San Joaquin Valley Drainage Authority
ERP-02D-P63

Task 10: Installation of a New Monitoring Station for the San Joaquin River

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Abstract

A water quality station has been established between the Head of Old River and the Stockton Deep Water Ship Channel (DWSC) at the Brandt Bridge Site on the San Joaquin River. This station was selected after water quality measurements were measured at three stations in the vicinity during 2005 through 2008 to identify and describe the location of a water quality monitoring station on the San Joaquin River that will yield representative constituent concentrations entering the DWSC and that originate upstream of the City of Stockton wastewater effluent outfall. Water quality sondes deployed at these three locations recorded water temperature, conductivity, pH, dissolved oxygen (DO), turbidity, and chlorophyll fluorescence on a 15 minute basis during the study period. High flows of 2005 and 2006 failed to yield data that provided evidence for the best station location, but the monitoring data collected in 2007 indicated that the Brandt Bridge Site would be close to the optimal location. Hardware was installed at the Brandt Bridge Station (BDT) in February, 2007 to transmit water quality data to a public Internet website. Monitoring performed in 2007 provided sufficient evidence to support continued monitoring at BDT as a reasonable location for quantifying water quality and loads to the DWSC even at net flows below 250 cfs.

Introduction and Background

Previous Task 10 reports have identified a 3-mile reach in the San Joaquin River that would best represent water quality entering the DWSC from Mossdale Crossing. The approximate location of this river segment is shown in Figure 1. The analysis and rationale for this study reach is included in Appendix A. In summary, this river segment was estimated to be above the influence of the City of Stockton's effluent discharge during tidal flood flows at net river flows ranging from 100 to 500 cfs. The upstream excursion of tidal flows when net flows fall below 500 cfs was one of the criteria that used for locating the new monitoring station. This and other possible locations were evaluated by deploying self-logging water quality monitoring sondes at the boundaries of the 3-mile study segment and near the DWSC to compare water quality parameters at several locations over a range of flow and tidal conditions.

The location for the proposed water quality monitoring station extends from San Joaquin River Mile 44.7 to 47.7. Existing structures were identified (shown in Figure 2) for the attachment of the self-logging water quality sondes. Low net daily flows in the San Joaquin River of approximately 500 cfs or less are required to determine the closest location to the DWSC that is still above the influence of the City of Stockton wastewater effluent discharge. Written permission was acquired in mid November, 2005 to attach sonde mounting hardware to the pump station pier at the Stockton Brick Company (SBC) site and in 2006 the California Department of Water Resources (DWR) provided access and allowed hardware modifications to their water quality station at Brandt Bridge (BDT). The SBC and BDT stations bound the 3-mile study reach, a third station was also established at the outfall pier (OP) located 4 miles below SBC and 1 mile above the DWSC. The high flows of 2005 and 2006 failed to yield a good data set to determine the best location for the permanent water quality station. However, the low flows of 2007 provided excellent conditions for comparing water quality data collected from the three station locations in and below the study reach.

The original scope of work for Task 10 called for the installation of a station that would monitor both water quality parameters and flow. As part of the adaptive management process, the scope of work was changed to focus on the objective of improved water quality monitoring. At the time the original scope of work was written, prior to March 2003, it was not known that the USGS had been measuring flow in the critical reach approximately 2 miles above the DWSC at the Garwood Bridge site since 1995. This data was first available from the California Data Exchange Center (CDEC) in August, 2003, several months after the scope of work was developed. In addition, the California Department of Water Resources also installed a flow station 5 miles upstream of the study reach below the Head of Old River (CDEC Station Id. SJL) and began providing data on CDEC in August, 2004. Both of these flow stations were capable of determining the net flow of the San Joaquin River to the DWSC, one of the objectives of the original Task 10 scope of work. Analysis of Task 10 data indicated that it would be redundant to install a third flow station, a decision confirmed by the Technical Work Group committee members as part of the adaptive management process. Under the adaptive management plan, resources were directed at establishing the best location for the new water quality station in the San Joaquin River below the Head of Old River and the DWSC prior to installing a permanent facility. This adaptive strategy required the installation and maintenance of three temporary stations (instead of the single station envisioned in the original scope of work). In addition, as part of this adaptive management strategy, the water quality data from one of the three stations was transmitted to a public Internet web site in real-time to help monitor the operation of the sonde and provide the provisional data for immediate use. Transmission of the data to the Internet was an addition to the original scope of work, approved by the Technical Working Group under the adaptive management plan.

Objectives

The primary purpose of the Task 10 station was to establish the location that would best represent water quality entering the DWSC that originated above the City of Stockton's wastewater effluent discharge and collect water quality data during the study period. Selection of the best location is complicated by tidal flows that reverse the direction of the flow twice a day in low or normal water years. In addition, the load of algae entering the DWSC has been identified as one of the important contributors to the low dissolved oxygen (DO) observed in the DWSC. As such, the concentration of chlorophyll *a* and directly associated parameters (e.g., pH and DO) are important to determine the algal load entering the DWSC. In this reach of the San Joaquin River, chlorophyll *a* decays significantly as it flows to the DWSC, further complicating the determination of the best monitoring location. During the first two years of the investigation, representative low flows were not observed in the San Joaquin River during the summer to assess differences in the chlorophyll *a* concentration within the proposed 3-mile reach for the station site. As such, a one-year, no-cost project extension was obtained to extend the monitoring in the hope that the last year of study would be a representative water year. In order to conserve resources to support this additional year of study, water quality monitoring during periods of high flows was suspended until flows subsided. The low net flows of 2007 did provide a data set sufficient to identify that the best monitoring station location above the DWSC would be at the Brandt Bridge site.

Materials and Methods

Three temporary water quality stations were established at BDT, SBC, and OP to deploy multi-parameter water quality sondes. Hydrolab 5XDS (Hach Environmental, Loveland, CO), and YSI 6600 Extended Deployment System (EDS) (YSI, Inc., Yellow Springs, OH) were used interchangeably at the three temporary installations by suspending the sonde, housed in a protective case, on a chain fastened to the pier below the waterline. Photographs of the BDT, SBC, and OP stations are provided in Appendix Figures A-8, A-9, and A-10. The chain deployment systems at BDT and SBC were replaced by permanently mounted 4-inch ABS pipe housings later in the fall of 2006. Deployment was achieved by lowering the sondes in the ABS pipe until the sensors were 6 inches below the submerged, open end of ABS housing. The sondes are suspended in the housing by a stainless steel cable or chain attached to the top of the ABS housing. A photograph of the permanently sonde housing at SBC is shown in Appendix Figure A-11. A similar ABS housing was also installed at BDT. For this station the sonde is accessible from within the locked DWR station house. In February, 2007, an EcoNet Data Acquisition System (YSI, Inc., Yellow Springs, OH) was installed in the DWR station house at BDT. This hardware captures sonde data from a YSI 6600 EDS sonde every 15 minutes and transmits the data via cellular telephone service to a public Internet website maintained by YSI, Inc. After the installation of the EcoNet system in February, 2007, only YSI 6600 EDS sondes were deployed at BDT.

Both the Hydrolab and the YSI sondes measured sonde depth (relative river stage), water temperature, conductivity adjusted to 25ºC (SC), dissolved oxygen (DO), pH, turbidity, and chlorophyll fluorescence. Measurements were logged or transmitted to the Internet (BDT only) every 15 minutes. The major difference in the two sondes was the type of dissolved oxygen sensor. A luminescent DO sensor was installed on the Hydrolab sondes, while the YSI sondes utilized a common membrane technology (Rapid PulseTM) for dissolved oxygen.

The sondes that were deployed during November 2005, December 2005, and January 2006 were calibrated in the laboratory and recalibrated in the field after each maintenance visit. However, since June 2006 field calibration was eliminated by switching the sonde out with a fresh laboratory-calibrated sonde. This practice has improved data quality, and reduced post calibration adjustment as temperature effects are much easier to control in a laboratory environment. The disadvantage to this approach is that every site requires two independent sondes. After removing the sonde from the field, it was taken back to the laboratory, cleaned, and its performance recorded against known standards (as used for the calibration). Flows permitting, the sondes were cleaned and recalibrated approximately every 2 to 3 weeks. Sensors were found to be quite stable over 2 to 4 week deployments. The algal fluorescence signal was calibrated in the laboratory with rhodamine WT standards, and then post-calibrated with river water samples collected during the deployment period that were analyzed for chlorophyll *a* and pheophytin *a* using an acetone extraction method (APHA 1998, 2005). Other sensors were calibrated in accordance with the manufacture's specifications or Standard Methods (APHA 1998, 2005). In addition to following the manufacturer's calibration specifications, the DO sensors were also checked with deionized water saturated with oxygen and in a zero dissolved oxygen solution prepared with a sodium sulfide and cobalt chloride solution. Reagent water was prepared by a Milli-Q Academic filter (Millipore, Inc., Billerica, MA).

Results

Sonde deployment

Sonde deployment was initiated on November 27, 2005 at the Brandt Bridge Station (BDT) and at the Outfall Pier (OP, one mile above the DWSC, rm41.0). The Outfall Pier station was selected to record the parameters characteristic of water flowing up the San Joaquin River from the DWSC during flood tides. A sonde was not placed at Stockton Brick Company (SBC) at this time as mounting hardware had not yet been installed. Temporary hardware was installed at the SBC pump pier in mid December. The temporary installations at all sites were designed to be below the water surface at extreme low tides to reduce the potential for theft and vandalism. However, mounting the sondes in this manner prevented deployment and recovery during elevated river stages occurring during extreme high flows. In 2006, to improve access to the sondes deployed at BDT and SBC, a 4" diameter ABS pipe rising well above the water surface was mounted to piles to house the sondes. The housing at SBC extends approximately 10 ft above the San Joaquin River and is capped with a locking cover to protect the sonde from vandalism. The BDT housing enters the DWR station house at the Brandt Bridge Station. In February, 2007, YSI Econet hardware was also installed in the DWR BDT station to transmit water quality data to a public Internet website every 15 minutes. This addition was part of the adaptive research program to improve the quality and record of the water quality data in the study reach. Data uploaded to the internet is checked every day to ensure that the sonde is operating properly. Water quality data at the BDT station will continue to be maintained through June, 2008 and can be viewed by the public at http://www.ysieconet.com/public/WebUI/Default.aspx?hidCustomerID=151.

Deployment of the sondes in the study reach was suspended during periods of high winter flows in the San Joaquin River were observed in both 2005 and 2006. As discussed earlier, low flows were needed to establish the best location for the permanent station; at flows greater than about 2000 cfs the water quality from the BDT Station to the DWSC were observed to be quite similar. As shown in Figure 3, the net daily flows measured in the San Joaquin River at the Garwood Bridge Station exceeded 7,000 cfs in 2005 and 15,000 cfs in 2006. Sondes were not deployed during high flow periods to conserve resources to support a 1-year, no-cost extension of the monitoring to June 2008, in hope that a third consecutive wet season would not occur. Sonde deployment resumed in June, 2006 after high flows had subsided. An example of the data of all parameters is shown for BDT in Figure 4 for 2006 through 2007. The gaps in the data were caused by hardware and software failures of the Hydrolab sondes deployed for this study. The sondes were eventually replaced by the manufacturer, new sondes were issued and after a final hardware correction the Hydrolab sondes performed reliably for the remainder of this study.

Permissions and Cooperating Agencies

Verbal and written permission was obtained to install temporary and permanent hardware on public and private structures preexisting in the San Joaquin River for the deployment of water quality sondes during the fall of 2005. The analysis of dye investigations above the DWSC indicated that the optimal station location was probably within a 3-mile reach of the San Joaquin River extending from approximately San Joaquin river mile 45 (rm45) to rm48 (see Appendix A). The California Department of Water Resources (DWR) monitoring station at the Brandt Bridge site (CDEC Station Id. BDT) exists near rm48 and a privately owned agricultural intake pump station near the former Stockton Brick Company Site (SBC) is located near rm45. The piles supporting these structures were utilized for attaching hardware to deploy water quality sondes in the river. Access to the locked DWR station was obtained in September, 2006.

Determining the Optimal Location for a Permanent Station

Regular deployment of the water quality sondes in the study reach was initiated in November, 2005. The high flows observed in 2006 inhibited the collection of data that would yield data to determine the best permanent monitoring station location. Monitoring was resumed at BDT in late June, 2006 once flows had subsided. While high flows have generally failed to yield the data necessary to determine the best permanent station location, two brief low flow periods occurred in December, 2005 and 2006 that proved valuable to the objectives of this study. Low net flows entering the DWSC in 2007 provided a data set sufficient to evaluate the best location for maintaining a permanent, continuous water quality monitoring station.

The optimal location for the monitoring station was determined by comparing water quality data collected from the three monitoring stations, BDT, SBC, and OP, during periods of low net flows to the DWSC. During 2005 and 2006 these periods were infrequent due to above-average precipitation, but the low precipitation and flows of 2007 provided data sufficient to identify the best location for a permanent water quality station. The discussion that follows presents the most recent data collected in 2007.

Observations during the brief low flow periods recorded in 2005 and 2006 are provided in Appendix B and are consistent with the 2007 data.

2007 Low Flow Behavior

Ideal flow conditions occurred in the summer of 2007 for evaluating the influence of tidal flows at the monitoring station locations above the DWSC. Sondes were deployed and maintained throughout 2007 at OP, SBC, and BDT. The specific conductance (conductivity at 25°C) data offers the best indicator of tidal excursion during flood tides for this period. Figure 20 presents the specific conductance measured at OP, SBC and BDT, and the tidally filtered average net daily flow measured at SJG from June through November, 2007. At the beginning of June the net flow was about 1000 cfs before dropping to zero for much of the summer. Net flow then increased to 1700 cfs during the fall VAMP period. As shown in Figure 5 the specific conductance is approximately the same at all three stations for net flows above 1000 cfs. When the net flow to the DWSC approaches zero, the variability in the specific conductance increases over the tidal cycle due to flow reversal during flood tides carrying DWSC water upstream. During the summer of 2007, the specific conductance ranged from about 400-500 μS/cm in the DWSC while values of 700-800 μS/cm were measured in the upper San Joaquin River. These differences in specific conductance provide evidence of the influence of the flood tidal excursion during low flow periods.

Figure 6 exhibits the specific conductance at OP, SBC and BDT during June and early July when the net flows decreased from 1000 to 0 cfs. All stations recorded a similar specific conductance of 500 μS/cm on June 19, when the net flow was 1000 cfs. On this date only the OP station exhibited the fluctuations associated with the flood tides transporting low conductivity water 1 mile above the DWSC. The conductivity measured at stations 5 miles upstream at SBC and 8 miles upstream at BDT were relatively uniform until the net flow decreased. At a net flow of 500 cfs, the specific conductance signal starts to show that the flood tide excursion has reached the SBC station, as shown in Figure 6 on June 22. The low specific conductivity water of the DWSC was not carried upstream to BDT until the net flow fell below 200 cfs on July 9, 2007.

Figure 7 shows the influence on the specific conductivity when the net flow increases from zero to 1700 in the fall of 2007. Low specific conductivity water of the DWSC is observed at BDT throughout the summer until September 7 when the net flow increases to about 250 cfs. Again, SBC appears to be within the flood tide excursion of the DWSC until the net flow increases above 500 cfs on October 9. Figures 8 through 16 present water temperature, pH, and dissolved oxygen data for the same periods discussed in Figures 5 to 7 for the specific conductance. These plots also support the recommendation that BDT be established as the best long-term monitoring station to estimate water quality and pollutant loads entering the DWSC during low flow summer months.

One of the goals of the study was to identify a station that would be close to the DWSC, but outside of the effect of the City of Stockton wastewater effluent discharge at a net flow of approximately 500 cfs. However, inspection of the sonde data sets from all three stations and City of Stockton effluent water failed to reveal a time in which the treated effluent could be detected in the temperature, pH, dissolved oxygen, conductivity, algal fluorescence or turbidity signals, even during weeks of zero net flow in the San Joaquin River. The water of the DWSC is clearly detectable upstream in the 3-mile study reach as shown earlier for specific conductance. Since the outfall pipe discharges to the San Joaquin River about 1.5 miles upstream of the DWSC, these data indicate that the SBC station is within the influence of the wastewater effluent at net flows in excess of 500 cfs. However, the BDT station is approximately 3 miles further upstream than SBC and it is not under the influence of the DWSC until net flows decrease below 200 cfs. It also appears that the BDT station is above the flood tide excursion of the wastewater effluent at net flows of 500 cfs because water quality data collected at SBC suggests that 500 cfs is the approximate threshold for influence from the DWSC and the wastewater outfall is only 1.5 miles above the DWSC. Thus, is appears that at 500 cfs a flood tide excursion will transport the wastewater effluent approximately 1.5 miles beyond SBC, but still 1.5 miles below BDT.

Another consideration in the selection of the monitoring location on the San Joaquin River is its performance at very low net flow conditions. At 2:00 a.m. on September 20, 2007 rhodamine WT dye was released at the Head of Old River (rm54) to evaluate the travel time of the tracer to the DWSC. Self-logging sensors were placed at the Dos Reis Boat Ramp (rm51), BDT (rm48), SBC (rm45) and OP (rm41). The time-series dye profiles from these sensors are presented in Figure 17. The dye was released at the beginning of an ebb tide and approximately 7 hours later the plume was recorded at BDT, approximately 6 miles downstream. The tidal flow reversed shortly after the plume passed the BDT station and therefore the dyed water didn't reach the SBC station during the first ebb tide. Also shown in Figure 17, the BDT station continued to measure the dye plume for the next 2 to 3 days at a net flow of 250 cfs. At lower net flows the plume would remain in the system longer and SBC could effectively provide a time series record of the decaying algae starting from the first ebb tide excursion from the Head of Old River. Even if the net flow to the DWSC is zero, it was estimated that algae from the Head of Old River would reach the BDT station on a single ebb tide because the tidal flows are not significantly influenced by net flows less than 250 cfs. Since water of various ages will be pass BDT site is located on the San Joaquin River where the water quality passing the station during periods of extreme low flows provides a dynamic set of data for water quality model calibration and performance evaluation.

Positioning the station at BDT could also provide a historic continuous data set that would facilitate the adaptive management of the San Joaquin River flow split at the Head of Old River and the operation of the DWR aerator in the DWSC. Since episodes of low dissolved oxygen in the DWSC are usually associated with net flows below 1500 cfs (Foe et al., 2002), positioning a real-time water quality station at BDT could also provide an excellent data set for predicting, in advance, the oxygen demand that would reach the DWSC. As discussed above BDT is in a unique location above the DWSC and below the Head of Old River that will yield a record of algae aging (changes in algal fluorescence) and therefore both the oxygen demand exerted and remaining as the water travels to the DWSC. Figure 18 presents the travel time for water flowing between the Head of Old River and the DWSC based on other dye tracking investigations. As shown in Figure 18, the travel time exceeds 5 days for net river flows below 250 cfs. Only 1 day is required for the flow to reach the DWSC from the Head of Old River at a net river flow of 1500 cfs. This plot also provides an indication of the expected time delay for algal loads reaching the DWSC and could be used in conjunction with the BDT data as a river management tool. For example, at a net DWSC flow of 750 cfs, water will reach the DWSC in approximately 2 days. Thus, if this water has a high oxygen demands (as detected by chlorophyll a fluorescence at Mossdale or above in the San Joaquin River) approximately 2 days of lead time is provided before the oxygen demand will be exerted in the DWSC. What is not known is the relationship between the oxygen demand of the water at the Head of Old River and the oxygen demand that will enter the DWSC. Positioning the station at BDT could provide a continuous data set capable of evaluating the fate of algae in the tidal reach of the San Joaquin River and provide good estimates of the associated oxygen demand load entering the DWSC. This idea could be extended to stations that measure algal fluorescence above Mossdale to increase the response time for adaptive watershed management. For example, the travel time from Vernalis to Mossdale is approximately 14 hrs at 3000 cfs and 24 hrs at 1000 cfs.

Lastly, the selection of BDT as a water quality station is also convenient because the California Department of Water Resources has installed a permanent station with electrical power at BDT for the purpose of measuring stage, water temperature, and specific conductance. Expansion of this station to include pH, dissolved oxygen, turbidity, and chlorophyll fluorescence is recommended.

Summary and Conclusions

Deployment of water quality monitoring sondes in the San Joaquin River have been conducted since 2005 to determine the best location for a permanent water quality station that will best represent water quality entering the DWSC and provide a continuous water quality data set. A three-mile reach of river above the DWSC was identified in the early Task 10 interim reports, excerpts are included in Appendix A. Written permission was obtained to utilize existing pump platform piers or other structures for mounting water quality instrumentation. Temporary hardware that was originally installed at BDT and SBC has been replaced with permanent mountings to improve access during high flows. The water quality data recorded at BDT is also being uploaded to a public Internet website. The site is checked daily to ensure that the sensors are functioning properly and the data is being recorded every 15 minutes.

