Report for 2001CO861B: Eutrophication of Reservoirs on the Colorado Front Range

- Other Publications:
  - Saito, Laurel; Brett Johnson, John Bartholow, and Blair Hanna, 2001, Assessing Effects of Reservoir Operations on the Reservoir Ecosystem Using Food Web-Energy Transfer and Water Quality Models, presented at Hydrology Days, 2001, Department of Civil Engineering, Colorado State University, Fort Collins, CO.

Report Follows:

SYNOPSIS

Project Number: 2001CO861B

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Title: Eutrophication of Reservoirs on the Colorado Front Range

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Focus Categories: WQL

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Problem and research objectives

Eutrophication, or the aging of lakes and reservoirs due to nutrient inputs, has been observed in many, if not most, Colorado Front Range reservoirs. Notable examples include Standley Lake, Lake Loveland, and Horsetooth Reservoir. While eutrophication is a natural process, the rapid pace with which it is occurring in Front Range reservoirs is a cause for concern. For many reservoirs in the region, a shift in use is occurring rapidly as well, away from irrigation water storage and toward municipal water supply, with generally more stringent requirements for water quality. In several reservoirs water quality has already been impacted to the extent that treatability for municipal water supply is affected, and in some cases recreation and aesthetics have been impacted also. In addition to taste and odor concerns associated with excess algae production, elevated levels of total organic carbon (TOC) are an increasing concern because of the harmful and stringently regulated disinfection by-products that result from chlorinating waters high in TOC. Management intervention may be necessary across the region for protecting these beneficial uses over the long term. Certainly, public awareness must be raised on a state-wide level.

To date, Front Range Reservoirs have been studied individually, and management has been addressed on a case-by-case basis. This approach makes sense in that each system is unique limnologically, and the uses of the reservoir are often primarily local. The disadvantages of this approach are, however, that there are very likely common lessons that could be learned regarding causes, effects, and potential solutions to the eutrophication problem. A regional approach, rather than an individual approach, is necessary to explore these commonalities.

Primary 0bjectives of the project are to

1. Review and synthesize existing data and information on the water quality conditions and trends of Front Range water supply reservoirs, concentrating on trophic status.
2. Identify gaps in data needed for determining the causal mechanisms that control trophic status and water quality of these systems.

3. As existing data permit, identify similarities and differences among the reservoirs that would suggest opportunities or constraints for developing regional approaches to management.
4. Review existing reservoir quality models and determine how well the characteristics of the reservoirs in the study match the assumptions and key governing relationships of each model
5. Determine whether a regional approach to modeling makes sense, and if so, which of the available models is most appropriate.

Objectives #4 and #5 have evolved over the course of the study.

Methodology

The research methodology has two components, the first is to develop, implement, and evaluate the results of a survey of Front Range water suppliers. And the second is to review and evaluate existing reservoir water quality models.

The survey was developed from an initial meeting with Front Range water suppliers. The survey was implemented by meeting with each participant and then having them supply detailed information on study reservoir characteristics and water quality issues of importance to them. The results were complied in an Access database for analysis.

Reservoir water quality models were evaluated by matching the assumptions and governing equations of each model to study reservoir characteristics. For a few cases, the models were actually run and results evaluated. A review of commonly applied eutrophication models including those from Alex Horne, BATHTUB, Chapra and Canale, CE-QUAL-W2, DYRESM-CAEDYM, EUTROMOD, Molot et al., MINLAKE, and Vollenweider was conducted to evaluate the model characteristics and ease of calibration. Models for further testing were selected based on the ability to have a working model within the time constraints (2-3 months) and the ability to model dissolved oxygen and TP, which are the causes of water quality concerns that the operators and managers have. The selected models by Alex Horne, Chapra and Canale, and Vollenweider were then applied to three reservoirs, Aurora Reservoir, Horsetooth Reservoir, and Standley Lake, that had readily available monitoring data to evaluate the ability to adequately model the constituents of concern and the model's ease of use.

Principal findings and significance

The survey identified a fairly wide range of reservoir physical characteristics, including size, depth, residence time and age. All but one of the study reservoirs was primarily off-line storage, meaning that more than half of the inflow was from out-of-basin sources. The top 5 issues identified via the survey were, in decreasing order of importance

1. nonpoint pollution
2. nutrient loading
3. watershed protection
4. eutrophication/trophic status, and
5. algae blooms.

Virtually every water supplier on the Colorado Front Range that depends on reservoir storage is concerned about these issues. The State of Colorado will be attempting to set nutrient criteria for lakes and reservoirs in the near future. The levels of nutrients that are important for many of the

Front Range drinking water reservoirs are low, and difficult to measure (especially phosphorus). Different sampling and analytical methods or different laboratories can yield very different results. Yet there is no consensus on what monitoring and approaches and laboratory methods should be used to measure standards compliance, much less on what numerical limits would be appropriate.

Based on the model characteristics and results, Chapra and Canale's model incorporating sediment feedback appears most favorable for implementation for most of the reservoirs looking at low cost, low time requirement solutions. The Alex Horne model is limited in the fact that it does not model anoxia over winter and does not allow changes in reservoir management and both Alex Horne and Vollenweider models are limited in that they don't consider the impact sediments have in buffering the change in TP once loading is reduced. Of the more complex models, CE-QUAL-W2 was the only one implemented due to the excessive data input required for DYRESM-CAEDYM and the inability to obtain a working model of MINLAKE. In addition, a decision tree was developed to aid in determination if modeling is a feasible and, if so, it helps select appropriate models based on reservoir and model characteristics and availability of time and funding.

The overall conclusion of the study is that future collaboration on monitoring is absolutely essential for effective management of Front Range drinking water supply reservoirs, especially in a regulatory setting. Collaboration on modeling may prove helpful as well, though the varying characteristics of the reservoirs may make application of a single model rather difficult. For management, information exchange on the effectiveness of management alternatives is the logical first step. Entrenched local policies, on recreational use of reservoir in particular, may make a common approach to management difficult in the near term. The Colorado Lake and Reservoir Management Association, CLRMA, continues to be an effective forum for information exchange and is the likely forum for future collaboration on monitoring, management, and modeling.