San Joaquin River Dissolved Oxygen Total Maximum Daily Load
Submission of Stockton Regional Water Control Facility Data Collected Fall of 1999
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Introduction

This report was prepared for the San Joaquin River dissolved oxygen (DO) total maximum daily load (TMDL) Technical Committee and evaluates data provided by staff of the City of Stockton Regional Water Control Facility's (RWCF). The study reach was defined by those monitoring stations established in Stockton's RWCF's NPDES permit. The study reach encompasses Mossdale to R8. Figure 1 graphically locates sampling locations as they are referred to in this report, in addition to referencing navigation lights as used in other sampling programs.

Flows

San Joaquin River

An ultrasonic velocity meter (UVM) operated and maintained by the United States Geological Survey (USGS) continuously monitors river flows at a location just upstream of the submerged pipe outfall at the RWCF. Measuring both river stage (feet mean sea level [msl]) and flow (cubic feet per second [cfs]), UVM data is provided at 15-minute intervals, suitable for measuring the daily tidal influence on the river at this location. Fifteen minute and daily average (daily net) river stage and flow charts are provided below for the months of August and September, 1999 (Figures 2-5). October data were not available by the date this report was prepared.

Review of the flow and stage charts allows clear visualization of the tidal forces acting on the river system. Spring and neap tides are visible in the river stage charts, spring tides (period of greatest tidal energy) represented by daily range in stage upwards of 4 feet and neap tides (period of lowest tidal energy) with daily range of about 3 feet. This is most evident in the month of August, where relatively stronger spring and neap tides were recorded.

Net flow through August and most of September is seen to remain fairly constant, at about 1,000 cfs. Towards the end of September, starting on the 23rd and 24th of September, river flows drop significantly, from a two month high of about 1,350 cfs to a low of 71 cfs on September 30th. Although flows drop significantly, a condition of net upstream flow past the UVM at Stockton was not witnessed. Tidal flows during spring tides in August show an upstream flow of almost 3,000 cfs, then reversing to a downstream flow of about 4,000 cfs (August 10). Such episodes would suggest the presence of relatively strong tidal induced mixing within the study segment encompassed by the Stockton Deep Water Ship Channel.

Review of flow and river stage data does not present significant cause for concern regarding operability problems with the UVM device. Although concern has been raised, no evidence in support of UVM malfunction is evident.

