Final

2002 Water Quality Monitoring

Mill River

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Introduction

This report presents results of ongoing studies by the Regional Water Authority (RWA) to document baseline dissolved oxygen (DO) and salinity concentrations in the Mill River downstream of the Lake Whitney water supply reservoir dam. Lake Whitney was used for public water supply from 1862-1991 and The Regional Water Authority will be resuming water withdrawals from the reservoir following construction of a new water treatment plant scheduled for completion in late 2004. The following monitoring results are discussed and summarized in Table 1.

- A long-term monitoring effort was conducted by deploying two data sondes in the Mill River from August 8th to September 17th, 2002. One data sonde was deployed in the plunge pool at the base of the Lake Whitney spillway overflow and the other one was deployed under the Orange Street bridge (Figure 1). The data sondes were programmed to collect water quality parameters every 30 minutes during the duration of the deployment. The parameters collected included DO, specific conductivity, temperature, and pH. However, an issue arose with one of the instrument probes that compromised part of the monitoring program.

- In July, August, and September, 2002, the RWA conducted weekly dawn DO and salinity monitoring at the Lake Whitney spillway overflow, the Lake Whitney spillway plunge pool, and at the Orange Street Bridge. During late September, DO and salinity measurements were also collected at the footbridge and the tide gates (Figure 1). The purpose of the monitoring was to assess relationships between flow and DO concentrations in the Mill River in the reach between the Whitney Dam and the Orange Street bridge. The results can be used to assess the DO concentrations necessary in the spillway plunge pool to maintain acceptable DO levels downstream. Additionally, turbidity and *E. coli* bacteria weekly measurements were made at the plunge pool and Orange Street to collect additional water quality information.

- In July and August, 2001, the RWA also conducted weekly dawn DO and salinity monitoring of the Lake Whitney spillway overflow, the Lake Whitney spillway plunge pool, and the Mill River at the Orange Street Bridge. Supplemental DO and salinity data were collected by the RWA on October 25, November 16, and November 19 to assess the effects of moderately low flow conditions that occurred in Fall of 2001. These data are also included in this report.

2002 Monitoring Results

Table 1 below presents a summary of the Mill River monitoring data collected in 2002.

TABLE 1. Mill RIver Monitoring Data collected in 2002

Frequency/Dates	Locations	Parameters
Continuous (August 8 – Sept. 17)	Plunge Pool	Temp., DO, Salinity, pH
	Orange St.	Temp., DO, Salinity, pH
Weekly – July through Sept. 13 (early morning)	Lake Whitney Spillway	Temp., DO, Salinity
	Plunge Pool	Temp., DO, Salinity, Turbidity, *E. coli*
	Orange St.	Temp., DO, Salinity, Turbidity, *E. coli*
Sept. 24 (afternoon)	Lake Whitney Spillway	Temp., DO, Salinity
	Plunge Pool	Temp., DO, Salinity
	Orange St.	Temp., DO, Salinity
	Footbridge	Temp., DO, Salinity
Sept. 25 & 27 (early morning)	Lake Whitney Spillway	Temp., DO, Salinity
	Plunge Pool	Temp., DO, Salinity
	Orange St.	Temp., DO, Salinity
	Tide Gates	Temp., DO, Salinity

Continuous Monitoring

Water quality parameters were recorded in the Mill River at the Whitney Dam plunge pool and at Orange Street from August 8th to September 17th, 2002, at 30 minute intervals. This monitoring was accomplished using Yellow Springs Instruments (YSI) Model 6920 data sondes, which recorded DO, specific conductivity, temperature, pH, and ORP. All the parameters were recorded successfully, with the exception of DO. The DO probe on the sonde deployed in the plunge pool failed almost immediately after deployment, and while the DO probe at Orange Street did not fail completely, it showed a significantly different response from the weekly measurements and the independent measurements recorded at the time of retrieval. Inspection of DO probes at both locations showed a high degree of biofouling which likely interfered with the readings. Therefore, the DO data recorded by the data sondes were deemed unusable and are not presented in the report.

Salinity

The continuous specific conductivity measurements recorded over this time period at the plunge pool and Orange Street locations were converted to salinity, and are shown in Figures 2 and 3, respectively. The salinity measurements in the plunge pool are consistently between 0.11 and 0.14 parts per thousand (ppt) during the duration of the continuous monitoring, with the exception of two marked decreases, which correspond with two large rain events in late August.

In contrast, the salinity readings at Orange Street fluctuated considerably with each tidal cycle, with readings in August generally around 5 ppt at low tide and between 15 and 20 ppt at high tide. A significant decrease in salinity occurred in late August, which corresponded with a large rain event. In September the salinity readings were considerably lower than in August, with readings less than 5 ppt at low tide and readings generally between 10 and 15 ppt at high tide (Figure 3).

Temperature

The temperature in the plunge pool varied from 22 to 28 $^{\circ}$C in August, with a peak in mid August, followed by a gradual decline in temperatures in September (Figure 4). The data also show a diurnal change in temperature in the plunge pool. At Orange Street, the water temperatures also showed a diurnal change, but were generally warmer, with readings of 24 to 30 $^{\circ}$C in August (Figure 4). The water temperature at Orange Street also declined less in September than did the water temperature in the plunge pool.

pH

The pH values in the plunge pool varied from approximately 8.0 to 9.0 during August and a slight decrease in September (Figure 5). Diurnal changes in pH can be observed in the data, with peak pH values occurring around mid-day, related to the decrease in CO_2 concentration as a result of primary production. The pH values at Orange Street also showed a diurnal fluctuation, but were also influenced by daily tidal cycles. The pH value at Orange Street was generally lower than those in the plunge pool, with values ranging from approximately 7.2 to 8.4 throughout the monitoring period (Figure 5).

Weekly Monitoring

Weekly monitoring of Mill River water quality was conducted by the RWA from July through mid-September, 2002 at top of the Lake Whitney spillway, the Whitney spillway plunge pool, and the Orange St. bridge. Additional supplemental data that included these stations, the footbridge, and the tide gates were collected in late September. Weekly DO and salinity measurements were made using a Hydrolab Quanta multi-parameter meter, while turbidity and *E. coli* samples were collected in the field and subsequently analyzed at the RWA's laboratory. The weekly monitoring data were collected during the early morning, generally between 5:00 and 6:00 am, with the exception of the data collected on September 24, which were collected in the afternoon. Monitoring data were collected at two water depths at the estuarine stations (Orange St. , tide gates, and the footbridge), near the surface (0.1 to 0.2 m depth) and near the bottom. At times during the weekly monitoring, additional supplemental data were collected at various other depths at some of the monitoring stations.

