Results of the August 5, 2003, Tour of the South Delta Channels

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with the assistance of
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As part of evaluating various options for managing the low-DO problem in the San Joaquin River (SJR) Deep Water Ship Channel (DWSC), there is interest in gaining a better understanding of water quality issues in the South Delta channels. It is known from the Department of Water Resources (DWR) monitoring data (see Lee and Jones-Lee, 2003a), that several of the South Delta channels, such as Old River and Grant Line Canal, at times have severe DO depletion problems. There are also aquatic life toxicity problems in some of the South Delta channels. Further, these channels tend to have high concentrations of planktonic algae and suspended sediment.

Several of the potential options for managing the low-DO problem in the DWSC involve altering flows of the SJR through the DWSC to reduce the residence time of oxygen demand loads in the critical reach of the DWSC between Channel Point and Turner Cut. The potential flow manipulations involving altering flows into or out of the South Delta, discussed by Lee and Jones-Lee (2003a), include operating a permanent barrier at the Head of Old River to greatly reduce the amount of SJR flow into the South Delta, thereby increasing the SJR flow through the DWSC. Another potential option includes installing low-head pumps at the permanent barriers that will be constructed on Old River, Grant Line Canal and Middle River within the South Delta, which would increase the flow of Sacramento River water that is brought to the South Delta via the State and Federal Project export pumps to the east side of the permanent barriers that are being constructed under a CALFED/CBDA Record of Decision (ROD). The purpose of the permanent barriers is to gain better control of water level and water quality in the South Delta, which has been significantly deteriorated by excessive pumping of South Delta water by the State and Federal Projects.

In order to gain a better understanding of the characteristics of the South Delta channels, Dr. G. Fred Lee worked with the DeltaKeeper (William Jennings) and Kari Burr of the DeltaKeeper staff to conduct a one-day boat tour of the South Delta channels. This tour took place on August 5, 2003. In addition to Dr. Lee and Kari Burr, Mark Gowdy, Les Grober, Pat Leary and Mike Kummer of the Central Valley Regional Water Quality Control Board (CVRWQCB) participated in the tour. Dr. Debra Denton of the US EPA and Barbara Marcotte and Lauren Hastings of the California Bay-Delta Authority (CBDA) also participated in the tour.

The DeltaKeeper boat captain was Scott Pickering, who volunteered his time on behalf of the DeltaKeeper.

The South Delta channels of interest are shown in Figure 1. Table 1 presents the distances between the various points of interest on the tour. This information provides a perspective on the setting between the various sampling points used on the tour.

The tour left the DeltaKeeper dock on the Calaveras River about 9:00 AM. The boat proceeded up the DWSC to Channel Point, and then up the SJR to the SJR Old River split. At that point the boat proceeded west on Old River all the way to the Old River temporary tidal barrier. The boat then backtracked up Old River to Crocker Cut, then turned up Crocker Cut to Doughty Cut to Grant Line Canal and proceeded down Grant Line to the temporary rock barrier. At that point the boat backtracked on Grant Line Canal to Old River, back up Old River to the San Joaquin River, and then back down to the Deep Water Ship Channel, the Calaveras River, and the DeltaKeeper dock. The boat arrived at the dock about 7:00 PM.

The low tide for the day in the SJR at Stockton occurred at 7:30 AM. High tide for the day occurred at (insert). The weather during the day was bright sun, with high temperatures in the mid-80s. There were moderate winds of 10 to 20 mph. Based on DWR data, the Delta inflow for August 5 was 27,889 cfs. The Delta exports for this day were 6,563 cfs at Banks, 4,256 cfs at Tracy, 226 cfs at Contra Costa, and 100 cfs at Barker Slough, for a total of 11,145 cfs. These are typical Delta export pumping rates.

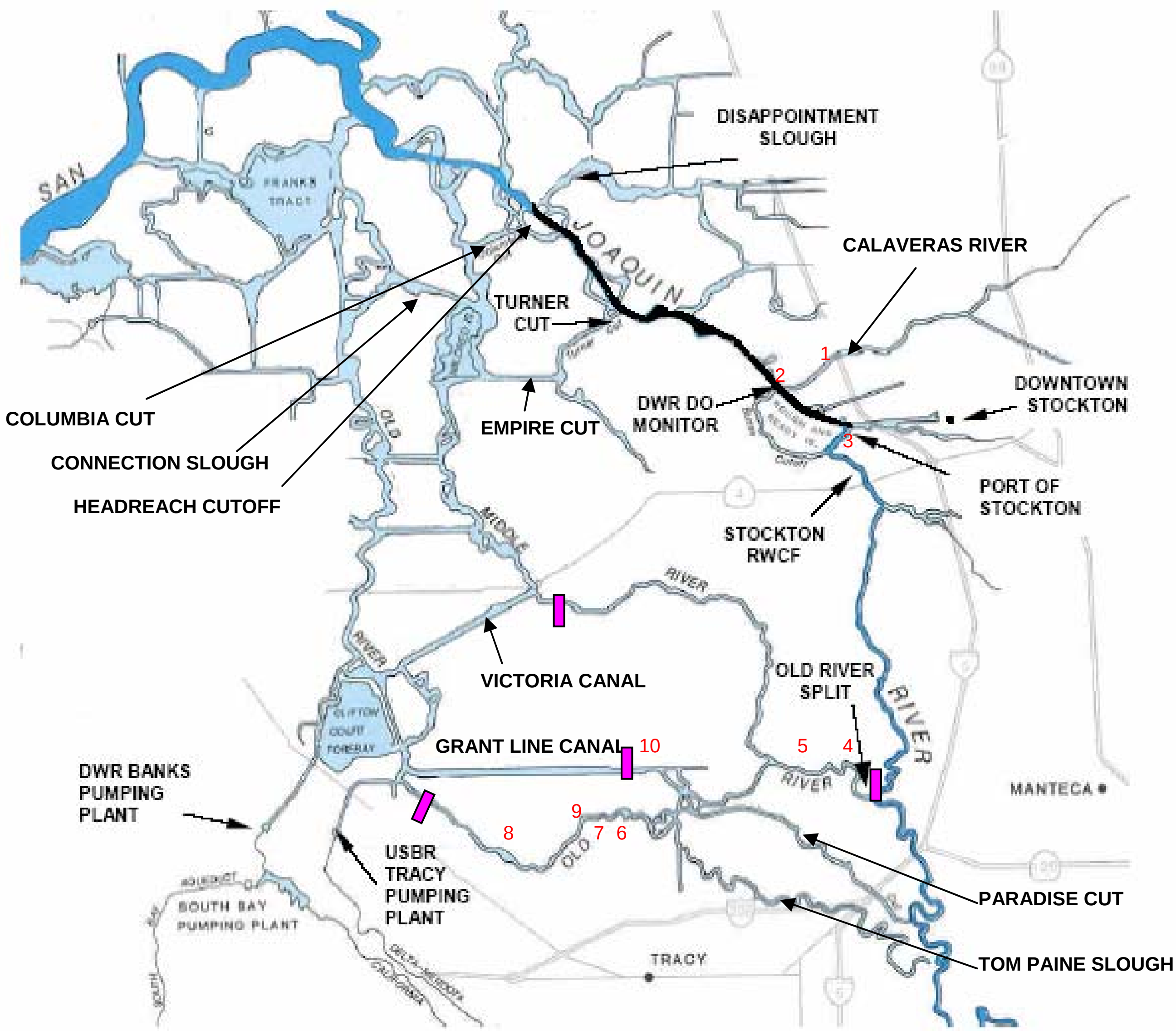
During the course of the tour, Kari Burr made measurements of temperature, dissolved oxygen, specific conductivity and pH, using a YSI Model 600 XL meter. Dr. Lee made measurements of temperature, specific conductivity and Secchi depth. Dr. Lee’s instrument was a YSI Model 33 SCT meter. The Secchi depth measurements were made with a 20-cm diameter Secchi disk painted with black and white quadrants. The depth of the water column at the point of measurement was determined from the boat fathometer. All specific conductivity measurements were corrected to 25°C using an instrument calibration which corrects for temperature at the rate of about 2 percent per degree. The conductivity meter was calibrated using a standard KCl solution. Dissolved oxygen near the water surface was measured by a YSI Model 600 XL meter with a submersible membrane electrode. The DO meter was calibrated in accordance with the equipment manufacturer’s recommendations. This calibration is periodically checked through a Winkler titration. The data obtained by K. Burr for DO and pH at each of the monitoring locations are presented in Table 2. This table also presents the data obtained by Dr. Lee for temperature, specific conductivity and Secchi depth.