Insert Figure 1

Figure 2
Stockton UVM Flow Data, August 1999

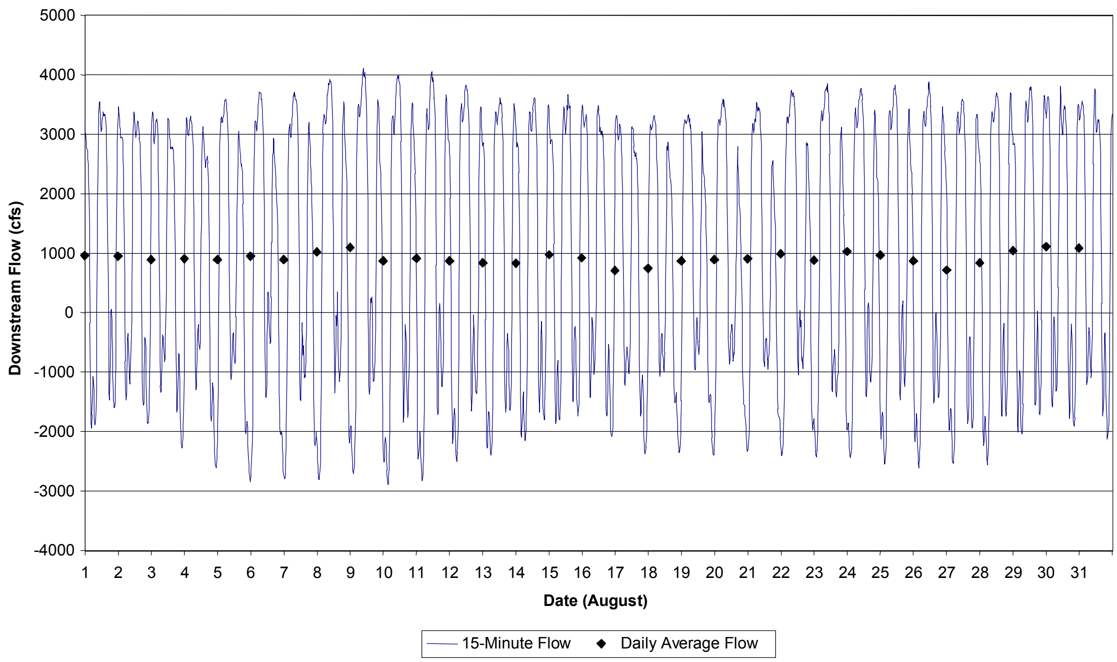


Figure 3
Stockton UVM Stage Data, August 1999

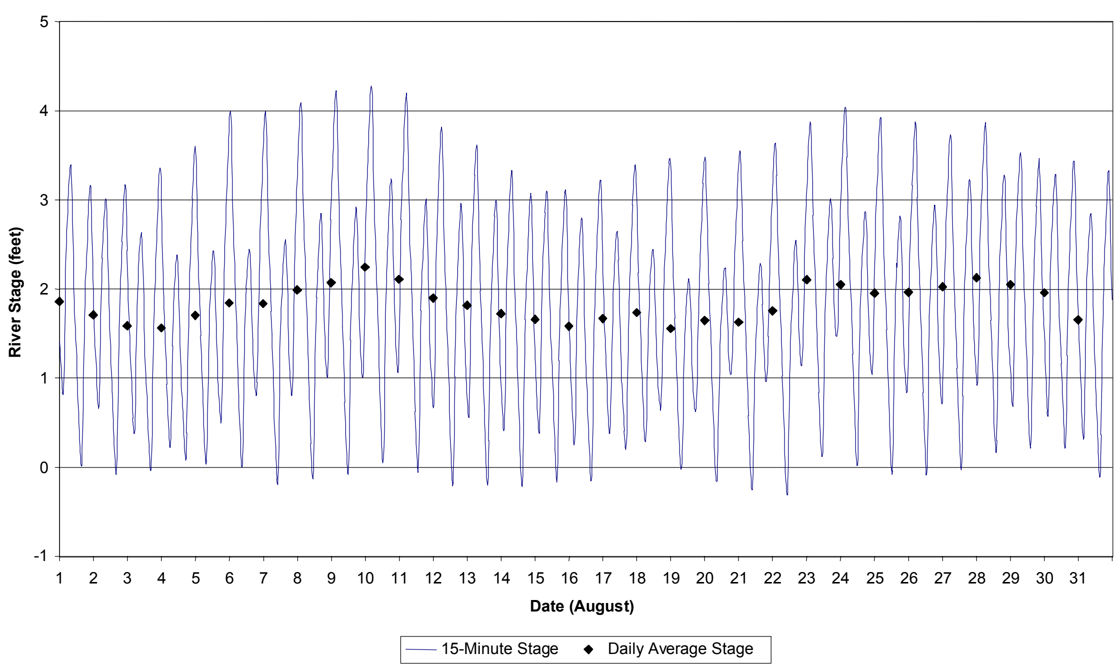


Figure 4
Stockton UVM Flow Data, September 1999

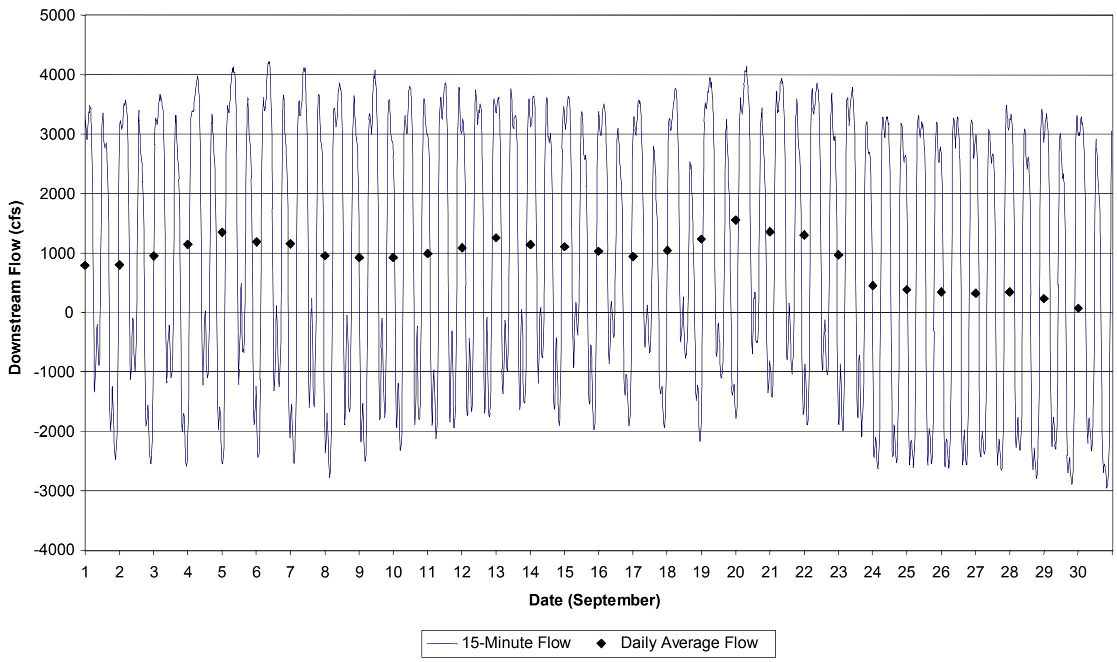
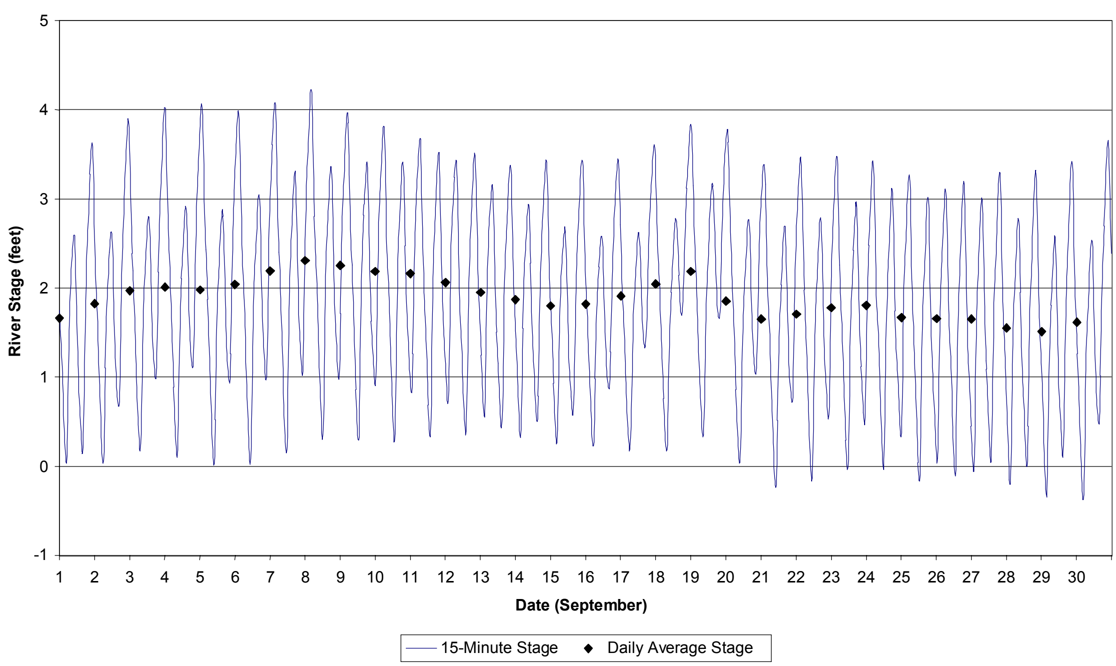