Dissolved Oxygen

The weekly DO monitoring data are presented in Figure 6. The DO data collected on September 24th were omitted from the figure to ensure comparability among the monitoring dates, since DO concentrations increase during the day due to photosynthesis. The lowest surface DO measured at Orange Street was 4.63 mg/L, which occurred on September 27th. The lowest bottom layer DO was measured on August 23rd, which was 3.42 mg/L. In contrast, the lowest DO concentrations measured at the plunge pool and Lake Whitney were 7.07 and 6.91 mg/L, respectively. The data show that DO concentrations at Orange Street were consistently lower than those at the plunge pool and Lake Whitney. DO concentrations near the bottom of the water column were consistently lower than DO concentrations near the surface at the Orange Street monitoring locations, with one exception on July 19. On this date the DO concentration in the bottom water was slightly higher than near the surface. It is also worth noting that on this date the DO concentrations at the plunge pool and Lake Whitney were very similar to those at Orange Street. The reason for this apparent anomaly is unknown.

Salinity

The weekly salinity monitoring data are presented in Figure 7. The salinity data show that the surface water layer at Orange Street rarely reaches more than 6 ppt salinity, while the bottom layer is heavily influenced by salt water intrusion during high tides, with salinity reaching as much as 14 ppt. During periods of high flow (e.g., August 30th and September 6th) the salt wedge does not appear to reach upstream to Orange Street, as both the surface and bottom layer of the water column remained below 1 ppt.

Turbidity

The weekly turbidity monitoring data are presented in Figure 8. The turbidity in the plunge pool was generally in the 2 to 8 NTU range throughout the monitoring period, with the exception of three sampling dates when turbidity was above 10 NTU. Increased turbidity is usually related to runoff and resuspension of sediment during precipitation and high flow events. However, only two of the peaks in turbidity can be correlated with precipitation events (August 23rd and August 30th). No precipitation occurred in the 72 hours prior to the other two observed peaks in turbidity on August 9th and August 16th. The turbidity at Orange Street was slightly lower than in the plunge pool, with values generally between 2 to 6 NTU, but showed a similar pattern of increased turbidity after precipitation events.

***E. coli* Bacteria**

The weekly *E. coli* bacteria monitoring data are presented in Figure 9. The levels of *E. coli* bacteria in the plunge pool samples were generally low during the monitoring, with levels under 30 colony forming units (CFU) per 100 ml on all but two sampling dates (August 9th and August 30th). One of these samples was collected on August 9th, when no rain preceded the sampling event, but the other occurred on August 30th, following 1.98 inches of rain. In contrast, the levels of *E. coli* bacteria in the Orange Street samples were generally above 50 cfu/100ml on each sampling date, with six samples exceeding 100 cfu/100ml and two samples exceeding 500 cfu/100ml. The highest bacteria count (770 cfu/100 ml) occurred at Orange St. following heavy precipitation (1.98 inches of rain in the previous 72 hours) suggesting that urban runoff and combined sewer overflow (CSO) discharges are likely responsible for the increased bacterial count.

Correlation of DO Concentrations in the Plunge Pool with DO Concentrations Downstream

The weekly 2002 monitoring data were evaluated for a potential correlation between DO concentrations in the plunge pool and DO concentrations downstream at the Orange Street bridge. To remove a confounding variable, the data were separated into two groups, wet weather data (rainfall occurred in the 72 hours preceding the monitoring event) and dry weather data (no rainfall in the 72 hours preceding the monitoring event. For the purposes of this evaluation, rainfall was defined as precipitation events greater than 0.13 inches, as measured at the Whitney Dam rainfall gauge. The data were segregated into wet and dry data sets because previous monitoring data had suggested that DO concentrations generally decreased after rain events, likely due to stormwater runoff and potentially CSO discharges. To check for a potential correlation the DO concentrations measured on each monitoring date at the plunge pool and Orange Street were plotted against each other and a linear regression analysis was performed. This evaluation was performed for both the surface water and the bottom water data.

2002 Weekly Monitoring Data

There was little correlation between the plunge pool DO concentrations and those at Orange Street in the 2002 wet weather data (Figure 10). However, the dry weather data showed a relatively strong correlation ($R^2 = 0.63$) between the surface water layer in the plunge pool and the surface water layer at Orange Street (Figure 11). Although, the correlation in DO concentrations in the bottom water layer was weaker ($R^2 = 0.29$) (Figure 11).

2001 and 2002 Weekly Monitoring Data

To increase the robustness of the evaluation, the 2001 and 2002 weekly monitoring data were combined and evaluated for potential correlation between DO concentrations at the plunge pool and Orange Street. Again, the data were separated into wet and dry weather groups and plotted against each other. This evaluation showed that the surface water DO concentrations at the plunge pool and Orange Street are strongly correlated ($R^2 = 0.80$) during dry weather conditions (Figure 12) but not during wet weather conditions ($R^2 = 0.08$) (Figure 13). The same relationship was observed for the bottom water layer. A strong correlation was found between DO concentrations in the plunge pool and DO concentrations in the bottom water layer at Orange Street during dry weather ($R^2 = 0.65$) (Figure 12), but no apparent correlation can be found in the wet weather data ($R^2 = 0.03$) (Figure 13).

Effect of the Tidal Cycle on the Downstream DO Correlation

Since salt water often reaches Orange Street during periods of high tide, and the salt water can negatively influence DO concentrations in the river because of generally poor water quality at the mouth of the Mill River, as documented in the 2001 monitoring (CH2M Hill, 2001) the data were further segregated into low and high tide groups to removed this confounding factor from the analysis. Thirteen monitoring dates were identified as dry weather (i.e., less than 0.13 inches of precipitation in the previous 72 hours). Of the thirteen dry monitoring events, six were identified as having occurred during high tide, five during low tide, and two during a mid-tide. When the dry weather, low tide data were plotted, very strong correlations were found between the DO concentrations in the plunge pool with those at Orange Street, for both surface water (R^2 = 0.83) and bottom water (R^2 = 0.93) (Figure 14). Although strong correlations were found, one caveat to note is the limited nature of the data. Only four data points were available for the surface water layer and three for the bottom water layer. The reason for this is that at low tide the water column near the Orange Street bridge is relatively shallow, therefore data were collected at only mid-depth on a few occasions in 2001.

To assess whether the tidal cycle or rainfall has more of a confounding effect on the correlation between DO concentrations in the plunge pool and those at Orange Street, the dry weather data were plotted for monitoring events that occurred during high tide (Figure 15). As shown in the figure, a very strong correlation (R^2 = 0.93) can still be observed for surface waters, even during high tide conditions. However, the data also show the confounding effect of the salt water intrusion, as during high tide, the bottom water data have a much weaker correlation (R^2 = 0.42) (Figure 15).

There were only three monitoring events that occurred at low tide during wet weather conditions. Therefore, there were not enough data to properly assess whether the strong correlation observed during dry weather, low tide conditions would be maintained during wet weather. Overall the data suggest that rainfall has a negative effect on DO concentrations in the Mill River at Orange Street (Figure 16). This effect is undoubtedly related to the increased biological oxygen demand (BOD) from urban runoff and CSO discharges to the river during rainfall events.

Conclusions

The data presented in this report suggest that a scientifically valid correlation can be drawn between DO concentrations in the plunge pool and DO concentrations in the Mill River at Orange St., if only data from dry weather conditions are used. Higher tide stage can weaken this relationship overall. However using only surface water DO values from Orange St can generally minimize this effect. This correlation will be useful for future management decisions regarding water withdrawal and maintaining water quality in the Mill River. However, the data also show that monitoring data collected during or soon after precipitation events should not be used to develop predictive models of DO concentrations in the river downstream of the Lake Whitney Dam.

