Final

1998 – 2003 Comprehensive Dissolved Oxygen Monitoring in the Lower Mill River

Hamden and New Haven, CT

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Prepared for

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Introduction

This report presents results of ongoing studies by the Regional Water Authority (RWA) to document baseline dissolved oxygen (DO) 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 RWA will be resuming water withdrawals from the reservoir following construction of a new water treatment plant scheduled for completion in late 2004. To respond to community concerns during the planning of the Lake Whitney Water Treatment Plant, the Authority hired a team of environmental scientists (Study Team) to conduct an environmental evaluation of the project's potential impacts on areas upstream and downstream of the Lake Whitney dam. A report summarizing findings and recommendations was completed in January of 1999. The report included recommendations for ongoing environmental monitoring and performance standards to mitigate potential impacts of future water withdrawals. The Authority adopted the Study Team's recommendations and prepared a Management Plan to ensure that the treatment plant is operated in a manner compatible with the surrounding environment.

On July 25, 2000, the RWA's Five-Member Authority Board adopted a Resolution that included the following obligation: "By November 30, 2003, the RWA shall undertake and complete a study of dissolved oxygen concentrations in the downstream Mill River Corridor from the Whitney dam to the Orange Street bridge, for the purpose of determining the dissolved oxygen concentrations in the spillway plunge pool necessary for maintaining acceptable dissolved oxygen levels downstream. The Management Plan, if necessary, shall be amended to reflect the results of such study." From 1998-2003, the RWA has conducted a DO monitoring program in the Mill River. Table 1 summarizes each of the monitoring periods.

This report, prepared to fulfill DO study obligation of the July 2000 Resolution, summarizes the results of the five years of DO monitoring. It examines relationships between spillway flow and downstream DO levels and DO concentrations in the spillway plunge pool associated with acceptable DO levels downstream. The weekly data collected in 2001-2003 represent the most consistent data and show trends over the summer period. Thus, this data set is the focus of this report. All of the monitoring locations are presented in Figure 1. Although other water quality parameters were collected, this report focuses on DO. The data sets used are the following:

- July and August 2001, 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 the Fall of 2001.
- July, August, and September, 2002, 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.

TABLE 1
Summary of Dissolved Oxygen Monitoring Efforts in the Mill River 1998-2003

1998 Short-term Monitoring	Day long studies were conducted on September 8, 1998 and October 7, 1998. On September 8, 1998, the lake level was dropped such that there was no flow over the spillway. On October 7, 1998, the flow over the dam was estimated at 5-10 million gallons per day (MGD).
2000 Short-term Monitoring	Day long study was conducted on August 1, 2000.
2001 Short-term Monitoring	Day long study was conducted on August 21, 2001
2001 Weekly Monitoring	From July through August, the RWA collected weekly water quality data at several of the monitoring locations. Supplemental data were also collected in October and November.
2002 Weekly Monitoring	From July through August, the RWA collected weekly water quality data at several of the monitoring locations. Supplemental data was also collected on several dates in September.
2002 Long-term Monitoring	Data sondes were deployed in the Mill River at the Plunge Pool and Orange Street from August 8, 2002 to September 17, 2002.
2003 Weekly Monitoring	From July through August, the RWA collected weekly water quality data at each of the monitoring locations.

- July and August 2003, weekly dawn DO and salinity monitoring at the Lake Whitney spillway overflow, the Lake Whitney spillway plunge pool, the Orange Street Bridge, the footbridge, and the tide gates.

Weekly Monitoring

Weekly DO and salinity measurements were collected using a Hydrolab Quanta multi-parameter meter. The weekly monitoring data were collected during the early morning, generally between 5:00 and 6:00 am. For the majority of monitoring events, data were collected at two water depths at the estuarine stations (Orange Street, tide gates, and the footbridge), near the surface (0.1 to 0.2 m depth) and near the bottom to account for salinity stratification. At times during the weekly monitoring, supplemental data were collected at various other depths at some of the monitoring stations.

From previous reports (CH2MHILL 2001 and 2002) it has been established that there are confounding factors beyond DO in the plunge pool and flow over the Whitney spillway that contribute to decreased downstream DO in the Mill River. These include stormwater related impacts (stormwater runoff and potential CSO discharge) and tidal inflow (poor water quality from New Haven Harbor). In general, tidal circulation in a river estuary consists of freshwater floating above a denser layer of higher salinity water. Mixing between the two layers does occur, and salinity at any point in time at a given location and

depth can be highly variable depending on factors such as tide stage, lunar effects, and freshwater flow.

In order to minimize the effects of stormwater and tidal flow on DO relationships, a second statistical analysis was performed after removing points from the data set meeting the following criteria: 1) data collected when precipitation totaled greater than 0.12 inches over the 72 hours prior to sampling, as measured at the Whitney Dam rainfall gauge; and 2) over-bottom data collected at the estuarine stations (Orange St. and the footbridge) such that only data from the "fresh" surface layer were used in the analysis. Although there is upward mixing of higher salinity water resulting in surface water salinities sometimes exceeding 6 ppt at Orange St., water quality influences related to flow discharge from Lake Whitney are more easily detected here than the bottom water layer where salinities can approach 15 ppt (Figure 2). Only data collected during early morning hours were used in the evaluation, when DO is expected to be at minimum daily levels due to nighttime respiration and lack of photosynthesis.