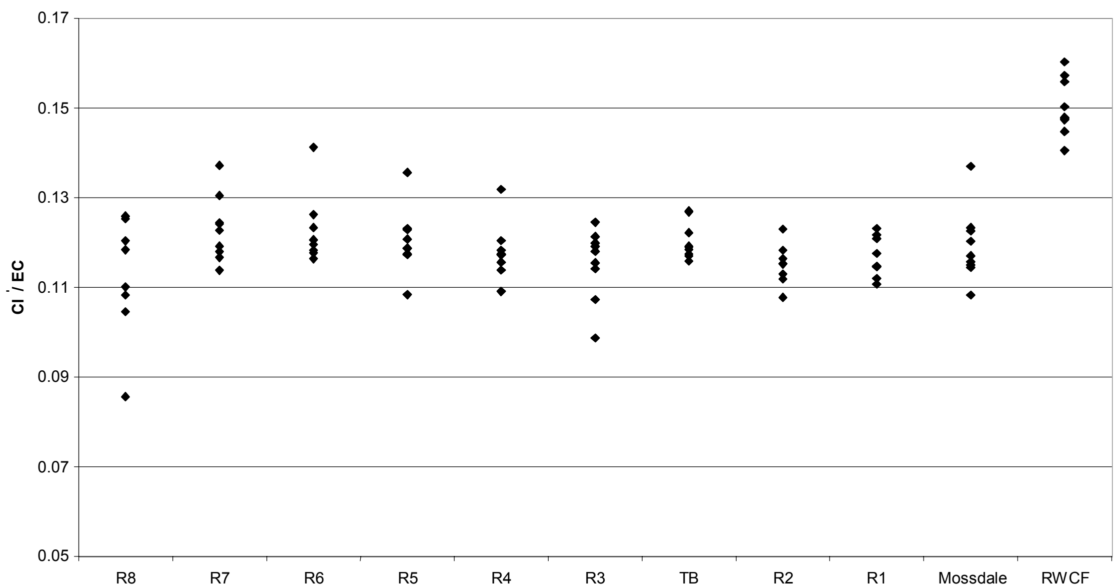
Figure 5
Stockton UVM Stage Data, September 1999



Source of Water in the Stockton Deep Water Ship Channel

Water column chloride (Cl^-) and electric conductivity (EC) are generally considered conservative constituents, and easily measured in water quality samples. For the Sacramento and San Joaquin rivers, each has its own unique Cl^-/EC ratio. Sacramento River Cl^-/EC is generally 0.05, where San Joaquin River Cl^-/EC is regularly seen to fluctuate between 0.10 and 0.15. Pure seawater generally has a Cl^-/EC of 0.35.

Figure 6
Chloride:Electric Conductivity Ratios for the San Joaquin River Encompassing Mossdale to R8
Fall 1999



During this special monitoring period (August 24-October 26), Stockton RWCF staff measured Cl^- and EC from Mossdale to R8 (see Figure 1 cross-referencing sampling locations). Figure 6 presents Cl^-/EC for monitoring stations within the study reach. During the fall period, Cl^-/EC generally was 0.12, suggesting the bulk of water within the segment was of San Joaquin River origin. Nevertheless, at the end of the study segment, around R8, Cl^-/EC was generally seen to be lower, with Cl^-/EC reaching as low as 0.086 on September 28. The study segment appears to be dominated by the San Joaquin River and not appreciably influenced by Sacramento River water, with exception to the downstream boundary at R8. Stations R3 to R7 will therefore be used to characterize water quality with the Stockton Deep Water Ship Channel.

Stockton RWCF Flow

Wastewater flow to the San Joaquin River is continuously recorded at the Stockton RWCF. For the Fall 1999 study period, RWCF flows were recorded on a 24 hour basis as daily averages. On six occasions, however, the Stockton RWCF did not discharge to the San Joaquin River. Four of these events were recorded in August (7th, 8th, 16th, and 17th) and a single event was recorded each for both September (29th) and October (12th).

Table 1 provides Stockton RWCF flow statistics for the fall study period. Mean flow presented in Table 1 includes no-flow events; however, minimum statistics present the lowest flow recorded not including those days when there was no flow (otherwise, all months would have record a minimum flow of zero).

Table 1
Stockton RWCF Effluent Flow (August-October

	mgd	cfs
August		
Mean	30.96	47.9
Maximum	47.03	72.8
Minimum	22.85	35.4
September		
Mean	26.15	40.5
Maximum	38.77	60.0
Minimum	11.37	17.6
October		
Mean	28.65	44.3
Maximum	39.50	61.1
Minimum	14.90	23.1

Note: Minimum values reflect only those periods with flow.
1 mgd = 1.55 cfs

As presented in Table 1, flows can fluctuate significantly.

Dilution and Residence Time

RWCF Dilution

Dilution and residence times were calculated for those days in which sampling was conducted in the study reach and those days where UVM data was available (August and September). Table 2 presents flow and concentration data as well as dilution factors and residence time for the months of August and September. River flow presented in Table 2 is net flow as recorded by the UVM. Because the UVM station is upstream of the RWCF discharge, the flow entering the Deep Water Ship Channel is the sum of the UVM and the RWCF discharge.

As presented in Table 2, dilution of RWCF flow ranged from 18:1 to 55:1, depending on river and discharge flow. Assuming no nitrification, ammonia dilution as measured mid-depth at R3 was greater than that which could be accounted for through straight flow dilution, with the exception of September 7 and September 21, where ammonia dilution was roughly equivalent to dilution attributed to flow.

Table 2
Dilution and Residence Time, August & September 1999

Date	River Flow UVM (cfs)	RWCF Flow (cfs)	RWCF NH_3 (mg/l)	Mossdale NH_3 (mg/l)	R3 NH_3 (mg/l)	R7 NH_3 (mg/l)
Aug. 24	1,032	49	3.9	< 0.2	0.3	< 0.2
Aug. 31	1,084	44	11	< 0.2	0.5	0.2
Sep. 7	1,155	30	12	< 0.2	0.5	0.3
Sep 14	1,143	44	17	0.2	0.4	0.3
Sep. 21	1,355	25	20	0.3	0.7	0.4
Sep. 28	344	20	25	0.2	1.0	< 0.2

Date	Dilution UVM vs. RWCF	NH_3 at Calculated Dilution Factor (mg/l)	NH_3 Dilution as Measured at R3	Residence Time to Turner Cut (days)
Aug. 24	22	0.38	39	7.4
Aug. 31	26	0.63	37	7.1
Sep. 7	40	0.50	40	6.7
Sep 14	27	0.83	85	6.7
Sep. 21	55	0.66	50	5.8
Sep. 28	18	1.57	31	21.9

Note: Residence time calculated for Stockton Deep Water Ship Channel from turning basin to Turner Cut (15,827 acre-feet)

Additional dilution beyond that expected simply due to flow could be attributed to several factors, including tidal mixing, ammonia volatilization, and ammonia nitrification. Because ammonia is a non-conservative and relatively reactive constituent, the later factors could play a substantial role. In addition, the relatively low concentrations of ammonia in Stockton RWCF effluent during August and most of September increase the uncertainty in the ammonia dilution estimates. The relative accuracy and precision of analytical and sampling techniques is quite limiting when attempting to estimate dilution through the use of ammonia as the tracer. To determine actual dilution of effluent in the study segment, as augmented through tidal action, a more discrete and sensitive tracer or dye study is recommended.

