1998 Fall Dissolved Oxygen Conditions in the Stockton Ship Channel

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Dissolved oxygen concentrations in the Stockton Ship Channel are closely monitored during the late summer and early fall of each year because levels can drop below 5.0 mg/L, especially in the eastern portion of the channel. The dissolved oxygen decrease in this area is apparently due to low San Joaquin River inflows, warm water temperatures, high biochemical oxygen demand (BOD), reduced tidal circulation, and intermittent reverse flow conditions in the San Joaquin River past Stockton. Low dissolved oxygen levels can cause physiological stress to fish and can block upstream migration of salmon.

As part of a 1969 Memorandum of Understanding between the Department of Water Resources (DWR), the US Fish and Wildlife Service, the US Bureau of Reclamation, and the Department of Fish and Game, the Department of Water Resources usually closes the head of Old River by installing a temporary rock barrier during periods of projected low fall outflow. The barrier increases net flows down the San Joaquin River past Stockton, and may contribute to the alleviation of low dissolved oxygen levels in the eastern Stockton Ship Channel. In 1998, however, DWR did not install the barrier because water year 1998 1 was classified as wet, and late summer and early fall (August through October) flows in the San Joaquin River were much higher than normal 2 . Average daily flows in the San Joaquin River past Vernalis ranged from 4,753 to 6,708 cfs from August through October, and average daily flows past Stockton ranged from 1,020 to 2,011 cfs. The average daily flows past Vernalis in 1998 were two to three times the flow (about 2,000 cfs) observed in the late summer and early fall of 1997, which far exceeded the average daily flows of 1,000 cfs or less observed in this area during the fall seasons of previous drought years. During previous years, intermittent reverse flow conditions were also present in the late summer and early fall in the San Joaquin River past Stockton.

Monitoring of dissolved oxygen levels in the Stockton Ship Channel was conducted six times by vessel between 7 August and 20 October 1998 3 . During each of the monitoring runs, fourteen sites were sampled from Prisoner's Point in the central delta (Station 1) to the Stockton Turning Basin (Station 14) at the terminus of the ship channel (Figure 1). For each site, Dissolved oxygen and water temperature data were collected near the surface and bottom of the water column during ebb slack tide using a Hydrolab Model DS-3 Multiparameter Surveyor.

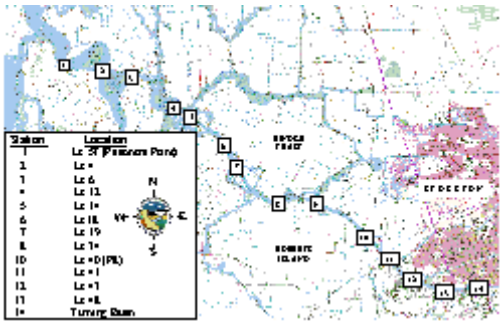

Figure 1 Dissolved oxygen monitoring sites in the Stockton Ship Channel

In 1998, all surface and bottom dissolved oxygen levels measured in the channel exceeded 5.0 mg/L and a dissolved oxygen sag (where dissolved oxygen levels were less than 5.0 mg/L) was not observed (Figure 2). In previous years, an oxygen sag developed in and immediately west of the Rough and Ready Island area (the Station 10 to 13 area) within the eastern channel during August and September. In 1998, however, San Joaquin River inflows into the eastern channel appear to have been sufficiently high to push the potential sag area from its historic location westward to where tidal fluctuations and

mixing maintained higher dissolved oxygen levels. The higher flows from the San Joaquin River into the channel immediately east of Rough and Ready Island also resulted in reduced residence times in this area, and potentially permitted greater dissolved oxygen saturation within the extreme eastern channel.

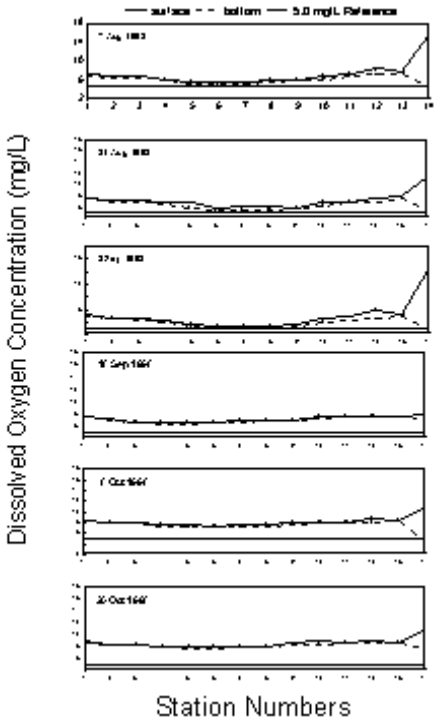

Figure 2 Dissolved oxygen concentrations in the Stockton Ship Channel in 1998

Despite improved flow conditions within the channel, a dissolved oxygen depression (an area within the channel where dissolved oxygen levels ranged from 5.0 to 6.0 mg/L) did exist within the system in 1998. Monitoring from August through early September 1998 showed a depression existed from Columbia Cut (Station 5) to Fourteen Mile Slough (Station 9). On 7 August, the lowest dissolved oxygen levels in the channel were measured from Columbia Cut to the west of Turner Cut (Station 7). On 21 August and 8 September, the dissolved oxygen depression shifted eastward to the area from the eastern end of Columbia Cut (Station 6) to Fourteen Mile Slough. These areas are consistently west of the historic sag area described previously.

