DOE/ID-10510(96-97)
Distribution Category: UC-1220

DOE Hydropower Program Biennial Report 1996–1997 (with an updated annotated bibliography)

Bennie N. Rinehart
James E. Francfort
Garold L. Sommers
Glenn F. Cada[a]
Michael J. Sale[a]

Published June 1997

Idaho National Engineering and Environmental Laboratory
Lockheed Martin Idaho Technologies Company
Idaho Falls, Idaho 83415

Prepared for the
U.S. Department of Energy
Assistant Secretary for Energy Efficiency and Renewable Energy
Under DOE Idaho Operations Office
Contract DE-AC07-94ID13223

a. Oak Ridge National Laboratory.

DISCLAIMER

ABSTRACT

This report, the latest in a series of biennial Hydropower Program reports sponsored by the U.S. Department of Energy, summarizes the research and development and technology transfer activities of fiscal years 1996 and 1997. The report discusses the activities in the six areas of the hydropower program:

- Advanced Hydropower Turbine Systems
- Environmental Research
- Hydropower Research and Development
- Renewable Indian Energy Resources
- Resource Assessment
- Technology Transfer.

The report also includes an annotated bibliography of reports pertinent to hydropower, written by the staff of the Idaho National Engineering and Environmental Laboratory,[a] Oak Ridge National Laboratory, Federal and state agencies, cities, metropolitan water districts, irrigation companies, and public and independent utilities. Most reports are available from the National Technical Information Service.

a. In January 1997, the name of the Idaho National Engineering Laboratory (INEL) was changed to the Idaho National Engineering and Environmental Laboratory (INEEL). INEEL will be used throughout the text of the document, except where use of INEL is historically important.

ACKNOWLEDGMENTS

The authors thank Peggy M. Brookshier and John V. Flynn of the Department of Energy for their active participation and leadership of hydropower research and development activities.

CONTENTS

ABSTRACT iii

ACKNOWLEDGMENTS v

INTRODUCTION AND BACKGROUND 1

Mission of the Hydropower Program 1

Description of the Technology 1

Applications and Uses of the Technology 4

ADVANCED HYDROPOWER TURBINE SYSTEMS 5

Advanced Hydropower Turbine System Program 5

ENVIRONMENTAL RESEARCH 8

Background 8

Environmental Mitigation Studies 9

HYDROPOWER RESEARCH AND DEVELOPMENT 10

RENEWABLE INDIAN ENERGY RESOURCES 12

RESOURCE ASSESSMENT 13

Computer Software to Aid Assessment of Resource Potential 13

Status of the Project to Assess Hydropower Potential 13

TECHNOLOGY TRANSFER 15

Technology Transfer Activities 15

ANNOTATED BIBLIOGRAPHY OF HYDROPOWER PUBLICATIONS 16

Technology Development 16

Resource Assessment 24

Environmental Research 28

National Energy Strategy 65

Engineering Research and Development 66

Technology Transfer 75

Legal and Institutional Aspects 78

General 81

Undated 82

DOE Hydropower Program Biennial Report 1996–1997

INTRODUCTION AND BACKGROUND

Mission of the Hydropower Program

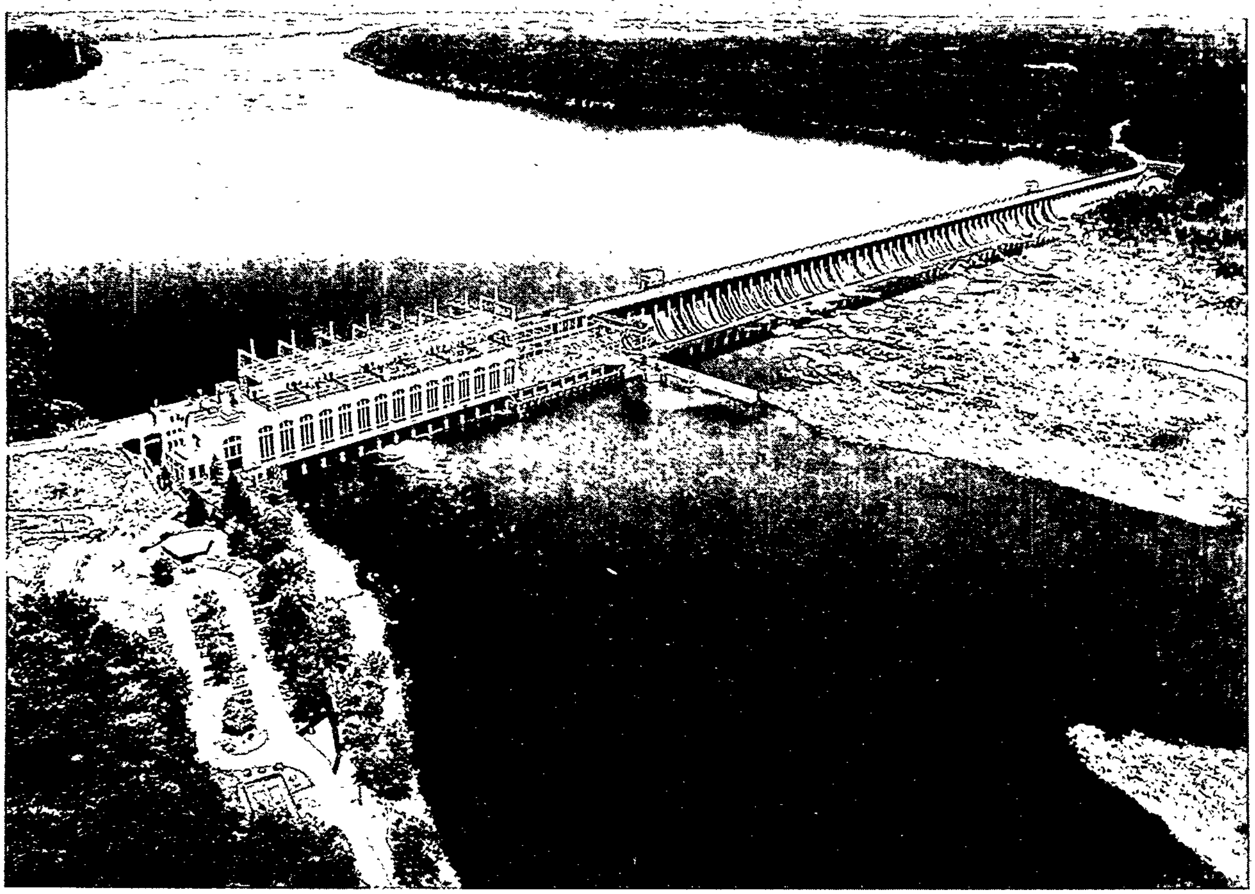
The mission of the U.S. Department of Energy's (DOE's) Hydropower Program is to develop, conduct, and coordinate research and development with industry and other Federal agencies to improve the technical, societal, and environmental benefits of hydropower. The DOE Hydropower Program is a part of the Office of Geothermal Technologies. The DOE Idaho Operations Office manages the Program, and directs the planning and performance of research, development, proof of concept, and technology transfer activities, with direct input from utilities and industrial groups, to encourage timely and cost-beneficial applications of research. In addition to providing the Departmental focus for expertise in these research areas, the Program interacts routinely with the commercial sector to foster cooperative and cost-shared energy supply development projects. This continuing close working relationship is essential to facilitate the development, commercialization, and use of renewable resource technologies, both nationally and internationally.

Description of the Technology

Hydropower plants capture the kinetic energy of falling water to generate electricity. A turbine and a generator convert the energy from the water to mechanical and then electrical energy. The turbines and generators are installed either in or adjacent to dams, or use pipelines (penstocks) to carry the pressured water below the dam or diversion structure to the powerhouse. Hydropower projects are generally operated in a run-of-river, peaking, or storage mode. Run-of-river projects use the natural flow of the river and produce relatively little change in the stream channel and stream flow. A peaking project impounds and releases water when the energy is needed. A storage project extensively impounds and stores water during high-flow periods to augment the water available during low-flow periods, allowing the flow releases and power production to be more constant. Many projects combine the modes. The power capacity of a hydropower plant is primarily the function of two variables: (1) flow rate expressed in cubic feet per second (ft^3/s), and (2) the hydraulic head, which is the elevation difference the water falls in passing through the plant. Project design may concentrate on either of these variables or both.

The principal advantages of using hydropower are its large renewable domestic resource base, the absence of polluting emissions during operation, its capability in some cases to respond quickly to utility load demands, and its very low operating costs. Disadvantages can include high initial capital cost and potential site-specific and cumulative environmental impacts. Potential environmental impacts of hydropower projects include altered flow regimes below storage reservoirs or within diverted stream reaches, water quality degradation, mortality of fish that pass through hydroelectric turbines, blockage of upstream fish migration, and flooding of terrestrial ecosystems by new impoundments. However, in many cases, proper design and operation of hydropower projects can mitigate these impacts. Hydroelectric projects also include beneficial effects such as recreation in reservoirs or in tailwaters below dams.

Hydropower technology can be categorized into two types: conventional and pumped storage. Conventional hydropower plants use the available water energy from a river, stream, canal system, or reservoir to produce electrical energy. In conventional multipurpose reservoirs and run-of-river systems, hydropower production is just one of many competing purposes for which the water resources may be used. Competing water uses include irrigation, flood control, navigation, and municipal and industrial water supply. Pumped storage plants pump the water resource, usually



Philadelphia Electric Co., Congowingo Hydroelectric Project (91-452-1-1).

through a reversible turbine, from a lower reservoir to an upper reservoir. While pumped storage facilities are net energy consumers, they are valued by a utility because they can be rapidly brought on-line to operate in a peak power production mode. The pumping to replenish the upper reservoir is performed during off-peak hours when electricity costs are lowest. This process benefits the utility by increasing the load factor and reducing the cycling of its base load units. In most cases, pumped storage plants run a full cycle every 24 hours.

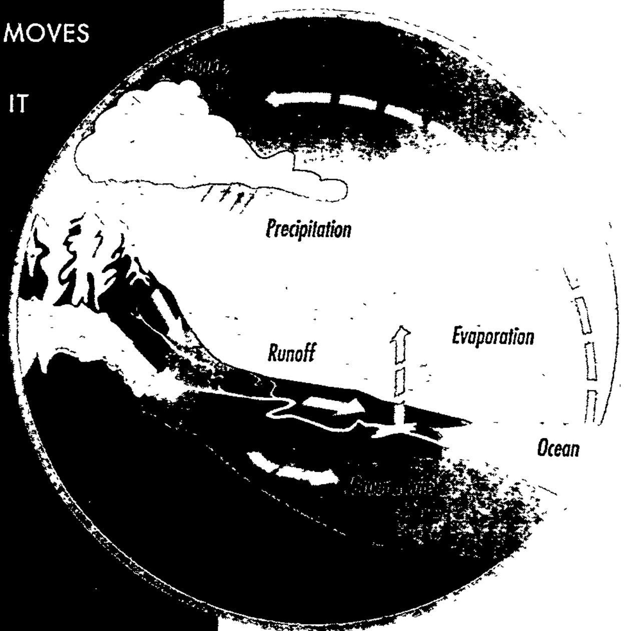
Most conventional hydropower plants include six major components:

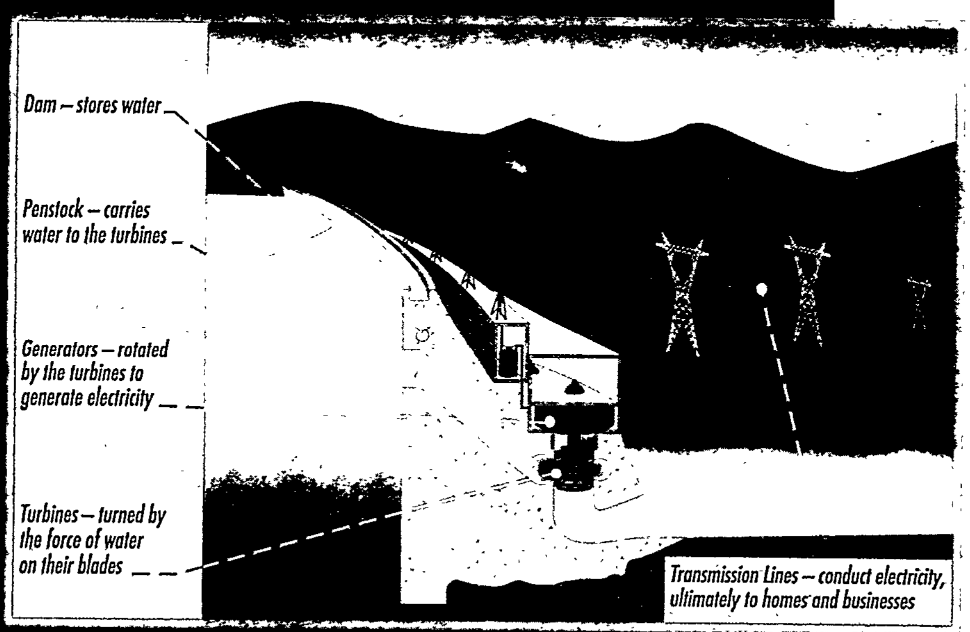
1. Dam. Controls the flow of water and increases the elevation to create the head. The reservoir that is formed is, in effect, stored energy.
2. Penstock. Carries water from the reservoir to the turbine in a power plant.
3. Turbine. Turned by the force of water pushing against its blades.
4. Generator. Connects to the turbine and rotates to produce the electrical energy.
5. Transformer. Converts electricity from the generator to usable voltage levels.
6. Transmission lines. Conduct electricity from the hydropower plant to the electric distribution system.

The following figure illustrates how hydropower works:

HOW HYDROPOWER WORKS

THE HYDROLOGIC CYCLE: WATER CONSTANTLY MOVES THROUGH A VAST GLOBAL CYCLE, IN WHICH IT EVAPORATES FROM LAKES AND OCEANS, FORMS CLOUDS, PRECIPITATES AS RAIN OR SNOW, THEN FLOWS BACK TO THE SEA. THE ENERGY OF THIS WATER CYCLE, WHICH IS DRIVEN BY THE SUN, IS TAPPED MOST EFFICIENTLY WITH HYDROPOWER.





Types of Hydropower Facilities

Impoundment Hydropower – Uses a dam to store water (see illustration). Water may be released either to meet changing electricity needs or to maintain a constant reservoir level.

Diversion Hydropower – Channels a portion of the river through a canal or a penstock, but may require a dam.

Pumped Storage – Pumps water from a lower reservoir to an upper reservoir at times when demand for electricity is low. During periods of high electrical demand, the water is released back to the lower reservoir to generate electricity.

Applications and Uses of the Technology

The major application for hydropower energy is in the bulk power market, where it accounts for about 78,000 MW conventional capacity and 18,000 MW of pumped storage capacity, or about 11% of the electric generating capacity in the United States. Plants are owned by Federal and state agencies, cities, metropolitan water districts, irrigation companies, and public and independent utilities. Individual persons also own small plants at remote sites for their own energy needs and for sale to utilities under the Public Regulatory Policies Act (PURPA). Hydropower is an essential contributor in the national power grid because of its ability to respond in seconds to large and rapidly varying loads, which other base load plants with steam systems powered by combustion or nuclear processes cannot accommodate.

The Dayton Dam on the Fox River is an example of a developed Illinois hydropower plant. The photo shows the Dayton power plant on the left side and the Dayton Reservoir dam in the background. The Dayton plant was constructed in the 1920s and has a nameplate rating of 3.6 MW. It has an additional undeveloped capacity of 630 kW at this 23-foot structure.

Advanced Hydropower Turbine System Program

The objectives of the DOE Advanced Hydropower Turbine System (AHTS) Program are to design, develop, build, and test one or more environmentally friendly advanced turbine system(s). The objectives will be achieved through the development of new concepts, application of cutting-edge technology, and exploration of innovative solutions. The DOE Program received guidance from a technical committee consisting of environmental and engineering experts from government and industry.

The AHTS Program was originally planned in three phases. Phase I—develop conceptual engineering designs; Phase II—build and test fully engineered models of the most promising designs; and Phase III—build and test full-scale prototypes of the most promising models in actual operating hydropower plants. Each phase of work was planned to be cost-shared by industry and DOE.

The request for proposals for Phase I was issued in late 1994. The proposals were evaluated and the cost-shared contracts awarded to Alden Research Laboratory, Inc. and Voith Hydro, Inc. in October 1995. Alden Research Laboratory, Inc. completed their conceptual design in February 1997. Voith Hydro, Inc. completed their conceptional design in July 1997.

The Alden Research Laboratory, Inc. conceptual design used as a starting point an existing pump impeller for developing a fish-tolerant turbine runner. The focus of this research project was to develop a new runner geometry that is effective in downstream fish passage and hydroelectric power studies that had been previously conducted to identify probable sources of injury to fish passing through hydraulic turbines. Criteria relative to hydraulic characteristics that are favorable for fish passage were prepared based on a reassessment of the available information. Important criteria used to develop the new runner design included low pressure change rates, minimum absolute pressures, and minimum shear. Other criteria that are reflected in the runner design are a minimum number of blades, minimum total length of leading edges, and large flow passages.

The Voith Hydro, Inc. conceptual design is divided into three tasks. Task 1 investigated a broad range of environmental issues and how the issues differed throughout the country. Three families of design concepts were chosen for further investigation addressing the most significant problem elements. Task 2 addressed fish physiology and turbine physics. During this task, the design team studied the state of available information, the mechanisms for injury, and methods to predict injury, and defined which design elements to address to improve fish survival at hydro sites. Task 3 investigated individual design elements needed for the refinement of the three concept families defined in Task 1. Advanced numerical tools for flow simulation in turbines are used to quantify characteristics of flow and pressure fields within turbine water passage.

The most active component of DOE's environmental research over the past 2 years has been deriving biological design criteria in support of the AHTS Program. Phase I of this AHTS Program involved considerable Computational Fluid Dynamics (CFD) modeling and engineering design studies to develop novel designs for fish-friendly turbines, i.e., turbines in which mortality of entrained fish is small. To accomplish this goal, quantitative biological criteria are required; that is, numbers which define a "safety zone" for fish within which all of the injury/mortality mechanisms experienced by turbine-passed fish (rapid and extreme water pressure changes, shear forces, cavitation, strike, and abrasion) are at acceptable levels for survival. If one of these injury mechanisms has over-riding importance compared to others, the designers could focus their efforts to "design out" this stress in the new generation of turbines.

Because the relative importance of each of these stresses is difficult to discern from field studies at hydropower plants, a critical review of biological and engineering literature was performed (Cada et al. 1997, DOE/ID-10578; see in Bibliography under Environmental Research, 1997). Published laboratory bioassays and similar studies of the responses of fish to the component stresses of turbine passage were reviewed, with the goal of deriving biological criteria for the turbine designers. In many cases there were few or no data to support quantitative biological criteria, so laboratory and field experimental techniques that could be used to fill gaps in existing information were described. Finally, the published literature on fish behavior was explored to determine whether particular species or sizes of fish are likely to exhibit predictable, directed movements, knowledge of which would be useful to turbine designers. The figure on the next page illustrates the fish passage issues discussed above.

In April 1996, the AHTS Program Technical Committee met to discuss the progress of the conceptual designs and the status of the program. At this meeting, the Technical Committee modified the scope of work for Phase II to include the development of:

- Biological Information and Hardware
- Detailed Design, Engineering, and Model Testing.

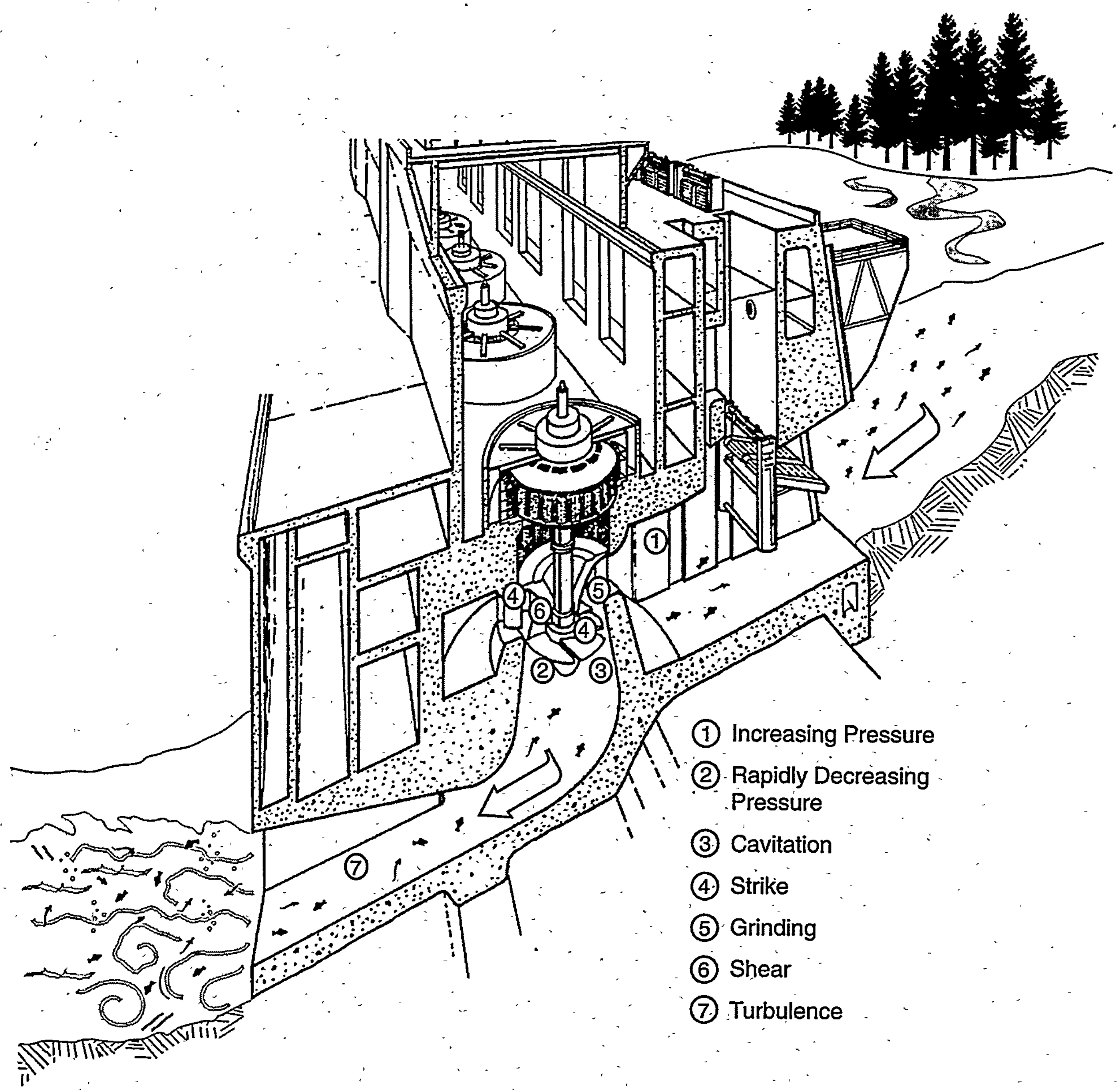
In October 1996, the Technical committee agreed that Phase II activities would initially focus on the following:

1. Developing the biological criteria for the high-priority issue (shear) with supporting laboratory studies.

2. Testing of a new runner design developed during the conceptual design phase. Includes laboratory and/or field tests for biological effects.

