockton Date/Comment	Other Locations Date/Comment
5/3/2007	11:30	Durham Ferry	3000	5/4/2007 9:51	5/4/2007 16:54			5/16/2007 2:14		
5/3/2007	11:30	Durham Ferry	3007	5/4/2007 10:13	5/5/2007 20:03					
5/3/2007	11:30	Durham Ferry	3014	5/4/2007 10:18	5/4/2007 15:01	5/4/2007 19:41				
5/3/2007	11:30	Durham Ferry	3021	5/4/2007 7:50	5/4/2007 14:49			5/8/2007 14:56	5/17-18,Tag Not Moving	
5/3/2007	11:30	Durham Ferry	3035	5/4/2007 4:03	5/4/2007 10:53	5/5/2007 21:14				
5/3/2007	11:30	Durham Ferry	3042						5/17-18,Tag Not Moving	
5/3/2007	11:30	Durham Ferry	3049	5/4/2007 10:14	5/4/2007 15:41	5/4/2007 22:29			5/17-18,Tag Not Moving	
5/3/2007	11:30	Durham Ferry	3056	5/6/2007 12:00	5/7/2007 0:43	5/7/2007 11:13		5/10/2007 19:40	5/17-18,Tag Not Moving	
5/3/2007	11:30	Durham Ferry	3077	5/4/2007 8:30	5/4/2007 13:04	5/4/2007 16:48				
5/3/2007	11:30	Durham Ferry	3084	5/4/2007 4:04	5/4/2007 17:01					
5/3/2007	11:30	Durham Ferry	3091	5/4/2007 8:58	5/4/2007 14:37		5/7/2007 7:49			
5/3/2007	11:30	Durham Ferry	3098	5/4/2007 12:01	5/4/2007 17:29				5/17-18,Tag Not Moving	
5/3/2007	11:30	Durham Ferry	3105	5/4/2007 4:42	5/4/2007 13:22					
5/3/2007	11:30	Durham Ferry	3112	5/4/2007 13:15	5/4/2007 17:10					
5/3/2007	11:30	Durham Ferry	3119	5/4/2007 0:34	5/4/2007 5:19					
5/3/2007	11:30	Durham Ferry	3126	5/4/2007 4:08					5/17-18,Tag Not Moving	
5/3/2007	11:30	Durham Ferry	3133	5/4/2007 13:25	5/4/2007 18:12	5/5/2007 22:23			5/17-18,Tag Not Moving	
5/3/2007	11:30	Durham Ferry	3140						5/17-18,Tag Not Moving	
5/3/2007	11:30	Durham Ferry	3147	5/4/2007 4:34	5/4/2007 13:16					
5/3/2007	11:30	Durham Ferry	3154	5/4/2007 12:49	5/4/2007 17:25	5/5/2007 9:06		5/8/2007 18:59	5/17-18,Tag Not Moving	
5/3/2007	11:30	Durham Ferry	3182	5/4/2007 2:16	5/4/2007 10:20	5/4/2007 14:47				
5/3/2007	11:30	Durham Ferry	3189	5/4/2007 4:51	5/4/2007 11:54					
5/3/2007	11:30	Durham Ferry	3196	5/4/2007 14:14	5/5/2007 8:02	5/5/2007 13:22	5/8/2007 6:28		5/17-18,Tag Not Moving	
5/3/2007	11:30	Durham Ferry	3203	5/6/2007 17:37	5/7/2007 11:16	5/7/2007 16:36			5/17-18,Tag Not Moving	
5/3/2007	11:30	Durham Ferry	3210	5/4/2007 6:25	5/4/2007 12:24	5/4/2007 15:28				
5/3/2007	11:30	Durham Ferry	3217	5/4/2007 13:00	5/4/2007 17:27					
5/3/2007	11:30	Durham Ferry	3231	5/4/2007 10:55	5/4/2007 16:00					
5/3/2007	11:30	Durham Ferry	3238	5/4/2007 15:46	5/4/2007 23:13					
5/3/2007	11:30	Durham Ferry	3245	5/4/2007 11:36	5/4/2007 18:00					
5/3/2007	11:30	Durham Ferry	3252	5/4/2007 21:20	5/5/2007 10:27					
5/3/2007	11:30	Durham Ferry	3259	5/4/2007 13:51	5/4/2007 18:18					
5/3/2007	11:30	Durham Ferry	3266	5/4/2007 6:00	5/4/2007 13:37	5/4/2007 17:38				
5/3/2007	11:30	Durham Ferry	3280	5/4/2007 12:30	5/4/2007 16:25					
5/3/2007	11:30	Durham Ferry	3287	5/4/2007 14:23						
5/3/2007	11:30	Durham Ferry	3294	5/4/2007 13:54	5/4/2007 18:20					5/8/07, CCFB
5/3/2007	11:30	Durham Ferry	3301	5/5/2007 10:29	5/5/2007 15:51			5/8/2007 16:49		
5/3/2007	11:30	Durham Ferry	3308	5/4/2007 14:39	5/4/2007 19:57	5/5/2007 18:38				
5/3/2007	11:30	Durham Ferry	3315	5/4/2007 8:08	5/4/2007 14:00	5/4/2007 18:17		5/9/2007 7:02		
5/3/2007	11:30	Durham Ferry	3322	5/4/2007 12:39	5/4/2007 16:21		5/6/2007 6:11			
5/3/2007	11:30	Durham Ferry	3350	5/4/2007 13:46	5/6/2007 10:38					
5/3/2007	11:30	Durham Ferry	3357	5/4/2007 11:43	5/4/2007 16:13					
5/3/2007	11:30	Durham Ferry	3378	5/4/2007 3:11	5/4/2007 11:09					
5/3/2007	11:30	Durham Ferry	3392	5/4/2007 1:01	5/4/2007 8:39					
5/3/2007	11:30	Durham Ferry	3399	5/4/2007 13:16	5/4/2007 18:16	5/5/2007 11:26		5/9/2007 9:01		
5/3/2007	11:30	Durham Ferry	3413	5/4/2007 8:15	5/4/2007 13:44					
5/3/2007	11:30	Durham Ferry	3427	5/4/2007 1:51	5/4/2007 10:01	5/4/2007 13:40	5/6/2007 8:41			
5/3/2007	11:30	Durham Ferry	3434	5/4/2007 3:47	5/4/2007 12:40	5/4/2007 19:11				

Appendix A-4 (cont.). Detections of acoustic-tagged salmon from May 3 & 4 releases upstream of the Head of Old River Barrier

Release Dates: May 3 and May 4, 2007 Relase Locations: Durham Ferry, Mossdale, Bowman Road, Stockton

