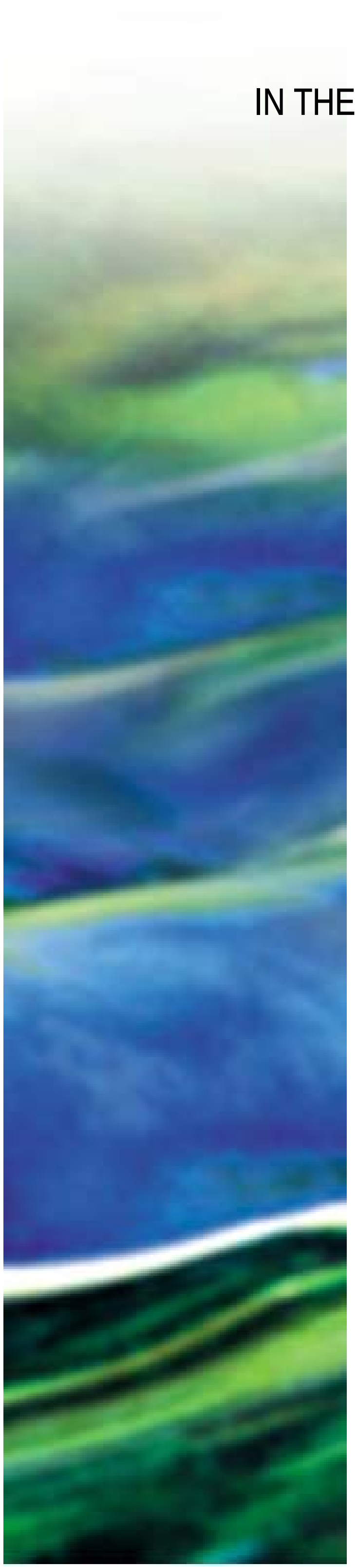
ASSESSMENT OF FISH MORTALITY OBSERVED IN THE SAN JOAQUIN RIVER NEAR STOCKTON IN MAY 2007



Prepared for:

CITY OF STOCKTON

Prepared by:

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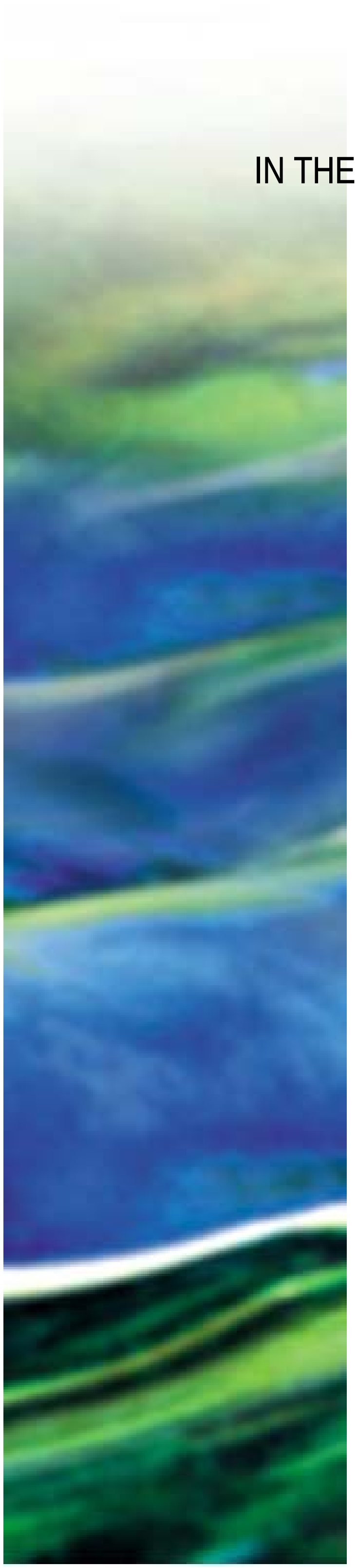
Specializing in Water and Power Resources

October 2007



ASSESSMENT OF FISH MORTALITY OBSERVED IN THE SAN JOAQUIN RIVER NEAR STOCKTON IN MAY 2007

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ACRONYMS AND ABBREVIATIONS

ADWF	average dry weather flow
CCB	chlorine contact basin
CCC	criteria continuous concentration
CDFG	California Department of Fish and Game
cfs	cubic feet per second
City	City of Stockton
CMC	criteria maximum concentration
Delta	Sacramento-San Joaquin Delta
DMR	Discharge Monitoring Report
DO	dissolved oxygen
DWSC	Deep Water Ship Channel
F	Fahrenheit
ft	feet
mgd	million gallons per day
mi	mile
NOEC	no observable effects concentration
NPDES	National Pollutant Discharge Elimination System
NRS	Natural Resource Scientists, Inc.
RM	river mile
RWCF	Regional Wastewater Control Facility
RWQCB	Regional Water Quality Control Board, Central Valley Region
SCADA	supervisory control and acquisition database
USGS	United States Geological Survey
VAMP	Vernalis Adaptive Management Plan
WET	whole effluent toxicity
WWTP	wastewater treatment plant

EXECUTIVE SUMMARY

The City of Stockton (City) owns and operates the Regional Wastewater Control Facility (RWCF), which provides sewerage service to the City, the Port of Stockton, and surrounding urbanized areas. On May 17 and 18, 2007, the acoustic transmitting tags from 116 tagged juvenile chinook salmon were discovered in the immediate vicinity of the railroad bridge located 450 feet upstream of the RWCF outfall. The tagged fish were part of a large-scale pilot study by Natural Resource Scientists, Inc., to characterize the emigration patterns of juvenile chinook salmon (*Oncorhynchus tshawytscha*).

The purpose of this assessment is to determine whether treated effluent discharged from the RWCF could have caused the salmon mortality observed in the vicinity of the railroad bridge in May 2007. Therefore, this report examined all water quality data collected by the RWCF and the results of all bioassays conducted during the period preceding the discovery of the acoustic tags (i.e., May 1–18, 2007). This assessment focused primarily on effluent-derived toxicity, but also examined other factors that may have been wholly or partially responsible for the mortality of the tagged juvenile chinook salmon.

The observed pattern of fish mortality, localized to a small well-defined site and with a substantial increase in tags from May 17 to May 18, is not indicative of chronic toxicity, but rather is indicative of acute toxicity, should toxicity have been the cause of the juvenile salmon mortality. This assessment is divided into two major sections to address the potential impacts of the RWCF effluent on juvenile chinook salmon passing though this reach of the San Joaquin River—a water quality assessment and a fisheries assessment.

Conclusions

The available May 2007 monitoring data from the RWCF indicated that all water quality parameters evaluated that have NPDES permit limits were within limits set forth in the RWCF's NPDES permit for the protection of aquatic life. Further consideration was given to ammonia concentrations to compare with water quality objectives and literature toxicity threshold values. Worst-case average ammonia concentrations in the San Joaquin River were found to be below the corresponding 30-day criteria continuous concentration (CCC) for toxicity to aquatic life. In addition, available water temperature and dissolved oxygen data for both the treated effluent and receiving water were well within the published tolerance values for juvenile chinook salmon. There is no indication that water temperatures were sufficiently elevated, nor were dissolved oxygen concentrations sufficiently decreased, to create a thermal barrier to fish migration. Based on this review of available data, it is unlikely that discharges of treated effluent from the RWCF caused the mortality of the 116 tagged juvenile chinook salmon in the vicinity of the railroad bridge in May 2007.

1 INTRODUCTION

1.1 Background

The City of Stockton (City) owns and operates the Regional Wastewater Control Facility (RWCF), which provides sewerage service to the City, the Port of Stockton, and surrounding urbanized areas. The RWCF is located immediately west-southwest of the City. This facility treats domestic and industrial wastewaters and discharges the treated municipal wastewater though a single outfall to the San Joaquin River (**Figure 1**) located approximately 1.5 miles upstream of the Deep Water Ship Channel (DWSC). The RWCF discharges an average of approximately 32 million gallons per day (mgd) (50 cubic feet per second [cfs]) through a 4-foot-diameter discharge pipe extending upward from the river channel bottom 25 feet from the west river bank into approximately 15 feet of water. The San Joaquin River channel is approximately 250 feet wide at the RWCF discharge location.