Dissolved Oxygen vs. Flow

Figure 3 presents weekly DO concentrations versus flow for 2001-2003. The no-spillway flow conditions (dam leakage estimated at 0.6 million gallons per day (MGD)) and low flow conditions (10 MGD) recorded in 1998 are also included in the figure. At the observed range of flows, there was no correlation between release over the spillway and DO concentrations at the plunge pool ($R^2 = 0.04$), the footbridge ($R^2 = 0.05$), or Orange Street ($R^2 < 0.01$).

Figure 4 presents weekly dissolved oxygen concentrations versus flow for flows between 0 and 50 MGD. There is a slight correlation between DO and flow at the plunge pool at flows less than 50 MGD ($R^2 = 0.46$) but no correlation with this range of flows at the footbridge and Orange Street stations. The lack of extended hot dry weather over the study periods coupled with the natural hydrology of Lake Whitney, i.e., large watershed area relative to storage volume, has thus far limited opportunities to monitor DO in the river under extreme low flow conditions.

Figure 5 presents the weekly dissolved oxygen concentrations versus flow for the days that meet the "dry weather, no salinity" criteria. There is no correlation between the flow and the dissolved oxygen at the plunge pool, footbridge or Orange Street during these conditions.

2001-2003 Weekly Monitoring Data Orange Street vs. the Plunge Pool

The weekly 2001-2003 monitoring data were evaluated for potential correlations between DO concentrations in the plunge pool and the Mill River at the Orange Street bridge and the footbridge in East Rock Park and a linear regression analysis was performed. Figure 6 presents all of the DO data collected at the Orange St station vs. DO at the plunge pool. The data show only a weak correlation ($R^2 = 0.33$) between the DO at these two locations.

Figure 7 presents the DO data at Orange St vs. the plunge pool for only dry weather and surface conditions. As shown from the figure, there is a stronger correlation between Orange Street and the Plunge Pool when the confounding factors of rainfall and high salinity bottom water are removed ($R^2 = 0.66$). It is important to note that when the plunge pool DO concentrations were greater than 7 mg/L, the DO at Orange Street was greater than 5 mg/L except for one sampling event. On July 5, 2002, the DO in the Plunge Pool was 7.07 mg/L and the DO at Orange Street surface layer was 4.87 mg/L. The one other dry weather instance that surface water DO measured at Orange Street was <5 mg/L occurred on August 10, 2001 (4.83 mg/L). However DO at the plunge pool was only 6.39 mg/L.

2001-2003 Weekly Monitoring Data Footbridge vs. the Plunge Pool

During dry weather conditions there was a strong correlation ($R^2 = 0.78$) between the DO at the footbridge and the plunge pool (Figure 8). Again it is important to note that when the plunge pool DO was above 7 mg/L, the DO at the footbridge was greater than 5 mg/L, in all cases.

Conclusions

The data presented in this report indicate a significant correlation between DO concentrations in the plunge pool versus DO concentrations in the Mill River at Orange Street and the footbridge, if surface water data during dry weather conditions are used. Saltwater intrusion in the bottom layer and storm events generally weaken this statistical relationship overall. It is important to note that on most of the dry-weather sampling dates over the study period when the DO in the plunge pool is greater than or equal to 7 mg/L, surface water DO at Orange Street is greater than or equal to 5 mg/L. At this point in time 7 mg/L appears to be a reasonable target concentration for DO in the plunge pool when the RWA is augmenting flows via downstream releases as described in the Management Plan. Although it has been shown that DO in Mill River surface waters at Orange Street occasionally falls slightly below the Connecticut State Water Quality standard of 5 mg/L during dry weather conditions, this appears to be infrequent. In most cases surface water DO at Orange Street should be at or above 5 mg/L during dry weather conditions, especially when plunge pool DO equals or exceeds 7 mg/L. DO concentrations <5 mg/L in the more tidally influenced bottom water (measured as low as 3.4 mg/L) or following storm events are more common (CH2M HILL, 2002) and need to be addressed by other means outside of the RWA's purview, such as programs targeted at non-point pollution sources, CSOs, and/or water quality improvements in Long Island Sound.

The vast majority of the time, daily water withdrawals from Lake Whitney will be a small fraction of the water that flows over the Whitney spillway and flow impacts on DO will not be an issue. During the study period, opportunities to assess the effects of low flows on river DO concentrations have been very limited. It is clear from previous studies (CH2M HILL, 1998) that DO concentrations in the stretch of river below the Lake Whitney dam are

severely impacted when there is no flow over the Lake Whitney spillway and only dam leakage is entering the river. This finding led to the development of the downstream release schedule prescribed in the Management Plan and other planned mitigation measures such as the installation of an aerator to supplement DO in the plunge pool when needed. Monitoring efforts during future low flow conditions (e.g., downstream release scenarios) will add to the understanding of DO relationships between flows from Lake Whitney and the downstream Mill River. Based on further study, adjustments to the Management Plan may be necessary to adequately manage DO concentrations in the lower Mill River.