Flow in the San Joaquin River was too high throughout most of 2005 and 2006 to determine the location of a monitoring station that would best represent water quality entering the DWSC above the City of Stockton wastewater effluent outfall location. However, low net average flows in the San Joaquin River entering the DWSC were observed during two brief periods during December, 2005 and 2006 and throughout the summer of 2007. Water quality data measured by the sondes during these times suggest that the Brandt Bridge location was not influenced by DWSC water or the Stockton wastewater effluent at net daily flows of greater than 200 or 500 cfs, respectively. Stockton effluent water appears to reach the SBC station when net flows fall below approximately 400 to 500 cfs.

It is recommended that pH, dissolved oxygen, turbidity, and chlorophyll fluorescence monitoring be continued at the BDT station. As discussed earlier, at low net flows the BDT location can provide a unique record of changes in algae concentrations and therefore the associated oxygen demand both below the Head of Old River and entering the DWSC. It is anticipated that the data transmitted from the BDT station will prove valuable when adaptively managing the flow split at the Head of Old River and the operation of the DWR aerator in the DWSC.

Since the permanent mounting hardware has been installed to facilitate access to the sondes during high flows, continued sonde deployment can be assumed by another entity at the end of this study. Preliminary conversations with representatives of the Department of Water Resources (DWR) indicate that they are interested in continuing the maintenance of this station upon completion of this Task.

References

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Foe, C., M. Gowdy, and M. McCarthy, 2002. Draft Strawman Allocation of Responsibility Report, California Regional Water Quality Control Board, Central Valley Region, January, Sacramento, CA.

Jones & Stokes, 2002. Evaluation of Stockton Deep Water Ship Channel Model Simulations of 2001 Conditions: Loading Estimates and Model Sensitivity*,* Prepared for the CALFED Bay-Delta Program 2001 Grant 01-N61, Sacramento, CA

Figure 1: The San Joaquin River near Stockton, CA and the reach for the proposed water quality monitoring station.

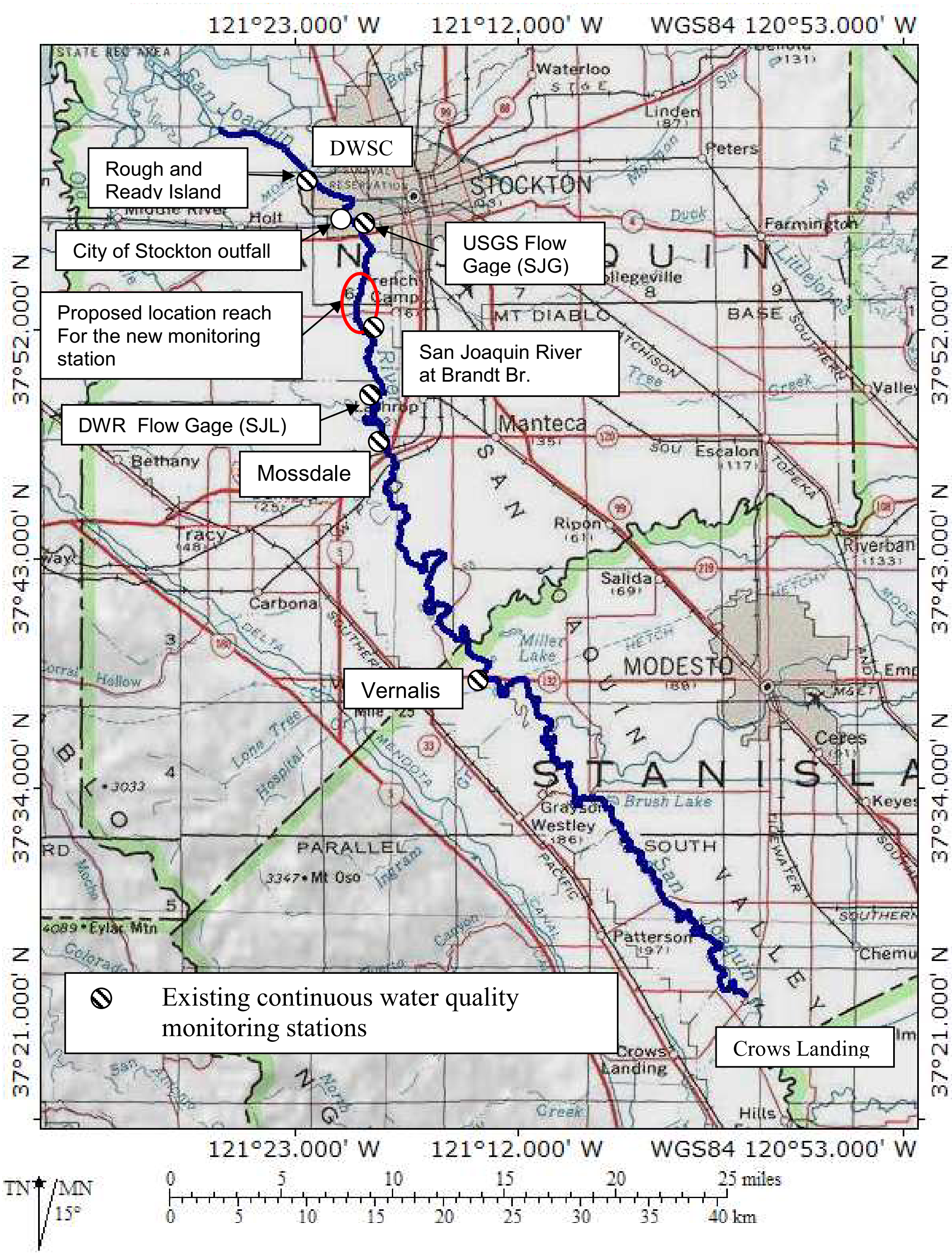

Figure 2: Proposed reach for the new continuous monitoring station location. Sites 1 through 7 are structures that offer piers for temporary instrumentation installation. Site 8 is the DWR Brandt Bridge Station.

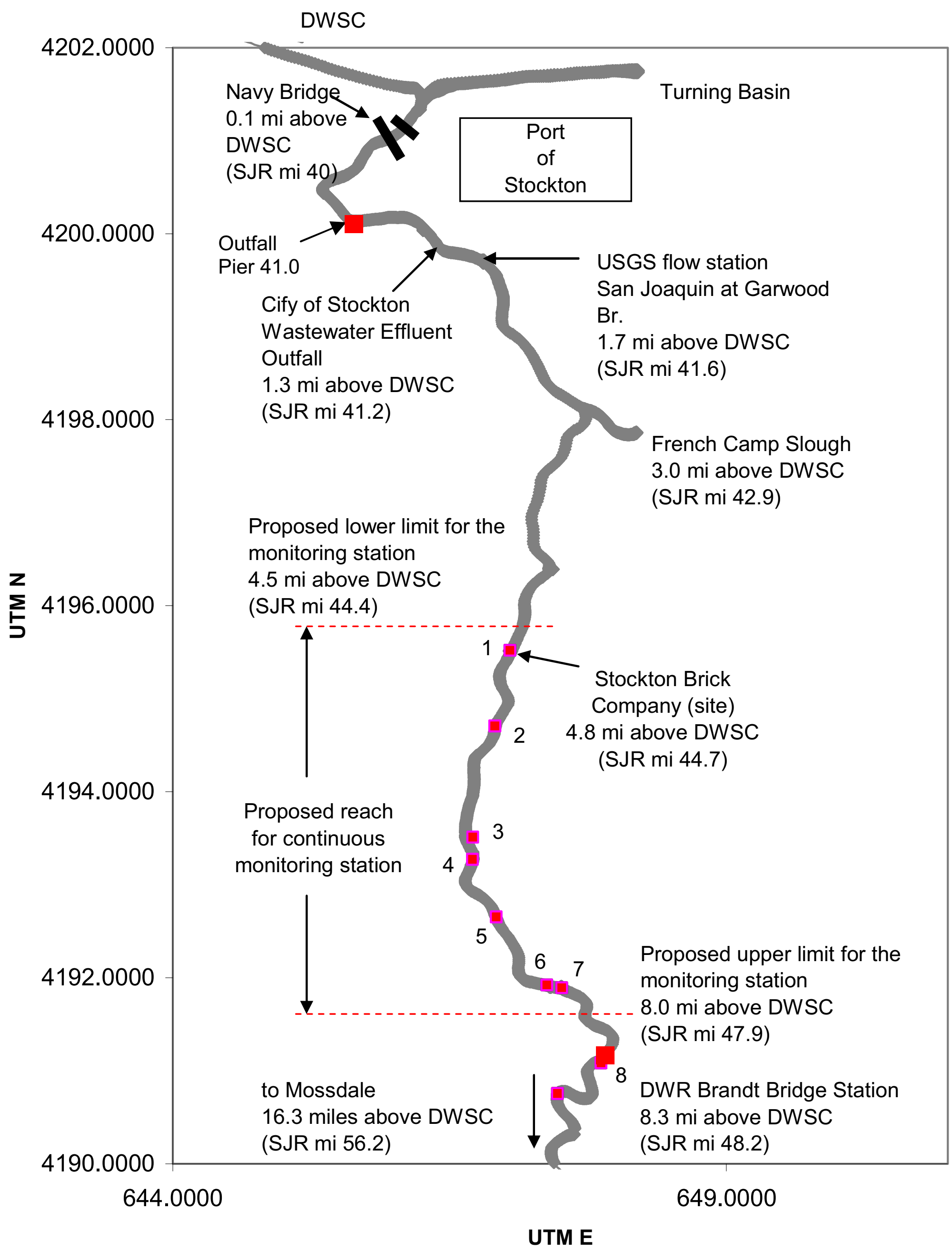

Figure 3: Net daily and instantaneous (15 minute interval) in the San Joaquin River flow entering the DWSC as measured at the Garwood Bridge Station (SJG).

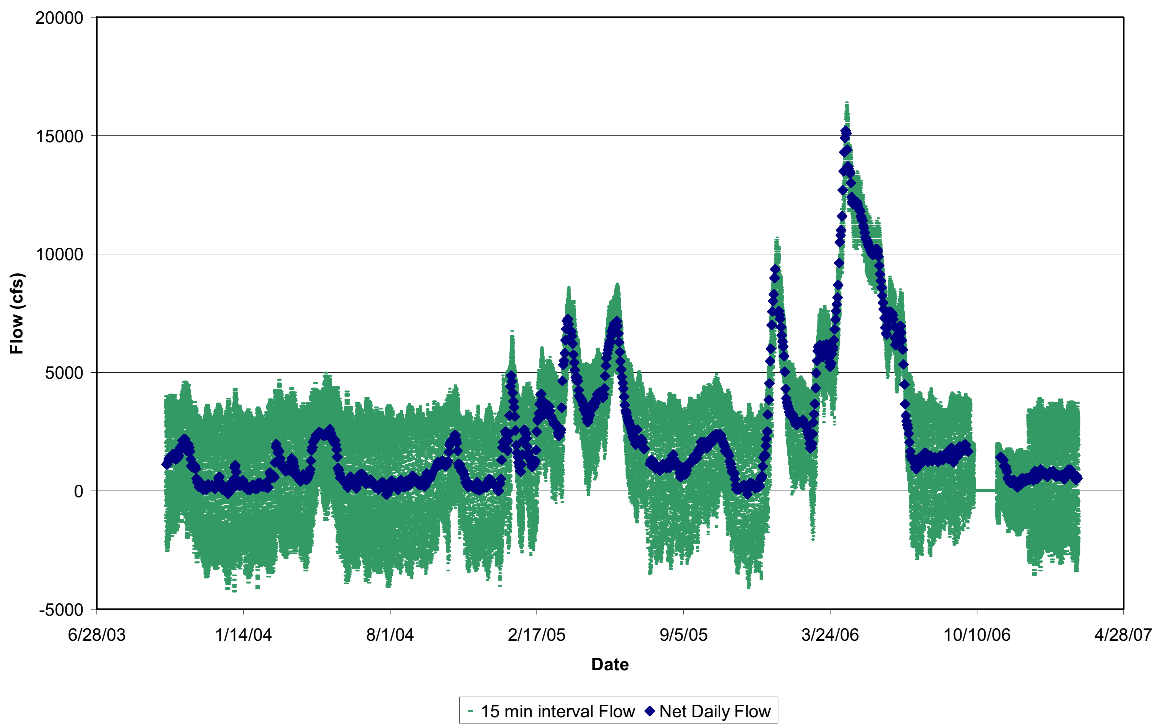

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Figure 4: Water quality data measured at BDT and the net daily flow at SJG from June 30, 2006 to March 9, 2007.

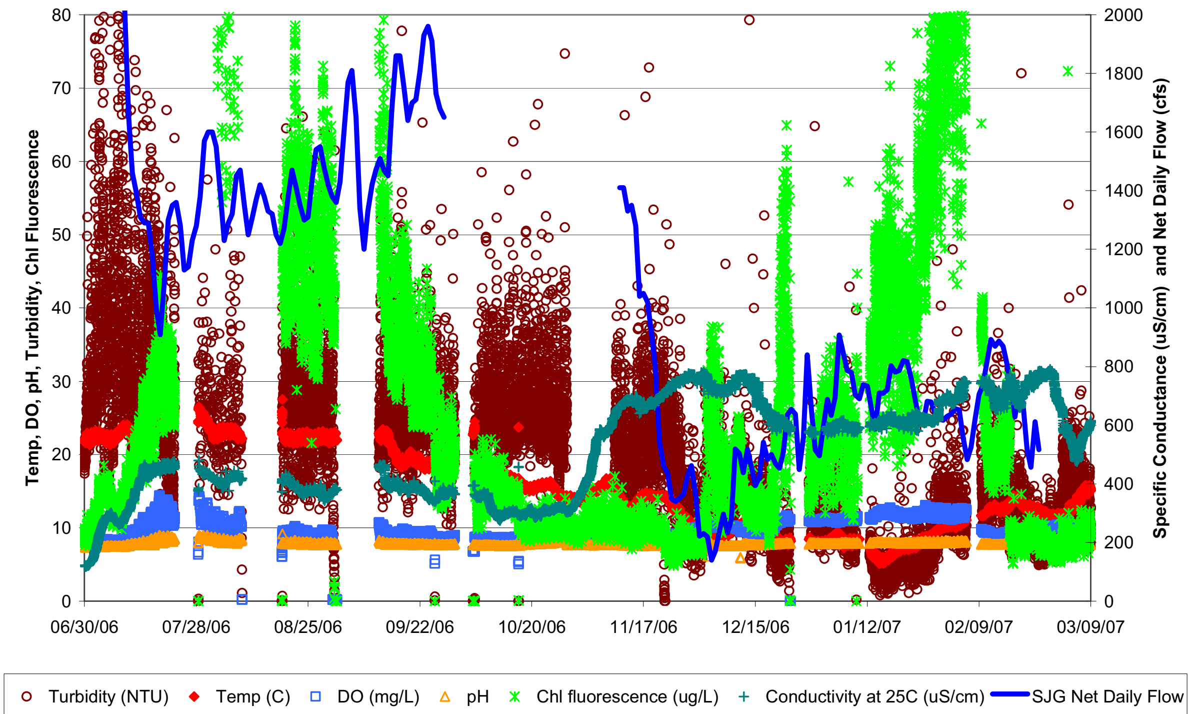


Figure 5: Specific conductance at BDT, SBC, and OP from June 1, 2007 to November, 30, 2007. The tidally filtered net flow entering the DWSC, measured at SJG, is also presented.

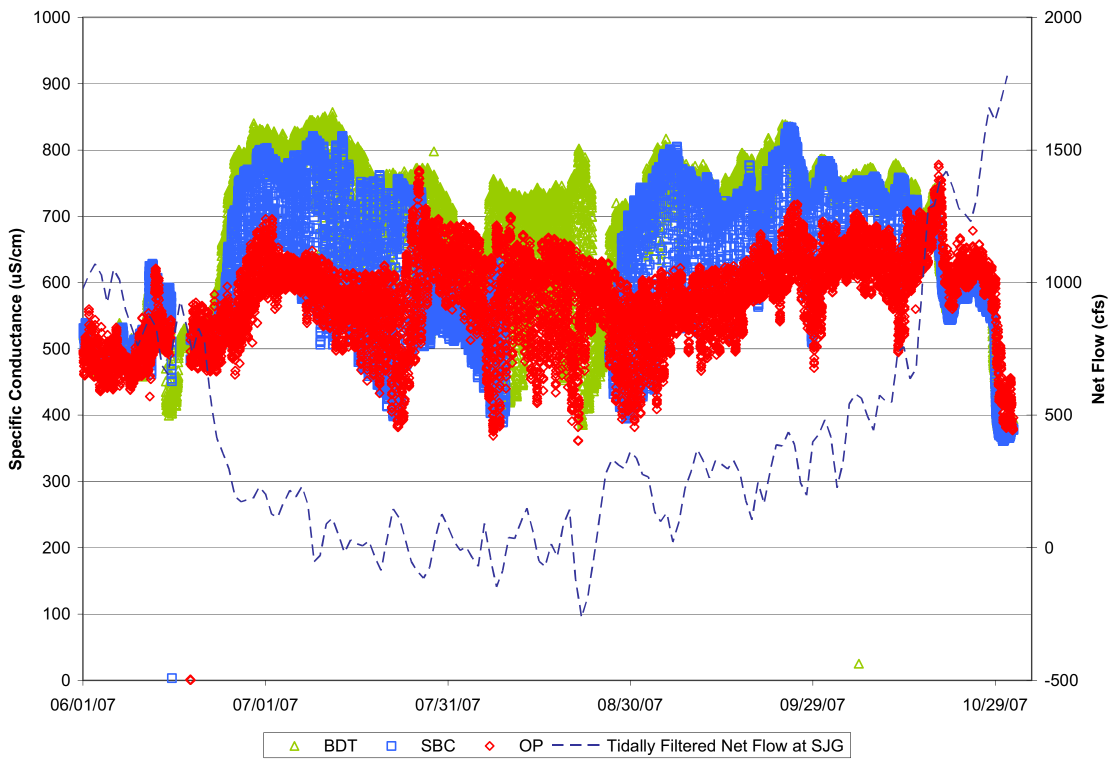


Figure 6: Specific conductance at BDT, SBC, and OP from June 19, 2007 to July 22, 2007. The tidally filtered net flow measured at SJG is also presented.

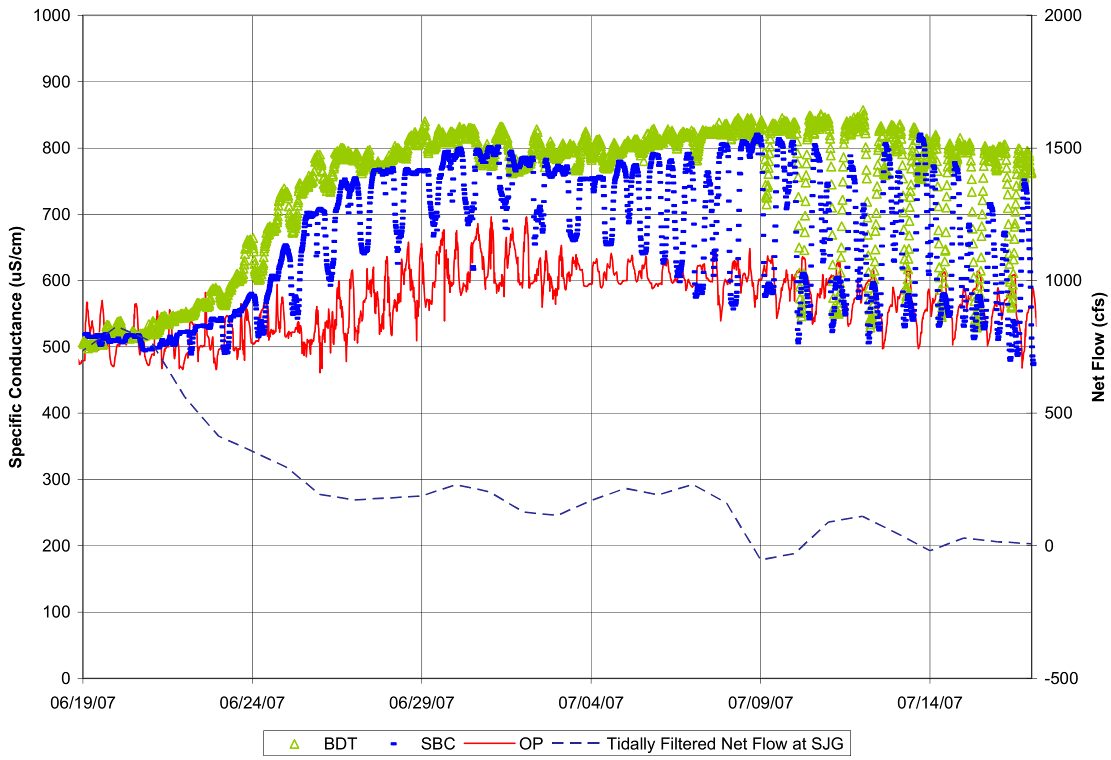


Figure 7: Specific conductance at BDT, SBC, and OP from August 6, 2007 to October 25, 2007. The tidally filtered net flow measured at SJG is also presented.

