Monitoring Plan for the Stockton Deep Water Ship Channel Aeration Project

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Monitoring Plan for the Stockton Deep Water Ship Channel Aeration Project

Introduction

A report has been prepared (Jones & Stokes and HDR 2004) that evaluates three preferred aeration devices to determine which device would be ideal for use in the Stockton Deep Water Ship Channel (DWSC). The selection process includes comparisons of the dissolved oxygen (DO) transfer efficiency, capital costs, and operation and monitoring costs. The report will be used to select a preferred device to increase the DO levels in the DWSC.

This report was prepared to outline and describe a long-term monitoring approach that will be used to evaluate the effectiveness of the selected aeration device in the DWSC. The monitoring strategy includes:

- descriptions of measurement parameters,
- sampling locations,
- frequency of sampling,
- format of future data reports, and
- suggested adaptive management methods to operate the aeration device only when needed to meet the target DO levels.

Background

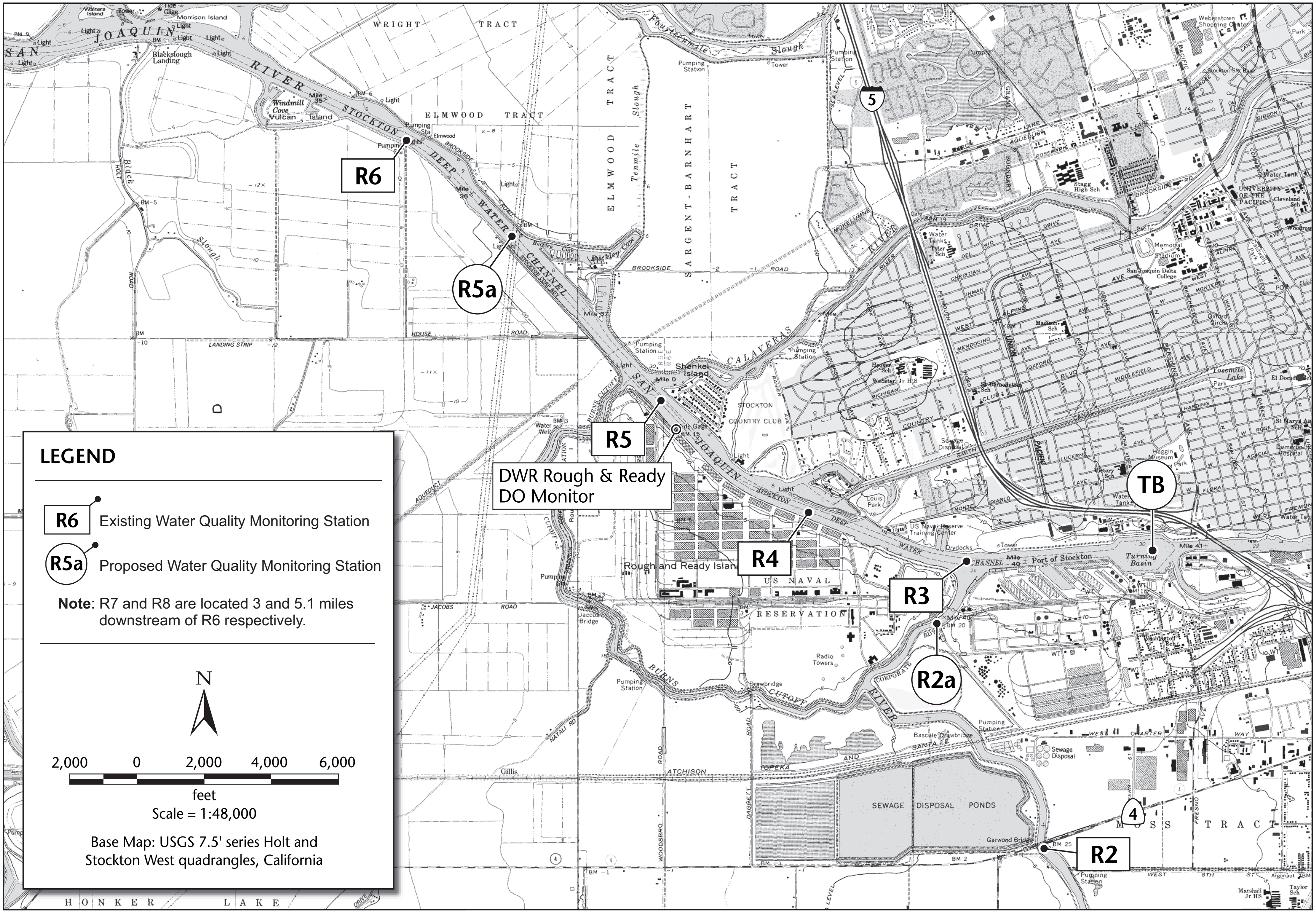
The DWSC is a maintained (i.e., dredged) portion of the San Joaquin River that begins at the mouth of the San Joaquin River near Antioch and terminates in Stockton, California. It is used as a shipping channel allowing large hauling vessels access to the interior of the Central Valley from the open sea. The terminus of the shipping channel is at the Port of Stockton East Complex. There is a sizable turning basin that allows the vessels to reverse their orientation before departing. The DWSC is dredged to a depth of at least 35 feet measured at the lowest low diurnal tidal cycle (mean lower low water [MLLW]). That is approximately 0 feet mean sea level (msl).