Recommendations

Based on the results of this study, 7 mg/L appears to be a reasonable target DO for the plunge pool during downstream release situations and should ensure no flow related degradation of existing conditions. It is expected under most circumstances that this will result in a surface water DO concentration above 5 mg/L at the Orange Street Bridge during dry weather conditions, although surface water DO concentrations slightly below 5 mg/L were occasionally observed during the study period. It may be necessary to make allowances to this target value when the DO in Lake Whitney is below 7 mg/L, since RWA has no control over low DO events in Lake Whitney. It is recommended that as climactic conditions allow, more data be gathered during low flow or downstream release conditions in the Mill River. This will better the understanding of DO relationships under these conditions and may lead to future adjustments to the Management Plan as advised by the Study Team. Potential alternatives to supplement downstream DO concentrations include plunge pool aeration, and/or changes in the downstream release schedule, e.g., short-term pulsing of higher flows during critical periods while maintaining overall daily prescribed release volume. Increased monitoring during low DO events in the plunge pool can be used to assess the degree and duration of impact at downstream river locations.

References

CH2M HILL, “Mill River Short Term Monitoring Study”, December 1998

CH2M HILL, “2001 Monitoring of Mill River Dissolved Oxygen and Salinity Hamden and New Haven, CT”, February 2002

CH2M HILL, “2002 Water Quality Monitoring Mill River Hamden and New Haven, CT”, December 2002

Figures

FIGURE 1. Locations Sampled during the 2001-2003 Mill River Monitoring.