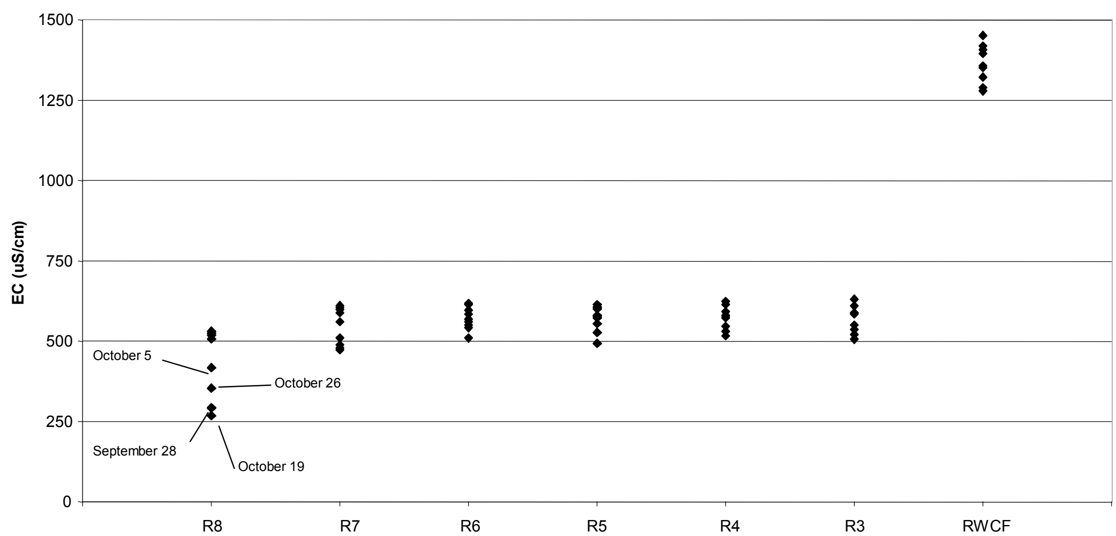
Residence time in the Stockton Deep Water Ship Channel was generally seven days during the study period. However, residence time appreciably increased with decreasing flows later in the month. At the lowest recorded net flow of 71 cfs on September 30th, residence time is calculated at 88 days. Clearly, stagnation of the Deep Water Ship Channel occurred during the end of September and likely extended briefly into October, although UVM river flows are not yet available.

Downstream Boundary Dilution

Significant dilution with Sacramento River water is expected at the downstream boundary of the study segment, possibly due to central valley and state water project pumping. EC, acting as a conservative water quality parameter, is a good means of reviewing downstream boundary dilution, a consequence of tide and Sacramento River mixing. Figure 7 charts EC within the Stockton Deep Water Ship Channel between R3 and R8 for those days sampled during the fall study period. As presented, noticeable boundary dilution occurred at R8, with little dilution witnessed further upstream where EC maintained approximately 550 microsiemens per centimeter *u*S/cm, indicative of San Joaquin River water. Sacramento River EC is typically within the range of 100-200 *u*S/cm. As such, as presented in Figure 7, there were periods where

Sacramento River strongly influenced water quality in the vicinity of R8. These periods of high Sacramento River influence occurred during late September and October where available UVM flow data suggests low San Joaquin River flow.

Figure 7
Electric Conductivity for the San Joaquin River Encompassing R3 to R8
Fall 1999



Stockton RWCF Loading

Stockton RWCF loadings to the study segment were calculated for Fall 1999 as monthly averages. For the fall study period, the Stockton RWCF reported daily average five-day biological oxygen demand (BOD_5) and ammonia concentrations in discharged effluent. Fall 1999 effluent charts are provided as an attachment.

Figures 8 and 9 depict the trend in total BOD_5 and ammonia load over the study period. As seen in Figure 8, total BOD_5 load and concentration remains fairly constant throughout the study period, with total BOD_5 concentration ranging from 5-10 mg/l and the corresponding load varying dependent upon discharge flow. In Figure 8, a clear trend is observed with ammonia concentration steadily increasing, plateauing at about 20-25 mg/l. As a consequence, ammonia load increases substantially from August to September.

Five-day total BOD, carbonaceous BOD (CBOD), and soluble BOD (SBOD) measurements were gathered during the study period. In addition, ammonia-nitrogen, nitrite-nitrogen, nitrate-nitrogen, and kjeldahl nitrogen were collected. Table 3 provides effluent summary statistics for parameters of interest. Only TSS, total BOD_5, $CBOD_5$, ammonia-nitrogen, and DO were collected every day there was discharge. The remainder of variables were collected on a weekly basis.

