

# *Klamath Hydroelectric Settlement Agreement*

## *Interim Water Quality Improvements (Interim Measure 11)*

### **Water Quality Study Progress Reports**

*June 25, 2012*

This document presents the current status of water quality studies and pilot projects now underway pursuant to Interim Measure 11 of the Klamath Hydroelectric Settlement Agreement (KHSA). Interim Measure 11 is intended to improve water quality in the Klamath River during the interim period leading up to dam removal under the KHSA. The emphasis of Interim Measure 11 is nutrient reduction projects to provide benefits to the mainstem Klamath River that will benefit environmental resources following potential dam removal, while also addressing water quality, algal and public health issues in reservoirs of the Klamath Hydroelectric Project and dissolved oxygen in J.C. Boyle reservoir. PacifiCorp worked with representatives of the KHSA Interim Measures Implementation Committee (IMIC) to develop study plans for six studies and pilot projects to be implemented prior to the Secretarial Determination with funding provided by PacifiCorp. These study plans were finalized in October 2010. The six studies currently underway include the following:

- Evaluation of Treatment Provided by Wetlands
- Evaluation of Organic Matter Removal from Keno Reservoir and the Upper Klamath River
- Evaluation of J.C. Boyle Reservoir Dissolved Oxygen Improvement
- Testing of Intake Cover for Water Quality Control at Iron Gate Reservoir
- Localized Treatment of Environmentally-Safe Algaecide
- Continued Development of the Water Quality Accounting Framework

A detailed status summary for each of the six studies and pilot projects follows.

*Klamath Hydroelectric Settlement Agreement: Interim Water Quality Improvements  
(Interim Measure 11)*

**Study Progress Report: Testing of Intake Cover for Water Quality Control at Iron Gate Reservoir**

*June 25, 2012*

**Background**

Seasonal impairment in Iron Gate reservoir as a result of upstream sources of nutrients, primarily from hypereutrophic Upper Klamath Lake, can lead to elevated levels of algae, including *Microcystis aeruginosa* (MSAE) and the associated toxin microcystin, in the reservoir. MSAE, as well as other phytoplankton, typically occupies the photic zone of lakes and reservoirs to take advantage of sunlight for photosynthesis. Thus, one approach to reducing the potential downstream movement of phytoplankton and toxin is through selective withdrawal. Specifically, by drawing deeper waters into the Iron Gate intake tower while limiting surface waters the potential downstream movement of MSAE and microcystin may be reduced.

PacifiCorp retained Watercourse Engineering, Inc. to assist with study activities and data collection and analysis, In August 2011, PacifiCorp installed a steel cover on the Iron Gate intake tower to explore the feasibility of water quality control through selective withdrawal (Figure 1). The purpose of the intake cover was to alter the depth at which water was withdrawn from the reservoir into the intake tower.



**Figure 1. Iron Gate Intake Tower with cover installed, but not lowered.**

**Experimental Approach, Results, and Status**

**Approach**

To assess the efficacy of a cover over the Iron Gate intake tower, the steel cover was installed and lowered to a depth of 12 feet. To assess the barrier's effect on in-reservoir and downstream conditions three study tasks were completed:

1. velocity measurements near the front of the intake tower were collected to assess the depths at which water enters the intake tower without the cover and with the cover in place,
2. sonde (water quality probe) measurements of water temperature, dissolved oxygen, and pH downstream of Iron Gate Dam were collected to assess changes in Klamath River conditions with and without the cover in place. In addition, vertical water quality sonde measurements of water temperature, dissolved oxygen, and pH were collected to characterize reservoir conditions during the experiment, and
3. nutrient and algal grab sampling in the river downstream of Iron Gate dam was conducted to assess the impacts of lowering the cover. Nutrient samples included total nitrogen (TN), nitrate/nitrite (NO<sub>3</sub>+NO<sub>2</sub>), nitrite (NO<sub>2</sub>), ammonia (NH<sub>4</sub>), total phosphorus (TP), orthophosphate (PO<sub>4</sub>), and dissolved organic carbon (DOC). Algal samples were analyzed for species identification and to determine density, biovolume, and blue-green algae cell count. Chlorophyll-*a* concentrations were also determined.

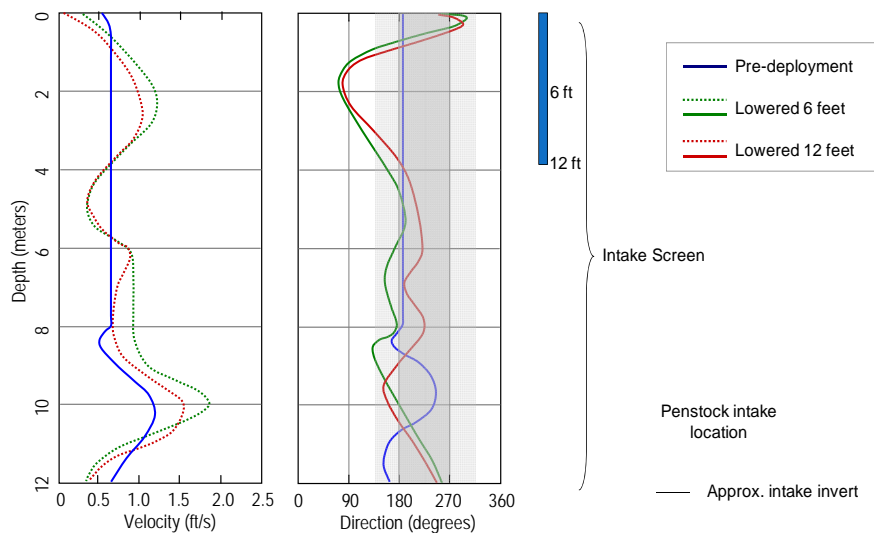
The cover consisted of a 12-foot high steel frame attached to pulleys atop the intake tower trash rack. During the study, the cover was lowered to six feet below the surface on August 29<sup>th</sup> to test deployment and retrieval, and to twelve feet below the surface on August 31<sup>st</sup> to assess the downstream water quality response. The cover was deployed for several hours before being raised to the surface at the end of each day. The goal was to identify differences in the pre- and post placement of the cover. A summary of the results for each of the above identified tasks is presented below.