The concentration of DO in the San Joaquin River is a function of three primary factors: flow conditions in the river, the geometry of the DWSC (e.g., depth and width), and upstream contributions of algae and oxygen-depleting constituents (e.g., ammonia). High San Joaquin River flows, greater than 2,000 cfs, can prevent low DO levels by diluting oxygen-depleting substances in the DWSC and by transporting the substances from the DWSC faster than lower river flows. The DWSC's depth causes San Joaquin River flows to slow through the channel, thereby increasing the residence time of water within the DWSC. Although algae can grow near the surface of the DWSC, the depth of the DWSC limits the net algae growth, and most of the inflowing algae will settle and decay in the DWSC. The algae can provide DO to the DWSC through photosynthesis, but the net effect of algae growth is to reduce DO levels as the algae respire and as bacteria decompose dead algae. Most ammonia in the DWSC is from discharges by the Stockton Regional Wastewater Control Facility (RWCF) and some upstream San Joaquin River sources.

The concentration of DO in any water body is also dependent on its saturation concentration, which is a function of temperature. For example, the saturation concentration of DO at 9ºC (48ºF) (the monthly average water temperature of the San Joaquin River near Stockton in January) is 12 mg/l. In August, the average temperature of the river increases to 25ºC (77ºF) and causes the saturation DO concentration to be reduced to 8 mg/l. The combination of warmer water temperatures and lower flows in the late summer and early fall provides ideal conditions for the oxidation of organic material and the nitrification of ammonia, resulting in the rapid depletion of DO in the water column.

Previous Water Quality and Flow Monitoring

Because of the many factors described above, the DWSC has low DO levels that are often less than the established water quality objectives during the summer months. As a result, the water quality of the DWSC and the San Joaquin River has been monitored more frequently in special studies in an effort to determine the causes of the low DO and to evaluate potential solutions (including aeration devices). The City of Stockton (City) is required as part of its National Pollutant Discharge Elimination System (NPDES) permit to collect mid-depth weekly vertical profile and grab sample data in the DWSC during the summer and early fall. In addition to the ongoing NPDES City sampling in which only a few water quality parameters are measured, the City performed special studies in 1999, 2000, and 2001 in which additional water quality parameters were analyzed. The City's measuring stations (numbered R1 through R8) for the NPDES sampling extend from upstream of the DWSC (on the San Joaquin River) to downstream of Turner Cut (Figure 1). The measuring stations within the DWSC include one in the turning basin and stations R3 through R7. Temperature and DO vertical profiles were measured every 2 feet at the DWSC stations. Data collected in 2000 and 2001 have been presented previously in Jones & Stokes (2001) and in Jones & Stokes (2002).



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Jones & Stokes

Figure 1
Stockton Deep Water Ship Channel Water Quality Stations

An ultrasonic velocity meter (UVM) operated and maintained by the U.S. Geological Survey (USGS) continuously monitors river stage and tidal flows at a location upstream of the submerged pipe outfall at the City of Stockton's RWCF. Flows recorded by the UVM have been used with water quality data to determine San Joaquin River nutrient, biochemical oxygen demand (BOD), and algae loads to the DWSC (Jones & Stokes 2002).

In addition to the water quality data collected by the City, the California Department of Water Resources (DWR) has a monitoring station at the downstream end of Rough & Ready Island that collects hourly data (Figure 1). DO concentrations, temperature, and pH data are measured hourly in the DWSC by DWR's surface (i.e., 3-foot-depth float within a perforated stilling well pipe) monitoring station.

Special Study Results—2001

Results from a 2001 water quality study are useful as examples of water quality conditions in the DWSC. In 2001, as part of an action grant directed by the CALFED Bay-Delta Program (CALFED), the City of Stockton conducted total maximum daily load (TMDL) special river surveys to support the DO TMDL studies funded by CALFED. The study reach included the river monitoring stations established for the NPDES sampling in the DWSC (stations R2–R8) and another station in the turning basin. The monitoring program provided a framework of weekly samples to characterize the water quality patterns within the DWSC and evaluate the potential relationships between RWCF effluent loads and San Joaquin River loads (Jones & Stokes 2002).

The results of this study provided important information on vertical stratification in the DWSC, the DO levels, longitudinal DO differences, and the effects of San Joaquin River flows on the water quality and DO in the DWSC. DO levels in the DWSC for all of 2001 are shown in Figure 2. Study results showed that the DWSC is generally well-mixed vertically (Jones & Stokes 2002). The measured surface temperature and DO at DWR's Rough & Ready Island station was sometimes elevated during the day, but was apparently almost always well-mixed during the night, as indicated by a slowly decreasing temperature and DO in the early morning hours each day. The vertical profiles of temperature often showed only a near-surface layer with a slightly higher temperature (1–2ºF), but the DO gradient was sometimes declining throughout the depth (Figures 3a and 3b). In addition to showing the DO differences between locations, Figures 3a and 3b demonstrate the DO and temperature changes that can occur from week to week. The temperature and DO stratification was more pronounced at the turning basin station (Figure 3b). Tidal mixing is less in the turning basin because most of the tidal flow moves up the San Joaquin River toward Mossdale. This suggests that the vertical mixing was fast relative to surface heating (mixing at least each night) but slow relative to DO decay processes. However, there are no measurements of daily stratification to verify that the temperatures are always mixed each night.