Figure 8
Daily Stockton RWCF Flow and Total BOD_5 Load
August-October 1999

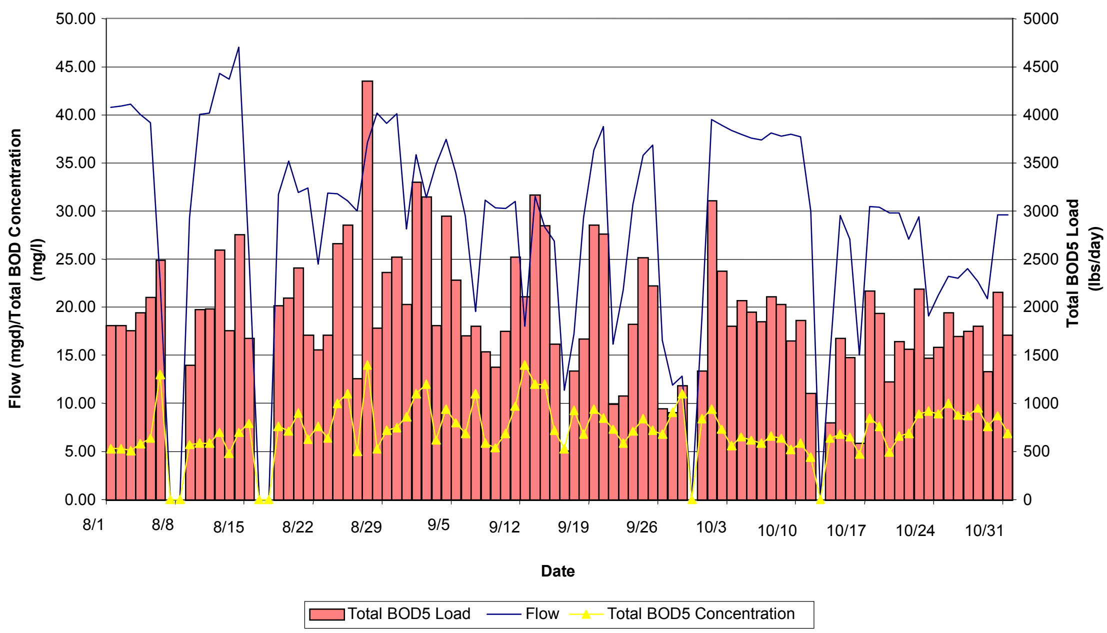
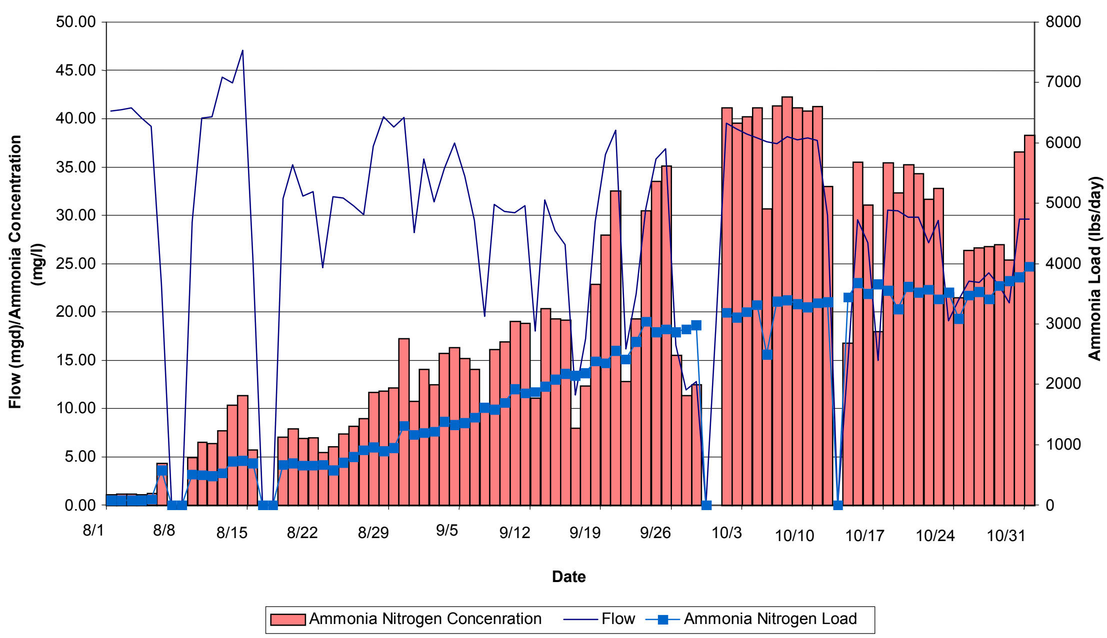


Figure 9
Daily Stockton RWCF Flow and Ammonia Load
August-October 1999



Insert Table 3

To calculate ultimate oxygen demand load in Stockton RWCF effluent, ultimate BOD was calculated, as well as ultimate CBOD plus ultimate ammonia oxidation. BOD decomposition kinetics provided by Dr. Litton provided decay rate (k) values for Stockton RWCF effluent. In the calculations of ultimate BOD and CBOD, k values of 0.128 for BOD and 0.133 for CBOD were used (averages of Trial 1 and 2 experiments). These k values resulted in 5-day to ultimate conversion coefficients of 2.11 for BOD and 2.06 for CBOD. For ammonia, a conversion coefficient of 4.5 was used, assuming complete stochiometric conversion of ammonia to oxidized nitrogen (nitrate).

Table 4 summarizes calculated ultimate loading. Ammonia is not fully oxidized in the 5-day BOD, so the best method for estimating the ultimate BOD load is to add the CBOD (ultimate) and ammonia (ultimate) loads.

Table 4
Calculated Stockton RWCF Loads

Month	Ultimate Ammonia Load	Ultimate CBOD Load	Ultimate CBOD + Ammonia Load
August	4,419	2,542	7,961
September	12,722	2,608	15,329
October	22,883	1,774	24,656

Stockton RWCF Particulate vs. Dissolved BOD

As part of the fall sampling program, Stockton RWCF staff conducted dissolved BOD_5 tests, in addition to the total BOD_5 tests previously discussed. Of interest is the fraction of effluent and river particulate BOD, because particulate BOD may contribute to sediment oxygen demand (SOD) in the Deep Water Ship Channel. In addition, total suspended solids (TSS) and volatile suspended solids (VSS) were measured. Table 5 summarizes Stockton RWCF BOD and suspended solids results. During the study period much of the suspended solids discharged were of organic nature (volatile suspended solids [VSS]) that could lead to water column BOD or SOD. However, over half of BOD measured was dissolved, where it would be expected to exert its demand in the water column rather than settle and exert demand in the sediment. This is not entirely unexpected, given the filtration treatment processes at the RWCF.