August 5, 2003, South Delta Tour Results

Examination of the data presented in Table 2 shows that at the DeltaKeeper dock (map position number 1) the water depth is about 1.7 m, the temperature was 26°C, DO was 6.0 mg/L with a saturation value of 8.1 mg/L, the EC (corrected to 25°C) was 556 µmhos/cm, the pH was 7.5 and the Secchi depth was 0.5 m. At location 2, which is just opposite the DWR Rough and Ready Island (RRI) monitoring station, measurements were taken at 9:15 AM. Water depth was 11.1 m, temperature was 26°C, DO was 4.5 mg/L (with saturation at 8.1 mg/L), EC was 638 µmhos/cm, pH was 7.0, and Secchi depth was 0.6 m. On August 5, 2003, the DWR RRI monitoring station had a conductivity reading of about 625 µmhos/cm.

On August 5, 2003, the DWR RRI monitoring station DO meter had a low reading for the day at about 6:00 AM of just above 3 mg/L, and a high DO for the day of almost 6 mg/L. At about 9:00 AM, the DO at the RRI station was recorded as about 3.2 mg/L. This is somewhat lower than the value measured at location 2 of 4.5 mg/L. This is to be expected, since, by that time of day, there is already photosynthesis occurring, with the result that there would be an

Figure 1
Map of the Delta



Adapted from Gowdy and Grober, CVRWQCB (2003)

= Temporary Barrier

Table 1
Estimated Distances – Old River/Middle River

Reach	Distance (statute miles)
SJR/Old River split to Old River/Middle River split	4.4
Old River/Middle River split to ½ way (Doughty Cut)	3.6
Doughty Cut to Grant Line Barrier	0.8
Grant Line Barrier to Tracy Blvd bridge on Grant Line Canal	0.7
Old River/Middle River split to Old River at Tracy Blvd bridge	6.0
Old River at Tracy Blvd bridge to TWA*	0.7
TWA* to Old River Barrier	6.6
Old River/Middle River split to Middle River at Howard Road bridge	4.7
Middle River at Howard Road bridge to Middle River at Tracy Blvd bridge	4.8
Middle River at Tracy Blvd bridge to Middle River Rock Barrier	1.9

* Tracy Wildlife Association facilities

Table 2
South Delta Water Quality Characteristics
August 5, 2003

Map No.	Location	Time	Water Depth (m)	Temp ** (°C)	DO* (mg/L)	DO Saturation (mg/L)	EC** (μmhos/cm at 25°C)	pH	Secchi Depth (m)
1	DeltaKeeper Dock on Calaveras River	8:58 AM	1.7	26	6.0	8.1	556	7.5	0.5
2	SJR DWSC at DWR RRI Monitoring Station	9:15	11.1	26	4.5	8.1	638	7.0	0.6
3	SJR at RR Bridge near Channel Pt	9:25	4.7	26	5.2	8.1	642	7.0	0.7
4	Old River 0.5 mile from SJR	10:21	2.4	24	7.8	8.4	645	7.7	0.4
5	Old River near Tracy Outfall (near HV power lines)	10:52	4.3	25	8.6	8.3	729	7.8	0.3
6	Old River at Tracy Blvd Bridge	11:40	3.0	25	3.8	8.3	787	7.4	0.6
7	Old River at Tracy Wildlife Association	11:50 11:52 11:54	3.4	25 25 24	3.8 surf 2.1 mid 1.4 bot	8.3 8.3 8.3	787 786 784	7.2 7.2 7.1	0.3
8	Old River near Mtn House proposed wastewater discharge	1:09 PM	2.9	25	9.0	8.3	864	7.8	0.3
9	Fish kill area 0.5 mile downstream of Tracy Wildlife Association	2:11 2:13 2:15	3.0	27 26 25	4.6 surf 2.9 mid 2.0 bot	8.0 8.1 8.3	791 790 790	7.4 7.0 7.0	0.35
10	Grant Line Canal east of Barrier	3:39	4.9	25	8.2	8.3	750	7.8	0.4

* All DO readings are surface readings except where other depths are indicated
** As measured by Kari Burr, DeltaKeeper

elevated DO in the surface waters where the measurements were made on the DeltaKeeper boat, compared to the RRI station, where the measurements represented an integrated upper about one-third of the water column, where most of the algae in the water column are not producing oxygen, due to limited light penetration.

