September 11, 2007

Ms. Mildred Godoy-Daniels
Wisconsin Power and Light Company
S9270A Dam Road
Prairie du Sac, WI 53578-9712

Subject: Recommendations to Address Dissolved Oxygen Deficiency in Powerhouse Discharge

Dear Mildred:

We have reviewed the dissolved oxygen (DO) data provided by Wisconsin Power and Light Company (WPL) to evaluate how often concentrations below 5.0 mg/l occur, typical and extreme low DO conditions observed, and variation in DO readings throughout the water column. Between June 26 and September 30, 2006, there were 25 such occurrences, ranging from 0.1 to 4.8 mg/l. For 17 of the occurrences, the lowest DO reading was 3.0 mg/l or higher. Very low DO readings were typically associated with flows of about 2,000 to 3,000 cubic feet per second (cfs). Based on this review, we defined a "typical case" for mitigation evaluation as DO concentration of 3.0 mg/l and flow of 2,000 cfs.

We reviewed methods used at various hydropower projects to increase dissolved oxygen in discharged flows and evaluated their applicability to the Prairie du Sac facility. This evaluation is summarized in the following table:

Evaluation of Dissolved Oxygen Mitigation Alternatives

Method	Advantages	Disadvantages	Costs	Applicability
Tailrace Submerged Diffusers: submerged air diffusers anchored in the tailrace fed by blowers located on the shore.	Oxygen transfer from diffusers is well established. Diffusers protected from upstream debris.	Inefficient oxygen transfer due to short hydraulic detention time and high velocities in tailrace.	High capital and operating cost due to inefficient oxygen transfer.	Not feasible unless a significant portion of the flow during low DO conditions is diverted to spill flows.

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Tail Race Surface Mixers: aeration devices located on the water surface in the tailrace that mix atmospheric oxygen into the discharge.	Oxygen transfer from aeration devices is well established. Diffusers protect from upstream debris.	Inefficient oxygen transfer due to short hydraulic detention time and high velocities in tailrace.	High capital and operating cost due to inefficient oxygen transfer.	Not feasible unless a significant portion of the flow during low DO conditions is diverted to spill flows. Estimated equipment requirements for design conditions are 13-150 horsepower aerators.
Tailrace Weirs: structure built across the tailrace where the discharge cascades over and atmospheric oxygen transfers to the discharge.	Can produce large increases in DO where sufficient head drop is available.	Amount of DO increase is limited by the amount of head available. Oxygen input can not be varied independent of flow rate once constructed.	Capital cost can be high and operating cost is low.	Existing tailrace weir and rapids below currently act like tailrace weirs. Construction of weirs where rapids are currently located my improve aeration efficiency.
Turbine Venting: introduction of air into discharge downstream of turbines through vacuum breakers.	Uses existing or slightly modified equipment.	Amount of DO increase is limited.	Low capital cost and slight loss in power generating capacity.	This option has been tested and did not significantly increase the DO in the discharge.
Spill Flows: non-power release of water over spillways.	Uses existing or slightly modified equipment.	Amount of DO increase is limited and there is a loss of power generating capacity.	Low capital cost and some loss in power generating capacity.	This option may be effective on its own or in combination with other mitigation measures.

Method	**Advantages**	**Disadvantages**	**Costs**	**Applicability**
Reservoir Destratification: mixing water column in the reservoir with diffused aeration or mixers.	Technology is well established and may reduce release of nutrients from reservoir sediments.	Adverse effect on cold water fisheries due to mixing warm and cold waters.	High capital and operation costs.	This option is not likely to be effective as there is limited reservoir stratification and deficient DO conditions can occur through the entire water column at times.
Hypolimnion or Forebay Aeration: discharge of compressed air or pure oxygen into diffusers located in the reservoir.	Good for high-head, high hydraulic capacity, and large DO deficits. High oxygen transfer efficiencies. Size of the oxygen supply can be reduced if there is a stable hypolimnion to store DO.	Sizing system is difficult for run-of-river projects and where reservoir sediment oxygen demand is high. Diffused aeration systems in the forebay area would require lots of maintenance do to debris from upstream.	Moderate capital cost and high operation costs.	Limited effectiveness in this application because of the unstable reservoir stratification. Forebay aeration is estimated to require 700 brake horsepower to provide enough aeration for the design condition and the diffusers would be spread approximately 300 feet upstream of the generator intakes.
Selective Withdrawal: Modify the elevation of water withdrawal from reservoir.	Takes advantage of stratification in reservoirs with high DO in epilimnion.	May raise release water temperatures and is not effective for reservoirs with large water level fluctuations.	Capital cost can be high to modify existing systems. Operating costs are low.	This would be effective when DO levels are high in the epolimnetic waters of the reservoir but not when the entire water column is DO deficient.

Method	Advantages	Disadvantages	Costs	Applicability
Sidestream Aeration: divert a portion of the discharge flow to pure oxygen aeration.	Highly efficient use of oxygen. Ideal for run-of-river applications.	Limited experience for large scale applications.	Moderate capital and operating costs.	This system has flexibility to handle fluctuating needs for supplemental aeration and the hydraulic constraints of the project.

The most promising approach appears to be a combination of some of these methods. The modification to the bar racks currently under design will raise the withdrawal elevation from the reservoir. This will raise the average DO in the discharge as the DO is generally higher in the epolimnetic waters in the reservoir but will not eliminate discharges with DO concentrations below 5.0 mg/l. Construction of a series of weirs downstream of the existing tailrace weir could also improve the DO in the discharge. There is approximately 6 feet of head drop in 200 feet of river downstream from the tailrace weir. Spill flows of water through the spill way may also be effective in mitigating DO deficiencies in the discharge water. The highly turbulent flow through the tainter gates and over the spillway will provide significant aeration to the spilled discharge water. Sidestream aeration with pure oxygen appears to be the most effective mechanical method to provide DO to the discharge. This system would withdrawal water from the tailrace pool and dissolve pure oxygen into it. The oxygen rich water would then be returned to the discharge. The amount of oxygen delivered could be varied based on the discharge flow rate and DO oxygen monitoring data upstream and downstream of the facility. Oxygen for the system could be delivered by vendors in rented storage tanks or generated on site. The cost effectiveness of generating the oxygen on site would depend on energy costs and the amount used annually.

To further evaluate the effectiveness of these methods for the Prairie du Sac facility, we recommend testing the impact of spillway discharges on discharge DO. This is potentially the lowest cost option to meet the DO mitigation requirements. Further investigation of the costs and effectiveness of sidestream aeration and construction of additional tailrace weirs for aeration should also be done to develop construction and operation costs.

If you have any questions or require additional information, please contact me.

Sincerely,

MEAD & HUNT, Inc.

Timothy J. Astfalk