The RWCF, which currently consists of a secondary treatment facility, has a design average dry weather flow (ADWF) of 42 mgd and a tertiary treatment facility with a design ADWF of 55 mgd. The City has largely completed a staged expansion of the secondary treatment facility. The expansion includes construction of additional anaerobic sludge digesters, improvements to the sludge management system, supervisory control and data acquisition (SCADA) improvements, biotower improvements, construction of additional primary sedimentation and other ancillary improvements. This expansion will increase the secondary design ADWF to 48 mgd when completed. The City has recently added nitrification biotowers and has achieved the designed ammonia removal.

During the 2007 Vernalis Adaptive Management Program (VAMP), researchers from Natural Resource Scientists, Inc. (NRS) conducted a large-scale pilot study to characterize the emigration patterns of juvenile chinook salmon (*Oncorhynchus tshawytscha*). Approximately 800 juveniles were surgically implanted with individually identifiable acoustic transmitting tags and released at five locations upstream of the RWCF outfall. On May 17 and 18, 2007, the acoustic transmitting tags from 116 of the tagged juvenile chinook salmon were discovered in the immediate vicinity of the railroad bridge located 450 feet upstream of the RWCF outfall (Figure 1). The tags were lying motionless on the river bottom and, therefore, the tagged fish are presumed to have perished. NRS published a report summarizing their investigation of the fish morality (NRS 2007; Appendix A). The report indicates that the "*…transmitters were either in dead fish or had been eaten by predators and defecated…*" However, in this report, the author also recommended an investigation of the site to determine if the cause of the fish mortality could have been related to water quality.

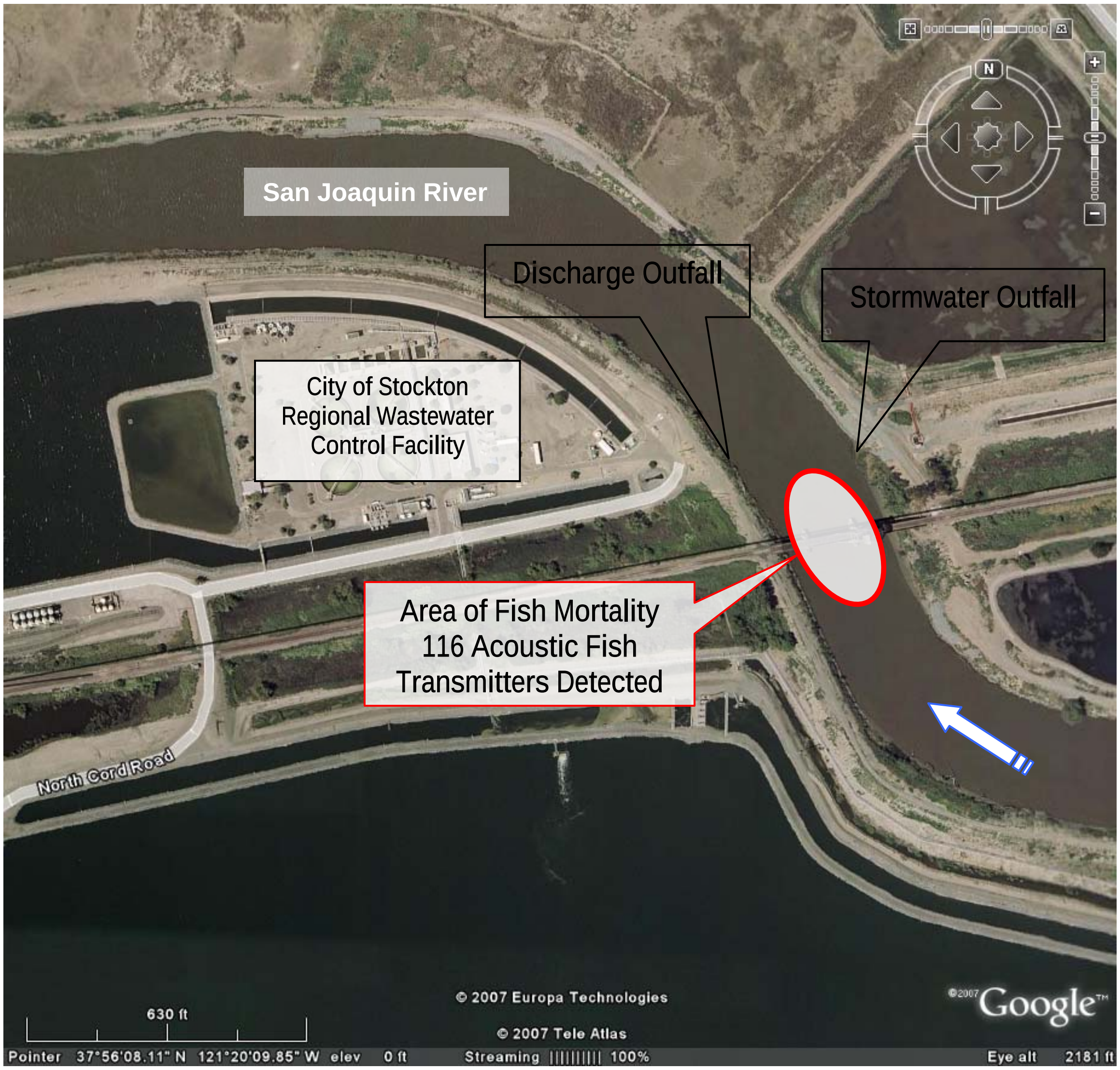

Figure 1. San Joaquin River in the vicinity of the fish mortality event.

1.2 Purpose of Assessment

On May 22, 2007, staff from the California Department of Fish and Game (CDFG) and California Regional Water Quality Control Board (Regional Water Board) conducted a one-day site inspection of the RWCF. The purpose of the investigation was to determine whether the RWCF caused the mortality of the juvenile salmon. Attending this inspection were Lieutenant Hector Orozca (Inland Pollution Coordinator, CDFG), Lori Oldfather (Warden, CDFG), and Patricia Leary (Senior Engineer, Regional Water Board). Agency staff were provided with a tour of the facility and allowed to examine relevant water quality data for the period in which the fish mortality was believed to have occurred. Based on the inspection of the facility and the water quality data, CDFG staff determined that the effluent discharged from RWCF did not cause the observed fish mortality. Consequently, no charges were filed and no report was submitted (Orozca, pers. comm., 2007). However, agency staff examined only a subset of the water quality data monitored by the RWCF, emphasizing the conventional water quality parameters that are typically associated with acute fish toxicity. Furthermore, analytical results of some of the water quality parameters may not have been reported at the time of their investigation and, therefore, would not have been available for their inspection. Therefore, this report will examine all water quality data collected by the RWCF and reported in the City's Discharge Monitoring Reports (DMRs) and the results of all bioassays conducted during the period preceding the discovery of the fish kill (i.e., May 1–18, 2007). The purpose of this assessment is to determine whether treated effluent discharged from the RWCF caused the salmon mortality observed near the railroad bridge in May 2007. This assessment will focus primarily on effluent-derived toxicity, but will also examine other factors that may have been wholly or partially responsible for the fish mortality, such as predation by pisivorous fishes holding near the railroad bridge.

1.3 Causes and Characteristics of Fish Kills

To determine whether discharges from the RWCF caused or contributed to the fish mortality that occurred upstream of the outfall in May 2007, it is important to understand the causes and characteristics of various types of fish kills. Fish kills may occur as a result of natural causes and/or in response to human-caused factors. The most common causes of fish kills in freshwater include natural causes, such as oxygen depletion, critically high or low temperatures, predation, toxic algae blooms, gas supersaturation, infectious agents (e.g., viral, bacterial, fungal, parasitic), naturally occurring toxic substances; as well as anthropogenic causes, which are primarily associated with discharges and/or runoff of elevated concentrations of toxic substances into water bodies (Southwick and Loftus 2003; Reid et al. 2002; Meyer and Barclay 1990).