Location 3, which is in the SJR at the railroad bridge near Channel Point, was sampled at 9:25 AM. Water depth at that location was 4.7 m. Water temperature was 26°C. DO was 5.2 mg/L with a DO saturation value of 8.1 mg/L. EC was 642 µmhos/cm. The pH was 7.0 and the Secchi depth was 0.7 m.

Location 4, which is about 0.5 mile down Old River from the SJR split, was sampled at 10:21 AM. The water depth was 2.4 m. The temperature was 24°C. The DO was 7.8 mg/L, with a saturation of 8.4 mg/L. EC was 645 µmhos/cm. pH was 7.7 and Secchi depth was 0.4 m. Basically, the first set of measurements shows that the EC was about 640 µmhos/cm, corrected to 25°C, in the SJR Deep Water Ship Channel and in the SJR upstream to the Old River split. The DO was depressed below the water quality objective at the RRI station, although at location 3 the DO was above the WQO of 5 mg/L and was near saturation in Old River. At this location and time, the water in Old River was from the SJR, since this was still a low-tide measurement.

Location 5, which was in Old River near where the city of Tracy domestic wastewater outfall occurs, was sampled at 10:52 AM. The water depth was 4.3 m, the temperature was 25°C, and DO was 8.6 mg/L with a DO saturation of 8.3 mg/L. Therefore, the water was slightly supersaturated. Specific conductance was 729 µmhos/cm, which represents an increase of about 90 µmhos/cm between the entrance to Old River at the SJR, and location 5. This increase is likely due to irrigation return water. pH was 7.8 at location 5, and the Secchi depth was 0.3 m. The Secchi depths in Old River indicate that there is appreciable inorganic turbidity present in the water from upstream erosion and stirring of sediments in the channel.

Location 6, which is in Old River near the Tracy Blvd. bridge, was sampled at 11:40 AM. Water depth was 3 m, temperature was 25°C, and DO was 3.8 mg/L, with a saturation of 8.3 mg/L. The EC was 787 µmhos/cm, the pH was 7.4 and the Secchi depth was 0.6 m. There is, therefore, a significant increase in electrical conductivity (total salts) from Old River near the Tracy outfall to Old River near the Tracy Blvd. bridge. This again is likely due to the agricultural irrigation return waters.

At location 7, which is in Old River at the Tracy Wildlife Association facilities a short distance downstream from location 6, there were a number of dead threadfin shad in the surface waters. The water depth at this point was 3.4 m and the temperature was 25°C. The DO at the surface was 3.8 mg/L, at mid-depth was 2.1 mg/L, and at the bottom was 1.4 mg/L. The DO saturation was 8.3. The EC was 787 µmhos/cm at the surface and 784 µmhos/cm near the bottom, which is the same as at the Tracy Blvd. bridge. The pH was 7.2, and the Secchi depth was 0.3 m. Just downstream from that location there were large numbers of dead threadfin shad in the water. It is estimated that there were many tens of thousands of dead fish that were one to two inches in length. Also in this region there were a few dead catfish, and there were other catfish gulping for air at the surface.

Sampling location 8 was reached at 1:09 PM. This location is several miles downstream from location 7, in Old River near the area where it was indicated by the CVRWQCB staff (Pat Leary) that the community of Mountain House has proposed to discharge its domestic wastewaters. The water depth was 2.9 m, temperature was 25°C, and DO was 9.0 mg/L (with saturation of 8.3 mg/L). At this point, which was in early afternoon, algal photosynthesis had caused supersaturation conditions to occur in the surface waters of Old River. The EC was 864 µmhos/cm, the pH was 7.8, and the Secchi depth was 0.3 m. The pH of 7.8 is another indication that there was considerable photosynthesis occurring in the water column, raising the pH from the values just upstream from there. The EC had increased significantly. There are a number of large agricultural returns on the south side of Old River, which were discharging at the time and were apparently the source of the increase in EC.

The DeltaKeeper boat proceeded as far as the Old River barrier. No samples were taken at this location. At the time of the visit, in early afternoon, there was no flow over the temporary rock barrier, and there was no head differential between the two sides, indicating that there was limited flow through the barriers.

On the way back up Old River from the barrier, the boat stopped at location 9, which is just a short distance downstream from location 7. This location was reached at 2:11 PM. The water depth was 3 m and the temperature was 27°C at the surface and 25°C at the bottom. The DO at the surface was 4.6 mg/L, at mid-depth was 2.9 mg/L, and at the bottom was 2.0 mg/L. DO saturation was 8.0 mg/L at the surface. The EC was 791 µmhos/cm at the surface.

The next measurement was made at 3:39 PM in Grant Line Canal just east of the barrier (location 10). The water depth was 4.9 m, temperature was 25°C, DO was 8.2 mg/L (with saturation at 8.3 mg/L), EC was 750 µmhos/cm, pH was 7.8, and Secchi depth was 0.4 m. There was about a two-foot head differential across the temporary rock barrier. The west side of the barrier had an elevated water level.

According to the USGS website, the San Joaquin River at Vernalis flow on August 5, 2003, was about 1,500 cfs. The flow had been steady for the previous three or four days, in the range of 1,500 to 1,700 cfs. Data provided by C. Ruhl of the USGS showed that the flow of the SJR through the DWSC on August 5 was about 400 cfs. Therefore, the flow of Old River into the South Delta was about 1,100 cfs. This estimate does not consider agricultural diversions in the SJR downstream of Vernalis that were occurring at that time. These diversions, however, would not be expected to significantly change the estimate of the Old River flow.

It was originally planned to tour Middle River from where it joins with Old River in the South Delta. However, this is a small channel that is essentially unnavigable, except in a shallow-draft boat.

Water Quality Problems in the South Delta

Lee and Jones-Lee (2003a) summarized the DWR monitoring data for selected aspects of water quality in the South Delta as part of their Synthesis Report that was finalized in March 2003. A comparison between the data found on the August 5, 2003, tour and previously collected DWR data for the same area is presented below.

Dissolved Oxygen. Overall, the water quality in the South Delta Old River channel on August 5, 2003, was significantly impaired due to low DO near the Tracy Blvd. bridge at the time the measurements were taken. The DWR monitoring station at the Tracy Wildlife Association facility, which is near where the dead fish were observed, showed that the August 5, 2003, DO from about midnight to about 6:00 AM was zero or near-zero throughout this period. It is likely that the fish kill that was observed in this region was due to low DO or a possible combination of low DO and toxicants (pesticides). For many toxic substances, low DO enhances the toxicity of the substance.