Figures

FIGURE 1. Locations Sampled during the 2002 Mill River Monitoring.

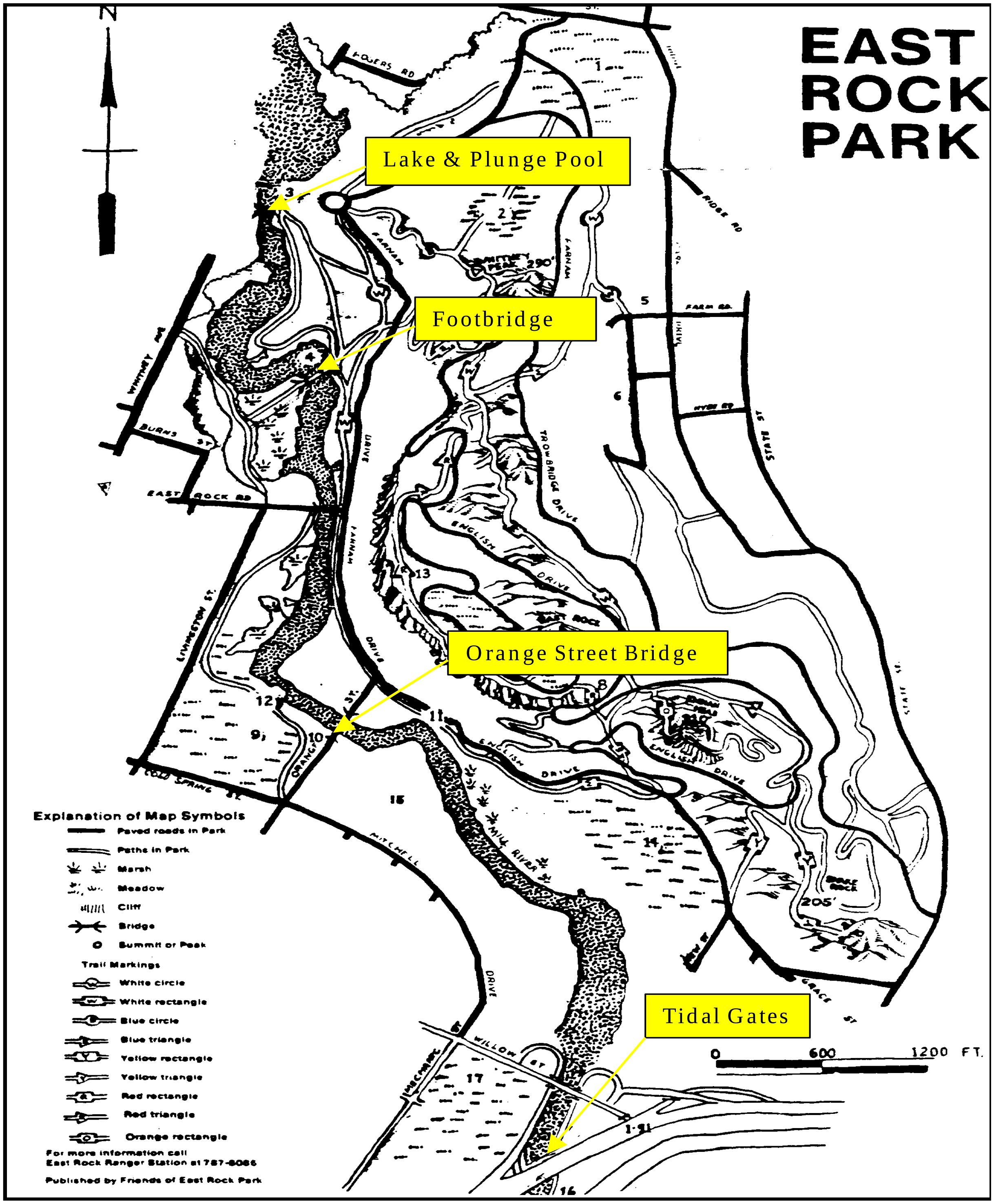

Figure 2.
2002 Mill River Continuous Monitoring (Plunge Pool Salinity)

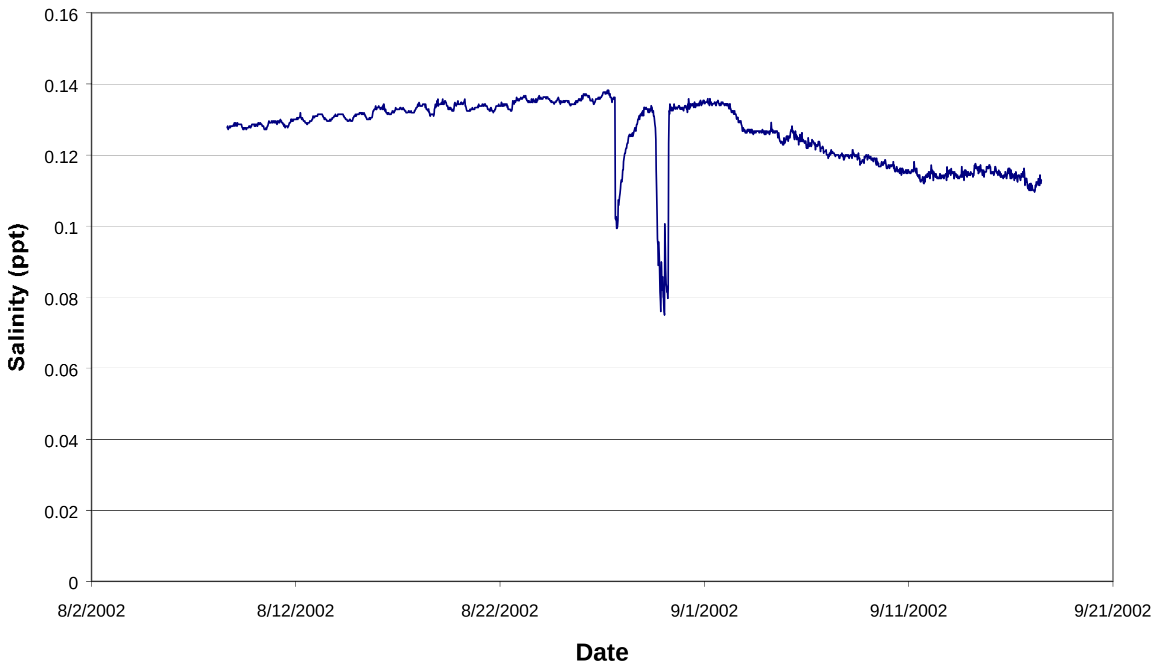

Figure 3.
2002 Mill River Continuous Monitoring (Orange Street Salinity)