Table 5
Stockton RWCF Effluent Particulate vs. Dissolved Fractions (mg/l)

Date	BOD_5	Dissolved BOD_5	Fraction Diss. BOD_5	TSS	VSS	Fraction VSS
August 24	7.7	5	0.65	14	13	0.93
August 31	9.1	5	0.55	11	9	0.82
September 7	11.8	7.5	0.64	13	12	0.92
September 14	16	9.6	0.60	16	14	0.88
September 21	12.1	9.2	0.76	8	7	0.88
September 28	12.4	7	0.56	12	10	0.83
October 5	8.4	6.4	0.76	11	8	0.73
October 19	9.3	6.7	0.72	11	8	0.73
October 26	12.5	7.8	0.62	13	10	0.77
Mean			0.65			0.83

Stockton Deep Water Ship Channel Concentration Gradients

Table 6 provides gradient summary statistics for water quality parameters measured during the fall 1999 season. Gradient ratios were calculated based on an average of mid-depth and bottom values for R3 and R7 and represent the proportional increase or decrease in the parameter within the Stockton Deep Water Ship Channel. For example, as presented in Table 6 for August 24, BOD_5 generally increased by 40 percent between R3 and R7 (gradient ratio of 1.4).

Table 6
Stockton Deep Water Ship Channel Downstream Gradient Ratios for R3 to R7, Fall 1999

Parameter	August 24	August 31	September 7	September 14	September 21	September 28	October 5	October 19	October 26	Mean
DO	1.1	0.9	1.1	0.8	0.8	1.6	1.2	0.6	0.7	1.0
Temp.	1.0	1.0	1.0	1.0	1.1	1.0	1.0	1.1	1.1	1.0
pH	1.0	1.0	1.0	1.0	1.0	1.1	1.0	1.0	1.0	1.0
BOD_5	1.4	0.9	0.9	1.1	1.2	0.5	0.7	1.0	1.0	1.0
$SBOD_5$	1.7	1.3	0.9	1.1	1.2	1.0	1.9	1.3	1.5	1.3
TOC	1.0	0.9	1.5	1.0	0.9	0.8	0.7	0.7	0.8	0.9
DOC	1.2	1.1	3.7	0.8	0.9	0.9	0.7	1.0	0.9	1.2
TSS	0.6	0.6	0.5	1.3	0.5	0.7	0.4	0.5	0.6	0.6
VSS	0.8	0.7	0.6	1.2	0.6	0.7	0.4	0.6	0.5	0.7
NH_3-N	0.8	0.4	0.6	0.6	0.5	0.2	0.1	0.3	0.2	0.4
Kjeldahl -N	1.1	0.8	0.5	1.1	0.5	0.5	0.2	0.6	0.3	0.6
NO_2+NO_3-N	1.0	0.9	0.9	1.0	0.9	0.7	1.1	1.2	1.2	1.0
Total Phosphorus	0.8	0.7	0.5	2.6	0.6	0.7	0.7	0.6	0.6	0.9
Soluble Phosphorus	0.9	1.0	0.9	1.1	1.0	0.6	0.7	0.7	0.9	0.9
Turbidity	0.7	0.6	0.6	1.1	0.7	0.6	0.5	0.5	0.6	0.7
EC	1.0	1.0	1.0	1.0	1.0	0.9	0.9	0.9	0.9	1.0
CL^-	1.0	1.0	1.0	0.9	1.2	0.9	0.9	1.0	1.0	1.0
Chlorophyll *a*	0.6	0.3	0.5	1.0	0.8	1.0	0.3	2.3	0.8	0.8
Phaeophytin *a*	0.2	0.8	0.3	0.6	0.3	1.9	0.3	0.3	0.4	0.6

Reviewing mean ratios in Table 6, it is observed that the Deep Water Ship Channel was generally uniform for physical properties and conservative chemical properties (Temp, pH, EC, Cl^-) showing no variation between upstream and downstream boundaries. Suspended solids are seen generally to decrease over the length of the ship channel, suggesting a settling of suspended matter, although a smaller proportion of VSS is seen to settle in comparison to TSS. Settling of suspended matter is further supported through a corresponding decrease in turbidity, as would be expected since turbidity and TSS are well correlated. In addition, chlorophyll and phaeophytin concentrations are generally lower at the downstream boundary. BOD_5, $SBOD_5$, and DOC are generally seen to remain constant throughout the ship channel, with $SBOD_5$ and DOC actually increasing between R3 and R7.

BOD_5 and ammonia mid-depth concentration gradients were plotted for the Stockton Deep Water Ship Channel bound between monitoring stations R3 to R7 (Figures 10 and 11). As depicted in Figure 10, BOD_5 gradients are generally uniform. This trend in BOD_5 is unexplained, since the BOD_5 was expected to decrease during the 7-day travel time.