## **Results**

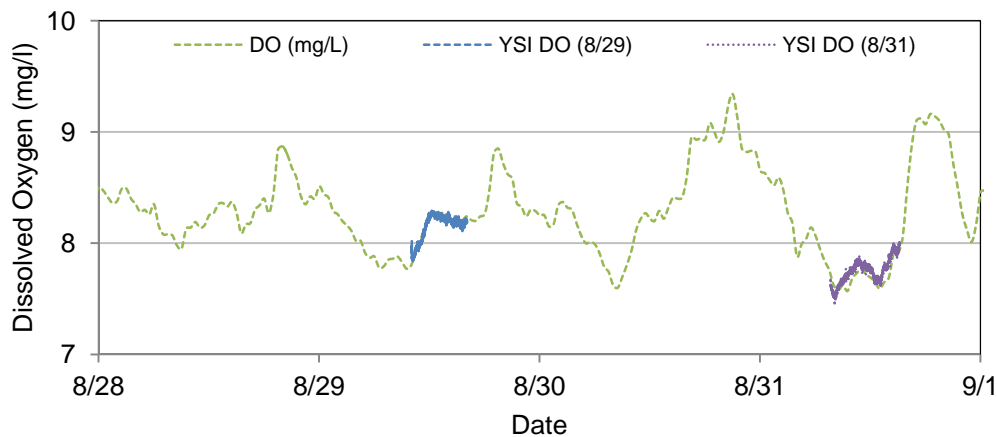
Velocity Measurements: A wide range of velocity measurements were collected at various locations in the reservoir to identify vertical velocity profiles in the vicinity of the intake tower. Those nearest the tower, at the A-Frame, provided the most detailed and useful information. (The A-Frame is a small log boom that forms a triangle upstream of the intake tower, see Figure 1). Using an Acoustic Doppler Current Profiler (ADCP), measurements were taken at five-minute intervals at the A-frame.

Vertical profile velocities and direction pre- and post-deployment are shown in Figure 2. Prior to cover deployment, velocity magnitude and direction in the top 25 feet were uniform at approximately 0.7 ft/s, and the direction almost due south ( $\approx 180^\circ$ ). The powerhouse penstock intake (12 ft diameter) is located at a depth ranging from approximately 25 feet to 38 feet, and velocities at this depth range are notably higher – exceeding 1 ft/s – and the flow direction is more from the northeast. Following deployment of the cover, velocities increased in the upper 12 feet of the reservoir, but they flowed away from the tower, and velocities in the vicinity of the penstock depth approached 2 ft/s. These results suggest that surface flows were being excluded from the intake tower. However, post-deployment velocities shown in Figure 2 also suggest that an equilibrium flow condition was not achieved in this relatively short experiment (i.e., velocities varied notably in magnitude and direction in the top 25 feet of the reservoir).

Sonde (Water Quality Probe) Measurements: In-reservoir temperature, dissolved oxygen, and pH were collected prior to and during the experiment to characterize thermal stratification and dissolved oxygen conditions. Deployment of the cover did not appear to have an impact on water temperatures or dissolved oxygen. Examining the dissolved oxygen trace below Iron Gate dam suggests that larger in-reservoir processes (perhaps associated with wind mixing, operations, diel changes in primary production, or other processes) have a larger effect on release concentrations than the installation of the cover (Figure 3). The Iron Gate turbine venting system was operating during the experiment.



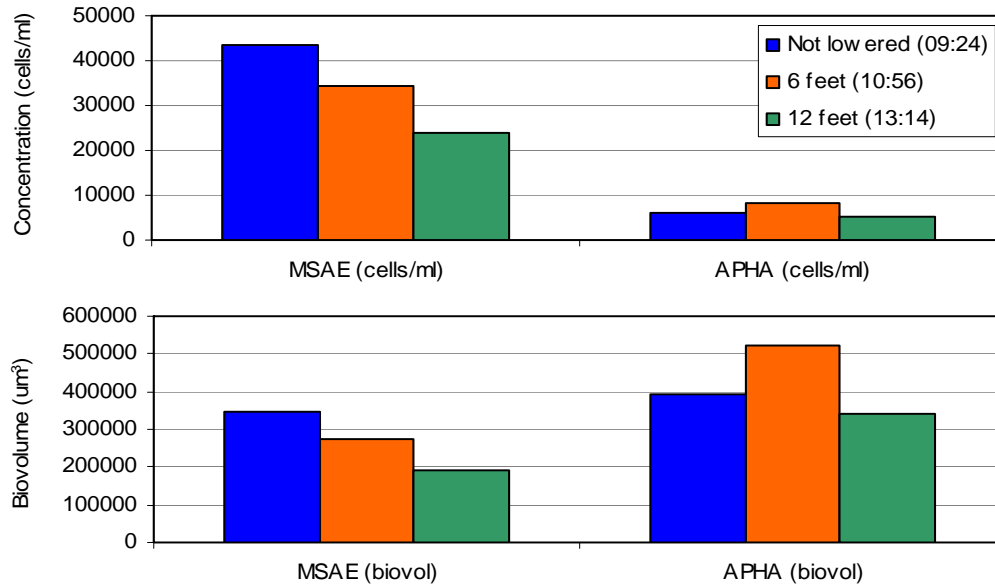
**Figure 2. Profiles of velocity (ft/s) and flow direction (degrees) taken near the A-frame. August 31, 2011.**