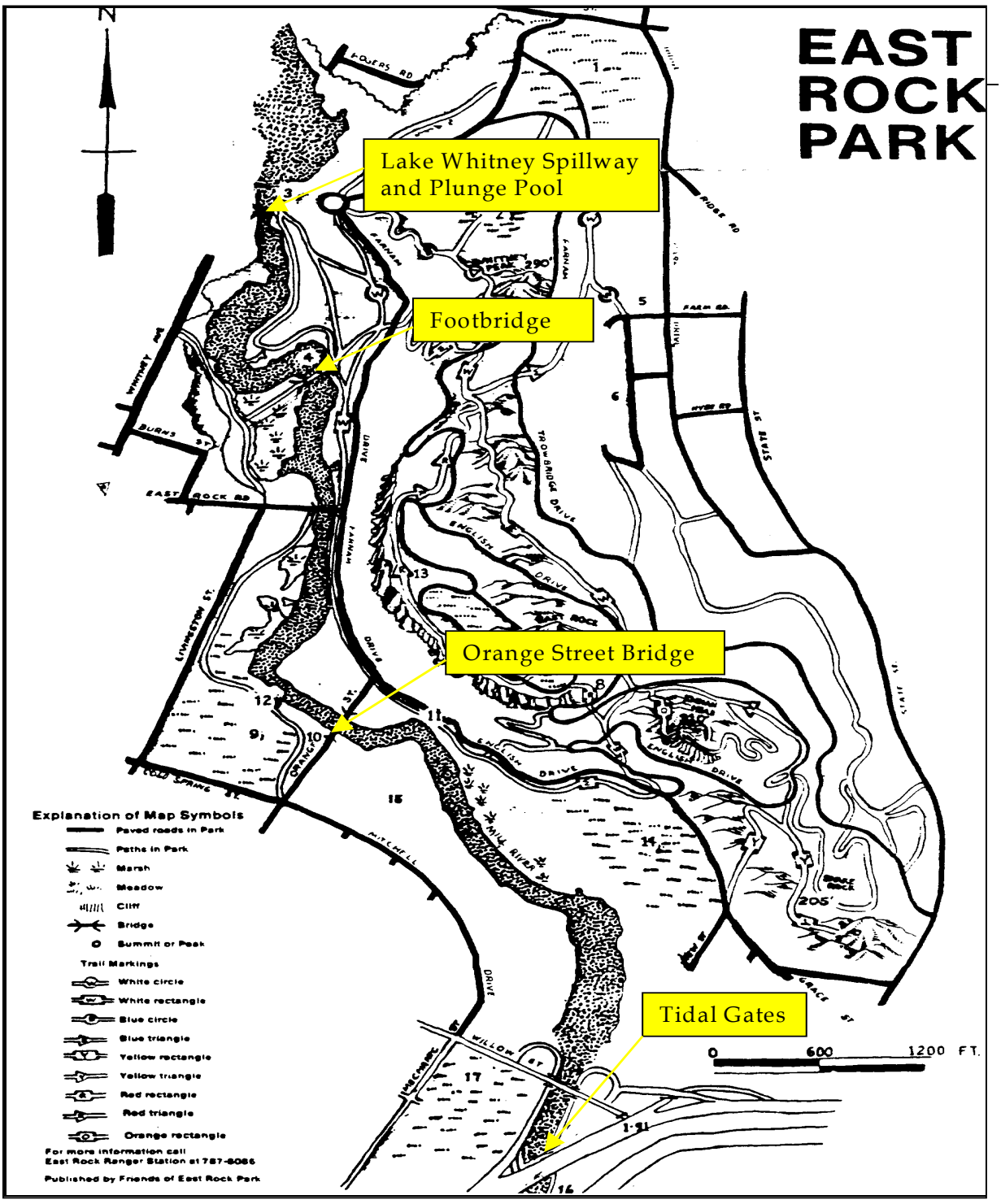

Figure 2
Mill River Salinity at Orange Street Data 2002-2003

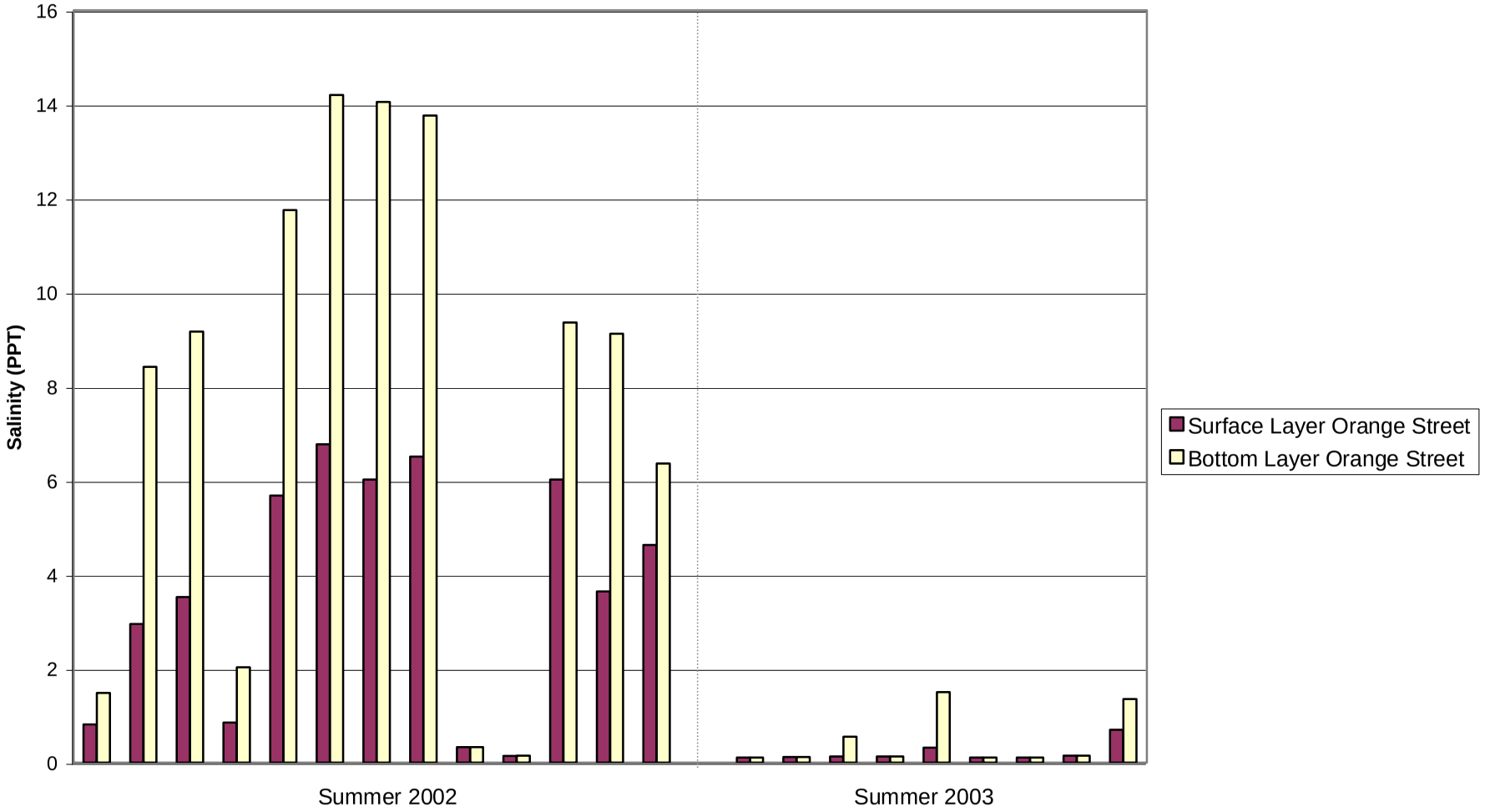

Figure 3
1998-2003 Mill River: DO vs Flow for Orange St., Footbridge, and Dam Plunge Pool