The observed decline in the mid-depth DO concentrations (DO sag) between R3 and R6 was always less than 2 mg/l in 2001 (Jones& Stokes 2002). The R3 DO concentrations were usually within 2 mg/l of saturation, suggesting that the lowest DO concentrations were about 4 mg/l. The hourly DWR station recorded values that were sometimes less than 4 mg/l. The lowest mid-depth DO concentrations of 4 mg/l are slightly less than the DO objectives of 5 mg/l from December through August and 6 mg/l from September through November.

Flows during the year 2001 survey period ranged from less than 750 cfs in June and July to more than 2,000 cfs in October. The DWSC residence time from Channel Point to the Rough & Ready Island station changed from more than 5 days in June and July to fewer than 5 days in October. The effects of flow changes on DO concentrations in the DWSC are apparently more complex than a simple dilution of RWCF and a reduction in residence time. The river load to the DWSC increases with flow if the flow change is the result of partial closure of the Head of Old River barrier. The river concentrations may be reduced if the flow change is from upstream reservoir releases. DWSC water quality may be influenced by changes in San Joaquin River flow, but there are several factors that interact to make it difficult to clearly observe the effects of flow on DO concentrations in the DWSC.

Dissolved Oxygen Objectives and Dissolved Oxygen Deficit

The DO objectives everywhere in the DWSC are 5 mg/l from December through August and 6 mg/l from September through November. Using the 2001 water quality data, a DO deficit was calculated to determine the quantity of oxygen that must be added by an aeration device to increase the DWSC DO levels to meet the water quality objectives. An aeration device is believed to be capable of maintaining DO at an acceptable level for an indefinite period until other actions reduce or remove the need for this approach. Data from the DWR's station and from the Stockton UVM flow station were used to estimate the DO deficit below applicable water quality objectives for the DWSC. The DO deficit in the DWSC was calculated using the following equation:

DO deficit (lbs/day) = 5.4 (Net Flow (cfs) ([Target DO (mg/l) – Minimum DO (mg/l)]

Where lbs/day = pounds per day.

A 0.5 mg/l DO buffer was added to the DO objective to allow for slight variations in the DWSC DO compared to the DO monitoring data. Based on the daily minimum DO concentrations at the DWR Rough & Ready Island station and the daily net flow measured at the Stockton UVM flow station, about 1 million pounds (lbs) of oxygen would have been needed in the summer of 2001. Estimated DO deficits in the DWSC during 2001 are shown in Figure 4. An aeration device that delivered about 10,000 lbs/day would have satisfied the measured DO deficit during the summer of 2001. It should be noted that water