It is important to note that, in order to determine or make a rational judgment regarding the cause of fish kill, the American Fisheries Society has published guidelines (Southwick and Lotus 2003) outlining the information and data that should be collected at the time, or shortly following, a reported fish kill. Furthermore, many state and federal agencies have developed their own recommended guidelines and/or established protocols for investigating fish kills. These guidelines typically include enumerating the number of dead fish observed (typically floating at the water surface), describing the site-specific physical characteristics, and collection of water samples for chemical analyses. A list of some of the most common conditions that may be observed at a fish kill site and some of the potential causes (Southwick and Loftus 2003) is provided in **Table 1**. Large-scale predation, which is not included in Table 1, is difficult to identify because the dead fish typically cannot be observed without capturing the predators (e.g., piscivorous fish, birds, mammals) and analyzing their stomach contents.

Table 1. Conditions that may be observed at a fish kill site and their possible causes (reproduced from Southwick and Loftus 2003).

Condition	Possible Cause
1. Fish come to the surface (usually larger fish) and gulp air, and the water has low dissolved oxygen (DO).	Organic matter has depleted the DO. Look for sewage treatment plant or life station live-stock feedlot, irrigation runoff, or algal bloom (green water).
2. Fish come to the surface and gulp air, but the water has adequate DO.	DO may have been depleted, but partly restored over time; look for the sources of organic matter listed above. Ammonia may have reached toxic concentrations; check water chemistry and look for a livestock feedlot. Check for an infestation of gillworms; for a toxic algal bloom if the water is discolored; and for a source of chlorine if scales or gills are bloody and sewage treatment is nearby.
3. Fish are dying after a heavy rain.	Pesticides or other chemicals may have been washed off adjacent agricultural fields, dumped from spraying equipment, or discharged during aerial spraying. Toxic or septic sediments could have been stirred up.
4. Water has an oily sheen.	A drilling operation, a refinery, or a leaky pipeline is in the area; or petroleum spilled from a truck or service station.
5. Streambanks and stream bottom are covered with an orange substance, and water conductivity is high.	Oil drilling operations have discharged brine water.
6. Water has low pH, with or without orange discoloration of substrate, but good water clarity.	Acidic water has discharged from a coal mine or a chemical spill has occurred.
7. Only small fish along the shoreline have died, and air temperature is subfreezing.	Fish were killed by excessive cold.
8. Many small fish are dead below a dam or an industrial plant that discharges heated water.	Fish were killed by passage through dam gates or hydroelectric turbines, or from thermal shock.
9. Kill is restricted to one species or size-class.	Fish may have died from spawning stress, disease pathogens, or schooling in poor-quality water.

2 ASSESSMENT APPROACH AND METHODOLOGY

The observed pattern of fish mortality, localized to a small well-defined site is not indicative of chronic toxicity, but rather is indicative of acute toxicity. This assessment is divided into two major sections to address the potential impacts of RWCF’s effluent on juvenile chinook salmon in the San Joaquin River at the time of the observed fish mortality—a water quality assessment and a fisheries assessment section.

In short, numerous factors/conditions can cause widespread or species-specific mortality. Chemical toxicity is but one potential cause worthy of evaluation. However, none of the water quality samples or other “protocol” data identified in Section 1.3 were collected on May 17–18, 2007 at the fish mortality location.

In the water quality assessment, RWCF’s effluent was assessed to determine whether toxicants were present in the effluent in amounts that would result in acute or chronic toxicity to juvenile chinook salmon in the San Joaquin River on or about May 17, 2007. This effluent quality assessment compared effluent quality to permit limitations and water quality objectives. Whole effluent toxicity (WET) bioassay results were also reviewed to determine evidence of indirect toxicity or additive/synergistic effects. Constituents present in effluent at concentrations below water quality standards would not cause acute lethality; therefore, those constituents were not considered further (except as additive/synergistic effects if WET testing indicated toxicity was present). Results are discussed with consideration to limitations of the monitoring data set and in light of treatment plant operations. Water quality parameters that did not meet water quality objectives in the effluent and projected to exceed objectives in the San Joaquin River are discussed further in the fisheries assessment.

For selected constituents, the fisheries assessment compared water quality to literature values for acute toxicity to aquatic life, primarily for salmonids, when information was available. In addition to this water quality assessment, this report briefly evaluates other known causes of fish mortality (i.e., natural causes, including naturally occurring toxins, predation, etc.).

2.1 Water Quality Assessment

As a reference point, the water quality assessment period is defined as May 1 to May 18. This time period includes the two labeled juvenile chinook fish release dates (May 3–4 and May 10–11) and the days when mortality was observed (May 17–18).

2.1.1 Examine Bioassay Data for Evidence of Effluent or Receiving Water Toxicity

Acute and chronic bioassay data were reviewed for test acceptability and evidence of effluent toxicity during the assessment period. Salmonid species are not part of the regular bioassay testing, so particular consideration was given to the species of fish that were used as part of the bioassay testing (i.e., *Pimephales promelas)*. Stockton RWCF evaluates acute toxicity to *Pimephales* on a weekly basis. Three-species chronic WET testing is performed quarterly with *Pimephales, Ceriodaphnia dubia,* and *Selenastrum capricornutum*. If toxicity was observed during the bioassays, monitoring data surrounding the bioassay test(s) was used to help identify key constituents for further screening of toxic effects; specifically, toxicity to juvenile salmon as discussed in Section 2.2.1.

2.1.2 Evaluate Effluent Monitoring Data for Exceedances of Permit Limits and Water Quality Objectives

Water quality data and operational information during the assessment period were collected from DMRs, from the AWCF operations (OP10) database, and from SCADA data logs. The DMRs provided a convenient summary of all monitoring data at a sampling interval of one day or longer. The OP10 database provided daily high and low values for continuously monitored variables. The SCADA data logs were accessed for constituents with continuous monitoring when the duration of daily high or low values was of concern. Water quality data from the assessment period were reviewed to determine if there were exceedances of aquatic life-based effluent limitations and water quality standards. Data from April–August 2007 was available for comparison and to identify either trends in the data or extreme values.

The impact of operational procedures, construction, and maintenance activities on effluent water quality was evaluated through discussion with and information from Harry Morrow, Director of Water Operations, and Greg White, Director of Wastewater Operations, both from OMI/Thames Water.

This assessment of the monitoring data is constrained by the following: (1) sampling may not have occurred when mortality occurred, (2) the cause of mortality may have been an unmonitored constituent, and (3) most data is provided as a daily average or grab sample that may not be representative of short-term conditions. Whether the monitoring data set affects the water quality assessment is discussed with the findings in Section 3.1.

2.1.3 Review Plant Operations Data for Evidence of Potential Effluent Toxicity

An initial review of operational information and the fish mortality report (NRS 2007; Appendix A) identified the following items for evaluation and discussion:

- Was there an explanation for a short-term foamy discharge from RWCF the afternoon of May 17, and if so, was there any indication that effluent quality was likewise variable?
- Was there any possibility that the installation of a chlorine contact basin (CCB) wall liner could have affected effluent quality?

A site visit to investigate a short-term foamy discharge near the RWCF outfall was made on October 16, 2007, to visually inspect for additional discharge pipes/outfalls. Any visual findings made were discussed with David Vogel (NRS) for comparison with conditions at the time of the fish mortality. In addition, 15-minute effluent flow data were reviewed to identify any rapid changes in flow.

OMI/Thames provided further information on the timing and nature of construction activities associated with installing the chlorine contact basin liner. Chlorine residual monitoring data was the basis for assessing whether chlorine toxicity was likely in the effluent.

2.1.4 Summary of Constituents of Concern

For any constituents of concern that may potentially have contributed to the fish mortality event based on effluent concentrations, the final concentration in the San Joaquin River was calculated. This was done based upon prior dilution study findings and with consideration of short-term maximum concentrations versus longer-term average receiving water concentrations.

2.2 Fisheries Assessment

2.2.1 Examine Potential for Acute Lethality to Salmonids

Characterize Salmonid Tolerance to Constituents of Concern

The final subset of constituents that may have been present in acutely toxic concentrations identified using the approach discussed in Section 2.1 was compared to literature values for acute toxicity to fish, focusing on juvenile salmonids, whenever such information was available. These data were then compared with available receiving water quality data and ratios of effluent discharge to San Joaquin River flow to determine the amount of dilution and resulting estimated concentrations to which juvenile chinook salmon may have been exposed.