3. Developing instrumentation to visualize the passage of fish through a turbine system.

The AHTS Program needs to be successful to preserve the current U.S. conventional hydropower capacity of about 78,000 MW. Over 13,000 MW of capacity is up for relicensing by 2005. As a result of relicensing consultations, these existing projects may have to address environmental issues for the first time. Any loss in hydropower capacity could result in an increased dependence on foreign oil, and jeopardize energy security.

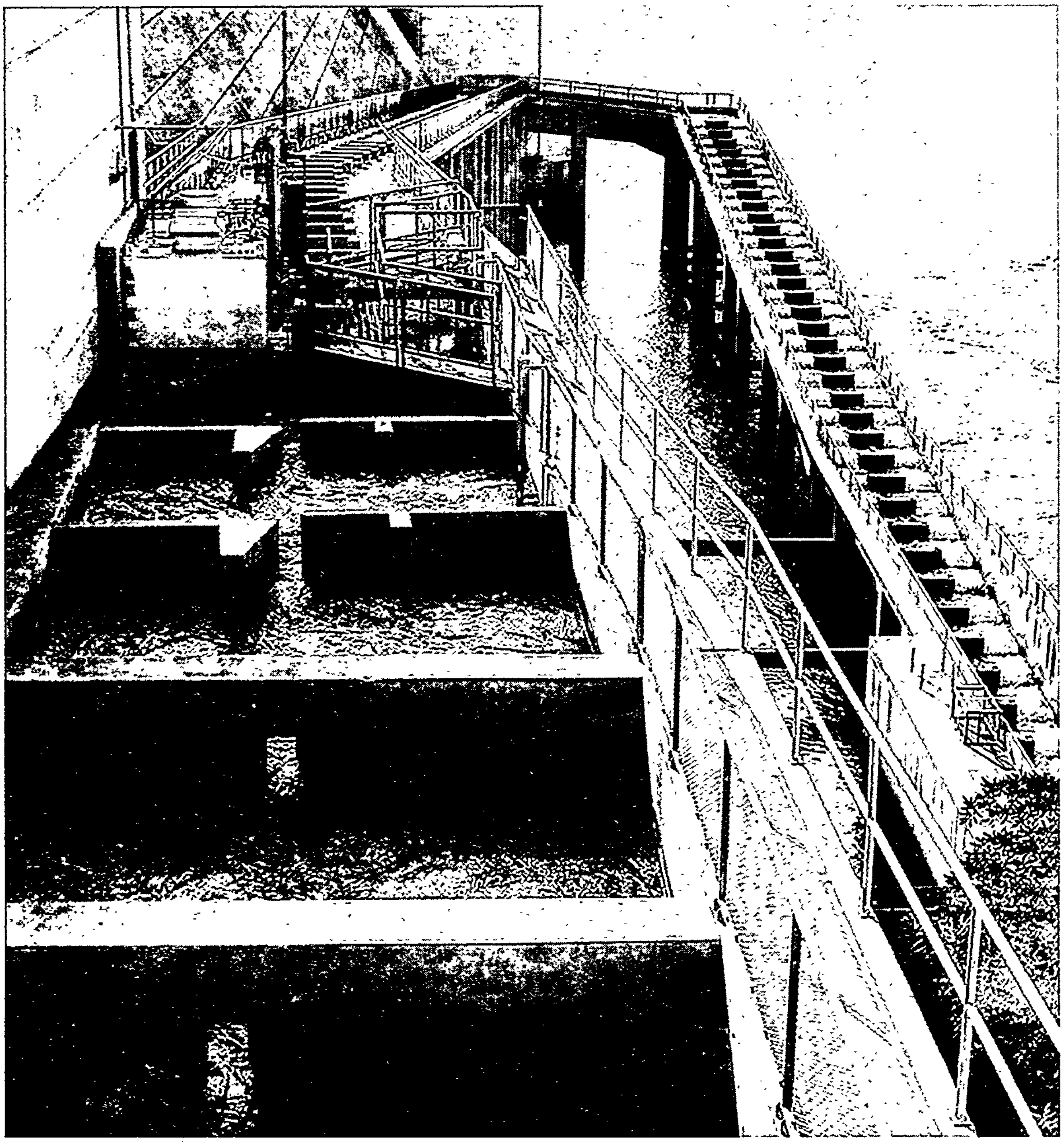


Hydropower turbine system—fish passage issues.

ENVIRONMENTAL RESEARCH

Background

The DOE Hydropower Program supports the development of environmentally sound hydroelectric resources and is conducting research on the unresolved environmental issues associated with hydropower development. Successful, cost-effective mitigation of environmental impacts is a critical element in successful project development. Recommendations to DOE from the hydropower industry, the Federal Energy Regulatory Commission, power marketing administrations, and the public have identified environmental research and development as a continuing need.



Fish ladder located on the left side of the U.S. Army Corps of Engineers' Lower Monumental Project on the Snake River in Washington State (92-513-3-24).

The Idaho National Engineering and Environmental Laboratory (INEEL) is DOE's lead laboratory for its Hydropower Program, with Oak Ridge National Laboratory (ORNL) the lead laboratory for environmental research on hydropower-related issues. Since 1978, the Environmental Sciences Division at ORNL has provided technical assistance to DOE and conducted research on the environmental effects of hydropower development. During 1996–97, ORNL continued its environmental research on major issues critical to hydropower development, concentrating primarily on DOE's Advanced Hydropower Turbine System Program. Technology transfer of the environmental expertise developed at ORNL is pursued through open-literature publications (see the Annotated Bibliography), intern training programs for students and faculty, and interactions with state and Federal regulatory agencies. Recent open-literature publications have dealt with the following subjects: hydrology; assessment methods for instream flow mitigation; relations between fish, flows, and river channel geomorphology; water quality effects of hydropower development; cumulative impacts of multiple projects; upstream and downstream fish passage issues; and the modeling response of fish populations to hydropower releases.

Environmental Mitigation Studies

DOE has published two Environmental Mitigation studies that were designed to clarify and resolve the controversial environmental mitigation issues with which the hydropower industry is confronted. They are:

Volume I.	Current Practices for Instream Flow Needs, Dissolved Oxygen, and Fish Passage [Sale et al. 1991; DOE/ID-10360(V1)]
Volume II.	Benefits and Costs of Fish Passage Mitigation Practices [Francfort et al. 1994; DOE/ID-10369(V2)]

These studies provide guidance to hydropower developers, regulators, and natural resource managers concerning the most effective mitigation practices and regulations. The studies are also intended to help prioritize research and development efforts by DOE, as well as in other agencies and organizations. These case-study analyses serve as guidance manuals for the selection and design of appropriate mitigation practices, targeted at a broad audience of developers, regulators, and resource managers.

HYDROPOWER RESEARCH AND DEVELOPMENT

Hydropower provides over 10% of the electricity and is the largest renewable energy source in the United States. Hydropower provides a relatively low-cost, renewable source of electricity that can be used on a vast scale, in some cases to meet demands for peaking power, and to minimize overall power production costs.

Although hydropower does not discharge pollutants into the environment, it is not free from adverse environmental effects. Efforts to reduce environmental problems associated with hydropower operations, such as providing safe fish passage and improved water quality, have received considerable attention in the past decade both at Federal facilities and non-Federal facilities licensed by the Federal Energy Regulatory Commission. Improvements in water quality in the Nation's rivers and the relicensing requirements for hundreds of non-Federal hydropower facilities provide an opportunity to reexamine operations and consider the possibility of restoring fisheries. Ongoing efforts to ensure the safety of dams and use newly available computer technologies to optimize operations provide additional opportunities to improve the environment. Yet, there are many unanswered questions about how best to maintain the economic viability of hydropower in the face of increased demands to protect fish and other environmental resources.

Many agencies and utilities actively pursue research and development (R&D) programs to improve the environmental performance of hydropower facilities. However, there is general acknowledgment that the level of available funding is likely to decline with reduced Federal budgets and increased deregulation of the electric utility industry.

A report was prepared in March 1997 as a first attempt at developing a single point source for information on current and proposed hydropower R&D, environmental as well as engineering, being conducted by government agencies, utilities, and other private companies. Entitled *Hydropower Research and Development* (DOE/ID-10575), this report compiles summaries of hydropower R&D activities and ascertains the level of funding directed at improved environmental protection. It is anticipated that such a compilation can help the government and the hydropower industry to develop a program to ensure that limited available resources are directed in the most beneficial ways. That is, that there is no unnecessary duplication, that research dollars are directed at priority issues, and that activities are coordinated and have adequate provisions for high-quality work that is transferable to other sites. It is hoped that this report will be useful to those conducting hydropower R&D, particularly during these times of declining R&D funding.

The effort to prepare this report was initiated when DOE convened a workshop of the Hydropower Coordination Team, a group of Federal agency and hydropower industry representatives, in April 1996. An information form was designed at the meeting and participants were encouraged to provide information on their ongoing and planned R&D activities. An initial deadline of July 1996 was set for completing the report. Delays in meeting deadlines and increased interest by the National Marine Fisheries Service, Office of Habitat Conservation, led to hiring a consultant in October 1996 to encourage participation by fish resource management agencies, analyze incoming information, and prepare this report.

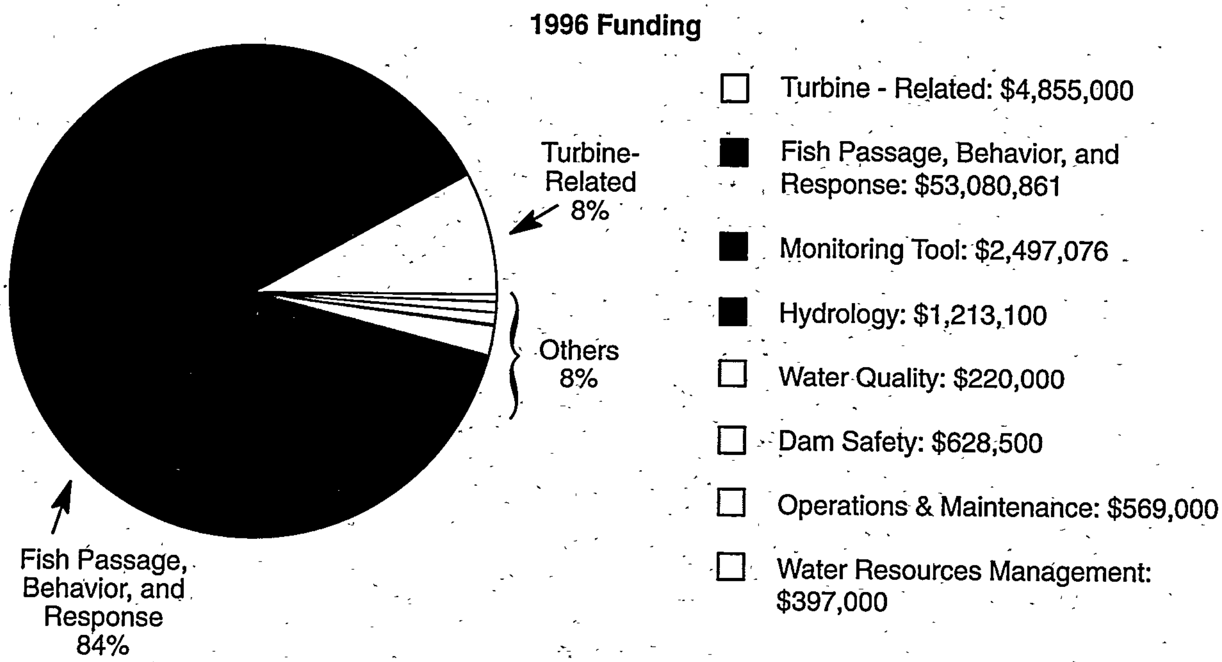
The report includes descriptions of ongoing and planned R&D activities, 1996 funding, and anticipated future funding. Summary information on R&D projects and funding is classified into eight categories:

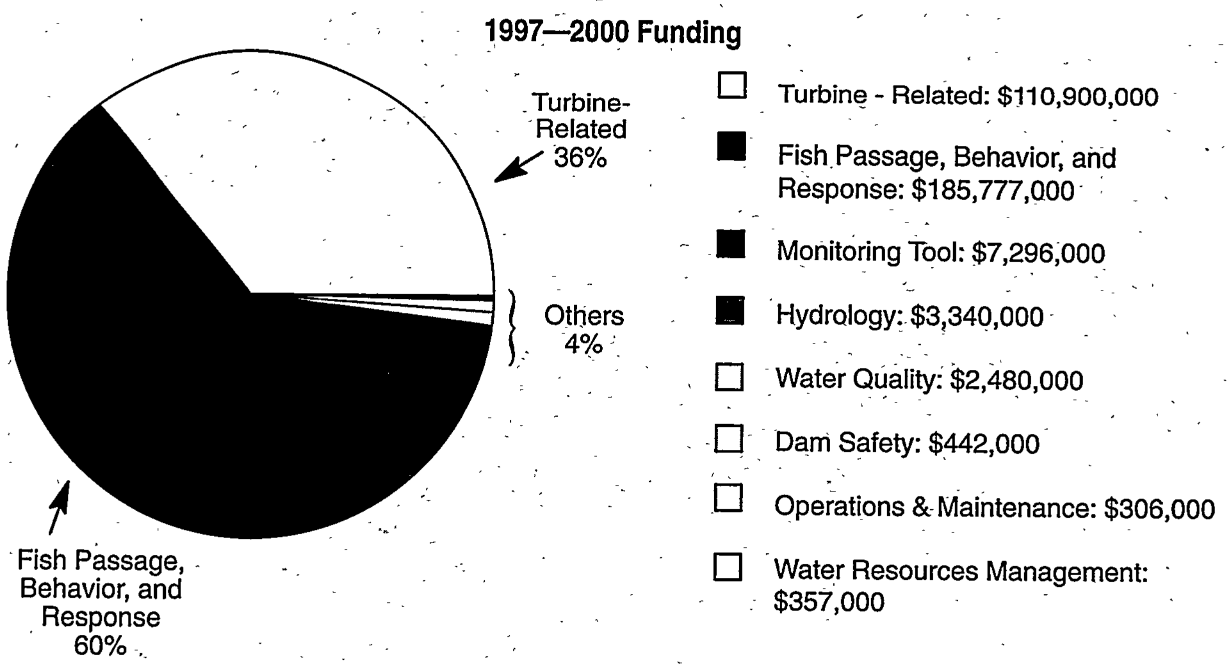
- Fish Passage, Behavior, and Response
- Turbine-Related Projects
- Monitoring Tool Development
- Hydrology
- Water Quality

- Dam Safety
- Operations & Maintenance
- Water Resources Management.

Several issues in hydropower R&D are briefly discussed: Duplication; Priorities; Coordination; Technical/Peer Review; and Technology Transfer/Commercialization.

The following graphs illustrate R&D funding for the eight categories listed above. The first shows the allocation of funds for 1996. The second shows anticipated funding from 1997 to 2000. Because not all utilities and vendors provided input to funding totals, the following graphs should be viewed with caution. The total amounts and the ratios may change as the quality of funding information improves.





RENEWABLE INDIAN ENERGY RESOURCES

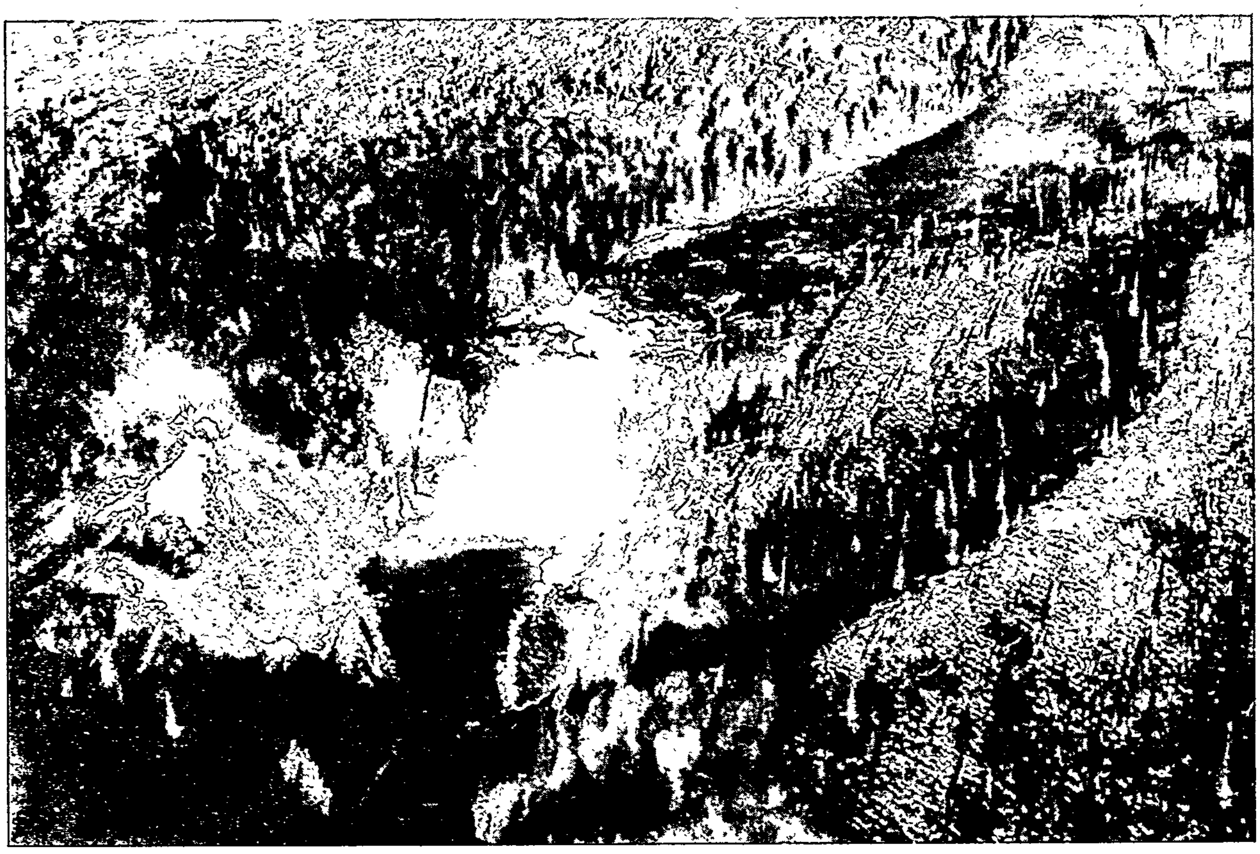
The DOE Hydropower Program is administering funding and providing technical assistance to hydropower projects in Alaska under the Renewable Indian Energy Resources program. These projects are intended to enable Native American communities to minimize dependence on expensive diesel fuel. The first project has begun operation, and three others are in the planning stage.

The Tazimina Hydroelectric Project, located on the Tazimina River, about 175 miles southwest of Anchorage, has an installed capacity of 824 kW, with provision for an additional 824 kW in the future. The electricity generated will serve the towns of the Iliamna, Newhalen, and Nondalton, whose electric cooperative owns and operates the plant. Construction began in the spring of 1996, and start-up took place in April 1997.

Funding has been appropriated for the following proposed additional projects:

- The Power Creek Hydroelectric Project is located near Cordova, about 65 miles southeast of Valdez, and has a planned capacity of 6 MW.
- The Reynolds Creek Hydroelectric Project is located on Prince of Wales Island, in southeast Alaska, and has a planned capacity of 1.5 MW.
- The Prince of Wales Island Regional Intertie has a planned transmission capacity of 34 kilovolts.

For further information concerning these projects contact Bennie N. Rinehart.



Tazimina Hydroelectric Project, located on the Tazimina River, near Iliamna, Alaska.

In June 1989, DOE initiated activities to identify the resources available to support the expanding demand for energy in the United States. Public hearings indicated that the undeveloped potential hydropower resources were not well-defined. Partial analysis of the database of undeveloped resources by industry groups indicated the data on potential hydropower included redundancies and errors which reduced confidence in the published estimates of the developable hydropower potential. As a result, DOE established an interagency hydropower resource assessment team to ascertain the resource. The team comprised representatives from each power marketing administration (Alaska Power Administration, Bonneville Power Administration, Western Area Power Administration, Southwestern Power Administration (SWPA), and Southeastern Power Administration), as well as the Bureau of Reclamation, the Army Corps of Engineers, the Federal Energy Regulatory Commission (FERC), the Idaho National Engineering Laboratory (INEL), and ORNL. The team completed a preliminary assessment of potential hydropower resources in February 1990. DOE has continued these resource assessment activities to develop a basis for correcting these deficiencies.

Computer Software to Aid Assessment of Resource Potential

To assess the hydropower potential in any area of the United States from a national perspective, a uniform set of criteria was developed and a probability factor computer model, called Hydropower Evaluation Software (HES), was designed to standardize the assessment. HES is a menu-driven software application. HES offers the user of a personal computer the ability to factor in environmental attributes of a hydropower site to calculate a relative development suitability factor for a project. The software is intended to be as user-friendly as possible while still fulfilling its mission. It contains a report submenu with several reporting formats. In addition, experienced database users can customize their own report formats.

These environmental attributes include whether a site has Wild and Scenic Protection or is on a tributary of a site with such protection, and other cultural, fishery, geologic, historic, recreational, or scenic attributes. The presence of threatened or endangered fish or wildlife influences the suitability factor. Other attributes include the potential project's location, including whether the site is within a national park, national grassland, national wildlife refuge, or another federal land. A combination of attributes results in a lower suitability factor because multiple environmental considerations reduce the likelihood that a site may be developed to its physical potential. Several sources of information are used to assign attributes, including the Nationwide Rivers Inventory, maintained by the U.S. Department of the Interior.

The HES was developed as a tool for regional or state agencies to obtain regional or state totals and is not intended to provide definitive potential development factors for individual sites. Further, because the software was developed as a generic measurement tool encompassing national issues, the use of regional and state totals must be conducted judiciously; various local issues may skew hydropower potential totals. Employing HES as a national measurement tool will smooth any local anomalies.

The INEL developed the HES in conjunction with the ORNL, which provided the essential environmental information. The INEL received valuable assistance from the SWPA, which defined the database requirements and reporting capabilities required by a power marketing administration.

