Total Dissolved Gas (TDG) Modeling Improvements

Water Quality Management in Hydropower Systems

Managing energy, water, and environmental priorities and constraints within a hydropower reservoir system is a challenging multi-objective optimization effort that requires advanced modeling and forecasting tools.

A network of dams may be co-managed for:

- Irrigation
- Flood Control
- Navigation
- Fish Passage
- Water Quality
- Power Production

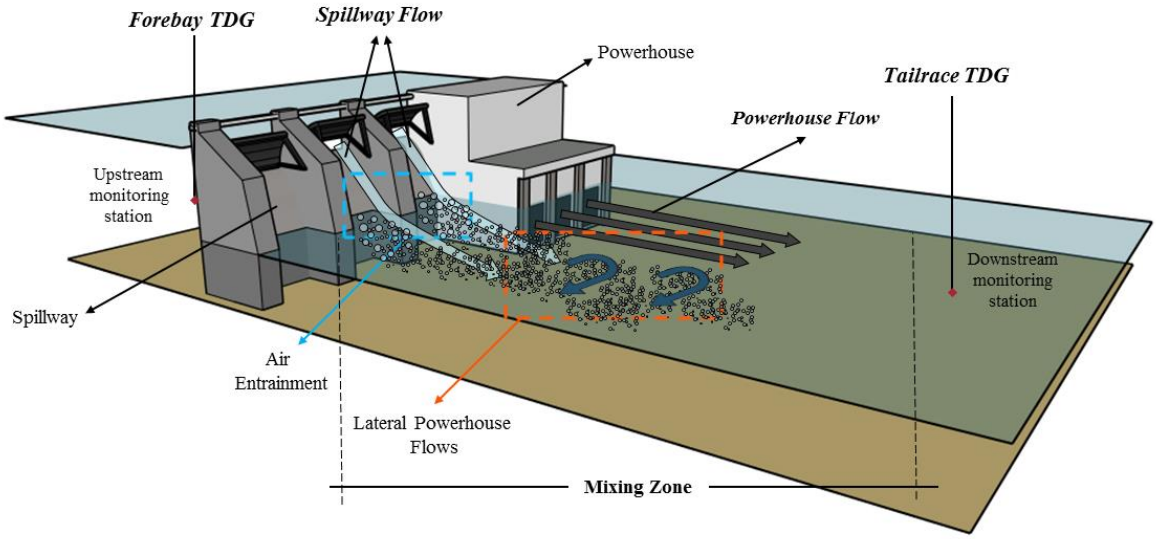
System-level management of multiple objectives is guided by a complex set of operational goals, rules, and limitations for both individual projects and groups of projects. Currently, there is a lack of specific solutions for predicting how coordinated operational decisions amongst numerous stakeholder groups can mitigate the environmental impacts of project operations while satisfying additional policy and hydropower generation objectives on an individual and collective basis. This challenge is particularly acute in the Pacific Northwest, where elevated levels of total dissolved gas (TDG) that persist throughout large hydropower systems are an ongoing threat to many fish species.

Modeling Improvements

The Department of Energy and Oak Ridge National Laboratory led a multi-year effort to advance the science of hydropower system modeling capabilities, developing a generalized TDG exchange model applicable to site specific dam operation.

Approach. The modeling effort leveraged techniques that simplify three-dimensional hydrodynamics into linear representations, easily extended to different types of hydropower facilities. This approach was applied to the seven dams on the mid-Columbia River hydropower system. The specific equations for total dissolved gas prediction at each structure were calibrated and validated using publically-available data from fixed monitoring stations.

TDG Prediction. Predictive capabilities were developed for two processes critical to TDG management - increase and exchange of TDG in the tailrace during high spill flow events, and the transport of TDG from the tailrace to the adjacent downstream reservoir. These capabilities have been incorporated into RiverWare, a general multi-objective river, reservoir, and hydropower optimization tool, to demonstrate and quantify the added value of advanced TDG and hydropower management.



Generalized schematic of the processes that govern total dissolved gas exchange at hydropower

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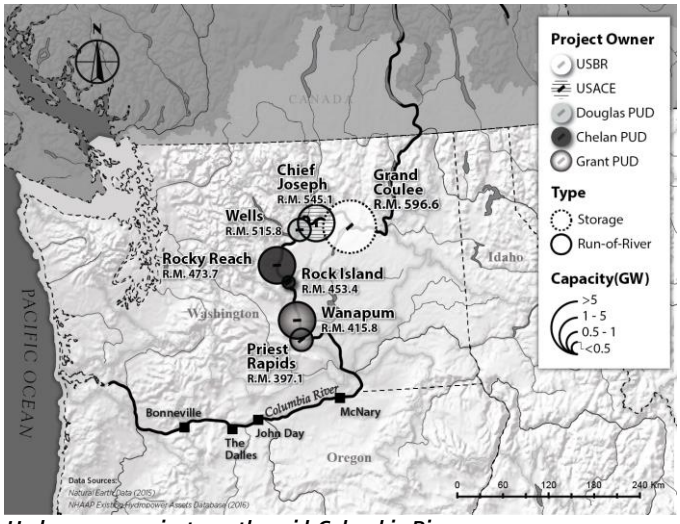

Hydropower projects on the mid-Columbia River.

Modeling Outcomes

A test case was constructed that quantified the response of power generation at a given project when TDG levels were constrained to a maximum value within a hydropower operators planning horizon. TDG exchange was structured as a qualitative policy constraint that must be satisfied by altering flow allocation and timing at upstream projects. Results were highly sensitive to the relative priority levels of TDG minimization and power generation requests, but suggested that a theoretical opportunity exists to lower maximum TDG levels and meet hydropower generation requirements. This multi-objective solution is unlikely to be realized with traditional TDG control efforts that are not capable of searching for and predicting an optimum system solution. Future research could study the effects of potential changes in policy and constraint satisfaction criteria on hydropower system operational philosophy in more detail.

Advancing the Science of Modeling

The innovations developed through this effort advance the science of modeling hydropower systems in many ways, creating new opportunities for systematic assessments of energy, water, and environmental objectives.

New Predictive Capabilities. The simplified techniques describing TDG exchange offer new pathways for dam operators to predict future water quality conditions at a level of accuracy consistent with more complex, time-consuming methodologies. Future cost and effort of developing a dependable site-specific model has been reduced by structuring this current research effort around easily obtained and reliable data.

Adaptability. The techniques developed are mathematically simple, allowing a straightforward incorporation into more complex optimization software. While the techniques stand alone in their predictive capabilities, they can be used to compliment or enhance existing models.

New Pathways for Optimization. A tool is now available to examine TDG and hydropower tradeoffs under different operating policy scenarios. Within complex, multi-objective optimization, flexibility generally exists with respect to how and how well operational constraints are satisfied. These tradeoffs and their broader system implications can now be examined in greater detail, leading to system-wide optimized outcomes.

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