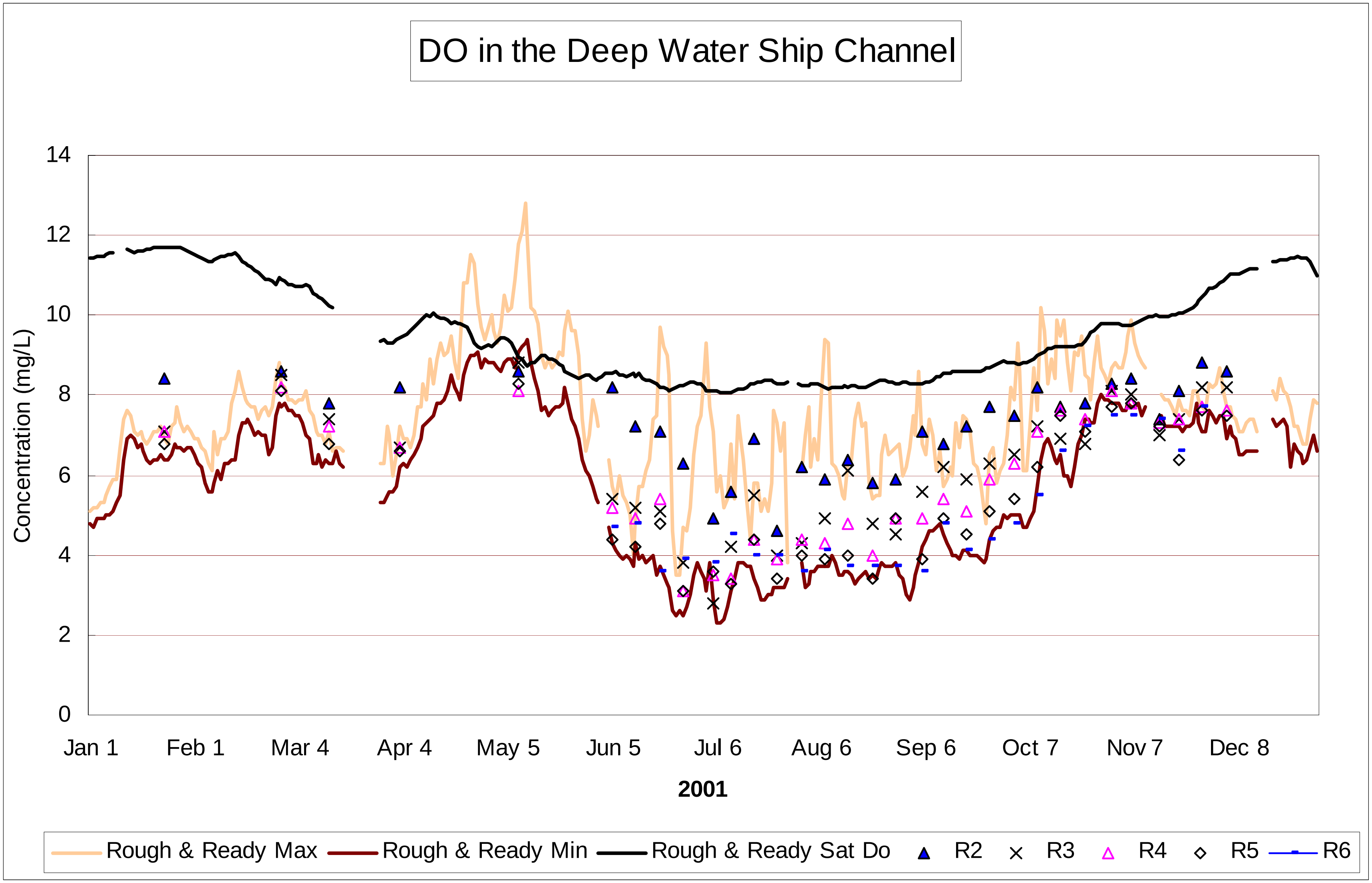

Figure 2. Dissolved Oxygen Concentrations in the Stockton Deep Water Ship Channel and in the San Joaquin River in 2001

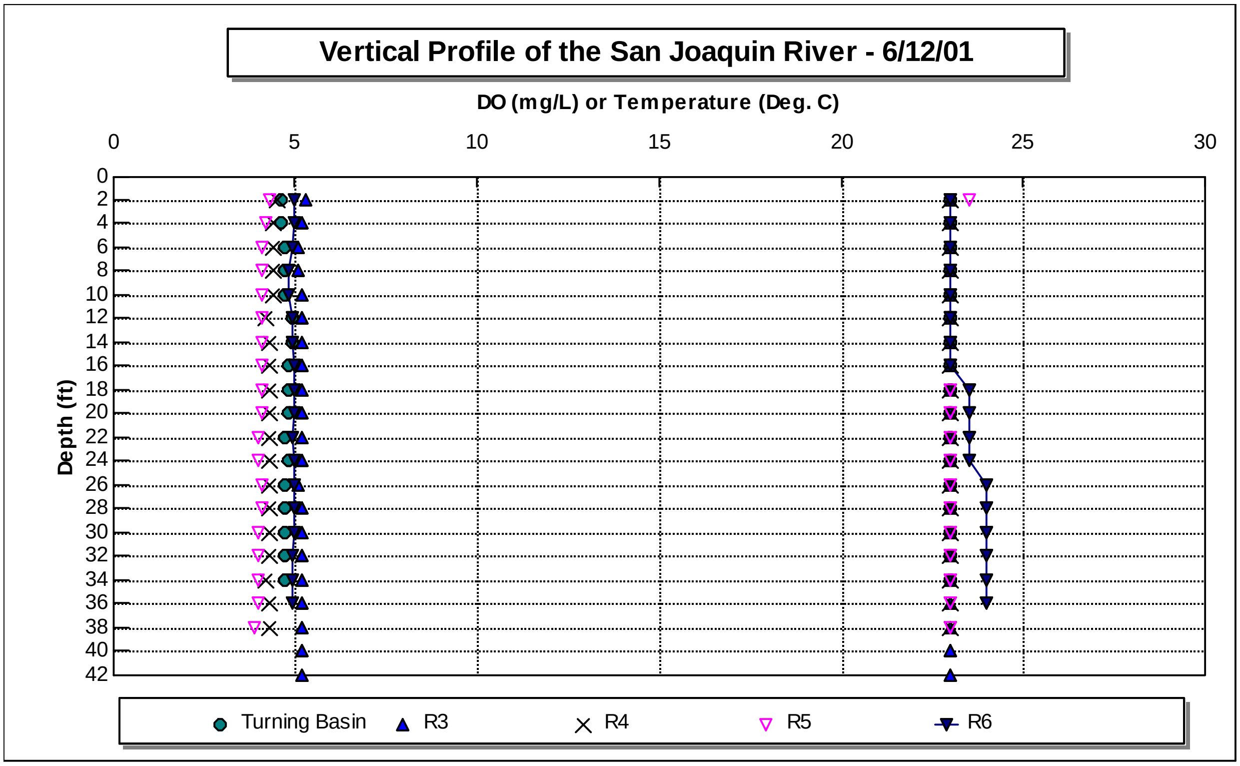

Figure 3a. Vertical Profiles of Dissolved Oxygen and Temperature in the Stockton Deep Water Ship Channel, June 12th, 2001