Status of the Project to Assess Hydropower Potential

To date, the resource assessment has been completed for 31 states, with the remaining 19 states currently in the state review phase:

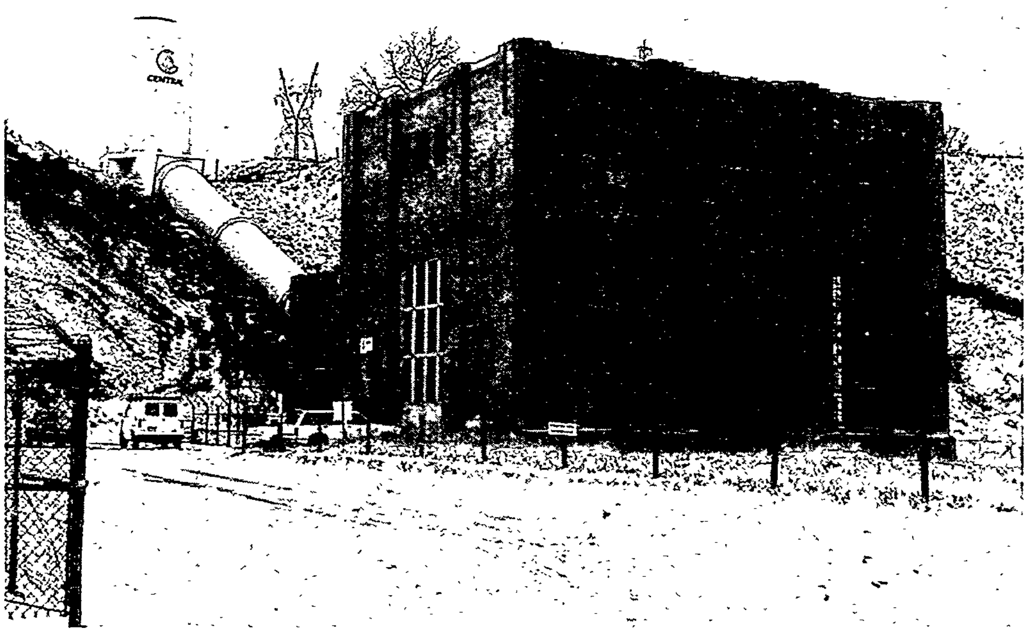
Completed States	
Alabama	Nebraska
Arkansas	New Hampshire
Colorado	New Jersey
Connecticut	New Mexico
Delaware	North Dakota
Hawaii	Oklahoma
Illinois	Rhode Island
Indiana	South Carolina
Iowa	South Dakota
Kansas	Tennessee
Louisiana	Texas
Massachusetts	Utah
Minnesota	Vermont
Mississippi	Wisconsin
Missouri	Wyoming
Montana	

The 31 states include approximately 3,400 sites with undeveloped hydropower power. These sites have a modeled undeveloped capacity of about 20,000 MW.

The goal is to assemble a resource database of all potential hydropower sites in the United States for use as a planning tool to determine the viable national hydropower potential. This potential is a source of renewable energy available to meet the growing energy needs of the United States. The HES makes this job easier and ensures a common basis for national assessment.

Those interested in obtaining the Hydropower Evaluation Software, an HES user's manual, and state reports should contact:

Lockheed Martin Idaho Technologies
P.O. Box 1625, MS 3830
2525 Fremont Avenue
Idaho Falls, ID 83415-3830
Attn: B. N. Rinehart Phone (208) 526-1002
Fax (208) 526-0969.



This hydropower plant, at Jeffrey Canyon, is on the Central Nebraska Public Power and Irrigation District System. This canal system was built in the 1930s, primarily as an irrigation project for the Platte River Valley.

TECHNOLOGY TRANSFER

The main objective of this activity is to transfer to industry and the public the experience gained, technology developed, and lessons learned from the DOE Hydropower Program.

Technology Transfer Activities

The general activities during the last two years are as follows:

- Published reports and articles on the active projects
- Published a Biennial Program Status Report
- Reviewed unsolicited proposals and new concepts
- Responded to inquiries and issued information and data upon request
- Monitored the environmental, technology, and regulatory issues and the status of the industry
- Supported and participated in the hydropower industry's conferences, workshops, and public education activities.

For further information concerning the DOE-sponsored Hydropower Program, contact the following:

DOE

Peggy A. M. Brookshier
U.S. Department of Energy
850 Energy Drive
Idaho Falls, Idaho 83402-1220
208/526-1403
208/526-5964 fax
brookspa@inel.gov

John V. Flynn
U.S. Department of Energy
1000 Independence Avenue, S.W.
Washington, D.C. 20585
202/586-8171
202/586-8185 fax

INEEL

Bennie N. Rinehart
Lockheed Martin Idaho Technologies
2525 Fremont Avenue
P.O. Box 1625, MS 3830
Idaho Falls, Idaho 83415-3830
208/526-1002
208/526-0969 fax
rinehabn@inel.gov

James E. Francfort
Lockheed Martin Idaho Technologies
2525 Fremont Avenue
P.O. Box 1625, MS 3830
Idaho Falls, ID, 83415-3875
208/526-6787
208/526-0969 fax
francfje@inel.gov

Garold L. Sommers
Lockheed Martin Idaho Technologies
2525 Fremont Avenue
P.O. Box 1625, MS 3830
Idaho Falls, Idaho 83415-3830
208/526-1965
208/526-0969 fax
sommergl@inel.gov

ORNL

Glenn F. Cada
Environmental Sciences Division
Oak Ridge National Laboratory
P.O. Box 2008, MS 6036
Oak Ridge, Tennessee 37831-6036
423/574-7320
423/576-8646 fax
gfc@ornl.gov

Michael J. Sale
Environmental Sciences Division
Oak Ridge National Laboratory
P.O. Box 2008, MS 6036
Oak Ridge, Tennessee 37831-6036
423/574-7305
423/576-8643 fax
jon@ornl.gov

ANNOTATED BIBLIOGRAPHY OF HYDROPOWER PUBLICATIONS

The following are reports of interest to the hydropower industry, arranged by topic and chronologically with newest publications first. The reports with NTIS identification numbers can be purchased from the National Technical Information Service, 5285 Port Royal Road, Springfield, Virginia 22161, (703) 487-4650. Reports of DOE-sponsored projects or reports received on foreign exchange agreements can be ordered from Oak Ridge, Tennessee, instead of Springfield, Virginia. Reports are available in paper, microfiche, microcomputer diskettes, and magnetic tape.

Telephone Orders—(703) 487-4650—NTIS Sales Desk and Customer Services are available between 8:30 a.m. and 5:00 p.m. Eastern Standard Time.

Fax—(703) 321-8547—Customers may Fax their orders to NTIS. These orders may be charged to an NTIS Deposit Account or an American Express, VISA, or MasterCard.

E-mail—Customers may e-mail requests to info@ntis.fedworld.gov.

Mail Orders—Orders should be sent to the National Technical Information Service, Document Sales, 5285 Port Royal Road, Springfield, VA 22161. We recommend you call Sales for prices before you place an order.

Method of Payment—Customers may pay for reports (and other NTIS products and services) by (a) credit card—American Express, VISA, or MasterCard, (b) check or money order on a U.S. bank payable to NTIS, (c) an NTIS deposit account, or (d) by asking to be billed (add $7.50 per order) United States, Canada, and Mexico only.

Handling Fee—A $4 handling fee per total order (not per item) applies to orders from the United States, Canada, and Mexico. Handling charges *DO NOT APPLY* to Rush Order Service or pick-up orders.

Postage and Shipping—Orders are shipped First Class mail, or equivalent, to addresses in the United States, Canada, and Mexico.

Order Turnaround Time—Orders for technical reports generally are shipped within 3 to 5 days of receipt. For faster service, NTIS offers rush order service.

RUSH Order Service—Call 1-(800) 553-NTIS. In Virginia, Canada, and Mexico, call (703) 487-4700. For NTIS Rush Order Service, add $15 per item. This guarantees that an order will be processed through NTIS within 24 hours of its receipt. These orders receive immediate, individual attention. The items ordered are delivered by First Class mail unless Express Order Service is requested. Call NTIS for information on Rush Order Service for computer products.

For Help in Tracing an Order—Call (703) 487-4650 and request the Customer Service option.

Technology Development

1991

Rinehart, B. N., 1991, *Department of Energy Small-Scale Hydropower Program Feasibility Assessment and Technology Development Summary Report*, Idaho National Engineering Laboratory. NTIS No. DOE/ID-10322.

The purpose of this report is to present an overview of two subprograms of the U.S. Department of Energy Small-Scale Hydroelectric Power Program. These subprograms are the Program Research and Development Announcement (PRDA) Feasibility Assessments, of which there were 55, and the program opportunity notice (PON) Technology Development Projects (formerly known as the Demonstration Projects), of which there were 20. The Feasibility Assessment program initiated by DOE, received and considered for support proposals adding hydroelectric generation capacity to existing dams. This PRDA was for adding hydroelectric generation capacity of between 1.5 kW and 50 MW to existing dams with heads of <20 m. Individuals, corporations, companies, educational institutions, nonprofit and not-for-profit institutions and others, including state and local governments, but not federal agencies, individually or as proposed project teams, who desired to have their hydroelectric feasibility analysis considered by DOE, responded to this PRDA. Two hundred fourteen responses were received, but only 55 received awards. These sites were selected to provide widespread geographical distribution, as well as a variety of water resources, hydroelectric power capacities, and dam or diversion structures. The assessments from these 55 sites were used to encourage development of renewable resources for power generation, which provided engineering, economic, environmental, safety, and institutional information. Under the PON, 19 proposals of the 89 submitted were awarded cooperative agreements. DOE participated in a sharing program for each project. The objectives of the Technology Development Program were: to use available technology in demonstrating the economic viability of small hydroelectric power; to identify engineering, economic, environmental, and institutional aspects associated with small-scale hydropower development; and to disseminate data on the construction and maintenance of these facilities.

1990

PA Hydroelectric Development Corporation, Flat Rock Dam Small-Scale Hydroelectric Power Demonstration Project, Project Summary Report, Philadelphia, Pennsylvania, October 1990, NTIS No. DOE/ID-12130.

The final summary report presents an overview of what a developer has to go through to obtain a license for a small hydroelectric facility.

1989

City of Paterson, New Jersey Great Falls Small-Scale Hydroelectric Power Demonstration Project, Final Operation and Maintenance Report, Paterson, New Jersey, September 1989, NTIS No. DOE/ID-12127-2.

The final operation and maintenance report on the City of Paterson, New Jersey/Independent Hydro Developers Hydroelectric facility summarizes operation, maintenance activities, and costs for 2 years of operation.

Green Mountain Power Corporation Bolton Falls Small-Scale Hydroelectric Power Demonstration Project, Final Operation and Maintenance Report, Burlington, Vermont, July 1989, NTIS No. DOE/ID-23212-4.

The final operation and maintenance report on the Bolton Falls Hydroelectric Facility summarizes operation, maintenance activities, and costs for 2 years of operation.

1988

Broad River Electric Cooperative, Inc., Cherokee Falls Small-Scale Hydroelectric Power Demonstration Project, Final Operation and Maintenance Report, Gaffney, South Carolina, August 1988, NTIS No. DOE/ID-12125-2.

The final operation and maintenance report on the Broad River Cooperative, Inc., Hydroelectric facility summarizes operation, maintenance activities, and costs for 2 years of operation.

City of Spokane, Washington, Small-Scale Hydroelectric Power Demonstration Project, Final Operation and Maintenance Report, Spokane, Washington, April 1988, NTIS No. DOE/ID-12118-1.

The final operation and maintenance report on the City of Spokane Hydroelectric facility summarizes operation, maintenance activities, and costs for 2 years of operation.

Boott Hydropower, Inc., Lowell, Massachusetts, Small-Scale Hydroelectric Power Demonstration Project, Final Operation and Maintenance Report, Lawrence, Massachusetts, March 1988, NTIS No. DOE/ID-12124-2.

The final operation and maintenance report on the Lowell, Massachusetts, Boott Hydropower, Inc., Hydroelectric facility summarizes of operation, maintenance activities, and costs for 2 years of operation.

City of Tallahassee, Florida, Small-Scale Hydroelectric Power Demonstration Project, Final Operation and Maintenance Report, Tallahassee, Florida, March 1988, NTIS No. DOE/ID-12128-2.

The final operation and maintenance report on the Jackson Bluff Hydroelectric Facility summarizes operation, maintenance activities, and costs for 2 years of operation.

1987

City of Spokane, Washington, Small-Scale Hydroelectric Power Demonstration Project, Rehabilitation After Dam Failure Report, Spokane, Washington, October 1987, NTIS No. CONF-8708124.

The rehabilitation after dam failure report on the City of Spokane Hydroelectric facility summarizes construction activities of both the old and new plant.

Reactivation of the Elk Rapids Hydroelectric Facility, Final Operation and Maintenance Report, Antrim County, Michigan, May 1987, NTIS No. DOE/RA/23209-1.

The final operation and maintenance report on the Elk Rapids Hydroelectric facility summarizes operation, maintenance activities, and costs for 2 years of operation.

Boott Hydropower, Lowell Hydroelectric Project, Final Technical and Construction Cost Report, Lowell, Massachusetts, 1987, NTIS No. DOE/ID-12124.

The final technical and construction cost report on Boott Hydropower, Lowell Small-Scale Hydroelectric Project addresses licensing and permits, environmental concerns, engineering and design, safety, material and equipment procurements, construction costs, publicity, and photographs.

Broad River Electric Cooperative, Inc., Cherokee Falls Small-Scale Hydroelectric Demonstration Project, Final Technical and Construction Cost Report, Gaffney, South Carolina, 1987, NTIS No. DOE/ID-12125.

The final technical and construction cost report on Broad River Electric Cooperative, Inc., Cherokee Falls Hydroelectric Project addresses licensing and permits, environmental concerns, engineering and design, safety, material and equipment procurements, construction costs, publicity, and photographs.

City of Gonzales, Texas, Small-Scale Hydroelectric Power Demonstration Project, Final Operation and Maintenance Report, Gonzales, Texas, 1987, NTIS No. DOE/ID-12121-3.

The final operation and maintenance report on the city of Gonzales Hydroelectric project summarizes operation, maintenance activities, and costs for 2 years of operation.

City of Paterson, New Jersey, Great Falls Small-Scale Hydroelectric Demonstration Project, Final Technical and Construction Cost Report, Paterson, New Jersey, 1987, NTIS No. DOE/ID-122127.

The final technical and construction cost report on City of Paterson, New Jersey, Great Falls Project addresses licensing and permits, environmental concerns, engineering and design, safety, material and equipment procurements, construction costs, publicity, and photographs.

Green Mountain Power Corporation Bolton Falls Hydroelectric Redevelopment, Final Technical and Construction Cost Report, Burlington, Vermont, 1987, NTIS No. DOE/RA/232121-2.

The final technical and construction cost report of Green Mountain Power Corporation's Small-Scale Hydroelectric Project addresses licensing and permits, environmental concerns, engineering and design, safety, material and equipment procurements, construction costs, publicity, and photographs.

1986

City of Tallahassee, Florida, Small-Scale Hydroelectric Power Demonstration Project, Final Technical and Construction Cost Report, Tallahassee, Florida, September 1986, NTIS No. DOE/ID-12128-1.

The final technical and construction cost report of the City of Tallahassee, Florida Hydroelectric Project addresses licensing and permits, environmental concerns, engineering and design, material and equipment procurement, construction costs, publicity, and photographs.

City of Idaho Falls Hydroelectric Demonstration Project, Final Operation and Maintenance Report, Idaho Falls, Idaho, May 1986, NTIS No. DOE/RA/01699-6.

The Final Operation and Maintenance Report on Idaho Falls' Hydroelectric Plant summarizes of operation and maintenance activities, and costs for 3 years of operation.

1985

Upper Mechanicville Hydroelectric Redevelopment Project, Final Operation and Maintenance Report, Mechanicville, New York, November 1985, NTIS No. DOE/RA/12117-5.

The Final Operation and Maintenance Report on New York State Electric and Gas Company's Upper Mechanicville Hydroelectric Project summarizes of operation, maintenance activities, and costs for 2 years of operation.

Garland Canal Shoshone Irrigation District Hydroelectric Project, Final Operation and Maintenance Report, Powell, Wyoming, October 1985, NTIS No. DOE/ID-12129-1.

The final report on the operation and maintenance of the Shoshone Irrigation District Hydroelectric Project summarizes operation, maintenance activities, and costs for 2 years of plant operation.

Riegel Textile Corporation, Fries, Virginia, Plant Hydro Project, Trash Rake Drawings, July 1985, NTIS No. DOE/RA/23213-4.

Drawings and specifications for the trash rake built by Riegel Fries plant personnel.

Reactivation of the Elk Rapids Hydroelectric Facility, Final Technical and Construction Cost Report, Antrim County, Michigan, May 1985, NTIS No. DOE/RA/23209.

The final technical and construction cost report on Antrim County, Michigan, Small-Scale Hydroelectric Project addresses licensing and permits, environmental concerns, engineering and design, safety, material and equipment procurements, construction costs, publicity, and photographs.

City of Gonzales, Texas, Small-Scale Hydroelectric Power Demonstration Project, Final Technical and Construction Cost Report, Gonzales, Texas, January 1985, NTIS No. DOE/ID-12121-T2.

The final technical and construction cost report on the City of Gonzales, Texas, Small-Scale Hydroelectric Project addresses licensing and permits, environmental concerns, engineering and design, safety, material and equipment procurements, construction costs, publicity, and photographs.

1984

City of Spokane, Washington, Small-Scale Hydroelectric Power Demonstration Project, Final Technical and Construction Cost Report, Spokane, Washington, December 1984, NTIS No. DOE/ID-12118.

The final technical and construction cost report on the City of Spokane, Washington, Small-Scale Hydroelectric Project addresses licensing and permits, environmental concerns, engineering and design, safety, material and equipment procurements, construction costs, publicity, and photographs.

Upper Mechanicville Hydroelectric Redevelopment Project, Final Technical and Construction Report, Mechanicville, New York, July 1984, NTIS No. DOE-RA/12117-4.

The final technical and construction cost report on New York State Electric & Gas Company's Upper Mechanicville Hydroelectric Project addresses licensing and permits, environmental concerns, engineering and design, safety, material and equipment procurements, construction costs, publicity, and photographs.

Shawmut Hydroelectric Redevelopment Project, Final Operation and Maintenance Report, Benton, Maine, June 1984, NTIS No. DOE/ID-12126-2.

The final report on the operation and maintenance of the Central Maine Power Shawmut Hydroelectric Plant summarizes operation and maintenance activities, costs, and revenues for 2 years of plant operation.

City of Tallahassee, Florida, Small-Scale Hydroelectric Power Demonstration Project, Emergency Action Plan, Tallahassee, Florida, May 1984, NTIS No. DOE/ID-12128.

This City of Tallahassee's plan for action to be taken in case of dam failure gives details of warning methods and describes the actions of personnel responding and directing action to ensure that no life is lost and damage is kept minimal.

Sawmill Hydrostation Redevelopment, Final Operations and Maintenance Report, Berlin, New Hampshire, April 1984, NTIS No. DOE/RA/23210-3.

The final report on the operations and maintenance of the sawmill Hydroelectric Project summarizes operation, maintenance activities, costs, and revenues for 3 years of plant operation.

Garland Canal Shoshone Irrigation District Hydroelectric Project, Final Technical and Construction Cost Report, Powell, Wyoming, March 1984, NTIS No. DOE/ID-12129.

The final technical and construction cost report of Shoshone Irrigation District's Small-Scale Hydroelectric Project addresses licensing and permits, environmental concerns, engineering and design, safety, material and equipment procurements, construction costs, publicity, and photographs.

Garvins Falls Hydroelectric Redevelopment Project, Final Operation and Maintenance Report, Bow, New Hampshire, January 1984, NTIS No. DE-84007793 or DOE/ID-12122-1.

The final report on the operation and maintenance of the Garvins Falls Hydroelectric Plant summarizes operation, maintenance activities, costs, and revenues for 2 years of plant operation.

Salt River Project, South Consolidated Hydroelectric Generating Station, Final Operating Report, Mesa, Arizona, January 1984, NTIS No. DE-84006378 or DOE/RA/23214-2.

The final report on the operations and maintenance of the South Consolidated Hydroelectric Plant summarizes operation, maintenance activities, costs, and revenues for 2 years of plant operation.

1983

Fries Virginia Plant Hydroproject, Final Operating Report, Fries, Virginia, December 1983, NTIS No. DOE/RA/23213-3.

This is the final report on the operations and maintenance of the Fries Hydroelectric Plant, summarizes operation, maintenance activities, costs, and revenues for 2 years of plant operation.

Salt River Project, South Consolidated Hydroelectric Generation Station, First Annual Operating Report, Mesa, Arizona, July 1983, NTIS No. DE-83015309 or DOE/RA/23214-1.

This first-year operation and maintenance report summarizes of operation, and maintenance activities, costs, and revenues for the first year of plant operation.

Fries Virginia Plant Hydroproject, First Annual Operating Report, Fries, Virginia, June 1983, NTIS No. DE-83016336 or DOE/RA/23213-2.

This first-year operation and maintenance report summarizes operation and maintenance activities, costs, and revenues for the first year of plant operation.

City of Idaho Falls Hydroelectric Demonstration Project, Final Technical and Construction Cost Report, Idaho Falls, Idaho, May 1983, NTIS No. DE-83013853 or DOE/RA/01699-4.

This is the final technical and construction cost report on Idaho Falls' hydroelectric plant project. Topics addressed include licensing and permits, environmental concerns, engineering and design, safety, material and equipment procurement, construction costs, publicity, and photographs.

Turlock Irrigation District Drop No. 1 Power Plant: Final Operation and Maintenance Report, Turlock, California, April 1983, NTIS No. DE-83013342 or DOE/RA/23215-3.

The final operation and maintenance report on Turlock Irrigation District's Drop No. 1 Plant summarizes operation, maintenance activities, costs, and revenues for the first 2 years of plant operation.

1982

Public Service Company of New Hampshire Drop No. 1 Power Plant Expansion of Garvins Falls Hydroelectric Plant, Final Technical and Construction Cost Report, Bow, New Hampshire, December 1982, NTIS No. DE-83007221 or 121221-T1 DOE/ID-121221-T1.

The final technical and construction cost report on Public Service Company of New Hampshire Garvins Falls Project addresses licensing and permits, environmental concerns, engineering and design, safety, material and equipment procurements, construction costs, publicity, and photographs.

Goodyear Lake Hydroelectric Generating Station Redevelopment, Final Operating Cost Report, Milford, New York, November 1982, NTIS No. DE-83004753 or DOE/RA/23211-4.

The final operation and maintenance report on Goodyear Lake summarizes operation, maintenance activities, costs, and revenues for 2 years of plant operation.

Goodyear Lake Hydroelectric Generation Station Redevelopment. Final Technical and Construction Cost Report, Milford, New York, October 1982, NTIS No. DOE/RA/23211.

This is the final technical and construction cost report on the Goodyear Lake Small-Scale Hydroelectric Project. Topics addressed include licensing and permits, environmental concerns, engineering and design, safety, material, equipment procurements, construction costs, publicity, and photographs.

Goodyear Lake Hydroelectric Generating Station Redevelopment, Second Annual Report, Milford, New York, October 1982, NTIS No. DE-83003156 or DOE/RA/23211-2.