Figure 10
Stockton Deep Water Ship Channel BOD_5 Gradients, Fall 1999

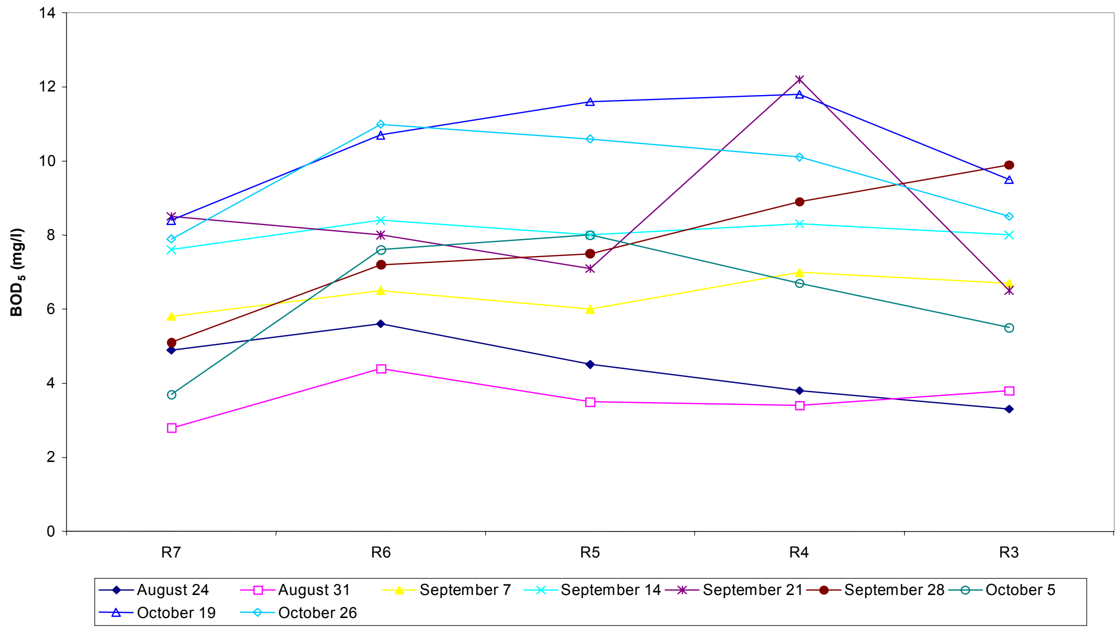
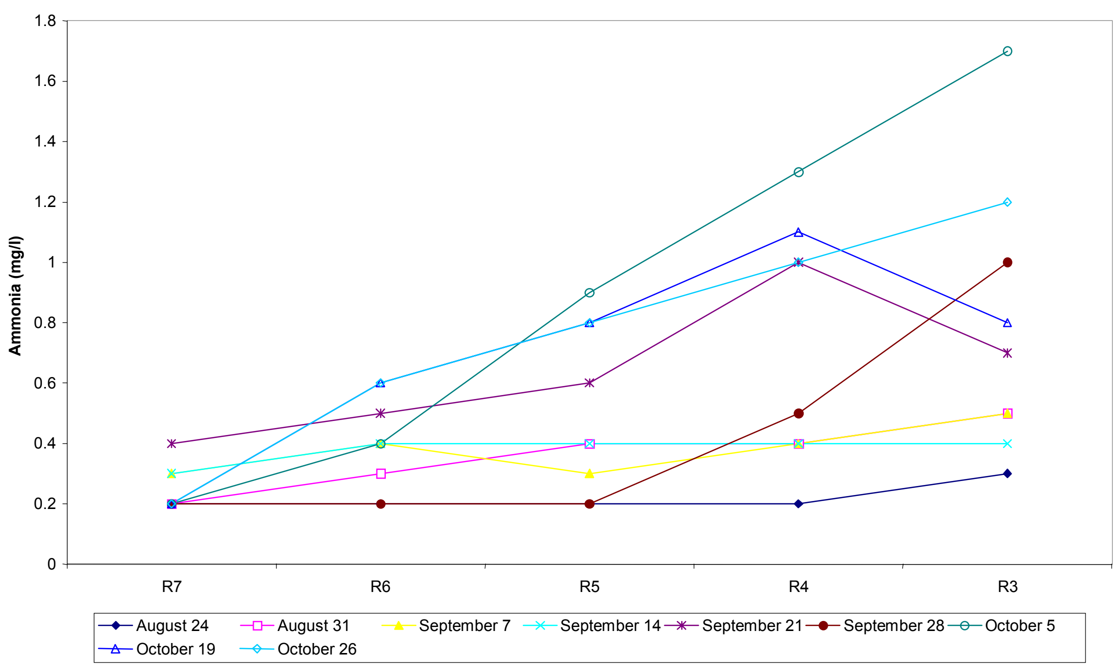


Figure 11
Stockton Deep Water Ship Channel Ammonia Gradients, Fall 1999



In Figure 11 a clear decreasing trend in ammonia is observed, indicating active ammonia removal within the Stockton Deep Water Ship Channel. Although nitrification would be a dominant removal process, other processes are possible, such as ammonia volatilization and uptake through algal growth. The extent that these processes play a role in ammonia removal was not determined.

Ammonia removal is most evident during the end of September and throughout October, when ammonia discharge from the Stockton RWCF was high at 20-25 mg/l. On October 5, initial R3 ammonia concentration of 1.7 mg/l is seen to markedly decrease by R7, to a river concentration of 0.2 mg/l, the reporting limit of the ammonia analysis. This 1.5 mg/l decrease in ammonia, if all could be accounted for by nitrification, would have resulted in as much as 6.75 mg/l of oxygen demand. San Joaquin River DO, as continuously measured near Burns Cutoff (between R4 and R5), averaged 2.6 mg/l on October 5, although the continuous meter was apparently experiencing difficulties at the time (data were discarded beginning mid- October 5). Stockton RWCF field DO measurements at mid-depth were recorded as 3.8 and 3.4 for R4 and R5, respectively. Although the measurements are not entirely in agreement, a period of severe DO depletion was occurring. Field temperature measurements suggest the DO saturation concentration on October 5 throughout the study reach to be approximately 8.9 mg/l.

Vertical Profiles

Stockton RWCF staff at monitoring stations R3-R7 and the turning basin collected DO and temperature profiles at two foot intervals from the surface to channel bottom. Vertical profile plots are provided in the attachment. In addition, water samples were collected at mid-depth and two feet from the channel bottom for laboratory analysis. Tables 7 and 8 summarize this mid-depth and channel bottom data.

Review of temperature, pH, EC and Cl^- ratios indicates a vertically well-mixed channel and turning basin, with no significant vertical stratification. The only exception would have been the turning basin where greater than a degree Celsius changes in temperature was measured on several days. Vertical DO profiles for the Deep Water Ship Channel showed little variation with depth at all monitoring stations. DO profiles in the turning basin indicate lower DO at the bottom on several sample dates.

In the Deep Water Ship Channel, particle deposition is evident. Suspended solids, turbidity phosphorus, chlorophyll and phaeophytin all showed increased values at the bottom. BOD_5 generally showed no vertical difference. Nevertheless, chlorophyll and phaeophytin did show signs of settling because concentration of these parameters generally increased with depth.

Strong vertical gradients are evident in the turning basin for some parameters. Suspended solids and turbidity were nearly three times greater near the basin's bottom in comparison to mid-depth measurements. Ammonia and kjeldahl nitrogen showed an increase with depth in the turning basin, unlike in the channel where ammonia and kjeldahl nitrogen were generally well mixed. Similarly, BOD_5 appears somewhat stronger in the basins bottom waters as well. The surface of the turning basin may be slightly warmer that the Deep Water Ship Channel so that tidal exchange allows water from the ship channel to enter the turning basin below the surface.