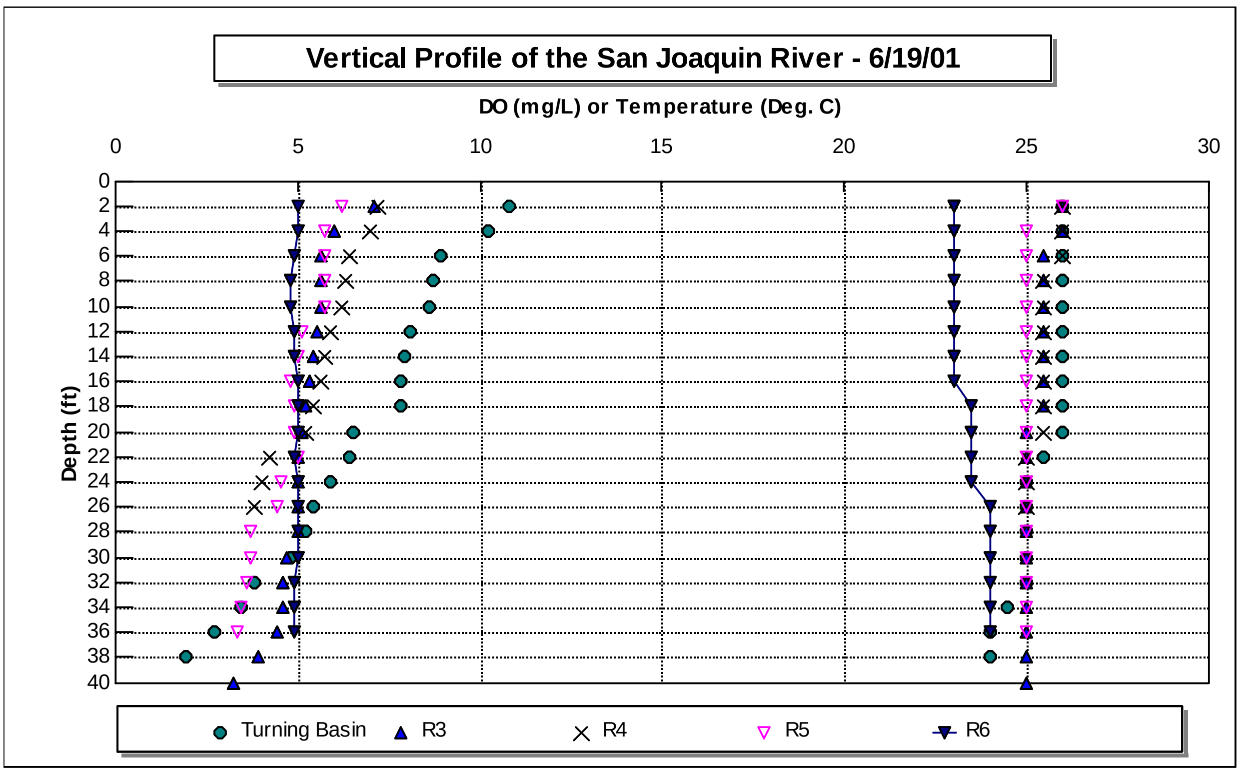

Figure 3b. Vertical Profiles of Dissolved Oxygen and Temperature in the Stockton Deep Water Ship Channel, June 19th, 2001