Release Date	Release Time	Release Site	Tag Code	Upstream of HORB Date/Time	Bowman Road Date/Time	Stockton Date/Time	Turner cut Date/Time	R16 Date/Time	Mobile Monitoring Near Stockton Date/Comment	Other Locations Date/Comment
5/3/2007	11:30	Durham Ferry	3441						5/17-18,Tag Not Moving	
5/3/2007	11:30	Durham Ferry	3448	5/4/2007 11:57	5/4/2007 16:37			5/10/2007 12:39		
5/3/2007	11:30	Durham Ferry	3469	5/4/2007 12:50	5/4/2007 17:30	5/5/2007 11:39				
5/3/2007	11:30	Durham Ferry	3490	5/3/2007 23:43	5/4/2007 8:44					
5/3/2007	11:30	Durham Ferry	3497	5/4/2007 2:02	5/4/2007 9:09					
5/3/2007	11:30	Durham Ferry	3504	5/4/2007 5:52	5/4/2007 12:24					
5/3/2007	11:30	Durham Ferry	3511	5/4/2007 5:51	5/4/2007 12:33					
5/3/2007	11:30	Durham Ferry	3518	5/5/2007 0:20	5/5/2007 17:24	5/6/2007 0:56				
5/3/2007	11:30	Durham Ferry	3539	5/10/2007 8:01						
5/3/2007	11:30	Durham Ferry	3546	5/6/2007 0:14	5/6/2007 5:54					
5/3/2007	11:30	Durham Ferry	3553	5/4/2007 16:25	5/4/2007 21:50	5/5/2007 14:37		5/9/2007 15:24		
5/3/2007	11:30	Durham Ferry	3560	5/6/2007 7:12	5/6/2007 13:45					
5/3/2007	11:30	Durham Ferry	3567	5/4/2007 10:20	5/4/2007 14:36	5/4/2007 19:37				
5/3/2007	11:30	Durham Ferry	3574	5/4/2007 1:12	5/4/2007 9:04		5/6/2007 4:01			
5/3/2007	11:30	Durham Ferry	3602	5/5/2007 1:08	5/5/2007 8:55	5/5/2007 12:37				
5/3/2007	11:30	Durham Ferry	3616	5/4/2007 10:16	5/4/2007 14:36					
5/3/2007	11:30	Durham Ferry	3623	5/4/2007 19:47	5/5/2007 4:51					
5/3/2007	11:30	Durham Ferry	3637	5/4/2007 4:26	5/4/2007 12:34		5/6/2007 7:34			
5/3/2007	11:30	Durham Ferry	3651	5/4/2007 11:29	5/4/2007 16:07					
5/3/2007	11:30	Durham Ferry	3658	5/7/2007 7:54	5/7/2007 14:23	5/7/2007 17:26				
5/3/2007	11:30	Durham Ferry	3665	5/6/2007 12:25	5/6/2007 16:40	5/7/2007 9:31				
5/3/2007	11:30	Durham Ferry	3672	5/4/2007 10:12	5/4/2007 16:06					
5/3/2007	11:30	Durham Ferry	3679	5/4/2007 4:38	5/4/2007 17:17					
5/3/2007	11:30	Durham Ferry	3686	5/4/2007 5:32	5/4/2007 20:37					
5/3/2007	11:30	Durham Ferry	3693	5/5/2007 1:41	5/5/2007 10:37	5/5/2007 14:12				
5/3/2007	13:00	Mossdale	3700	5/3/2007 15:17	5/3/2007 22:08					
5/3/2007	13:00	Mossdale	3707	5/3/2007 18:26	5/4/2007 1:20					
5/3/2007	13:00	Mossdale	3714	5/3/2007 18:30	5/4/2007 1:16					
5/3/2007	13:00	Mossdale	3721	5/3/2007 15:58	5/4/2007 0:39					
5/3/2007	13:00	Mossdale	3728	5/3/2007 15:41	5/4/2007 0:20					
5/3/2007	13:00	Mossdale	3735	5/3/2007 15:27	5/3/2007 23:06			5/8/2007 15:36		
5/3/2007	13:00	Mossdale	3742	5/3/2007 18:05	5/5/2007 9:24	5/5/2007 13:20				
5/3/2007	13:00	Mossdale	3749	5/3/2007 15:00	5/3/2007 20:30					
5/3/2007	13:00	Mossdale	3756	5/3/2007 16:14	5/4/2007 10:06	5/4/2007 13:53				
5/3/2007	13:00	Mossdale	3763	5/3/2007 15:49	5/3/2007 22:21	5/4/2007 9:10				
5/3/2007	13:00	Mossdale	3770	5/3/2007 15:23	5/4/2007 7:09					
5/3/2007	13:00	Mossdale	3777	5/3/2007 15:27	5/3/2007 23:38	5/4/2007 9:52		5/8/2007 20:36		
5/3/2007	13:00	Mossdale	3784	5/3/2007 15:59	5/3/2007 23:40	5/4/2007 8:30				
5/3/2007	13:00	Mossdale	3791	5/3/2007 16:56	5/4/2007 9:31	5/4/2007 19:23				
5/3/2007	13:00	Mossdale	3798	5/3/2007 14:49	5/4/2007 0:29			5/9/2007 11:14		
5/3/2007	13:00	Mossdale	3805	5/3/2007 15:53	5/3/2007 22:49					
5/3/2007	13:00	Mossdale	3812	5/3/2007 16:22	5/4/2007 0:45	5/4/2007 11:52				
5/3/2007	13:00	Mossdale	3819	5/3/2007 15:51	5/4/2007 7:36					
5/3/2007	13:00	Mossdale	3826	5/3/2007 17:32						
5/3/2007	13:00	Mossdale	3833	5/3/2007 16:12	5/4/2007 9:42					
5/3/2007	13:00	Mossdale	3840	5/3/2007 23:09	5/4/2007 13:25	5/5/2007 13:06				
5/3/2007	13:00	Mossdale	3847	5/3/2007 16:00	5/3/2007 23:18					

Appendix A-4 (cont.). Detections of acoustic-tagged salmon from May 3 & 4 releases upstream of the Head of Old River Barrier

Release Dates: May 3 and May 4, 2007 Relase Locations: Durham Ferry, Mossdale, Bowman Road, Stockton

Release Date	Release Time	Release Site	Tag Code	Upstream of HORB Date/Time	Bowman Road Date/Time	Stockton Date/Time	Turner cut Date/Time	R16 Date/Time	Mobile Monitoring Near Stockton Date/Comment	Other Locations Date/Comment
5/3/2007	13:00	Mossdale	3854	5/3/2007 16:10	5/3/2007 23:36	5/4/2007 8:55				
5/3/2007	13:00	Mossdale	3861	5/3/2007 15:50	5/3/2007 22:27					
5/3/2007	13:00	Mossdale	3868	5/3/2007 15:44	5/3/2007 21:04	5/4/2007 9:24				
5/3/2007	13:00	Mossdale	3875	5/3/2007 16:11	5/4/2007 6:20	5/4/2007 13:34				
5/3/2007	13:00	Mossdale	3882	5/3/2007 15:27						
5/3/2007	13:00	Mossdale	3889	5/3/2007 17:00	5/3/2007 23:27					
5/3/2007	13:00	Mossdale	3896	5/3/2007 15:57	5/3/2007 22:25	5/4/2007 8:53				
5/3/2007	13:00	Mossdale	3903	5/3/2007 15:03	5/3/2007 22:41	5/4/2007 10:58				
5/3/2007	13:00	Mossdale	3910	5/3/2007 15:17	5/3/2007 21:44	5/4/2007 8:24	5/5/2007 12:09			5/9/07 06:58, Hwy 4
5/3/2007	13:00	Mossdale	3910	5/3/2007 15:17	5/3/2007 21:44	5/4/2007 8:24	5/5/2007 12:09			5/9/07 13:27, Tracy
5/3/2007	13:00	Mossdale	3917	5/3/2007 15:10	5/4/2007 0:16					
5/3/2007	13:00	Mossdale	3924	5/3/2007 22:08	5/4/2007 9:16					
5/3/2007	13:00	Mossdale	3931	5/3/2007 15:14	5/4/2007 10:09					
5/3/2007	13:00	Mossdale	3938	5/3/2007 15:50	5/4/2007 10:27			5/12/2007 9:25		
5/3/2007	13:00	Mossdale	3945	5/3/2007 15:52	5/4/2007 3:17	5/4/2007 11:56				
5/3/2007	13:00	Mossdale	3952	5/3/2007 15:58	5/3/2007 23:02	5/4/2007 9:03		5/10/2007 11:53		
5/3/2007	13:00	Mossdale	3959	5/3/2007 17:16	5/4/2007 1:51					
5/3/2007	13:00	Mossdale	3966	5/3/2007 15:29	5/3/2007 22:52					
5/3/2007	13:00	Mossdale	3973	5/3/2007 15:58						
5/3/2007	13:00	Mossdale	3980	5/3/2007 15:58	5/3/2007 23:13					
5/3/2007	13:00	Mossdale	3987	5/3/2007 17:53						
5/3/2007	13:00	Mossdale	3994	5/3/2007 15:13						
5/3/2007	13:00	Mossdale	4001	5/3/2007 15:57	5/3/2007 22:05	5/4/2007 10:53				
5/3/2007	13:00	Mossdale	4008	5/3/2007 15:28	5/4/2007 13:16	5/4/2007 16:48				
5/3/2007	13:00	Mossdale	4015	5/3/2007 22:05	5/4/2007 5:29	5/4/2007 14:38	5/7/2007 22:47			
5/3/2007	13:00	Mossdale	4022	5/3/2007 16:14	5/3/2007 23:32					
5/3/2007	13:00	Mossdale	4029	5/3/2007 16:31	5/4/2007 1:13					
5/3/2007	13:00	Mossdale	4036	5/3/2007 14:48						
5/3/2007	13:00	Mossdale	4043	5/3/2007 17:01	5/3/2007 23:42					
5/3/2007	13:00	Mossdale	4050	5/3/2007 18:22	5/4/2007 2:02					
5/3/2007	13:00	Mossdale	4057	5/3/2007 14:49	5/3/2007 19:42	5/4/2007 10:05				
5/3/2007	13:00	Mossdale	4064	5/3/2007 15:29	5/4/2007 10:00	5/4/2007 17:35				
5/3/2007	13:00	Mossdale	4071	5/3/2007 15:41	5/3/2007 21:51	5/4/2007 10:06				
5/3/2007	13:00	Mossdale	4078	5/3/2007 16:43	5/4/2007 0:42	5/4/2007 10:35				
5/3/2007	13:00	Mossdale	4092	5/3/2007 15:59						
5/3/2007	13:00	Mossdale	4099	5/3/2007 19:43	5/4/2007 14:00					
5/3/2007	13:00	Mossdale	4106	5/3/2007 15:57	5/4/2007 0:25	5/4/2007 10:15				
5/3/2007	13:00	Mossdale	4120	5/3/2007 21:30	5/4/2007 3:40			5/9/2007 6:21		
5/3/2007	13:00	Mossdale	4127	5/3/2007 15:17	5/4/2007 0:04	5/4/2007 10:13				
5/3/2007	13:00	Mossdale	4134	5/3/2007 16:45						
5/3/2007	13:00	Mossdale	4141	5/3/2007 15:59	5/5/2007 6:03					
5/3/2007	13:00	Mossdale	4148	5/3/2007 17:05	5/4/2007 12:37			5/11/2007 18:58		
5/3/2007	13:00	Mossdale	4155	5/3/2007 15:50						
5/3/2007	13:00	Mossdale	4162	5/3/2007 15:58	5/5/2007 4:12					
5/3/2007	13:00	Mossdale	4169	5/3/2007 15:47	5/3/2007 22:23					
5/3/2007	13:00	Mossdale	4176	5/3/2007 15:31	5/3/2007 21:26	5/4/2007 9:03			5/17-18,Tag Not Moving	
5/3/2007	13:00	Mossdale	4183	5/3/2007 17:41	5/4/2007 0:37		5/5/2007 7:20			
5/3/2007	13:00	Mossdale	4190	5/3/2007 23:38						
5/3/2007	13:00	Mossdale	4197	5/3/2007 15:19	5/4/2007 9:33					

Appendix A-4 (cont.). Detections of acoustic-tagged salmon from May 3 & 4 releases upstream of the Head of Old River Barrier