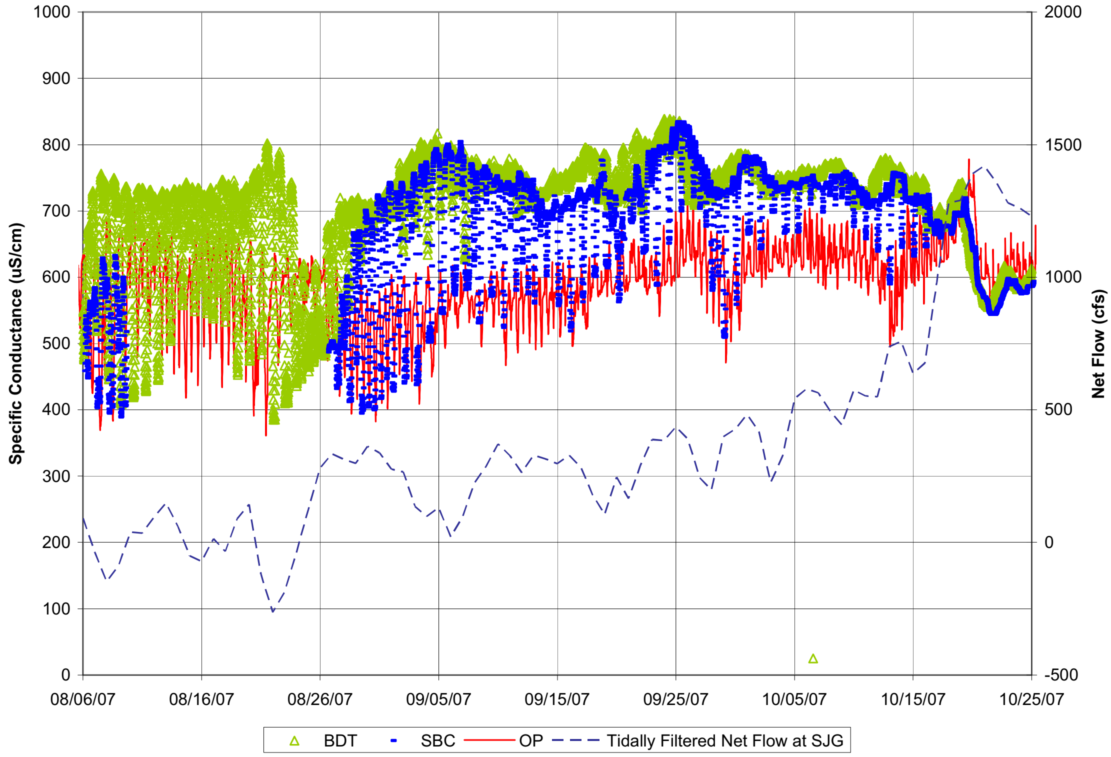


Figure 8: Temperature at BDT, SBC, and OP from June 1, 2007 to November 30, 2007. The tidally filtered net flow measured at SJG is also presented.

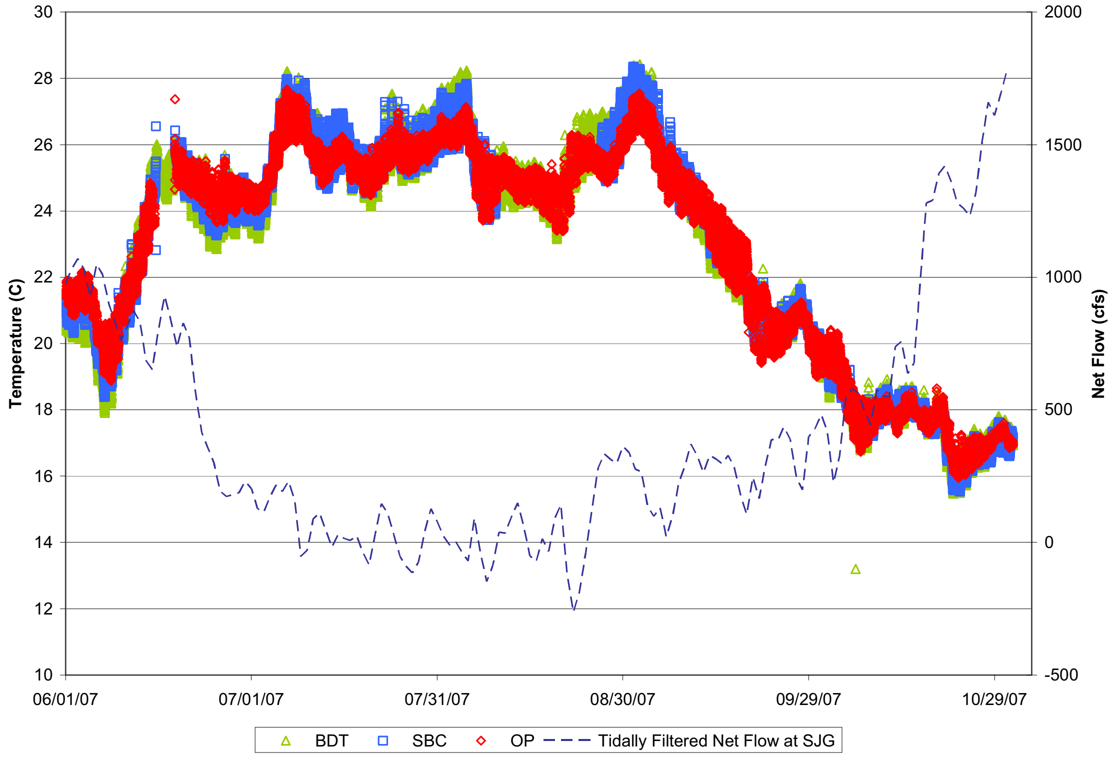


Figure 9: Temperature at BDT, SBC, and OP from June 19, 2007 to July 22, 2007. The tidally filtered net flow measured at SJG is also presented.

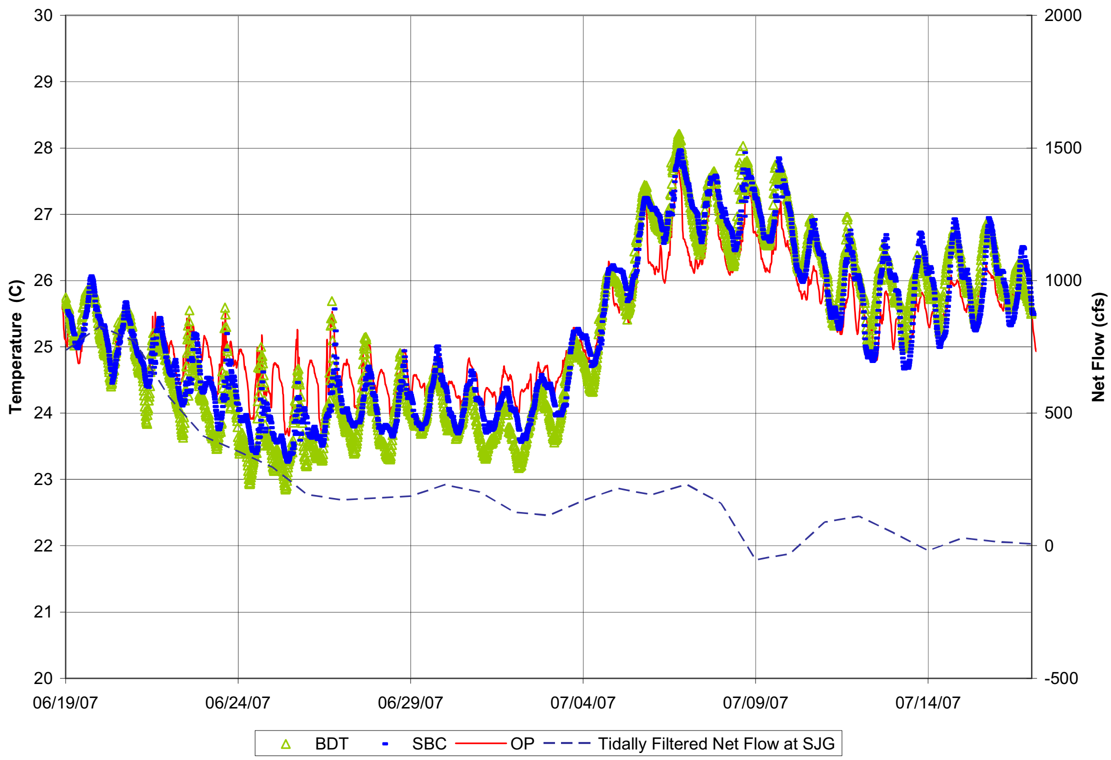


Figure 10: Temperature at BDT, SBC, and OP from August 6, 2007 to October 25, 2007. The tidally filtered net flow measured at SJG is also presented.

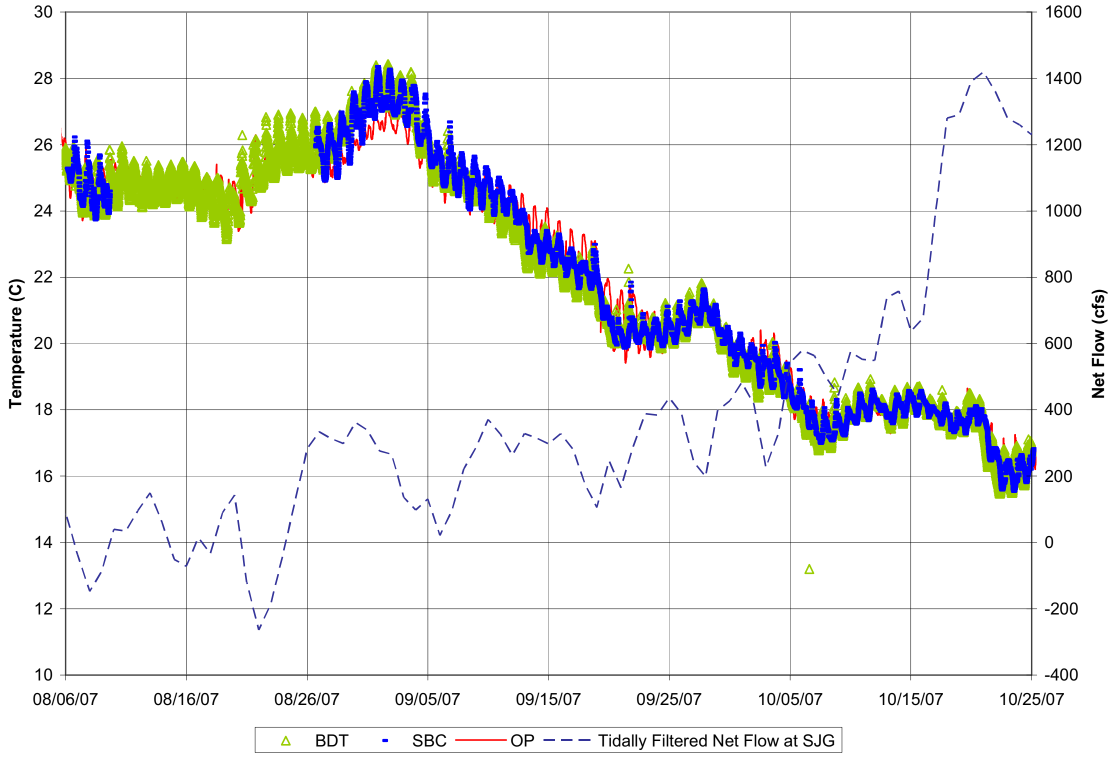


Figure 11: Measurements of pH at BDT, SBC, and OP from June 1, 2007 to November 30, 2007. The tidally filtered net flow measured at SJG is also presented.

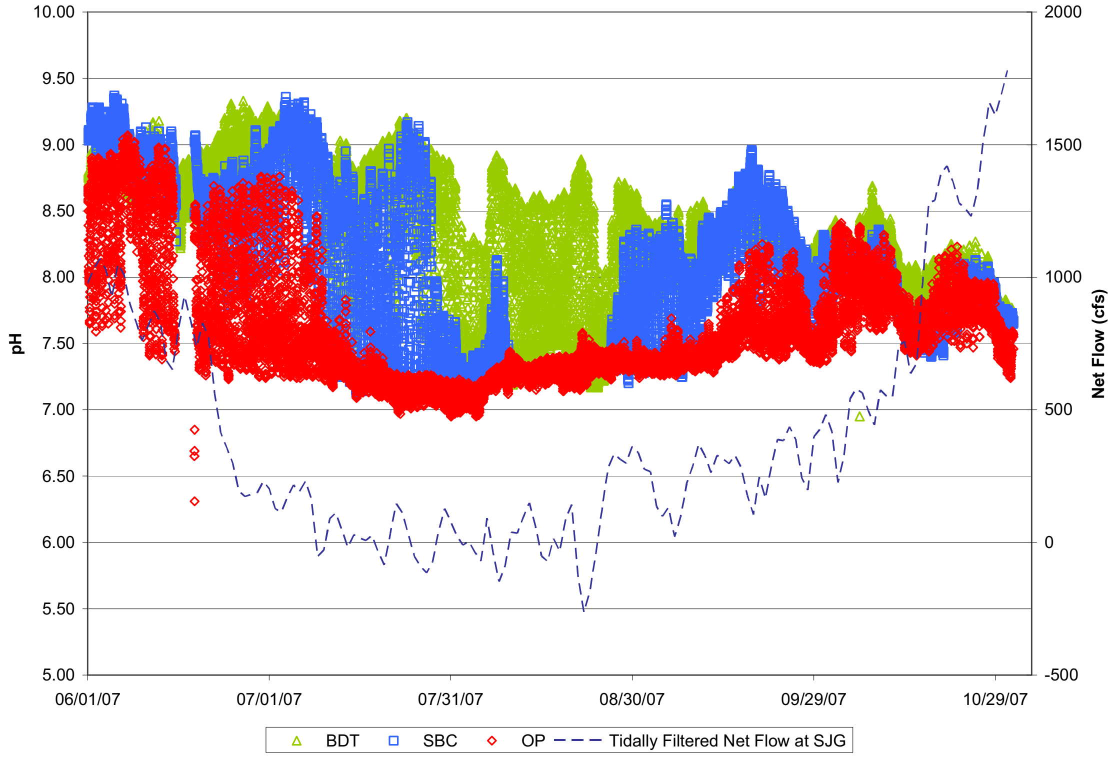


Figure 12: Measurements of pH at BDT, SBC, and OP from June 19, 2007 to July 22, 2007. The tidally filtered net flow measured at SJG is also presented.

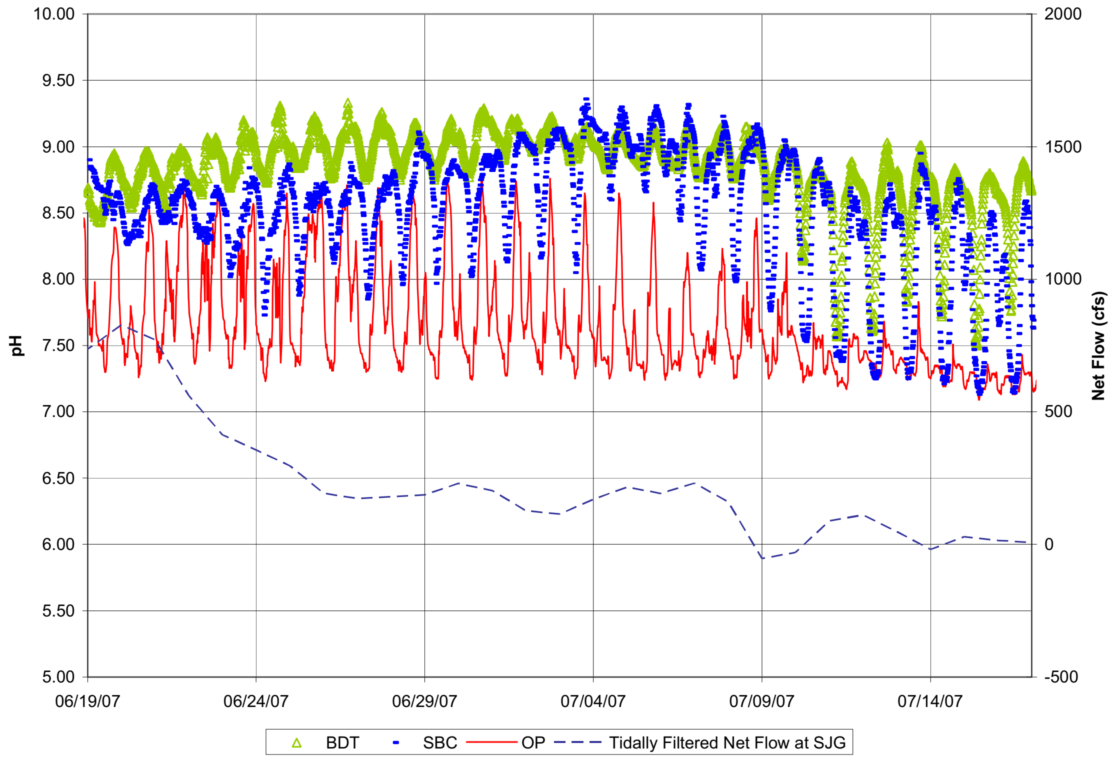


Figure 13: Measurements of pH at BDT, SBC, and OP from August 6, 2007 to October 25, 2007. The tidally filtered net flow measured at SJG is also presented.

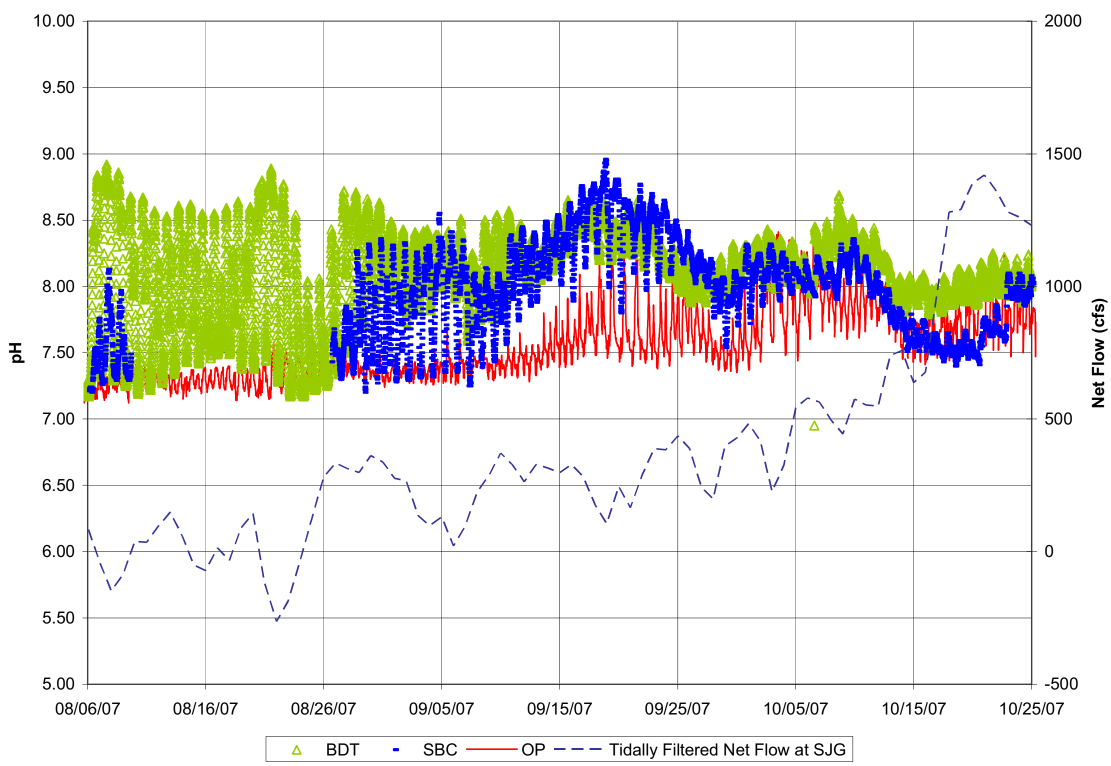


Figure 14: Dissolved oxygen at BDT, SBC, and OP from June 1, 2007 to November 30, 2007. The tidally filtered net flow measured at SJG is also presented.

