Results of 2010 Turbine Venting Tests to Improve Dissolved Oxygen below Iron Gate Dam

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Background

Daily mean dissolved oxygen (DO) conditions are at or near saturation throughout the Klamath River downstream of Iron Gate dam due to rapids and riffles along the river that provide mechanical reaeration (PacifiCorp 2008). An exception is the reach immediately below Iron Gate dam during the late summer and fall periods. During this time, the thermal stratification in Iron Gate reservoir begins to weaken and the low oxygen water in the hypolimnion of the reservoir begins to mix with the water discharging from the powerhouse tailrace. In 2008, PacifiCorp investigated turbine venting as a means to increase DO levels below Iron Gate dam. The results of the studies showed a positive improvement in DO concentration measured in the Klamath River below Iron Gate powerhouse. DO levels increased by up to about 2 mg/L and 20 percent saturation as a result of full air admission through the existing turbine vent valve design at turbine flows of 1,000 cfs to 1,500 cfs (Carlson and Foster 2008). The increases in DO from turbine venting were seen throughout the study area which covered approximately 6 miles below the powerhouse. In 2009, PacifiCorp attempted to augment DO enhancement from turbine venting with the installation of a forced air blower to enhance aeration, but mechanical failure of the device prevented an assessment of effectiveness. A new blower was installed in 2010 and monitoring was subsequently performed during periods of low DO below Iron Gate dam to test the effectiveness of this system. The results of this testing are discussed below.

Objectives

During November 1 - 19, 2010, PacifiCorp assessed DO levels under three DO enhancement conditions (i.e., treatments): (1) turbine venting only; (2) blower operation only; and (3) turbine venting in combination with blower operation. The effectiveness of DO enhancement under these three operating conditions was then assessed by comparing DO resulting from these operations to ambient DO levels occurring without any enhancement actions (i.e., no treatment). The objectives of the study were to determine: (a) the effectiveness of the three potential enhancement conditions relative to no treatment; and (b) the longitudinal trend of DO levels below Iron Gate dam under each of the three testing conditions as well as ambient conditions.

Study Methods

PacifiCorp maintains a water quality station approximately 300 yards downstream of the Iron Gate Powerhouse that measures water quality conditions with a multi-parameter data sonde instrument. The instrument measures and records temperature and DO (concentration and percent saturation) as well as pH, blue green algae concentration, and conductivity at 30 minute intervals. Data collected from this fixed station was used to assess and compare DO levels under the three DO enhancement treatments and no treatment. A second data sonde was used from a boat in "roving" mode to measure DO levels (concentration and percent saturation) along the river downstream during the three DO enhancement treatments and no treatment. Equipment was serviced and calibrated prior to obtaining measurements during enhancement treatments.

The roving data sonde was used to measure the downstream longitudinal profile of DO levels by floating the Klamath River in a boat with the data sonde suspended from the bow line (referred to below as a "drift"). The data sonde sampled DO at 10-second intervals, and was synchronized with a GPS that tracked the boat's location. The initial drift (which occurred during the Venting Only treatment condition) extended from the boat launch at the Hatchery Bridge (approximately 300 yards below dam) to the boat launch at the Fish Hook Restaurant (two miles downstream of the dam). Based on results from this drift, the remaining three drifts were extended to the Klamathon Bridge (six miles downstream of the dam)

PacifiCorp applied each of the three treatments for at least 48 hours. The treatment schedule is found in Table 1.

Table 1. Treatment schedule for 2010 DO enhancement test

Treatment	Date Range	Float Schedule
Blower + Venting	Sept. 16 – Oct. 30	N/A
Venting Only	Oct. 30 – Nov. 1	Nov. 1
Blower Only	Nov. 1 – Nov. 3	Nov. 4
No Treatment	Nov. 3 – Nov. 13	Nov. 4
Blower + Venting	Nov. 13 – Nov. 19	Nov. 19

Pre-Test Background Conditions

The DO enhancement testing period occurred between October 30 and November 19, 2010. This period corresponded with a seasonal decrease in DO that occurs during the fall turnover of Iron Gate reservoir (Figure 1). Although water temperatures were declining during the test period (Figure 2), the fall turnover allows the hypoxic water in the deeper strata of the reservoir to mix with the oxygenated surface water.