Release Dates: May 3 and May 4, 2007 Relase Locations: Durham Ferry, Mossdale, Bowman Road, Stockton

Release Date	Release Time	Release Site	Tag Code	Upstream of HORB Date/Time	Bowman Road Date/Time	Stockton Date/Time	Turner cut Date/Time	R16 Date/Time	Mobile Monitoring Near Stockton Date/Comment	Other Locations Date/Comment
5/3/2007	13:00	Mossdale	4204	5/3/2007 15:10	5/3/2007 20:12	5/4/2007 9:06				
5/3/2007	13:00	Mossdale	4211	5/3/2007 15:46	5/3/2007 21:19					
5/3/2007	13:00	Mossdale	4218	5/3/2007 16:04	5/4/2007 0:58	5/5/2007 17:38				
5/3/2007	13:00	Mossdale	4225	5/3/2007 15:52	5/4/2007 0:42					
5/3/2007	13:00	Mossdale	4232	5/3/2007 19:28	5/4/2007 1:47	5/4/2007 10:35				
5/3/2007	13:00	Mossdale	4239	5/3/2007 17:14	5/5/2007 9:53					
5/3/2007	13:00	Mossdale	4246	5/3/2007 21:12	5/4/2007 7:10					
5/3/2007	13:00	Mossdale	4253	5/3/2007 15:58	5/3/2007 21:57					
5/3/2007	13:00	Mossdale	3728	5/3/2007 15:41	5/4/2007 0:20					
5/3/2007	13:00	Mossdale	3735	5/3/2007 15:27	5/3/2007 23:06			5/8/2007 15:36		
5/3/2007	13:00	Mossdale	3742	5/3/2007 18:05	5/5/2007 9:24	5/5/2007 13:20				
5/3/2007	13:00	Mossdale	3749	5/3/2007 15:00	5/3/2007 20:30					
5/3/2007	13:00	Mossdale	3756	5/3/2007 16:14	5/4/2007 10:06	5/4/2007 13:53				
5/3/2007	13:00	Mossdale	3763	5/3/2007 15:49	5/3/2007 22:21	5/4/2007 9:10				
5/3/2007	13:00	Mossdale	3770	5/3/2007 15:23	5/4/2007 7:09					
5/3/2007	13:00	Mossdale	3777	5/3/2007 15:27	5/3/2007 23:38	5/4/2007 9:52		5/8/2007 20:36		
5/3/2007	13:00	Mossdale	3784	5/3/2007 15:59	5/3/2007 23:40	5/4/2007 8:30				
5/3/2007	13:00	Mossdale	3791	5/3/2007 16:56	5/4/2007 9:31	5/4/2007 19:23				
5/3/2007	13:00	Mossdale	3798	5/3/2007 14:49	5/4/2007 0:29			5/9/2007 11:14		
5/3/2007	13:00	Mossdale	3805	5/3/2007 15:53	5/3/2007 22:49					
5/3/2007	13:00	Mossdale	3812	5/3/2007 16:22	5/4/2007 0:45	5/4/2007 11:52				
5/3/2007	13:00	Mossdale	3819	5/3/2007 15:51	5/4/2007 7:36					
5/3/2007	13:00	Mossdale	3826	5/3/2007 17:32						
5/3/2007	13:00	Mossdale	3833	5/3/2007 16:12	5/4/2007 9:42					
5/3/2007	13:00	Mossdale	3840	5/3/2007 23:09	5/4/2007 13:25	5/5/2007 13:06				
5/3/2007	13:00	Mossdale	3847	5/3/2007 16:00	5/3/2007 23:18					
5/3/2007	13:00	Mossdale	3854	5/3/2007 16:10	5/3/2007 23:36	5/4/2007 8:55				
5/3/2007	13:00	Mossdale	3861	5/3/2007 15:50	5/3/2007 22:27					
5/3/2007	13:00	Mossdale	3868	5/3/2007 15:44	5/3/2007 21:04	5/4/2007 9:24				
5/3/2007	13:00	Mossdale	3875	5/3/2007 16:11	5/4/2007 6:20	5/4/2007 13:34				
5/3/2007	13:00	Mossdale	3882	5/3/2007 15:27						
5/3/2007	13:00	Mossdale	3889	5/3/2007 17:00	5/3/2007 23:27					
5/3/2007	13:00	Mossdale	3896	5/3/2007 15:57	5/3/2007 22:25	5/4/2007 8:53				
5/3/2007	13:00	Mossdale	3903	5/3/2007 15:03	5/3/2007 22:41	5/4/2007 10:58				
5/3/2007	13:00	Mossdale	3910	5/3/2007 15:17	5/3/2007 21:44	5/4/2007 8:24	5/5/2007 12:09			5/9/07 06:58, Hwy 4
5/3/2007	13:00	Mossdale	3910	5/3/2007 15:17	5/3/2007 21:44	5/4/2007 8:24	5/5/2007 12:09			5/9/07 13:27, Tracy
5/3/2007	13:00	Mossdale	3917	5/3/2007 15:10	5/4/2007 0:16					
5/3/2007	13:00	Mossdale	3924	5/3/2007 22:08	5/4/2007 9:16					
5/3/2007	13:00	Mossdale	3931	5/3/2007 15:14	5/4/2007 10:09					
5/3/2007	13:00	Mossdale	3938	5/3/2007 15:50	5/4/2007 10:27			5/12/2007 9:25		
5/3/2007	13:00	Mossdale	3945	5/3/2007 15:52	5/4/2007 3:17	5/4/2007 11:56				
5/3/2007	13:00	Mossdale	3952	5/3/2007 15:58	5/3/2007 23:02	5/4/2007 9:03		5/10/2007 11:53		
5/3/2007	13:00	Mossdale	3959	5/3/2007 17:16	5/4/2007 1:51					
5/3/2007	13:00	Mossdale	3966	5/3/2007 15:29	5/3/2007 22:52					
5/3/2007	13:00	Mossdale	3973	5/3/2007 15:58						
5/3/2007	13:00	Mossdale	3980	5/3/2007 15:58	5/3/2007 23:13					
5/3/2007	13:00	Mossdale	3987	5/3/2007 17:53						
5/3/2007	13:00	Mossdale	3994	5/3/2007 15:13						
5/3/2007	13:00	Mossdale	4001	5/3/2007 15:57	5/3/2007 22:05	5/4/2007 10:53				

Appendix A-4 (cont.). Detections of acoustic-tagged salmon from May 3 & 4 releases upstream of the Head of Old River Barrier

Release Dates: May 3 and May 4, 2007 Relase Locations: Durham Ferry, Mossdale, Bowman Road, Stockton

Release Date	Release Time	Release Site	Tag Code	Upstream of HORB Date/Time	Bowman Road Date/Time	Stockton Date/Time	Turner cut Date/Time	R16 Date/Time	Mobile Monitoring Near Stockton Date/Comment	Other Locations Date/Comment
5/3/2007	13:00	Mossdale	4008	5/3/2007 15:28	5/4/2007 13:16	5/4/2007 16:48				
5/3/2007	13:00	Mossdale	4015	5/3/2007 22:05	5/4/2007 5:29	5/4/2007 14:38	5/7/2007 22:47			
5/3/2007	13:00	Mossdale	4022	5/3/2007 16:14	5/3/2007 23:32					
5/3/2007	13:00	Mossdale	4029	5/3/2007 16:31	5/4/2007 1:13					
5/3/2007	13:00	Mossdale	4036	5/3/2007 14:48						
5/3/2007	13:00	Mossdale	4043	5/3/2007 17:01	5/3/2007 23:42					
5/3/2007	13:00	Mossdale	4050	5/3/2007 18:22	5/4/2007 2:02					
5/3/2007	13:00	Mossdale	4057	5/3/2007 14:49	5/3/2007 19:42	5/4/2007 10:05				
5/3/2007	13:00	Mossdale	4064	5/3/2007 15:29	5/4/2007 10:00	5/4/2007 17:35				
5/3/2007	13:00	Mossdale	4071	5/3/2007 15:41	5/3/2007 21:51	5/4/2007 10:06				
5/3/2007	13:00	Mossdale	4078	5/3/2007 16:43	5/4/2007 0:42	5/4/2007 10:35				
5/3/2007	13:00	Mossdale	4092	5/3/2007 15:59						
5/3/2007	13:00	Mossdale	4099	5/3/2007 19:43	5/4/2007 14:00					
5/3/2007	13:00	Mossdale	4106	5/3/2007 15:57	5/4/2007 0:25	5/4/2007 10:15				
5/3/2007	13:00	Mossdale	4120	5/3/2007 21:30	5/4/2007 3:40			5/9/2007 6:21		
5/3/2007	13:00	Mossdale	4127	5/3/2007 15:17	5/4/2007 0:04	5/4/2007 10:13				
5/3/2007	13:00	Mossdale	4134	5/3/2007 16:45						
5/3/2007	13:00	Mossdale	4141	5/3/2007 15:59	5/5/2007 6:03					
5/3/2007	13:00	Mossdale	4148	5/3/2007 17:05	5/4/2007 12:37			5/11/2007 18:58		
5/3/2007	13:00	Mossdale	4155	5/3/2007 15:50						
5/3/2007	13:00	Mossdale	4162	5/3/2007 15:58	5/5/2007 4:12					
5/3/2007	13:00	Mossdale	4169	5/3/2007 15:47	5/3/2007 22:23					
5/3/2007	13:00	Mossdale	4176	5/3/2007 15:31	5/3/2007 21:26	5/4/2007 9:03			5/17-18,Tag Not Moving	
5/3/2007	13:00	Mossdale	4183	5/3/2007 17:41	5/4/2007 0:37		5/5/2007 7:20			
5/3/2007	13:00	Mossdale	4190	5/3/2007 23:38						
5/3/2007	13:00	Mossdale	4197	5/3/2007 15:19	5/4/2007 9:33					
5/3/2007	13:00	Mossdale	4204	5/3/2007 15:10	5/3/2007 20:12	5/4/2007 9:06				
5/3/2007	13:00	Mossdale	4211	5/3/2007 15:46	5/3/2007 21:19					
5/3/2007	13:00	Mossdale	4218	5/3/2007 16:04	5/4/2007 0:58	5/5/2007 17:38				
5/3/2007	13:00	Mossdale	4225	5/3/2007 15:52	5/4/2007 0:42					
5/3/2007	13:00	Mossdale	4232	5/3/2007 19:28	5/4/2007 1:47	5/4/2007 10:35				
5/3/2007	13:00	Mossdale	4239	5/3/2007 17:14	5/5/2007 9:53					
5/3/2007	13:00	Mossdale	4246	5/3/2007 21:12	5/4/2007 7:10					
5/3/2007	13:00	Mossdale	4253	5/3/2007 15:58	5/3/2007 21:57					
5/3/2007	13:00	Mossdale	4260	5/3/2007 15:27	5/3/2007 22:08					
5/3/2007	13:00	Mossdale	4267	5/3/2007 15:40						
5/3/2007	13:00	Mossdale	4274	5/3/2007 18:16	5/4/2007 9:37			5/9/2007 4:38		
5/3/2007	13:00	Mossdale	4281	5/3/2007 15:27	5/3/2007 22:09	5/4/2007 10:36				
5/3/2007	13:00	Mossdale	4288	5/3/2007 15:33	5/3/2007 22:19	5/4/2007 8:22				
5/3/2007	13:00	Mossdale	4302	5/3/2007 18:38						
5/3/2007	13:00	Mossdale	4309	5/3/2007 18:56	5/4/2007 13:03					
5/3/2007	13:00	Mossdale	4316	5/3/2007 16:09						
5/3/2007	13:00	Mossdale	4323	5/3/2007 16:27	5/3/2007 23:25					
5/3/2007	13:00	Mossdale	4330	5/3/2007 15:04	5/4/2007 0:28					
5/3/2007	13:00	Mossdale	4337	5/3/2007 15:54	5/3/2007 23:22	5/4/2007 9:11				
5/3/2007	13:00	Mossdale	4344	5/3/2007 15:10	5/3/2007 23:49					
5/3/2007	13:00	Mossdale	4351	5/3/2007 14:57	5/3/2007 22:05					
5/3/2007	13:00	Mossdale	4358	5/3/2007 16:20	5/3/2007 23:25					
5/3/2007	13:00	Mossdale	4365	5/3/2007 17:01						