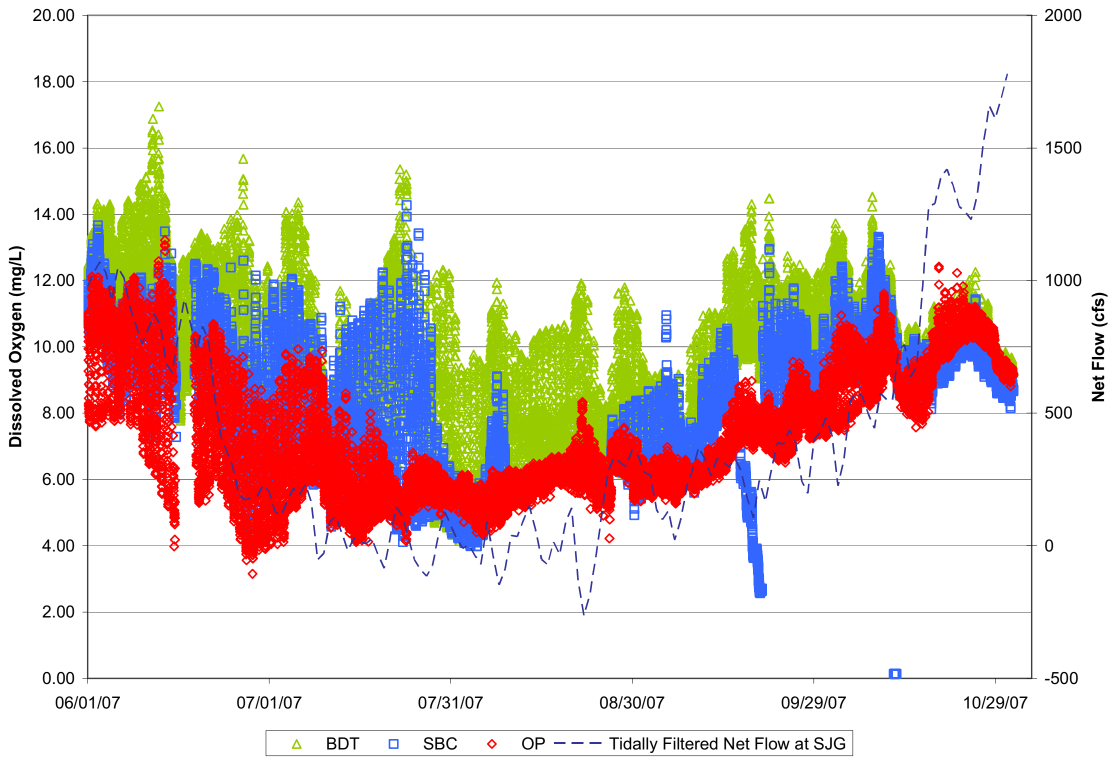


Figure 15: Dissolved oxygen at BDT, SBC, and OP from June 19, 2007 to July 22, 2007. The tidally filtered net flow measured at SJG is also presented.

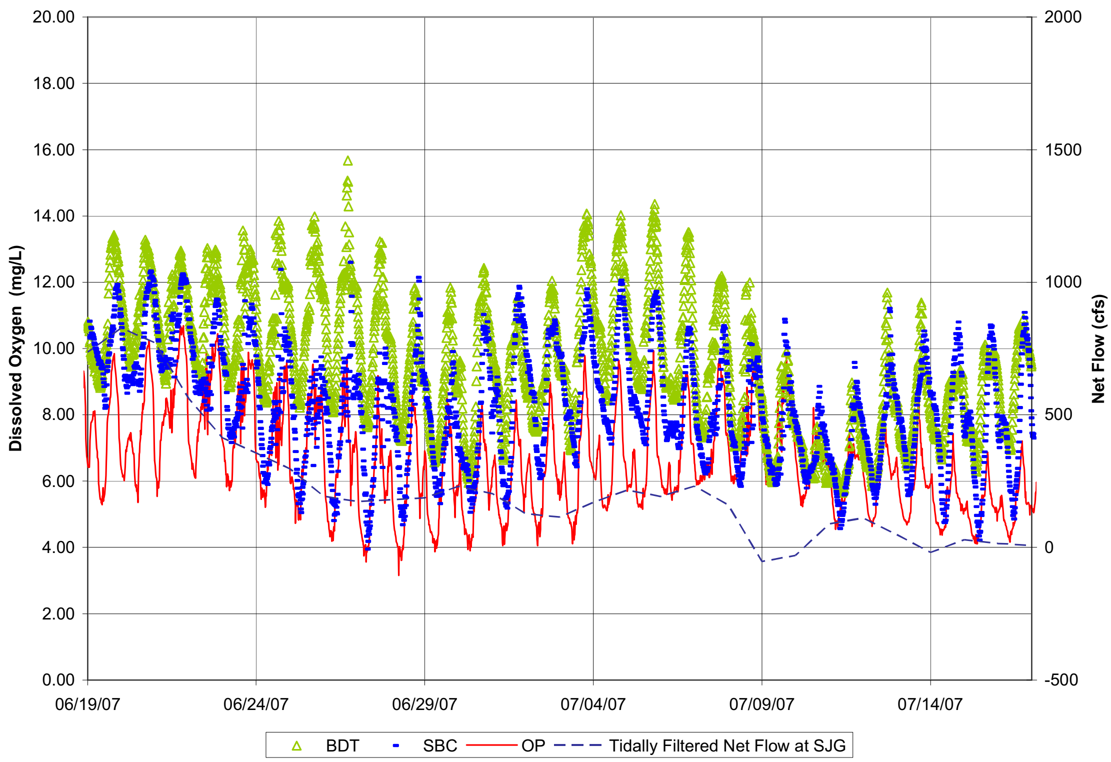


Figure 16: Dissolved oxygen at BDT, SBC, and OP from August 6, 2007 to October 25, 2007. The tidally filtered net flow measured at SJG is also presented.

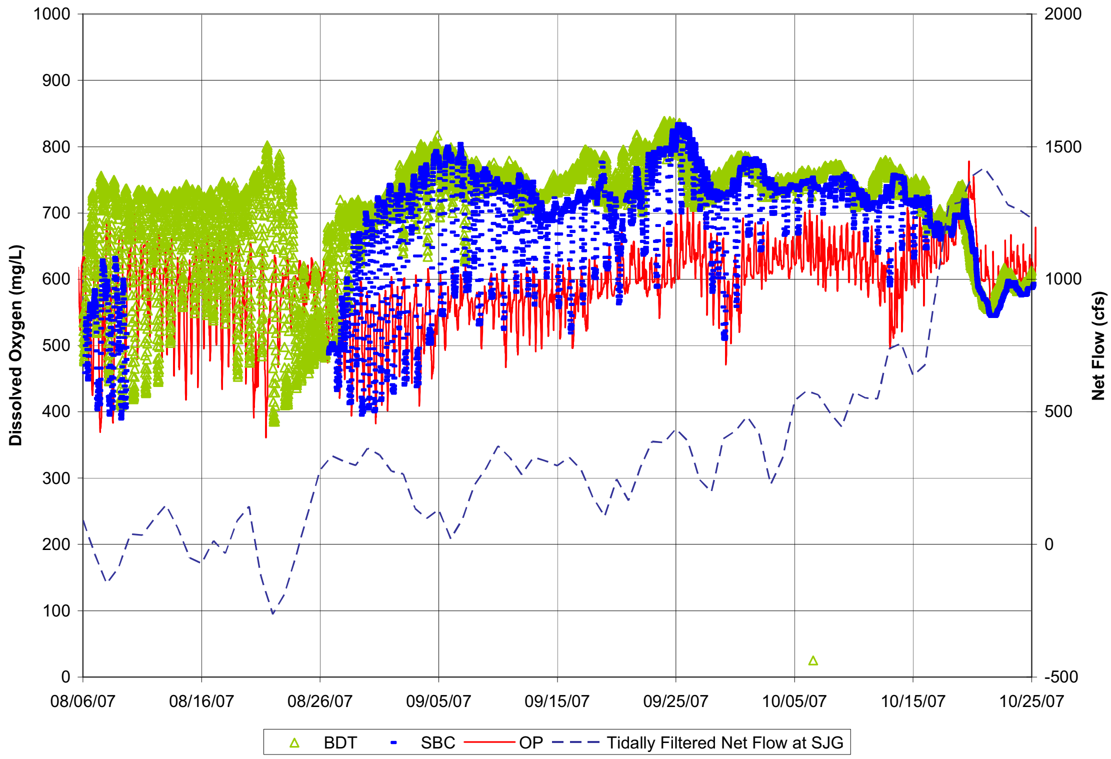


Figure 17: Rhodamine WT tracer profiles released at the Head of Old River on September 20 passing fixed sensors at rm51.1, rm47.5, and rm41. The net flow in the San Joaquin River to the DWSC was 250 cfs.

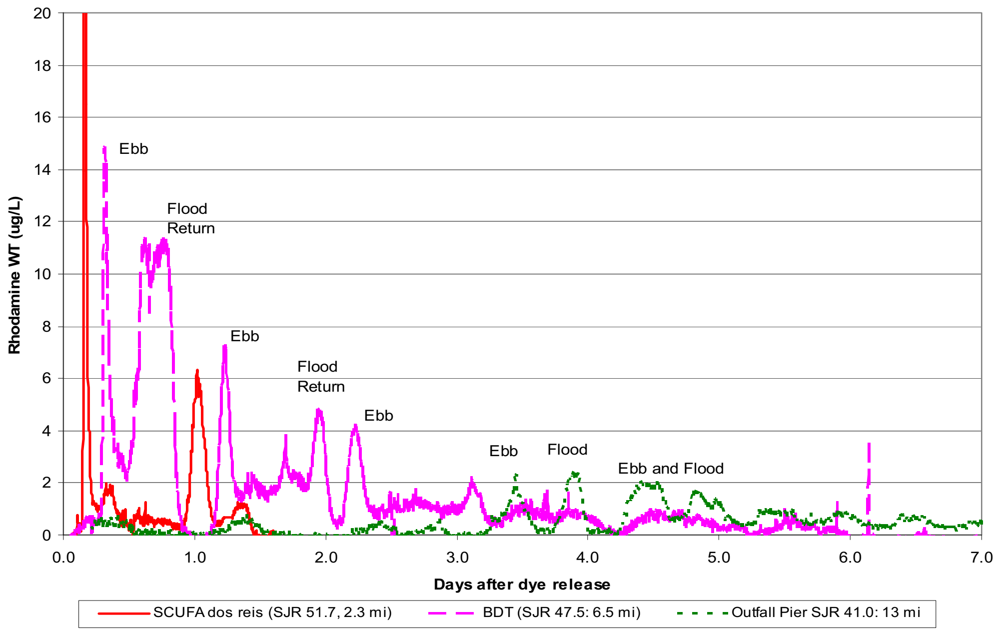
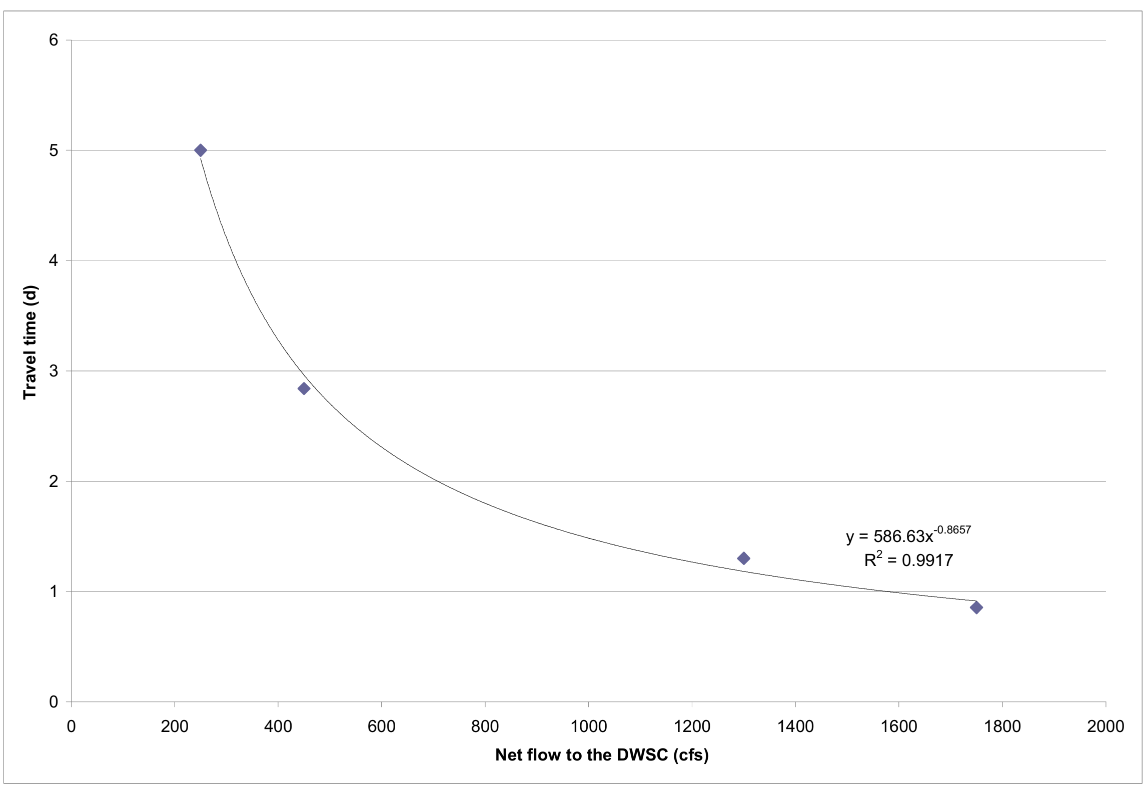


Figure 18: Residence time from the Head of Old River to the DWSC as a function of net flow into the DWSC as determined with tracer releases.



Appendix A Site Selection and Description of San Joaquin River Segment Recommended for the Monitoring Station

Site Selection (as presented in earlier reports)

The Department of Water Resources maintains a continuous water quality station that monitors dissolved oxygen and chlorophyll *a* at Mossdale Crossing, approximately 16 river miles above the Port of Stockton. These data may not be representative of the water quality entering the DWSC. Often the concentration of chlorophyll *a* is half that measured at Mossdale. *A* new continuous station will be installed closer to Stockton, CA to better monitor water quality parameters entering the DWSC from the San Joaquin River above Stockton, especially those constituents associated with algae and its growth. However, the City of Stockton discharges treated wastewater effluent 1.3 miles upstream of the DWSC. Thus, it is desired to locate the new monitoring station outside of the influence of this outfall. These criteria require that the station be located as close to the DWSC as possible, yet still upstream of the Stockton outfall. The location of the outfall, City of Stockton, the DWSC, and the proposed reach for the water quality station shown were shown earlier in Figures 1 and 2.

Tidal flows in the San Joaquin River transport Stockton wastewater effluent upstream during flood tides. Tidal flows typically range from 2000 to 3000 cfs and are usually greater than the net river flow. Tidal excursion above the effluent outfall was recently measured during a tracer study to evaluate the performance of the Port of Stockton aerator. Figure A-1 presents the extent of dye transport above aeration facility, located at the confluence of the San Joaquin River and the DWSC. As shown in Figure A-1, the rhodamine WT profile measured at the end of two flood tides indicates that the upstream movement on September 1 and 2 was approximately 15,000 to 17,000 ft above the aerator. The net river flow during the tracer investigation was approximately 540 cfs.

Tidal excursion upstream of the DWSC is a function of the net river flow and tidal phases. On occasion, management of water resources in the Delta and upstream reservoirs can reverse the net flow of the San Joaquin River at Stockton. A net flow reversal was observed as recently as August, 2004. To evaluate the influence of net flow on the upstream tidal excursion, a series of calculations were performed with flow data measured by the USGS at the Garwood Bridge station. Figure A-2 exhibits the calculated movement of a parcel of dye released from the aerator at 16:15 on September 1, 2004 at low slack tide. Neglecting dispersion, this estimate indicates that the tracer moved upstream approximately 15,000 ft during the first flood tide on September 1 at approximately 22:15. This estimate of the tidal excursion is in good agreement with the tracer measurements shown earlier in Figure A-1.

Additional tide excursion calculations were also performed for other days in 2004 under different net flows and tidal conditions. The results of these estimates are summarized in

Table A-1. Plots of the tidal excursion for each of these dates are presented Figures A-2 to A-5.

The upstream excursion was calculated for three different net flow conditions to better estimate the influence of net flow on the extent of upstream tidal transport. Ideally the new station should always be above the influence of the Stockton wastewater outfall. However, this is not possible at extremely low flows or during flow reversal of the San Joaquin River. The results of the calculations shown in Table A-1 indicate that the upstream excursion exceeds approximately 5 miles for net average flows of about 300 cfs. At net flows of 100 cfs, the excursion increases upstream an addition mile for the tidal conditions of July 14 and 15. Tidal phases, such as spring and neap tides, will also influence the extent of upstream excursion. These effects were not explored in detail here, but were directly assessed during the temporary deployment of multiparameter sondes during the study period.

During 2003 water year, the net average flow measured at the USGS Garwood Bridge gage was less than 500 cfs, more than 50 percent of the time. Since an upstream tidal excursion of approximately 3.5 miles is associated with net flows of approximately 500 cfs, these data suggests that the proposed station should be located at least about 3.5 miles above the City of Stockton wastewater outfall if the measurements are not to be impacted by the effluent on most days. The site of the Stockton Brick Company (SBC) is adjacent to the river at this location. Ammonia measurements of water samples collected from the San Joaquin River at SBC during 2003 and 2004 have been consistently below a detection limit of 0.2 mg-N/L (Litton, unpublished data). These data suggest that this location may be sufficiently upstream to remain out of the influence of the high ammonia concentrations in the treated effluent discharged at the Stockton outfall. However, since these measurements were performed intermittently they do not reflect a comprehensive record of water quality at SBC, and a continuous record is needed to establish the permanent station location.

The cumulative distribution of flow in the San Joaquin River at Garwood for the 2003 water year are shown in Figure A-7. The average daily net flow at the Garwood Bridge was less than 100 cfs approximately 10 percent of the time, which may be characteristic of seasons with below average precipitation. At this low flow, the previous excursion calculations indicate that the station would need to be located greater than 6.5 miles above the outfall to remain out of the influence of the Stockton effluent 90 percent of the time. This distance probably represents the upper extreme for locating the water quality monitoring station since this point is midway between Mossdale and the DWSC. This upper location is also near the DWR water quality monitoring station at Brandt Bridge. The Brandt Bridge station operated by DWR measured stage, electrical conductivity, and water temperature prior to Task 10 work.

These estimates of tidal excursion are approximate, but probably bracket the most probable river segment for the new station. It was recommended that the station be installed on a temporary basis to first consider dispersion effects and a wider range of flow and tidal conditions on excursion. This would be accomplished by installing one or more multiparameter, internal logging sondes within the proposed reach and manually downloading the data during weekly maintenance visits. The average net flows at Garwood have ranged from 726 to over 6800 cfs since January 1, 2005 due to above average precipitation during the 2004 water year. At these high flow rates, monitoring at the Stockton Brick Company (SBC) site would not be influenced by the Stockton effluent discharge. It was recommended to temporarily install a multiparameter sonde at SBC and monitor the data as flows subside later this summer or fall. If flows become low enough for the wastewater to influence water quality, the station would be moved progressively upstream. In this manner the excursion calculations provided earlier could be refined, and the effects of dispersion more carefully considered in the locating the new water quality monitoring station. A second sonde installed at the DWR Brandt Bridge station would remain fixed throughout 2005 and until April, 2006.

The proposed reach for the new water quality station is delineated in Figure 2 of report. It will extend from approximately 4.5 to 8 miles above the DWSC. Within this reach eight water diversion pump platforms, bridges or stations exist that can be used to temporarily mount instrumentation during the study. These locations are also shown in Figure 2 and their coordinate positions are listed in Table A-2. Verbal permission to use these structures on a temporary basis has been obtained and written documentation has been requested. Written permission was subsequently obtained for the Brandt Bridge station operated by the DWR and the privately owned pump station at SBC.

Description of the Station

A river reach extending from approximately 3.5 to 7 miles above the Stockton outfall is proposed for the new monitoring station location as previously shown in Figures 1 and 2. Deployment of temporary instrumentation was proposed for 2005 to refine the position for the permanent installation. If the 2004 water year yields data over a wide range of flows, a permanent location will be identified and the station will be installed in 2006.

A listing of possible temporary measurement locations within the proposed monitoring station reach was listed in Table A-2. Figure A-8 presents the bathymetry of the San Joaquin River for the proposed monitoring reach. In this river segment, water depths range from about 10 to 20 feet along the thalwag. Mixing in this region is sufficient to yield uniform lateral and vertical water quality profiles, except during brief periods between tidal flow reversals. Tidally induced velocities often exceed 1 ft/s.