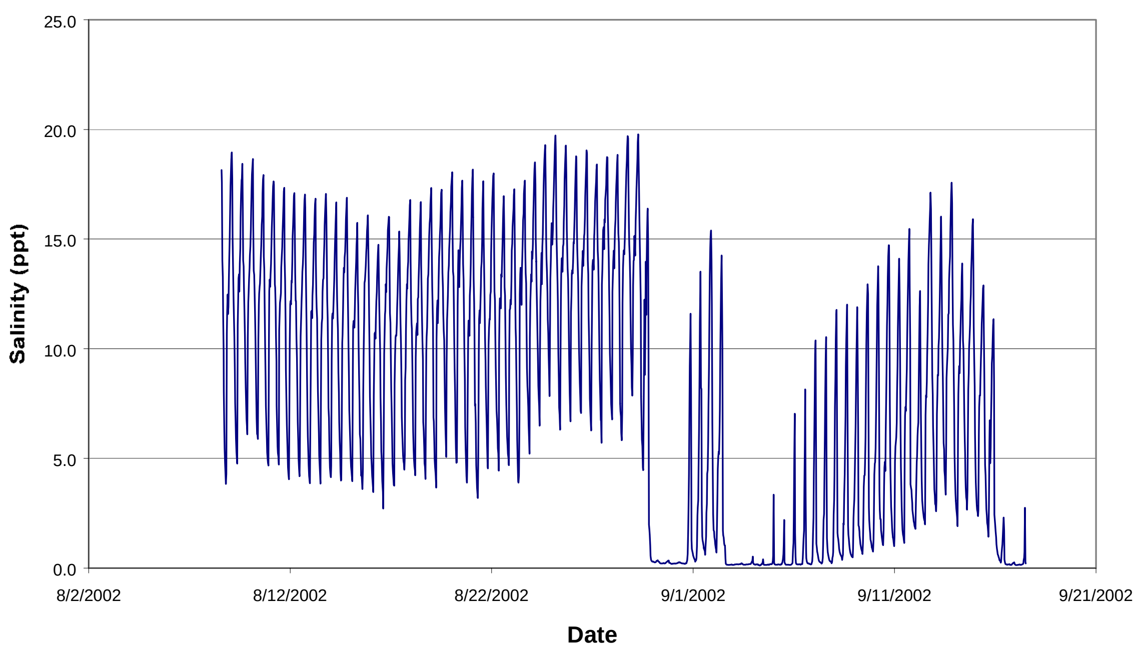

Figure 4.
2002 Mill River Continuous Monitoring (Temperature)

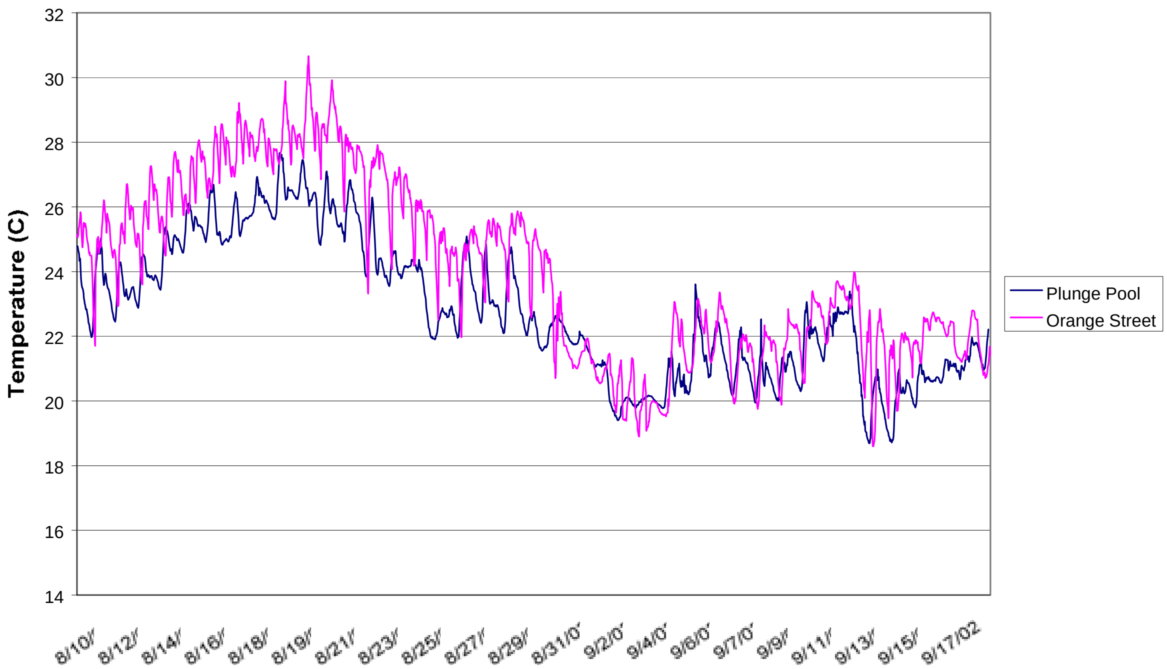

Figure 5.
2002 Mill River Continuous Monitoring (pH)

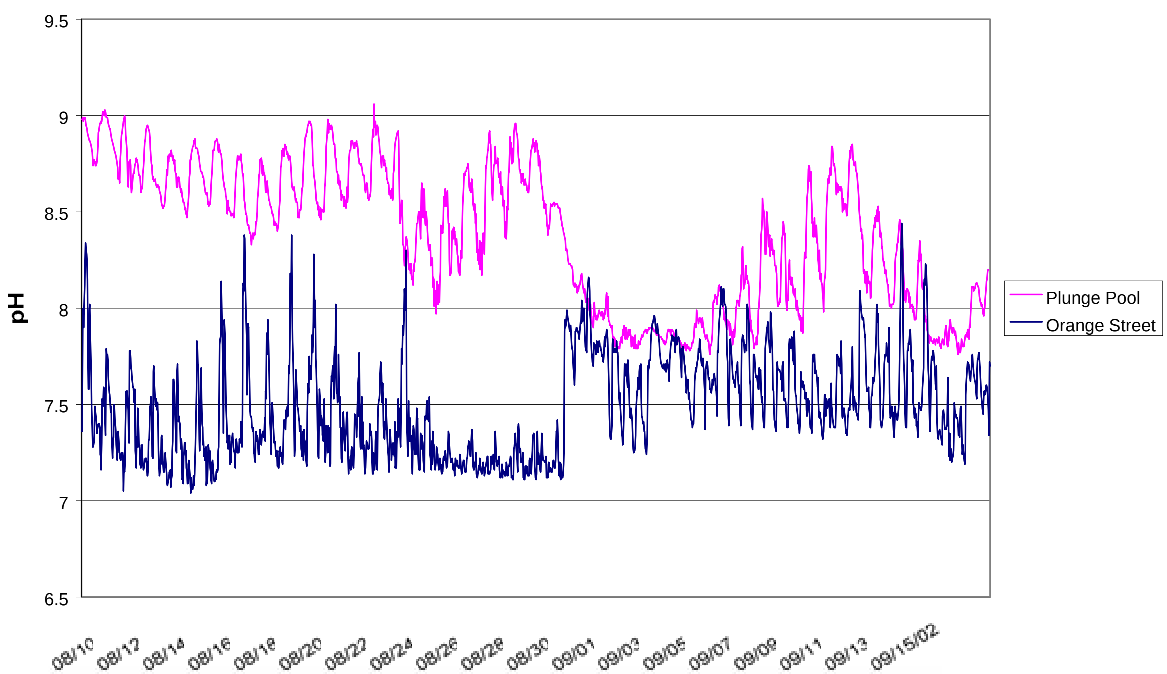

Figure 6.
2002 Mill River Weekly Monitoring (Dissolved Oxygen)