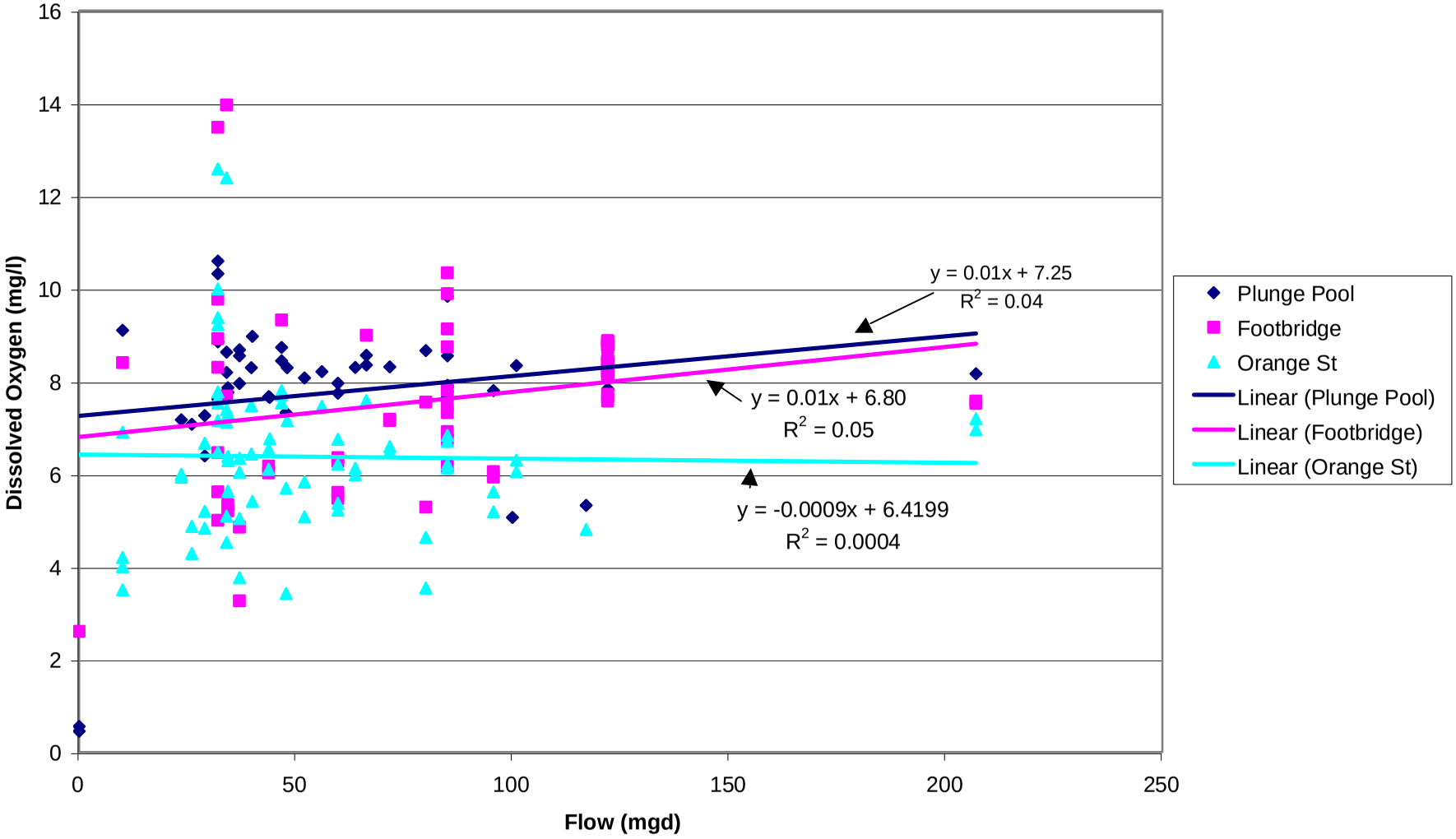

Figure 4
1998-2003 Mill River: DO vs Flow for Orange St., Footbridge, and Dam Plunge Pool
0 - 50 MGD