Appendix A-4 (cont.). Detections of acoustic-tagged salmon from May 3 & 4 releases upstream of the Head of Old River Barrier

Release Dates: May 3 and May 4, 2007 Relase Locations: Durham Ferry, Mossdale, Bowman Road, Stockton

Release Date	Release Time	Release Site	Tag Code	Upstream of HORB Date/Time	Bowman Road Date/Time	Stockton Date/Time	Turner cut Date/Time	R16 Date/Time	Mobile Monitoring Near Stockton Date/Comment	Other Locations Date/Comment
5/3/2007	13:00	Mossdale	4372	5/3/2007 15:59	5/3/2007 23:20					
5/3/2007	13:00	Mossdale	4379	5/3/2007 15:51	5/3/2007 23:15		5/7/2007 11:30			
5/3/2007	13:00	Mossdale	4386	5/3/2007 15:57	5/4/2007 1:36	5/4/2007 11:47		5/9/2007 17:40		
5/3/2007	13:00	Mossdale	4393	5/3/2007 16:23	5/4/2007 9:42					
5/3/2007	12:15	Bowman Rd.	5107			5/4/2007 18:26				
5/3/2007	12:15	Bowman Rd.	5142			5/4/2007 18:59				
5/3/2007	12:15	Bowman Rd.	5156			5/4/2007 16:26				
5/3/2007	12:15	Bowman Rd.	5163						5/17-18,Tag Not Moving	
5/3/2007	12:15	Bowman Rd.	5177			5/5/2007 9:56				
5/3/2007	12:15	Bowman Rd.	5184			5/4/2007 15:42				
5/3/2007	12:15	Bowman Rd.	5196						5/17-18,Tag Not Moving	
5/3/2007	12:15	Bowman Rd.	5198			5/6/2007 21:20				
5/3/2007	12:15	Bowman Rd.	5205			5/4/2007 19:59				
5/3/2007	12:15	Bowman Rd.	5219						5/17-18,Tag Not Moving	
5/3/2007	12:15	Bowman Rd.	5233			5/4/2007 16:19				
5/3/2007	12:15	Bowman Rd.	5240			5/4/2007 15:30				
5/3/2007	12:15	Bowman Rd.	5247			5/4/2007 18:25				
5/3/2007	12:15	Bowman Rd.	5254			5/4/2007 16:13				
5/3/2007	12:15	Bowman Rd.	5261					5/6/2007 7:21		
5/3/2007	12:15	Bowman Rd.	5268			5/4/2007 16:55				
5/3/2007	12:15	Bowman Rd.	5282			5/4/2007 15:41				
5/3/2007	12:15	Bowman Rd.	5303			5/4/2007 17:22				
5/3/2007	12:15	Bowman Rd.	5317			5/4/2007 17:00				
5/3/2007	12:15	Bowman Rd.	5331			5/4/2007 16:00				
5/3/2007	12:15	Bowman Rd.	5352			5/4/2007 19:58				
5/3/2007	12:15	Bowman Rd.	5359					5/8/2007 15:37		
5/3/2007	12:15	Bowman Rd.	5373			5/4/2007 19:33				
5/3/2007	12:15	Bowman Rd.	5387			5/6/2007 5:42				
5/3/2007	12:15	Bowman Rd.	5401			5/4/2007 18:41	5/7/2007 17:09			
5/3/2007	12:15	Bowman Rd.	5408			5/6/2007 21:20			5/17-18,Tag Not Moving	
5/3/2007	12:15	Bowman Rd.	5429					5/9/2007 19:15		
5/3/2007	12:15	Bowman Rd.	5527			5/4/2007 18:12				
5/3/2007	12:15	Bowman Rd.	5548			5/4/2007 18:45				
5/3/2007	12:15	Bowman Rd.	5583			5/4/2007 16:04		5/8/2007 20:28		
5/3/2007	12:15	Bowman Rd.	5618			5/4/2007 19:19				
5/3/2007	12:15	Bowman Rd.	5632			5/4/2007 16:38			5/17-18,Tag Not Moving	
5/3/2007	12:15	Bowman Rd.	5688			5/4/2007 16:36				
5/3/2007	12:15	Bowman Rd.	5716			5/4/2007 16:36				
5/3/2007	12:15	Bowman Rd.	5751			5/4/2007 17:17		5/9/2007 13:00		
5/3/2007	12:15	Bowman Rd.	5765			5/4/2007 19:18				
5/3/2007	12:15	Bowman Rd.	5786			5/4/2007 18:48				
5/4/2007	12:51	Stockton	5800				5/7/2007 3:22			
5/4/2007	12:51	Stockton	5898				5/6/2007 8:22			
5/4/2007	12:51	Stockton	6381				5/6/2007 10:57			
5/4/2007	12:51	Stockton	5912					5/9/2007 6:31		
5/4/2007	12:51	Stockton	5919					5/8/2007 22:20		
5/4/2007	12:51	Stockton	6003					5/9/2007 17:07		
5/4/2007	12:51	Stockton	6031					5/8/2007 17:42		
5/4/2007	12:51	Stockton	6038						5/17-18,Tag Not Moving	

Appendix A-4 (cont.). Detections of acoustic-tagged salmon from May 3 & 4 releases upstream of the Head of Old River Barrier

Release Dates: May 3 and May 4, 2007 Relase Locations: Durham Ferry, Mossdale, Bowman Road, Stockton

Release Date	Release Time	Release Site	Tag Code	Upstream of HORB Date/Time	Bowman Road Date/Time	Stockton Date/Time	Turner cut Date/Time	R16 Date/Time	Mobile Monitoring Near Stockton Date/Comment	Other Locations Date/Comment
5/4/2007	12:51	Stockton	6059					5/8/2007 21:25		
5/4/2007	12:51	Stockton	6122					5/8/2007 15:34		
5/4/2007	12:51	Stockton	6171					5/9/2007 7:28		
5/4/2007	12:51	Stockton	6022						5/17-18,Tag Not Moving	
5/4/2007	12:51	Stockton	6262						5/17-18,Tag Not Moving	
5/4/2007	12:51	Stockton	6269						5/17-18,Tag Not Moving	
5/4/2007	12:51	Stockton	6276						5/17-18,Tag Not Moving	
5/4/2007	12:51	Stockton	6311					5/10/2007 18:38		
5/4/2007	12:51	Stockton	6367						5/17-18,Tag Not Moving	
5/4/2007	12:51	Stockton	6458					5/8/2007 21:25		

Appendix A-5. Detections of acoustic-tagged salmon released May 4 downstream of the Head of Old River Barrier (table)