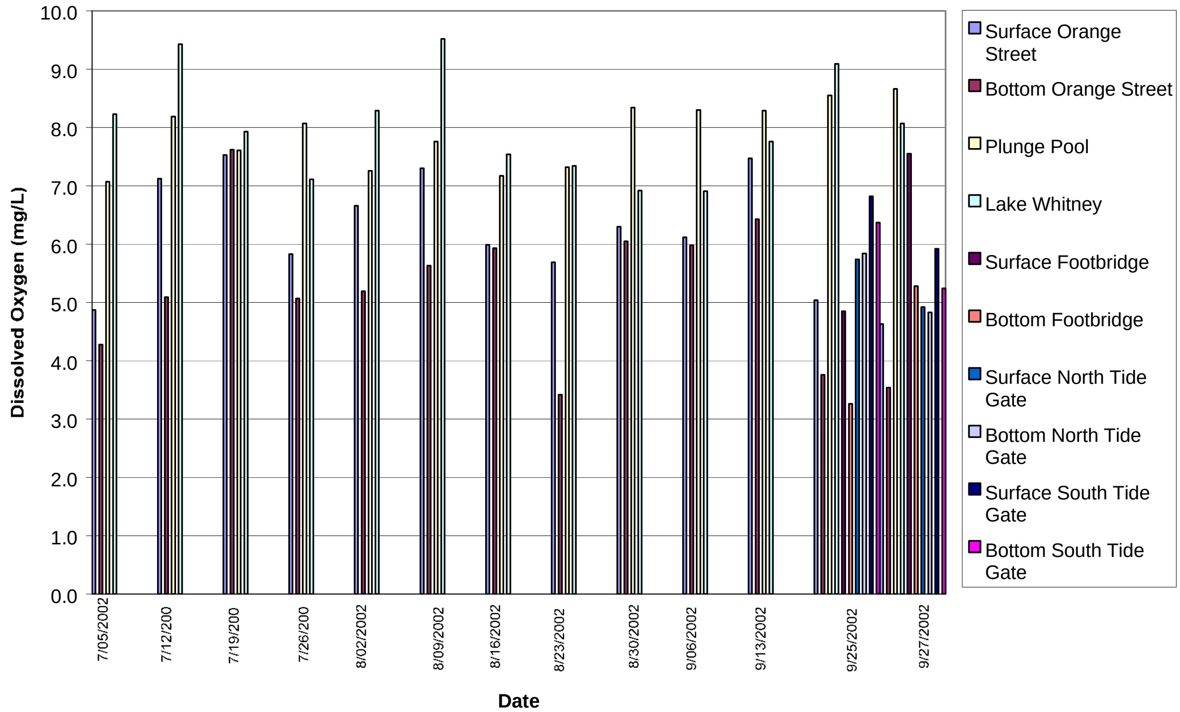

Figure 7.
2002 Mill River Weekly Monitoring (Salinity)

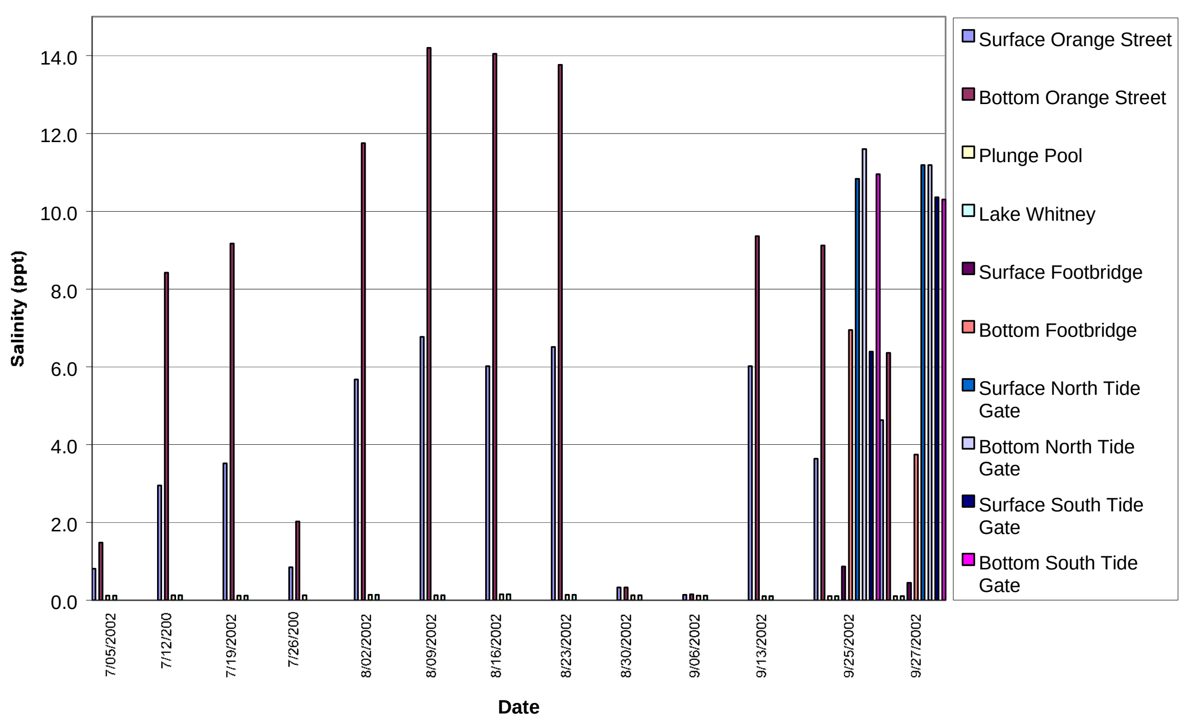

Figure 8.
2002 Mill River Weekly Monitoring (Turbidity)