This first-year operation and maintenance report summarizes operation, maintenance activities, costs, and revenues for the first year of operation.

Goodyear Lake Hydroelectric Generating Station Redevelopment, Second Annual Report, Milford, New York, October 1982, NTIS No. DE-83003156 or DOE/RA/23211-3.

This second-year operation and maintenance report summarizes operation, maintenance activities, costs, and revenues for the second year of plant operation.

James River-New Hampshire Electric, Inc., Sawmill Hydrostation Redevelopment, Final Report, Berlin, New Hampshire, August 1982, NTIS No. DE-83000446 or DOE/RA/23210-2.

The final technical and construction cost report on James River's Sawmill Small-Scale Hydroelectric Project addresses licensing and permits, environmental concerns, engineering and design, safety, material and equipment procurements, construction costs, publicity, and photographs.

Shawmut Hydroelectric Redevelopment Project, Final Technical and Construction Cost Report, Benton, Maine, August 1982, NTIS No. DE-82021007 or DOE/ID-12126.

The final technical and construction cost report on Central Main Power's Shawmut Small-Scale Hydroelectric Project addresses licensing and permits, environmental concerns, engineering and design, safety, material and equipment procurements, construction costs, publicity, and photographs.

Upper Mechanicville Hydroelectric Redevelopment Project, Project Management Plan, Mechanicville, New York, July 1982, NTIS No. DE-83009353 or DOE/RA/12117-3.

This project management plan for the New York State Electric & Gas (NYSEG) Mechanicville Hydroelectric Project addresses definition of project objectives, organizational composition of the management team, responsibilities of all participants in the project, project controls, and the required reports and meetings.

Riegel Textile Corporation, Fries, Virginia Plant Hydroproject, Final Technical and Construction Cost Report, Fries, Virginia, June 1982, NTIS No. DE82020698 or DOE/RA/23213.

The final technical and construction cost report on Riegel's Fries, Virginia, Small-Scale Hydroelectric Project addresses licensing and permits, environmental concerns, engineering and design, safety, material and equipment procurements, construction costs, publicity, and photographs.

City of Idaho Falls Low-Head Hydroelectric Demonstration Project, Emergency Action Plan, Idaho Falls, Idaho, June 1982, NTIS No. DE-82021385 or DOE/RA/01699-T1.

This is the City of Idaho Falls' plan for action to be taken in case of failure of one of the three dams, or any combination of them, including all three. It gives details of warning methods, and describes the actions of personnel responding and directing action to ensure no life is lost and damage is kept minimal.

1981

Upper Mechanicville Hydroelectric Redevelopment Temporary Construction Emergency Action Plan, Mechanicville, New York, December 1981, NTIS No. DE-82007868 or DOE/RA/12117-2.

This emergency action plan presents standard procedures for personnel at the construction site if failure of cofferdam should occur.

South Consolidated Hydroelectric Project, Final Technical and Construction Cost Report, Mesa, Arizona (Salt River Project), October 1981, NTIS No. DOE-RA-23214.

The final technical and construction cost report on South Consolidated Small-Scale Hydroelectric Project addresses licensing and permits, environmental concerns, engineering and design, safety, material and equipment procurements, construction costs, publicity, and photographs.

Green Mountain Power Corporation Bolton Falls Hydroelectric Redevelopment, First Annual Report, Burlington, Vermont, March 1981, NTIS No. DOE/RA/232121-T1.

The Green Mountain Power Corporation's first annual report on redevelopment of the Bolton Falls Hydro Site summarizes of major events, project status, expenditures, schedules, costs, management organization, and photographs.

Turlock Irrigation District Drop No. 1 Power Plant, Final Technical and Construction Cost Report, Turlock Irrigation District, Turlock, California, January 1981, NTIS No. DE-83015148 or DOE/RA/23215.

The final technical and construction cost report on the Drop No. 1 Small-Scale Hydroelectric Project addresses licensing and permits, environmental concerns, engineering and design, safety, material and equipment procurements, construction costs, publicity, and photographs.

Turlock Lake Powerhouse, Design Report and Operations Manual, Turlock, California, January 1981, NTIS No. DOE/RA/23215-2.

This report presents the design and operational criteria used by Turlock Irrigation District for their Drop No. 1 Plant.

1980

Project Design Criteria Manual: Upper Mechanicville Hydroelectric Redevelopment Project, Acres American Inc., for New York Electric & Gas Corporation, Binghamton, New York, December 1980, NTIS No. DOE/RA-12117.

This design criteria manual was used by the New York Electric & Gas Corporation to design their upper Mechanicville Hydroelectric Redevelopment Project.

Sawmill Hydrostation Redevelopment, First Annual Report, Brown Company Engineering Department, Berlin, New Hampshire, November 1980, NTIS No. DOE/RA/23210-T-1.

The Brown-New Hampshire, Inc., annual report on the construction of a Sawmill Small-Scale Hydroelectric Project addresses licensing and permits, environmental concerns, engineering and design, safety, material and equipment procurement, construction, publicity, and photographs.

1979

Idaho Falls Hydroelectric Project, Project Definition Phase Report, International Engineering Company, Inc., February 1979, NTIS No. ID0-10078.

This report presents the results of the project definition phase of the Idaho Falls Low-Head Hydroelectric Demonstration Project. The project resulted in the redevelopment of three existing power plants on the Snake River in or near Idaho Falls, Idaho, using bulb turbogenerators. The project was partially funded by the U.S. Department of Energy, and will demonstrate that bulb turbine technology is an economically viable and environmentally acceptable means of developing new or upgrading old hydropower sites. The report also discusses benefits, costs, schedules, licensing, and financing of the project.

1978

Idaho Falls Hydroelectric Project, Design Criteria, International Engineering Company, Inc., December 1978, NTIS No. ID0-1699-1.

This report presents the basic minimum design criteria and requirements for the civil and mechanical works of the Idaho Falls Hydroelectric Project.

Idaho Falls Hydroelectric Project, Selection of Unit Size, International Engineering Company, Inc., October 1978, NTIS No. ID0-1699-2.

This report presents the studies that IECO made to select the unit size for the Idaho Falls Hydroelectric Project. The following factors were considered: water availability, estimated costs for furnishing and installing the units, the value of the power benefits established for the project, unit efficiencies, and estimated construction costs. The optimum turbine size was found to be 8.0 MW (6000 cfs discharge capacity), which would produce energy at a cost of 21 mil/kWh.

Idaho Falls Hydroelectric Project, Preliminary Report, International Engineering Company, Inc., February 1978, NTIS No. ID0-10071.

This report includes a brief appraisal of the existing generation facilities and condition of the existing concrete structures; a geological reconnaissance of the Upper and Lower Plant Sites; an analysis of the power potential of the two sites; investigation and comparative evaluation of four alternatives for redeveloping the stream flows for power generation; selection of the most suitable alternative for development; and preparation of drawings and detailed quantity and cost estimates for the recommended development.

Idaho Falls, City Hydroelectric Power Plant: Preliminary Report, International Engineering

Company, Inc., February 1978, NTIS No. ID0-10073.

This report documents the investigation and comparative evaluation of four alternatives for redeveloping the hydroelectric potential of the stream flows at the City Plant, selection of the most suitable redevelopment alternatives, and evaluation of the existing environment and the environmental aspects of the recommended development.

Resource Assessment

1997

*Conner, A. M. and J. E. Francfort, 1997, *U.S. Hydropower Resource Assessment for South Carolina,* DOE/ID-10430(SC), U.S. Department of Energy, Idaho Operations Office, Idaho Falls, ID.

*Conner, A. M. and J. E. Francfort, 1997, *U.S. Hydropower Resource Assessment for Tennessee,* DOE/ID-10430(TN), U.S. Department of Energy, Idaho Operations Office, Idaho Falls, ID.

*Conner, A. M. and J. E. Francfort, 1997, *U.S. Hydropower Resource Assessment for Nebraska,* DOE/ID-10430(NE), U.S. Department of Energy, Idaho Operations Office, Idaho Falls, ID.

*Conner, A. M. and J. E. Francfort, 1997, *U.S. Hydropower Resource Assessment for New Mexico,* DOE/ID-10430(NM), U.S. Department of Energy, Idaho Operations Office, Idaho Falls, ID.

*Conner, A. M. and J. E. Francfort, 1997, *U.S. Hydropower Resource Assessment for Illinois,* DOE/ID-10430(IL), U.S. Department of Energy, Idaho Operations Office, Idaho Falls, ID.

1996

*Conner, A. M. and J. E. Francfort, 1996, *U.S. Hydropower Resource Assessment for Indiana.* DOE/ID-10430(IN), U.S. Department of Energy, Idaho Operations Office, Idaho Falls, ID.

*Conner, A. M. and J. E. Francfort, 1996, *U.S. Hydropower Resource Assessment for Iowa,* DOE/ID-10430(IA), U.S. Department of Energy, Idaho Operations Office, Idaho Falls, ID.

*Francfort, J. E., 1996, *U.S. Hydropower Resource Assessment for Hawaii,* DOE/ID-10430(HI), U.S. Department of Energy, Idaho Operations Office, Idaho Falls, ID.

*Francfort, J. E., 1996, *U.S. Hydropower Resource Assessment for Minnesota,* DOE/ID-10430(MN), U.S. Department of Energy, Idaho Operations Office, Idaho Falls, ID.

*Conner, A. M. and J. E. Francfort, 1996, *U.S. Hydropower Resource Assessment for Wisconsin,* DOE/ID-10430(WI), U.S. Department of Energy, Idaho Operations Office, Idaho Falls, ID.

*Conner, A. M. and J. E. Francfort, 1996, *U.S. Hydropower Resource Assessment for New Jersey,* DOE/ID-10430(NJ), U.S. Department of Energy, Idaho Operations Office, Idaho Falls, ID.

*Conner, A. M., J. E. Francfort, and B. N. Rinehart, 1996, *Uniform Criteria for U.S. Hydropower Resource Assessment: Hydropower Evaluation Software Status Report - II,* DOE/ID-10430.1, U.S. Department of Energy, Idaho Operations Office, Idaho Falls, ID.

*Conner, A. M. and J. E. Francfort, 1996, *U.S. Hydropower Resource Assessment for Vermont,* DOE/ID-10430(VT), U.S. Department of Energy, Idaho Operations Office, Idaho Falls, ID.

1995

Francfort, J. E., 1995, *U.S. Hydropower Resource Assessment for Massachusetts,* DOE/ID-10430(MA), U.S. Department of Energy, Idaho Operations Office, Idaho Falls, ID.

* An asterisk (*) before the title indicates the publication has been added to the Bibliography in this biennial report.

Francfort, J. E., 1995, *U.S. Hydropower Resource Assessment for Maine*, DOE/ID-10430(ME), U.S. Department of Energy, Idaho Operations Office, Idaho Falls, ID.

Francfort, J. E., 1995, *U.S. Hydropower Resource Assessment for Rhode Island*, DOE/ID-10430(RI), U.S. Department of Energy, Idaho Operations Office, Idaho Falls, ID.

Francfort, J. E., 1995, *U.S. Hydropower Resource Assessment for Connecticut*, DOE/ID-10430(CT), U.S. Department of Energy, Idaho Operations Office, Idaho Falls, ID.

Francfort, J. E., 1995, *U.S. Hydropower Resource Assessment for Colorado*, DOE/ID-10430(CO), U.S. Department of Energy, Idaho Operations Office, Idaho Falls, ID.

1994

Francfort, J. E., 1994, *U.S. Hydropower Resource Assessment for Montana*, DOE/ID-10430(MT), U.S. Department of Energy, Idaho Operations Office, Idaho Falls, ID.

Francfort, J. E., 1994, *U.S. Hydropower Resource Assessment for North Dakota*, DOE/ID-10430(ND), U.S. Department of Energy, Idaho Operations Office, Idaho Falls, ID.

Francfort, J. E., 1994, *U.S. Hydropower Resource Assessment for South Dakota*, DOE/ID-10430(SD), U.S. Department of Energy, Idaho Operations Office, Idaho Falls, ID.

Francfort, J. E., 1994, *U.S. Hydropower Resource Assessment for Utah*, DOE/ID-10430(UT), U.S. Department of Energy, Idaho Operations Office, Idaho Falls, ID.

Francfort, J. E., 1994, *U.S. Hydropower Resource Assessment for Wyoming*, DOE/ID-10430(WY), U.S. Department of Energy, Idaho Operations Office, Idaho Falls, ID.

1993

Francfort, J. E., 1993, *U.S. Hydropower Resource Assessment for Arkansas*, DOE/ID-10430(AR), U.S. Department of Energy, Idaho Operations Office, Idaho Falls, ID.

Francfort, J. E., 1993, *U.S. Hydropower Resource Assessment for Kansas*, DOE/ID-10430(KS), U.S. Department of Energy, Idaho Operations Office, Idaho Falls, ID.

Francfort, J. E., 1993, *U.S. Hydropower Resource Assessment for Louisiana*, DOE/ID-10430(LA), U.S. Department of Energy, Idaho Operations Office, Idaho Falls, ID.

Francfort, J. E., 1993, *U.S. Hydropower Resource Assessment for Missouri*, DOE/ID-10430(MO), U.S. Department of Energy, Idaho Operations Office, Idaho Falls, ID.

Francfort, J. E., 1993, *U.S. Hydropower Resource Assessment for Texas*, DOE/ID-10430(TX), U.S. Department of Energy, Idaho Operations Office, Idaho Falls, ID.

Francfort, J. E., 1993, *U.S. Hydropower Resource Assessment for Oklahoma*, DOE/ID-10430(OK), U.S. Department of Energy, Idaho Operations Office, Idaho Falls, ID.

Francfort, J. E., K. M. Moore, and B. N. Rinehart, 1993, *Uniform Criteria for U.S. Hydropower Resource Assessment*, DOE/ID-10430, U.S. Department of Energy, Idaho Operations Office, Idaho Falls, ID.

The DOE's National Energy Strategy and Interagency Hydropower Resource Assessment Team requires a representative estimate of the conventional hydropower development potential in this country. The Hydropower Evaluation Software is a computer model that was developed by the Idaho National Engineering Laboratory for this purpose.

* An asterisk (*) before the title indicates the publication has been added to the Bibliography in this biennial report.

The Hydropower Evaluation Software measures the potential hydropower resources available in the United States, using a national uniform criteria for measurement. This software was developed and tested employing hydropower information and data provided by the Southwestern Power Administration. It is a dBASE III PLUS and dBASE IV menu-driven software application. Hydropower Evaluation Software provides the personal computer user with the ability to assign environmental attributes to potential hydropower sites, to calculate development suitability factors for each site based on the environmental attributes present, and to generate reports based on these suitability factors.

This status report details the development of the Hydropower Evaluation Software, the data requirements, and application to the 12 states assessed to date. The reports includes a summary and a plan for future assessments.

1992

Francfort, J. E., and B. N. Rinehart, 1992, "Assessing Hydropower Resources," *Independent Energy*, May/June, pp. 83–84.

Historical estimates of the undeveloped hydropower potential in the United States have often been performed in an indiscriminate manner, with no consideration given to the development of a uniform approach. Additionally, the environmental constraints impacting hydropower development have infrequently been contemplated when estimating hydropower potential. This article describes the methodologies employed in the development of a computer model used to overcome past measurement deficiencies. Environmental (such as fish, wildlife, recreation, historic, scenic, cultural, or geologic values), legal (such as threatened/endangered protection) and institutional (such as federal land ownership) constraints to development are considered as to their impacts on the likelihood of development. A probabilistic value is used to determine reduced developable hydropower capacities. A menu-driven report capability and user-friendly input screens minimize the computer knowledge requirements to successfully use the model. The model is intended to derive regional hydropower potentials, identifying sources of developable renewable energy.

1991

Francfort, J. E., S. D. Matthews, and B. Rinehart, 1991, *Uniform Criteria for U.S. Hydropower Resource Assessment*, EG&G Idaho, Inc., May, DOE/ID-10338.

1989

Hydro and Electric Resources of the United States National Hydropower Association (NHA), 1989, For sale by NHA 11332 1st Street, N.W. Suite 500 Washington, D.C. 20036 (202) 331-7551.

1988

Federal Energy Regulatory Commission (FERC), 1988, *Hydroelectric Power Resources of the United States, Developed and Undeveloped*, FERC-0070.

This report presents data as of January 1, 1988, on the capacity, generation, and other characteristics of the developed and undeveloped hydroelectric power resources of the United States.

1984

FERC, 1994, *Hydroelectric Power Resources of the United States, Developed and Undeveloped*, FERC-0070.

This report presents data as of January 1, 1984, on the capacity, generation, and other characteristics of the developed and undeveloped hydroelectric power resources of the United States.

1983

U.S. Army Corps of Engineers, 1983, *National Hydroelectric Power Resources Study,* For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (202) 783-3238 or -3311.

This plan identifies a set of best-candidate sites for future study of hydroelectric power potential. The plan includes both Federal and non-Federal sites. The final report comprises the following 23 volumes:

Volume	Title	GPO Number
I	Executive Summary	008-022-00212-0
II	National Report	008-022-00213-8
III	1978 Electric Power Demand and Supply	008-022-00198-1
IV	Future Electric Power Demand and Supply	008-022-00199-9
V	Legal and Institutional Aspects of Hydroelectric Power Development and Operation	008-022-00190-5
VI	A Review of Economic Criteria for Federal Hydroelectric Power Projects	008-022-00193-0
VII	Marketing and Transmission of Hydroelectric Power	008-022-00208-1
VIII	Environmental Assessment	008-022-00209-0
IX	Potential for Increasing the Output of Existing Hydroelectric Plants	008-022-00191-3
X	An Assessment of Hydroelectric Pumped Storage	008-022-00194-8
XI	Technology Assessment of Hydroelectric Power Development	008-022-00195-6
XII	Data Base Inventory	008-022-00196-4
XIII	Data Base Inventory Support Studies	008-022-00171-2
XIV	Northeast Power Coordinating Council	008-022-00171-9
XV	Mid-Atlantic Area Electric Reliability Coordination Agreement	008-022-00172-7
XVI	Southeastern Electric Reliability Council & Puerto Rico	008-022-00173-5
XVII	East Central Area Reliability Coordination Agreement	008-022-00177-8
XVIII	Mid-American Interpool Network	008-022-00179-4
XIX	Mid-Continent Area Reliability Coordination Agreement	008-022-00174-3
XX	Southwest Power Pool	008-022-00175-1
XXI	Electric Reliability Council of Texas	008-022-00176-0
XXII	Western Systems Coordinating Council	008-022-00180-8
XXIII	Alaska and Hawaii	008-022-00178-6

Environmental Research

1997

*Bao, Y., R. D. Perlack, and M. J. Sale, 1997, *Alternative methods to determine headwater benefits,* Federal Energy Regulatory Commission, Washington, D.C.

Under Section 10(f) of the Federal Power Act, the Federal Energy Regulatory Commission (Commission) is required to assess charges to downstream owners of non-federal hydropower projects that are directly benefited from headwater improvements. Headwater benefits are defined in the Code of Federal Regulations (18 CFR) as the additional energy (i.e., energy gains) derived from the flow-regulating activities of the headwater project. The CFR requires that the Commission use the Headwater Benefits Energy Gains (HWBEG) model to calculate energy gains, except for headwater benefits determinations that are not complex, or in which the headwater benefits are expected to be low. In 1992, the Commission began using Flow Duration Analysis (FDA) to assess headwater benefits in basins where the use of the HWBEG model is clearly inappropriate. This report presents the results of ORNL's validation of the FDA method. The validation is based on a comparison of energy gains using the FDA method with energy gains calculated using the HWBEG model. Comparisons of energy gains are made on a daily and monthly basis for a complex river basin (the Alabama River Basin) and a basin that is considered relatively simple hydrologically (the Stanislaus River Basin). FDA method refinements and improvements were carried out using the James River Basin as a test case.

*Bao, Y., R. D. Perlack, and M. J. Sale, 1997, "Evaluating and Improving Flow Duration Analysis Method to Determine Headwater Benefits," *Waterpower '97, Proceedings of the International Conference & Exposition on Hydropower, Atlanta, Georgia, August 5–8,* New York: American Society of Civil Engineers, in press.

Headwater benefits are energy gains at a downstream hydropower project that are directly realized from installation of upstream reservoirs. The high costs of making headwater benefits determinations prohibit the use of a complicated model in basins where the magnitude of the benefits is expected to be small. A simple alternative method, such as flow duration analysis (FDA), is needed to reduce the assessment costs. This paper evaluates the application of the FDA method for determining energy gains in these smaller basins. The standard FDA method is enhanced by (1) using an appropriate flow step in the numerical integration, (2) replacing a power-to-turbine flow ratio by a variable flow-head-efficiency relationship, and (3) expanding FDA to derive the unregulated flows based on regulated flow and reservoir storage changes. A computer model (HWBFDA) was developed to automate the process of applying this enhanced FDA method. The enhancements significantly improve the accuracy of the FDA method and efficiency in application. The model has been applied in various river basins.

*Bevelhimer, M. S., W. Van Winkle, and C. C. Coutant, 1997, "Temporal and Spatial Effects of Dam Operation on Downstream Thermal Regimes and Subsequent Effects on Fish Populations," *Proceedings of the Annual American Fisheries Society Symposium, Monterey, California, August 1997,* in press.

Many streams undergo large diurnal temperature fluctuations (>10°C) during certain seasons, primarily in response to ambient meteorological conditions and stream hydrology. Human-induced factors, such as dams, diversions, and controlled releases, can change average daily temperatures, and also dampen or exaggerate diurnal variation. We used actual and simulated temperature data from two western streams (Madison River, Montana, and Tule River, California) to evaluate diurnal temperature variation, the impact of dam operations, and potential effects on resident fish.

* An asterisk (*) before the title indicates the publication has been added to the Bibliography in this biennial report.

A one-dimensional hydrodynamic model coupled with a river temperature model was used to evaluate various dam operation scenarios. Impoundments on these rivers tend to dampen the diurnal temperature fluctuation immediately downstream, but sometimes increase diurnal variation at greater distances. Although increases in stream temperature sometimes result in an acute response (i.e., a fish kill) by the fish community, chronic responses (e.g., reduced growth, thermal stress, and increased disease susceptibility) may actually be more important. We used an individual-based model to evaluate population-level effects of chronic exposure to high temperature, both intermittent and continuous. We compared alternative bioenergetic/growth and mortality formulations, including damage-repair models. Results illustrate the need for innovative, individual-based field and laboratory research on the effects of chronic exposure (particularly intermittent) to high temperature created by a variety of realistic river thermal regimes.

*Bevelhimer, M. S., V. Alavian, B. A. Miller, and G. Hauser, 1997, Modeling thermal effects of operational and structural modifications at a hydropower facility on a premier trout stream in southwestern Montana, *Waterpower '97, Proceedings of the International Conference & Exposition on Hydropower, Atlanta, Georgia, August 5–8,* New York: American Society of Civil Engineers, in press.