Release Date: May 4, 2007				Release Location: Old River downstream of HORB			
Release Date	Release Time	Release Site	Tag Code	Tracy Fish Facilities Date/Time	Clifton Court Inlet Date/Time	Skinner Fish Facilities Date/Time	Old River At Hwy 4 Date/Time
5/4/2007	10:17	D/S of HORb	4400	5/6/2007 6:04	5/9/2007 5:47		
5/4/2007	10:17	D/S of HORb	4407				5/6/2007 18:40
5/4/2007	10:17	D/S of HORb	4449	5/10/2007 11:14	5/7/2007 3:54		
5/4/2007	10:17	D/S of HORb	4456				5/14/2007 12:29
5/4/2007	10:17	D/S of HORb	4477		5/6/2007 13:10		
5/4/2007	10:17	D/S of HORb	4505	5/10/2007 0:26			
5/4/2007	10:17	D/S of HORb	4512	5/5/2007 23:07			
5/4/2007	10:17	D/S of HORb	4519				5/11/2007 5:14
5/4/2007	10:17	D/S of HORb	4526				5/9/2007 20:09
5/4/2007	10:17	D/S of HORb	4547				5/7/2007 15:03
5/4/2007	10:17	D/S of HORb	4561	5/9/2007 6:16			
5/4/2007	10:17	D/S of HORb	4568		5/6/2007 12:18		
5/4/2007	10:17	D/S of HORb	4610	5/11/2007 1:42			5/8/2007 19:46
5/4/2007	10:17	D/S of HORb	4617	5/7/2007 14:02			
5/4/2007	10:17	D/S of HORb	4631	5/9/2007 6:51			5/7/2007 18:14
5/4/2007	10:17	D/S of HORb	4645				5/6/2007 12:20
5/4/2007	10:17	D/S of HORb	4659	5/8/2007 1:26			
5/4/2007	10:17	D/S of HORb	4673	5/9/2007 12:38	5/7/2007 4:29		5/6/2007 16:20
5/4/2007	10:17	D/S of HORb	4694				5/6/2007 14:16
5/4/2007	10:17	D/S of HORb	4701	5/8/2007 0:40			5/7/2007 15:18
5/4/2007	10:17	D/S of HORb	4708	5/9/2007 7:24			
5/4/2007	10:17	D/S of HORb	4715	5/6/2007 6:56			5/8/2007 16:50
5/4/2007	10:17	D/S of HORb	4722	5/5/2007 23:13			5/6/2007 16:44
5/4/2007	10:17	D/S of HORb	4743		5/6/2007 2:26	5/7/2007 9:00	
5/4/2007	10:17	D/S of HORb	4771	5/16/2007 16:46			
5/4/2007	10:17	D/S of HORb	4757		5/6/2007 13:08		
5/4/2007	10:17	D/S of HORb	4785		5/8/2007 4:48	5/9/2007 20:09	5/7/2007 17:23
5/4/2007	10:17	D/S of HORb	4799		5/9/2007 5:48		
5/4/2007	10:17	D/S of HORb	4834				5/7/2007 10:31
5/4/2007	10:17	D/S of HORb	4841		5/7/2007 4:45		
5/4/2007	10:17	D/S of HORb	4848		5/6/2007 13:37		
5/4/2007	10:17	D/S of HORb	4855	5/9/2007 14:24			
5/4/2007	10:17	D/S of HORb	4862				5/7/2007 17:41
5/4/2007	10:17	D/S of HORb	4869		5/6/2007 11:49		
5/4/2007	10:17	D/S of HORb	4883		5/6/2007 2:52	5/9/2007 7:50	
5/4/2007	10:17	D/S of HORb	4897		5/8/2007 4:18		
5/4/2007	10:17	D/S of HORb	4904	5/7/2007 11:37			
5/4/2007	10:17	D/S of HORb	4932	5/6/2007 5:40	5/9/2007 5:54		5/8/2007 18:08
5/4/2007	10:17	D/S of HORb	4939	5/7/2007 12:01			
5/4/2007	10:17	D/S of HORb	4946				5/7/2007 5:09
5/4/2007	10:17	D/S of HORb	4988		5/6/2007 13:11	5/7/2007 6:18	
5/4/2007	10:17	D/S of HORb	4995	5/5/2007 19:58			5/6/2007 15:03
5/4/2007	10:17	D/S of HORb	5002		5/6/2007 12:14		
5/4/2007	10:17	D/S of HORb	5009				5/6/2007 19:47
5/4/2007	10:17	D/S of HORb	5016				5/7/2007 14:00
5/4/2007	10:17	D/S of HORb	5044	5/7/2007 12:18			
5/4/2007	10:17	D/S of HORb	5051	5/12/2007 18:13			5/7/2007 18:13
5/4/2007	10:17	D/S of HORb	5065		5/7/2007 13:20		
5/4/2007	10:17	D/S of HORb	5072		5/7/2007 14:15		5/6/2007 15:43

Appendix A-6. Detections of acoustic-tagged salmon from May 10 & 11 releases upstream of the Head of Old River Barrier (table)

Release Date	Release Time	Release Site	Tag Code	Upstream of HORB Date/Time	Bowmand Road Date/Time	Stockton Date/Time	Turner Cut Date/Time	R16 Date/Time	Near Stockton Date/ Comment	Other Locations Date/Comment
5/10/2007	11:40	Durham Ferry	3003	5/10/2007 23:05						
5/10/2007	11:40	Durham Ferry	3010					5/13/2007 13:51		
5/10/2007	11:40	Durham Ferry	3017						5/17-18, Tag Not Moving	
5/10/2007	11:40	Durham Ferry	3031						5/17-18, Tag Not Moving	
5/10/2007	11:40	Durham Ferry	3038	5/11/2007 1:55	5/11/2007 8:05	5/11/2007 23:09			5/17-18, Tag Not Moving	
5/10/2007	11:40	Durham Ferry	3045	5/11/2007 13:15	5/11/2007 20:31				5/17-18, Tag Not Moving	
5/10/2007	11:40	Durham Ferry	3052	5/11/2007 3:51	5/11/2007 14:16	5/11/2007 19:10			5/17-18, Tag Not Moving	
5/10/2007	11:40	Durham Ferry	3059	5/11/2007 9:29	5/11/2007 18:26				5/17-18, Tag Not Moving	
5/10/2007	11:40	Durham Ferry	3066	5/11/2007 8:14						
5/10/2007	11:40	Durham Ferry	3073	5/11/2007 4:22	5/11/2007 10:32	5/11/2007 14:38				
5/10/2007	11:40	Durham Ferry	3080	5/11/2007 1:58	5/11/2007 8:15	5/13/2007 0:04			5/17-18, Tag Not Moving	
5/10/2007	11:40	Durham Ferry	3087	5/11/2007 1:23	5/11/2007 11:29				5/17-18, Tag Not Moving	
5/10/2007	11:40	Durham Ferry	3094						5/17-18, Tag Not Moving	
5/10/2007	11:40	Durham Ferry	3101	5/11/2007 11:24					5/17-18, Tag Not Moving	
5/10/2007	11:40	Durham Ferry	3108	5/11/2007 4:34	5/11/2007 11:34				5/17-18, Tag Not Moving	
5/10/2007	11:40	Durham Ferry	3115						5/17-18, Tag Not Moving	
5/10/2007	11:40	Durham Ferry	3122	5/11/2007 8:38						
5/10/2007	11:40	Durham Ferry	3129	5/11/2007 9:04	5/11/2007 16:12				5/17-18, Tag Not Moving	
5/10/2007	11:40	Durham Ferry	3136	5/11/2007 1:27						
5/10/2007	11:40	Durham Ferry	3143	5/11/2007 7:07	5/11/2007 12:25					
5/10/2007	11:40	Durham Ferry	3150						5/17-18, Tag Not Moving	
5/10/2007	11:40	Durham Ferry	3157						5/17-18, Tag Not Moving	
5/10/2007	11:40	Durham Ferry	3171	5/11/2007 1:29					5/17-18, Tag Not Moving	
5/10/2007	11:40	Durham Ferry	3185						5/17-18, Tag Not Moving	
5/10/2007	11:40	Durham Ferry	3192	5/11/2007 0:20	5/11/2007 8:35				5/17-18, Tag Not Moving	
5/10/2007	11:40	Durham Ferry	3199	5/11/2007 5:10						
5/10/2007	11:40	Durham Ferry	3206					5/13/2007 19:41		
5/10/2007	11:40	Durham Ferry	3213	5/11/2007 11:02	5/11/2007 22:32			5/13/2007 9:11		
5/10/2007	11:40	Durham Ferry	3220	5/11/2007 15:02						
5/10/2007	11:40	Durham Ferry	3227	5/11/2007 14:43	5/11/2007 20:34			5/14/2007 11:01		
5/10/2007	11:40	Durham Ferry	3262	5/11/2007 6:11	5/11/2007 12:14					
5/10/2007	11:40	Durham Ferry	3269	5/11/2007 6:04						
5/10/2007	11:40	Durham Ferry	3276	5/11/2007 0:36	5/11/2007 9:18					
5/10/2007	11:40	Durham Ferry	3290	5/10/2007 21:40						
5/10/2007	11:40	Durham Ferry	3297	5/11/2007 3:35	5/11/2007 12:34				5/17-18, Tag Not Moving	
5/10/2007	11:40	Durham Ferry	3311	5/11/2007 0:01						
5/10/2007	11:40	Durham Ferry	3332	5/11/2007 1:06	5/11/2007 7:39					
5/10/2007	11:40	Durham Ferry	3339	5/11/2007 4:57	5/11/2007 13:00			5/13/2007 9:29		
5/10/2007	11:40	Durham Ferry	3360	5/11/2007 3:27	5/11/2007 16:12					
5/10/2007	11:40	Durham Ferry	3367	5/11/2007 2:11	5/11/2007 9:16					
5/10/2007	11:40	Durham Ferry	3374	5/11/2007 0:49						
5/10/2007	11:40	Durham Ferry	3381	5/11/2007 1:54						
5/10/2007	11:40	Durham Ferry	3409	5/11/2007 2:19	5/11/2007 8:43					
5/10/2007	11:40	Durham Ferry	3437	5/11/2007 5:00	5/11/2007 10:54					
5/10/2007	11:40	Durham Ferry	3444	5/11/2007 1:17						
5/10/2007	11:40	Durham Ferry	3465	5/11/2007 9:00	5/11/2007 14:38					
5/10/2007	11:40	Durham Ferry	3472	5/11/2007 8:52	5/11/2007 18:00	5/11/2007 21:47				
5/10/2007	11:40	Durham Ferry	3493	5/11/2007 5:31	5/11/2007 11:22	5/12/2007 17:13				
5/10/2007	11:40	Durham Ferry	3500	5/11/2007 11:29	5/11/2007 18:23	5/12/2007 8:58		5/13/2007 19:03		
5/10/2007	11:40	Durham Ferry	3507	5/11/2007 3:39	5/11/2007 10:28					
5/10/2007	11:40	Durham Ferry	3521	5/11/2007 8:29	5/11/2007 13:34			5/13/2007 18:03		
5/10/2007	11:40	Durham Ferry	3535	5/11/2007 10:17	5/11/2007 17:32	5/12/2007 8:25				
5/10/2007	11:40	Durham Ferry	3549	5/11/2007 14:41						
5/10/2007	11:40	Durham Ferry	3556	5/10/2007 23:05						
5/10/2007	11:40	Durham Ferry	3577	5/11/2007 8:03						