Another potential factor contributing to low DO levels is the corresponding crash of the blue-green algae bloom in Iron Gate reservoir (Figure 3), when the decomposing algae cells could consume oxygen in the epilimnion.

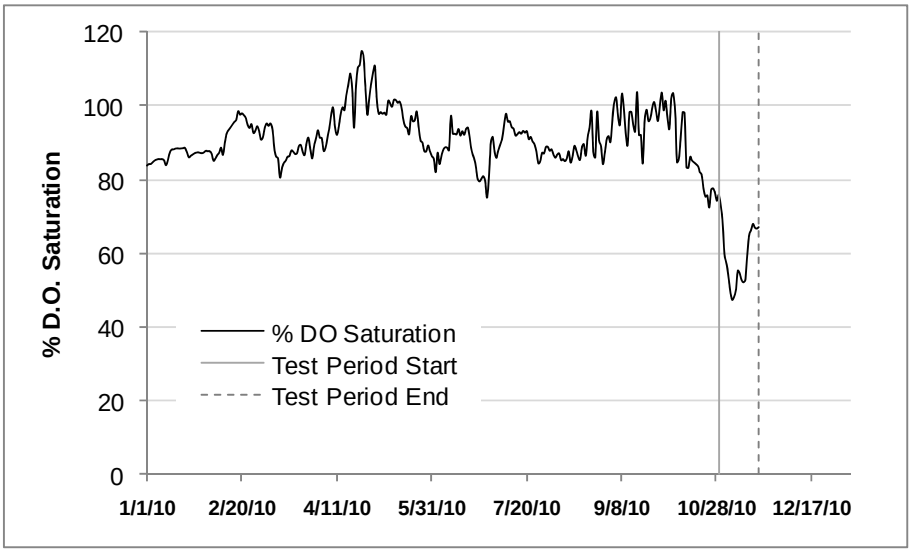

Figure 1. 2010 daily average %DO saturation at Iron Gate water quality station

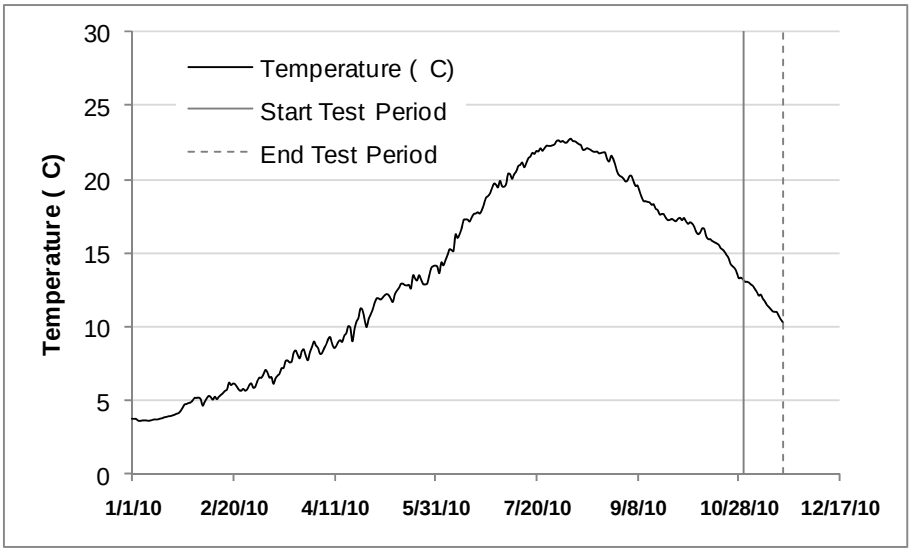

Figure 2. 2010 daily average temperature at Iron Gate water quality station

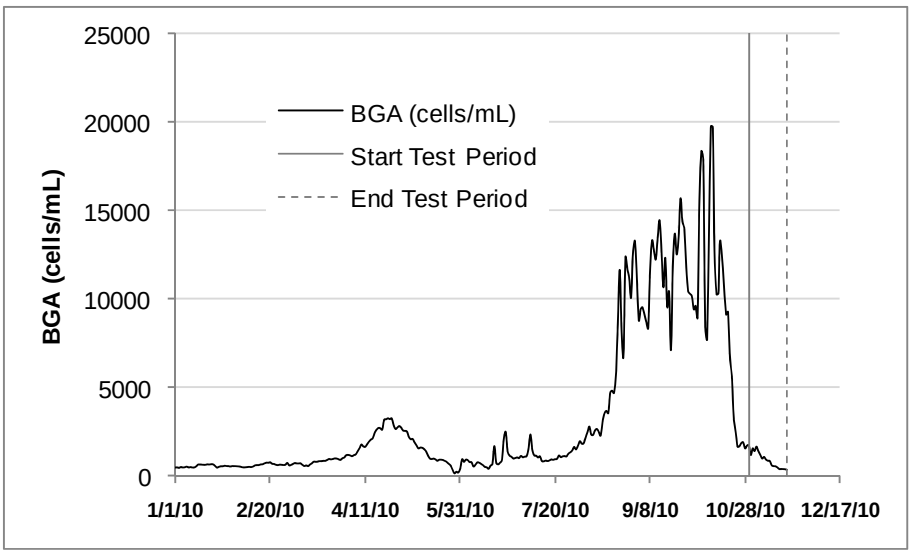

Figure 3. 2010 daily average blue-green algae levels at Iron Gate water quality station

Test Results

Iron Gate Water Quality Station

Table 2 summarizes the DO concentrations observed at the water quality station downstream of the Iron Gate powerhouse during the testing period. In general, these data demonstrate that turbine venting in combination with operation of the blower (Blower + Venting) results in the highest DO levels. The testing period began under these conditions. A decrease in DO levels was observed when the blower was turned off (Venting Only), and another decrease occurred when the blower was turned on but venting was disengaged (Blower Only). DO levels fell again when no enhancement method was in use (No Treatment). DO levels increased again once the turbine venting system with the blower (Blower + Venting) treatment resumed.

Table 2. Summary of DO, temperature, and blue-green algae measured at the Iron Gate water quality station

Treatment	Date Range	Mean DO (mg/L)	Mean % DO Sat	Mean Temp (°C)	Mean BGA (cells/mL)	Remarks
Blower + Venting (1)	Oct. 26 – 30	7.91	76	13.50	1831	
Venting Only	Oct. 30 – Nov. 1	6.99	66	13.05	1368	Flow ramp 10/31: 1100 cfs to 1300 cfs
Blower Only	Nov. 1 – 3	6.01	57	12.97	1616	
No Treatment	Nov. 3 –13	5.56	52	12.03	999	
Blower + Venting (2)	Nov. 13 – 19	7.37	67	10.79	473	