**Figure 3. Continuous dissolved oxygen concentrations near the Iron Gate Hatchery bridge based on PacifiCorp sonde (green) and Watercourse sonde (blue (testing on Aug 29th) and purple (cover deployed on August 31st)).**

**Nutrient and Algae Grab Sampling:** Nutrient data at the downstream location above the hatchery bridge suggested the deployment of the cover did not affect nutrient concentrations downstream. However, the algae data, particularly for MSAE, illustrated clear differences. At the downstream location, the deployment of the cover at both six feet and twelve feet below the surface reduced MSAE cell (cells/ml) counts by 20 percent and 44 percent, respectively, with similar findings in biovolume (Figure 4). The observed cell count and biovolume for APHA did not follow this trend (Figure 4). One possible explanation for this is that MSAE may occupy near-surface waters while APHA are distributed over a greater depth. Cyanobacteria algae tend to move vertically depending on the time of day in response to several environmental factors (Walsby 1970, Walsby 1971, Thomas and Walsby 1984), and this tendency may play a role in the observed performance of the cover in reducing movement of MSAE downstream of Iron Gate dam.

Finally, chlorophyll-*a* concentrations showed a small, but consistent, reduction from 15.5 mg/l with no cover, 14.8 mg/l with the cover deployed to 6 feet, and 14.2 mg/l with the cover deployed to 12 feet. The modest difference in chlorophyll-*a* may be due to representation of all algal species present, wherein larger species (e.g., APHA) constitute a larger biovolume than smaller species (e.g., MSAE) (see Figure 4).



**Figure 4. Blue-green algae concentration (cells/ml) and biovolume at the downstream location near the Hatchery Bridge on August 31, 2011. Sampling times are indicated in parentheses in the legend.**

In summary, it appears that deployment of the cover had little effect on downstream temperature, dissolved oxygen, and nutrient concentrations. However, velocity profiles indicate that the hydraulic conditions in the vicinity of the tower did not reach equilibrium in these short experiments. MSAE cell counts were observed to be notably lower downstream when the cover was in place. Interestingly, *Aphanizomenon flos-aquae* (APHA) species counts did not illustrate this reduction. Both species of cyanobacteria have the ability to exhibit some control of their buoyancy, but are markedly different in size with APHA being much larger than MSAE.

### Status

The final report on the 2011 outlet tower cover experiment will be completed in early summer. Additional studies are proposed for 2012 to examine the potential vertical movement of cyanobacteria to determine their ability to control their vertical position in the water column. If these species, particularly MSAE, are consistently found in the near-surface waters, the approach of selective withdrawal may be a viable, cost-effective approach to reducing the potential downstream movement of MSAE and microcystin into the Klamath River without adverse impacts to other water quality parameters. An additional element of proposed further study would include a longer-term deployment of several weeks to ascertain longer-term performance of selective withdrawal effects.

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*Klamath Hydroelectric Settlement Agreement: Interim Water Quality Improvements  
(Interim Measure 11)*

**Study Progress Report: Evaluation of J.C. Boyle Reservoir Dissolved Oxygen Improvement**

*June 25, 2012*

The purpose of this study is to conduct planning for, and testing of technologies for improving dissolved oxygen (DO) conditions in J.C. Boyle reservoir. J.C. Boyle reservoir is classified as eutrophic (nutrient-enriched) due to the large inflow loads of nutrients and organic matter from upstream sources, notably Upper Klamath Lake. Because of these large loads, J.C. Boyle reservoir experiences reduced DO concentrations at certain times of the year. J.C. Boyle is generally well-mixed, but temporary vertical gradients (weak stratification) can occur during summer, particularly where the reservoir is deepest near the dam. During such temporary stratification, lower DO concentrations can develop in this deeper area.

PacifiCorp previously prepared Reservoir Management Plans (RMPs) to evaluate the effectiveness and feasibility of various technologies and measures to improve water quality conditions in J.C. Boyle reservoir (PacifiCorp 2008a), as well as in Copco and Iron Gate reservoirs (PacifiCorp 2008b). The J.C. Boyle reservoir RMP identified several potential techniques for DO enhancement in lakes and reservoirs as described by Cooke et al. (2005), Thornton et al. (1990), and Cooke and Kennedy (1989). Of these techniques, three targeted at improving DO were further evaluated in the RMP development process: (1) water column circulation, (2) epilimnion methods, and (3) hypolimnetic methods. Because J.C. Boyle reservoir is generally well-mixed with only temporary weak stratification (as noted above), specific epilimnion and hypolimnetic methods lack applicability to J.C. Boyle reservoir, leaving water column circulation as the most appropriate approach for potential application to J.C. Boyle reservoir.

Study activities have included gathering information on three water column circulation methods, and evaluating their potential application to J.C. Boyle reservoir. The three methods include: (a) aeration or air injection; (b) oxygenation; and (c) mechanical mixing. Aeration or air injection (diffuser) systems utilize a compressor on shore that delivers air through diffusers placed near the bottom of the lake. The rising air bubbles cause water in the bottom water layer to also rise, entraining water and transporting it into the surface water layer. Oxygenation systems are similar to aeration or air injection systems except that pure oxygen rather than air is used. An advantage of oxygenation systems is that, in addition to providing circulation and mixing, oxygen is directly added to the water. Mechanical mixing is accomplished using axial flow pumps to set up a circulation pattern. A flotation platform and frame support an electric motor, gearbox, drive shaft, and large propeller (6 to 15 foot diameter). The propeller is suspended just a few feet below the water surface. Its rotation “pushes” water from the reservoir surface downward, setting up a vertical circulation pattern. Deeper water is circulated to the reservoir surface, where oxygen transfer from the atmosphere can then occur.