Lee and Jones-Lee (2003a) presented a summary of the summer DO data that DWR had been collecting on several South Delta channels for 2001 and 2002, which showed a number of violations of the DO water quality objective of 5 mg/L. In order to examine the DO situation over the summer and fall relative to what was found on August 5, 2003, the 2003 DWR DO data for the continuous monitoring station on Old River at the Tracy Wildlife Association were examined. These data show that the DO was above the 5 mg/L water quality objective throughout the winter and spring. Beginning in early June, there were periods of several days when DO concentrations were found to be below the 5 mg/L water quality objective. Beginning on July 25 there were DO concentrations consistently below the 5 mg/L water quality objective in the morning hours each day. There was a period at the end of July and early August when the minimum DO concentrations were near zero each day. Throughout this period there were marked diel changes in DO typically of several mg/L from early morning to late afternoon. Except for about a week in mid-August, the DO concentrations each day were below the 5 mg/L water quality objective throughout the month until mid-September. After that time through the removal of the Old River temporary barrier at the west end of Old River (DMC barrier), there were occasional DO values below the water quality objective; however, most values were above. With the removal of the barrier, there were no values recorded that were below the water quality objective.

On August 5 the water was turbid, with limited water clarity (as measured by Secchi depth). This was due to planktonic algae and inorganic turbidity. The low DO was likely due to the discharge of oxygen-demanding materials from the agricultural return waters or other unidentified sources, as well as the death and decay of algae that had developed in the channel. Several of the agricultural returns were discharging substantial amounts of surface-active material as foam near the discharge, indicating it was rich in organics.

J. Herrick (pers. comm., 2003), manager of the South Delta Water Agency, has indicated that there is limited circulation of water through Old River near the Tracy Blvd. bridge as a result of the installation of the temporary barriers designed to control water levels in the South Delta channels associated with the export pumping of South Delta water in the federal and state projects. This, in turn, was allowing the growth of algae, their death and decay in the lower parts of the water column. Limited circulation, in turn, allows time for exertion of the oxygen demand added to the Old River channel. See Appendix A for additional discussions of the impact of the federal and state export projects on South Delta water issues.

As discussed by Lee and Jones-Lee (2003a), the DWR data clearly show that there are severe low-DO problems at times at several locations in the South Delta. The low-DO situation has led to the South Delta channels being listed on the Clean Water Act 303(d) list of impaired waterbodies, which requires that a TMDL be developed to control the oxygen demand sources and conditions that lead to the violations of the DO water quality objective in the South Delta.

Total Salts. One of the measurements made during the tour was electrical conductivity. Electrical conductivity is composed of ionic chemicals in solution, principally the bulk ions, such as sodium, calcium, magnesium, chloride, sulfate and occasionally nitrate. Total salts are important in water quality since they affect the use of water for domestic and agricultural purposes. They also affect aquatic life habitat, in that some forms of aquatic life are sensitive to salt.

A review of Table 2 shows that Old River just downstream from the split with the SJR had an electrical conductivity (corrected to 25°C) of about 645 µmhos/cm. That value is quite similar to the SJR values that were taken further downstream at the railroad bridge near Channel Point (642 µmhos/cm) and off of the DWR Rough and Ready Island monitoring station (638 µmhos/cm). However, by the time Old River reached the area near the Tracy Outfall (map location 5 on Figure 1), the EC had increased to 729 µmhos/cm, and at Old River at Tracy Blvd. bridge, it had increased to 787 µmhos/cm. At the Tracy Wildlife Association, the EC was also 787 µmhos/cm. At location 8, near the proposed Mountain House wastewater discharge, it was 864 µmhos/cm. Therefore, there was a substantial increase in the EC along Old River on the day of the tour, from about 645 µmhos/cm to about 865 µmhos/cm.

The primary flow of Old River water from the SJR split is up through Solomon Slough/Doughty Cut to Grant Line Canal. There is little Old River flow through Old River by the Tracy Blvd. bridge. At the Grant Line Canal barrier, the electrical conductivity was 750 µmhos/cm. All of these values have been corrected for temperature, to 25°C; therefore, they reflect an increase in salts. Typically, the electrical conductivity multiplied by about 0.55 to 0.7 equals the total dissolved solids (TDS) in mg/L (APHA, et al., 1995). Grober (pers. comm., 2003) has indicated that the TDS/EC ratio in the SJR at Vernalis is on the order of 0.59 to 0.65.

It is apparent that there is addition of salt to Old River through to Grant Line Canal or to the Old River temporary barrier. In order to examine the cause of this increase, information was obtained on one potential source – namely, the city of Tracy’s wastewater discharges. Kummer (pers. comm., 2003) provided information on the EC content of Tracy’s wastewater discharges. He reported that average monthly flows for the Tracy wastewater discharge are 8.1 mgd, which translates to 12 cfs. Tracy’s wastewaters’ average monthly electrical conductivity is 1,700 µmhos/cm. These wastewaters discharge into the SJR. At the time of the tour, upstream of this location near the SJR Old River split had a conductivity of 645 µmhos/cm. Near the Tracy wastewater discharge, the electrical conductivity was 729 µmhos/cm. Therefore, in passing from the SJR Old River split to location 5, there is an appreciable addition of salt. This salt, however, was not coming from the wastewaters. As discussed above, the flow of Old River at the time of the tour near Tracy’s wastewater discharge was on the order of 1,000 to 1,100 cfs. The maximum calculated increase in salt due to Tracy’s discharge is about 14 µmhos/cm above the Old River background. Therefore, Tracy is not at this time a significant source of salt.

The situation with respect to the significance of the impact of Tracy's wastewater input on Old River's water quality can change, however, during the time when limited amounts of SJR water are allowed to pass into the South Delta through the SJR Old River split. These conditions can potentially occur when the Head of Old River barrier is in place – i.e., preventing most of the SJR water at Vernalis from entering Old River. It is understood from discussions with DWR staff, however, that, even when the Head of Old River barrier is in place, appreciable flow of SJR Vernalis water is allowed to pass into the South Delta via Old River.

The other source of salt is irrigation return water. Agricultural activities along Old River are removing water from Old River, using the water for irrigation, and returning the tailwater, with essentially the same salt load, back to Old River – i.e., there is not a major buildup of salts in the soils, except as discussed below. While the agricultural use of the water generally does not add any salts to the water that were not already there, removing water and leaching the salts that are present in the irrigation water from the soils, which is then discharged back to the channels in irrigation return water, results in an increase in salt that is seen, proceeding from the SJR Old River split to the western part of Old River and to Grant Line Canal at the barrier.