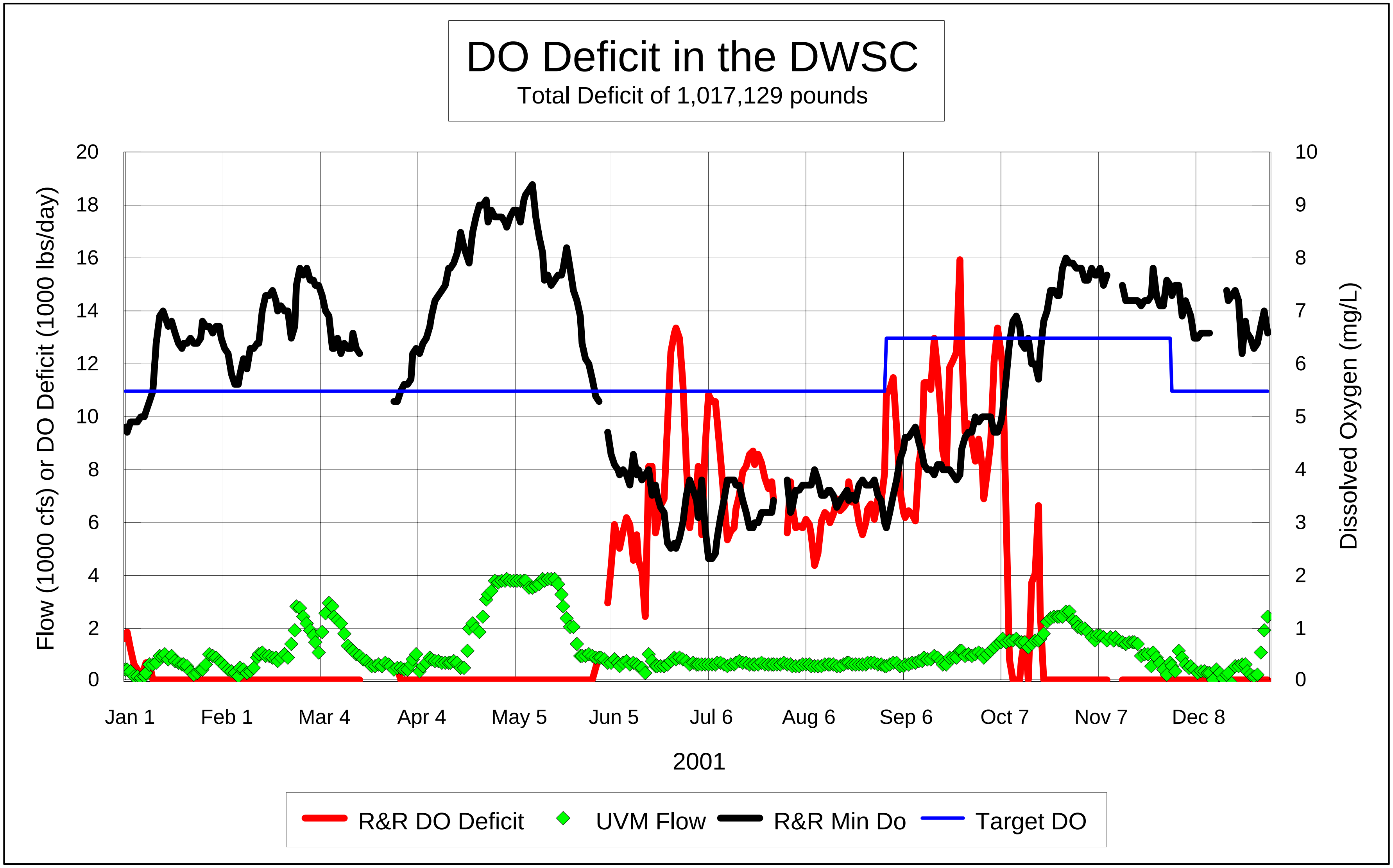

Figure 4. Dissolved Oxygen Deficit in the Stockton Deep Water Ship Channel Calculated for 2001

year 2001 was a slightly below-normal year and that during a dry or critical year with lower river flows, the oxygen deficit could be greater than 10,000 lbs/day. However, the maximum daily DO deficit of about 10,000 lbs was generally the same during many recent years (Jones and Stokes 2003). The periods when a DO deficit may develop and the total annual DO deficit may vary from year to year.

Monitoring Approach

The monitoring approach, to determine the effectiveness of the aeration device was developed by combining the information provided in the following sources:

- past water quality data (especially DO longitudinal and vertical trends) measured in the DWSC,
- the expected location of the aeration device and its diffusers,
- previous DWSC flow and mixing data and trends, and
- the monitoring locations and sampling procedures of the DWR and the City.

Suggested water quality parameters, monitoring stations, sampling frequencies, and strategies for the operation of the aeration device are described below.

Monitoring Parameters and Locations

Grab samples, vertical profiles, and continuous monitoring will be used to evaluate the water quality of the DWSC and the water quality of the San Joaquin River upstream of the DWSC and San Joaquin River confluence. The measured parameters will be similar to those shown in Table 1 and will include DO, temperature, pH, and oxygen-depleting substances (e.g., 5-day biochemical oxygen demand (BOD_5), volatile suspended solids (VSS), chlorophyll *a* (Chl*a*)). This water quality data will be used to calculate loads into the DWSC from the San Joaquin River and to evaluate the effectiveness of the aeration device. The Stockton UVM flow data will be used in the load calculations. Temperature, DO, pH and fluorescence will be measured at mid-depth every 15 minutes at the continuous monitoring stations. Measuring at mid-depth is preferred over measuring at the surface because the mid-depth results will provide similar diurnal trends and less noise or variation in the data. Vertical profiles will be taken for temperature, DO, pH, and electrical conductivity every 2 feet. Sampling for vertical profiles will take place at all sites before 10:00 a.m. to ensure that, as much as possible, the minimum daily DO concentrations are observed throughout the DWSC. Vertical profiles generally will be conducted weekly but will be conducted daily when the oxygen device is operating. Weekly grab sample data will be collected for all other parameters listed in Table 1.

Water quality monitoring stations for the first year following device implementation will include R3 through R6, the turning basin, DWR's Rough & Ready Island station, and two new stations (R5a and R2a). Station R2a is located on the San Joaquin River upstream of Channel Point (i.e., the confluence with the DWSC) at the inside edge of the nearby railroad bridge. Station R5a would be located between stations R5 and R6 in the DWSC. Descriptions of the monitoring locations and sampling frequencies are provided in Table 1. Continuous 15-minute measurements will be collected at stations R2a, R4, DWR Rough & Ready Island, and R6. Vertical profiles will measured at stations TB, R3, R4, R5, R5a, and R6. Weekly grab samples will be collected at stations R2a, TB, R3, R4, R5, and R6.

The R3 through R6 monitoring stations, the DWR station, and the turning basin station will provide water quality data in the DWSC. Monitoring downstream of R6 is likely unnecessary because past R7 data indicate low DO problems did not occur at that site. The R3 through R6 sites were chosen to maximize the period of available data and facilitate temporal water quality comparisons by choosing sites where water quality data have been collected previously. The R2a station was selected to provide San Joaquin River water quality data characterizing inflow into the DWSC. However, the R2a station will record San Joaquin River inputs to the DWSC only during ebb tide flows because during flood tide water from the DWSC will travel upstream into the San Joaquin River and affect the R2a measurements.