Appendix A-6 (cont.). Detections of acoustic-tagged salmon from May 10 & 11 releases upstream of the Head of Old River Barrier

Release Date	Release Time	Release Site	Tag Code	Upstream of HORB Date/Time	Bowmand Road Date/Time	Stockton Date/Time	Turner Cut Date/Time	R16 Date/Time	Near Stockton Date/ Comment	Other Locations Date/Comment
5/10/2007	11:40	Durham Ferry	3584	5/11/2007 11:44	5/11/2007 19:12					
5/10/2007	11:40	Durham Ferry	3591	5/11/2007 4:47	5/11/2007 19:08	5/12/2007 2:41				
5/10/2007	11:40	Durham Ferry	3598	5/11/2007 8:54						
5/10/2007	11:40	Durham Ferry	3612	5/11/2007 4:32						
5/10/2007	11:40	Durham Ferry	3619	5/10/2007 21:29	5/11/2007 3:04					
5/10/2007	11:40	Durham Ferry	3633	5/11/2007 7:33	5/11/2007 13:49		5/13/2007 8:06	5/12/2007 19:05		
5/10/2007	11:40	Durham Ferry	3640	5/11/2007 0:41	5/11/2007 8:21				5/17-18, Tag Not Moving	
5/10/2007	11:40	Durham Ferry	3668	5/11/2007 4:46						
5/10/2007	11:40	Durham Ferry	3689	5/11/2007 2:00	5/11/2007 8:01				5/17-18, Tag Not Moving	
5/10/2007	11:40	Durham Ferry	3696	5/11/2007 10:16	5/11/2007 21:46					
5/10/2007	12:30	Mossdale	3703	5/10/2007 16:24	5/10/2007 21:30	5/11/2007 5:12				
5/10/2007	12:30	Mossdale	3710	5/10/2007 16:54	5/10/2007 21:32	5/11/2007 5:25				
5/10/2007	12:30	Mossdale	3717	5/10/2007 15:06						
5/10/2007	12:30	Mossdale	3724	5/10/2007 18:57	5/11/2007 0:12				5/17-18, Tag Not Moving	
5/10/2007	12:30	Mossdale	3731	5/10/2007 16:27						
5/10/2007	12:30	Mossdale	3738	5/10/2007 15:17	5/10/2007 19:18			5/13/2007 20:21		
5/10/2007	12:30	Mossdale	3745	5/10/2007 15:45	5/11/2007 7:08		5/12/2007 15:19			
5/10/2007	12:30	Mossdale	3752	5/10/2007 17:40						
5/10/2007	12:30	Mossdale	3759	5/10/2007 18:52	5/11/2007 12:12					
5/10/2007	12:30	Mossdale	3766	5/10/2007 15:41	5/10/2007 19:22					
5/10/2007	12:30	Mossdale	3773	5/10/2007 15:16	5/10/2007 22:47					
5/10/2007	12:30	Mossdale	3780	5/10/2007 18:01	5/11/2007 0:06		5/15/2007 17:23	5/13/2007 8:26		
5/10/2007	12:30	Mossdale	3787	5/10/2007 16:53	5/10/2007 21:06					
5/10/2007	12:30	Mossdale	3794	5/10/2007 16:26						
5/10/2007	12:30	Mossdale	3801	5/10/2007 17:56	5/11/2007 6:01	5/11/2007 10:50	5/12/2007 1:42			5/14/07, Hwy 4
5/10/2007	12:30	Mossdale	3808	5/10/2007 16:13	5/10/2007 20:25					
5/10/2007	12:30	Mossdale	3815	5/10/2007 15:29						
5/10/2007	12:30	Mossdale	3822	5/10/2007 15:07	5/10/2007 19:00	5/11/2007 5:22			5/17-18, Tag Not Moving	
5/10/2007	12:30	Mossdale	3829	5/10/2007 16:26	5/10/2007 20:08					
5/10/2007	12:30	Mossdale	3836	5/10/2007 16:00	5/10/2007 23:29				5/17-18, Tag Not Moving	
5/10/2007	12:30	Mossdale	3843	5/10/2007 16:19						
5/10/2007	12:30	Mossdale	3850	5/10/2007 17:28	5/12/2007 4:53					
5/10/2007	12:30	Mossdale	3857	5/10/2007 15:57	5/10/2007 19:31					
5/10/2007	12:30	Mossdale	3871	5/10/2007 16:16	5/11/2007 3:12					
5/10/2007	12:30	Mossdale	3878	5/10/2007 17:06	5/11/2007 6:24					
5/10/2007	12:30	Mossdale	3885	5/10/2007 16:54	5/10/2007 22:06	5/11/2007 8:04				
5/10/2007	12:30	Mossdale	3892	5/10/2007 16:00	5/10/2007 20:01	5/11/2007 5:46			5/17-18, Tag Not Moving	
5/10/2007	12:30	Mossdale	3899	5/10/2007 15:42	5/10/2007 19:22	5/11/2007 5:09		5/13/2007 20:34		
5/10/2007	12:30	Mossdale	3906	5/10/2007 16:43	5/10/2007 21:01	5/11/2007 4:55				
5/10/2007	12:30	Mossdale	3913	5/10/2007 15:16	5/10/2007 20:15	5/11/2007 2:57	5/13/2007 15:12	5/12/2007 19:28		
5/10/2007	12:30	Mossdale	3920	5/10/2007 17:01						
5/10/2007	12:30	Mossdale	3927	5/10/2007 17:40	5/11/2007 5:40			5/13/2007 12:01		
5/10/2007	12:30	Mossdale	3934	5/10/2007 16:50	5/10/2007 22:35	5/11/2007 6:20			5/17-18, Tag Not Moving	
5/10/2007	12:30	Mossdale	3948	5/10/2007 16:47						
5/10/2007	12:30	Mossdale	3955	5/10/2007 16:54	5/10/2007 21:30					
5/10/2007	12:30	Mossdale	3962	5/10/2007 15:57	5/10/2007 19:28					
5/10/2007	12:30	Mossdale	3969	5/10/2007 16:46	5/10/2007 21:42					
5/10/2007	12:30	Mossdale	3976	5/10/2007 15:43	5/10/2007 19:53					
5/10/2007	12:30	Mossdale	3983	5/10/2007 15:39	5/10/2007 19:55	5/11/2007 7:06				
5/10/2007	12:30	Mossdale	3990	5/10/2007 18:41	5/11/2007 0:50	5/11/2007 11:02				
5/10/2007	12:30	Mossdale	3997	5/10/2007 17:34	5/11/2007 0:42					
5/10/2007	12:30	Mossdale	4004	5/10/2007 16:54						
5/10/2007	12:30	Mossdale	4011	5/10/2007 17:54	5/11/2007 3:39				5/17-18, Tag Not Moving	
5/10/2007	12:30	Mossdale	4018	5/10/2007 17:21	5/10/2007 21:41	5/11/2007 5:40				
5/10/2007	12:30	Mossdale	4025	5/10/2007 17:21						
5/10/2007	12:30	Mossdale	4032	5/10/2007 17:07	5/10/2007 22:41				5/17-18, Tag Not Moving	

Appendix A-6 (cont.). Detections of acoustic-tagged salmon from May 10 & 11 releases upstream of the Head of Old River Barrier