Examination of the EC data for the SJR as it enters Old River, compared to the EC data at the Grant Line Canal temporary barrier obtained on the same day, shows that there is an increase in EC of about 100 µmhos/cm between the two locations. Since apparently there are no other major sources of salts, this increase appears to be due to agricultural tailwater discharges. Based on DWR data for northern and Central Delta islands, the authors (Lee and Jones-Lee, unpublished) have found that agriculture on the Delta islands takes water from the channels at one conductivity, and returns it to the channels in tailwater at three times that conductivity – i.e., there is a 3-to-1 evaporative concentration of salts associated with agricultural activities in the northern and Central Delta. From these results, it appears, that part of the salt buildup in South Delta channel water is due to irrigation return water. Grober (pers. comm., 2003) provided the following discussion of this issue.

> *"I think a 3 to 1 ratio is extremely high (and unlikely) for tailwater returns but... to better answer your question we should get some definitions in order. Tailwater, as name implies, is water that runs off the tail end of a field during and immediately after an irrigation event. Little or no evapoconcentration of this water can occur during the short time the water is on the field. The water is more likely to mobilize new salts from the soil than it is to evapoconcentrate salts in the irrigation water. Most evapoconcentration will occur in the root zone when water is used by the crop and salt is left in this zone. There could easily be a 3 to 1 or more net evapoconcentration of salt in the root zone when you factor in subsequent irrigations that mobilize residual salt from prior irrigations. This salt must either build-up in the root zone or be leached to groundwater.*
>
> *Since many areas of the Delta are at or below sealevel, shallow groundwater must be pumped to provide drainage for crops. I imagine it's this pumped groundwater that you're considering. In many parts of the Delta there are deep ditches in which tailwater returns and shallow groundwater commingle and are then pumped back into the Delta.*

It is not unreasonable to assume an application efficiency of 65% for the San Joaquin Valley/ Delta. If one further assumes that there is no leaching requirement, all of the salts in the supply water must be conveyed by the 35% (or less) of the water remaining after crop requirements (over the long term). Or, in equation form, 100% salt divided by 35% = 2.8, roughly a factor of 3."

A. Hildebrand (pers. comm., 2003) added the following comment to Grober's discussion.

"The assimilative capacity of the river is being more than used up by the drainage of imported salt from the CVP westside service area. A crop must consume a rather fixed amount of water that is evaporated through its leaves in order to grow a pound of biomass. This necessarily results in drainage water that contains most of the salt in incoming irrigation water with substantially less dilution. The only way a farmer can prevent this is to stop irrigating and go out of business.

Pre-CVP there was no salinity problem in the South Delta. Indigenous salts in surface waters result largely from the weathering of soils. They enter the stream system primarily during high flows and reach the ocean before concentration becomes a problem."

As discussed above, the western Delta channels, which include Old River near Tracy Blvd., are listed as 303(d) impaired waterbodies due to excessive salt, with agriculture as the source (US EPA, 2003). It appears from the information available through the results of the tour and analysis of the DWR data, that the salts that are causing this impairment are derived from the SJR watershed upstream of the SJR at Vernalis. There is local South Delta input of salts primarily from agricultural use of the water that enters the Delta from the SJR. Hildebrand (pers. comm., 2003) stated that,

"Violation of the salinity standards in South Delta channels can be avoided by restoring unidirectional flow in each channel reach, and by using the barriers to provide intermittent flushing of the Tracy sewer outfall."

A key issue in this matter is that the SJR at Vernalis has been found to contain excessive salt, resulting in a TMDL being issued to control the salt content. The SWRCB (1998) has established the water quality objective for EC for the San Joaquin River at Airport Way Bridge, Vernalis; Old River near Middle River; Old River at Tracy Blvd. Bridge; and San Joaquin River at Brandt Bridge for the maximum 30-day running average of mean daily measurements as 700 µmhos/cm for the period April 1 through August 31, and 1,000 µmhos/cm for the period September 1 through March 31

At a Public Workshop for the control of Salt and Boron Discharges to the San Joaquin River held on January 30, 2004, Herrick indicated that irrigation in the South Delta occurs for some farmers through the fall and winter. Therefore, the SWRCB salinity water quality objective for the South Delta channels of 1,000 µmhos/cm for September 1 through March 31 may need to be lowered to 700 µmhos/cm to protect South Delta irrigated agriculture from excess salt.

Table 3 presents a summary of the EC data for the DWR monitoring stations on the South Delta channels. The data presented in Table 3 are based on DWR's South Delta barrier water quality monitoring program. The DWR EC data is presented in Table 3 in µS/cm, which is equivalent to the µmhos/cm discussed in other sections of this report. As discussed by Lee and Jones-Lee (2003a), DWR maintains two sets of monitoring stations in the South Delta. In 2003 there were three locations where EC, DO and several other parameters were monitored every 15 minutes. As shown, DWR has been expanding the number of continuous monitoring locations from 2001 through 2003. A map showing the DWR South Delta barrier sampling locations is presented in Figure 2.

The mean and standard deviation of the monthly EC data were computed from the DWR database and recorded in Table 3 out of the continuous monitoring dataset. The change in EC shown in the last week of October is associated with the removal of the temporary barriers. Table 3 also presents the weekly grab sampling EC data obtained by DWR at several locations in South Delta channels. The four (or five) weekly sampling events were averaged for the month and the standard deviation computed. These values are also presented in Table 3. As shown, at times the EC of the South Delta channels during the summer is considerably above the water quality objective for the South Delta channels. Note that some of the grab sampling data show major changes in the EC from one week to the next, likely reflecting the influence of Sacramento River water entering the South Delta at times, causing a significantly lower EC.

As Lee and Jones-Lee (2004) discuss, in order for irrigated agriculture to continue in the South Delta and not cause violations of the existing water quality objective for South Delta channels, the salt loads that are contributed to Old River by the San Joaquin River will need to be significantly decreased from that proposed in the current TMDL. At the Public Workshop for the control of Salt and Boron Discharges to the San Joaquin River held on January 30, 2004, several participants suggested that ultimately there will be need to reduce the water quality objective for EC at Vernalis below the current objective of 700 µmhos/cm during irrigation season. Until this is done, there will be violations of the EC water quality objective in the South Delta channels, primarily caused by salts delivered to the South Delta by the SJR, with some small increase in salt concentrations caused by South Delta irrigation.