We used a one-dimensional hydrodynamic model coupled with a river temperature model to evaluate the relative heating and cooling of the Madison River to evaluate various alternatives proposed to mitigate warm temperatures downstream of the hydropower facility at Madison Dam. The model requires inputs of local meteorological data, stream geometry, flow, and river temperature throughout the 109-mile reach modeled. The simulated alternatives included proposals to remove the dam, increase the height of the dam, and bypass the river around the lake. The model was calibrated to water travel times determined during dye studies and to historical temperature records. A sensitivity analysis of the model indicated that water temperatures in the lower reaches of the river are more sensitive to release temperatures upstream at the powerhouse than to changes in ambient air temperature or flow. Model results indicated that none of the proposed alternatives was likely to produce a significant decrease in water temperature 20 miles below the dam. Due to the river geometry, removal of the dam and restoration of the river to its natural state would actually cause downstream temperatures to be higher than they are with the dam in place. Other alternatives might produce some thermal benefit, but associated economic and ecological costs may not justify the slight thermal improvements.

*Cada, G. F., C. C. Coutant, and R. R. Whitney, 1997, *Development of Biological Criteria for the Design of Advanced Hydropower Turbines,* DOE/ID-10578, U.S. Department of Energy Idaho Operations Office, 85 pp.

Phases I and II of the Advanced Hydropower Turbine System (AHTS) Program involve considerable Computational Fluid Dynamics (CFD) modeling and engineering design studies to develop novel designs for fish-friendly turbines, i.e., turbines in which mortality of entrained fish is small. In order to accomplish this, the designers need quantitative biological criteria as input. That is, the engineers need numbers which define a "safety zone" for fish within which all of the injury/mortality mechanisms experienced by turbine-passed fish (rapid and extreme water pressure changes, shear forces, cavitation, strike, and abrasion) are at acceptable levels for survival. If one of these injury mechanisms has overriding importance compared to others, the designers could focus their efforts to "design out" this stress in the new generation of turbines. Because the relative importance of each of these stresses is difficult to discern from field studies at hydropower plants, a critical review of biological and engineering literature was performed. Published laboratory bioassays and similar studies of the responses of fish to

* An asterisk (*) before the title indicates the publication has been added to the Bibliography in this biennial report.

the component stresses of turbine passage were reviewed, with the goal of deriving biological criteria for the turbine designers. In many cases there were few or no data to support quantitative biological criteria, so laboratory and field experimental techniques that could be used to fill gaps in existing information were described. Finally, the published literature on fish behavior was explored to determine whether particular species or sizes of fish are likely to exhibit predictable, directed movements, knowledge of which would be useful to turbine designers.

*Cada, G. F., "Shaken, Not Stirred: the Recipe for a Fish-Friendly Turbine," *Waterpower '97, Proceedings of the International Conference & Exposition on Hydropower, Atlanta, Georgia, August 5–8,* New York: American Society of Civil Engineers, in press.

It is generally agreed that injuries and mortalities among turbine-passed fish can result from several mechanisms, including rapid and extreme water pressure changes, cavitation, shear, turbulence, and mechanical injuries (strike and grinding). Advances in the instrumentation available for monitoring hydraulic conditions and Computational Fluid Dynamics (CFD) techniques now make it possible both to estimate accurately the levels of these potential injury mechanisms in operating turbines and to predict the levels in new turbine designs. This knowledge can be used to "design-out" the most significant injury mechanisms in the next generation of turbines. However, further improvements in turbine design are limited by a poor understanding of the levels of mechanical and hydraulic stresses that can be tolerated by turbine-passed fish. The turbine designers need numbers (biological criteria) that define a safety zone for fish within which pressures, shear forces, cavitation, and chance of mechanical strike are all at acceptable levels for survival. This paper summarizes the results of a literature review of fish responses to the types of biological stresses associated with turbine passage, as studied separately under controlled conditions in the laboratory rather than in combination at field sites.

*Coutant, C. C., L. D. Calvin, M. W. Erho, Jr., J. A. Lichatowich, W. J. Liss, W. E. McConnaha, P. R. Mundy, J. A. Stanford, R. R. Whitney, R. N. Williams, D. L. Bottom, C. A. Frissell, 1997, "The Normative River: An Ecological Vision for the Recovery of the Columbia River Salmon," *Waterpower '97, Proceedings of the International Conference & Exposition on Hydropower, Atlanta, Georgia, August 5–8,* New York: American Society of Civil Engineers, in press.

The Independent Scientific Group, the scientific review arm of the Northwest Power Planning Council, concluded that to foster recovery of depressed salmon stocks, the Council should adopt a salmonid life history ecosystem concept as a guiding foundation to move the regulated Columbia River system toward a normative condition (i.e., typical river basin meeting basic fish needs). The concept recognizes that salmonid populations exist as both stable regional core areas essential for maintaining and rebuilding regional population structure and more transient local stocks. It uses scientifically defined normative river conditions to naturally restore salmonid diversity and productivity. Salmonid fishes in the Columbia River basin need to be managed for population diversity, not just increased production. Salmonid reserves are needed, which provide special protection of intact habitats containing remaining core populations. Key elements of a return to more normative conditions include restoration of habitat for all life history stages, management of stocks with a more complete understanding of salmon migratory behavior and the limitations this behavior places on modes of river regulation, reduction of the sources of mortality (including harvest), planning of hydropower mitigation measures in the context of the normative river concept, and empirical evaluation of mitigation for effectiveness in reaching fish-restoration objectives. The normative river concept does not imply a return to pristine conditions everywhere. Rather, it is management of both

* An asterisk (*) before the title indicates the publication has been added to the Bibliography in this biennial report.

natural and cultural features to more closely meet the key norms or standards of ecosystem function that allow productive salmonid populations. Artificial measures, such as transportation of smolts by barge and truck around hydropower dams, should be unnecessary in a river system managed for normative objectives.

*Coutant, C. C., and R. R. Whitney, 1997, "Fish Behavior in Relation to Modeling Fish Passage Through Hydropower Turbines: A Review," *Proceedings, Fish Passage Workshop, Milwaukee, Wisconsin, May 6–8*, Electric Power Research Institute.

We evaluated the literature on fish behavior as it relates to passage of fish near or through hydropower turbines. The goal was to foster compatibility of engineered systems with the normal behavior patterns of fish species and life stages such that entrainment into turbines and injury in passage are minimized. We focused on aspects of fish behavior that could be used for computational fluid dynamics (CFD) modeling of fish trajectories through turbine systems. Downstream-migrating salmon smolts are generally surface-oriented and follow flow. Smolts orient to the ceilings of turbine intakes but are horizontally distributed more evenly, except as affected by intake-specific turbulence and vortices. Smolts often enter intakes oriented head-upstream. Nonsalmonids are entrained episodically, suggesting accidental capture of schools (often of juveniles or in cold water) and little behavioral control during turbine passage. Models of fish trajectories should not assume neutral buoyancy throughout the time a fish passes through a turbine, largely because of pressure effects on swim bladders. Fish use their lateral line system to sense obstacles and change their orientation, but this sensory-response system may not be effective in the rapid passage times of turbine systems. Effects of preexisting stress levels on fish performance in turbine passage are not well known but may be important. There are practical limits of observation and measurement of fish and flows in the proximity of turbine runners that may inhibit development of information germane to developing a more fish-friendly turbine. We provide recommendations for CFD modelers of fish passage and for additional research.

*Jager, H. I. and E. J. Pert, 1997, "Comment: Utility of Depth and Velocity Preferences for Predicting Steelhead Parr Distribution at Different Flows," *Transactions of the American Fisheries Society*, in press.

One assumption of the instream flow incremental methodology (IFIM) is that depth and velocity preferences are independent of streamflows. Beecher et al. (1995) claimed that they validated this assumption, but we disagree. First, the study compared habitat preference at the low flow with habitat use (not preference) at the high flow. Second, the statistical approach used by Beecher et al. (1995) can lead to the conclusion that preferences at two flows are the same, even when most reasonable scientists would consider them clearly different with respect to velocity and depth. In this comment, we address statistical issues with comparisons of habitat distributions that are based on preference rather than velocity and depth and we recommend new techniques for comparison.

*Jager, H. I., W. Van Winkle, B. D. Holcomb, and S. F. Railsback, "A Climate Change Forecast for California Brown and Rainbow Trout," *Transactions of the American Fisheries Society*, Submitted.

We predicted the ecological consequences of climate change for sympatric brown (*Salmo trutta*) and rainbow trout (*Oncorhynchus mykiss*) populations in a Sierra Nevada stream with an individual-based trout population model. We evaluated the effects of both a seasonal shift in hydrology and elevated temperature. We found that both temperature and flow changes associated with climate change influenced persistence of the two species. First, we hypothesized a substantial decrease in the fall-spawning brown trout population as a result of high winter flows

* An asterisk (*) before the title indicates the publication has been added to the Bibliography in this biennial report.

and scouring of brown trout redds. Although scouring showed the expected pattern, the model predicts that neither species benefitted from the shift in streamflow. Second, because trout are cold-water fishes, we hypothesized that a rise in stream temperature would be harmful to both species. In the higher elevation reach simulated here, a 2°C increase in stream temperature aided brown trout, but a 3°C increase caused extinction. With a 3°C increase, the model predicted that climate change would favor California's native rainbow trout because (1) brown trout were more sensitive to high temperature and (2) rainbow trout experienced competitive release. In warmer reaches and in response to larger temperature increases, rainbow trout would probably also be lost. Additional simulations explored the idea that evolution of thermal tolerance might permit trout to persist in response to gradual climatic changes.

*Pryfogle, P. A., B. N. Rinehart, E. G. Ghio, 1997, *Aquatic Plant Control Research*, INEL/EXT–97–00362.

The Northwest region of the United States contains extensive canal systems that transport water for hydropower generation. Nuisance plants, including algae, that grow in these systems reduce their hydraulic capacity through water displacement and increased surface friction. Most control methods are applied in an ad hoc fashion. The goal of this work is to develop cost-effective, environmentally sound, long-term management strategies to prevent and control nuisance algal growth. This paper reports on a multi-year study, performed in collaboration with the Pacific Gas & Electric Company, to investigate algal growth in their canal systems, and to evaluate various control methodologies. Three types of controls, including mechanical, biological, and chemical treatment, were selected for testing and evaluation. As part of this study, water quality data were collected and algal communities were sampled from numerous stations throughout the distribution system at regular intervals. This study resulted in a more comprehensive understanding of conditions leading to the development of nuisance algal growth, a better informed selection of treatment plans, and improved evaluation of the effectiveness for the control strategies selected for testing.

*Jager, H. I., H. E. Cardwell, M. J. Sale, M. S. Bevelhimer, C. C. Coutant, and W. Van Winkle, 1997, "Modeling the Linkages between Flow Management and Salmon Recruitment in Rivers," *Ecological Modeling*, in press.

We developed a simulation model to predict instream flow effects on smolt production for fall chinook salmon (*Oncorhynchus tshawytscha*) in regulated rivers. The principal purpose of this model is to serve as a management tool to evaluate effects on salmon of instream releases from upstream reservoirs. The dramatic decline in chinook salmon in California rivers suggests a need for such a tool. We developed an individual-based and spatially explicit model to simulate the influences of riverine habitat on each life stage leading to successful outmigration of chinook salmon. Model predictions of development, growth, and survival showed good agreement with 4 years of field data collected in the Tuolumne River, California. Our analysis of parameter sensitivities identified flow-related redd mortality and temperature-related juvenile mortality as limitations on smolt production.

*Jager, H. I., W. Van Winkle, B. D. Holcomb, D. J. Orth, S. F. Railsback, T. K. Studley, "Spatial simulation of stream habitat relevant to fish populations," *Rivers*, in review.

Most attempts to predict the influence of stream flow on fish populations assume that the effect of flow is mediated by changes in the spatial distributions of velocity and depth. Habitat distributions observed in a relatively small collection of transects placed across a stream are used to represent the rest of the river by weighting the results for each mesohabitat type by the proportion of the river's length it represents. In this paper, we improve on this method by supplementing transect data with habitat mapping informa-

* An asterisk (*) before the title indicates the publication has been added to the Bibliography in this biennial report.

tion. EXTRAP, our habitat extrapolation model, reduced the uncertainty in predictions of fish habitat response to flow on large spatial scales. Cross-validation showed that EXTRAP predicted the distribution of mean column velocities and depths better than methods that rely solely on transect data. Based on this analysis, we recommend that future instream flow studies use EXTRAP as a basis for habitat analysis in Physical HABitat SIMulation Model (PHABSIM).

*Jager, H. I., H. E. Cardwell, M. J. Sale, M. S. Bevelhimer, and C. C. Coutant, "Optimizing Instream Flows for Fall Chinook Salmon (*Oncorhynchus tshawytscha*)," *Canadian Journal of Fisheries and Aquatic Sciences*, in revision.

We used an individual-based and spatially explicit recruitment model to find a seasonal pattern of river flows that would maximize smolt production by fall chinook salmon (*Oncorhynchus tshawytscha*) in the Tuolumne River, California. The model simulates the influences of riverine habitat on each lifestage leading to successful outmigration of chinook salmon, including upmigration, adult spawning, and the growth, movement, and survival of early lifestages. The model identified an optimal flow regime with relatively low winter flows and high spring flows. This seasonal pattern mimics historical averages in the natural hydrology of snowmelt-dominated rivers to which salmon are adapted.

*Sale, M. J., G. F. Cada, and J. M. Munro, 1997, "Making Room at the Table: Providing Fish Flows in Fully Allocated Watersheds of California's Central Valley," *Proceedings of the XXVII Congress of the International Association for Hydraulic Research (IAHR), San Francisco, California, August, 1997,* in press.

The Central Valley of California is a good example of how new multiple-use pressures are causing major changes in the management of large water resources systems. Environmental quality objectives, such as the restoration and enhancement of fish resources, are demanding a larger share of water in areas where available resources are already fully allocated. New assessment and regulatory approaches are evolving to address this challenge.

*Sale, M. J., and W. Van Winkle, 1997, "The Evolving Role of Individual-Based Models in Instream Flow Studies," *Proceedings, Symposium on River Ecosystems: New Directions and Challenges in Evaluating Instream Flows, Monterey, California, August 27, 1997,* American Fisheries Society.

As assessment tools for determining instream flow needs have evolved over two decades, more attention has been given to modeling fish populations. Individual-based models are one approach to meet this need. The individual-based approach accounts for the life history of individuals over short time steps, then aggregates individual responses to the population level. These models were originally designed for research purposes, not as assessment tools, and have a relatively high degree of realism and complexity. Perceived weaknesses of the individual-based modeling approach include (1) high requirements for programming skill and biological expertise; (2) computational intensity, (3) excessive data requirements, and (4) the lack of a track record. The strengths of this approach are (1) focus on relevant endpoints (i.e., population-level parameters); (2) high spatial and temporal resolution; and (3) flexibility to address a wide range of stress responses. Strengths and weaknesses are discussed in context of two recent applications in California: rainbow and brown trout in the Tule River and chinook salmon in the Tuolumne River. Advances in technology and successful applications such as these indicate that this modeling approach has a strong role to play in instream flow assessment.

*Sale, M. J., S. H. Snider, Y-S. Bao, and J. Van Dyke, 1997, *Cost of Removing Edwards Dam on the Kennebec River, Maine,* Federal Energy

* An asterisk (*) before the title indicates the publication has been added to the Bibliography in this biennial report.

Regulatory Commission, Washington, D.C., May 1997.

This report constitutes an independent estimate of the cost of removing the Edwards dam on the Kennebec River near Augusta, Maine. The Edwards Hydroelectric Project (FERC Project No. 2389) is one of eleven projects in the river basin that the Federal Energy Regulatory Commission (FERC) is cumulatively evaluating for licensing or relicensing. We consider four principal alternatives in this report: (1) the approach described by FERC staff in the draft environmental impact statement, (2) a set of approaches with different cofferdam designs proposed by the Kennebec Coalition, (3) an approach proposed by the U.S. Department of Interior , and (4) an approach that we recommend based on our independent review. Our evaluation of the alternatives focuses on flow condition, reservoir drawdown, engineering assumptions, temporary gate and cofferdam structures, project schedule, disposition of demolition debris, and stabilization of remaining structure. The draft EIS limit of drawing down the Edwards impoundment no faster than 1 foot per week appears to be excessive; our analysis indicates that a limit of 5 foot per week would offer sufficient protection and that the construction activities can therefore be completed in one season. Construction of a cofferdam to protect the initial breach and to allow a more controlled drawdown is a prudent measure and should be included in the task; a lined gravel cofferdam similar to one of the Kennebec Coalition's designs would be sufficient. Removal of the earth fill that is presently along the dam's upstream face should be included as part of the dam removal task. Based on our analyses of the public record and our estimate of applicable unit costs, the total cost of dam removal, including the cost of measures to mitigate the direct effects of dam removal would be $2.7 million.

*Sale, M. J., G. F. Cada, B. E. Rinehart, G. L. Sommers, and P. A. M. Brookshier, 1997, "DOE's Advanced Hydropower Turbine Systems Program: Progress and Future Directions," *Proceedings, Fish Protection Workshop, May 6-8, 1997, Milwaukee, Wisconsin,* Electric Power Research Institute.

Hydropower research within the U.S. Department of Energy (DOE) has been focused for the last two years on the development of new turbine designs that can produce hydroelectricity without such adverse environmental effects as fish entrainment/impingement or degradation of water quality. In partnership with the hydropower industry, DOE's advanced turbine program issued a Request for Proposals for conceptual designs in FY 1995. Two contracts were awarded for this initial program phase, work on which will be complete this year. A technical advisory committee with representatives from industry, regulatory agencies, natural resource managers was also formed to guide the DOE turbine research. The lack of quantitative biological performance criteria was identified by the committee as a critical knowledge gap. To fill this need, a new literature review was completed on the impact mechanisms of fish mortality during turbine passage (e.g., scrape/strike, shear, pressure change) and how these stresses can be measured. The results of DOE's turbine design research are presented in this paper, complimentary to other papers at this workshop, and current plans for the next phase of the program are discussed.

*Van Winkle, W., C. C. Coutant, H. I. Jager, J. S. Mattice, D. J. Orth, R. G. Otto, S. F. Railsback, and M. J. Sale, 1997, "Uncertainty and Instream Flow Standards: Perspectives Based on Hydropower Research and Assessment," *Fisheries,* in press.

This essay promotes further discussion on the important issue of instream flow management. The authors discuss three requirements needed to obtain the benefits of more flexible approaches such as adaptive management. First, adaptive management requires a high level of institutional, legal, and political flexibility-more than now typically occurs. However, the benefits of flexible

* An asterisk (*) before the title indicates the publication has been added to the Bibliography in this biennial report.

requirements are being recognized and gradually implemented. Second, a challenge to any assessment approach based on population-level or community-level effects is achieving agreement on management objectives that are acceptable to the public, simple to understand, ecologically meaningful, and measurable before designing a monitoring program or a model. Third, the adaptive management approach requires several key components, including flow manipulations, a monitoring program, and one or more models. The PHABSIM and individual-based modeling approaches are briefly considered.

*Williams, R. N., L. D. Calvin, C. C. Coutant, M. W. Erho, Jr., J. A. Lichatowich, W. J. Liss, W. E. McConnaha, P. R. Mundy, J. A. Stanford, R. R. Whitney, D. L. Bottom, and C. A. Frissell, 1996, *Return to the River: Restoration of Salmonid Fishes in the Columbia River Ecosystem*, Prepublication draft for public comment, Northwest Power Planning Council, Portland, Oregon, 584 pp.

The Independent Scientific Group, the scientific review arm of the Northwest Power Planning Council, and two invited consultants concluded that to foster recovery of depressed salmon stocks, the Council should adopt a salmonid life history ecosystem concept as a guiding foundation to move the regulated Columbia River system toward a normative condition (i.e., typical river basin meeting basic fish needs). The concept recognizes that salmonid populations exist as both stable regional core areas essential for maintaining and rebuilding regional population structure and more transient local stocks. It uses scientifically defined normative river conditions to naturally restore salmonid diversity and productivity. Salmonid fishes in the Columbia River basin need to be managed for population diversity, not just increased production. Salmonid reserves are needed, which provide special protection of intact habitats containing remaining core populations. Key elements of a return to more normative conditions include: restoration of habitat for all life history stages, management of stocks with a more complete understanding of salmon migratory behavior and the limitations this behavior places on modes of river regulation, reduction of the sources of mortality (including harvest), planning of hydropower mitigation measures in the context of the normative river concept, and empirical evaluation of mitigation for effectiveness in reaching fish-restoration objectives. The normative river concept does not imply a return to pristine conditions everywhere. Rather it is management of both natural and cultural features to more closely meet the key norms or standards of ecosystem function that allow productive salmonid populations. Artificial measures, such as transportation of smolts by barge and truck around hydropower dams, should be unnecessary in a river system managed for normative objectives.

1996

*Cada, G. F., 1996, "Fish Passage Mitigation of Impacts from Hydroelectric Power Projects in the United States," *Proceedings of the International Conference on Fish Migration and Fish Bypass-Channels*, Vienna, Austria, September 25, 1996, in press.

In recent years, the research and development efforts of the U.S. Department of Energy's (DOE's) Hydropower Program have focused on the mitigation of impacts of upstream and downstream fish passage. An initial study of 707 recently licensed hydropower projects in the United States indicated that approximately 11% were required to provide upstream fish passage and 28% were required to provide downstream fish passage. Despite considerable effort to design and install fish passage devices, many projects had no detailed performance criteria and no performance monitoring requirements. The author describes a follow-up study of the effectiveness of fish passage mitigative measures at 16 hydropower projects.

* An asterisk (*) before the title indicates the publication has been added to the Bibliography in this biennial report.

As an alternative to downstream fish passage screening, the DOE Advanced Hydropower Turbine Systems Program has begun a phased effort to design, build, and test a fish-friendly turbine, i.e., a turbine system in which environmental attributes such as entrainment survival, instream flow needs, and/or water quality enhancement are emphasized.

*Galindo, Ed, and Ben Rinehart, 1996, *Indian Summer II Project: 1996 Shoshone-Bannock Student Streamside Egg Incubation Experiment.*

The Indian Summer II project, conducted during the summer of 1996, was sponsored by the U.S. Department of Energy, Office of Science Education Programs. DOE helped fund the Shoshone-Bannock tribes with a fish recovery project on 19 streams and tributaries of the Salmon River in the Sawtooth National Recreation Area. It involved 22 students, four staff members, and support from the INEEL, U.S. Army, J. R. Simplot Corp., Idaho Rivers United, and First Interstate Bank. The goals were to increase the hatch and survival rate of steelhead, and involved placing about 600,000 eggs in 24 hatch boxes in near-stream conditions. The project was divided into two parts, a North end managed by the Forest Service, and the South end managed by the Sho-Ban students. The student's portion of the experiment resulted in a 89% hatch rate.

*Van Winkle, W., H. I. Jager, and B. D. Holcomb, 1996, *An Individual-Based Instream Flow Model for Coexisting Populations of Brown and Rainbow Trout,* TR-106358, Electric Power Research Institute, Palo Alto, California.