Although temperature and blue-green algae concentrations changed during the testing period, the relative effects of turbine venting with the blower were consistent. The difference in average DO levels between the initial turbine venting with blower period and the no treatment period indicate that percent DO saturation fell by 24.3 percentage points (a 32% decrease), and average DO concentration fell by 2.35 mg/L (a 30% decrease) when turbine venting and blower operations were discontinued. DO increased by similar magnitudes following the change from no treatment to the second period of operations with turbine venting and the blower: average percent DO saturation increased by 14.9 percentage points (a 29% increase) and average DO concentration increased by 1.81 mg/L (a 33% increase).

Downstream DO Profiles

The longitudinal profiles of DO levels measured in the river downstream from Iron Gate dam are displayed in Figure 4. Similar to the data collected at the Iron Gate water quality station, these results suggest that operation of the turbine venting system with the blower provides the greatest benefit in DO levels, followed by turbine venting alone, and then operation of the blower alone. Each of the operational methods increased DO levels as compared to ambient conditions measured during periods of no treatment. Linear trend lines were added to the data sets because the distance of the downstream monitoring varied between the venting only treatment (two miles) and the other three observed conditions (six miles), as indicated in Figure 4. The latter three trend lines fit the six-mile drifts relatively well, so it reasonable to assume that extrapolating the vent only data with a linear trend line represents conditions fairly well over the additional four miles below the termination of this monitoring drift.