Other Water Quality Problems. There are also aquatic life toxicity problems (Lee and Jones-Lee, 2004), where South Delta channels are listed for OP-pesticide-caused toxicity and unknown-caused toxicity as part of the Clean Water Act 303(d) listing. Further, the DWR data show that there are excessive nutrients (nitrogen and phosphorus compounds) that lead to the excessive algal growth found in the South Delta channels, especially the Old River channel near the Tracy Blvd. bridge. The South Delta channels are also impacted by upstream and, likely, local erosion of the channels, which leads to increased turbidity, low light penetration and shoaling. This, in turn, is adverse to aquatic life habitat.

While not specifically monitored, another expected problem with South Delta water quality is excessive total organic carbon (TOC) compared to the concentration that the US EPA has recommended for raw water supplies that can be treated without TOC removal. Since this water is exported, to some extent, for domestic water supply purposes, the high organic content

Table 3
2001 South Delta Specific Conductivity

Month	**Location**									
	Head of Old River	Old River at Tracy Blvd	Old River at Tracy Wildlife Association	Old River at Delta Mendota Canal	Doughty Cut	Grant Line Canal above barrier	Grant Line Canal at Tracy Blvd.	Middle River at Union Point	Middle River at Tracy Blvd.	Middle River at Undine Rd.
EC (µS/cm)* - Continuous Measurements										
June	-	-	894±102	-	-	-	-	-	-	-
July	737±34	-	883±38	-	-	-	-	-	-	-
Aug	761±29	-	907±29	-	-	-	-	-	-	-
Sept	751±36	-	860±50	-	-	-	-	-	-	-
Oct - 1st 3 wks	689±12 **	-	855±20 **	-	-	-	-	-	-	-
Oct - final wk	-	-	-	-	-	-	-	-	-	-
EC (µS/cm)* - Grab Samples										
June	678±55	884±101	-	-	745±114	765±55	763±56	351±11	381±16	732±29
July	695±30	840±50	-	-	775±25	802±32	796±32	323±33	371±32	730±17
Aug	742±22	899±32	-	-	808±35	808±16	806±17	380±45	422±46	756±22
Sept	701±34	816±58	-	-	778±62	796±54	824±84	468±10	575±104	741±50
Oct - 1st 3 wks	667±21	860±37	-	-	742±14	745±32	742±29	493±35	724±38	629±110
Oct - final wk	386±4	657	-	-	497	395	477	552	502	383

* EC is expressed as a monthly average ± one standard deviation
- Data not available
** Measurement based on only 2.5 days of data

Table 3 (continued)
2002 South Delta Specific Conductivity

Month	**Location**										
	Head of Old River	Old River at Tracy Blvd	Old River at Tracy Wildlife Association	Old River at Delta Mendota Canal		Doughty Cut	Grant Line Canal above barrier	Grant Line Canal at Tracy Blvd.	Middle River at Union Point	Middle River at Tracy Blvd.	Middle River at Undine Rd.
EC (µS/cm)* - Continuous Measurements											
June	769±28	-	935±53	482±104		-	-	-	-	-	769±28
July	748±27	-	857±28	844±139		-	-	-	-	-	744±27
Aug	795±37	-	905±33	967±125		-	-	-	-	-	791±38
Sept	803±30	-	905±31	1036±70		-	-	-	-	-	800±39
Oct - first 3 wks	751±37	-	1008±53	1094±98		-	-	-	-	-	750±29
Oct - final wk	444±49	-	713±103	1063±126		-	-	-	-	-	435±40
EC (µS/cm)* - Grab Samples											
				Upstream	Dnstream						
June	717±31	915±76	-	443±110	474±136	825±59	813±41	811±48	320±56	367±54	755±46
July	717±60	868±37	-	702±268	798±263	788±50	820±17	814±14	269±30	298±47	758±23
Aug	777±27	898±29	-	965±119	998±148	864±47	865±35	864±33	332±30	394±101	813±37
Sept	766±23	852±94	-	1077±28	1073±39	861±19	857±12	857±15	426±22	650±198	817±25
Oct - first 3 wks	721±43	998±61	-	1140±73	1137±65	834±38	841±46	831±46	505±84	784±26	691±132
Oct - final wk	471±2	746	-	969	966	449	444	439	465	416	718

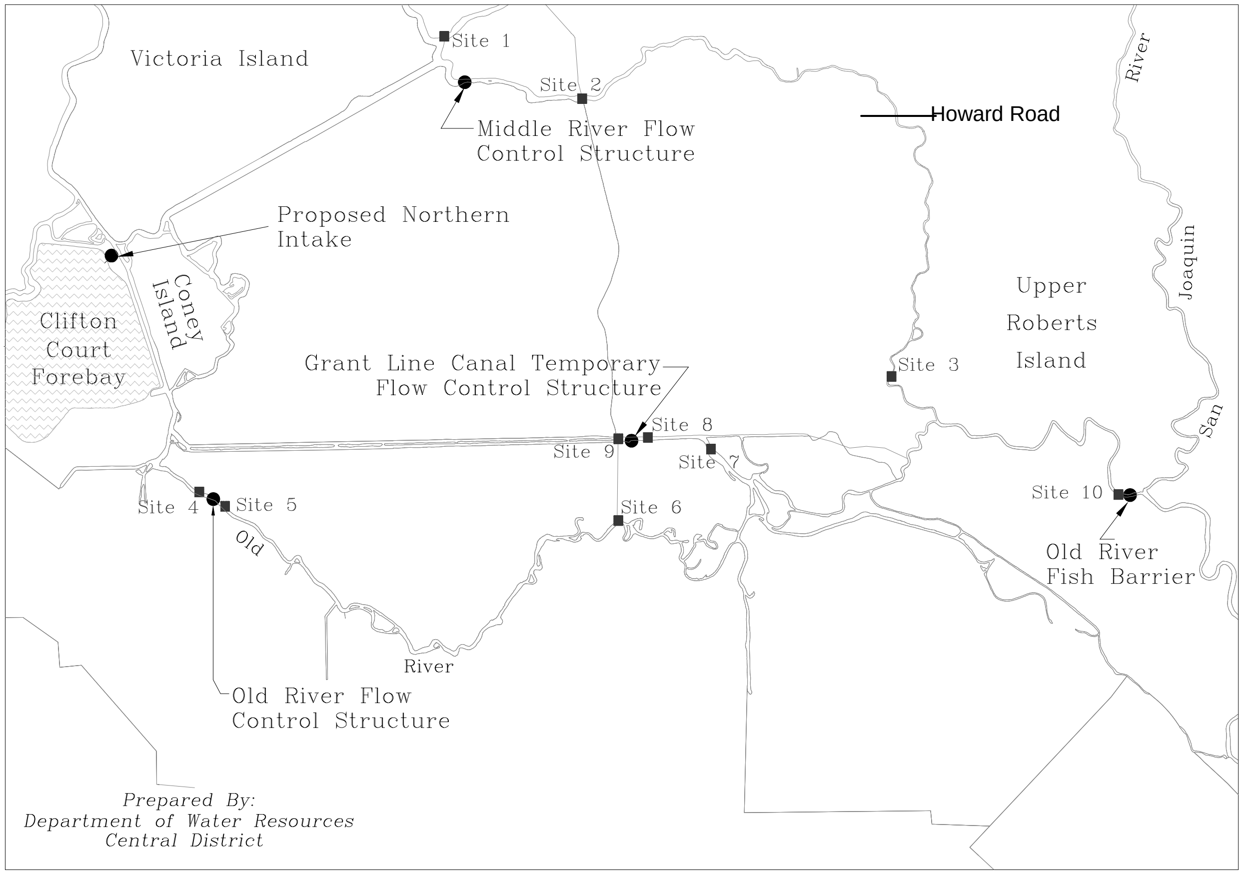
* EC is expressed as a monthly average ± one standard deviation
\- Data not available