We describe a tool for predicting flow effects on trout populations by linking the hydraulic component of the Physical Habitat Simulation (PHABSIM) methodology and an individual-based population modeling approach. PHABSIM simulates the spatial distribution of depth and velocity at different flows. The individual-based model simulates the reproduction, foraging, consumption, energetic costs, growth, habitat utilization, movement, and mortality of individual fish, and enables population attributes to be determined from relevant attributes of individual fish. The spatially explicit nature of the model permits evaluation of behavioral responses used by fish to mitigate temporary setbacks in habitat quality. This linked mechanistic modeling approach readily lends itself to the iterative process of making predictions, testing against field data, improving the model, and making more predictions. We describe the application of the model to a stream segment in the Tule River, California.

1995

Cada, G. F. and J. E. Francfort, 1995, "Examining the benefits and costs of fish passage and protection measures," *Hydro Review,* Vol. 14, No. 1, pp. 47-55.

Sixteen case studies of upstream and/or downstream fish passage mitigation measures at hydroelectric projects are examined. The fish passage and protection mitigation measures include fish ladders and lifts, an Eicher (penstock) screen, spill flows, airburst-cleaned inclined and cylindrical wedgewire screens, vertical barrier screens, and submerged traveling screens. The costs and benefits of these measures are summarized.

*Galindo, Ed, and Ben Rinehart, 1995, *Indian Summer Project: Shoshone-Bannock Student Streamside Egg Incubation Experiment.*

The Indian Summer project, conducted during the summer of 1995, was sponsored by the U.S. Department of Energy, Office of Science Education Programs, and involved students and teachers from the Shoshone–Bannock Tribe of Idaho. The goals of the project were to increase the hatch and survival rate of steelhead, and to teach the Sho-Ban students how to use scientific methods. It involved placing 22,000 eggs in one hatch box in Squaw Creek in the Sawtooth National Recreation Area in central Idaho. The results were a

* An asterisk (*) before the title indicates the publication has been added to the Bibliography in this biennial report.

97.3% egg survival rate, a rate higher than could be obtained in a hatchery or in the wild.

1994

Cada, G. F., and J. E. Francfort, 1994, *Mitigation of Environmental Impacts at Hydroelectric Power Plants in the United States*, Chapter 14, "Alternative Fuels and the Environment," F. Sterett, ed., Lewis Publishers, Chelsea, Michigan, pp. 223–234.

Hydroelectric power production is free of several classes of environmental impacts that severely constrain nonrenewable (and some renewable) energy sources, i.e., air emissions, solid wastes, and significant fuel cycle externalities. Unlike many other sources of renewable energy, hydropower is a well-developed technology that is already contributing substantially to U.S. electricity needs. In order to ensure that hydropower continues to play an important role in the U.S. electricity mix, the often unique environmental issues must be resolved. Our assessment of mitigative measures at non-Federal hydropower projects in the United States indicates that license requirements associated with the most common environmental issues increased during the 1980s, most notably in the area of downstream fish passage/protection. Numerous innovative concepts and designs are being considered to mitigate adverse impacts of hydroelectric generation, but adequate performance monitoring has been rare. The ecological impacts of hydroelectric generation can be serious, but they are not insurmountable. Mitigative measures are available to deal with these issues, and the challenge is to develop an understanding of the true costs and benefits of the most effective measures.

Cardwell, H., H. I. Jager, and M. J. Sale, 1994, "Instream releases, fish populations and water supply planning: linking the issues," extended abstract, in *AWRA's Spring Symposium Multiple Objectives in Water Resources Management and Planning*, pp. 303–306.

The licensing of non-Federal hydropower projects and the mandated reevaluation of Federal water projects (e.g., the Central Valley Project Improvement Act, P.L. 102-575, Title XXXIV) require policymakers to balance the human use of water with environmental goals. While the benefits and costs of changes of water availability to hydropower, agriculture, and municipal uses may be well-quantified, the relationship of flow to environmental objectives is not. Here we present a mathematical modeling framework that links the mass balance models for water supply planning and operation to biological models of fish population dynamics. We focus on the links between instream flow releases, suitable habitat, fish life stages, and population size of fall-run chinook salmon. For wet, normal, dry, and critical water years, we consider the relative instream flow needs of each life stage and the effects of instream releases for fisheries on competing human demands for water. Our modeling framework uses a planning-level optimization model to identify alternative minimum flow requirements, and then uses simulation models to more precisely forecast the resultant hydrology and the effects on both fish and water supply. Information from the simulation models can be used in an iterative fashion to modify the optimization model and generate improved minimum flow schedules.

Francfort, Jim, and Ben Rinehart, 1994, "Protecting Fish," *Independent Energy Magazine*, Vol. 4, No. 8, pp. 72–76.

A study of fish passage and protection costs demonstrates some of the economic challenges faced by project owners in the U.S. hydropower market. Sixteen case studies are used to demonstrate the costs and practices of various mitigation methods at hydropower plants that range in capacity sizes from 400 kW to 840 MW, and have river flows from 50 cubic feet to 80,000 cubic feet per second. Various methods, such as ladders, lifts, and trapping and hauling, are used for upstream mitigation; while the downstream mitigation methods include screens, bar racks, and bypasses, to safely pass fish downstream as well as to exclude fish from turbine passage. The mitigation costs per kWh range from 0.09 mills (less than one-hundredth of a cent) to 21.1 mills

(2.1 cents), and twenty-year total costs range from $48,000 to $132 million.

Francfort, J. E., G. F. Cada, D. D. Dauble, R. T. Hunt, D. W. Jones, B. N. Rinehart, G. L. Sommers, and R. J. Costello, 1994, *Environmental Mitigation at Hydroelectric Projects. Volume II. Benefits and Costs of Fish Passage and Protection*, DOE/ID-10360(V2). U.S. Department of Energy Idaho Operations Office, Idaho Falls, Idaho.

This study examines environmental mitigation practices that provide upstream and downstream passage and protection at hydroelectric projects. The study includes a survey of fish passage and protection mitigation practices at 1,825 hydroelectric plants regulated by the FERC to determine frequencies of occurrence, temporal trends, and regional practices based on FERC regions. The study also describes, in general terms, the fish passage/protection mitigation costs at 50 non-Federal hydroelectric projects. Sixteen case studies are used to examine in detail the benefits and costs of fish passage and protection. The 16 hydroelectric projects are located in 12 states and range in capacity from 400 kilowatts to 840 megawatts.

Sale, M. J., and R. O. Wadlington, 1994, "Responses to Changing Multiple-Use Demands: New Directions for Water Resources Planning and Management," *Proceedings of Extended Abstracts, AWRA 1994 Annual Spring Symposium.* American Water Resources Association, Bethesda, Maryland. 506 pp.

This proceedings publication contains extended abstracts from a symposium held in Nashville, Tennessee, April 17-20, 1994. Plenary sessions addressed current federal and non-federal activities in multipurpose water resources management, including a special focus on hydropower projects, and the Great Missouri/Mississippi Flood of 1993. Contributed papers describe water and hydropower-related issues throughout the U.S., from the Central Valley of California to Maine. Papers demonstrate many exciting examples of how creative solutions are being implemented.

1993

Cada, G. F., and M. J. Sale, 1993, "Status of Fish Passage Facilities at Nonfederal Hydropower Projects," *Fisheries*, Vol. 18, No. 7, pp. 4–12.

The status of mitigation practices for fish passage was assessed as part of an ongoing, multiyear study of the costs and benefits of environmental mitigation measures at non-Federal hydroelectric power plants. Information was obtained from the FERC, hydropower developers, and state and federal resource agencies involved in hydropower regulation. Fish ladders were found to be the most common means of passing fish upstream; elevators/lifts were less common, but their use appears to be increasing. A wide variety of mitigative measures is employed to prevent fish from being drawn into turbine intakes, including spill flows, narrow-mesh intake screens, angled bar racks, and light- or sound-based guidance measures. Performance monitoring and detailed, quantifiable performance criteria were frequently lacking. Of the projects that had downstream fish passage measures, 82% had no performance monitoring requirements; 70% of the project operators indicate that no performance objectives had been specified for the mitigative measures. Despite considerable effort (and success) in recent years to design and install fish passage devices, field studies are still needed to evaluate their biological effectiveness.

Kondolf, G. M., M. J. Sale, and M. G. Wolman, 1993, "Modification of fluvial gravel size by spawning salmonids," *Water Resources Research* Vol. 29, No. 7, pp. 2265–2274.

Salmon manipulate sediments in rivers during the construction of their redds for spawning and incubation of fertilized eggs. The gravels and interstitial fine sediments excavated during this process are exposed to currents and transported downstream differentially, depending on sediment characteristics. Data are presented to quantify this process. The results are useful to fisheries biologists who must evaluate gravel suitability for salmonid spawning and for assessment of hydropower impacts.

Sale, M. J., C. C. Coutant, W. Scarbough, A. Gabbard, 1993, A. Trivelpiece, and C. Krause, "Hydropower: licensed to protect the environment," *Oak Ridge National Laboratory Review*, Vol. 26, Nos. 3&4, pp. 2–19.

This review article is written in a question and answer, interview style, describing ORNL's experiences in assessment and research activities for the hydropower industry over more than two decades. Issues addressed include hydropower technologies, ORNL's role in hydropower development, the diminishing federal authority over hydropower, and ORNL's expanding activities in multiple-use water resources management.

Jager, H. I., et al., 1993, "An Individual-based Model for Smallmouth Bass Reproduction and Young-of-Year Dynamics in Streams," *Rivers*, Vol. 4, No. 2, pp. 91–113.

This paper summarizes the first step in the development of a new tool to evaluate the influence of alternative flow regimes on smallmouth bass recruitment in streams. The paper has two goals: (1) to describe and demonstrate a mechanistic model that simulates the relationship between stream flow and smallmouth bass recruitment and (2) to present the results of the first round in an ongoing process of model validation. The model couples the hydraulic simulation method of the Physical Habitat Simulation System (PHABSIM) directly with an individual-based model for smallmouth bass reproduction and young-of-year dynamics, thereby eliminating reliance on the habitat-based component of PHABSIM. We compare simulated reproductive success and first-year growth with field observations from the North Anna River in Virginia. While the model predictions compare favorably with empirical data in many respects, there is room for improvement. For example, our comparisons of reproduction and larval growth suggest that improvements are needed in our understanding of (1) the nesting behavior and renesting capabilities of individual spawners in streams and (2) the bioenergetics of larval smallmouth bass. We conclude that research in these two areas, followed by model improvement and a second round of model validation, is needed. Because it is mechanistic and amenable to iterative refinement, the model's potential value as a tool for evaluating the effects of alternative flow regimes on smallmouth bass recruitment is high.

Cada, G. F., and D. W. Jones, "Benefits of Fish Passage and Protection Measures at Hydroelectric Projects," *Proceedings of Waterpower '93: An International Conference on Hydropower*, American Society of Civil Engineers, New York, New York, 1993, pp. 139–148.

DOE's Hydropower Program is engaged in a multi-year study of the costs and benefits of environmental mitigation measures at non-Federal hydroelectric power plants. An initial report (Volume I) reviewed and surveyed the status of mitigation methods for fish passage, instream flows, and water quality; this paper focuses on the fish passage/protection aspects of the study. Fish ladders were found to be the most common means of passing fish upstream; elevators/lifts were less common, but their use appears to be increasing. A variety of mitigative measures is employed to prevent fish from being drawn into turbine intakes, including spill flows, narrow-mesh intake screens, angled bar racks, and light-or sound-based guidance measures. Performance monitoring and detailed, quantifiable performance criteria were frequently lacking at non-Federal hydroelectric projects. Volume II considers the benefits and costs of fish passage and protection measures, as illustrated by case studies for which performance monitoring has been conducted. The report estimates the effectiveness of particular measures, the consequent impacts on the fish populations that are being maintained or restored, and the resulting use and nonuse values of the maintained or restored fish populations.

Francfort, J. E., B. N. Rinehart, and G. L. Sommers, "Fish Passage/Protection Costs at Hydroelectric Projects," *Proceedings of Waterpower 93: An International Conference on*

Hydropower, American Society of Civil Engineers, New York, New York, 1993, pp. 129–138.

The U.S. Department of Energy's Hydropower Program is engaged in a multiyear study of the costs and benefits of environmental mitigation measures at hydroelectric power plants. The initial report (Volume I., Current Practices for Instream Flow Needs, Dissolved Oxygen, and Fish Passage—December 1991) reviewed and surveyed the status of mitigation methods for fish passage, instream flows, and water quality. Information on mitigation practices at non-Federal hydroelectric projects was obtained from FERC databases, provided by hydroelectric developers, and provided by state resource agencies involved in hydroelectric regulation. The types of mitigation costs incurred by the hydroelectric developers and examined include capital, study, operations and maintenance, annual reporting, and lost generation costs. The costs are reported by capacity categories.

Whereas Volume I was a broad brush study, the Volume II report focuses in detail on the costs and benefits of fish passage and protection measures. This involves an in-depth analysis of projects reporting upstream and downstream fish passage and protection mitigation. Case studies and information from developers are used to acquire detailed information for all incurred costs. This paper examines the costs and frequencies of fish passage/protection environmental mitigation.

Smith, I. M., and M. J. Sale, 1993, "Standardizing Instream Flow Requirements at Hydropower Projects in the Cascade Mountains, Washington," *Proceedings of Waterpower '93: An International Conference on Hydropower*, American Society of Civil Engineers, New York, New York, pp. 286–295.

Instream flow requirements are common mitigation measures for hydroelectric diversion projects. Currently, there are two extremes among the ways to determine instream flow requirements: generic standard-setting methods and detailed, habitat-based assessment methods such as the Instream Flow Incremental Methodology (IFIM). Data from streams in Washington state show a consistent pattern in the instream flow requirements resulting from the IFIM. This pattern can be used to refine the simpler standard-setting approaches and thereby provide better estimates of flow needs during early stages of project design.

Cada, G. F., M. D. Deacon, S. V. Mitz, and M. S. Bevelhimer, 1993, "Review of information pertaining to the effect of water velocity on the survival of juvenile salmon and steelhead in the Columbia River basin," *Report to the Northwest Power Planning Council*, Portland, Oregon, 70 pp.

Restoration of salmon and steelhead stocks in the Columbia River Basin depends in large part on the adequacy of streamflows needed to transport juveniles safely downstream to the ocean through a series of dams and reservoirs. Compared to pre-impoundment conditions, lower river flows and decreased water velocities are believed to increase juvenile salmonid travel times to the ocean, and potentially to reduce survival. Because of continuing disagreement about the quantities of flow releases needed to increase smolt survival, we reviewed literature from within and outside of the Columbia River Basin relating to the influence of water velocity on survival of juvenile salmon and steelhead. Most of the studies reviewed found a positive relationship between outmigration flows and survival, but there is substantial uncertainty about many of the estimates. Early survival estimates made in the basin did not quantify variance, and contain biases, errors, or reflect interactions with factors other than water velocity. Other influential factors that were examined included predation, water quality, and physiological state of the smolts at the time of migration. Despite the limitations of existing data, the general relationship of increasing survival with increasing flow in the Columbia River Basin still appears to be reasonable.

1992

Francfort, J. E., and B. N. Rinehart, 1992, "Weighing The Costs," *Independent Energy*, September, pp. 96–98.

Environmental mitigation requirements are often imposed at hydroelectric projects, with no consideration given to identifying the costs of those requirements. This article examines the costs of mitigation at 141 FERC-licensed sites throughout the United States. The capital, study, operations and maintenance, and annual reporting costs are examined for the following types of mitigation requirements: instream flows, dissolved oxygen, upstream fish passage, and downstream fish passage. The study background and results as average costs per project, costs per kilowatt of capacity, and annual costs in mills per kilowatt hour of energy produced are discussed. The potential future total cost to the nation, based on anticipated relicensing trends, is also discussed. The article concludes with a discussion of the difficulties of measuring environmental benefits and the need for a more systematic valuing of the trade-offs between mitigation benefits and costs.

Chang, L. H., C. T. Hunsaker, and J. D. Draves, 1992, "Recent Research on Effects of Climate Change on Water Resources," *Water Resources Bulletin*, Vol. 28, No. 2.

Concentrations of atmospheric CO_2 and other radioactively active trace gases have risen since the Industrial Revolution. Such atmospheric modifications can alter the global climate and hydrologic cycle, in turn affecting water resources. The clear physical and biological sensitivities of water resources to climate, the indication that climate change may be occurring, and the substantial social and economic dependencies on water resources have instigated considerable research activity in the area of potential water resource impacts. We discuss how the literature on climate change and water resources responds to three basic research needs: (1) a need for water managers to clearly describe the climatic and hydrologic statistics and characteristics needed to estimate climatic impacts on water resources, (2) a need to estimate the impacts of climate change on water resources, and (3) a need to evaluate standard water management and planning methods to determine uncertainty regarding fundamental assumptions (e.g., hydrologic stationarity). The climatic and hydrologic information needs for water resource managers can be found in a number of sources. A proliferation of impact assessments use a variety of methods for generating climate scenarios, and apply both modeling approaches and historical analyses of past responses to climate fluctuations for revealing resource or system sensitivities to climate changes. Traditional techniques of water resources planning and management have been examined, yielding, for example, suggestions for new methods for incorporating climate information in real-time water management.

Chang, L. H., S. F. Railsback, and R. T. Brown, 1992, "Use of a Reservoir Water Quality Model to Simulate Global Climate Change Effects on Fish Habitat," *Climatic Change*, Vol. 20, pp. 277–296.

A case study was conducted on the potential impacts of climate change on fish habitat in a southeastern reservoir. A reservoir water quality model and one year of baseline meteorologic, hydrologic, and inflow water quality input were used to simulate current reservoir water quality. Total adult striped bass habitat, defined by specific quantitative temperature and dissolved oxygen criteria, was simulated. Daily reservoir volumes with optimal, suboptimal, and unsuitable temperature and DO were predicted for the year. Output from recent runs of atmospheric general circulation models (GCMs), in which atmospheric carbon dioxide concentrations have been doubled, was then used to adjust the baseline inputs to the water quality model. New sets of input data were created for two grid cells for each of three GCMs. All six climate scenarios are predicted to cause overall declines in the available summer striped bass habitat, mostly caused by lake water temperatures exceeding striped bass tolerance levels. These predictions are believed to result from the consensus among GCM scenarios that air temperatures and humidity will rise, and from the sensitivity of the reservoir model to these parameters.

The reservoir model was found to be a promising tool for examining potential climate-change impacts. Some of the assumptions required to apply GCM output to the reservoir model, however, illustrate the problems in using large-scale grid cell output to assess small-scale impacts.

Irving, J. S., R. C. Rope, and R. P. Breckenridge, 1992, *Contaminant Monitoring Strategy for Henry's Lake, Idaho*, EG&G Idaho, EGG-EEL-10523, Idaho Falls, ID.

The objectives of this effort were to (1) develop a long-term contaminant monitoring strategy specifically designed for the Henry's Lake watershed, (2) further test the Contaminant Monitoring Assessment Process (developed for the U.S. Fish & Wildlife Service), and (3) provide the State and other Federal agencies with a consistent approach for developing long-term monitoring strategies. A Workshop was held in December 1992 to gather information on Henry's Lake from Federal, state, and local agencies, sportsman organizations, and private individuals. Based on information from the Workshop, monitoring objectives were developed. The monitoring strategy for Henry's Lake includes sampling several media (e.g., air, groundwater, surface water, sediment, and biological). Strategies identify the presence and amount of contaminant problems within the Henry's Lake watershed. Most sampling occurs in or near the lake; however, results may suggest potential problems throughout the watershed. Several parameters and locations were selected (e.g., water level, dissolved oxygen, pH) for monitoring from various media (e.g., air, groundwater, surface water, sediment).

Sale, M. J., R. E. Gibson, and J. A. Shaakir-Ali, 1992, *Information Analysis System for Environmental Mitigation at Hydropower Projects: A Feasibility Study in Support of the National Energy Strategy*, U.S. Department of Energy, Office of Policy, Planning and Analysis, Washington, D.C..

Although a large number of hydropower-related mitigation practices have been implemented over the last 10–20 years, the collective experience (i.e., successes, failures, costs, and benefits) of these practices is not well-documented or accessible to hydropower developers. The lack of adequate information contributes significantly to the risks and total costs of project development. A study was conducted to identify alternative design strategies and costs of establishing an information analysis system for mitigation issues at hydroelectric projects. This new source of information is needed to facilitate development of hydroelectric resources and to improve the technical basis for decision-making in the evaluation and approval of hydropower projects. Existing sources of relevant information on mitigation practices vary widely, ranging from newsletters and periodicals to computerized systems such as electronic bulletin boards and bibliographic databases. The largest single source of information may well lie in specialized studies conducted as part of the FERC licensing process. This feasibility study evaluated several different aspects of organizing information, including the data management system (software and hardware) to be used, requirements for analyzing incoming information prior to its incorporation, and modes of access and distribution of information in the system. Three primary alternatives are described to establish a consolidated source of mitigation information: (a) a limited bibliographic database that organizes existing information into an operational system, (b) a fully implemented system that includes a data directory and a bibliographic database with new classification of all records to facilitate use (a value-added concept), and (c) an Information Center that includes sufficient staff to provide full-time support services to users, such as customized searches, and direct links to the FERC licensing process.

1991

Sale, M. J., et al., 1991, *DOE Hydropower Program Environmental Mitigation at Hydroelectric Projects Report Volume 1. Current Practices for Instream Flow Needs, Dissolved Oxygen, and Fish Passage,* EG&G Idaho, Inc., NTIS DOE/ID-10360.

This report of the Environmental Mitigation Study examines current mitigation practices for water quality (specifically, dissolved oxygen), instream flows, and upstream and downstream fish passage. This review describes information on the types and frequency of mitigation methods in use, their environmental benefits and effectiveness, and their economic costs. The project was conducted jointly by the Idaho National Engineering Laboratory and Oak Ridge National Laboratory.

Chang, L. H., and S. W. Christensen, 1991, "Use of a Bioenergetics Model to Evaluate Effects of Dissolved Oxygen Mitigation at Norris Dam," M. J. Sale and P. M. Presley (eds.), *Proceedings, Fourth Tennessee Water Resources Symposium, Knoxville, Tennessee, September 24–26*. Tennessee Section American Water Resources Association and Oak Ridge National Laboratory, Oak Ridge, Tennessee, 1991.

The management of tailwater fisheries, aquatic ecosystems, and hydropower can have conflicting objectives. For example, the installation and operation of hydroelectric facilities affect downstream biological resources by changing flow regimes, temperatures, and water quality. Special interest groups vigorously support and promote each of these resources: tailwater sport fisheries, which enhance the economic and cultural life of a region; natural aquatic ecosystems, which contribute to biological diversity; and hydroelectric power, which can boost economic growth. Conflicts among these interests may multiply in the next three years as the licenses of hundreds of hydroprojects in the nation expire and applications for relicense are evaluated for renewal. When the physical costs to each resource can be presented in quantitative terms and the basis on which these costs are determined is available to review, all parties can benefit because many different solutions can be examined and their consequences quantified. This paper shows how a fish growth model influenced by environmental conditions such as water temperature and dissolved oxygen concentrations can be used to generate information about the costs and benefits of different hydropower development and mitigation scenarios. Models can provide defensible, objective, and accessible insight into outcomes of different development, mitigation, or non-development decisions.