Table 1. Monitoring Stations and Proposed Water Quality Sampling

Station Name	Station Location	A. Continuous 15-Minute Monitoring*	B. Vertical Profiles (Weekly; Daily if Device Operating)*	C. Grab Samples (Weekly)*
R2a	On San Joaquin River, upstream of Channel Point at railroad bridge	X	–	X
Turning Basin (TB)	River Mile 40.7	–	X	X
R3	River Mile 39.4	–	X	X
R4	River Mile 38.5	X	X	X
DWR Rough & Ready Island Station	River Mile 37.8	X	–	–
R5	River Mile 37.3	–	X	X
R5a	Approximately River Mile 36.3	–	X	–
R6	River Mile 35.5	X	X	X

* These columns indicate the type of water quality sampling that will be performed at each station. An X in the column indicates that type of sampling will occur, while a – in the column indicates that type of sampling will not occur.

Following the first year of intensive sampling and monitoring, vertical profiles and grab samples will not be conducted. It is assumed that the intensive water quality sampling in the first year will provide enough information to characterize the water quality throughout the DWSC and determine the effectiveness of the device. Thus, after the first year, the effectiveness of the aeration device will be determined only from the continuous monitoring stations (R2a, R4, DWR Rough & Ready Island, and R6).

Dye Study of Lateral Mixing in the DWSC

A dye study will be performed during the summer months, when flows and DO levels are typically lowest, to evaluate how rapidly dye will spread from the aeration device across the DWSC to the opposite shore. This lateral spreading or mixing of the dye will indicate how well the selected aeration technology would spread water with an increased DO concentration across and throughout the DWSC. The DWSC is approximately 500 feet wide with a mean depth of 30 feet, so the cross-section area is about 15,000 square feet. These results will be compared with results from a previous dye study.

The previous dye study was conducted from Rough & Ready Island dock to test the lateral mixing of flows, from a pilot-scale aeration device (mounted oxygen bubble injector [MOBI]), in the DWSC. The MOBI device is an inverted U-tube constructed of 20-inch-diameter PVC pipe. The legs of the tube are each 20 feet long and about 6 feet apart. Details on the device and the dye study are included in Jones & Stokes 2003. Dye was injected into the MOBI device at a rate of 50 grams per minute (g/min) for 45 minutes while the device was operated to produce a water flow of about 3 cfs. A dye cloud about 1,500 feet long was produced. A boat-towed dye fluorometer and water quality–monitoring array measured the lateral and longitudinal dispersion. Vertical and lateral contours of dye concentration at 5-foot-depth intervals were used to characterize the vertical and lateral spreading across the DWSC.

Results of the previous study indicate lateral mixing of dye concentrations were nearly uniform after 24 hours (Figure 5) as a result of tidal mixing that moves water about 1 mile upstream or downstream during each tidal cycle. The DO device can therefore add some oxygen over a 2-mile reach (1 mile upstream and 1 mile downstream of the device). Thus, the specific location of the device is not extremely critical because the mixing can move the high-DO water within a 2-mile reach.

Aeration Device Operation

The aeration device will be operated only when the DO levels in the DWSC are lower than a determined trigger point. The maximum quantity of oxygen the device will diffuse into the DWSC is 10,000 lbs in a day and approximately 1,000,000 lbs of oxygen in a year. Thus, a trigger point must allow a sufficient time buffer such that a maximum input of 10,000 lbs of oxygen per day would maintain the DO levels throughout the DWSC above the objectives. During the first year of operation, the device initially will be turned on when a DO concentration at any of the monitoring sites is less than 6 mg/l during the 5 mg/l objective period or 7 mg/l during the 6 mg/l objective period. The minimum DO measurement, observed either in the vertical profiles (performed in the morning) or in the continuous monitoring measurements, will be used each day to determine whether the device should be operated. Thus, if any of the DO measurements is less than 6 mg/l (during the 5 mg/l–objective period) or 7 mg/l (during the 6 mg/l–objective period), the device will be operated. As data are collected during the first year, the trigger points may change to increase or decrease the buffer time. Monitoring data and data collected during a dye study (described below) will be used to determine travel times of the high-DO water from the diffuser through the DWSC and therefore the amount of buffer time necessary. Operation of the aeration device will cease whenever all monitoring stations have minimum DO concentrations greater than the trigger points. The devices can be operated to provide any quantity of oxygen by varying the operating time. Partial operation of the selected device may become part of the adaptive management strategy following testing and evaluation during the first year.

After the first year of monitoring, the device will be operated based only on the minimum DO concentrations at the continuous monitoring sites (R2a, R4, Rough & Ready, and R6). Past DO measurements indicate the lowest DO level (i.e., DO sag) does not occur downstream of R6. Thus, DO levels throughout the DWSC will probably be greater than the objective if the device is operated based only on DO measurements at these continuous DO monitoring stations.