The August and early September dissolved oxygen depression within the channel appears to be partly due to warm water temperatures. Water temperatures throughout the channel ranged from 24-26 °C on 7 August, 22-24 °C on 21 August, and 23-25 °C on 8 September. The well-established inverse relationship between dissolved oxygen level and water temperature (higher water temperature, lower dissolved oxygen level 4) applies here. At the range of water temperature values recorded in the late summer of 1998 (22-26 °C), dissolved oxygen levels have been low (less than 5.0 mg/L) in the eastern channel during the late summer in previous years.

In past years, intermittent reverse flow conditions past Stockton appeared to contribute to low summer and fall dissolved oxygen conditions in the eastern channel. In late summer and early fall 1998, however, reverse flow conditions past Stockton were absent because of the high San Joaquin River flows described previously. In fact, average daily flows past Stockton ranged from 1,003 to 1,979 cfs from August through mid-September. Thus, reverse flow conditions in the San Joaquin River past

Stockton did not contribute to low dissolved oxygen conditions in the eastern channel in 1998.

By 18 September 1998, the late summer dissolved oxygen depression present in the channel had been eliminated. Surface and bottom dissolved oxygen levels measured on 18 September exceeded 6.5 mg/L throughout the channel. By 20 October, these levels had improved to 8.0 mg/L or greater throughout the channel. Because of the full recovery of dissolved oxygen conditions in October, monitoring was not conducted in November.

Cooler water temperatures appear to have contributed to the improved fall dissolved oxygen conditions in the channel. Surface and bottom water temperatures within the channel ranged from 20-22 °C on 18 September, 17-18 °C on 8 October, and 15-16 °C on 20 October. The significant decrease in water temperature in the fall contributed to the elimination of the late summer dissolved oxygen depression within the channel, and the ultimate elevation of dissolved oxygen to the high levels historically measured in November in previous years.

Average daily San Joaquin River flows past Vernalis from mid-September through the end of October ranged from 5,058 cfs to 6,694 cfs, and average daily San Joaquin flows past Stockton ranged from 1,113 to 2,011 cfs. These fall flows are similar to the late summer (August through mid-September) flows and show that flow conditions were consistently high and essentially constant throughout the entire study period.

Exceptionally high surface and low bottom dissolved oxygen levels were periodically measured in the Stockton Turning Basin throughout the study period. Sampling on 7 August, 21 August, and 8 September 1998 showed surface dissolved oxygen levels ranging from 11.4 to 15.4 mg/L and bottom dissolved oxygen levels ranging from 4.4 to 5.6 mg/L. On 18 September, the distinct dissolved oxygen stratification subsided, and surface and bottom dissolved oxygen levels were 7.9 and 7.3 mg/L, respectively. On 8 and 20 October 1998, however, a lesser dissolved oxygen stratification returned. Surface dissolved oxygen levels ranged from 10.5 to 10.7 mg/L and bottom dissolved oxygen levels ranged from 4.2 to 7.8 mg/L.

The highly stratified dissolved oxygen conditions detected in the basin throughout much of the 1998 study period appear to be the result of localized biological and water quality conditions occurring in the basin. The basin is at the eastern, dead-end terminus of the ship channel and is subject to reduced tidal activity, restricted water circulation, and increased residence times when compared to the remainder of the channel. As a result, water quality and biological conditions within the basin have historically differed from those within the main downstream channel and have led to extensive late summer and fall algal blooms and dieoffs. The late summer and early fall of 1998 were no exception, and a series of intense algal blooms composed primarily of crytomonads, diatoms, flagellates, and blue-green and green algae were detected. Blooms appear to produce stratified dissolved oxygen conditions in the water column of the basin in the following way: high algal productivity at the surface of the basin produces elevated surface dissolved oxygen levels and dead or dying bloom algae settle out of the water column and sink to the bottom to contribute to high BOD. Bottom dissolved oxygen levels in the basin are further degraded by additional BOD loadings in the area such as regulated discharges into the San Joaquin River and from recreational activities adjacent to the basin. When bloom activity subsides, the dissolved oxygen stratification is reduced, and basin surface and bottom dissolved oxygen levels become less diverse.