Determine Duration of Exposure

The duration that the tagged juvenile chinook salmon may have been exposed to elevated concentrations of any constituents of concern was estimated by determining how long and how frequently concentrations of constituents of concern exceeded published thresholds for acute toxicity and how long juvenile salmon may have been exposed to these concentration when migrating through the area. In the event that acutely toxic concentrations of any constituents were detected, a determination was made as to whether or not the tagged fish would have been present near the RWCF outfall by first calculating the distance upstream to the monitoring sensor with which the tagged fish were last detected and multiplying this by the average migration rates of the tagged salmon calculated for the NRS (2007) study to determine the earliest date at which fish may have occurred in the vicinity of the mortality. Since there is no way of knowing the date and time at which the fish were killed, May 18, the date on which all of the 116 tags were discovered, was used as a worst-case cutoff date for determining exposure duration.

Determine Likelihood of Acute Toxicity to Juvenile Salmonids

In order to assess whether the tagged juvenile chinook salmon could have have been killed as a result of toxic conditions, resulting from discharges of treated effluent from the RWCF, the worst-case concentrations (accounting for receiving dilution) of the final constituents of concern identified in Section 2.1 and the worst-case duration of exposure were compared to available published studies to determine if these exceeded or approached any lethal thresholds for salmonids.

2.2.2 Examine Other Potential Causes of Salmon Mortality

In addition to identifying any constituents of concern discharged from the RWCF that may have caused the fish mortality, other factors described in Section 1.3 were examined to determine whether they could have been wholly or partially responsible for the fish kill. Assessment of other factors was complicated by: (1) a lack of site-specific data and/or information regarding the physical condition of the site (Table 1), which is required to make many of these assessments; and (2) the fact that no dead fish were observed, nor were any of the tagged fish recovered. Available water temperature and dissolved oxygen (DO) data for both the effluent and receiving water were examined and compared with literature values to determine whether conditions occurred during the assessment period that could have created a “thermal barrier,” thereby contributing to an increased risk of mortality (e.g., from predation) or toxicity, due to delaying out migration and prolonging time spent in the area.

3 RESULTS AND FINDINGS

3.1 Characterization of Effluent and Receiving Water Quality

3.1.1 Bioassay Results

During the assessment period, two acute bioassays were performed and found *Pimephales* survivability of 100% and 95% on May 7 and May 14, respectively. For the week prior and after the assessment period, survivability was 100%. These test results exceed the permit requirements (RWQCB 2002) that:

> *“Survival of aquatic organisms in 96-hour bioassays of undiluted waste shall not be less than:*
>
> *a. Minimum for any one bioassay 70%*
> *b. Median for any three or more consecutive bioassays 90%”*.

Chronic quarterly three-species WET monitoring occurred in April and July 2007. In May, however, the following short-term chronic bioassay tests were performed with the indicated start date:

- *Selenastrum* on May 14 as part of monthly follow-up testing to evaluate the presence/absence of ongoing algal toxicity, and
- *Pimephales* and *Ceriodaphnia* on May 23 at the Regional Board's request and in support of the VAMP study.

The no observable effects concentration (NOEC) was 100% effluent for all the chronic bioassays indicating that no lethality or sublethal effects were observed in the effluent (see **Table 2)**. A review of the QA/QC data did not indicate any test abnormalities.

Table 2. Summary of Stockton's WRF chronic bioassay results identifying the "no observed effects concentration" (NOEC), May 2007.

Test Initiation Date	Species and Bioassay Test				
	Selenastrum Growth	Ceriodaphnia Survival	Ceriodaphnia Reproduction	Promephales Survival	Promephales Growth
May 14, 2007	100	--	--	--	--
May 23, 2007	--	100	100	100	100

3.1.2 Monitoring Results

The review of RWCF monitoring data from DMRs, the OP10 database daily high and low values for continuously monitored constituents, and additional information from the SCADA logs found one monitored constituent to be greater than aquatic life-based receiving water quality criteria in the effluent: 30-day effluent ammonia levels. All other monitored constituents did not exceed aquatic life-based permit limits or aquatic life-based water quality criteria. This evaluation was made after adjustment for pH, temperature, and hardness as dictated by the limits/criteria.

Ammonia criteria maximum concentration (CMC), assuming salmonids and early life stages were present, were calculated for 1-hour exposure periods based on the maximum daily pH with the following exception: the maximum effluent pH on May 6, 2007 was 7.9. Examination of the SCADA data logs indicates that this pH value occurred for less than 15 minutes as the 15-minute average was 6.9. Therefore, the value 6.9 was used as the maximum pH for the 1-hour CMC. No exceedances of the ammonia CMC criteria, calculated daily, were observed during the assessment period. Neither were there any exceedances of the 4-day chronic ammonia CCC criteria.

Exceedances of the 30-day average CCC were calculated to have occurred in the effluent as indicated in **Table 3**; however, San Joaquin River monitoring data indicates that receiving water concentrations were well below the effluent 30-day average CCC.

Table 3. Effluent ammonia criteria continuous concentrations (CCC) and corresponding effluent ammonia and San Joaquin River ammonia values for days when the CCC was exceeded in the effluent. Ammonia concentration units are mg/L as N.

Date	Effluent Ammonia		San Joaquin River	
	30-day Average CCC	30-day Average Concentration	R2 (0.5 miles upstream) [1]	R2a (0.5 miles downstream) [1]
5/13/2007	4.88	5.03	--	--
5/14/2007	4.80	5.04	--	--
5/15/2007	4.73	5.04	0.2	0.2
5/16/2007	4.68	4.98	--	--
5/17/2007	4.61	4.98	--	--
5/18/2007	4.52	4.90	--	--

Note: [1] Relative to the RWCF outfall.

Based on a review of daily high and low values for parameters with continuous monitoring data, there were no short-term variations in effluent quality, for the period May 16–18, that would result in exceedances of aquatic life criteria.

Other than ammonia discussed above, there were no exceedances of aquatic life-based effluent limitations or aquatic life objectives. **Appendix B** provides tables summarizing monitoring data relevant to aquatic life, the corresponding effluent limits, the relevant aquatic life objectives, and an indication of the number of exceedances of limits or objectives (i.e., none other than the discussion for ammonia above).

3.1.3 Plant Operations

As indicated in Section 2.1.3, an initial review of operational information and the fish mortality report (NRS 2007; Appendix A) identified the following two items for evaluation and discussion:

1) Was there an explanation for a short-term foamy discharge from RWCF the afternoon of May 17, and if so, was there any indication that effluent quality was likewise variable?
2) Was there any possibility that the installation of a CCB wall liner could have affected effluent quality?

Effluent flow records on May 17, 2007, indicate that there were three periods, lasting from 15 minutes to one hour, when the discharge was interrupted and restarted. The rapid change in flow from zero flow to, at times, 50 mgd in as little as 15 minutes may have caused short-term, transient foaming from turbulent mixing. There was no indication of coincident changes in effluent quality.

Beginning May 7, 2007, and continuing through June 7, 2007, DC Taylor installed a liner along the walls of the chlorine contact basin (CCB). During the liner installation, the water level in the CCB was always 2–3 feet below the bottom of the footing of the new walls and 2–3 feet below the CCB liner. The water level was not raised above the bottom of the liner until sometime after June 7, 2007. Furthermore, DC Taylor was provided guidelines in the installation of the CCB liner and was required to report any accidental spillage immediately to the Operations staff. Special controls were in effect to allow time for Operations to react to a spill if one did occur. The installation of the CCB liner was closely supervised by both DC Taylor and the Design/Build team at all times. During the installation of the CCB liner, there were no reported spills by DC Taylor or the Design/Build Team (Morrow 2007).

3.1.4 Projected Constituent Concentrations in the San Joaquin River

For the one monitored constituent that exceeded objectives in the effluent, 30-day average ammonia concentrations, an analysis follows to determine the corresponding ammonia concentrations that would result from the RWCF discharge during the assessment period.

Available Dilution

The outfall discharge flow provides a zone of initial jet mixing that extends out with a radius of 125 feet from the discharge pipe. Dilution within the 125-foot-radius is provided by jet mixing and the dilution varies from 7 to 10, depending on the tidal flow deflection of the jet plume.