Release Date	Release Time	Release Site	Tag Code	Upstream of HORB Date/Time	Bowmand Road Date/Time	Stockton Date/Time	Turner Cut Date/Time	R16 Date/Time	Near Stockton Date/ Comment	Other Locations Date/Comment
5/10/2007	12:30	Mossdale	4039	5/10/2007 16:39	5/10/2007 22:08					
5/10/2007	12:30	Mossdale	4046	5/10/2007 15:07	5/10/2007 19:17	5/12/2007 13:50				
5/10/2007	12:30	Mossdale	4053	5/10/2007 18:56	5/11/2007 1:01	5/11/2007 15:10		5/13/2007 12:04		
5/10/2007	12:30	Mossdale	4060	5/10/2007 15:28	5/10/2007 19:47					
5/10/2007	12:30	Mossdale	4074	5/10/2007 15:06	5/10/2007 20:08					
5/10/2007	12:30	Mossdale	4081	5/10/2007 17:16	5/10/2007 21:36	5/11/2007 7:37			5/17-18, Tag Not Moving	
5/10/2007	12:30	Mossdale	4088	5/10/2007 15:28						
5/10/2007	12:30	Mossdale	4095	5/10/2007 15:51	5/11/2007 4:40				5/17-18, Tag Not Moving	
5/10/2007	12:30	Mossdale	4102	5/10/2007 16:25	5/10/2007 20:32				5/17-18, Tag Not Moving	
5/10/2007	12:30	Mossdale	4109	5/10/2007 16:08			5/13/2007 6:09	5/12/2007 21:04		
5/10/2007	12:30	Mossdale	4116	5/10/2007 15:00						
5/10/2007	12:30	Mossdale	4123	5/10/2007 15:21	5/10/2007 19:45		5/13/2007 1:06			
5/10/2007	12:30	Mossdale	4130	5/10/2007 18:51	5/13/2007 0:35					
5/10/2007	12:30	Mossdale	4137	5/10/2007 15:15	5/10/2007 19:56	5/11/2007 8:03			5/17-18, Tag Not Moving	
5/10/2007	12:30	Mossdale	4144	5/10/2007 17:22	5/10/2007 21:56	5/11/2007 20:11				
5/10/2007	12:30	Mossdale	4151	5/10/2007 16:33	5/10/2007 20:43	5/11/2007 23:35				
5/10/2007	12:30	Mossdale	4158	5/10/2007 15:58	5/10/2007 19:29					
5/10/2007	12:30	Mossdale	4165	5/10/2007 15:01						
5/10/2007	12:30	Mossdale	4179	5/10/2007 16:54	5/10/2007 21:50	5/11/2007 5:57				
5/10/2007	12:30	Mossdale	4186	5/10/2007 16:00	5/10/2007 21:35	5/11/2007 6:09			5/17-18, Tag Not Moving	
5/10/2007	12:30	Mossdale	4193	5/10/2007 15:39	5/14/2007 19:48					
5/10/2007	12:30	Mossdale	4200	5/10/2007 15:57	5/10/2007 19:29					
5/10/2007	12:30	Mossdale	4207	5/10/2007 18:01						
5/10/2007	12:30	Mossdale	4214	5/10/2007 17:00	5/10/2007 23:24			5/14/2007 22:43		
5/10/2007	12:30	Mossdale	4221	5/10/2007 15:41	5/10/2007 19:45				5/17-18, Tag Not Moving	
5/10/2007	12:30	Mossdale	4228	5/10/2007 15:40	5/10/2007 20:05	5/11/2007 4:52				
5/10/2007	12:30	Mossdale	4235	5/10/2007 15:39	5/10/2007 20:29			5/13/2007 20:55		
5/10/2007	12:30	Mossdale	4242	5/10/2007 15:06	5/10/2007 19:43	5/11/2007 4:48				
5/10/2007	12:30	Mossdale	4249	5/10/2007 16:54	5/10/2007 21:47	5/11/2007 5:47				
5/10/2007	12:30	Mossdale	4256	5/10/2007 17:01	5/10/2007 21:21	5/11/2007 4:31				
5/10/2007	12:30	Mossdale	4263	5/10/2007 18:29	5/11/2007 0:02	5/13/2007 1:18				
5/10/2007	12:30	Mossdale	4270	5/10/2007 16:42	5/10/2007 21:57	5/11/2007 10:30				
5/10/2007	12:30	Mossdale	4277	5/10/2007 20:34						
5/10/2007	12:30	Mossdale	4284	5/10/2007 15:06	5/10/2007 20:20	5/12/2007 21:11				
5/10/2007	12:30	Mossdale	4291	5/10/2007 15:07	5/10/2007 19:00					
5/10/2007	12:30	Mossdale	4298	5/10/2007 15:57	5/10/2007 19:34					
5/10/2007	12:30	Mossdale	4305	5/10/2007 15:05	5/10/2007 21:32	5/11/2007 7:00			5/17-18, Tag Not Moving	
5/10/2007	12:30	Mossdale	4312	5/10/2007 15:21	5/11/2007 3:35					
5/10/2007	12:30	Mossdale	4319	5/10/2007 15:36	5/11/2007 0:19		5/14/2007 2:25			
5/10/2007	12:30	Mossdale	4326	5/10/2007 15:28	5/10/2007 19:55					
5/10/2007	12:30	Mossdale	4333	5/10/2007 16:54	5/11/2007 2:47					
5/10/2007	12:30	Mossdale	4340	5/10/2007 15:33	5/11/2007 5:24			5/13/2007 12:27		
5/10/2007	12:30	Mossdale	4347	5/10/2007 16:54	5/10/2007 22:09	5/11/2007 10:29		5/13/2007 9:18		
5/10/2007	12:30	Mossdale	4354	5/10/2007 16:43	5/10/2007 20:30			5/16/2007 11:48		
5/10/2007	12:30	Mossdale	4361	5/10/2007 16:34						
5/10/2007	12:30	Mossdale	4368	5/10/2007 16:54	5/10/2007 21:45	5/11/2007 5:52		5/11/2007 18:16		
5/10/2007	12:30	Mossdale	4375	5/10/2007 15:28	5/10/2007 19:47	5/11/2007 5:01				
5/10/2007	12:30	Mossdale	4382	5/10/2007 17:51						
5/10/2007	12:30	Mossdale	4396	5/10/2007 16:33						
5/11/2007	12:05	Bowman Rd.	5110			5/11/2007 18:41			5/17-18, Tag Not Moving	
5/11/2007	12:05	Bowman Rd.	5117			5/19/2007 21:47			5/17-18, Tag Not Moving	
5/11/2007	12:05	Bowman Rd.	5131					5/13/2007 20:01		
5/11/2007	12:05	Bowman Rd.	5145						5/17-18, Tag Not Moving	
5/11/2007	12:05	Bowman Rd.	5166			5/11/2007 19:02				
5/11/2007	12:05	Bowman Rd.	5229			5/11/2007 20:08		5/13/2007 9:00		
5/11/2007	12:05	Bowman Rd.	5243						5/17-18, Tag Not Moving	

Appendix A-6 (cont.). Detections of acoustic-tagged salmon from May 10 & 11 releases upstream of the Head of Old River Barrier