In 2009, PacifiCorp retained Alex Horne and Associates (AHA) and CH2M HILL to perform a feasibility assessment of an air injection (diffuser) system in J.C. Boyle reservoir. Horne et al. (2009) performed calculations of oxygen demands and requirements, and estimated system sizing and layouts for an air injection system in J.C. Boyle reservoir. Horne et al. (2009) determined that the most appropriate system for J.C. Boyle reservoir would be an air injection system located in the deeper, lower portion of the reservoir. Horne et al. (2009) developed a preliminary conceptual design and associated cost estimates for an air injection (diffuser) system in the deeper, lower portion of J.C. Boyle reservoir that would include several diffuser arrays, serviced by a 22 kW (30 hp) air compressor. Horne et al. (2009) recommended a focus on DO enhancement in the deeper, lower portion of the reservoir because a system in the upper part of the reservoir would lack efficiency and effectiveness for two key reasons: (1) the high inflow load of biochemical oxygen demand (BOD) to the upper end of the reservoir could not be overcome by an air injection system; and (2) the upstream part of the reservoir is too shallow, so that the mixing and air plume effects from a system would be small. In addition, the length of diffuser pipe for a system in the upper part of the reservoir would

be long, presenting difficulties of balancing the airflow over long lengths of pipe (although the use of individually regulated diffusers may overcome this drawback).

During 2011, study activities included assessment of a specific oxygenation method with potential application to J.C. Boyle reservoir – the Supersaturated Dissolved Oxygen (SDOX®) system. The SDOX® technology involves withdrawing a small stream of water from the body of water to be treated, bringing that stream up to a pressurized saturation tank where oxygen gas is pre-dissolved into the stream to achieve a supersaturated DO concentration. The stream of water is then re-injected back into the main water body, thereby increasing the DO concentration in the receiving water.

During September 2011, BlueInGreen LLC conducted a pilot test of the SDOX® technology at J.C. Boyle reservoir. For this pilot test, a trailer-mounted SDOX® 400 system, which has a full-rated capacity to deliver 1,540 pounds of DO per day (lbs/day), was deployed adjacent to the shoreline near the upper end of the reservoir. The SDOX® system operated nearly continuously over a five-day test period, delivering an estimated total of 5,175 lbs of DO to the reservoir at an average rate of approximately 1,150 lbs/day. The pilot demonstration showed formation of a DO plume mainly along the southern portion of the reservoir downstream of the injection point, and a rise in DO levels within the plume area of approximately 0.5-1.5 mg/L. The data collected in the pilot will be used to evaluate sizing for a larger system. BlueInGreen LLC is currently putting together additional information for PacifiCorp on the specifications for a larger system.

Study activities conducted to date have also included a technology review of mechanical mixing techniques with potential application to J.C. Boyle reservoir, and an assessment of their efficacy for DO improvement in the reservoir. Axial flow pumps are the most prevalent mechanical mixing technology for lakes or reservoir (e.g., Punnett 1991, Lawson and Anderson 2007). The technology review to date has included the two most common types of pre-engineered axial flow pump systems that are currently on the market: (1) an up-flow solar-powered axial flow technology; and (2) a down-flow grid powered axial flow system. The up-flow solar-powered axial flow technology is a lower-energy mixing system that is primarily designed to disrupt algal growth by increasing lateral surface velocity and is not intended for use in the destratification of lakes. PacifiCorp tested this technology on Copco reservoir in 2008 and determined that it did not demonstrably improve water quality, including DO, in the reservoir (Carlson and Foster 2009).

The down-flow axial flow technology represents a higher-energy mixing system that is primarily designed for lake water column mixing and destratification. Technical documents obtained from a manufacturer of this technology indicate successful reservoir destratification and subsequent increases in hypolimnetic oxygen concentrations from several currently-operating installations in the United States and Australia. Unpublished data viewed at a recent conference, however, reveal lack of destratification in one application.

On the basis of the above information, the down-flow technology is considered the more viable of these two mixing systems for potential application to J.C. Boyle reservoir. However, further analysis during 2011 by CH2M HILL indicates that potential application of the down-flow technology to J.C. Boyle reservoir may also be problematic. The down-flow system analyzed includes a flexible shroud used to induce vertical mixing. Because J.C. Boyle reservoir is a relatively fast-flushing mainstem impoundment, water currents that occur in J.C. Boyle reservoir under most flow conditions could significantly affect the performance of the flexible shroud in this application.

CH2M HILL is currently completing a report on activities conducted for this study through early 2012. The report is expected to be issued by PacifiCorp to the IMIC by the end of July 2012.

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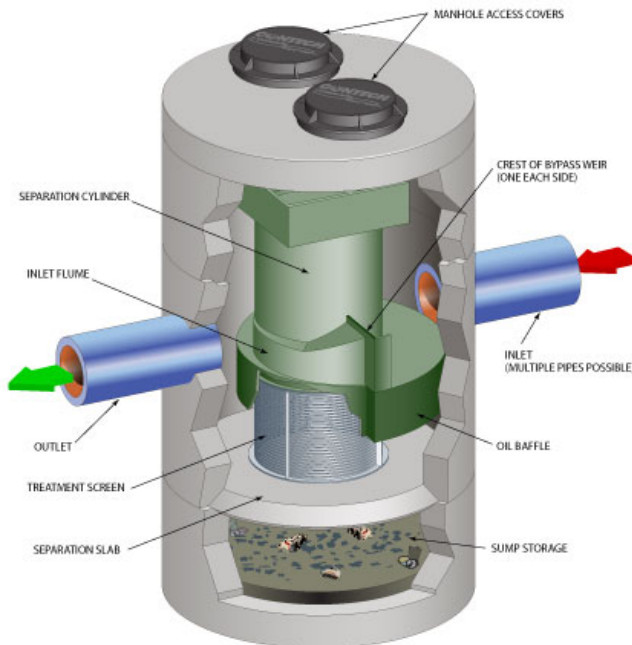
*Klamath Hydroelectric Settlement Agreement: Interim Water Quality Improvements  
(Interim Measure 11)*