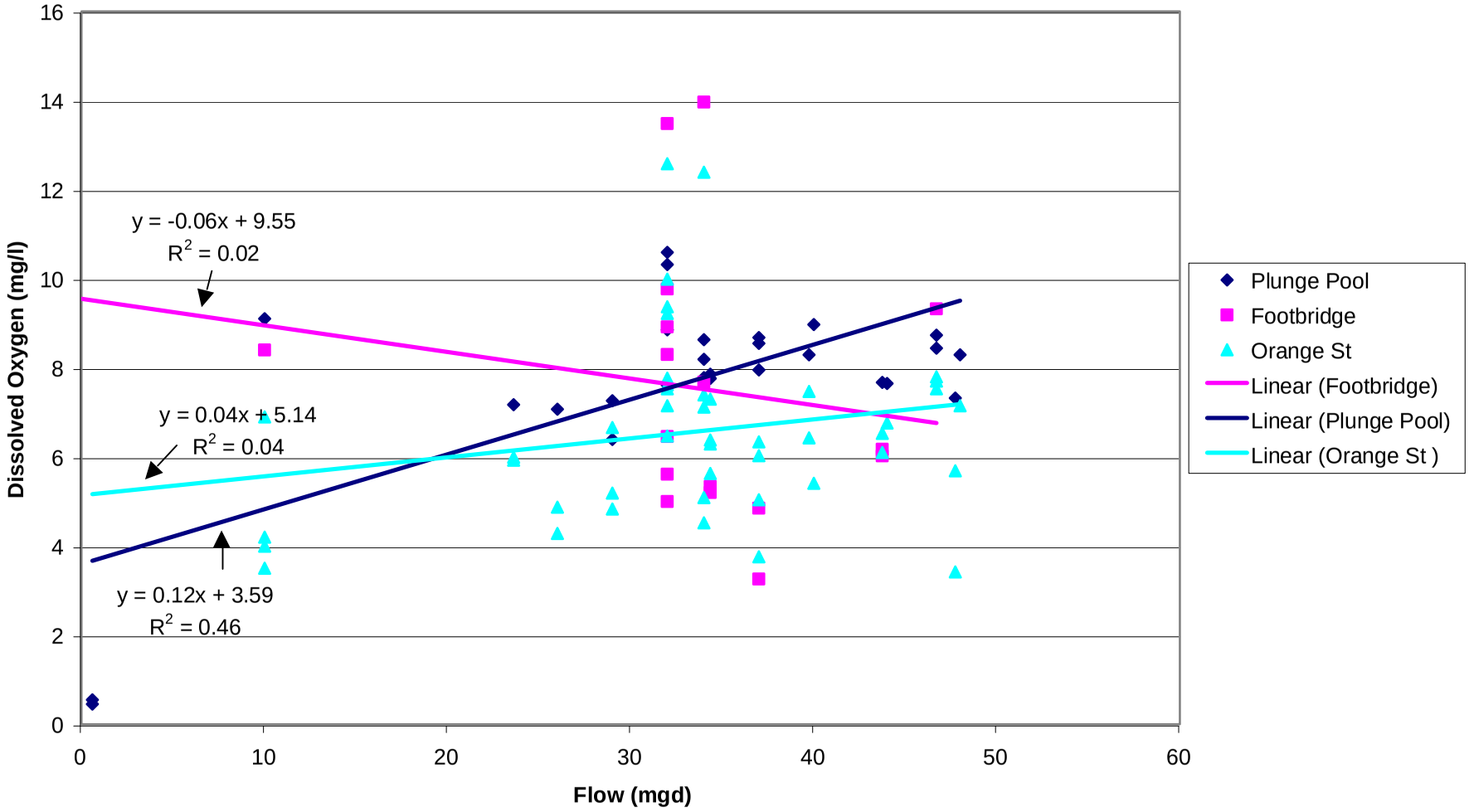

Figure 5
2001-2003 Mill DO vs Flow Dry Weather Surface Data

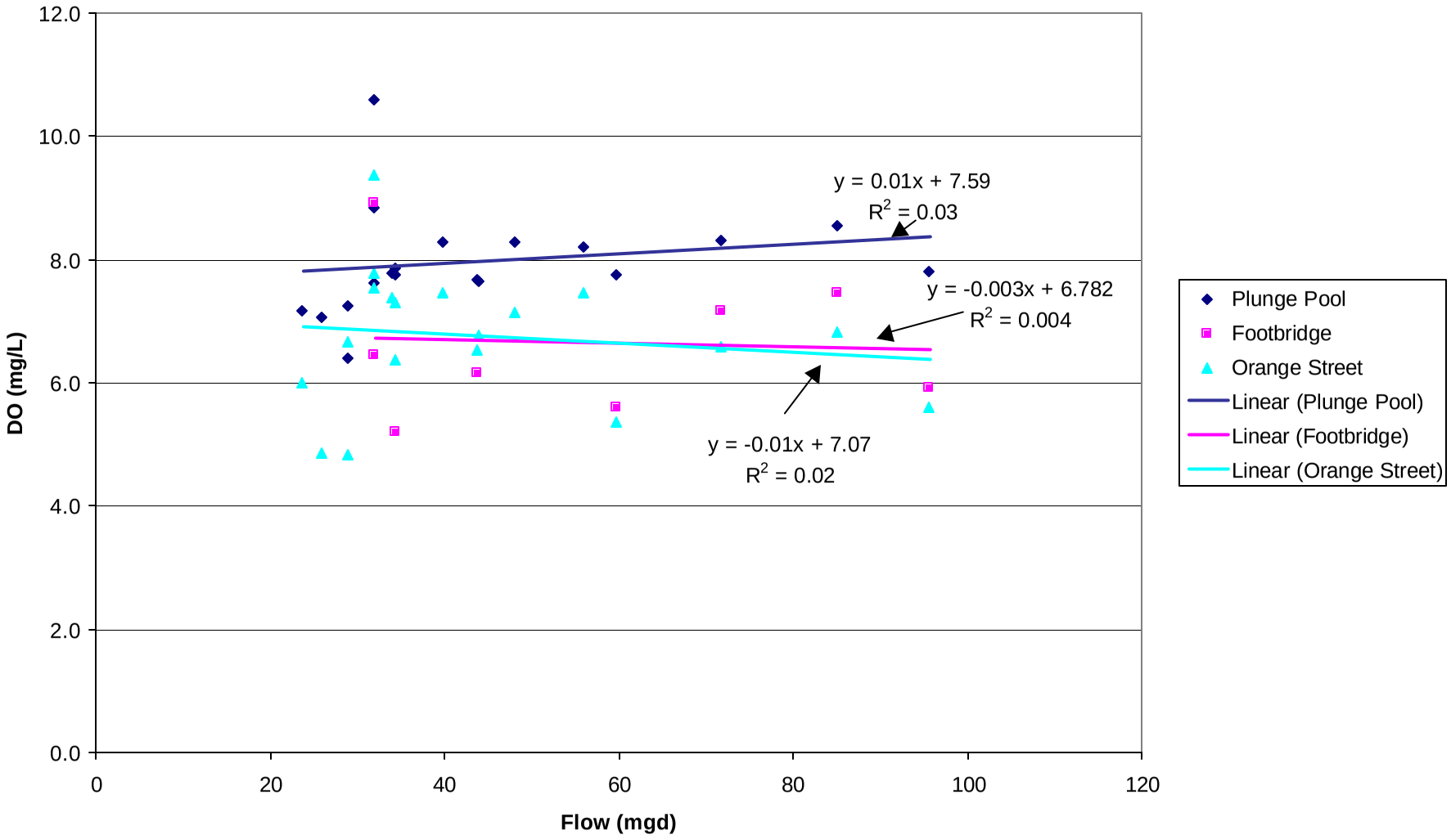

Figure 6