The tidal flow in the San Joaquin River at the discharge location moves river water past the discharge point several times before the net river flow pushes the water downstream. Each time river water moves back and forth, it is subjected to repeated dosing by the RWCF's discharge. The worst-case scenario for multiple dosing occurs at slack tide after a high tide, and with low net river flow. Under these conditions, the effluent is discharged into zero net flow, due to the slack tide, and the duration is extended because there is little net river flow to assist the tidal reversal.

To account for the cumulative impacts of multiple dosing on RWCF effluent dilution in the San Joaquin River, a dilution study was performed that modeled river concentrations based on a 50 cfs (32 mgd) discharge and various low net river flows (150, 450, and 950 cfs) (Jones & Stokes 2001). A field study, performed to verify the dilution model, occurred when the San Joaquin River net flow was 1,250 cfs. Since the modeling did not evaluate net river flows greater than 950 cfs, the field study dilution results (net river flow of 1,250 cfs) were used for this assessment, as explained further below. The minimum measured river dilution on the west side of the river at the discharge location was 6.6:1 during the field dilution study. The area of elevated effluent contribution was approximately 550 feet long by 63 feet wide. The average observed dilution at the discharge location during the field dilution study was greater than 16.7:1.

The USGS maintains a tidal stage and flow monitoring station approximately 2,200 feet upstream of the discharge location called the San Joaquin River at Garwood Bridge. During the assessment period, the net daily flow, as measured at the USGS flow station, varied from 2,020 cfs to 2,590 cfs. The RWCF did not discharge on three days (May 1, 2, and 10). On the remaining days the average daily discharge flow varied from 11.4 to 32.6 mgd with an overall average discharge of 27 mgd. Thus, the discharge flows are comparable to those considered in the dilution study (Jones & Stokes 2001), while the San Joaquin River flows from May 1–18, 2007, are larger then the flows modeled or measured in the dilution study. These larger net river flows provide greater dilution than occurred during the field study.

Therefore, under the conditions in the first half of May 2007, the minimum dilution of 6.6:1 is conservative because the observed net river flows are about twice the river flows when this dilution ratio was measured. This level of dilution was used to evaluate acute toxicity consideration (i.e., acute ammonia toxicity). The average observed dilution at the discharge location during the field dilution study was 16.7:1. To assume this as the minimum dilution for chronic toxicity assessment is conservative since net river flows in May 1–18, 2007, were twice the net river flows during the field dilution study.

Ammonia Concentrations in the San Joaquin River

The 30-day ammonia CCC can be calculated from the pH and temperature data in the San Joaquin River on May 15, 2007 (see Appendix B) for the R2 and R2a monitoring locations, (0.5 miles upstream and downstream, respectively, of the RWCF outfall). The 30-day CCC at R2 would be 1.4 mg/L ammonia (as N), while the corresponding criteria at R2a would be 1.63 mg/L (as N). **Table 4** summarizes average ammonia concentrations in the San Joaquin River, given the observed effluent and receiving water quality during May 1–18, 2007, and the lower limit of 16:7 dilution (the R1 upstream ammonia was 0.2 mg/L on May 15, 2007).

Table 4. Ammonia concentrations (mg/L as N) in effluent and in the receiving water based on the minimal low-flow dilution study (Jones and Stokes 2001) for days when the 30-day CCC was exceeded in the effluent.

Date	30-day Effluent Average	R1 [1]	Worst-case dilution (15:1) at R2/R2a	Observed R2/R2a on May 15, 2007
5/13/2007	5.03	0.2	0.47	
5/14/2007	5.04	0.2	0.47	
5/15/2007	5.04	0.2	0.47	0.2
5/16/2007	4.98	0.2	0.47	
5/17/2007	4.98	0.2	0.47	
5/18/2007	4.90	0.2	0.47	
Notes: [1] based on May15, 2007 monitoring data.				

3.2 Fisheries Assessment Findings

3.2.1 Assessed Potential for Acute Lethality to Salmonids

Three monitored constituent parameters (i.e., 30-day average effluent ammonia, dissolved oxygen, and temperature) were evaluated in this fisheries assessment for potentially lethal impacts to juvenile chinook salmon. The ammonia fisheries assessment was triggered by 30-day average effluent ammonia exceeding aquatic life-based criteria. The resultant ammonia concentrations in the San Joaquin River were calculated in the previous section. Dissolved oxygen and temperature were considered because they are two of the most common causes of fish kills.

Threshold Toxicity Values and Toxicity Potential in the San Joaquin River

Ammonia toxicity to salmonids has been incorporated into the existing EPA-recommended ammonia criteria along with protective criteria for early life stages. As such, the water quality criteria were used as the appropriate toxicity threshold value for ammonia. A review of Table 4 indicates that San Joaquin River ammonia concentration did not exceed the most restrictive 30-day CCC (1.4 mg/L at R2) even when the 30-day CCC was exceeded in the effluent (May 13–18, 2007). Compliance with the ammonia criteria, particularly when demonstrating compliance in the receiving water, is deemed sufficient to demonstrate an absence of toxicity due to discharges of ammonia from the RWCF.

Dissolved Oxygen Depletion

One of the most common causes of fish kills is depletion of DO concentrations. DO concentrations measured in the RWCF effluent during the assessment period ranged from 6.6 to 9.0 mg/L. DO concentrations measured in the San Joaquin River at R1 (i.e., upstream of the outfall) and at R2 (i.e., downstream of the outfall) were higher yet, ranging from 8.8 to 9.7 mg/L. Based on a compilation and review of published salmonid DO requirements, Hicks (2000) reported that salmonid mortality would not be expected when DO concentrations are as low as 3.5 to 4.0 mg/L when temperatures are as high as 68°F. Because the DO values in both the treated effluent and the receiving water were within the criteria for protection of aquatic life and published thresholds for salmonids, it is unlikely that the tagged fish were killed as a result of DO depletion. This conclusion is further supported by the fact that no reports of large numbers of dead fish were reported (e.g., by fishermen), nor were other characteristic indications of critical oxygen depletion (e.g., fish “gulping” at the surface) reported.

Elevated Temperatures

Fish may be killed as a result of exposure to sufficiently elevated temperatures or by short-term exposure to substantial rapid temperature changes (i.e., “thermal shock”). Brett (1952) reported that spring-run juvenile chinook salmon acclimated to a temperature of 59°F had an upper lethal temperature of >77°F (for a one-week exposure). Bjornn and Reiser (1991) also state that salmonids usually try to avoid stressful temperature conditions when possible by moving to other areas. Gray et al. (1977) reported that juvenile chinook salmon avoided heated thermal plumes when plume temperatures were 16°F to 19°F above ambient water temperature. These authors report that behavioral adaptations may prevent juvenile chinook salmon in nature from experiencing lethal conditions from thermal discharges. Kerr (1953) subjected yearling fall-run chinook salmon acclimated to 55–56°F to instantaneous rises of up to 27°F for 3.5 to 5 minutes and found no mortality with a 25°F rise and reported a maximum temperature tolerance of 83°F. Boles (1988) reviewed numerous studies conducted on thermal tolerance of salmonids and reported that the upper lethal temperature for long-term exposure among fingerling chinook salmon in the Sacramento River to be 78.5°F, although higher temperatures can be tolerated for brief periods.

The maximum effluent temperature recorded between the time the tagged juvenile fish were released and the tags were discovered was 73.9°F (May 9, 2007). Furthermore, the maximum temperature recorded on the days in which the tags were initially discovered (May 17, 2007) and the following day, when more tags were discovered, was 69.6°F. Weekly grab samples at the R1 and R2 monitoring stations during the assessment period indicate that temperatures reached 68°F (Appendix B). Given the fact that measured effluent temperatures were below the published thermal tolerances for juvenile chinook salmon, combined with the substantial dilution that occurs at the outfall location, the tagged fish were not directly killed as a result of exposure to an acutely lethal thermal plume created by discharges from the RWCF.