**Study Progress Report: Evaluation of Organic Matter Removal from Keno Reservoir and  
the Upper Klamath River**

*June 25, 2012*

**Background**

The Klamath River from Link River to Keno dam commonly experiences poor water quality conditions in the summer, partly due to notably high organic matter (OM) concentrations which deplete oxygen, creating unfavorable conditions for fish and other aquatic organisms. As part of the Klamath Hydroelectric Settlement Agreement (KHSA) Interim Measure 11, an initial study (2011) was developed to assess the potential efficacy of separating particulate OM from waters of the Klamath River using stormwater treatment technology (hydrodynamic separation). The approach identified for this study is the use of hydrodynamic separators (Figure 1). These devices utilize low head conditions to separate particulate matter from water, and can work on negatively and positively buoyant materials.



**Figure 1. Schematic of a hydrodynamic separator unit.**

Source: <http://www.conteches.com/Products/Stormwater-Management/Treatment/CDS.aspx>

During the 2011 study several design improvements to the prototype separator device were identified that were necessary to more fully characterize the efficacy of this technology for application in the upper Klamath Basin. Another experiment (proposed to be conducted in 2012) would extend the 2011 study by testing an improved prototype OM separator using different flow rates (60 gpm and 115 gpm), separator screen sizes (2.4 mm and 1.2 mm), conveyance methods (pump vs. siphon), and locations (Keno Reservoir and Iron Gate Reservoir).

## **Approach and Preliminary Results**

### **Approach**

In 2011, a pilot scale OM removal device was designed, built, and employed at both Keno and Iron Gate Reservoirs. The removal device included a pumping system, fish screen, and separator elements. The separator elements consisted of a large tank and sump, a specially designed hydrodynamic to create a vortex, and a screen to segregate particulate matter from water. The separator was mounted on a trailer for transportation. Samples were collected in the river, post-pump, and at the outlet of the separator. Particulate carbon (PC), particulate nitrogen (PN), and particulate phosphorus (PP), as well as algae species were collected at each location to characterize removal efficiencies.

### **Results**

Initial sampling results suggested that particulates were reduced after passing through the prototype separator, but that the initial system was not designed to provide sufficient flexibility to conclusively assess removal efficiencies. A principal sampling challenge was the lack of flexibility in changing screen sizes, notably limiting the range of experimentation. Furthermore, large portions of OM were removed by the required fish screen, such that the OM concentration entering the separator was low, which meant that changes between pre- and post-separator OM concentrations were not always evident. Nevertheless, findings from the 2011 experiment suggest that OM removal using stormwater treatment technology may potentially be an effective water quality improvement strategy for the Klamath River.

Improvements in the equipment design are required to facilitate more efficient field operations. In 2012, a smaller system (approximately 2-3 ft diameter; 3 to 4 feet in height) that utilizes the same hydrodynamic separation technology could be employed to allow for ease of transport, more readily change screen sizes, provide for easier flow rate monitoring, and easier sampling. Scale-up issues were also taken into consideration in the development of the new prototype separator, which was designed by the original equipment manufacturer (Contech Engineered Solutions).

# *Klamath Hydroelectric Settlement Agreement: Interim Water Quality Improvements (Interim Measure 11)*

## **Study Progress Report: Evaluation of Treatment Provided by Wetlands**

*June 25, 2012*

The purpose of this study is to provide information for use in considering and planning approaches to possible development of engineered treatment wetland systems in the Upper Klamath basin. Constructed treatment wetlands have been identified as a potentially viable means of improving water quality conditions in the upper Klamath River (Lyon et al. 2008, Deas and Vaughn 2006). Target water quality improvements include reduced total suspended solids, organic matter (biochemical oxygen demand), nutrients and local water temperature improvements. These treatment wetland systems can be designed in a variety of configurations and with various augmentation technologies.

Study activities conducted to date have included: (1) an overview of treatment wetlands and their effectiveness; (2) estimates of treatment wetland sizes and effectiveness to achieve specific water quality improvement objectives in the Upper Klamath basin; (3) reviews of potential supplemental technologies to enhance treatment wetland effectiveness; and (4) reviews of relevant treatment wetland case studies elsewhere that may serve as useful “analogies” for applications in the Upper Klamath Basin. Additional planning activities that may be conducted (pending further coordination with the IMIC and other stakeholders) include: (1) development of specific goals and objectives for treatment using wetland systems in the Upper Klamath basin; (2) investigation of potential partnerships, land acquisition opportunities, and water rights requirements; (3) further specific sub-basin planning for application and siting of potential treatment wetlands; (4) possible specific treatment wetland pilot studies and tests; and (5) stakeholder and public involvement.

PacifiCorp retained CH2M HILL to perform the four study activities that have been completed to date (as listed above). CH2M HILL conducted study activities during 2011, including a presentation to the IMIC in August 2011 on study status and preliminary findings, and prepared a detailed report on the final results of study activities that was submitted to the IMIC in March 2012. The report is available on PacifiCorp’s Klamath River website under KHSA Implementation: <http://www.pacificorp.com/es/hydro/hl/kr.html#>.

