CONF-9102100--1

U. S. Department of Energy Reservoir Research Activities at Oak Ridge National Laboratory

Steven F. Railsback
Environmental Sciences Division
Oak Ridge National Laboratory[1]

CONF-9102100--1
DE91 009933

Introduction

The U. S. Department of Energy (DOE) does not directly manage large reservoirs, but DOE laboratories conduct research on reservoir monitoring, assessment, and enhancement under several activities. These activities include (1) studies and remedial actions for reservoirs affected by releases from DOE facilities, (2) industry-sponsored research on reservoir and stream fish, (3) climate change research, (4) hydropower impact assessment studies conducted for the Federal Energy Regulatory Commission (FERC), and (5) the DOE hydropower program. These activities fall under DOE's missions of providing support for environmentally sound energy technologies and managing the legacies of past waste disposal practices at DOE facilities.

Contaminant Transport and Fate Studies

Several environmental laws require federal facilities to investigate the need for remediation of contaminants that may have migrated off site. DOE facilities at Hanford, Washington, and Oak Ridge, Tennessee, are conducting such offsite contamination studies of downstream reservoirs.

Runoff from the three DOE plants at Oak Ridge drains through several small streams into Watts Bar Reservoir, part of the Tennessee River reservoir system operated by the Tennessee Valley Authority (TVA). Oak Ridge National Laboratory (ORNL) staff are conducting field studies to determine the extent and nature of contamination in the reservoir. The contaminants of greatest concern are radionuclides and heavy metals (especially mercury). Concentrations of these compounds in water, sediments, and fish are being measured. These concentration measurements are used to estimate (1) human health risks through all potential exposure pathways, and (2) ecological risks to exposed organisms. Preliminary risk assessments using historic data have been used to determine what contaminants and pathways require further investigation, and these additional investigations are currently underway (Hoffman et al. 1990, Suter 1990).

Part of the offsite remedial action research at Oak Ridge involves modeling contaminant transport and fate in the reservoir. A model developed by TVA (Bender et al. 1990) has been calibrated for Watts Bar reservoir and can be used to simulate transport of soluble contaminants and deposition of sediment-associated contaminants.

---

[1]P. O. Box 2008, Oak Ridge, TN, 37831-6036. The Oak Ridge National Laboratory is managed by Martin Marietta Energy Systems, Inc., under contract DE-AC05-84OR21400 with the U.S. Department of Energy.

MASTER

DISCLAIMER

However, this model, like most reservoir models, is not designed to simulate remobilization of contaminants from the reservoir sediments. Remobilization may occur through scouring of sediments during high flows (the Tennessee River reservoirs are generally shallow with short residence times and have relatively high velocities during high flows) and as a result of biological activity at the sediment-water interface. Development of a model capable of simulating contaminant remobilization is a current ORNL research activity.

One objective of the RCRA offsite investigations is to design remedial actions where they are necessary. At Oak Ridge, the only reservoir contaminant removal action required to date is for confining sediments from a small embayment from entering the reservoir. Later investigations may include comparison of remedial action alternatives for contamination buried in the deep reservoir sediments.

Fish Population Modeling

The Electric Power Research Institute is funding research at ORNL to develop individual-based fish life cycle and population models that will be appropriate for assessment of impacts to reservoir and tailwater fisheries. These models are innovative because the life cycle, growth, and location of each individual fish is tracked separately; other commonly applied fish population models simulate members of an age class using a single set of aggregate parameters. The individual-based models offer a number of advantages (Huston et al. 1988) by allowing simulation of the ability of populations to compensate for mortality and other stresses (e.g., turbine mortality or water quality effects) and simulation of the effects of microhabitat changes (e.g., instream flow changes). The project is now adapting the individual-based model to stream smallmouth bass populations in reservoir tailwater sites in Minnesota and Virginia.

Climate Change Research

The DOE conducts an extensive climate change and carbon dioxide research program that includes activities relevant to reservoir water quality. One study directly related to reservoirs investigated potential effects of climate change on fish habitat in a southeastern reservoir (Chang et al. 1991). Input to a reservoir model developed and calibrated by TVA for Douglas Reservoir, near Knoxville, Tennessee, was modified to simulate climate change scenarios. The climate change scenarios were based on simulations by three general circulation models of climate with doubled atmospheric carbon dioxide concentrations. The reservoir model was then used to predict water temperature and dissolved oxygen concentrations under current conditions and under the climate change scenarios. The availability of adult striped bass habitat, as defined in earlier ORNL studies (Coutant 1985) by temperature and dissolved oxygen criteria, was compared among the different scenarios. All of the climate change scenarios were found to result in significant reductions in striped bass habitat, mostly as a result of increased water temperatures. Although a number of simplifying assumptions were made in this study, it indicates that climate change could have significant effects on reservoir water quality and fisheries

Environmental Impact Assessment of Hydropower Projects

FERC is an independent unit of DOE that regulates non-federal hydropower development. FERC must assess environmental impacts prior to issuing an operating license or an exemption from licensing for new projects or a new license for an old project. ORNL and other DOE laboratories conduct some of FERC's more complex environmental assessment studies, especially basin-wide and cumulative assessments of multiple projects (Cada and Hunsaker 1990).

Examples of FERC hydropower assessments include environmental impact statements prepared for multiple projects in the Owens River (California) basin, the San Joaquin (California) basin, the Snohomish River (Washington) basin, the upper Ohio River (Pennsylvania, West Virginia, Kentucky, and Ohio) basin, and projects currently underway in the Skagit and Nooksack river basins (Washington). An impact statement was also prepared at ORNL for the proposed Susitna Project in Alaska. The upper Ohio River basin assessment was innovative because the effects of the proposed projects on dissolved oxygen concentrations on the system of navigation reservoirs are clearly cumulative and interactive. For this assessment aerated spill flows, as water quality mitigation, were designed to provide optimal hydropower generation while meeting water quality criteria at a basin-wide scale (Railsback et al. 1989).