In the proposed reach, the San Joaquin River is highly channelized with steep levee banks armored with rock, brick and concrete debris as shown in Figure A-9 at the Stockton Brick Company site. The smoke stack of the former Stockton Brick Company is seen in the background of the photograph. Aerial photographs of the proposed monitoring station reach are presented in Figures A-10 and A-11. As shown in these photographs the adjacent properties consist of agriculture lands irrigated with water from the San Joaquin River. Above the DWSC there are numerous water diversions and tailwater return outfalls that support agricultural activities along the San Joaquin River.

A multiparameter sonde was installed to one of the piers supporting the water diversion pump station located near the Stockton Brick Company site after the owner's permission was obtained. A photograph of the pump station is shown in Figure A-12. The water depth at the outside piers was approximately 9 feet on February 4, 2005 when the net river flow was 1867 cfs. Disturbance of sediments during the operation of the diversion pump is not anticipated due to the relative depths of the intake and river, but this will be carefully evaluated during the first week of monitoring. A second sonde will also be installed at the DWR Brandt Bridge site to collect data at the extremes of the proposed range. A photograph of the station is shown in Figure A-13.

Hydrolab DX5S and YSI 6600 EDS sondes were used to continuously monitor water quality within the proposed monitoring station reach at three locations. Water stage, temperature, dissolved oxygen, electrical conductivity, pH, fluorescence (chlorophyll *a*), and turbidity were recorded at 15 minute intervals. The data was be downloaded and maintained on approximately a 2 to 4 week basis. Manufacture defects in the internal software of the sondes has resulted in an equipment recall. Hardware failures continued after the Hydrolab sondes were replaced with new instruments. In the spring of 2006, these sondes were selected for a beta troubleshooting study initiated by Hach. All four Hydrolab sondes were retrofitted with new hardware and returned for testing. Reliable performance has been achieved since the summer of 2006 during which time the sondes have been continually used.

Appendix A Tables and Figures

Table A-1: Maximum upstream tidal excursion for selected dates and net river flows.

Dates	25-hr tidal day net river flow (cfs)	Upstream excursion (ft)	Upstream movement (mi)
July 14 and 15, 2004	116	33,000	6.2
June 1 and 2, 2004	299	27,000	5.1
June 25 and 26, 2004	617	20,000	3.8
Sept 1 and 2, 2004	540	17,000	3.2

Table A-2: Locations of structures that may be used for temporary mounting of water quality instrumentation.

Location No.	Name	SJR mi	UTM E	UTM N
1	Stockton Brick Co. (SBC)	44.7	647.0459	4195.5196
2	River diversion/pump station	45.5	646.9109	4194.7051
3	River diversion/pump station	46.6	646.7095	4193.5099
4	Howard Road Bridge	46.8	646.7079	4193.2715
5	River diversion/pump station	47.1	646.9213	4192.6519
6	River diversion/pump station	47.4	647.3788	4191.9219
7	River diversion/pump station	47.5	647.5143	4191.8892
8	DWR Brandt Bridge station	48.2	647.8691	4191.0835

Figure A-1: Excursion of rhodamine WT tracer above the DWSC measured on September 1 and 2, 2004.

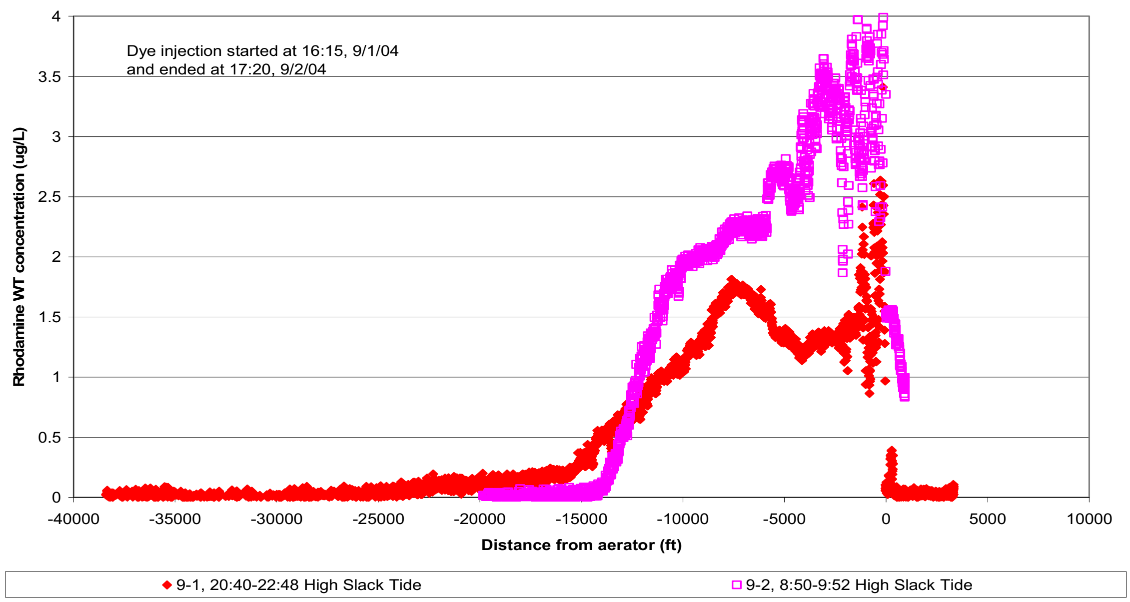


Figure A-2: Calculated rhodamine WT excursion during the tracer injection of September 1 and 2, 2004 at the Port of Stockton aeration facility.

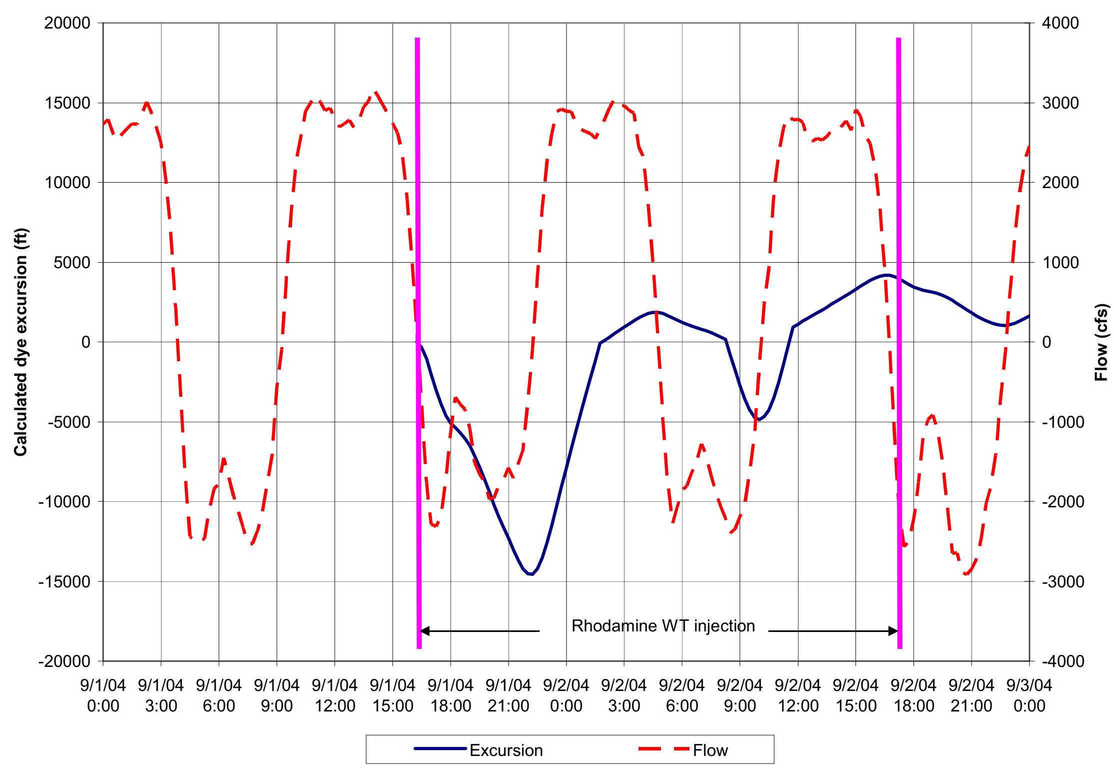


Figure A-3: Estimated tidal excursion in the San Joaquin River above the DWSC for Sept 1 and 2, 2004.

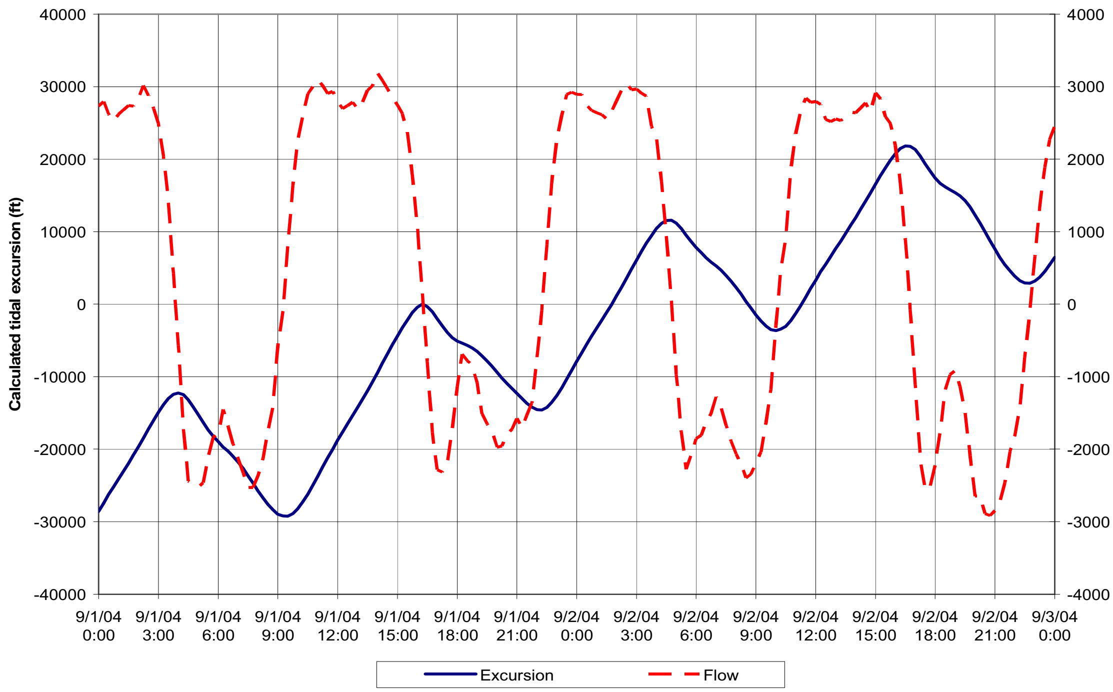


Figure A-4: Calculated tidal excursion for July 14 and 15, 2004 based on measured flow at the Garwood Bridge gage. The average net flow for the 25-hr tidal day starting at 14:15 on July 14 was 116 cfs.

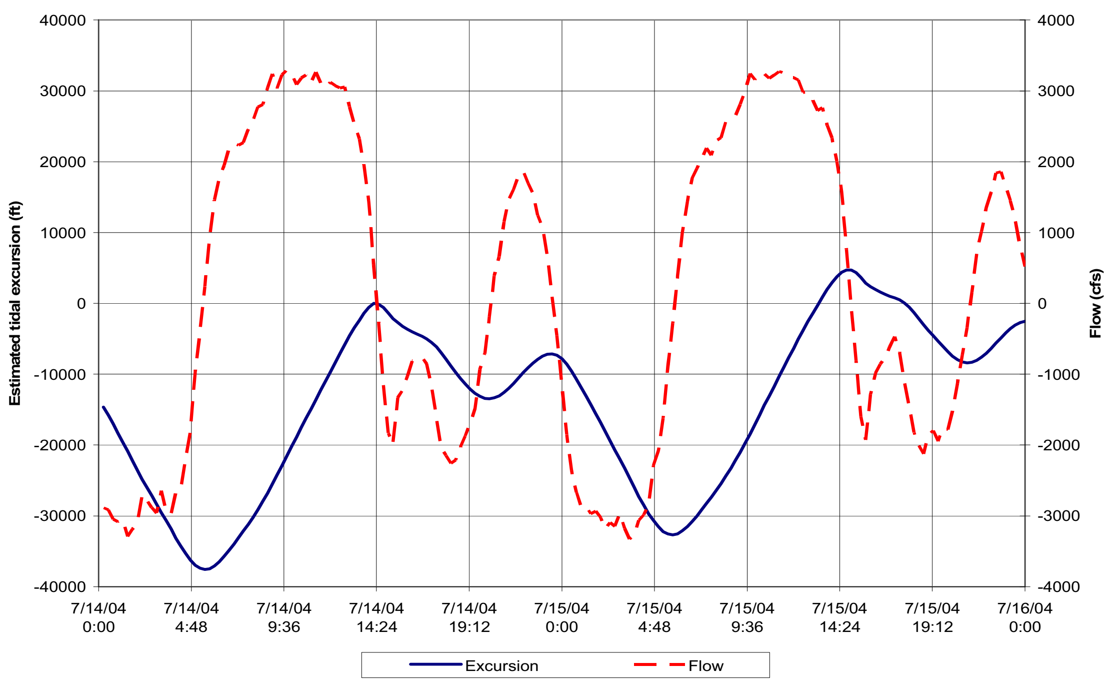


Figure A-5: Calculated tidal excursion for June 1 and 2, 2004 based on measured flow at the Garwood Bridge gage. The average net flow for the 25-hr tidal day beginning at 14:15 on June 1 was 299 cfs.

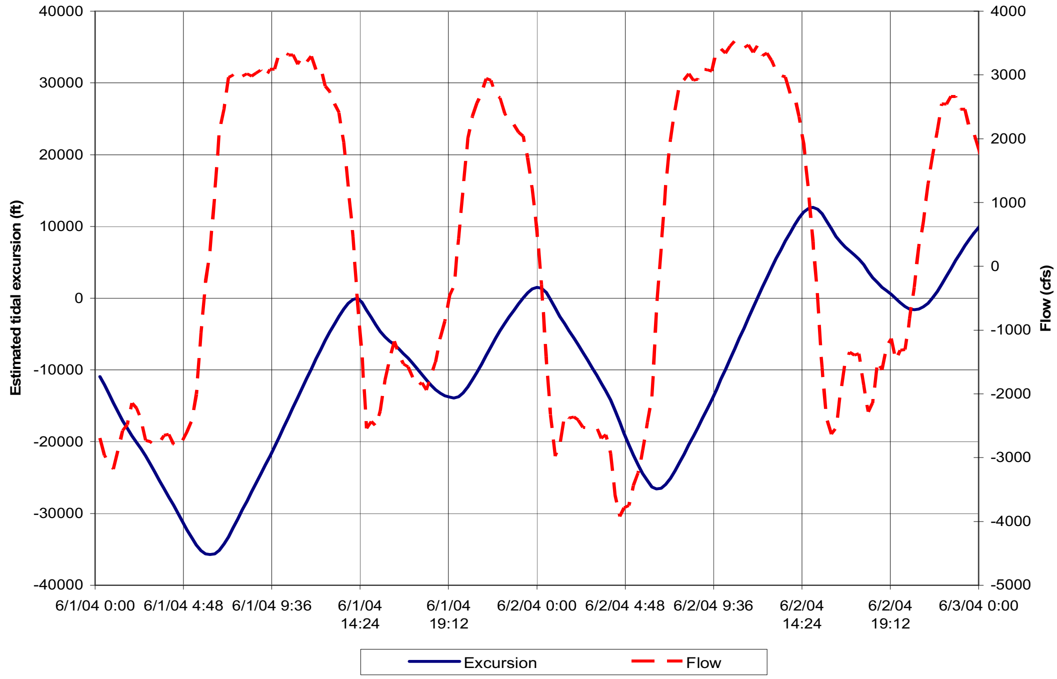


Figure A-6: Calculated tidal excursion for June 25 and 26, 2004 based on measured flow at the Garwood Bridge gage. The average net flow for the 25-hr tidal day starting at 8:30 on June 25 was 617 cfs.

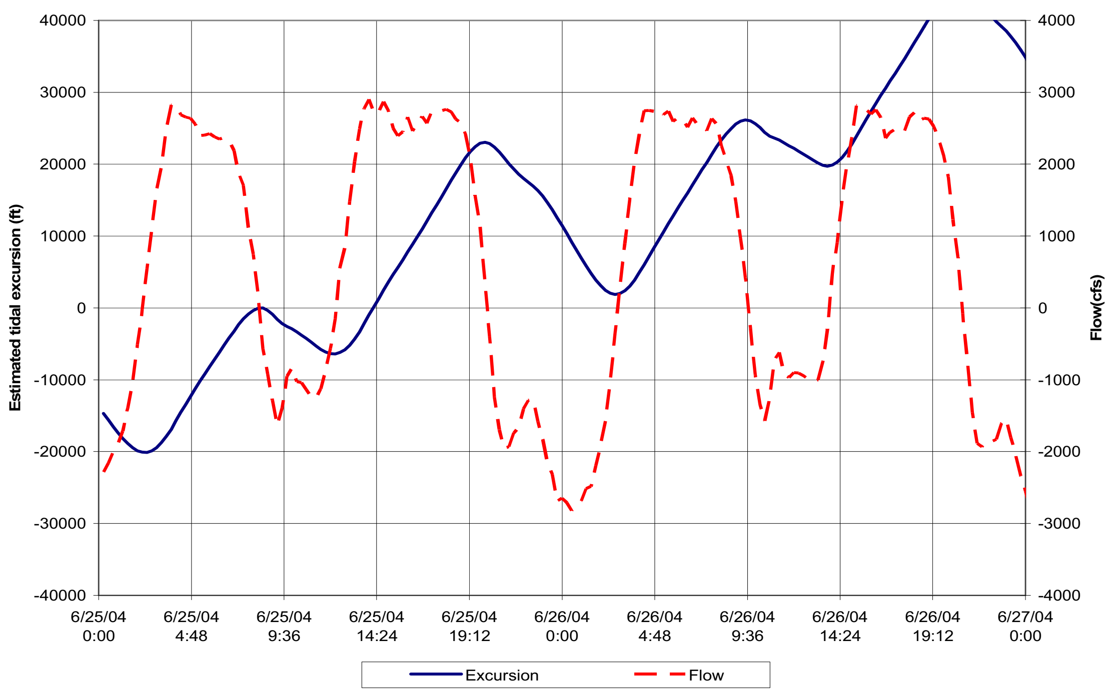


Figure A-7: Cumulative distribution of observed flows entering the DWSC for the 2003 water year.

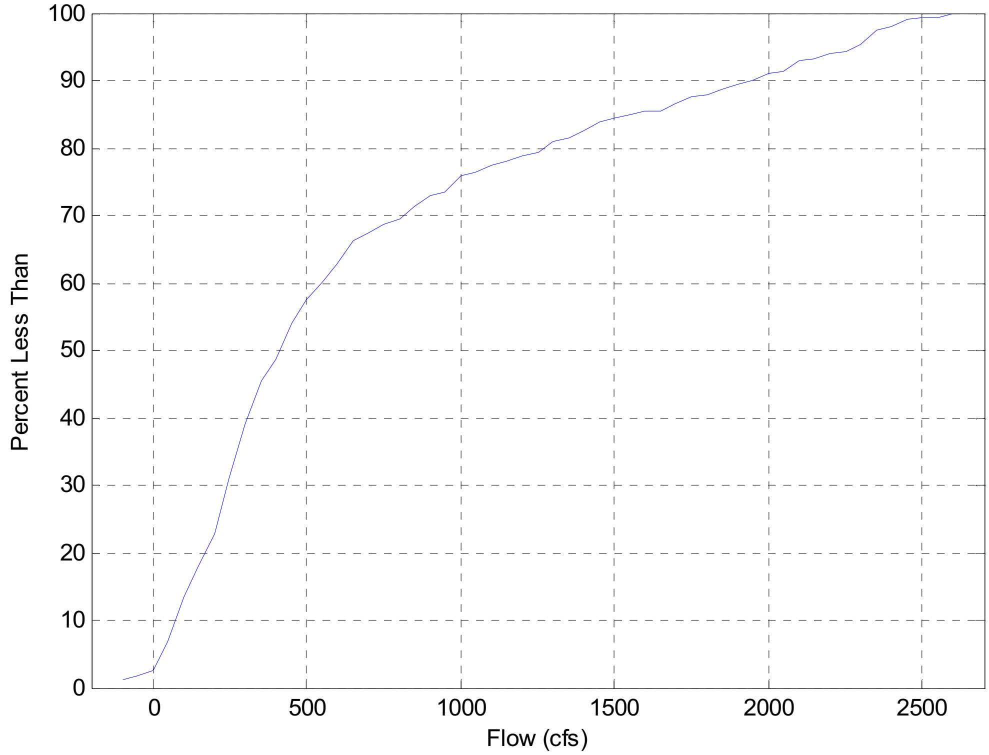


Figure A-8: Bathymetry of the San Joaquin River above the DWSC.