Table 3 (continued)
2003 South Delta Specific Conductivity

Month	**Location**									
	Head of Old River	Old River at Tracy Blvd.	Old River at Tracy Wildlife Association	Old River at Delta Mendota Canal	Doughty Cut	Grant Line Canal above barrier	Grant Line Canal at Tracy Blvd.	Middle River at Howard Road	Middle River at Tracy Blvd.	Middle River at Undine Rd.
EC (µS/cm)* - Continuous Measurements										
June	514±31	-	647±45	503±145	-	-	-	490±81	263±39	518±28
July	670±78	-	749±79	606±100	-	-	-	533±171	217±28	662±61
Aug	685±34	-	786±34	888±97	-	-	-	687±120	232±29	710±33
Sept	689±33	-	818±45	898±67	-	-	-	623±145	318±39	725±49
Oct - 1st 3 wks	641±44	-	905±53	951±166	-	-	-	525±78	445±21	635±50
Oct - final wk	435±56	-	701±99	877±114	-	-	-	544±95	468±25	444±74
EC (µS/cm)* - Grab Samples										
	Head of Old River	Old River at Tracy Blvd.	Old River at DMC - upstream	Old River at DMC-downstream	Doughty Cut	GLC above barrier	GLC at Tracy Blvd.	Middle River at Union Point	Middle River at Tracy Blvd.	Middle River at Undine Rd.
June	480±45	617±55	459±122	372±55	494±23	541±21	536±13	217±40	293±73	511±46
July	655±60	792±60	500±53	426±95	718±43	729±72	726±68	185±18	214±29	684±70
Aug	688±21	800±34	768±189	661±229	739±35	754±41	745±27	203±8	247±48	724±41
Sept	671±23	818±46	849±62	844±62	745±22	744±19	746±26	294±59	348±29	743±56
Oct - 1st 3 wks	617±1**	898±89	956±114	994±219	728±50	703±33	588±168	414±21	458±6	646±24
Oct - final wk	451±57**	617	917	917	447	442	476	415	529	355

* EC is expressed as a monthly average ± one standard deviation
\- Data not available
** These data were averaged based on the first two weeks, and the last two weeks

Figure 2
Map of South Delta Showing DWR Water Quality Monitoring Stations



Site	Location
1.	Middle River @ Union Point
2.	Middle River @ Tracy Blvd
3.	Middle River @ Undine Road
4.	Old River Downstream of DMC Barrier
5.	Old River Upstream of DMC Barrier
6.	Old River @ Tracy Blvd
7.	Grant Line Canal @ Doughty Cut
8.	Grant Line Canal Above Barrier
9.	Grant Line Canal @ Tracy Blvd
10.	Old River @ Head

could lead to the potential for water quality problems in the use of this water for domestic purposes. As discussed by Lee and Jones-Lee (2003b), some – possibly a substantial part – of the TOC in South Delta waters is labile TOC that would be decomposed before it reaches the domestic water supply treatment works.

Lee and Jones-Lee (2004) have discussed the water quality problems in the South Delta associated with excessive bioaccumulation of organochlorine legacy pesticides (such as DDT, dieldrin, chlordane, etc.) and PCBs in edible fish. This is another issue that needs to be addressed as part of managing water quality in the South Delta.

According to the CALFED/CBDA Record of Decision (ROD), permanent operable barriers are to be installed in the South Delta by 2007. The operation of these barriers when installed will likely significantly change the flow and the water quality characteristics of South Delta channels. DWR is supposed to release a draft CEQA discussion of the South Delta Water Management Plan in March 2004. It is unclear at this time whether this plan will adequately and reliably address how the operations of the South Delta barriers are planned to be conducted and, most importantly, what impact their operations will have on South Delta water quality.

Recommended South Delta Water Quality Monitoring

While DWR, as part of the South Delta barrier operations, has been conducting a limited-scope monitoring program of certain aspects of South Delta channel water quality, there is need to greatly expand this program to provide a comprehensive assessment of the full magnitude of the water quality problems in the South Delta, their cause, and, based on this, develop a management program. Presented in Table 4 is a listing of the parameters that should be monitored in the South Delta at selected locations in each of the channels. Further information on the parameters listed in this table is provided in Lee and Jones-Lee (2002). The monitoring locations should include Old River just downstream of where the SJR discharges to Old River and just upstream and downstream of the city of Tracy domestic wastewater discharge to Old River. Other Old River monitoring points would be just upstream of the Tracy Blvd. bridge and near the Tracy Wildlife Association facilities. A monitoring point should also be established in the vicinity of where Mountain House has proposed to discharge its domestic wastewaters to Old River, and another just upstream of the Old River temporary (later to become permanent) barrier.

Monitoring should also be conducted about halfway up Solomon Slough from where it joins with Old River, and where Solomon Slough joins with Grant Line Canal. A monitoring point should be established in Grant Line Canal just upstream of the temporary barrier and a quarter-mile or so downstream of the barrier on this Canal, possibly at the Tracy Blvd. bridge. Monitoring stations should also be established on Middle River just upstream and downstream of the temporary (later to become permanent) barrier and within about half a mile of where Middle River joins with Grant Line Canal. In general, the monitoring stations near the barriers should be at the same location as the DWR current grab sampling and continuous monitoring stations. At least one monitoring station should be established on Paradise Cut and Tom Paine Slough, at a distance about halfway up the slough, where there is relatively easy access from the bank.