3.2.2 Other Potential Causes of Salmon Mortality

Given the absence of any indication that discharges of toxic compounds or degraded water quality stemming from the RWCF may have caused the fish mortality observed near the railroad bridge over the San Joaquin River upstream of the outfall, other potential causes of the mortality were examined. It is difficult, if not impossible, to conclusively identify whether any of the potential causes described in Table 1 were responsible for the observed fish mortality because no formal protocol to characterize the physical conditions at the site was followed, nor is there sufficient San Joaquin River water quality data in the vicinity to determine if acutely lethal conditions for juvenile salmon existed at the time of their passage through this reach. However, given the available information provided by the RWCF, the NRS (2007) report, and anecdotal information, some potential conclusions can be made regarding the fate of the tagged salmon.

It is important to note that there were no other reports of fish kills in the San Joaquin River near Stockton in May 2007. Fish kills resulting from elevated concentrations of toxic compounds or DO depletion would be expected to cause a die-off of multiple species and life stages. Consequently, relatively large numbers of dead fish would likely be observed floating on the water surface. However, no dead fish were reported and none of the tagged fish that are presumed to have been killed were ever observed or recovered.

The supports for the railroad bridge and remnant supports located under the railroad bridge (**Figure 2**), create hydraulic breaks in the river, which often harbor piscivorous fish, such as striped bass (*Morone saxatilis*), largemouth bass (*Micropterus salmoides*), smallmouth bass (*Micropterus dolomieui*), catfish (*Ictalurus* spp.) and Sacramento pikeminnow (*Ptychocheilus grandis*). These fish are opportunistic ambush predators that will hold in the low-velocity water near cover and prey upon smaller fish as they pass by. Anecdotal information (e.g., from fishermen and RWCF staff) indicates that the San Joaquin River immediately upstream, downstream, and underneath the railroad bridge is a popular fishing spot for these game fish, especially during the spring months, when striped bass are relatively abundant in the lower San Joaquin River.

Figure 2. Railroad bridge located upstream of the RWCF. Note the bridge supports and remnant supports underneath the bridge, which provide holding habitat for piscivorous fish.

Furthermore, the NRS (2007) report indicates that the tags from the lost fish were located in a relatively concentrated area immediately upstream, downstream, and underneath the railroad bridge. Had the fish died of the potential causes listed in Table 1, the tags would likely have been spread over a larger area. Furthermore, had the fish been killed as a result of elevated concentration of toxic compounds discharged from the RWCF, the tags likely would have been distributed upstream and downstream of the RWCF outfall. The high concentration of tags scattered around the bridge, coupled with the fact that no dead fish were observed, provides evidence supporting the idea that the tagged chinook salmon were simply eaten by predators that were holding near the railroad bridge and the tags were defecated at this predatory fish holding site.

Given the available information, it is not known if the susceptibility of the tagged juvenile chinook salmon to predation was exacerbated as a result of degraded water quality. Elevated water temperatures combined with depressed DO concentrations across the entire channel cross-section can create “barriers” to fish migration, in which emigrating fish will hold upstream of the degraded water until conditions are more favorable for migration. Likewise, emigrating juveniles will often avoid toxic plumes by holding and/or by moving upstream when no unaffected zone of passage occurs at a point-source input. In the case of the lower San Joaquin River near the railroad bridge, if such conditions were temporarily created by the RWCF discharges and/or other point-source discharges in the vicinity (e.g., the outfall located on the east bank), the tagged juvenile chinook salmon could potentially have been holding near the railroad bridge and, consequently, increased their risk of being preyed upon by larger fish holding around the structure. However, based on available water quality data for both the effluent and receiving water (Appendix B), there is no indication that treated effluent discharged from the RWCF caused such conditions.

Juvenile chinook salmon may temporarily delay their migrations when encountering sufficiently elevated temperatures and/or depressed DO concentrations. Whitmore et al. (1960) reported that juvenile chinook salmon avoided DO concentrations of 4.5 mg/L or less, but displayed no avoidance behavior at 6 mg/L during the summer period when water temperatures were elevated. Gray et al. (1977) reported that juvenile chinook salmon avoided heated thermal plumes when plume temperatures were 16°F to 19°F above ambient water temperature. Based on the available water temperature data collected from grab samples (Appendix B), temperature differences between RWCF effluent and receiving water were much less than this. Given the available water temperatures and DO concentrations measured in both the RWCF effluent and the San Joaquin River in the vicinity of the outfall, there is no indication that water temperatures were sufficiently elevated and/or DO concentrations were depressed as a result of RWCF discharges to levels that would cause juvenile chinook salmon to delay their migrations. Thus, it is unlikely that a thermal barrier or hypoxic conditions contributed to an increased rate of predation.

4 CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions

The available May 2007 monitoring data from the RWCF indicate that all water quality parameters were within limits set forth in the RWCF's NPDES permit. Further consideration was given ammonia concentrations to compare with water quality objectives and literature toxicity threshold values. Worst-case average ammonia concentrations in the San Joaquin River were found to be below the corresponding 30-day CCC objectives.

Furthermore, available water temperature and dissolved oxygen data for both the treated effluent and receiving water were well within the published tolerance values for juvenile chinook salmon. There is no indication that water temperatures were sufficiently elevated, nor were dissolved oxygen concentrations sufficiently decreased, to create a thermal barrier to fish migration. Based on this review of available data, it is unlikely that any of the constituents assessed herein that are influenced by the RWCF discharges caused the mortality of the 116 tagged juvenile chinook salmon observed in the vicinity of the railroad bridge in May 2007.

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5.2 Personal Communications

Orozca, Hector. Inland Pollution Coordinator. California Department of Fish and Game. October 23, 2007 – phone conversation with Dave Thomas (RBI) regarding the CDFG and Regional Water Board inspection of the RWCF on May 22, 2007.

APPENDIX A

NATURAL RESOURCE SCIENTISTS, INC. FISH MORTALITY REPORT

NATURAL RESOURCE SCIENTISTS, INC.
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May 20, 2007

Subject: High fish mortality near Stockton, California

Priority: High

To: Participating agencies in the 2007 Vernalis Adaptive Management Program

During the 2007 Vernalis Adaptive Management Program (VAMP), a large-scale pilot study was conducted by releasing juvenile fall Chinook salmon with surgically-implanted, individually-identifiable acoustic transmitters (tags) at five locations in the San Joaquin River and Delta. The fish movements were subsequently monitored with strategically-placed acoustic receivers (data loggers) (Figure 1). Additionally, mobile telemetry monitoring took place at various locations in the Delta.

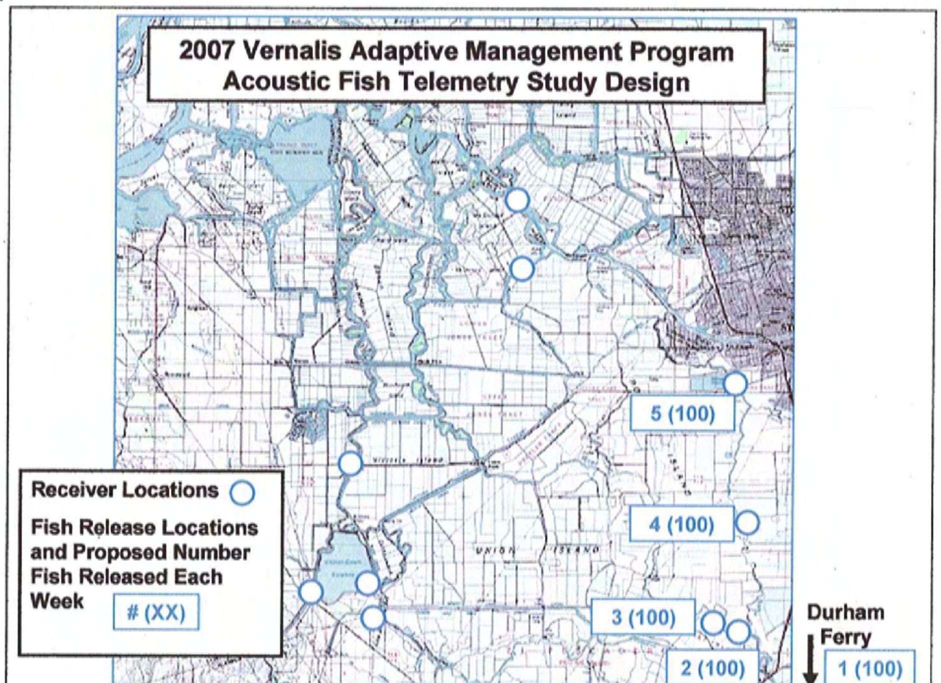

Figure 1. Acoustic-tagged juvenile Chinook salmon release locations and acoustic receiver locations during the 2007 Vernalis Adaptive Management Program.