Release Date	Release Time	Release Site	Tag Code	Upstream of HORB Date/Time	Bowmand Road Date/Time	Stockton Date/Time	Turner Cut Date/Time	R16 Date/Time	Near Stockton Date/ Comment	Other Locations Date/Comment
5/11/2007	12:05	Bowman Rd.	5264			5/11/2007 23:30				
5/11/2007	12:05	Bowman Rd.	5285			5/15/2007 20:50			5/17-18, Tag Not Moving	
5/11/2007	12:05	Bowman Rd.	5313						5/17-18, Tag Not Moving	
5/11/2007	12:05	Bowman Rd.	5327				5/17-18, Tag Not Moving			
5/11/2007	12:05	Bowman Rd.	5334				5/17-18, Tag Not Moving			
5/11/2007	12:05	Bowman Rd.	5341		5/14/2007 16:03	5/13/2007 18:12				
5/11/2007	12:05	Bowman Rd.	5348				5/17-18, Tag Not Moving			
5/11/2007	12:05	Bowman Rd.	5362			5/13/2007 21:21				
5/11/2007	12:05	Bowman Rd.	5390	5/11/2007 18:25			5/17-18, Tag Not Moving			
5/11/2007	12:05	Bowman Rd.	5404	5/12/2007 23:31						
5/11/2007	12:05	Bowman Rd.	5411				5/17-18, Tag Not Moving			
5/11/2007	12:05	Bowman Rd.	5418			5/14/2007 20:24				
5/11/2007	12:05	Bowman Rd.	5425			5/12/2007 17:04				
5/11/2007	12:05	Bowman Rd.	5432	5/11/2007 19:43						
5/11/2007	12:05	Bowman Rd.	5446	5/11/2007 16:16						
5/11/2007	12:05	Bowman Rd.	5453				5/17-18, Tag Not Moving			
5/11/2007	12:05	Bowman Rd.	5460				5/17-18, Tag Not Moving			
5/11/2007	12:05	Bowman Rd.	5474	5/11/2007 15:47	5/13/2007 15:59	5/13/2007 12:39				
5/11/2007	12:05	Bowman Rd.	5481	5/11/2007 16:48						
5/11/2007	12:05	Bowman Rd.	5502	5/11/2007 15:47			5/17-18, Tag Not Moving			
5/11/2007	12:05	Bowman Rd.	5516			5/13/2007 19:32				
5/11/2007	12:05	Bowman Rd.	5523	5/11/2007 22:04						
5/11/2007	12:05	Bowman Rd.	5530				5/17-18, Tag Not Moving			
5/11/2007	12:05	Bowman Rd.	5537			5/12/2007 20:55				
5/11/2007	12:05	Bowman Rd.	5544				5/17-18, Tag Not Moving			
5/11/2007	12:05	Bowman Rd.	5565	5/15/2007 3:45						
5/11/2007	12:05	Bowman Rd.	5579				5/17-18, Tag Not Moving			
5/11/2007	12:05	Bowman Rd.	5593	5/12/2007 15:30						
5/11/2007	12:05	Bowman Rd.	5600	5/11/2007 18:14			5/17-18, Tag Not Moving			
5/11/2007	12:05	Bowman Rd.	5614			5/13/2007 9:36				
5/11/2007	12:05	Bowman Rd.	5628	5/11/2007 18:20						
5/11/2007	12:05	Bowman Rd.	5642	5/13/2007 3:45			5/17-18, Tag Not Moving			
5/11/2007	12:05	Bowman Rd.	5663	5/11/2007 19:43			5/17-18, Tag Not Moving			
5/11/2007	12:05	Bowman Rd.	5698			5/12/2007 20:02				
5/11/2007	12:05	Bowman Rd.	5677				5/17-18, Tag Not Moving			
5/11/2007	12:05	Bowman Rd.	5684				5/17-18, Tag Not Moving			
5/11/2007	12:05	Bowman Rd.	5691				5/17-18, Tag Not Moving			
5/11/2007	12:05	Bowman Rd.	5705				5/17-18, Tag Not Moving			
5/11/2007	12:05	Bowman Rd.	5719	5/13/2007 17:24			5/17-18, Tag Not Moving			
5/11/2007	12:05	Bowman Rd.	5754	5/13/2007 10:06						
5/11/2007	12:05	Bowman Rd.	5761	5/11/2007 19:51						
5/11/2007	12:05	Bowman Rd.	5782	5/12/2007 6:02						
5/11/2007	12:05	Bowman Rd.	5796	5/17/2007 2:36			5/17-18, Tag Not Moving			
5/11/2007	12:43	Stockton	5803				5/17-18, Tag Not Moving			
5/11/2007	12:43	Stockton	5824				5/17-18, Tag Not Moving			
5/11/2007	12:43	Stockton	5838			5/13/2007 19:13				
5/11/2007	12:43	Stockton	5845			5/12/2007 17:57				
5/11/2007	12:43	Stockton	5873				5/17-18, Tag Not Moving			
5/11/2007	12:43	Stockton	5901				5/17-18, Tag Not Moving			
5/11/2007	12:43	Stockton	5915				5/17-18, Tag Not Moving			
5/11/2007	12:43	Stockton	5936			5/13/2007 8:50				
5/11/2007	12:43	Stockton	5943				5/17-18, Tag Not Moving			
5/11/2007	12:43	Stockton	5950				5/17-18, Tag Not Moving			
5/11/2007	12:43	Stockton	5971				5/17-18, Tag Not Moving			
5/11/2007	12:43	Stockton	5978			5/12/2007 8:16		5/13/07 21:12, Tracy		
5/11/2007	12:43	Stockton	5985				5/17-18, Tag Not Moving			

Appendix A-6 (cont.). Detections of acoustic-tagged salmon from May 10 & 11 releases upstream of the Head of Old River Barrier

Release Date	Release Time	Release Site	Tag Code	Upstream of HORB Date/Time	Bowmand Road Date/Time	Stockton Date/Time	Turner Cut Date/Time	R16 Date/Time	Near Stockton Date/ Comment	Other Locations Date/Comment
5/11/2007	12:43	Stockton	5999				5/17-18, Tag Not Moving			
5/11/2007	12:43	Stockton	6020			5/13/2007 13:51				
5/11/2007	12:43	Stockton	6062				5/17-18, Tag Not Moving			
5/11/2007	12:43	Stockton	6083				5/17-18, Tag Not Moving			
5/11/2007	12:43	Stockton	6090				5/17-18, Tag Not Moving			
5/11/2007	12:43	Stockton	6097				5/17-18, Tag Not Moving			
5/11/2007	12:43	Stockton	6111				5/17-18, Tag Not Moving			
5/11/2007	12:43	Stockton	6118				5/17-18, Tag Not Moving			
5/11/2007	12:43	Stockton	6174				5/17-18, Tag Not Moving			
5/11/2007	12:43	Stockton	6181			5/13/2007 9:54				
5/11/2007	12:43	Stockton	6188				5/17-18, Tag Not Moving			
5/11/2007	12:43	Stockton	6195				5/17-18, Tag Not Moving			
5/11/2007	12:43	Stockton	6202				5/17-18, Tag Not Moving			
5/11/2007	12:43	Stockton	6230				5/17-18, Tag Not Moving			
5/11/2007	12:43	Stockton	6251				5/17-18, Tag Not Moving			
5/11/2007	12:43	Stockton	6258				5/17-18, Tag Not Moving			
5/11/2007	12:43	Stockton	6265				5/17-18, Tag Not Moving			
5/11/2007	12:43	Stockton	6293			5/14/2007 10:26				
5/11/2007	12:43	Stockton	6300				5/17-18, Tag Not Moving			
5/11/2007	12:43	Stockton	6307				5/17-18, Tag Not Moving			
5/11/2007	12:43	Stockton	6314				5/17-18, Tag Not Moving			
5/11/2007	12:43	Stockton	6321		5/13/2007 6:25					
5/11/2007	12:43	Stockton	6328			5/12/2007 19:00				
5/11/2007	12:43	Stockton	6342				5/17-18, Tag Not Moving			
5/11/2007	12:43	Stockton	6384				5/17-18, Tag Not Moving			
5/11/2007	12:43	Stockton	6391				5/17-18, Tag Not Moving			
5/11/2007	12:43	Stockton	6405				5/17-18, Tag Not Moving			
5/11/2007	12:43	Stockton	6412			5/13/2007 19:40				
5/11/2007	12:43	Stockton	6419		5/12/2007 11:07					

Appendix A-7. Detections of acoustic-tagged salmon released May 11 downstream of the Head of Old River Barrier (table)

Release Date: May 11, 2007				Release Location: Old River downstream of HORB			
Release Date	Release Time	Release Site	Tag Code	Tracy Fish Facilities Date/Time	Clifton Court Inlet Date/Time	Skinner Fish Facilities Date/Time	Old River at Hwy 4 Date/Time
5/11/2007	11:22	D/S of HORB	4403			5/13/2007 15:58	
5/11/2007	11:22	D/S of HORB	4424	5/14/2007 14:32		5/18/2007 16:06	5/13/2007 20:41
5/11/2007	11:22	D/S of HORB	4431	5/13/2007 17:00			
5/11/2007	11:22	D/S of HORB	4438	5/13/2007 17:19			
5/11/2007	11:22	D/S of HORB	4452	5/15/2007 17:11			
5/11/2007	11:22	D/S of HORB	4466	5/13/2007 20:30			
5/11/2007	11:22	D/S of HORB	4487			5/14/2007 4:48	
5/11/2007	11:22	D/S of HORB	4494	5/15/2007 14:32			
5/11/2007	11:22	D/S of HORB	4501	5/13/2007 14:56			
5/11/2007	11:22	D/S of HORB	4515	5/14/2007 2:15			5/14/2007 12:14
5/11/2007	11:22	D/S of HORB	4522	5/13/2007 14:40			
5/11/2007	11:22	D/S of HORB	4529	5/15/2007 11:01			
5/11/2007	11:22	D/S of HORB	4536				5/13/2007 21:50
5/11/2007	11:22	D/S of HORB	4543				5/14/2007 21:42
5/11/2007	11:22	D/S of HORB	4564	5/15/2007 1:08			
5/11/2007	11:22	D/S of HORB	4585				5/13/2007 17:36
5/11/2007	11:22	D/S of HORB	4592	5/14/2007 0:45			
5/11/2007	11:22	D/S of HORB	4599	5/12/2007 19:58			
5/11/2007	11:22	D/S of HORB	4606	5/13/2007 9:25			
5/11/2007	11:22	D/S of HORB	4620				5/13/2007 18:14
5/11/2007	11:22	D/S of HORB	4669	5/13/2007 14:51			
5/11/2007	11:22	D/S of HORB	4683	5/13/2007 0:00			
5/11/2007	11:22	D/S of HORB	4704				5/14/2007 1:40
5/11/2007	11:22	D/S of HORB	4725	5/16/2007 2:11			
5/11/2007	11:22	D/S of HORB	4746	5/13/2007 2:12			
5/11/2007	11:22	D/S of HORB	4760	5/14/2007 14:28			5/13/2007 21:00
5/11/2007	11:22	D/S of HORB	4781	5/12/2007 19:11			
5/11/2007	11:22	D/S of HORB	4802	5/15/2007 14:09			
5/11/2007	11:22	D/S of HORB	4809	5/18/2007 17:34			
5/11/2007	11:22	D/S of HORB	4830	5/13/2007 11:58			
5/11/2007	11:22	D/S of HORB	4837				5/14/2007 18:39
5/11/2007	11:22	D/S of HORB	4844	5/14/2007 1:37			
5/11/2007	11:22	D/S of HORB	4879	5/13/2007 23:07			
5/11/2007	11:22	D/S of HORB	4900	5/15/2007 1:00			
5/11/2007	11:22	D/S of HORB	4942	5/13/2007 18:04			
5/11/2007	11:22	D/S of HORB	5033	5/13/2007 8:33			
5/11/2007	11:22	D/S of HORB	5054	5/13/2007 8:09			
5/11/2007	11:22	D/S of HORB	5068				5/14/2007 6:11
5/11/2007	11:22	D/S of HORB	5082	5/14/2007 15:08			
5/11/2007	11:22	D/S of HORB	5096	5/16/2007 18:38			