Future Data Report

At the end of the first year, a detailed data report will be created that will present:

- a description of the sampling methods used in the water quality monitoring;
- a discussion of water quality trends (particularly DO levels in the DWSC and loads of oxygen-depleting substances from the San Joaquin River), which will include
  - graphs of the recorded daily minimums, means, and maximums at the continuous monitoring sites throughout the year,
  - graphs of the daily means and maximums from the vertical profiles throughout the year, and
  - tables of all of the vertical profile data and grab sample data collected;
- a summary of flows in the DWSC during the year;
- results of the dye study; and
- a discussion of the effectiveness of the aeration device, which will include

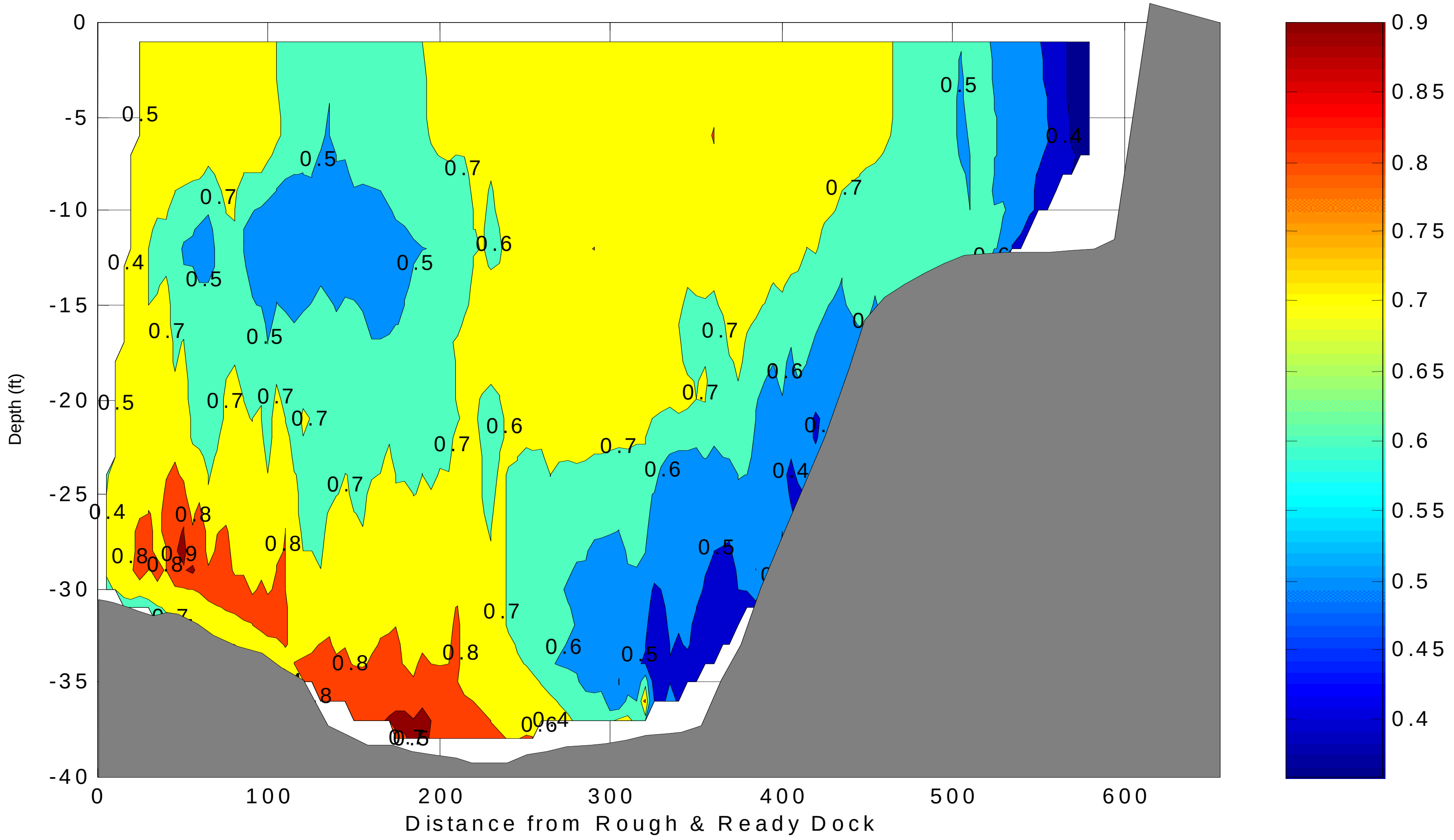

Figure 5. Vertical and Lateral Distribution of Dye after 24 hours (downstream 1,000 feet)

- a discussion of the initial trigger points and the effects of potential decisions to alter the trigger points,
- calculated DO transfer efficiencies,
- travel times of the high-DO water to the location with the lowest DO concentration,
- any potential problems with the device or the operation of the device, and
- adaptive management techniques used to improve the operation of the device and maintain the DO levels above the trigger points.

The report will provide information about the amount of oxygen needed to maintain the DO objectives. Procedures for allocating responsibilities for providing the DO increases will be described, according to the DO TMDL basin plan amendment.

Following the first year of intensive monitoring, annual data reports will be produced until the operations of the aeration device permanently cease. These data reports will be less detailed but will still include a discussion of travel times from the device throughout the DWSC, a discussion of the effectiveness of the device, and the water quality and flow trends observed in that year.

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