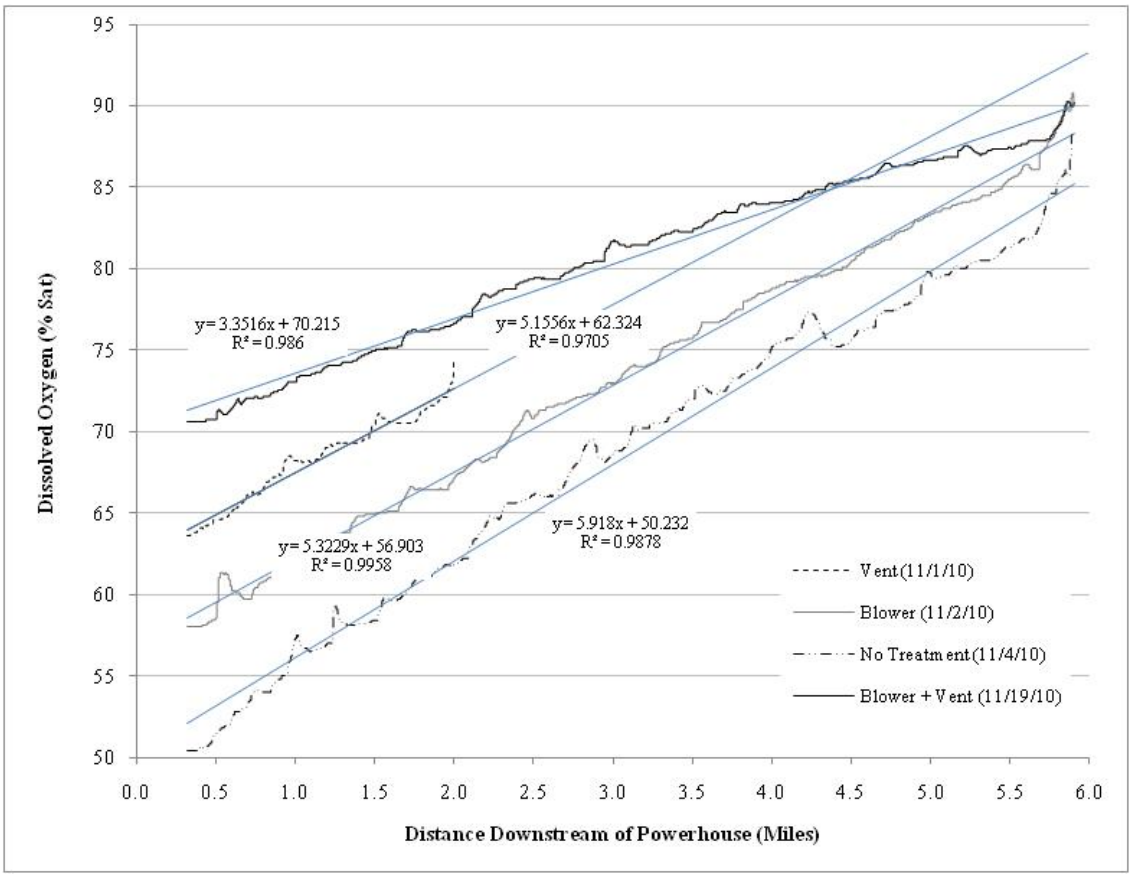

Figure 4. Downstream DO trends in Klamath River below Iron Gate Dam during various enhancement methods

Summary

All enhancement methods increased DO levels over ambient conditions (i.e., no treatement). Turbine venting in combination with operations of the blower was the most effective of the three methods tested. These results are consistent with previous testing performed by PacifiCorp in 2008, which demonstrated that DO levels below Iron Gate dam can be increased through mechanical means.

References

Carlson, K. and K. Foster. 2008. Water Quality Monitoring During Turbine Venting Tests at the Iron Gate Powerhouse, Klamath Hydroelectric Project. Prepared by Ken Carlson (CH2M HILL) and Kaylea Foster (Mason, Bruce, & Girard). December 2008.

PacifiCorp. 2008. Application for Water Quality Certification Pursuant to Section 401 of the Federal Clean Water Act for the Relicensing of the Klamath Hydroelectric Project (FERC No. 2082) in Siskiyou County, California. Prepared for: State Water Resources Control Board Division of Water Quality, Water Quality Certification Unit, 1001 I Street, 15th Floor, Sacramento, California 95814. Prepared by: PacifiCorp, 825 N.E. Multnomah, Suite 1500, Portland, Oregon 97232. March 2008.