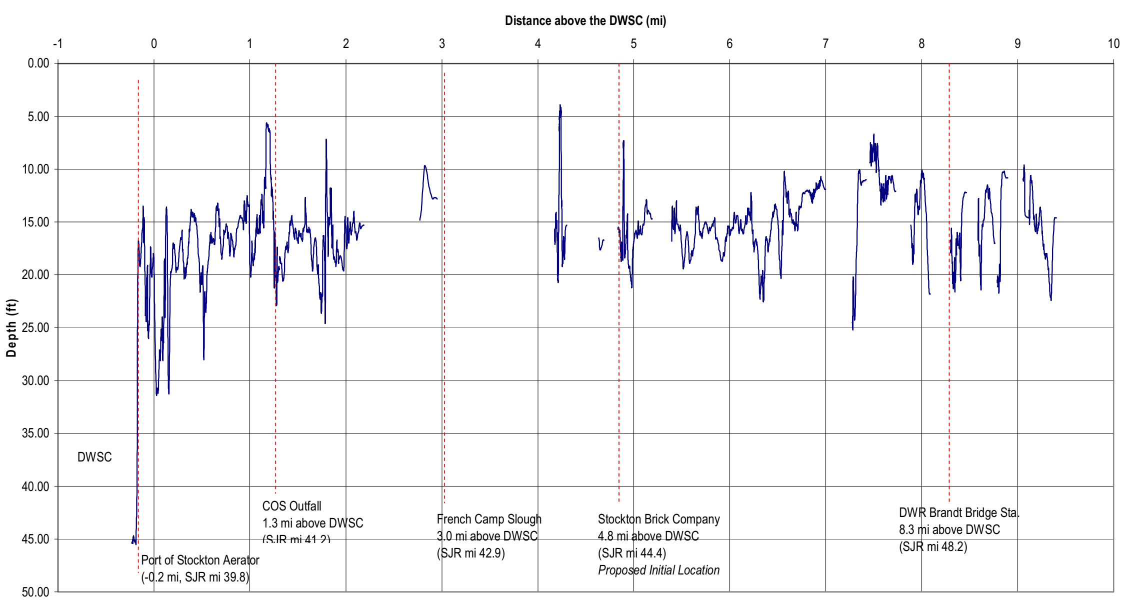


Figure A-9: The San Joaquin River at the Stockton Brick Company Site.

Figure A-10: An aerial photograph of the proposed monitoring station reach from SJR mi 44.7 to SJR mi 47. Locations of selected temporary monitoring sites are also presented.

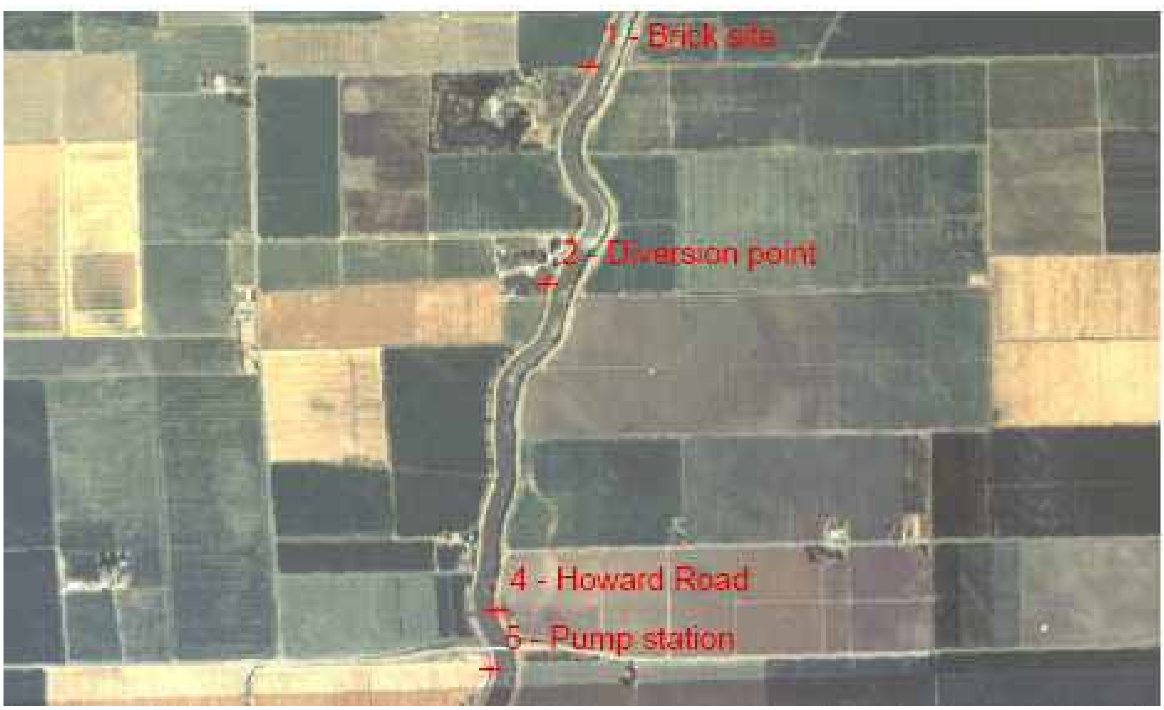


Figure A-11: An aerial photograph of the proposed monitoring station reach from SJR mi 47 to SJR mi 47.9 . Locations of selected temporary monitoring sites are also presented.

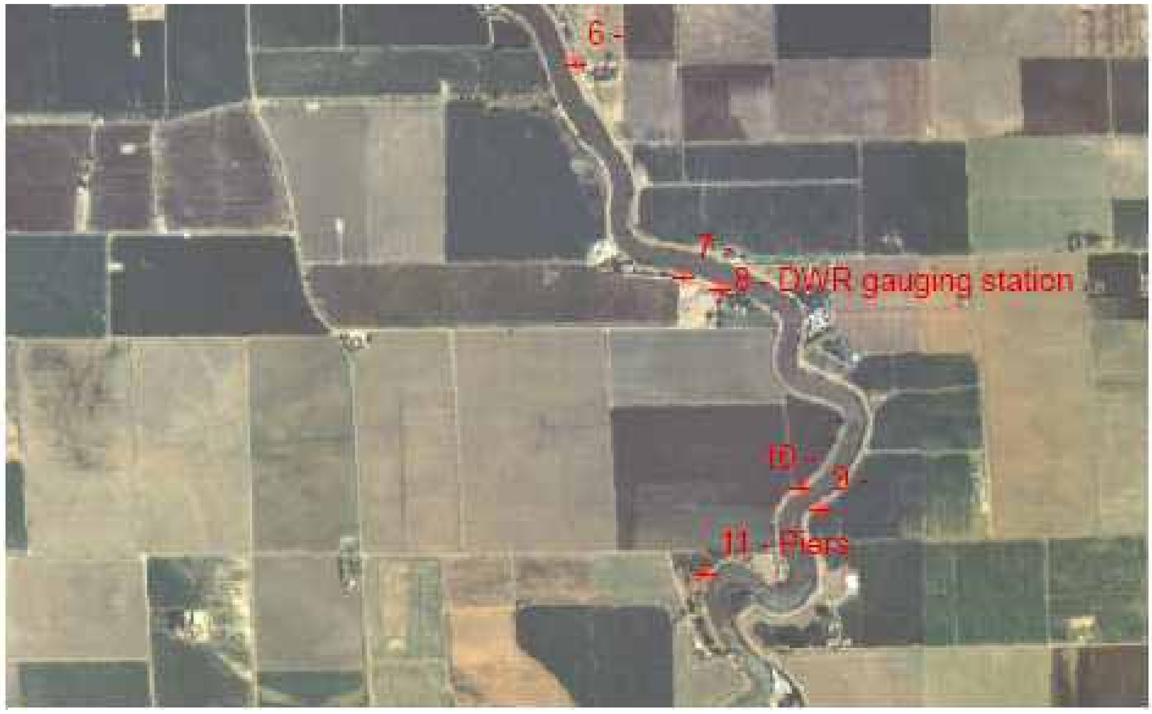


Figure A-12: The water diversion pump at the Stockton Brick Company.

Figure A-13: The DWR Brandt Bridge Station

Figure A-14: Piers used at OP for chain-mounted sonde deployment.

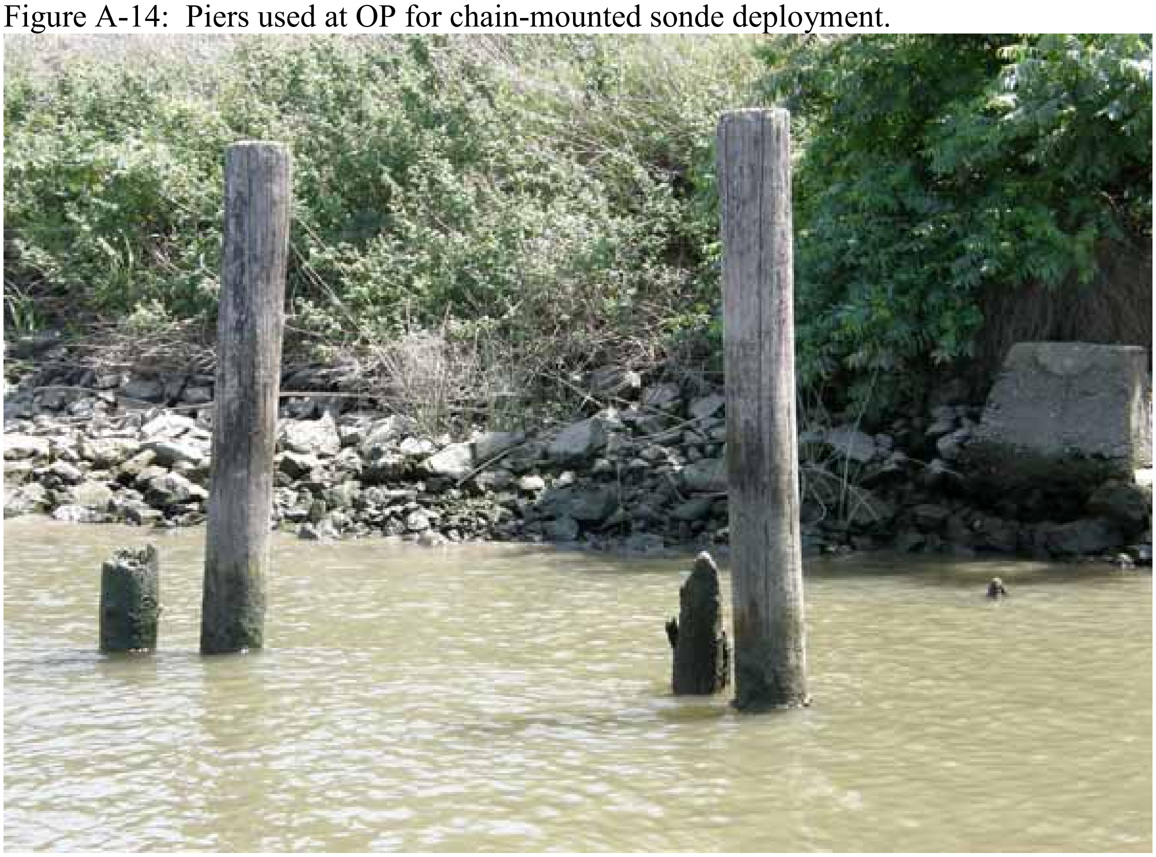


Figure A-15: The permanent 4” ABS pipe sonde housing installed at SBC.

Appendix B Water quality observations observed during selected low net San Joaquin River flow periods for 2005 and 2006

December, 2005 Low Flow Behavior

Water quality data was measured at the Brandt Bridge Station and the Outfall Pier from November 27, 2005 through January, 2006. Comparisons of the measured relative river stage at the Brandt Bridge and the Outfall Pier are shown in Figures B-1 and B-2. The average stage increases significantly for flows approaching 4000 cfs. The average Brandt Bridge stage is approximately 5 ft higher at 4000 cfs when compared to river elevations at flows less than 1000 cfs. Figure 6 presents only three days in December during low net flows to exhibit the tidal stage characteristics entering the San Joaquin River above the DWSC and at Brandt Bridge Station. As shown in Figure 6, the change in stage at both stations is similar but the slack tide maxima and minima at Brandt Bridge arrive about 30 to 45 minutes after passing the Outfall Pier, a distance of approximately 6.7 miles.

Water temperature data at Brandt Bridge and the Outfall Pier are shown in Figure B-3. Temperatures at Brandt Bridge are usually colder than the downstream water. The Outfall Pier temperature exhibit a greater fluctuation during each 24 hour period due to the warmer water of the DWSC flowing upstream during flood tides at times of low net flows.

The dissolved oxygen at the Brandt Bridge Station and the Outfall Pier are presented in Figure B-4. This graph dramatically illustrates the difference in the DO entering the DWSC and the DO in the DWSC. When the net daily river flows were less than 500 cfs the dissolved oxygen was approximately 4 mg/L lower in the DWSC than the water entering the DWSC. This difference decreased to 2 mg/L at 1000 cfs and then less than 1 mg/L for flows greater than approximately 1500 cfs. This phenomenon is caused by the reduction of residence time in the DWSC as the flow increases (Jones & Stokes, 2002; Foe *et al.,* 2002*)*. At flows of 2500 cfs or higher, DO measurements are similar suggesting that either station could equally well represent the DO entering the DWSC. However, at critically low flows this is not the case, thus motivating this investigation to determine the closest location to the DWSC at which DWSC water or City of Stockton wastewater effluent would exhibit little influence on measured parameters. Similar behavior is also seen in the pH data shown in Figure B-5.

The turbidity measured at Brandt Bridge and the Outfall Pier is presented in Figure B-6. Both stations yield similar turbidities at low and high net river flows. Some spatial differences in turbidity may exist at low flows as tidal flows and particle setting during slack tides may be important. However, assessing the importance of these mechanisms will require careful analysis of more data. The increase of turbidity with flow suggests that streambed erosion and perhaps nonpoint source runoff are dominant sources.

Chlorophyll fluorescence converted to concentration is shown in Figure B-7 for Brandt Bridge and the Outfall Pier Stations. Chlorophyll a is shown to be approximately 2-3 μg/L at Brandt Bridge during late November and December. However, near the DWSC the chlorophyll a concentration are much higher and exhibit significant variation associated with tidal excursion during flood flows. Algae growing in the DWSC are moved up the river beyond the Outfall Pier Station during each flood tide. The high chlorophyll fluorescence concentration at flows in excess of 2000 cfs appear to be associated with the high turbidity.

December, 2006 Low Flow Behavior

The net daily flow in the study reach of the San Joaquin River again fell below 500 cfs in late November as shown in Figure B-8 and remained below 500 cfs until mid December. The influence of the flow on water temperature at BDT, SBC, and OP is also shown in Figure B-8. Daily temperature fluctuations become amplified at all sites when the flow dropped below 500 cfs. This effect appears to be caused by reduced residence time in the reach during which daily solar radiation has a more pronounced effect. An alternative explanation is that the warmer water from the DWSC flows up the San Joaquin River during flood tide episodes. Figure B-9 presents the water temperature data on December 1 and 2, 2006, a time period for which the net daily flow was approximately 225 cfs. Also presented on this plot is the river stage and instantaneous flow at the SJG station, located between the OP and SBC stations as presented earlier in Figures 1 and 2. The OP station is clearly within the tidal influence of the DWSC as shown by the two maxima in temperature per day associated with warmer water flowing up the San Joaquin River during flood tides. Reverse flood tide flows are shown with negative values in the SJG 15 minute flow. The temperature data for SBC and BDT do not exhibit the bimodal daily behavior observed at OP, but instead one maxima and minima are observed per day. At SBC and BDT the minimum temperatures are observed in early morning (7-9 AM) and maximum temperatures occur at in late afternoon (3-4 PM) and as such tidal excursion from the DWSC did not appear to reach BDT or SBC (4.8 miles above the DWSC). However, the longer term effects of tidal dispersion occurring over several days may well have the effect of a slightly elevated SBC temperature relative to the farther upstream station BDT. Tidal dispersion effects are evident in Figure 12 as seen in the 4-6 day delay in the daily temperature fluctuation response to the drop in the net flow.

Figure B-10 presents the relative stage at BDT, SBC, and OP during the two day period. As discussed earlier for 2005 data, the time lag for slack tides is about 30 to 45 minutes from OP to BDT. As expected the SBC slack tides fall between the slack periods for the OP and BDT stations, which are downstream and upstream of SBC, respectively.

The conductivity at 25ºC during the December 2006 low flow period also provides evident for the extent of the tidal excursion upstream from the City of Stockton treatment plant outfall. Figure B-11 presents the conductivity data for BDT, SBC, and OP from

November 18 to December 8, 2006. As discussed earlier, the net daily flow in the San Joaquin River decreased from 820 cfs to less than 200 cfs during this period. The response in the conductivity also exhibits greater daily variability once flows fell below approximately 400 cfs. Net flows were lowest (approximately 200 cfs) from December 1 to December 6, 2006, a period that also exhibited the greatest fluctuation in the SBC conductivity data. As shown in Figure B-12, the conductivity at SBC spiked at the end of each flood tide. This spike appears to be associated with the high conductivity of the City of Stockton's wastewater effluent discharge (approximately 1200 μS/cm). The spikes do not appear to be associated with DWSC waters as their conductivities are lower than all other values upgradient in the San Joaquin River.

Conductivity and temperature data measured at SBC are plotted together in Figure B-13. While daily temperature fluctuation increase as the net flow decreases, these fluctuations appear to be associated with solar radiation and not tidal flows. The daily variation in the conductance shown in Figure B-13 is associated with reverse tidal flows carrying high conductivity Stockton effluent water upstream. Daily variations appear to start when the net flow falls below about 400 cfs. Therefore, the SBC station appears to outside the tidal excursion whenever the net daily flow is greater than about 400-500 cfs. The conductivity of SBC and BDT are again shown in Figures B-14 and B-15. These comparisons indicate that Stockton wastewater effluent was detected at SBC from December 1 to December 8, but fails to show an influence at BDT, with the possible exception on December 4. These data suggest that the BDT station will be above the flood tide excursion associated with the Stockton effluent discharge at all but extremely low net flows.

Figure B-1: The relative river stage at the Brandt Bridge Station and the Outfall Pier. The net daily flow measured at the Garwood Bridge (RM 41.8) is also presented.

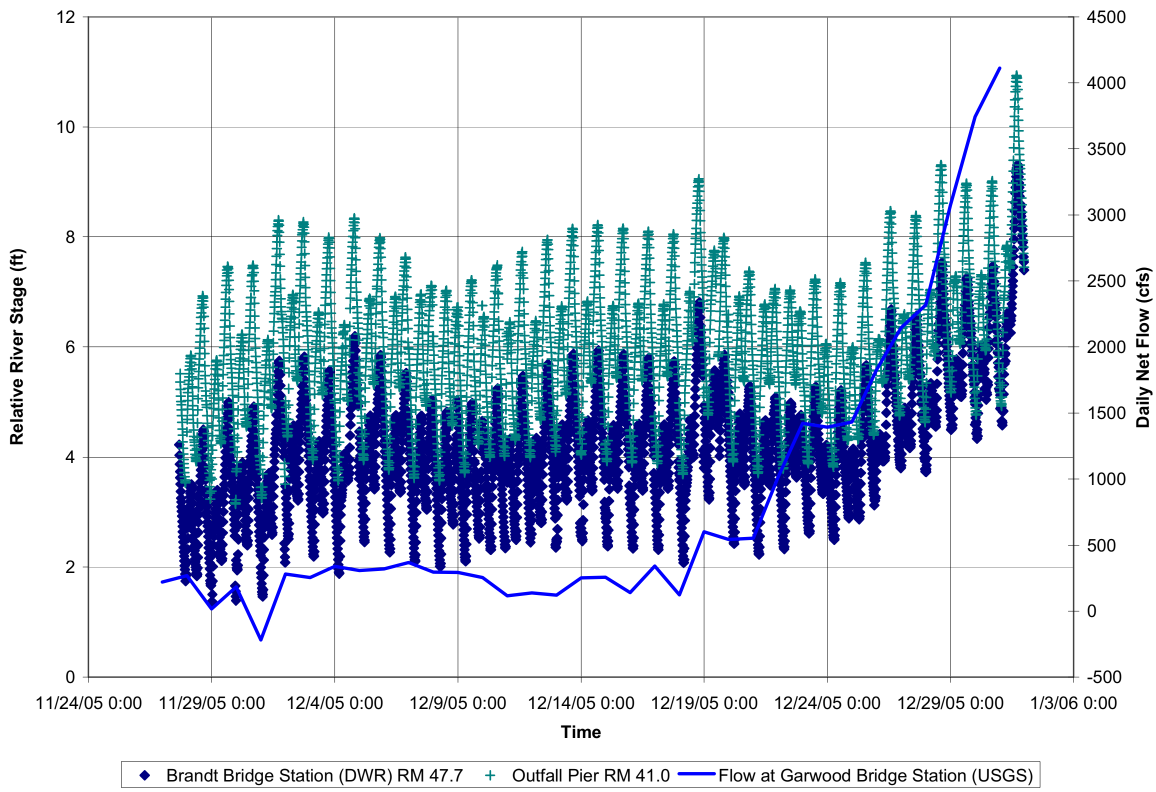


Figure B-2: The relative river stage at the Brandt Bridge Station and the Outfall Pier during three days in December. The net daily flow measured at the Garwood Bridge (RM 41.8) is also presented.