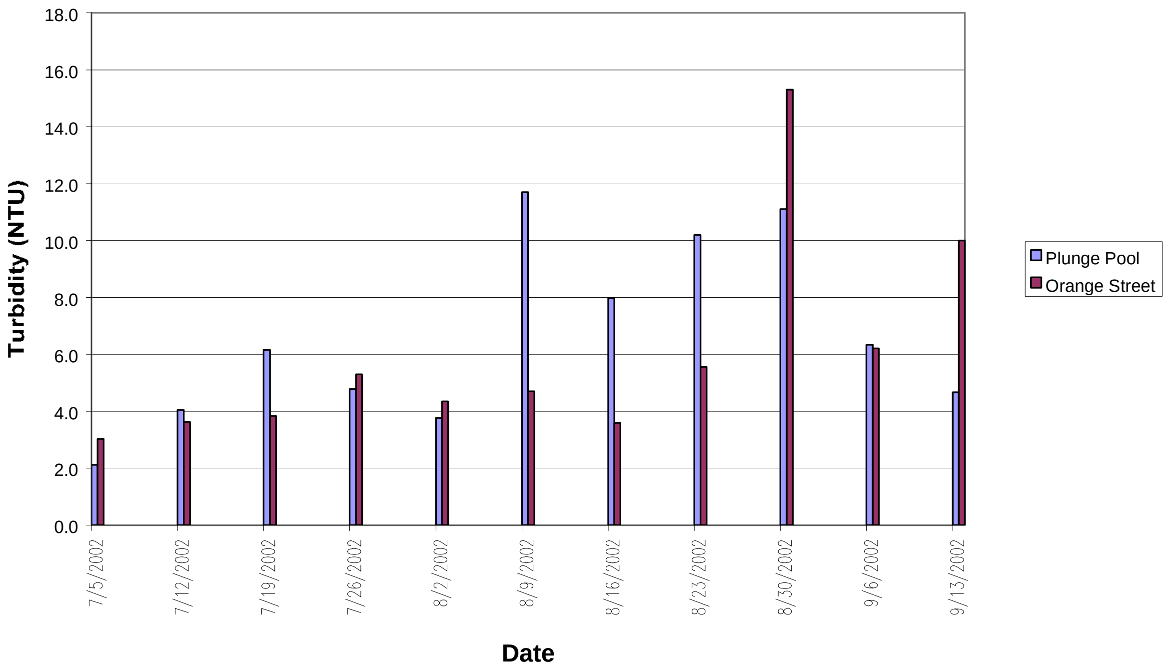

Figure 9.
2002 Mill River Weekly Monitoring (E. coli Bacteria)