The FERC hydropower assessment studies have provided the opportunity to develop and apply methods for such reservoir-related issues as (1) instream flow needs for fisheries, riparian vegetation, recreation, and aesthetics; (2) turbine mortality; (3) dissolved oxygen and temperature changes and their effects on fish growth; (4) application of systems analysis methods to mitigation design; and (5) tradeoffs between economic and noneconomic benefits of water resources.

Studies of Environmental Mitigation for Hydropower

DOE is conducting a multi-year study of environmental mitigation practices at hydroelectric projects (Railsback et al. 1991). Many of the results of this study will be directly applicable to federal reservoir management. The mitigation study currently includes two activities. The first is collection and analysis of data on mitigation measures used at non-federal projects for dissolved oxygen (aeration), instream flows for fisheries, and upstream and downstream fish passage. The second activity is the analysis of costs and benefits of example mitigation measures at case study sites. The environmental analyses for this study are being conducted at ORNL and the cost analyses are being conducted by DOE's Idaho National Engineering Laboratory.

Data on mitigation practices were obtained from ~300 projects licensed by FERC after 1979; this number represents 40% of all the projects licensed during this time interval that were identified from FERC records as having relevant mitigation requirements.

The projects for which information was obtained include ~60 with dissolved oxygen mitigation requirements, 170 with instream flow requirements, 35 with upstream fish passage facilities, and 85 with downstream fish passage facilities. The information obtained from projects includes the specific mitigation requirements imposed on the project, the specific objectives or purposes of mitigation, the mitigation measures chosen to meet the requirement, the kind of postproject monitoring conducted, and the costs of mitigation. These data are being used to characterize existing mitigation practices and to identify mitigation research priorities. One observation apparent from the data is that monitoring adequate to determine the benefits of mitigation is rarely conducted.

The case study analyses are being used to compare the costs and biological benefits of different mitigation measures, to the extent they can be quantified. Innovative measures of benefits are being applied when necessary; an example is the use of a fish bioenergetics model to quantify the benefits of increased dissolved oxygen concentrations to fish growth and health.

The DOE hydropower mitigation study is expected to expand in future years. Additional mitigation issues such as instream flows for recreation and riparian vegetation may be added. Research on the specific topics identified as priorities will be initiated. The overall goal of the continuing project is to reduce costs of mitigation at hydroelectric projects.

Research Priorities

DOE has not prioritized its research on issues related to reservoir water quality. However, the following are important topics of current research efforts.

Contaminant remobilization. Little is known about the mechanisms and rates of physical and biological remobilization of contaminants in reservoir sediments. The hydraulics of shallow reservoirs are unique, so remobilization processes are different than those in rivers and lakes. Models of sediment resuspension and other remobilization processes are needed.

Risk assessment methods. Remedial action decisions are based on assessments of the human health and ecological risks posed by contaminants. Risk assessment methods, especially for processes occurring at the sediment-water interface, need improvement. Sediment quality criteria are still in a relatively early stage of development and the relevant chemical processes and analytical techniques are complex.

Cost-effective mitigation for hydropower projects. In its role as advocate of environmentally sound energy development, DOE actively seeks ways to reduce environmental impacts of hydropower development at acceptable costs. Specific issues identified as needing research include improved methods to determine instream flow needs and alternatives to spill flows for aeration at low-head dams.

References Cited[2]

Bender, M. D., G. E. Hauser, M. C. Shiao, and W. D. Proctor. 1990. BETTER: A Two-Dimensional Reservoir Water Quality Model, Technical Reference Manual and User's Guide. TVA Report no. WR28-2-590-152, Tennessee Valley Authority Engineering Lab, Norris, Tennessee.

Cada, G. F., and C. T. Hunsaker. 1990. Cumulative impacts of hydropower developments: reaching a watershed in impact assessment. *The Environmental Professional* 12:2-8.

Chang, L. H., S. F. Railsback, and R. T. Brown. 1991. Use of a reservoir water quality model to simulate global climate change effects on fish habitat. Submitted to *Climatic Change.*

Coutant, C. C. 1985. Striped bass, temperature, and dissolved oxygen: A speculative hypothesis for environmental risk. *Transactions of the American Fisheries Society* 114:31-61.

Hoffman, F. O., et al. 1990. Preliminary screening of contaminants in off-site surface water environment downstream of the U.S. Department of Energy Oak Ridge Reservation. ORNL/ER-9, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Huston, M. A., D. L. DeAngelis, and W. M. Post. 1988. New computer models unify ecological theory. *BioScience* 38(10):682-691.

Railsback, S. F., G. F. Cada, L. H. Chang, and M. J. Sale. 1991. Review of mitigation methods for fish passage, instream flows, and water quality. In: *WATERPOWER '91*. D. D. Darling, ed. American Society of Civil Engineers, New York.

Railsback, S. F., M. J. Sale, and S-Y. Chang. 1989. Development of flow releases for water quality protection at hydroelectric plants at Ohio River Basin navigation dams. In: *Water Resources Planning and Management, Proceedings of the 16th Annual Conference.* S. C. Harris, ed. American Society of Civil Engineers, New York.

Suter, G. W. II. 1991. Screening level risk assessment for off-site ecological effects in surface waters downstream from the U.S. Department of Energy Oak Ridge Reservation. ORNL/ER-8, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

[2]A bibliography of ORNL publications related to reservoirs and hydropower is available from the author upon request.