

WATER QUALITY EVALUATION OF THE LOWER DESCHUTE RIVER, OREGON WITH SELECTIVE WITHDRAWAL

**Stephen A. Breithaupt, Ph.D., Tarang Khangaonkar, Ph.D., PE,
Zhaoqing Yang, Ph.D., Kevin Marshal, PE**

Stephen A. Breithaupt, Ph.D.
Battelle – Seattle Research Center
4500 Sand Point Way NE, Seattle, WA 98105
Ph: (206) 528-3058, Fax: (206) 528-3551, E-mail: BreithauptS@battelle.org

INTRODUCTION

Portland General Electric (PGE) owns and operates the Pelton Round Butte Hydroelectric Project on the Deschutes River, near Madras, Oregon. It consists of three hydropower dams and reservoirs: Lake Billy Chinook behind Round Butte Dam; Lake Simtustus behind Pelton Dam; and the Reregulating Reservoir behind Reregulating Dam. The Lower Deschutes River below the Reregulating Dam flows a distance of 161 Km before its confluence with the Columbia River (Figure 1). As a part of the current re-licensing process, PGE has developed an adaptive management plan for re-establishing natural anadromous fish runs above Round Butte Dam. Previous modeling studies (DeGasperi, et al, 2000; Yang, et al, 2002) showed that the selective withdrawal operation, with blending of surface and bottom waters, provided improved currents and allowed compliance with temperature criteria immediately downstream. However, water quality impacts of the proposed modifications in the Lower Deschutes River were not clear. This paper describes the development of a water quality model of the Lower Deschutes River for temperature, dissolved oxygen (DO), and pH for evaluation of the proposed operational changes on Lower Deschutes River.

MODEL SETUP

The finite element models RMA2 and RMA4q were chosen for the Lower Deschutes River modeling study, primarily because RMA4q includes a periphyton submodel. The model was calibrated using data from 1999 and verified with data from 1997. The Existing condition scenario was developed for 1995, which is the baseline condition for analysis of the project.

Hydraulic Model

Existing cross-section data for the Lower Deschutes River were limited, so PGE surveyed additional cross-sections to ensure adequate spatial resolution. The cross-section data were processed to create the 1-D model grid. Node spacing averaged about 250 meters. Tributary channels for Shitike and Trout Creeks and Warm Springs and White Rivers were also added to the system. The model was run at hourly time steps over the 1-year simulation periods.

Water Quality Model

The water quality model RMA4q utilizes the same grid as developed for the RMA2 hydraulic model, as well as the velocity and depth results generated by RMA2. The meteorological data collected near the Project site, with temperature corrected for elevation, were input into three

separate reaches of the system to consider variations in longitudinal characteristics of the system. Based on previous studies (E&S 2000) periphyton is assumed to dominate the algae and its affect on the water column. Phytoplankton growth in the water column is relatively insignificant because of the short residence time of the river. Input data for the periphyton model were defined spatially to allow reach-by-reach adjustment of calibration parameters.

The model boundary conditions include water quality data at the Reregulating Dam withdrawal (from the upstream model of Lake Simtustus), Shitike Creek, Trout Creek, Warm Springs River, and White River. These include temperature, alkalinity, total inorganic carbon, dissolved oxygen, ortho phosphate, nitrate, nitrite, ammonia, and suspended algae. Periphyton were the primary agent affecting dissolved oxygen and pH and are limited by nitrate.

APPLICATION RESULTS

After calibration and verification, the model was applied to the 1995 conditions (Existing) and selective withdrawal (Blend 16) scenario for water quality impacts analysis. Previously, the Blend 16 scenario for Lake Billy Chinook had been developed through an iterative modeling process that looked at a number of possible combinations of blending of surface and bottom waters to meet target pre-dam temperatures immediately below the Reregulating Dam discharge location (DeGasperi, et al 2000). The Blend 16 scenario is presented in Figure 2, which shows the percentage and timing of blending surface and bottom waters from Lake Billy Chinook. The scenario attains compliance for 7-day maximum temperature standard.

Figure 3 shows the boundary time series for temperature at the Reregulating Dam used for each scenario analyses. Blend 16 temperatures more closely approximate natural (pre-dam) conditions, with the annual peak occurring earlier than Existing. While not shown, DO and pH are elevated at the Reregulating Dam for Blend 16 over the Existing scenario, and nitrate tends to be lower in Blend 16 than in the Existing scenario.

Temperature

Figure 3 presents temperature time series for the Existing and Blend 16 scenarios at several stations. The data are 7-day averages of daily maximum temperatures. Modeled pre-dam temperature results are also shown. Releasing blended water from Lake Billy Chinook maintains temperatures below the pre-dam conditions in the Lower Deschutes River for several miles. As expected, the temperature for both the Existing and Blend 16 conditions increases downstream due to heat exchange. At the river's mouth, the data from each run are nearly identical, showing the equilibrating effect of the heat-exchange processes.

Dissolved Oxygen

A beneficial effect of the Blend 16 scenario is that it produces higher DO concentrations in the Lower Deschutes River that lasts a considerable distance downstream. By the time the river flows reach the river mouth, the difference between Existing and Blend 16 DO time series is minimal as the river tends towards equilibrium. This is explained by the production and consumption of oxygen by periphyton, and the reaeration with the atmosphere driven by the tendency towards oxygen saturation in the water column.

pH

The model results indicate that at various times of the year, the pH in the Blend 16 scenario is up to 0.5 units higher than the Existing condition at the Reregulating Dam. pH is partially governed by carbon dioxide concentrations that in turn are produced by periphyton respiration and consumed by periphyton growth. As water flows downstream, the difference in pH values declines relatively quickly and reaches a minimum by RK 93. Carbon dioxide is subject to reaeration similarly to dissolved oxygen, and its saturation values vary with water temperature.

SUMMARY AND CONCLUSIONS

A water quality model of the Lower Deschutes River has been implemented using the models RMA2 and RMA4q, in the 1D dynamic mode, with an emphasis on temperature, dissolved oxygen, and pH. Other constituents were also simulated as part of the complete eutrophication cycle. Model calibration was performed using synoptic data collected in the year 1999 and verified with survey data from 1997. Conventional, water column, phytoplankton kinetics could not describe the observed water quality, and periphyton kinetics were used as the likely dominant mechanism controlling water quality in the Lower Deschutes River. Nitrate was found to be the primary limiting nutrient, as expected from low N:P molar ratios (with measured values near a value of 6).

The model was applied to 1995 (Existing) conditions, the selective withdrawal Blend 16 scenario, and pre-dam temperatures. The application boundary conditions were taken from Lake Simtustus withdrawal data provided by an upstream model. The results can be summarized as follows. (1) Selective withdrawal lowers temperatures during the peak summer months in the Lower Deschutes River, hence it is feasible to alter the temperatures in the Lower Deschutes River through selective withdrawal at Lake Billy Chinook. (2) The beneficial effect of cooler, summertime, discharge temperatures, with the Blend 16 scenario, persists several miles downstream, at least to RM 57. (3) The Blend 16 scenario results in higher DO concentrations than under existing conditions. This improvement is apparent through about RM 57. (4) pH levels are slightly elevated in the Blend 16 scenario, in comparison with Existing conditions.

References

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FIGURES