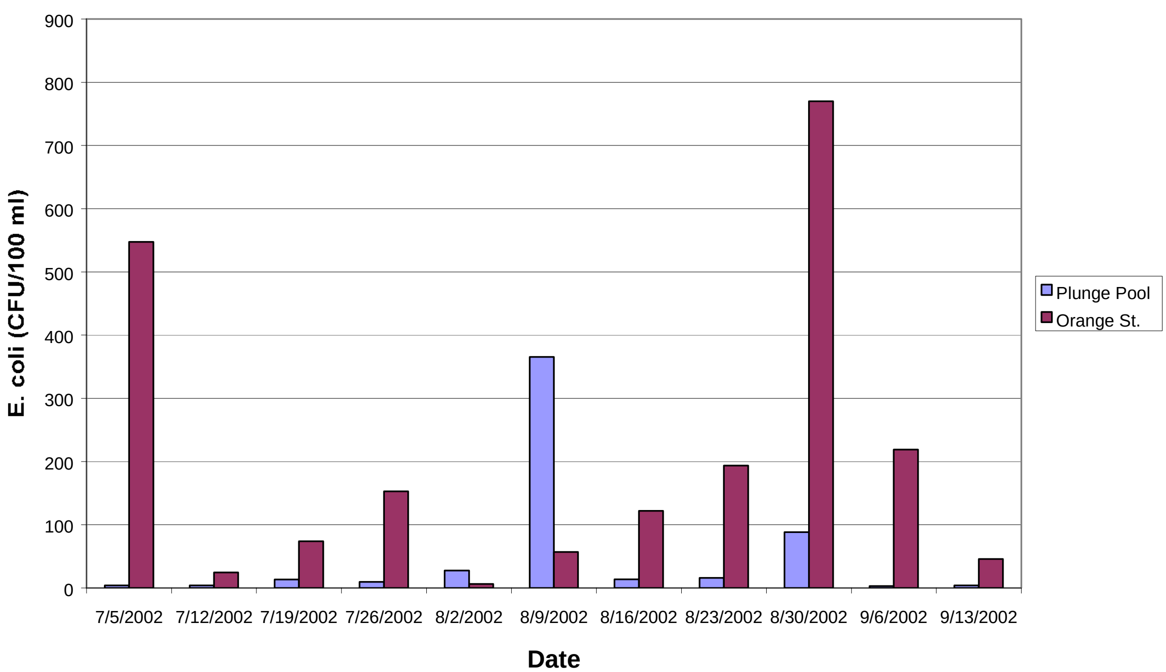

Figure 10.
2002 Mill River Wet Weather Data

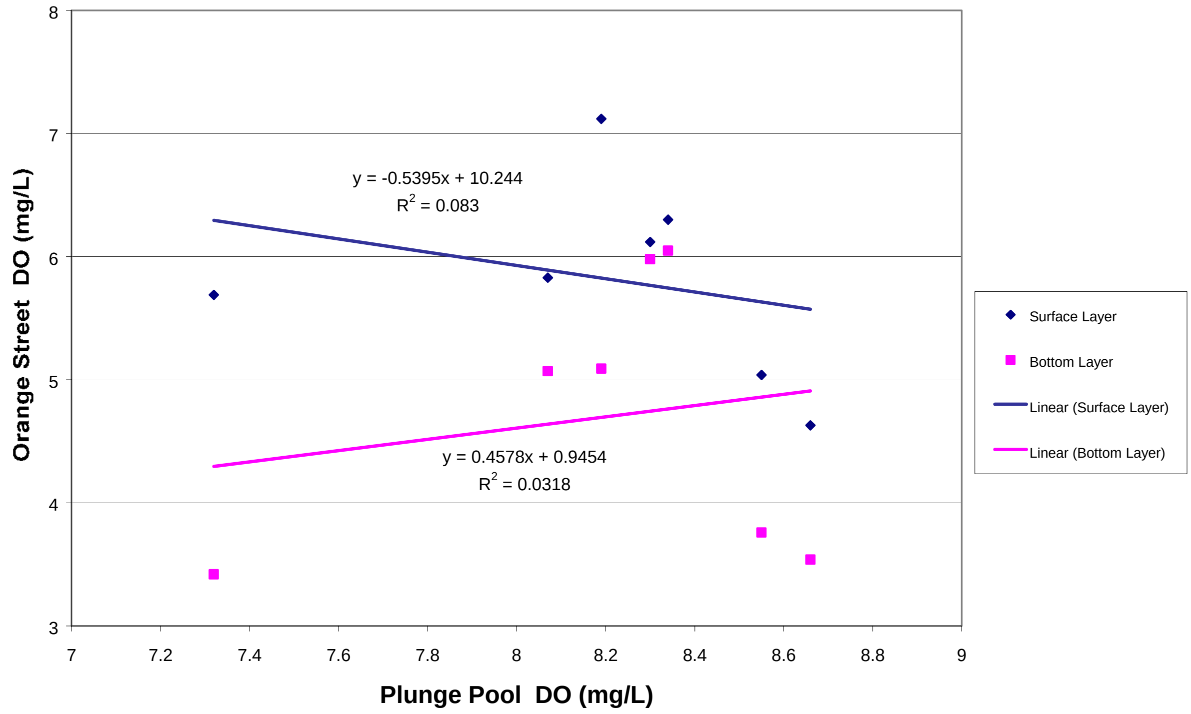

Figure 11.
2002 Mill River Dry Weather Data

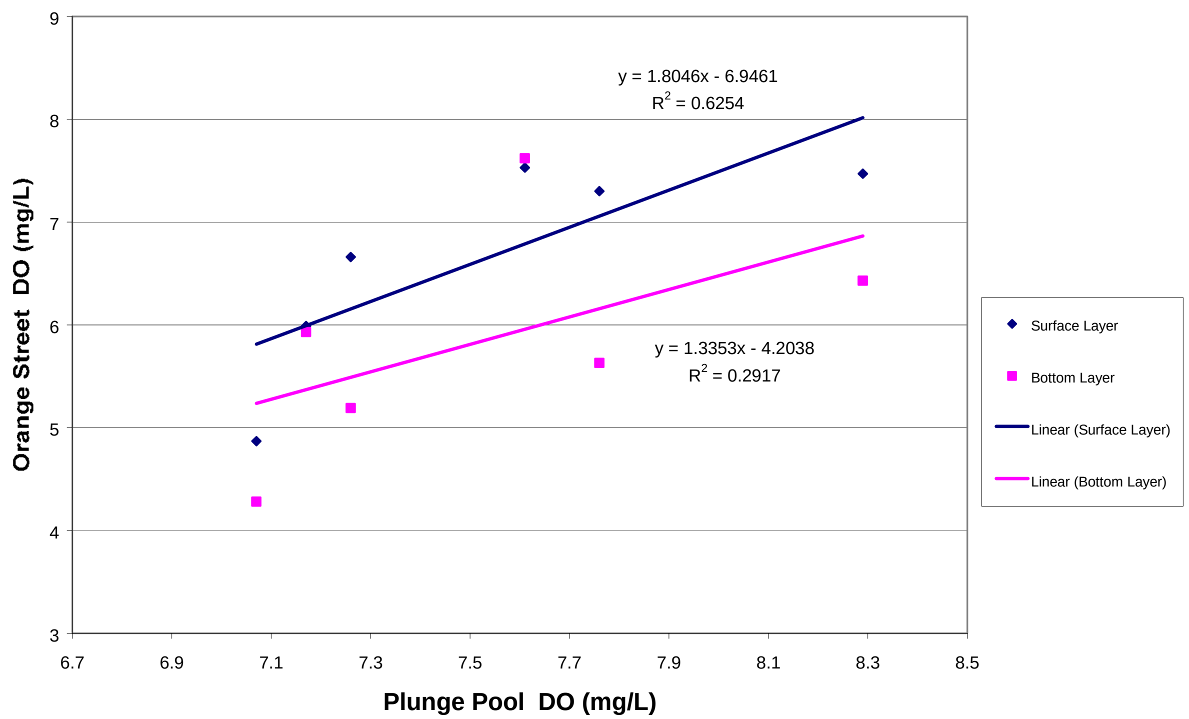

Figure 12.
2001-2002 Mill River Dry Weather Data

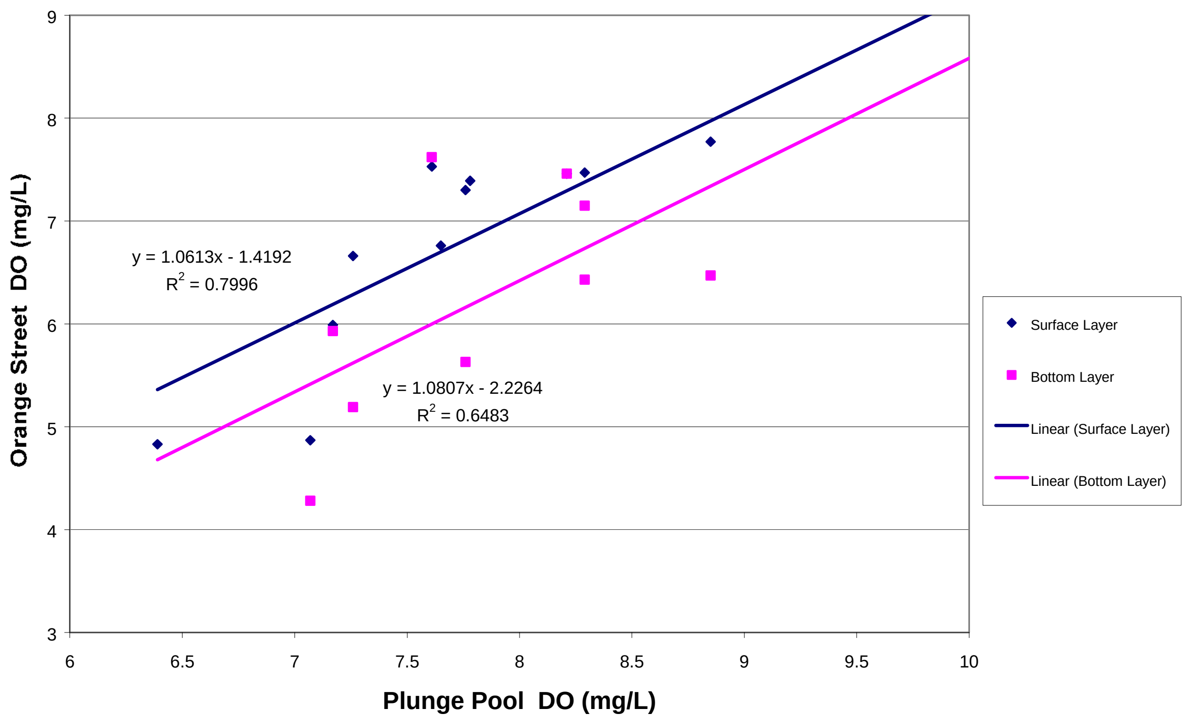

Figure 13.