Railsback, S. F., et al., 1991, "Review of Mitigation Methods for Fish Passage, Instream Flows, and Water Quality" *Proceedings, International Conference on Hydropower: "Waterpower '91," Denver, Colorado, July 24–26*, pp. 209–218.

Current environmental mitigation practices at non-Federal hydropower projects were analyzed, using information obtained from project developers on dissolved oxygen (DO), instream flow, and fish passage issues. The most common method for DO mitigation is the use of spill flows, which are costly because of lost power generation. DO concentrations are commonly monitored, but biological effects (i.e., benefits) are not. At many projects, instream flow requirements have been set without reference to formalized methods, or with reliance on professional judgements. Very few projects monitor fish populations to verify that instream flows are effective. Angled bar racks are the most commonly used mitigation practice for downstream fish passage, and fish ladders are the most common for upstream fish passage. Fish passage rates or populations have been monitored to verify the effectiveness of passage mitigation at few projects. This analysis is the first stage of an evaluation of the costs, benefits, and effectiveness of mitigation measures.

Sale, M. J., and R. G. Otto, 1991, "Improving the Assessment of Instream Flow Needs for Fish Populations" *Proceedings, International Conference on Hydropower: "Waterpower '91," Denver, Colorado, July 24–26*, pp. 76–84.

Instream flow requirements are one of the most frequent and most costly environmental issues that must be addressed in developing hydroelectric projects. Existing assessment methods for determining instream flow requirements have been criticized for not including all the biological response mechanisms that regulate fishery resources. A new project has been initiated to study the biological responses of fish populations to altered stream flows and to develop improved ways of managing instream flows. The proposed assessment approach uses individual-based population modeling that represents fish populations as a collection of individuals and focuses on the life history processes of individual fish by life stage. The assessment models developed under this project should provide a more realistic way of examining the tradeoffs between flow regulation and fish resources below hydroelectric projects.

Cada, G. F., 1991, "Effects of hydroelectric turbine passage on fish early life stages," *Proceedings of Waterpower '91: A New View of Hydro Resources*, American Society of Civil Engineers, New York, New York, pp. 318–326.

Turbine-passage mortality has been studied extensively for juveniles and adults of migratory fish species, but few studies have directly quantified mortality of fish eggs and larvae. An analysis of literature relating to component stresses of turbine passage (i.e., pressure changes, blade contact, and shear) indicates that mortality of early life stages of fish would be relatively low at low-head, bulb turbine installations. The shear forces and pressure regimes normally experienced are insufficient to cause high mortality rates. The probability of contact with turbine blades is related to the size of the fish; less than 5% of entrained ichthyoplankton would be killed by the blades in a bulb turbine. Other sources of mortality (e.g., cavitation and entrainment of fish acclimated to deep water) are controlled by operation of the facility and thus are mitigable. Because turbine-passage mortality among early life stages of fish can be very difficult to estimate directly, it may be more fruitful to base the need for mitigation at any given site on detailed knowledge of turbine characteristics and the susceptibility of the fish community to entrainment.

Railsback, S. F., et al., 1991, *Environmental Impacts of Increased Hydroelectric Development at Existing Dams*, ORNL/TM-11673, Oak Ridge National Laboratory, Oak Ridge, Tenn.

This report describes the environmental impacts of a proposed DOE initiative to promote the development of hydropower resources at existing dams. This development would include upgrading existing hydropower plants and retrofitting new projects at dams where no hydropower currently exists. Hydropower development at existing dams has, in general, fewer impacts than development of additional fossil-fueled resources or hydropower at new dams, although potential cumulative impacts of developing multiple hydropower projects have not been explicitly addressed. Environmental review of project impacts and mitigation needs can ensure that additional hydropower development at existing dams can provide a renewable, domestic energy resource with fewer impacts than alternative resources.

1990

Railsback, S. F., et al., 1990, "Aeration at Ohio River Basin Navigation Dams," *Journal of Environmental Engineering*, Vol. 116, No. 2, pp. 361–375.

Aeration was measured and modeled at 28 navigation dams in the upper Ohio River basin to assess impacts of retrofitting hydropower turbines. Dissolved oxygen (DO) concentrations upstream and downstream of the dams, water temperatures, and flow rates were measured under a variety of low-flow, high-temperature conditions. The DO concentration downstream of each dam was modeled as a linear function of the other variables. The DO deficit upstream was found to be a consistently significant predictor of DO deficits downstream of a dam. Inclusion of temperature and flow rate generally did not improve the statistical aeration models. The field data show that super saturation can occur at some dams; this means that the reaeration ratio used by many aeration models, including Gameson's equation, cannot be assumed to model dam aeration accurately. The linear models reproduced historic aeration measurements as well as Gameson's equation did when a least-squares parameter estimation method was used to parameterize the equation. For dams where supersaturation occurs, Gameson's equation did not predict aeration as well as the linear model. These results are applicable to assessing the impacts of hydropower that reduces aerated flows at navigation dams.

Railsback, S. F., C. C. Coutant, and M. J. Sale, 1990, "Improving the Effectiveness of Fisheries Agencies in Developing Hydropower Mitigation," *Fisheries* Vol. 15, No. 3, pp. 3–8.

New legislation and FERC regulations increase the responsibilities of state and federal fisheries management agencies for developing mitigation for hydropower projects. Having participated in some of the first major licensing cases since these changes, we offer observations on how agencies can be more effective in recommending mitigation measures that protect fisheries. Fisheries agencies need access to expertise in fields outside traditional fisheries management to address diverse hydropower impacts. Agencies need effective policies that can be applied to the specific conditions at each project. Coordination and communication between regulatory and resource agencies and with project applicants are important to establish agreement on mitigation recommendations and to share expertise. Agencies will often need to make recommendations on issues for which complete information is not available; if carefully designed, such recommendations can be defensible and conservative. A thorough understanding of current FERC procedures and policies is essential. Many of these same recommendations for effective mitigation are included in the U.S. Fish and Wildlife Service's hydropower mitigation policy.

Cada, G. F., 1990, "The Effects of Turbine Passage on Fish Early Life Stages." Submitted to the *North American Journal of Fisheries Management* Vol. 10, No. 4, pp. 418–426.

Although few studies have directly quantified ichthyoplankton mortality at hydroelectric installations, there is a considerable body of literature that examines the various stresses (i.e., pressure changes, blade contact, and shear) affecting turbine-entrained eggs and larvae. Analysis of this information indicates that turbine-passage mortality of early life stages of fish would be relatively low at low-head, bulb turbine installations. The shear forces and pressure regimes experienced are unlikely to cause mortality. Probability of contact with turbine blades is related to the size of the fish; less than 5 percent of entrained ichthyoplankton would be affected. Potential additional sources of mortality that are related to the design and operation of the hydroelectric facility, and thus are mitigable, include withdrawal of deep water and cavitation.

Cada, G. F., and C. T. Hunsaker, 1990, "Cumulative Impacts of Hydropower Development: Reaching a Watershed in Impact Assessment." *The Environmental Professional,* Vol. 12, pp. 2–8.

The "hydropower rush" brought about by passage of the Public Utility Regulatory Policy Act of 1978 caused concerns about cumulative impacts of multiple hydroelectric developments. These concerns have led the FERC, which is responsible for licensing non-federal hydroelectric projects, to conduct cumulative impact assessments. Hydropower impacts can be grouped into four potential pathways, ranging from simple, additive effects of a single project to synergistic effects arising from multiple projects. The fisheries and water quality aspects of studies for three basins (San Joaquin, Owens, and Ohio river basins) are described in this context. These regional studies and the national study of environmental impacts of hydropower development (required by the Electric Consumers Protection Act of 1986) illustrate appropriate spatial and temporal scales for effective cumulative impact assessments. Although regional assessments of cumulative impacts are often necessary to give context to local assessments, the lack of regional models and adequate temporal and spatial data frequently hinders the quantification of cumulative impacts.

Cada, G. F., 1990, "Assessing fish mortality rates," *Hydro Review,* Vol. 9, pp. 52–60.

One of the major environmental issues facing hydroelectric development is fish mortality resulting from turbine passage. Whether the action involves licensing a proposed new installation or relicensing an existing facility, the potential for turbine operation to kill significant numbers of fishes must be considered. Turbine-passage mortality has been studied extensively for migratory fishes, but little is known about corresponding impacts to resident fisheries resources of inland waters, the location of many existing and planned facilities. Studies of the susceptibility of fish eggs and larvae (i.e., ichthyoplankton) to turbine-passage mortality have been especially rare, probably because of the extreme difficulty of obtaining reliable estimates.

Although few studies have directly examined the issue of turbine-caused ichthyoplankton mortality, the same types of stresses experienced by turbine-passed fishes have been considered in other contexts, notably entrainment studies at thermal power plants and pumped storage projects. This article reviews and synthesizes the results of these studies to estimate the level of ichthyoplankton mortality that could be expected at hydroelectric power plants.

Chang, L. H., and S. F. Railsback, 1990, "Predicting Effects of Global Climate Change on Reservoir Water Quality and Fish Habitat," *Optimizing the Resources for Water Management, Proceedings of the 17th Annual National Conference, Water Resources Planning and Management Division*, R. M. Khanbilvardi and T. C. Gooch, eds., American Society of Civil Engineers, New York, pp. 545–550.

The output from three general circulation models (GCMs) was used with a reservoir model to predict changes in water temperature, dissolved oxygen, and adult striped bass habitat that would result from global climate change. The predicted changes in air temperature, humidity, runoff, solar radiation, and wind speed were used to adjust input to a two-dimensional water quality model of Douglas Reservoir, a multipurpose project in eastern Tennessee. The reservoir model was used to simulate water temperatures and dissolved oxygen concentrations in each of over 150 volume elements. The reservoir model also simulates adult striped bass habitat, which is defined as the volume of water with both dissolved oxygen concentration and temperature within ranges acceptable to this fish. Simulations of a full year were conducted with data from 1974, a climatically typical year for which the model was calibrated. Uncertainties in the use of GCMs for studies of climate change impacts on ecosystems include differences in climate change predictions among the various GCMs, errors induced by the coarse spatial resolution of GCMs, and approximations included in the GCM formulations for modeling climatic processes (especially for surface hydrology). The GCM uncertainties are in addition to the uncertainties normally occurring in reservoir modeling. However, simulations made with the different GCM-generated climate scenarios all predicted summer water temperature increases sufficient to cause major decreases in striped bass habitat. Sensitivity analyses showed that increases in wind speed, which some of the GCMs predict, could reduce the habitat loss to some extent. Despite the uncertainties involved in using GCMs to predict the effects of global climate change, the consensus among results obtained with different GCMs supports the conclusion that climate change will result in significantly higher water temperatures and reduced habitat for adult striped bass in Douglas Reservoir. GCM results can be used with a reservoir model to predict local effects of global climate change.

Irving, J. S., G. L. Olson, R. M. Lugar, and R. P. Breckenridge, 1990, *Development of Technology to Treat and Dispose of Fish Farm Waste*, EG&G Idaho, Inc., Annual Report, Idaho Falls, ID.

Fish manure, silt, and unused feed are by-products of aquaculture operations. Although most of the solids occur naturally in free-flowing systems, the unnaturally high concentrations from fish farming can pose environmental threats. When flushed into waterways, the solids cause algae blooms, turbidity, dissolved oxygen sags, and nitrate pollution. This paper reports on the investigations to evaluate and test (1) solids removal techniques from fish farm raceways and (2) sludge disposal technology. A variety of methods were designed to collect and remove solids from hatchery raceways. Some fish farms pump fish manure slurry directly from the settling basin, through irrigation pipes, to agricultural fields. Others stockpile the manure and dispose of it in landfills. Current techniques for removing fish manure from the raceways are labor intensive. Six prototype systems designed to remove solids from the raceways were evaluated. Fish manure was analyzed for nutrient and trace element content. Also, the nutrient potential of fish waste was tested in greenhouse and field experiments using Idaho crops (wheat and corn). The experiments compared the agronomic performance of fish manure to commercially available nutrient sources.

Railsback, S. F., and M. J. Sale, 1990, "Application of Optimized Water Quality Mitigation to Hydropower Development in the Ohio River Basin," *Water Resource Systems Application*, S. P. Simonovic et al., eds, University of Manitoba, Winnipeg, Canada, pp. 413–422.

An optimization model was used to determine spill flow requirements for 16 proposed hydropower projects at existing navigation dams in the upper Ohio River Basin. Spill flows are required to provide aeration sufficient to meet dissolved oxygen criteria in this system where effects of individual projects are interactive and cumulative. The optimization model maximizes total power generation of the projects while meeting the dissolved oxygen criteria during critical design conditions. Although some fisheries agencies disputed the use of modeling to determine spill flow requirements, the modeling technique was accepted by the hydropower licensing commission and the results were included in the operating licenses for the 16 projects.

1989

Irving, J. S., and M. B. Bain, 1989, "Assessing Cumulative Impact on Fish and Wildlife in the Salmon River Basin, Idaho," *The Scientific Challenges of NEPA: Future Direction Based on 20 Years of Experience, Knoxville, TN, October 24–27,* pp. 357–372.

The National Environmental Policy Act of 1969 (NEPA) alluded to cumulative impacts, although no formal definition was recognized until 1978 when the Council on Environmental Quality (CEQ) addressed the issue. Subsequently, several legislative acts, Federal and state regulations, and court rulings require environmental impact assessments to include cumulative impact studies. Attempts to include cumulative impacts in environmental impact assessments, however, did not begin until the early 1980s. One such effort began when the FERC received over 1,200 applications for hydroelectric projects in the Pacific Northwest. Federal and state agencies, Indian tribes, and environmental groups became concerned that many small developments could have potentially significant cumulative impacts on fish and wildlife resources. In response to the concern, FERC developed the Cluster Impact Assessment Procedure (CIAP), which consists of (1) public scoping meetings; (2) interactive workshops designed to identify projects with potential for cumulative effects, resources of concern, and available data; and (3) preparation of a NEPA document (EA or EIS). The procedure was modified to assess the cumulative impacts of fifteen hydroelectric projects in the Salmon River Basin, Idaho. The methodology achieved its primary objective of evaluating the impact of multiple hydroelectric developments on fish and wildlife resources. However, the paucity and low quality of data limited the analysis. In addition, the use of evaluative techniques to express and analyze impacts and interactions among proposed projects hindered acceptance of the conclusions. Notwithstanding these problems, the cumulative impact study provided a basis for decision makers to incorporate the potential impact of multiple projects into the hydropower licensing process.

Sale, M. J., et al., 1989, "Balancing Hydropower Development in the Ohio River Basin," *Proceedings, International Conference on Hydropower: Waterpower '89, Buffalo, New York, August 23–25,* pp. 886–896.

Many retrofit hydroelectric projects have been proposed at existing navigation dams in the Ohio River basin. These proposals involve potentially adverse environmental impacts, including reduced dissolved oxygen concentrations from decreased aeration at dams. The FERC completed an environmental impact statement for 24 proposed projects at 19 dams on the Ohio, Monongahela, Allegheny, and Muskingum rivers, evaluating the cumulative impacts of hydropower development on more than 500 miles (800 km) of river. The use of models in this assessment proved extremely valuable for understanding the cumulative impacts of hydropower development on water quality in the basin and for balancing power and environmental quality considerations in the licensing process.

Chang, S. Y., et al., 1989, "Methods For Generating Hydroelectric Power Development Alternatives," *Systems Analysis for Water Resources Management: Closing the Gap Between Theory and Practice*, D. P. Loucks (ed.). IAHS Publication No. 180, International Association of Hydrologic Sciences, Wallingford, United Kingdom, pp. 43–52.

Hydropower development on large rivers can result in a number of environmental impacts, including potential reductions in dissolved oxygen (DO) concentrations. This study presented a methodology for generating different hydropower development alternatives for evaluation. This methodology employs a Streeter-Phelps model to simulate DO, and the Bounded Implicit Enumeration algorithm to solve an optimization model formulated to maximize hydroelectric energy production subject to acceptable DO limits. The upper Ohio River basin was used to illustrate the use and characteristics of the methodology. The results indicate that several alternatives that meet the specified DO constraints can be generated efficiently, meeting both power and environmental objectives.

Hildebrand, S. G., and G. F. Cada, 1989, *Case Studies Defining Environmental Issues for Non-Federal Hydroelectric Development in the United States*. UNESCO International Hydroelectric Program Phase III Report.

This paper reviews five recent examples of FERC hydroelectric licensing actions: the Susitna project in Alaska, multiple-project development in the Owens (California) and upper Ohio River basins, the El Portal project (California), and a national assessment of federal incentives for development at new dams and diversions. Each project is briefly discussed, significant findings regarding environmental impacts are summarized, and recommendations resulting from the impact analyses and the ultimate decision on the projects are reviewed. These projects represent a range of actions typical of hydroelectric development in the United States.

Kondolf, G. M., et al., 1989, "Distribution of Potential Salmonid Spawning Gravels in Steep Boulder-Bed Streams of the Eastern Sierra Nevada," *Transactions of the American Fisheries Society.*

Geomorphic and hydraulic characteristics of salmonid spawning habitat were studied in high-gradient, boulder-bed streams atypical of the more commonly described lower-gradient channels. Gravel deposits were not abundant in the study reaches, occurring only in microenvironments of relatively low shear stress. Gravel mobility was accompanied by substantial scour and fill and other changes in many of the channel cross sections. This mobility may explain the relative abundance of brown trout over rainbow trout in the study reaches, where high flows occur every May and June during snowmelt season. Brown trout are fall spawners; their fry emerge long before the high snowmelt flows. Rainbow trout are spring spawners; their eggs are in the gravel, and thus vulnerable to scour, during snowmelt flows.

Petrich, C. H., S. F. Railsback, and M. M. Swihart, 1989, "Assessment of Instream Flow Impacts on Recreational and Aesthetic Resources." *Legal, Institutional, Financial, and Environmental Aspects of. Water Issues*, G. R. Baumli (ed.), American Society of Civil Engineers, New York, pp. 100–107.

This paper examined means for identifying and protecting recreational and aesthetic resources that could be affected by water resource development. Water resource managers need to understand when instream flows to protect recreational and aesthetic values should be considered along with competing water uses. The recreational value of proposed instream flow rates can be estimated from surveys of users and changes or projected changes in tourist industry income, recreational usage, and aquatic habitat. From quantification of these values, concerns about minimum flow rates can be factored into impact analyses and management decisions. Secondary impacts to recreation and aesthetics resulting from changes in riparian vegetation and fish populations can also be assessed. In some cases, dollar values can be reasonably assigned. Recreational and aesthetic values need no longer be addressed in only a cursory way, because reliable techniques for their quantification are now available and are compatible with methods used to evaluate other resource-related impacts of changes in instream flows.

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," *Water Resources Planning and Management, Proceeding of the 16th Annual Conference*, S.C. Harris (ed.), American Society of Civil Engineers, New York, pp. 555–558.

The upper Ohio River system, including the Monongahela and Allegheny rivers, is used for navigation, recreation, waste assimilation, and power plant cooling. The installation of hydroelectric plants is proposed at 18 existing navigation dams along 740 river km of this system. Six additional plants are already operating or under construction. Because these projects are on canalized rivers, aeration at dams is an important source of dissolved oxygen (DO). The FERC must decide whether to license each of the proposed projects. To aid decision-making, a modeling study was conducted to predict the effects of changes in dam aeration on water quality. The assessment used a system-wide water quality model to determine the cumulative changes in DO concentrations resulting from changes in aeration at the chain of navigation dams. An optimization model was developed to determine aeration releases at each dam that would maintain desired DO concentrations and maximize power production in the basin.

Railsback, S. F., J. J. Beauchamp, and D. J. Downing, 1989, "Comparison of Time-Series and Regression Methods for Synthesizing Missing Streamflow Records on the Merced River, California." *Water Resources Bulletin.*

Regression and time-series techniques have been used to synthesize and predict the stream flow at the Forest Bridge gauge from information at the upstream Pohono Bridge gauge on the Merced River near Yosemite National Park. Two techniques were evaluated for their ability to model the variation in the observed flows and to predict stream flow at the Forest Bridge gauge in 1979 using data from the 1986 water year. Both techniques produced reasonably good estimates and forecasts of the flow at the downstream gauge. However, the regression model was found to have a significant amount of autocorrelation in the residuals, which were eliminated in the time-series model. The time-series technique presented can be of great assistance in arriving at reasonable estimates of flow in data sets with many missing observations.

Railsback, S. F., B. D. Holcomb, and M. G. Ryon, 1989, *A Computer Program for Estimating Fish Population Sizes and Annual Production Rates*, ORNL/TM-11061, Oak Ridge National Laboratory, Oak Ridge, TN.

A computer program to estimate fish population sizes and annual production rates from multiple-pass sampling data was developed. The multiple-pass sampling method is commonly used to study fish populations in streams, but software to calculate annual production rates from general multiple-pass data has not been available. The program uses the Carle and Strub maximum weighted likelihood method to estimate population sizes, and the size-frequency method of Garman and Waters to estimate annual production. The program was designed to be easily applied to a wide variety of sample sites, fish species, and fish sizes. New techniques to estimate the variance in annual production rates were incorporated.

Sale, M. J., 1989, "Multiple-Resource Management of Tailwaters for Downstream Needs," *Tailwater Ecology Workshop, Proceedings/Summary of a North American Lake Management Society Session, St. Louis, Missouri, 15 November 1988*, S. Campbell (ed.), U.S. Bureau of Reclamation, Denver, Colorado, pp. 52–53.

Managing tailwaters means allocating water among competing uses. The water quality and quantity released from dams is important to numerous downstream uses, including fish and wildlife habitat needs, recreation, navigation, hydroelectric generation, public industrial water supply, sediment transport, and waste assimilation. As a result, multipurpose management is unavoidable. No single user can dominate and users who approach the decision-making table without an appreciation for their competitors' needs will be at an extreme disadvantage. To conduct multipurpose management, it is necessary to make the tradeoffs among competing uses, hopefully using rational methods. When the parties in a water allocation problem do not participate in the negotiation process by evaluating their water uses and objectives, the loser is usually one or more of the resources.

1988

Cada, G. F., J. M. Loar, and M. J. Sale, 1988, "Evidence of Food Limitation of Rainbow and Brown Trout in Southern Appalachian Soft-Water Streams." *Transactions of the American Fisheries Society*, Vol. 116, No. 5, pp. 692–702.