Late last week, while performing mobile telemetry monitoring in the San Joaquin River near Stockton, I located a high number of acoustic transmitters at a very small, localized site 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 waste water treatment facilities (Figure 2).

Figure 2. Location of high mortality among juvenile acoustic-tagged Chinook salmon.

The following is a summary of last week's survey data that I processed this weekend. Using an acoustic telemetry receiver, I located 116 acoustic tags at this site; the tags were from salmon that had been released at four upstream locations (Table 1). Although the original intended number of acoustic-tagged salmon for each of these release groups was 100 fish each week (800 fish total), about 20 fewer fish were actually released.[1] I won't know the exact numbers until we receive the tagging forms, fish release data sheets, and process acoustic data collected at the release sites. Also, it is important to note that the actual number of fish reaching the high-mortality site would be considerably less after accounting for tags detected at upstream locations that were believed to have been preyed upon and defecated by predatory fish (e.g., the scour hole in the San Joaquin River adjacent to the head of Old River). Additionally, some of the batteries in acoustic tags from the first week's fish release likely died prior to last week's survey.

[1] Approximately 200 acoustic-tagged salmon were released in Old River downstream of the head of Old River barrier and are not included in these numbers.

Table 1. 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	May 3, 2007	12
Mossdale	May 3, 2007	1
Brandt Gauge (Bowman Rd)	May 4, 2007	5
USGS Gauge near Stockton	May 4, 2007	6
Durham Ferry	May 10, 2007	21
Mossdale	May 10, 2007	14
Brandt Gauge (Bowman Rd)	May 11, 2007	26
USGS Gauge near Stockton	May 11, 2007	31
	TOTAL	116

These transmitters were either in dead fish or had been eaten by predators and defecated because most transmitters were motionless. Using a highly-sensitive hydrophone and receiver in a fixed position, lack of motion can be determined using software that depicts tag voltage strength and displays Doppler-type visual imaging effects. One data file showing 88 individual tags in the area of the railroad bridge[2] is shown in Figure 3.

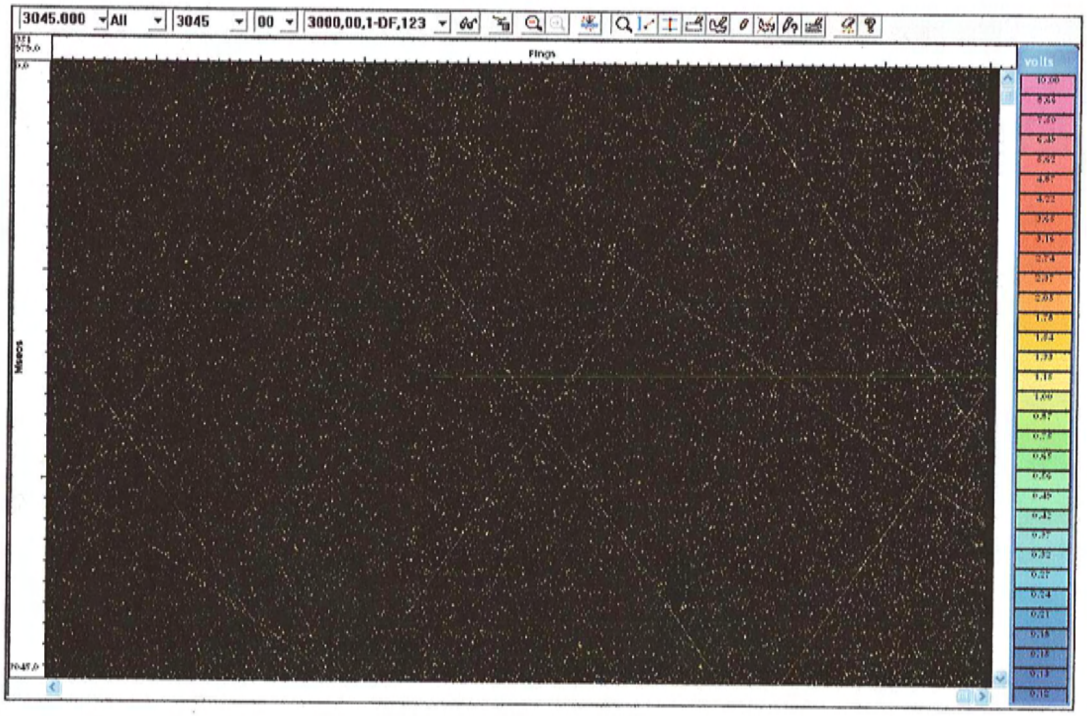

Figure 3. May 18, 2007 data file showing transmissions from 88 acoustic transmitters "pinging" at individually-identifiable repetition rates between 3,031 and 6,405 milliseconds.

[2] The other 28 tags were either detected at a nearby site in the same vicinity to avoid an acoustic "shadow" created by the bridge piers or on the prior day.

In comparison to Figure 3, Figure 4 shows a data file from another location in the Delta with no acoustic tag transmissions.

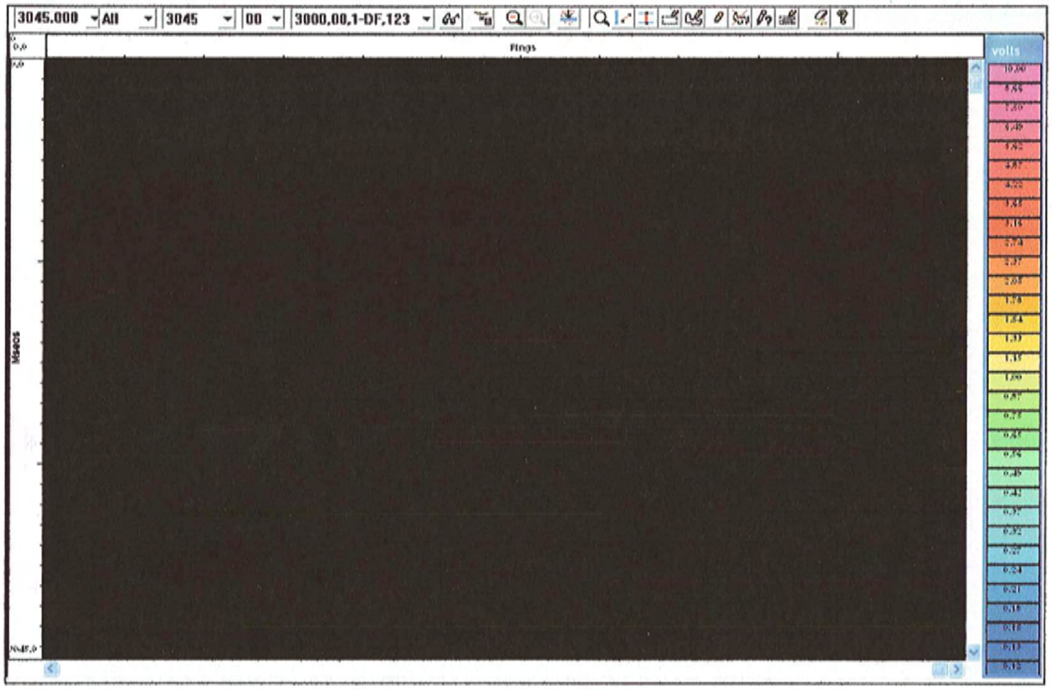

Figure 4. Data file showing no acoustic transmitters.

Some of the channel features of the site include the railroad bridge and a discharge pipe located just downstream of the bridge (Figure 5). The area is under strong tidal influence, water turbidity is high, and the channel is approximately 12 feet deep during low tide. During the survey, late afternoon on May 17^{th}, I observed a short-term, large discharge from the pipe with a plume of foamy water extending across the 240-foot-wide channel. The discharge occurred during what I believe was either a slack or flood tide condition.