Mill River DO Data 2001-2003- all data
Plunge Pool vs. Orange Street

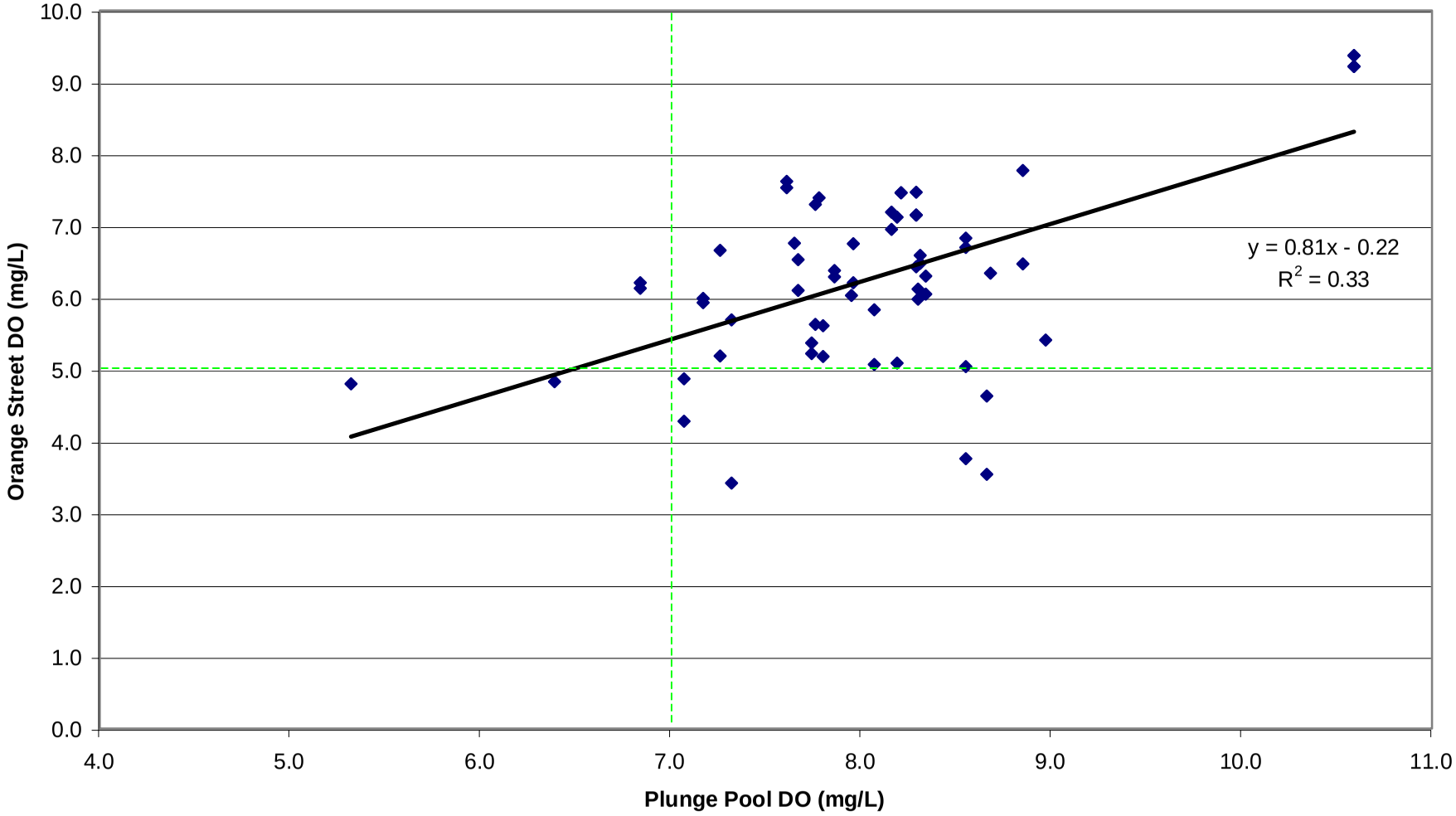

Figure 7
2001-2003 Mill River Dry Weather Surface Data