This program should complement the DWR monitoring program, with the following changes in the parameters measured by DWR. An evaluation should be made as to whether the specific conductivity measurements are corrected to 25°C. Further, all data in the future should be reported at the temperature to which the correction was made. In the range of specific conductivities that are being found in these channels relative to the current EC water quality objective for the South Delta, and the 2 percent per degree change in specific conductivity as a function of temperature, it is important to have a reliable temperature correction.

Table 4
Candidate Monitoring Parameters

Field Measurements

- pH
- dissolved oxygen
- temperature
- Secchi depth
- estimated flow and water velocity at time of measurement
- time of sample collection
- weather conditions, including air temperature, wind velocity, cloud cover and precipitation, at time of sampling and for the previous 24 hours
- presence of floating foam and or algal scum,
- unusual color, such as that associated with wetlands releases
- general extent (estimated percent) of area near monitoring location that is covered by floating macrophytes (hyacinth, duck weed), emergent aquatic plants and/or attached algae.

Laboratory Measurements

In general, the analytical methods for the following parameters are those listed in Standard Methods, APHA, *et al*. (1998) or those listed by the US EPA (2000a). Note: some of the specific methods for a particular parameter in Standard Methods are not suitable for these measurements. Further, the method should have adequate sensitivity to reliably determine the constituent of concern at concentrations below those that represent regulatory limits, such as WQOs. The specific analytical methods used should be approved by the CVRWQCB.

- total phosphorus, with a quantitation limit of 10 µg/L P
- soluble orthophosphate with a quantitation limit of 5 µg/L P
- ammonia, with a quantitation limit of 0.1 mg/L N
- organic nitrogen, with a quantitation limit of 0.5 mg/L N
- nitrate plus nitrite, with a quantitation limit of 0.1 mg/L N
- electrical conductivity at 20 or 25 degrees C
- planktonic algal chlorophyll-*a*, using acetone extraction
- planktonic algal pheophytin-*a*
- turbidity
- color (true and apparent)
- BOD_{10}
- total suspended solids (TSS)
- total dissolved solids (TDS)
- alkalinity
- total organic carbon (TOC)
- dissolved organic carbon (DOC)
- UV_{254}
- boron
- bromide
- selenium
- mercury, with a quantitation limit of about 1 ng/L
- heavy metals, such as copper, zinc, cadmium, lead, nickel, chromium, iron, manganese (all heavy metals should be measured in the total and dissolved forms using "clean" sampling techniques)
- molybdenum
- arsenic
- barium
- scans for OP pesticides, carbamate pesticides, organochlorine pesticides, and chlorinated hydrocarbon herbicides, using most sensitive methods readily available
- scan fish tissue for organochlorine pesticides, PCBs, dioxins, and mercury each fall

Table 4 (continued)

(for the OCls, use sufficient sensitivity to detect the OCls at OEHHA fish screening values for protection of human health)
chemicals such as pesticides, soil amendments, etc. added to agricultural lands
tastes and odors?
biological measurements
  dominant types of algae and zooplankton
  sediment organism assemblages
    dominant benthic/epibenthic macro-organisms
  three species aquatic life toxicity, including assessing total toxic units and TUa due to OP pesticides, with and without PBO addition
  sediment toxicity using *Hyalella*
E. coli, (contact recreation),
total coliforms (shellfish)?,
fecal coliforms (local health department)?
bulk parameters to be measured quarterly
  calcium
  magnesium
  sodium
  chloride
  sulfate

For those parameters that are only monitored by grab samples and measurements at the time of sampling, such as for DO, pH and temperature, it will be important to sample under conditions of the range that is expected – i.e., early morning and late afternoon. This will give a more reliable indication of temperatures, dissolved oxygen concentrations and pH values than is being gathered today. Currently the data being gathered for these parameters are of limited utility in interpreting water quality characteristics of the waters at the location being sampled.

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Appendix A
Correspondence from John Herrick, Manager, South Delta Water Agency

Dear Dr. Lee:

I want to clarify one of your remarks regarding the cause of the decreased DWSC flows. It is correct that the projects fundamentally alter south Delta flows and are thus the cause of the decreased flows in the ship channel. However, under current conditions, the projects are not exporting any (substantial) water arising from Old River's split with the mainstem. With the three tidal barriers operating, as they are now, the water that flows into Old River remains behind (upstream) of those barriers and does not reach the export pumps. [There is some backflow over the barriers and so there is some small amount of Old River water reaching the export pumps.]

The water flowing into Old River at its split with the mainstem, in combination with the water entering the south Delta from tidal action feeds local agricultural diversion needs, and other instream depletions. Absent the export projects, the Delta always had water as the channels are below sea level. Natural inflow typically kept the quality of the pool such that early farmers had no problems. Only once in recorded history did high salinity reach very far upstream in the south Delta. [There were times during extreme droughts when high salinity reached far up the Sacramento side.]

Now, the projects decrease inflow AND export significant quantities AND alter flow patterns. The result is insufficient quantity and quality to support beneficial uses that pre-date the projects. Therefore, it is correct that the exports are the cause of the low flow in the DWSC, but it is not the case that they are exporting the SJ River flow through Old River. [For clarity, a map is needed as the export pumps draw from Old River at a point well downstream from its split from the mainstem, but that water arises mainly from the Sacramento , traveling upstream via the Central Delta.]

During this same time period of low DWSC flows, Tom Paine Slough water levels dropped to the point that local diversions were prevented. Since the Slough is upstream of the tidal barriers, we conclude that local diversion needs (it was a hot spell) exceeded SJ River inflow and tidal inflow. The River inflow is controlled by permits on upstream diverters, none of whom are required to make releases to provide for the riparian, pre-1914, and superior appropriative rights in the south Delta, and the operation of the State export pumps decreased the height and duration of the incoming tides. The result? The south Delta upstream of the barriers became a pool of water decreasing in size. This harms water quality and insured little flow down to the DWSC

You will hear by some that the Delta isn't entitled to the upstream water and that therefore the problem is our local diversions. This is nonsense; there is no factual dispute that prior to the operation of the upstream and export projects, the fully developed Delta agriculture never had water level/quantity or quality problems. I believe DO was never a problem either until someone dug the DWSC and started daily exporting more than the entire flow of the San Joaquin.

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