2001-2002 Mill River Wet Weather Data

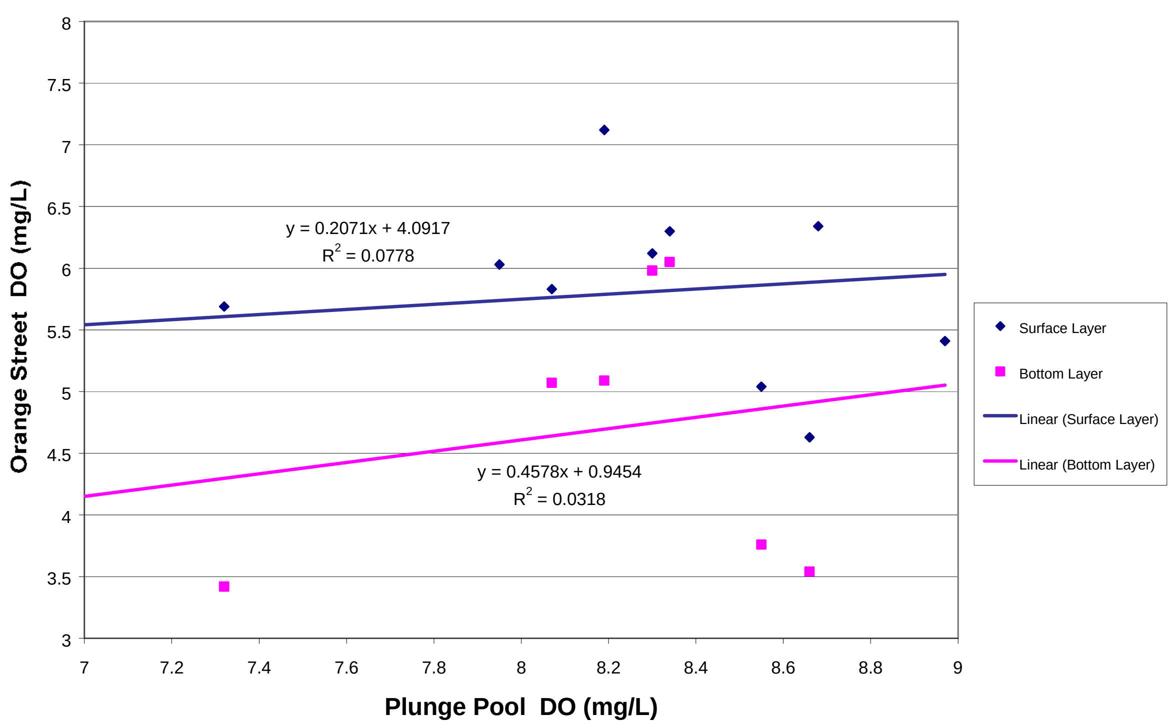

Figure 14.
2001-2002 Mill River Dry Weather Data (Low Tide)

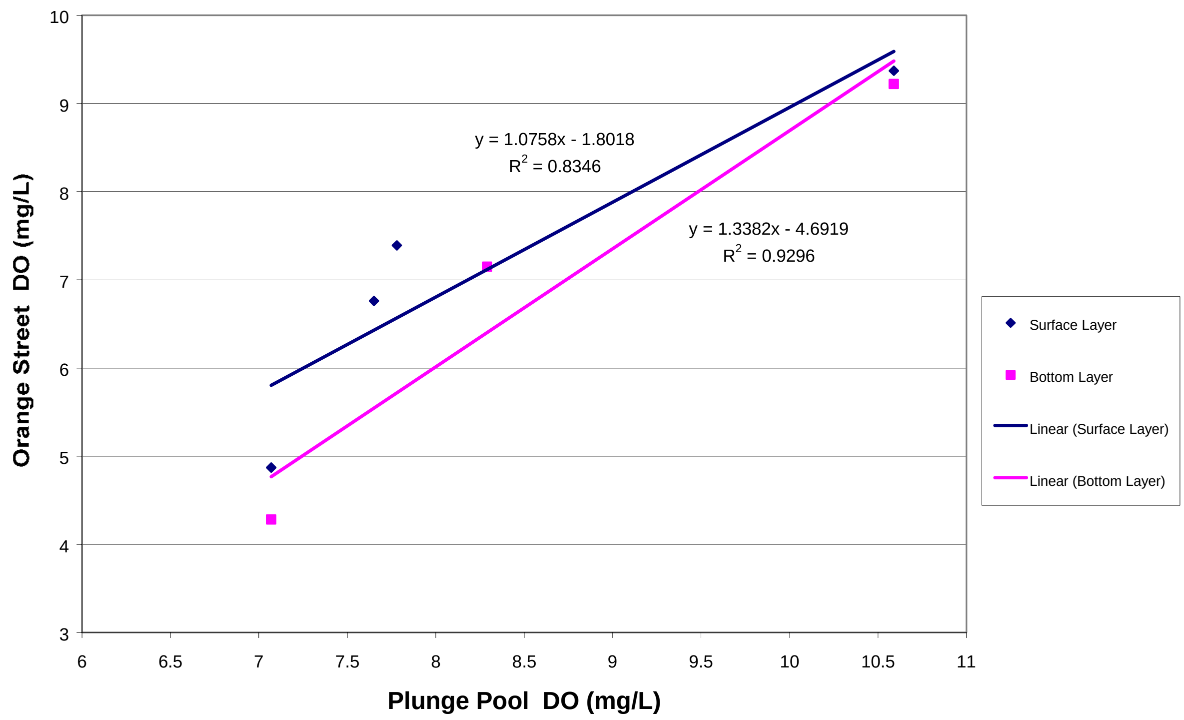

Figure 15.
2001-2002 Mill River Dry Weather Data (High Tide)

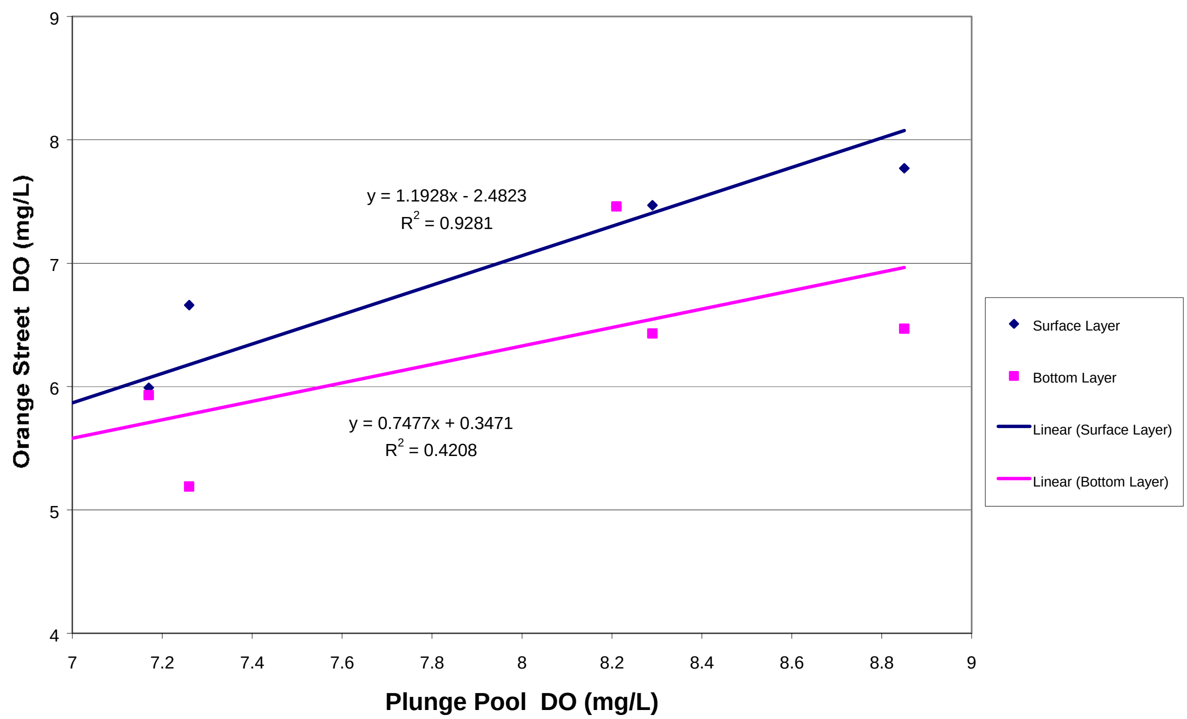

Figure 16.
2001-2002 Orange St. Surface DO
vs. Prior 72-hr Rainfall