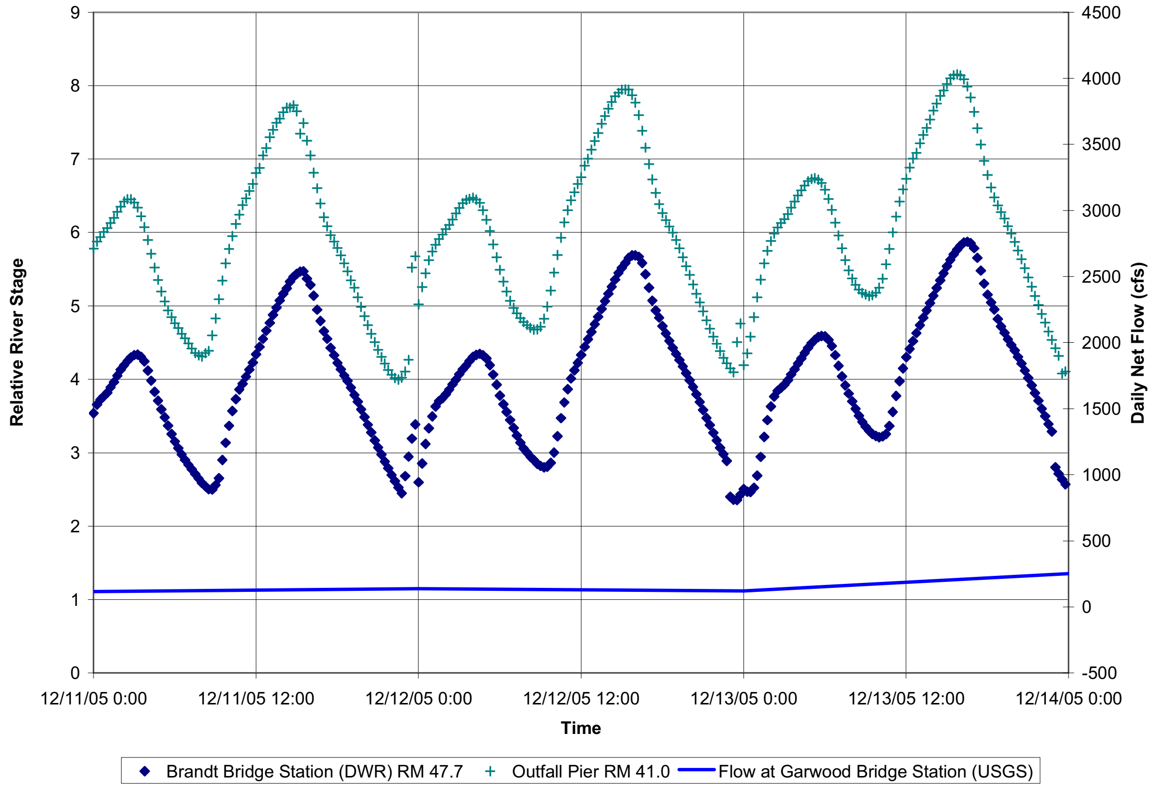


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Figure B-3: The water temperature at the Brandt Bridge Station and the Outfall Pier from November 27 to December 31, 2005. The net daily flow measured at the SJG (RM 41.8) is also presented.

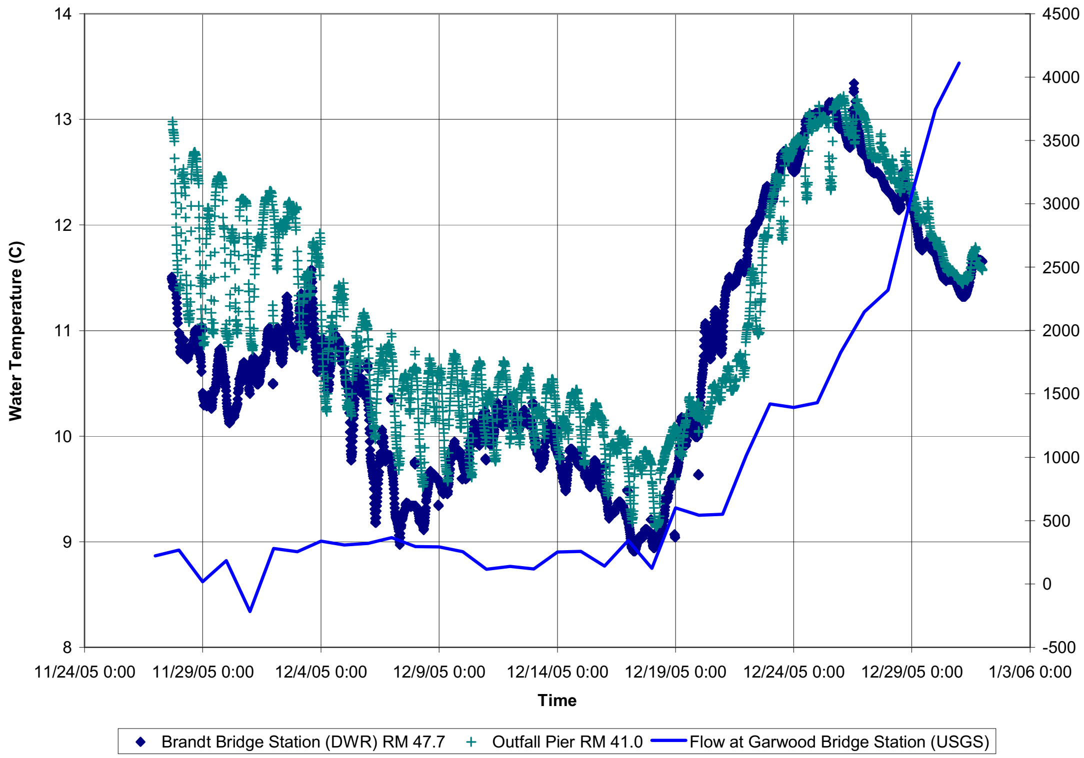

Figure B-4: The dissolved oxygen at the Brandt Bridge Station and the Outfall Pier from November 27 to December 31, 2005. The net daily flow measured at SJG (RM 41.8) is also presented.

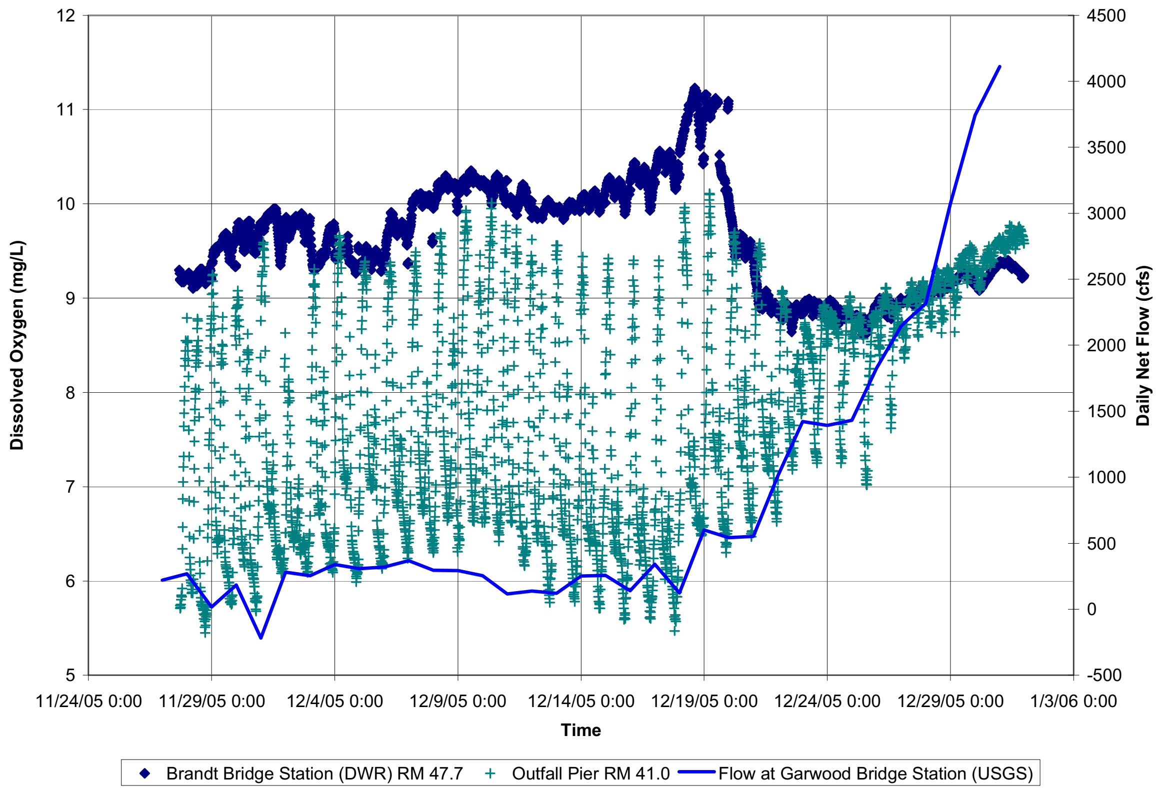

Figure B-5: The pH at the Brandt Bridge Station and the Outfall Pier from November 27 to December 31, 2005. The net daily flow measured at SJG (RM 41.8) is also presented.

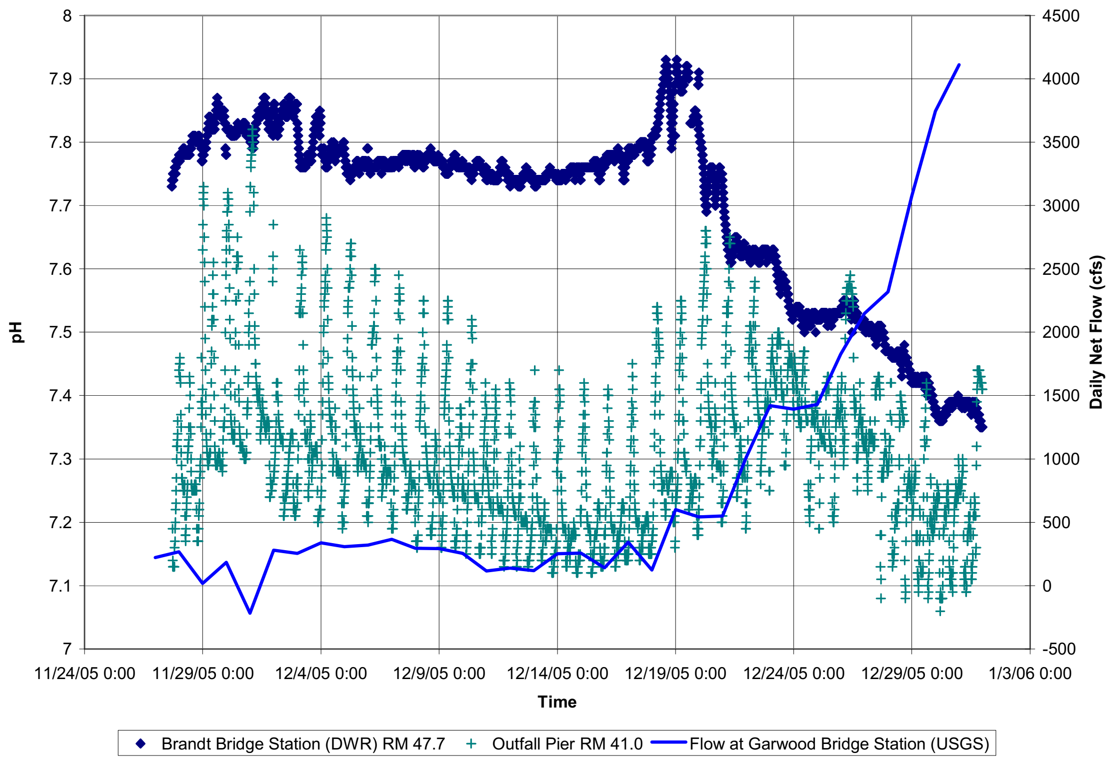

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Figure B-6: The turbidity at the Brandt Bridge Station and the Outfall Pier from November 27 to December 31, 2005. The net daily flow measured at SJG (RM 41.8) is also presented.

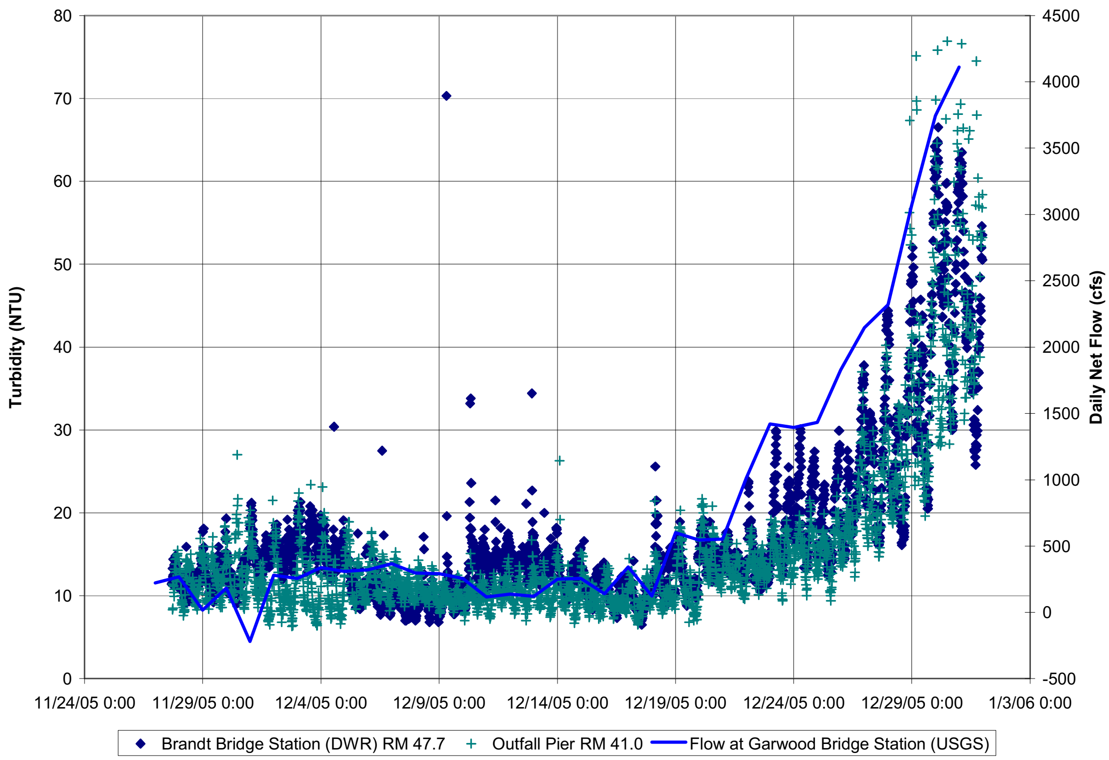

Figure B-7: The chlorophyll fluorescence at the Brandt Bridge Station and the Outfall Pier from November 27 to December 31, 2005. The net daily flow measured at SJG (RM 41.8) is also presented.

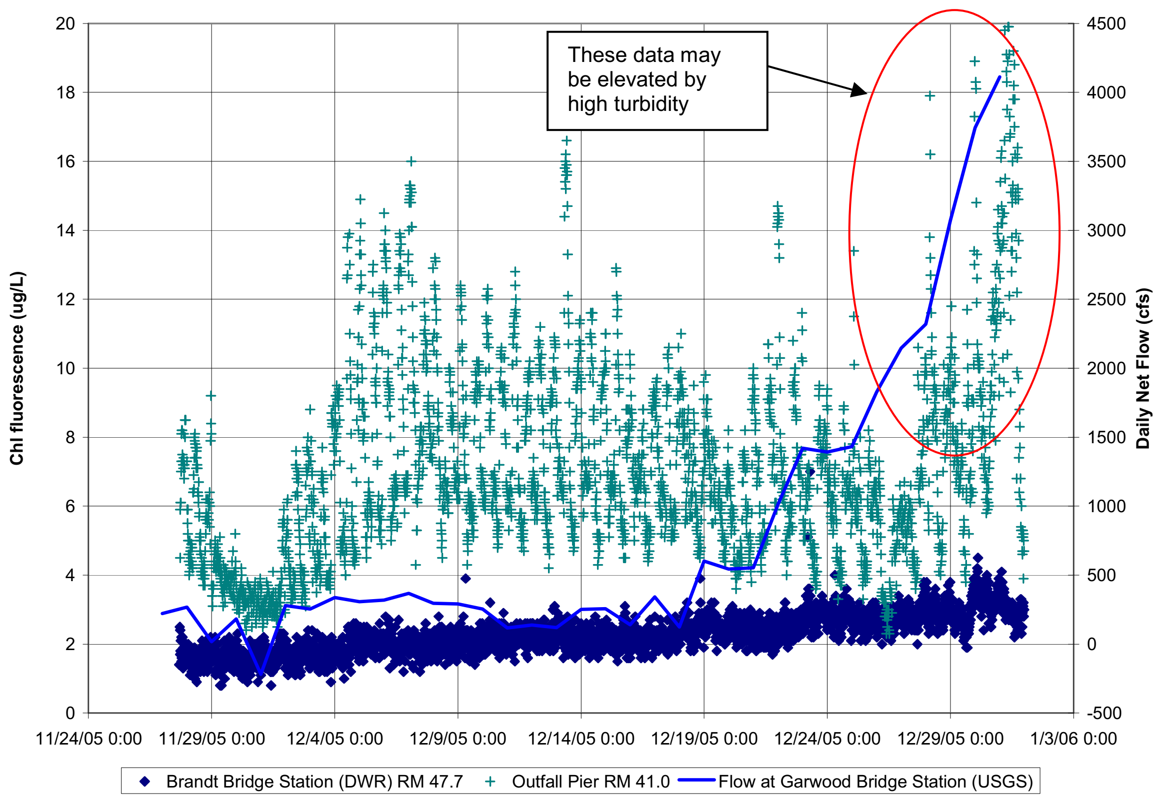

Figure B-8: Water temperature (ºC) recorded at BDT, SBC and OP stations on November 18 to December 15, 2006. Also shown is the net daily flow measured at SJG.