This information is preliminary and provided to you at this time for the following reason. I recommend that those agencies responsible for investigating potential problems of fish mortality immediately investigate the site to determine potential causal factors for the high mortality among the acoustic-tagged salmon. I recommend that water quality parameters (e.g., dissolved oxygen, pH, temperature, etc.) be measured and water samples be taken under a variety of tidal phases (particularly a flood tide). Samples should be taken across the channel and vertically in the water column.

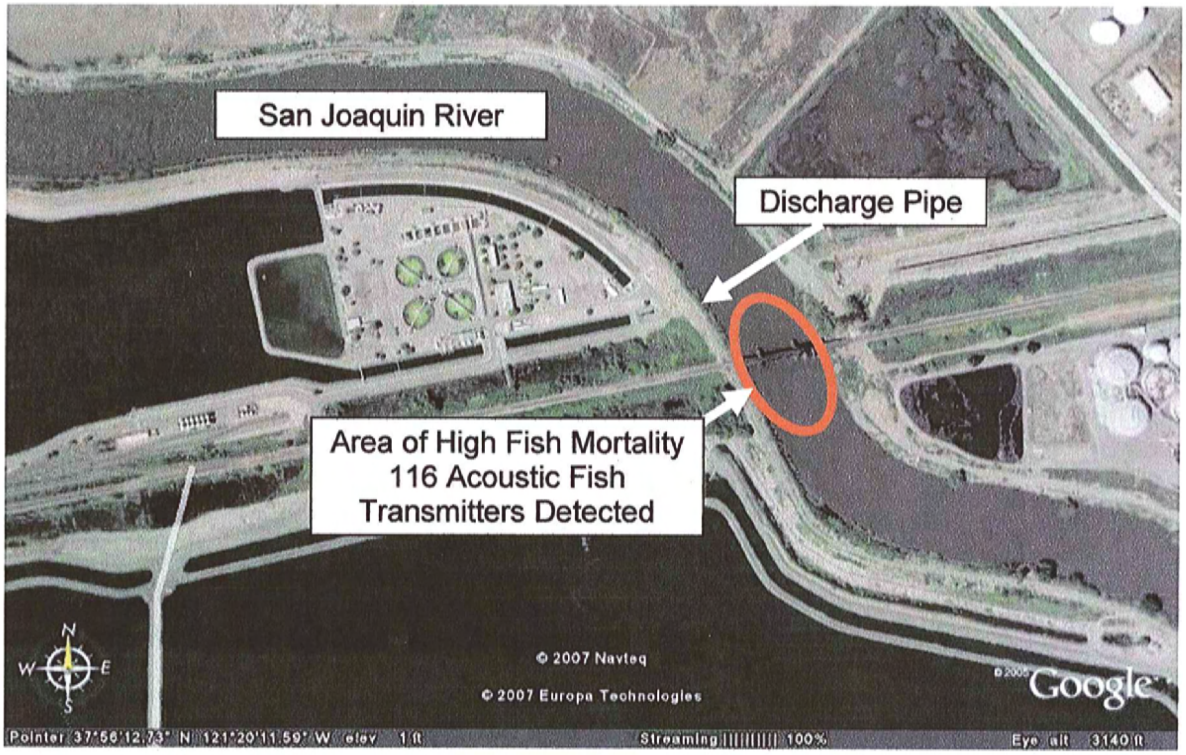

Figure 5. Location where 116 acoustic fish transmitters were located in the San Joaquin River near Stockton on May 17 and 18, 2007.

Please contact me if you have any questions.

Sincerely,
David A. Vogel
Senior Scientist

APPENDIX B

SUMMARY OF EFFLUENT AND RECEIVING WATER QUALITY DATA

Table B–1. General RWCF effluent water quality parameters for the period May 1–18, 2007.

Date	Flow (mgd)	Minimum pH	Maximum pH	Temp (°C)	Dissolved Oxygen (mg/L)	Ammonia (mg/L as N)	Electrical Conductivity (µS/cm)
5/1/2007	NA	NA	NA	NA	NA	NA	--
5/2/2007	NA	NA	NA	NA	NA	--	--
5/3/2007	18.6	6.5	6.8	18.3	8.6	--	--
5/4/2007	31.2	6.6	6.8	17.2	9	11.0	--
5/5/2007	32.7	6.5	6.7	17	8.7	--	--
5/6/2007	32.6	6.5	6.6	18.6	7.6	--	--
5/7/2007	31.7	6.3	7.9	21.1	7.1	7.1	--
5/8/2007	31.3	6.3	6.6	23.2	8.2	--	1144
5/9/2007	11.4	6.4	6.6	23.3	6.6	6.7	--
5/10/2007	NA	NA	NA	NA	NA	--	--
5/11/2007	28.6	6.5	6.7	22.1	8.6	6.7	--
5/12/2007	32.3	6.5	6.7	20.5	8.8	--	--
5/13/2007	32.2	6.3	7.2	20.6	8.8	--	--
5/14/2007	27.9	6.3	7.0	21.8	8.6	5.2	--
5/15/2007	17.3	6.3	7.0	21.1	8.6	--	1159
5/16/2007	28.4	6.3	6.7	20.9	8.7	2.9	--
5/17/2007	26.7	6.4	7.0	20.9	8.6	--	--
5/18/2007	22.7	6.4	7.2	20.9	8.7	2.1	--

NA = not available

Table B–2. General San Joaquin River water quality parameters for the period May 1–18, 2007.

	Dissolved Oxygen (mg/L)		Temperature (°C)		pH		Ammonia (mg/L as N)		Electrical Conductivity (µS/cm)	
Date	R2	R2a	R2	R2a	R2	R2a	R2	R2a	R2	R2a
5/1/2007	9.7	9.8	19.4	19.6	8.32	8.43	0.1	<0.1	430	440
5/2/2007	--	--	--	--	--	--	--	--	--	--
5/3/2007	--	--	--	--	--	--	--	--	--	--
5/4/2007	--	--	--	--	--	--	--	--	--	--
5/5/2007	--	--	--	--	--	--	--	--	--	--
5/6/2007	--	--	--	--	--	--	--	--	--	--
5/7/2007	--	--	--	--	--	--	--	--	--	--
5/8/2007	9.5	9.7	19.3	19.6	8.03	7.77	0.2	0.4	408	452
5/9/2007	--	--	--	--	--	--	--	--	--	--
5/10/2007	--	--	--	--	--	--	--	--	--	--
5/11/2007	--	--	--	--	--	--	--	--	--	--
5/12/2007	--	--	--	--	--	--	--	--	--	--
5/13/2007	--	--	--	--	--	--	--	--	--	--
5/14/2007	--	--	--	--	--	--	--	--	--	--
5/15/2007	8.9	9.1	19.6	19.6	8.15	8.05	0.2	0.2	360	386
5/16/2007	--	--	--	--	--	--	--	--	--	--
5/17/2007	--	--	--	--	--	--	--	--	--	--
5/18/2007	--	--	--	--	--	--	--	--	--	--
NA = not available										

Table B–3. Current RWCF effluent limitations of relevance to aquatic life and the number of exceedances from May 1–18, 2007.

Constituent	**Units**	**1-Hour**	**Daily**	**4-Day**	**Weekly**	**Monthly**	**CCC**	**Exceedances**
cBOD5	mg/L	--	25	--	--	--		NA
TSS	mg/L	--	60	--	45	30		NA
Chlorine residual	mg/L	0.02	0.01	--	--	--		NA
Settleable solids	mL/L	--	0.5		0.1	--		NA
Dissolved Oxygen	mg/L	--	--	--	--	--		NA
Copper	µg/L	--	4.8	--	--	2.4	12.2	NA
Cyanide	µg/L	--	9.2	--	--	4	5.2	NA
Diazinon	µg/L	--	0.1	--	--	--		NA

NA = not applicable
(1) April 1st through October 31st
(2) Based on a minimum hardness of 143 mg/L as $CaCO_3$

Table B–4. Constituents monitored in RWCF effluent with aquatic life toxicity concerns and the corresponding water quality standards and number of exceedances from May 1–18, 2007.

Constituent	Units	CCC	Exceedances
Chromium (VI)	µg/L	11 (1)	NA
Lead	µg/L	3.71 (1)	NA

NA = not applicable
(1) Based on a minimum hardness of 143 mg/L as $CaCO_3$