Plunge Pool vs. Orange Street

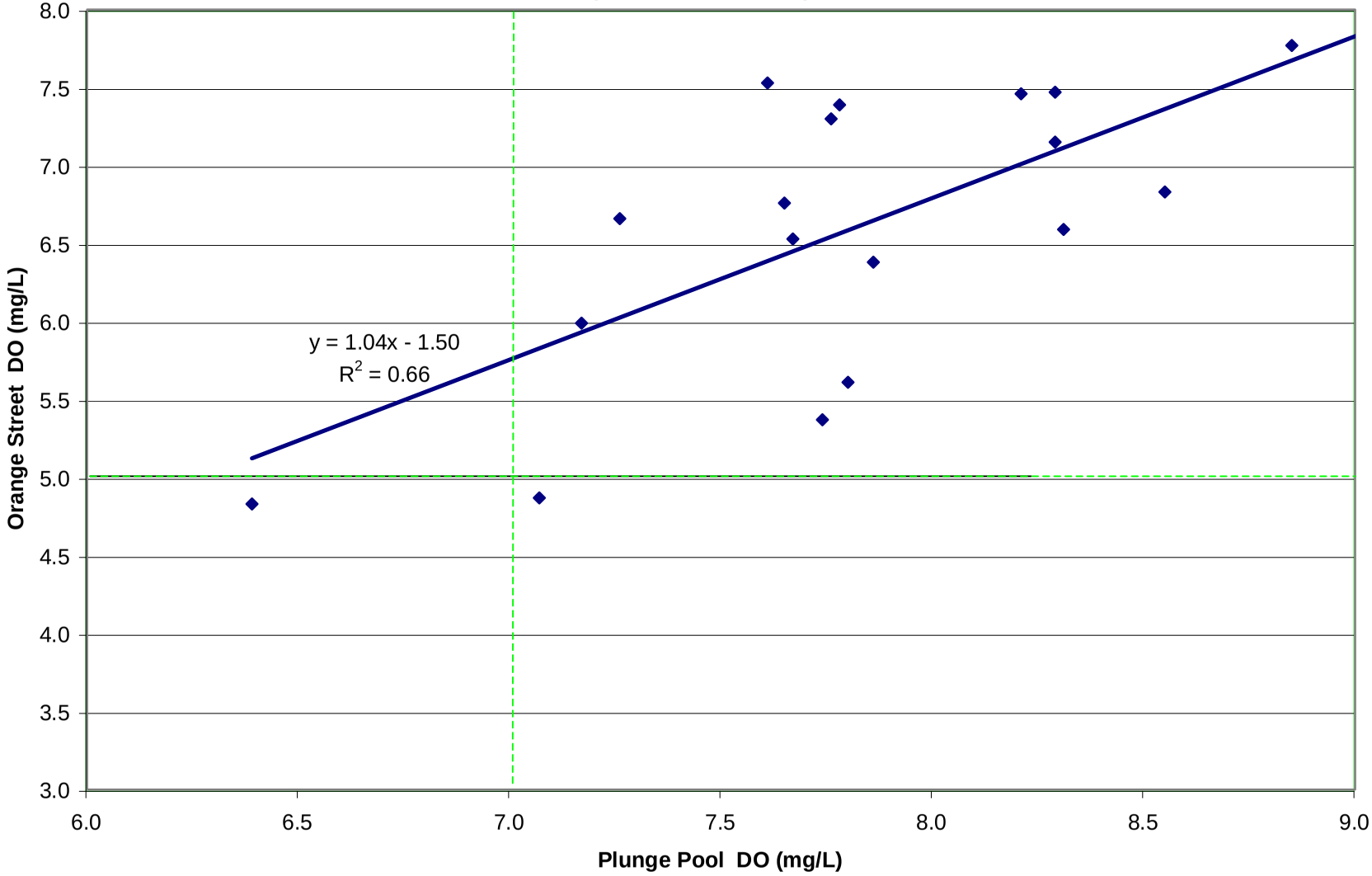

Figure 8
2001-2003 Mill River Dry Weather Data
Plunge Pool vs. Footbridge