CH2M HILL used a first-order area-based treatment wetland model to estimate the approximate magnitude of wetland acres that would be needed to achieve nutrient load reductions in the Upper Klamath basin. These estimates are primarily useful as conservative “side boards” for further planning purposes, since it is not considered realistic that reductions of nutrient loads in the Klamath River would be accomplished solely by restoration and construction of wetlands. Nonetheless, these calculations suggest that wetlands treatment offers a potentially important tool in a broader overall strategy for reducing nutrient loads that would also necessarily involve other technologies.

The report presents detailed information on several potential supplemental technologies to enhance treatment by wetlands (Chapter 5), including constructed emergent vegetation surface flow wetland systems, submerged aquatic vegetation (SAV) systems, periphyton-based treatment systems, various supplemental chemical treatment approaches, and systems combining chemical, settling and solids separation, and filtration. Each of these supplemental technologies are described, including their relative effectiveness, advantages and disadvantages, costs, and potential for application to potential application in the Upper Klamath basin.

CH2M HILL reviewed a number of treatment wetland cases from elsewhere in the region and across the country, and the report presents several case studies in the report that serve as important potential analogies to the Upper Klamath Basin situation. As analogies, the implementation experiences and level-of-effectiveness of these other projects provide insights for use in evaluation and planning for potential treatment wetlands in the Upper Klamath Basin. Detailed summaries of each example are provided in the report, including the implementation experiences and

level-of-effectiveness of these other projects, as well as the situational similarities relative to potential application to the Upper Klamath basin.

CH2M HILL identified several considerations and recommendations for potential next steps in the planning and implementation of treatment wetlands in the Upper Klamath basin. These included a recommendation to define the specific goals for treatment by wetlands in the Upper Klamath basin, since specific goals will likely drive many, if not most, aspects of wetland planning, design, construction, operation, and maintenance. The final chapter in CH2M HILL's report describes several important factors and constraints that should be anticipated and addressed in future planning, including water use and water rights, land availability and suitability, regulatory permitting and approvals, and complex local climatology and hydrology conditions.

As follow-up to the report's submittal to the IMIC, CH2M HILL made a presentation of study results to the IMIC in April 2011. PacifiCorp and CH2M HILL subsequently received letters with comments on the report from the Yurok Tribe, the State of California North Coast Regional Water Quality Control Board ("Regional Board"), and the Oregon Department of Environmental Quality ("DEQ"). PacifiCorp and CH2M HILL are planning clarifications and revisions to the report to address the comments from the Yurok Tribe, Regional Board, and DEQ. Among other clarifications and revisions in the report, CH2M HILL will be conducting, in consultation with the IMIC, an additional sensitivity analysis of estimated wetland areas using the first-order area-based treatment wetland model, an additional assessment of potential water temperature treatment by wetlands in the basin. A revised final report is expected to be completed in August, 2012.

# Klamath Hydroelectric Settlement Agreement: Interim Water Quality Improvements (Interim Measure 11)

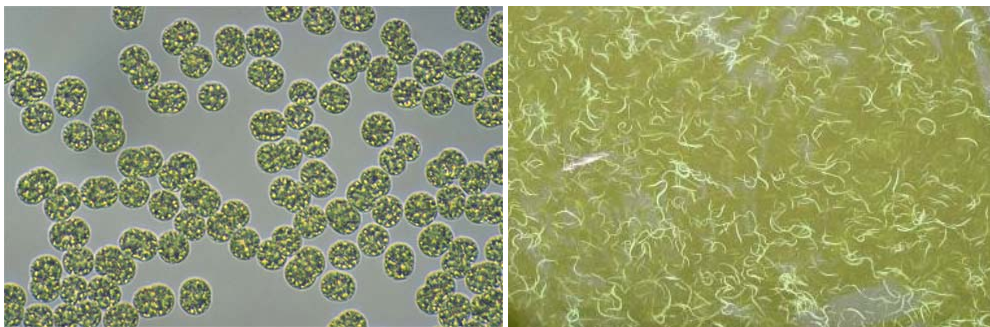
## **Study Progress Report: Localized Treatment of Environmentally-Safe Algaecide**

June 25, 2012

### **Background**

PacifiCorp's Klamath Hydroelectric Project includes several reservoirs along the Klamath River (including Copco and Iron Gate reservoirs) that are seasonally impacted by algal blooms. These blooms are caused by large seasonal nutrient loads from upstream sources such as Upper Klamath Lake. In water samples collected between 2001 and 2009, the most abundant phytoplankton group in Copco and Iron Gate reservoirs was cyanobacteria (mainly consisting of *Microcystis aeruginosa* and *Aphanizomenon flos-aquae*) (Figure). Cyanobacteria concentrations in these reservoirs tend to exceed California guidelines by mid-July, thus necessitating the issuance of public health advisories.

The application of algaecide is a common method of reducing cyanobacteria concentrations in water, and can provide rapid removal of algae from the water column. PacifiCorp explored algaecide applications to assess the potential efficacy of local applications, recognizing that system wide application may not be economical or feasible as a complete control mechanism given the large influx of nutrients from upstream.



**Figure 1. *Microcystis aeruginosa* (left photo) and *Aphanizomenon flos-aquae* (right photo).**

In 2008, Watercourse Engineering, Inc. performed a preliminary bench-top algaecide experiments to assess the efficacy of various algaecides. Further testing of two types of sodium carbonate peroxyhydrate (non-copper) algaecides, GreenCleanPro granular and GreenClean Pro liquid, occurred in 2009 and 2011. GreenCleanPro's two algaecides break down algal cell walls leading to cell death, but also act to break down organic matter. The reaction works quickly, reducing the likelihood of mutational resistance and acts preferentially on cyanobacteria (when applied at the appropriate dosages). The sodium carbonate peroxyhydrate breaks down into natural compounds, such as water, oxygen, and elements of organic acids.