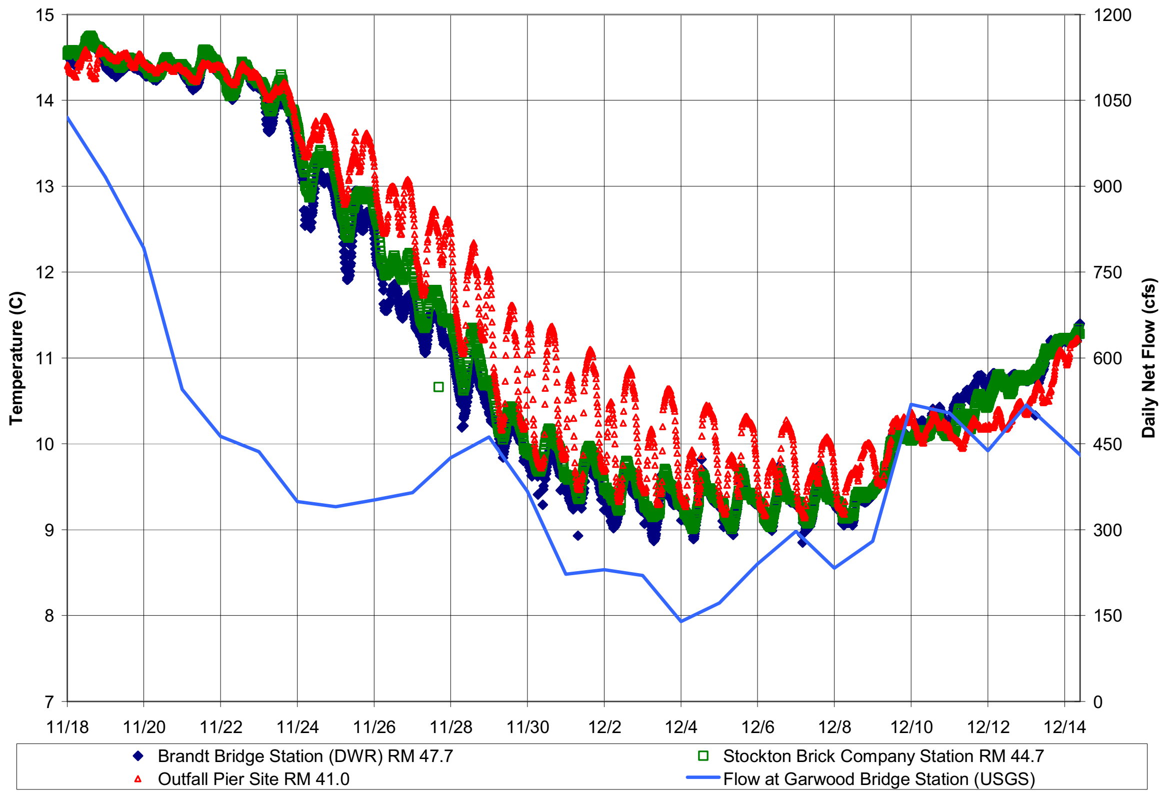

Figure B-9: Water temperature (ºC) recorded at BDT, SBC and OP stations on December 1 and 2, 2006. Also shown are the stage and flow measured at SJG. The net daily flow for these days was approximately 225 cfs.

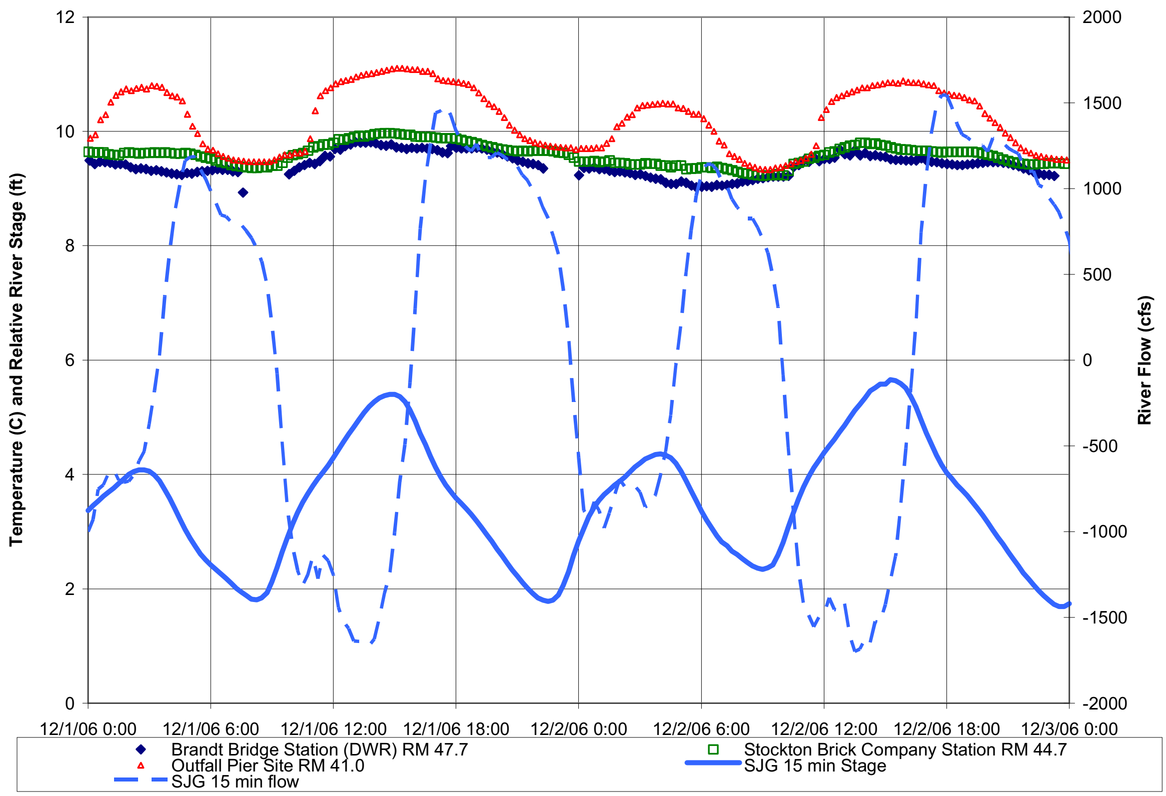

Figure B-10: Water temperature (ºC) and relative river stage (ft) recorded at the BDT, SBC and OP stations on December 1 and 2, 2006. The net daily flow for these days was 225 cfs.

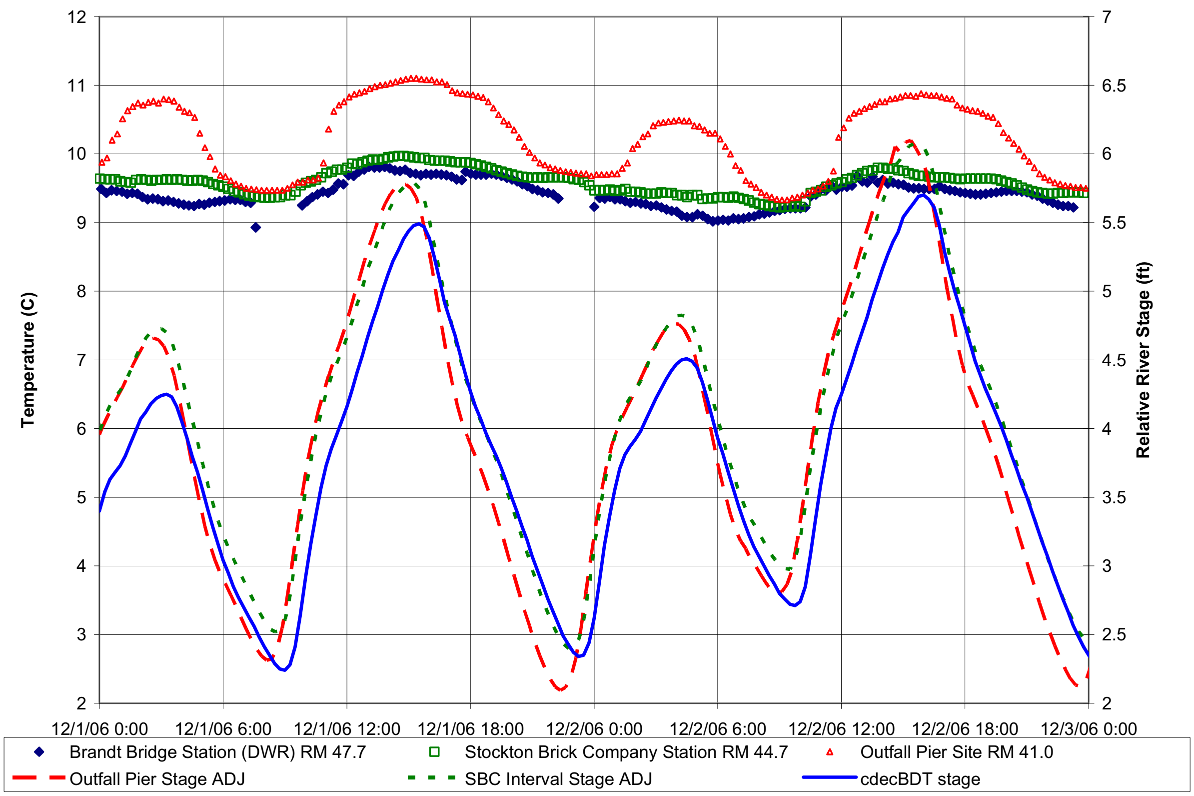

Figure B-11: Specfic conductance at BDT, SBC, and OP November 18 to December 8, 2006. Also shown is the net daily flow San Joaquin River flow measured at SJG.

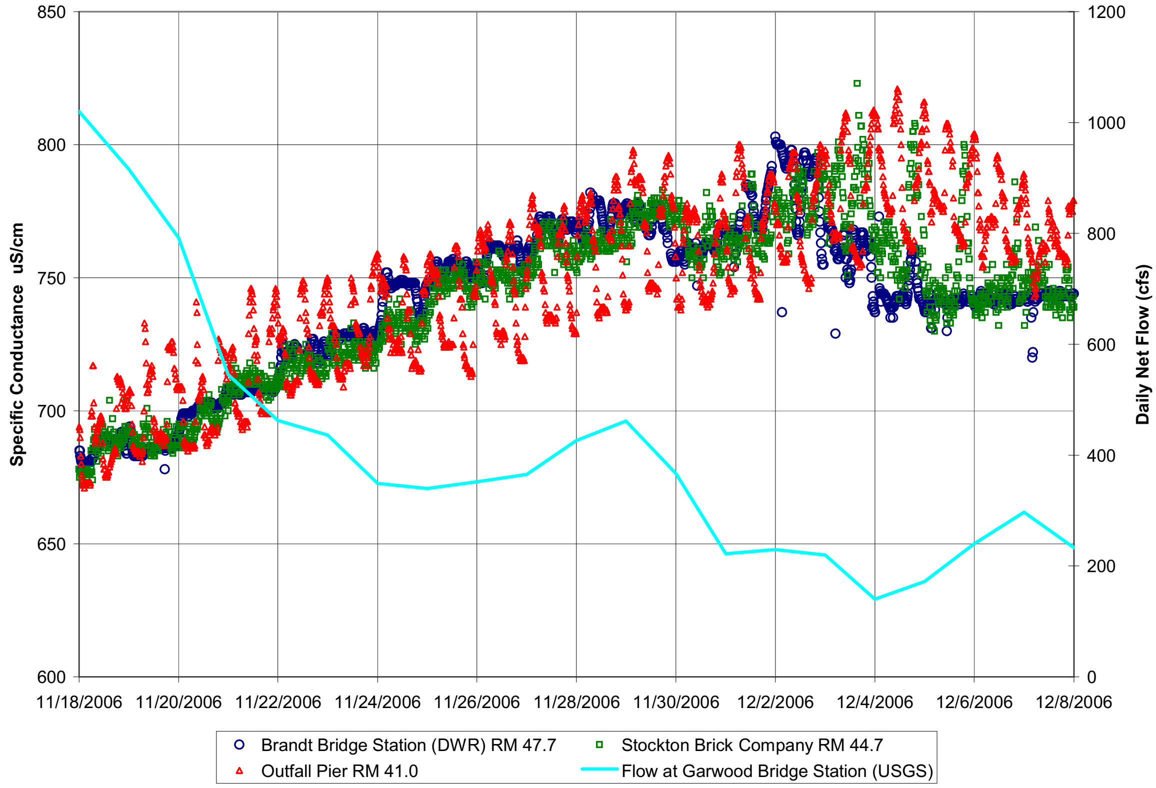

Figure B-12: Specfic conductance at BDT, BDT-DWR, SBC, OP and RRI-DWR December 1 to December 5, 2006. Also shown is the flow San Joaquin River flow measured at SJG.

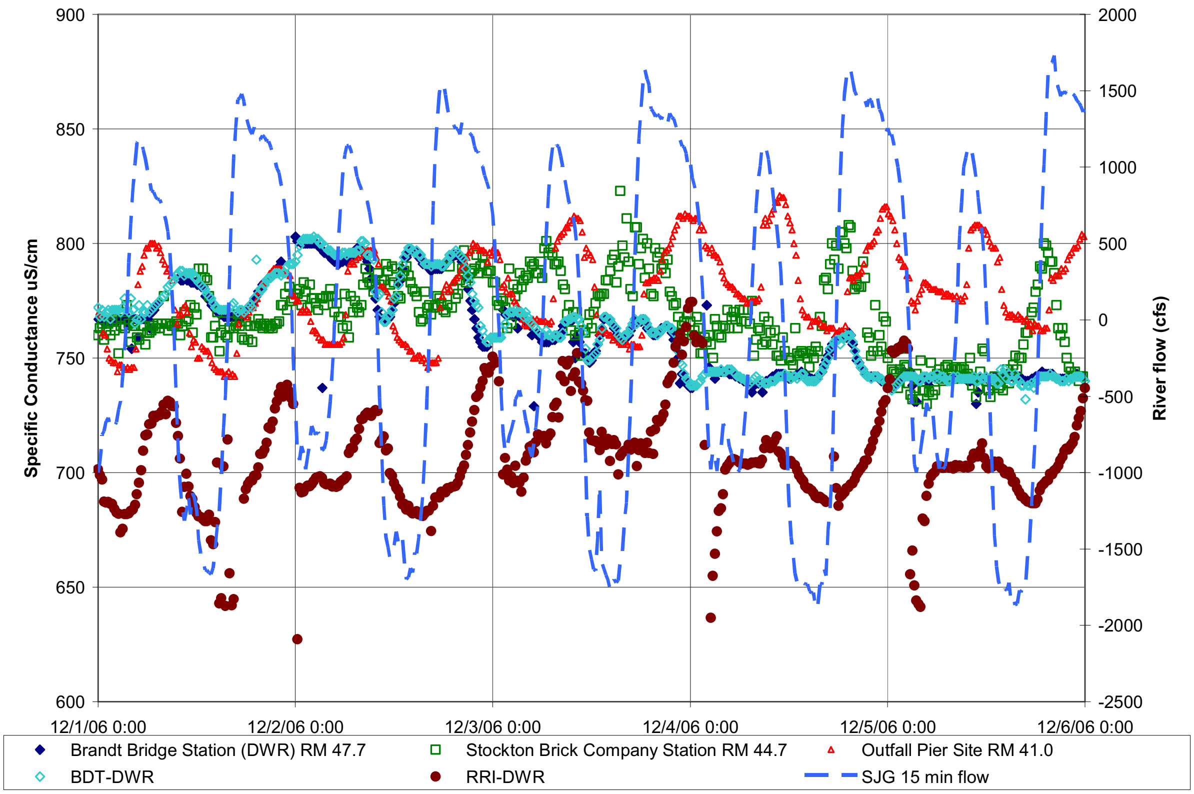

Figure B-13: The conductivity at 25ºC and temperature at SBC from November 18 to December 8, 2006. The net daily flow at SJG is also shown.

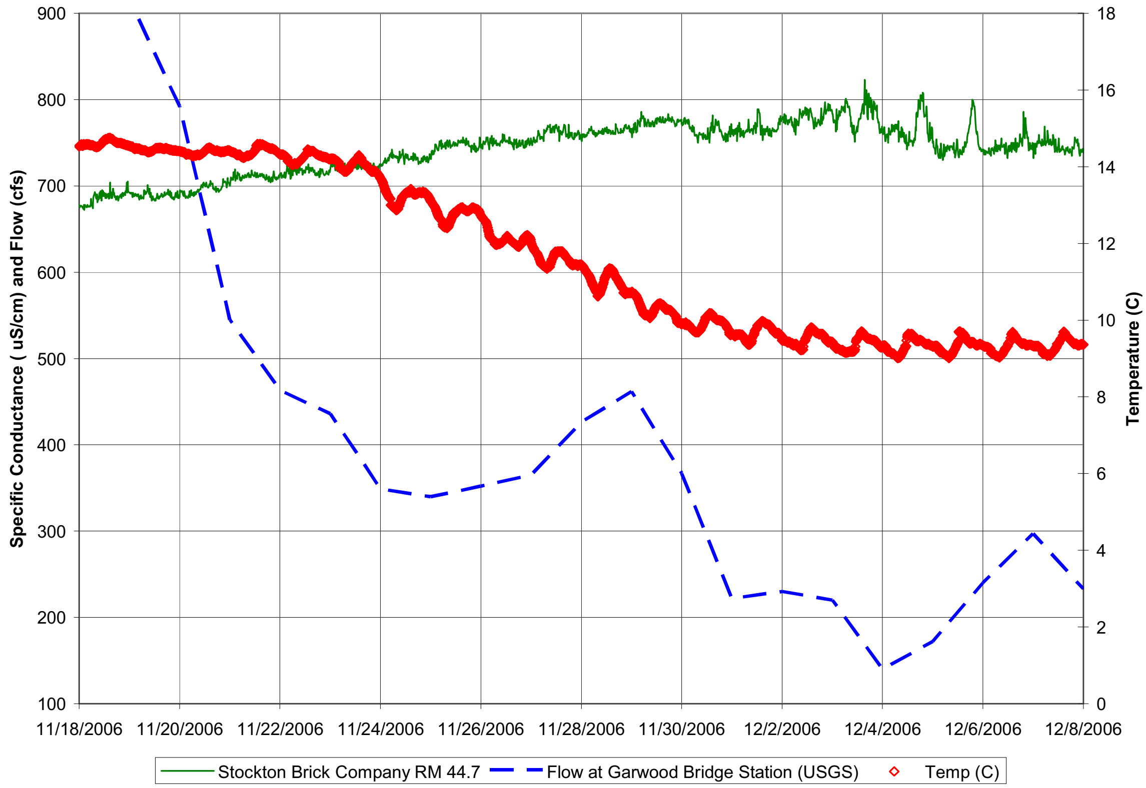

Figure B-14: The conductivity at 25ºC at SBC and BDT during a period of low net daily flow as measured at the SJG station.

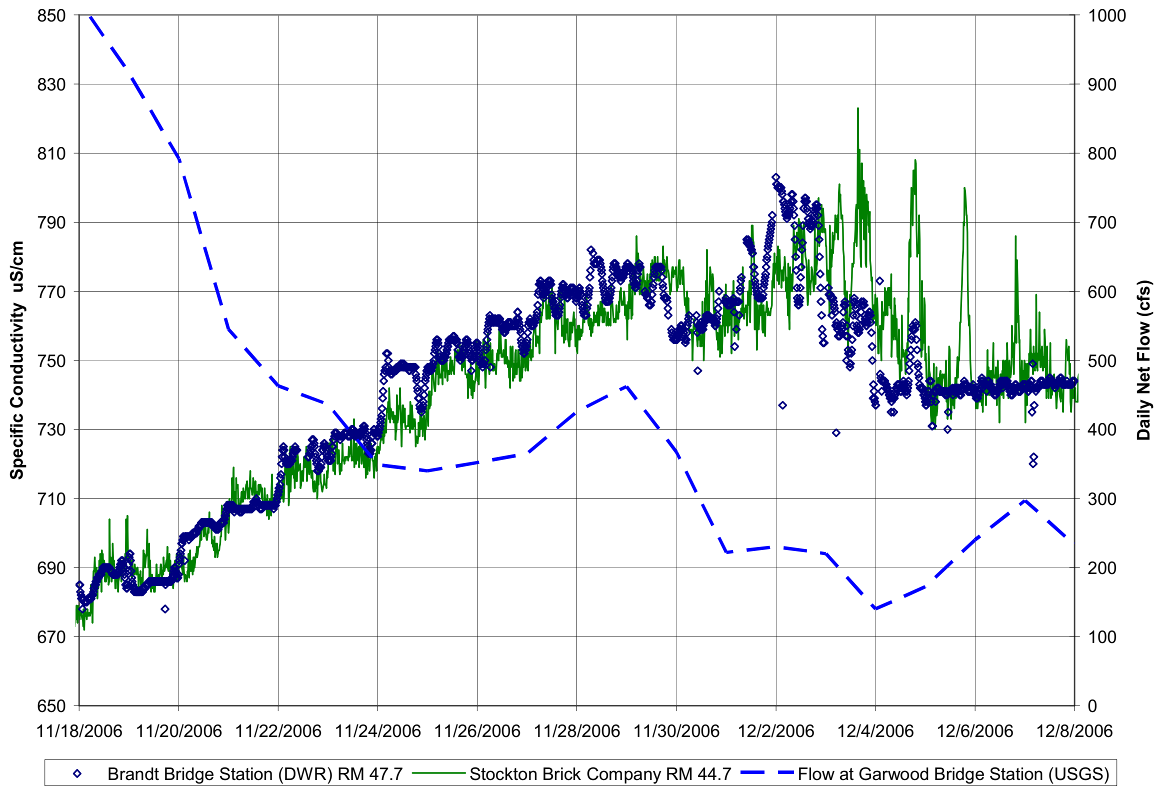

Figure B-15: Water conductivities measured at BDT and SBC from December 1 to December 5, 2006 when net daily flow was less then 230 cfs. The instantaneous flow measured at SJG shows the direction of flow (negative values indicate flood tidal flows) during this 5 day period.