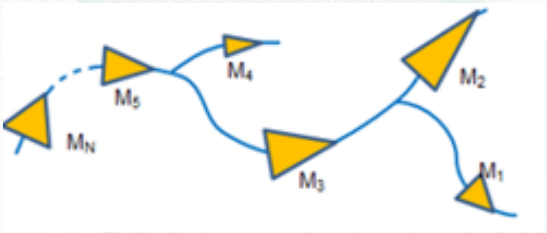
Water Quality Modeling Improvements for Use with Hydropower Optimization

Importance of Water Quality for Hydropower Optimization

Hydropower operations can significantly impact and also be impacted by water quality through changes in temperature, dissolved oxygen, and sediment loads, especially where flow variations are significant, particularly through "peaking." The ability for a hydropower facility to generate more electricity while maintaining adequate water quality and reservoir system conditions is normally obtained through the optimization of hydro operations that maximizes or increases generation while improving water quality related issues.



Reservoir system schematic layout used in water quality modeling and optimization scheme.

Water Quality Decision Support System Model

Oak Ridge National Laboratory in collaboration with Vanderbilt University and Lipscomb University have developed a state-of-the-art Decision Support System for a multi-function reservoir system on the Cumberland River that incorporates innovative methods for utilizing water quality modeling applications in an optimization framework. This fully integrated approach addresses environmental quality and energy production issues for hydropower generation planning and forecasting in a way that is beneficial and applicable to today's water resource system stewards and operators.

Water Quality Modeling Approach Characteristics

The Water Quality Decision Support System model is a more efficient tool for planning and forecasting purposes as compared to applications and uses of traditional water quality modeling approaches. Whereas traditional model application methods are plagued by costly run-times, this innovative approach reduces the computational resources and overhead associated with obtaining high- fidelity modeling results. The model fully utilizes results to effectively and comprehensively optimize a hydropower system with environmental constraints, ultimately enhancing the feasibility and applicability of accessing and utilizing "complex water quality modeling" results in a useful manner.

Innovative Improvement of Water Quality Modeling Application

The innovation of this effort lies in the state-of-the-art technique for enabling the delegation of high-fidelity water quality computer simulation results into a form that is efficient for use within an optimization scheme.

Technique. Simplified surrogate models contain high-fidelity results representing a multitude of combinatory conditions and operations obtained with complex water quality simulations. The surrogate models are developed using a neural network application that accesses the high-fidelity simulation results to "learn" the response of a reservoir system and the effect on water quality based on specified hydropower operating conditions and initial water quality conditions.

Implementation. Surrogate models containing high-fidelity model results can be quickly accessed and used in conjunction with the optimization scheme to improve generation based on water quality constraints in a fraction of time associated with performing multiple actual water quality simulations runs for every possible condition.

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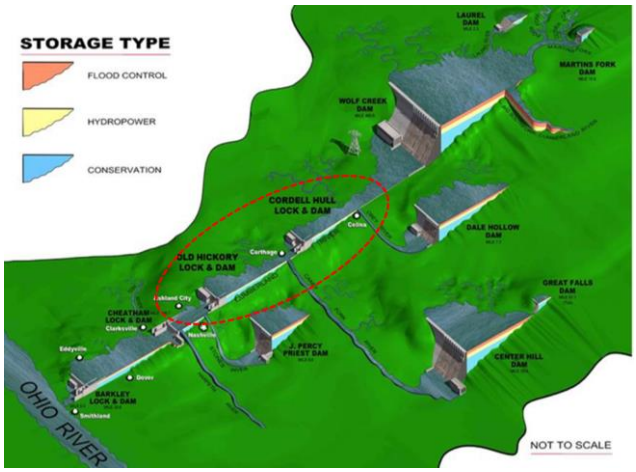

Projects along the Cumberland River with Cordell Hull and Old Hickory hydropower facilities circled as projects of interest. (courtesy of USACE Nashville District).

Model Application & Performance

The modeling approach has been applied to the Old Hickory and Cordell Hull reservoir systems on the Cumberland River and demonstrated an improved ability to increase hydropower generation revenue by approximately 7.4 % while maintaining or improving water temperature and dissolved oxygen concentrations. These results indicate that there are substantial advantages for the extension of this application to larger reservoir systems not only on the Cumberland River, but across the nation as the methodologies are scalable and applicable to a wide array of water quality type applications where there are competing demands for reservoir system resources

Technology Transfer & Industry Value

The innovative use of surrogate models within an optimization framework as implemented in the Decision Support Model is an easily transferable technology to targeted users such as reservoir system planners, engineers, and forecasters. The technology is also scalable to larger and more complex systems containing more reservoirs and hydropower facilities. The value of this tool to the hydropower industry as well as environmental stakeholders include:

- Improved ability to attain increased energy as well as improved water quality, navigation, and management of recreation pool levels.
- Capacity to evaluate benefits and trade-offs between power generation and various ecological resources and anthropogenic interests.

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