### **Experimental Approach, Results, and Status**

#### **Approach**

The 2011 study aimed to assess:

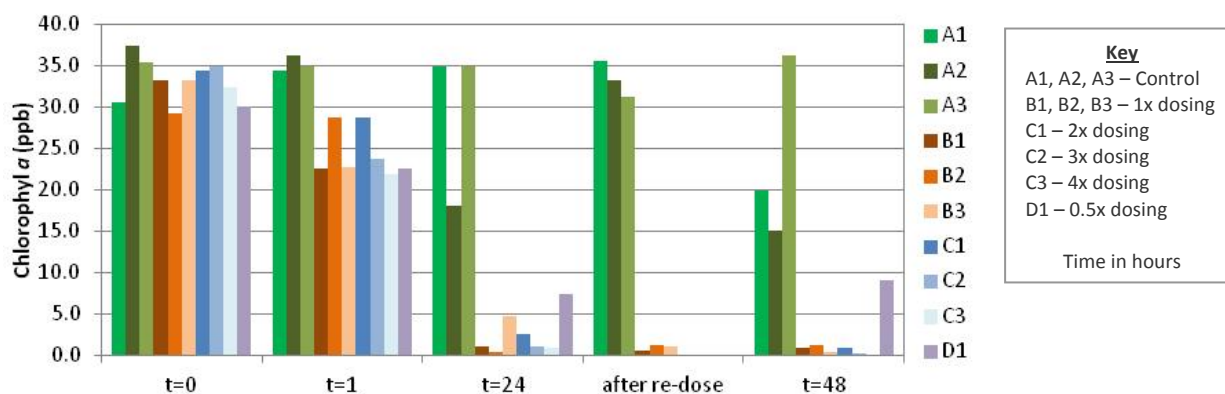
1. the efficacy of the algaecide GreenClean Liquid at different doses on different algae species (e.g., Blue Green Algae vs. Diatoms);
2. whether inorganic nitrogen and phosphorus increased after treatment due to lysing of algal cells; and
3. the impacts of applying a strong oxidant (sodium carbonate peroxyhydrate) on microcystin concentrations.

Specifically, the study explored whether the application of GreenClean would lead to increases in microcystin from lysed cells, would decrease microcystin (because the toxin is an organic molecule and subject to oxidation), or have no effect on microcystin concentrations.

Water samples were obtained from Copco Reservoir in mid to late summer 2011 and placed in 200 liter barrels. Ten discrete barrels were used to provide a control and to assess multiple dosages, as well as re-dosing. The primary studies assessed the efficacy of the algacides at the recommended dosage levels with one re-dosing after twenty-four hours, while a secondary study assessed the effects of alternative dosages. The primary study was conducted using triplicate samples. The dosage study applied half, double, triple, and quadruple dosages (0.5x, 2x, 3x, and 4x, respectively). Water samples were taken prior to treatment and then one hour, twenty-four hours, and forty-eight hours after treatment. Water samples were collected and submitted for analysis of nutrients, chlorophyll-*a*, algae species, and microcystin.

## Results

The application of GreenClean had a direct impact on phytoplankton populations as illustrated in chlorophyll-*a* concentrations, with a 5 to 20 percent decrease in chlorophyll-*a* in the first hour and 80 to 95 percent decreases after 24 hours (Figure 2). Species counts did not reflect this reduction. The product manufacturer recommends basing the efficacy of GreenClean on chlorophyll-*a* versus species counts.



**Figure 2. Chlorophyll-a concentrations (ppb) at time intervals (t in hours) for dosage treatments.**

Upon treatment (t = 1 hr), inorganic nitrogen (ammonia, and nitrate) and phosphorus (orthophosphorus) increased. Total inorganic nitrogen increased between 20 to over 200 percent, while orthophosphate increased 15 to 25 percent. These findings suggest that lysing of cells during treatment potentially increased bioavailable nutrients. The implications of this increase were not examined (e.g., biostimulation). The increase largely persisted through the experiment, suggesting that possibly over the relatively short duration of the experiment reductions in phytoplankton standing crop resulted in excess nutrient (i.e., there were fewer living algae to utilize available nutrients).

Finally, an approximately 50 percent reduction in microcystin concentrations was observed twenty-four hours after treatment in all applications. Re-application of the recommended dosage had relatively minor impacts on microcystin concentrations. The microcystin concentrations were relatively low (2 µg/L pre-treatment), and the efficacy of GreenClean reducing microcystin concentrations at higher treatment levels was not explored and is not known.

## Status

Currently, the report is in draft form, and Watercourse is working with the manufacturer as well as other researchers working with sodium carbonate peroxyhydrate-based products to identify remaining questions (e.g., species count data that do not show the same level of reduction as chlorophyll-*a* data). The final report for this phase of the study is expected at the end of July.

# *Klamath Hydroelectric Settlement Agreement: Interim Water Quality Improvements (Interim Measure 11)*

## **Study Progress Report: Continued Development of the Water Quality Accounting Framework**

*June 25, 2012*

### **Background**

The Klamath River Total Maximum Daily Loads (TMDLs) and associated Implementation Plans for Oregon and California (ODEQ 2010, Regional Water Board 2010) recommend several potential implementation actions to address water quality impairments in the Klamath River. One of these actions is development of a “water quality improvement tracking and accounting program” for the Klamath Basin. PacifiCorp is working in cooperation with the Regional Water Board, Oregon Department of Environmental Quality, U.S. Environmental Protection Agency Regions 9 and 10, and other interested stakeholders to develop the Klamath basin water quality improvement tracking and accounting program (TAP).