Table 7
Stockton Deep Water Ship Channel Vertical Gradient Ratios for R3 to R7, Fall 1999

Parameter	August 24	August 31	September 7	September 14	September 21	September 28	October 5	October 19	October 26	Mean /a/
DO	1.0	1.0	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Temp.	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
pH	1.0	1.0	1.0	1.0	/b/	1.0	1.0	1.0	1.0	1.0
BOD_5	1.1	1.1	1.1	1.0	0.9	0.8	1.0	1.0	1.0	1.0
$SBOD_5$	1.2	1.1	1.1	1.0	0.8	0.8	1.0	1.0	1.0	1.0
TOC	0.9	1.2	1.0	1.0	1.0	1.0	1.0	0.9	1.0	1.0
DOC	1.1	0.9	0.8	1.1	0.9	1.2	0.9	1.0	1.0	1.0
TSS	1.2	1.6	1.5	2.1	1.6	1.3	1.4	1.3	1.4	1.5
VSS	1.5	1.5	1.4	1.6	2.2	1.2	1.2	1.3	1.4	1.5
NH_3-N	1.0	1.1	0.8	0.9	0.9	0.9	0.9	1.0	1.0	1.0
Kjeldahl -N	1.1	1.1	1.2	0.9	1.0	1.0	0.8	0.9	1.1	1.0
NO_2+NO_3-N	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Total Phosphorus	1.0	1.0	11.0	2.0	1.2	1.0	1.0	1.0	1.0	2.3
Soluble Phosphorus	1.0	1.0	10	1.0	1.0	1.0	1.1	1.0	1.0	1.0
Turbidity	1.3	1.5	1.3	1.5	1.2	1.1	1.2	1.1	1.2	1.3
EC	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
CL^-	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Chlorophyll *a*	1.8	1.9	1.4	2.6	1.6	0.9	0.9	1.0	1.0	1.5
Phaeophytin *a*	2.3	1.5	1.4	1.1	1.4	0.9	1.5	1.5	1.0	1.4

/a/ Mean calculated from individual values.
/b/ Channel bottom pH samples were not collected on this date

Table 8
Turning Basin Vertical Gradient Ratios for R3 to R7, Fall 1999

Parameter	August 24	August 31	September 7	September 14	September 21	September 28	October 5	October 19	October 26	Mean /a/
DO	0.3	1.0	0.6	0.7	1.1	1.0	0.7	0.9	2.6	1.0
Temp.	0.9	1.0	1.0	0.8	1.0	1.0	1.0	0.9	1.0	1.0
pH	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
BOD_5	1.9	0.9	1.3	1.0	1.2	1.0	0.9	1.1	1.1	1.2
$SBOD_5$	2.3	0.8	1.2	1.1	1.1	0.9	0.7	1.0	1.0	1.1
TOC	0.8	1.0	1.1	1.1	0.9	0.9	1.0	1.1	0.9	1.0
DOC	1.3	1.0	0.9	1.4	0.9	1.1	1.1	0.8	1.0	1.1
TSS	1.8	2.7	4.1	3.1	2.9	1.5	3.0	2.9	6.6	3.2
VSS	2.0	1.7	3.5	2.0	2.3	1.3	1.7	2.3	5.5	2.5
NH_3-N	1.0	2.0	1.0	1.5	1.0	1.5	3.7	2.0	3.0	1.9
Kjeldahl -N	1.2	1.4	1.2	0.7	1.8	1.0	1.5	2.1	2.0	1.4
NO_2+NO_3-N	0.9	1.1	1.1	1.1	1.0	1.0	0.8	0.9	0.7	0.9
Total Phosphorus	1.1	1.3	0.3	1.2	1.2	0.9	2.0	1.8	1.3	1.2
Soluble Phosphorus	0.9	1.2	1.0	1.1	0.9	0.9	1.4	1.1	0.8	1.0
Turbidity	1.7	2.5	3.9	2.4	2.1	1.5	2.3	2.7	4.9	2.7
EC	1.0	1.0	1.0	1.0	1.0	1.0	0.9	1.0	0.9	1.0
CL^-	1.0	1.1	1.0	1.0	1.0	1.0	0.9	1.0	0.8	1.0
Chlorophyll *a*	1.7	0.5	4.5	1.3	2.7	0.4	0.3	0.9	1.6	1.5
Phaeophytin *a*	3.0	0.9	2.4	0.7	1.7	3.2	0.3	1.6	3.2	1.9

/a/ Mean calculated from individual values.

Figure 12
Stockton Deep Water Ship Channel TSS Gradients, Fall 1999

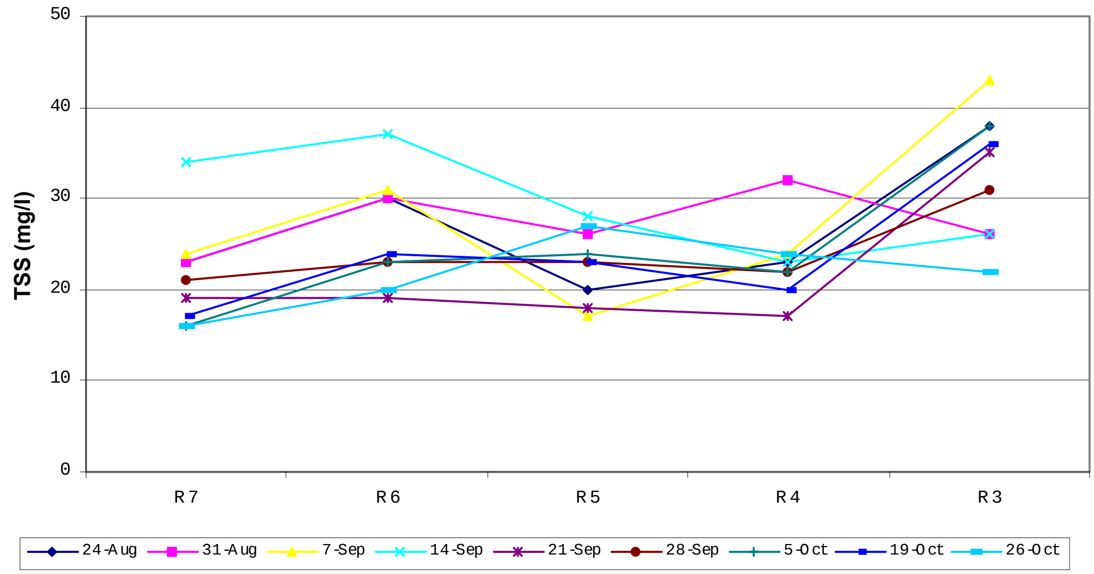


Figure 13
Stockton Deep Water Ship Channel VSS Gradients, Fall 1999