PacifiCorp initiated discussions with the NCRWQCB and ODEQ during the drafting of the TMDL in late 2008. The first meeting was held in early 2009 and PacifiCorp has been directly and continuously involved since the inception. Throughout, PacifiCorp has been committed to a comprehensive, robust, and scientifically defensible program that is capable of addressing the complex challenges that exist at both the small and large scale in the Klamath Basin. PacifiCorp has a genuine interest in advancing the concept of a water quality accounting and tracking protocol for the Klamath basin that could serve as the basis for water quality credit trading. Such a program could lead to a lower cost for compliance and more effective environmental improvements in the Basin for the resources expended. PacifiCorp's interest in advancing such a program has been apparent in that, unique among regulated entities within the Klamath basin, PacifiCorp has committed resources to the development of such a program, in partnership with EPA Regions 9 and 10, the North Coast Regional Water Quality Control Board, and the Oregon Department of Environmental Quality. This effort has been a priority despite the controversy surrounding Klamath basin water quality issues. While there has been discussion of immediately establishing a broader framework that considers ecosystem services and also identifies priority areas for restoration efforts, PacifiCorp believes focusing on nutrient and temperature water quality tracking and crediting is the best way to advance this overall concept within the basin, given the complexity of the basin, and the unique regulatory and stakeholder context of the Klamath.

PacifiCorp has been an active participant in developing the program, including producing multiple documents, participating in meetings and workshops, and providing review of working group products and documents (Table 1). The purpose of the study plan is to continue development of a water quality improvement tracking and accounting program, and framework elements. The key concept behind the program is to facilitate opportunities for collaboration among Basin stakeholders to reduce nutrient loads, temperature loads, and loads of other constituents from upstream sources to reduce and offset water quality impairments in the Klamath River. This program will provide a record of individual actions and provide a potential basis for a market that facilitates a higher level of activity and collaboration than could be achieved by individual entities and dischargers alone.

### **Approach, Results, and Project Status**

#### **Approach**

PacifiCorp's role in the Klamath TAP has been one of participation in the TAP Working Group<sup>1</sup> supporting development of TAP elements and developing technical documents in support of TAP elements.

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<sup>1</sup> The Klamath Basin Tracking and Accounting Program working group consists of representatives from Oregon Department of Environmental Quality; North Coast Regional Water Quality Control Board; U.S. Environmental Protection Agency, Regions IX and X; PacifiCorp, Environmental Incentives, the Willamette Partnership, Klamath Watershed Partnership, The Nature Conservancy, the National Fish and Wildlife Foundation, the Oregon Watershed Enhancement Board, the Klamath Basin Rangeland Trust, and Watercourse Engineering, Inc. This working group is tasked with guiding the development of a water quality tracking and accounting program to improve water quality in the Klamath Basin.

## Results

Ongoing engagement with the working group has focused largely on meetings and developing the protocols document. Additional work has included working with selected members of the working group (e.g., the North Coast Regional Water Quality Control Board) to refine trading ratio areas and trade ratio values.

## Project Status

Working in cooperation with Oregon and California, ongoing work will focus on program definition, expanding stakeholder roles, program technical and policy elements, and ultimately program implementation. Ongoing work will focus on developing pilot projects to test the draft protocols.

**Table 1: Summary of PacifiCorp Activities and Products for Klamath TAP Process 2009-2011**

Date	Activity or Product
Feb 2009	<b>Document:</b> Benefits of A Pollutant Trading Program In the Klamath Basin
Mar 2009	<b>Document:</b> Klamath Basin Pollutant Trading Program - Proposed Program Goal and Objectives
April 2009	<b>Document:</b> Klamath Basin Water Quality Improvement Accounting and Tracking Program: Program Development and Technical Study Plan
April 2009	<b>Document:</b> Klamath Basin Pollutant Accounting Framework - Draft Development Roadmap
May 2009	<b>Document:</b> Klamath Basin Water Quality Improvement Accounting and Tracking Program: Stakeholder Information and Participation Plan
	Development was placed on hold while the North Coast Regional Water Quality Control Board and EPA IX, secured funding for Environmental Incentives (EI)
Nov 2009	Participated in developing charter with Working Group
Mar 2010	<b>Document:</b> Task 6B: Identify potential program participants and other stakeholders and modes of participation
Jun 2010	<b>Document:</b> Task 6A: Identify WQ constituents amenable to accounting
Jun 2010	Participated in drafting Frequently Asked Questions (FAQ) document
Jul 2010	Participated in developing agenda for Yreka workshop, attended and participated in workshop, invited M. Keiser to participate, presented on task 6A and 6B documents
Aug 2010	<b>Document:</b> Task 6C. Credit trading tools
Nov 2010	Participated in Webinar (stakeholder outreach)
Dec 2010	<b>Document:</b> Sub-watershed needs document
Jan 2011	Participated in developing and planning February workshop
Feb 2011	<b>Document:</b> Identifying load reduction opportunities (including tributaries) - draft
Feb 2011	<b>Document:</b> Constituents amenable to tracking (Final Task 6A)
Feb 2011	Reviewed and provided comment on CIG grant
Feb/Mar 2011	<b>Document:</b> Task 6D3. Pollutant delivery ratios and tributary or reach specific definitions of success document
Feb/Mar 2011	Reviewed EI documents related to 4-week scoping process
Mar 2011	Prepare for workshop
Apr 2011	Participated in developing agenda for Yreka workshop, attended and participated in workshop, presented on constituents amenable to tracking. <b>Note:</b> At the workshop EI identifies they are low on money. A program cannot be developed with the budget in hand. New focus is to develop a scope of work for the various elements identified in the workshop.
May 2011	<b>Document:</b> Load reduction opportunities and Potential Project Types
Sep 2011	Review KTAP protocols document
Meeting participation	
Oct '09-Apr '11	Assisted in developing agenda and facilitated all monthly calls.
May '11-present	Continue to participate in all monthly calls, as well as in technical and policy subgroup calls.