Seasonal patterns of age-specific growth rates and condition factors of rainbow (*Salmo gairdneri*) and brown trout (*S. trutta*) were studied in relation to the available food resources in five streams of the southern Appalachian mountains. Benthic standing crops and total drift rates were lower than in comparable-sized streams in other geographic areas. Numbers of prey items per trout stomach were small and directly related to drift rate, reflecting the limited food base. Condition factors of Age 1 trout declined during summer, and growth rates among Age 1 and older trout were generally lower in summer than in winter, despite favorable summer water temperatures. This "inverted" seasonal pattern of growth was likely due to an inadequate food base. The likely reason that growth rates were relatively low in summer was that much of the limited energy intake was devoted to metabolism, with little energy let for growth. Higher growth rates occurred in winter because energy requirements for metabolism were reduced at lower water temperatures. An important function of habitat in food-limited streams may be to partition overall fish production among age classes by providing energy-efficient feeding sites for different sizes of fish.

Gatz, A. J., and J. M. Loar, 1988, "Petersen and Removal Population Size Estimates: Combining Methods to Adjust and Interpret Results When Assumptions are Violated," *Environmental Biology of Fishes*, Vol. 21, No. 4, pp. 293–307.

Presented are ways to test the assumptions of the Petersen and removal methods of population size estimation and ways to adjust the estimates if violations of the assumptions are found. The facts were that (1) results of using both methods are commonly reported without any reference to the testing of assumptions, (2) violations of the assumptions are more likely to occur than not in natural populations, and (3) the estimates can be grossly in error if assumptions are violated. In many cases two days in the field is the most time fish biologists can spend in obtaining a population estimate, so the use of alternative models of population estimation that require fewer assumptions is precluded. Hence, for biologists operating with these constraints and only these biologists, a two-day technique that combines aspects of both capture-recapture and removal methods is described and recommended. How to test most of the assumptions of both methods and how to adjust the population estimates obtained if violations of the assumptions occur are indicated. Also illustrated is the use of this combined method with data from a field study. The results of this application further emphasize the importance of testing the assumptions of whatever method is used and making appropriate adjustments to the population size estimates for any violations identified.

Railsback, S. F., 1988, "Dissolved Oxygen Strategies for Hydropower Licensing." *Hydro Review* Vol. 7, No. 3, pp. 52–64.

Dissolved oxygen is an important environmental concern at many hydropower projects. For proposed new developments, license applicants should consider whether or not their project would cause DO problems, by considering whether they would create a stratified reservoir, or whether their project would alter important sources of aeration. A license applicant should define the scope and magnitude of the DO problem as accurately as possible, to reduce the uncertainty in the amount of mitigation required. Predictive methods, such as statistical or mathematical models, should be developed as necessary to evaluate DO concentrations under various operating conditions. Once the range of DO concentrations (over space and time) resulting from the project has been determined, and the DO concentrations likely to be required by the permitting process have been determined, the need for mitigation can be determined. A thorough understanding of the processes that add DO to and consume DO in the river is useful in finding the most cost-effective way to increase DO concentrations. Cost-effective mitigation is important, because it affects the economic benefits of the project, which is a major consideration to FERC in making licensing decisions.

Kondolf, G. M., J. Warren Webb, M. J. Sale, and T. Felando, 1988, "Basic Hydrologic Studies for Assessing Impacts of Flow Diversions on Riparian Vegetation: Examples from Streams of Eastern Sierra Nevada, California, U.S.A.," *Environmental Management*, Vol. 11, February, pp. 757–769.

As the number of proposals to divert streamflow for power production has increased in recent years, interest has grown in predicting the impacts of flow reductions on riparian vegetation. Because the extent and density of riparian vegetation depends largely on local geomorphic and hydrologic setting, site-specific geomorphic and hydrologic information is needed. The purposes of this paper are (1) to describe methods for collecting relevant hydrologic data, and (2) to report the results of such studies on seven stream reaches proposed for hydroelectric development in the eastern Sierra Nevada, California. The methods described are (1) preparing geomorphic maps from aerial photographs, (2) using well level records to evaluate the influence of stream flow on the riparian water table, (3) taking synoptic flow measurements to identify gaining and losing reaches, and (4) analyzing flow records from an upstream-downstream pair of gauges to document seasonal variations in downstream flow losses. In the eastern Sierra Nevada, the geomorphic influences on hydrology and riparian vegetation were pronounced. For example, in a large, U-shaped glacial valley, the width of the riparian strip was highly variable along the study reach and was related to geomorphic controls, whereas the study reaches on alluvial fan deposits had relatively uniform geomorphology and riparian strip width. Flow losses of 20% were typical over reaches on alluvial fans. However, one stream gained up to 275% in a mountain valley because of geomorphically controlled groundwater contributions.

FERC, 1988, *Hydroelectric Development in the Upper Ohio River Basin-Final Environmental Impact Statement*, FERC/FEIS-0051, Docket No. EL85-19-114, Federal Energy Regulatory Commission, Office of Hydropower Licensing, Washington, D.C. (Prepared by ORNL).

Twenty-four hydroelectric projects (including competing applications at five sites) that would produce a total of 1,910 gigawatt-hours per year of electric power were evaluated to determine the environmental effects and economic benefits. Four hydroelectric generation alternatives and a 400-megawatt coal-fired power plant were examined in the assessment. The cumulative and site-specific impacts of the projects were analyzed, taking into account the potential for mitigating adverse impacts. The staff recommended an alternative which would allow development of hydroelectric projects at 16 of the 19 proposed sites. The recommended alternative would permit 1,560 gigawatt-hours of new hydroelectricity to be produced (82% of the power proposed by project applicants); would prevent projects from causing dissolved oxygen concentrations low enough to affect aquatic life; and would avoid significant adverse impacts to wetlands, fisheries, and recreation.

FERC, 1988, *PURPA Benefits at New Dams and Diversions*. Final Staff Report, Docket No. EL 87-9, Federal Energy Regulatory Commission, Office of Hydropower Licensing, Washington, D.C. (Prepared by ORNL and ELI).

This study, mandated by the Electric Consumers Protection Act (ECPA) of 1986, evaluated the economic and environmental effects of granting or denying PURPA benefits for hydroelectric projects located at new dams and diversions throughout the U.S. Staff concluded that the continuation of PURPA benefits without the environmental constraints defined by ECPA would provide incentives for private or nonutility (i.e., PURPA-qualified) development of up to 84 new projects, with a total capacity of about 1,500 MW, that would not be developed without PURPA benefits. However, this unconstrained development at new dams and diversions would also involve the potential for substantial adverse environmental impacts to anadromous and other important fisheries and to recreational and aesthetic resources, particularly in the Pacific Northwest, California, and Colorado. The continuation of PURPA benefits with the environmental constraints defined by ECPA would provide incentives for private or nonutility development of 34 new projects with a capacity of about 500 MW and with minimal environmental impacts. The ECPA environmental constraints would effectively preclude the development of approximately 50 sites with a capacity of 1,050 MW, but would have the intended benefits of minimizing potential adverse environmental impacts.

Railsback, S. F. and H. I. Jager, 1988, *Simulation Modeling of Hydropower Impacts on Dissolved Oxygen in the Upper Ohio River Basin*, RNL/TM-10953, Oak Ridge National Laboratory, Oak Ridge, TN.

A deterministic simulation model was developed to assess the impacts of hydropower development at navigation dams on dissolved oxygen (DO) concentrations in the upper Ohio River basin. Field data were used to fit statistical models of aeration at each dam. The Streeter-Phelps equations were used to model DO concentrations between dams. Input data sources were compiled, and the design conditions used for assessment of hydropower impacts were developed. The model was implemented both as a Lotus 1-2-3 spreadsheet and as a FORTRAN program. The report contains users guides for both of these implementations. The sensitivities and uncertainty of the model were analyzed. Modeled DO concentrations are sensitive to water temperature and flow rates, and sensitivities to dam aeration are relatively high in reaches where dam aeration rates are high. Uncertainty in the model was low in reaches dominated by dam aeration and higher in reaches with low dam aeration rates. The 95% confidence intervals for the model range from about ±0.5 mg/L to about ± 1.5 mg/L.

Sale, M. J., G. F. Cada, and J. M. Loar, 1988, "Trout-Habitat Relations in Southern Blue Ridge Streams," *Proceedings, An Instream Flow Workshop for Fish Biologists*, Tech Aqua, Tennessee Technological University, Cookeville, Tennessee, pp. 19–20.

A study was conducted to evaluate the validity of physical habitat indices for predicting the response of trout populations to changes in stream flow, focusing fish/habitat relationships. The results showed that habitat values do appear to be related to trout resources (e.g., biomass and abundance), and that the presence of food limitation does not eliminate a positive response to habitat. To predict the response of trout populations to flow alteration, it is recommended that (1) habitat variables be carefully chosen with respect to critical life stages and periods of the year, (2) site-specific interactions between target species be considered, and (3) management objectives be clearly defined. The most appropriate habitat indices are those based on minimum values calculated over the period that a given life state is present. When used properly, habitat variables can be useful in assessing changes in fishery resources resulting from flow alterations.

1987

Kondolf, G. M., G. F. Cada, and M. J. Sale, 1987, "Assessment of Flushing Flow Requirements for Brown Trout and Spawning Gravels, Eastern Sierra Nevada," *Water Resources Bulletin*, Vol. 23, No. 5, pp. 927–935.

Flushing flows are releases from dams designed to remove fine sediment from downstream spawning habitat. Flushing flows were evaluated on reaches proposed for hydroelectric diversions on seven streams in the eastern Sierra Nevada, California, with wild populations of brown trout (*Salmo trutta*). The study reaches are steep (average map slopes range from 7–17%), are dominated by boulder cascades, and afford few opportunities for gravel deposition. Methods for estimating flushing flows from flow records, developed from studies in other localities, produced widely differing results when applied to the study streams, probably reflecting differences in the hydrologic and geomorphic characteristics of the streams on which the methods were developed. Tracer gravel experiments demonstrated that all sampled gravels were washed out by the flows of 1986, a wet year. Size analyses of gravel samples and hydraulic data from field surveys were used in tractive-force calculations in an attempt to specify the flow required to flush the gravels. However, these calculations produced some unrealistic results because the flows were nonuniform in the study reaches. This suggests that the tractive-force approach may not be generally applicable to small, steep streams where nonuniform flow conditions prevail.

Cada, G. F., J. M. Loar, and D. K. Cox, 1987, "Food and Feeding Preferences of Rainbow and Brown Trout in Southern Appalachian Streams," *American Midland Naturalist* Vol. 117, No. 2, pp. 374–385.

The stomach contents of Age 1 and older rainbow (*Salmo gairdneri*) and brown trout (*S. trutta*) in five, southern Appalachian, soft-water streams were compared with concurrent drift samples. A wide range of food items was consumed, and no prey genus comprised an average of more than 2.5% by number of the diet of either trout species. Seasonal changes in composition of drift from June to November were generally mirrored by shifts in trout diets. The contribution of terrestrial organisms to drift and to diets was highest in late summer and autumn. Averaged overall samples, terrestrial taxa comprised 36, 45, and 50% of the drift, rainbow, and brown trout diets, respectively. Both trout species exhibited statistically significant feeding preferences for particular taxa (notably terrestrial organisms), but most prey were consumed in proportions similar to the abundance in the drift. Opportunistic feeding lends stability to trout populations in streams with relatively low autochthonous food production by allowing trout to capitalize on terrestrial input. Our findings emphasize the importance of both protecting riparian vegetation (which is a source of terrestrial prey) and considering aquatic habitat elements in which trout can efficiently capture surface drift when determining minimum streamflow requirements for water-diversion projects.

Gatz, A. J., M. J. Sale, and J. M. Loar, 1987, "Habitat Shifts in Rainbow Trout: Competitive Influences of Brown Trout," *Oecologia*, Vol. 4, pp. 7–19.

Compared habitat use by rainbow trout sympatric (three streams) and allopatric (two streams) with brown trout to determine whether competition occurred between these two species in the southern Appalachian Mountains. Measured are water depth, water velocity, substrate, instance to overhead vegetation, sunlight, and surface turbulence both at the trout collection site and for the streams in general, separating the effects of habitat availability from possible competitive effects. The results provided strong evidence for asymmetrical interspecific competition. Habitat use varied significantly between allopatric and sympatric rainbow trout in 68% of the comparisons made. Portions of some differences reflected differences in habitats available in the several streams. However, for all habitat variables measured except sunlight, rainbow trout used their preferred habitats less in sympatry with brown trout than in allopatry if brown trout also preferred the same habitats. Multivariate analysis indicated that water velocity was the most critical habitat variable in the competition and water depth was least important.

Kondolf, G. M., L. M. Maloney, and J. G. Williams, 1987, "Effect of Bank Storage and Well Pumping on Base Flow," *Journal of Hydrology*, Vol. 91, pp. 351–369.

Bank storage contributions to base flow may be important on alluvial rivers with highly permeable bank materials, such as the lower Carmel River, Monterey County, California. The recharge phase of bank storage occurs during flood stage in the river when a hydraulic gradient exists from the river into the banks. In general, discharge from bank storage is most important on the recession limb of individual floods, with most stored water typically being discharged within 2–3 flood periods. As the river stage continues to fall, a hydraulic gradient from the banks to the river will be maintained and stored water will drain from the banks. On the Carmel River, the seasonal recession limb provides conditions of a gradually declining stage over several months. In 1982, a moderately wet year, bank storage contributions were detected two months after the last peak flow of the winter rainy season, during a period of critical importance to steelhead trout and probably to riparian vegetation. However, in 1983, an extremely wet year, bank storage was undetectable two months after the season's last peak flow, probably because the sustained base flow from the upper basin overwhelmed the more transient bank storage contribution. Groundwater withdrawal from the alluvial aquifer locally lowered the water table so that streamflow was influent to the banks in the reach of major pumping wells. This effect was striking in its persistence, whether the Carmel River was gaining or losing overall in its alluvial reach. Pumping rates were roughly comparable to flow losses across the well field.

Nettles, D. C., and S. P. Gloss, 1987, "Outmigration of Landlocked Atlantic Salmon Smolts and Effectiveness of an Angled Trash Rack/Fish Bypass Structure at a Small Scale Hydroelectric Facility," *North American Journal of Fisheries Management*, Vol. 7, pp. 562–568.

Downstream movements by Atlantic salmon smolts (*Salmo solar*) were monitored with radio telemetry to assess the effectiveness of an angled trash rack/fish bypass structure at a small hydroelectric dam on the Boquet River, New York. Telemetry of 170 Atlantic salmon smolts and visual observations of stocked smolts were used to determine aspects of Atlantic salmon outmigration behavior. Smolts initiated mass migrations after river temperatures reached or exceeded 10°C.

Many radio-tagged smolts interrupted movements upon reaching ponded waters and/or the dam. River flow did not ($P>0.05$) affect the frequency of migratory movements, passages, or rate of movement. Migrations lasted approximately 30 days. Passages at the dam occurred primarily at Night (61%) with diurnal passages (17%) and crepuscular passages (17%) of secondary importance. Timing of 5% of the passages was undetermined. All passages that occurred when angled trash racks were in place were through the bypass or over the spillway. Six passages occurred when trash racks perpendicular to the penstock were in place: three of these were penstock passages. The angled trash rack and bypass structure significantly reduced entrainment through the penstock and turbine ($P > 0.05$).

1986

Stier, D. J., and B. Kynard, 1986, "Use of Radio Telemetry to Determine the Mortality of Atlantic Salmon Smolts Passing Through a 17-Megawatt Kaplan Turbine at a Low Head Hydroelectric Dam," *Transactions of the American Fisheries Society*, Vol. 115, No. 5, pp. 771–775.

Mortality among 108 radio-tagged 2-year-old smolts of Atlantic salmon (*Salmo salar*) passing through a 17-MW Kaplan turbine was estimated at Holyoke Dam on the Connecticut River. The survival of test and control fish in 1981 was determined by comparing their rate of downstream movement with that of 28 prekilled fish. The survival of test fish in 1982 was determined as in 1981 by using nine prekilled fish. At full power generation, the mean percent turbine-induced mortality at 2 hours (95% confidence interval in parentheses) was 11.8 (3.8–18.0) in 1981 and 13.7 (1.9–22.5) in 1982.

Gatz, A. J., J. M. Loar, and G. F. Cada, 1986, "Effects of Repeated Electroshocking on Instantaneous Growth of Trout," *North American Journal of Fisheries Management*, Vol. 6, No. 2, pp.176–182.

Instantaneous growth rates were calculated for age 1, 2, and 3 + wild rainbow trout (*Salmo gairdneri*) and brown trout (*Salmo trutta*) at each of eight sites on five streams in western North Carolina and eastern Tennessee. Growth rates of individual trout that had been electroshocked with pulsed direct current 2 to 7 times within a 12-month period were lower than the average growth rates for trout of the same age and species at their respective sites. This decrease in growth rate occurred significantly more often among Age 1 and 2 trout than among those 3 years and older, and more often among trout that had been electroshocked within the last 2.5 months than among trout that had 3 or more months to recover from electroshocking. These results indicated that fisheries management studies such as instream flow assessments should be designed to avoid repeated electroshocking, especially at intervals of less than 3 months. Growth studies in which more than a small fraction (e.g., <20%) of the fish are repeatedly electroshocked at short (<3 month) intervals are likely to underestimate growth rates.

Bell, C. E. and B. Kynard, 1986, "Mortality of Adult American Shad Passing Through a 17-Megawatt Kaplan Turbine at a Low Head Hydroelectric Dam," *North American Journal of Fisheries Management*, Vol. 5, No. 1, pp. 33–38.

In May 1982, the mortality of prespawning American shad (*Alosa sapidissima*) was studied over a 5-hour period after passage through the 17-MW Kaplan turbine at Holyoke Dam, Connecticut River, Massachusetts. Radio telemetry was used to determine the survival of 36 test fish during seven experiments by comparing their movement patterns with those of 21 sacrificed fish that were also passed through the turbine. Sixty-nine control fish fitted with dummy tags were released and held in an instream net for direct observation of mortality because of handling, tagging, and introduction procedures. The mean turbine mortality (M_T) was 21.5% (95% confidence limits of 3.3 to 36.2%). Similar preliminary experiments with postspawned American shad indicated that mortalities during their normal outmigration should be higher than the mortality estimate for prespawned fish.

Loar, J. M., et al., 1986, "Instream Flow Needs to Protect Fishery Resources," *Water Forum '86: Work Water Issues in Evolution, Vol. 2*. American Society of Civil Engineers, New York, NY, pp. 2098–2105.

Numerous methods have been developed over the past several decades to assess the effects of flow regulation on fishery resources and to provide a basis for the determination of suitable instream flow regimes to protect these resources. Many of these methods rely on historical flow records without considering the specific requirements of aquatic biota. Such methods are inflexible, are difficult to defend from an ecological basis, and offer no opportunity for the type of trade-off analysis necessary in water resource today. Even state-of-the-art methods that can quantify changes in physical habitat as a function of stream flow may be inadequate because they do not consider other (biological) variables that may be significant determinants of population abundance. Future research must emphasize the role of all factors that limit population size if we are to be successful in including hydrologic parameters in fish production models. Although some methods are adequate for determining minimum flows needed to maintain existing habitat conditions, no method is currently capable of adequately predicting responses of fish populations to flow modifications. Selection of an appropriate method for evaluating potential impacts of water development projects must consider (1) limitations of the various methods, (2) project design and operation, and (3) status of the fishery resources and current management objectives.

1985

Bain, M. B., 1985, *Fish Community Structure in Rivers with Natural and Modified Daily Flow Regimes*, Ph.D. Dissertation, University of Massachusetts, Amherst, Massachusetts.

The effects of artificial flow fluctuation on stream fish communities was examined during a 2-year period. A "natural experiment," comparing fish community structure in a river with a natural daily flow regime and a river with dramatic daily flow fluctuations, was used to address questions concerning (a) appropriate macrodescriptors for examining the relationship between fish and habitat, (b) the effect of variable habitat conditions on stream fish communities, and (c) predictions of the intermediate-disturbance hypotheses. The density of fish in each type of stream habitat (shallow slow, general) was compared between rivers and along a gradient of flow fluctuations in the modified river.

Fish that required shallow slow habitat ("specialists") appeared to be reduced in abundance by flow fluctuations. Under fluctuating habitat conditions, fish with more broad habitat requirements ("generalists") were found in greater abundance. It was concluded that (a) artificial flow fluctuations alter fish community structure, (b) the response of fish to variable habitat depends on their microhabitat use patterns, (c) fish specializing on shallow slow microhabitat were reduced in abundance while other fish were either increased or unaffected, and (d) changes in fish community structure associated with frequent habitat disturbances were consistent with the predictions of the intermediate-disturbance hypothesis.

Cada, G. F., and R. B. McLean, 1985, "An Approach for Assessing Fisheries Impacts of Basin-Wide Hydropower Development," in *Small Hydro and Fisheries, Symposium Proceedings, American Fisheries Society, Bethesda, Maryland*, edited by F. Olsen et al.

The recent emphasis on small-scale hydroelectric development has resulted in a confusing patchwork of applications for hydropower licenses, exemptions, and preliminary permits, all with the same river basin. Although the National Environmental Policy Act requires an assessment of the cumulative environmental impacts of existing and planned developments, there is no widely accepted methodology for performing such an analysis. One promising approach to assessing cumulative impacts on fisheries is the use of matrices that display the key components of this resource and quantitatively describe how hydropower development may affect them. In addition to its value in predicting impacts, the matrix is a useful framework for negotiations among involved parties and may be used to determine the effects of mitigative measures. This paper describes an application of the matrix technique to the assessment of hydropower impacts on resident trout in the Upper San Joaquin River basin in California. Advantages and limitations of the approach as a tool for assessing multiple-project impacts, as well as its potential for assessing cumulative impacts, are described. Recommendations are made for further development of basin-level impact-assessment methods.

Cushman, R. M., 1985, "Review of Ecological Effects of Rapidly Varying Flows Downstream from Hydroelectric Facilities," *North American Journal of Fisheries Management.*

Rapid changes in flow below hydroelectric facilities result from peaking operations, where water is typically stored in a reservoir at night and released through turbines to satisfy increased electrical demand during the day. Potential impacts of these short-term, recurring disturbances of aquatic systems below dams are important considerations in hydropower development. Reduced biotic productivity in tailwaters may be due directly to flow variations or indirectly to a variety of factors related to flow variations, such as changes in water depth or temperature, or scouring of sediments. Many riverain fish and invertebrate species have a limited range of conditions to which they are adapted. The relatively recent pattern of daily fluctuations in flow is not one to which most species are adapted; thus, such conditions can reduce the abundance, diversity, and productivity of these riverain organisms. Information needs for site-specific evaluations of potential impacts at hydroelectric peaking projects are outlined, along with management and mitigation options to reduce anticipated adverse effects.

Hildebrand, S. G., et al., 1985, "National Perspective on Environmental Constraints to Hydroelectric Development," *Perspectives on Nonpoint Source Pollution, Proceedings of a National Conference, Kansas City, Missouri, May 19–22.*

This paper describes major environmental issues on which the U.S. Department of Energy's Small-Scale Hydropower Program has concentrated. The three issues common to nonpoint source problems and hydroelectric development are (a) dissolved oxygen concentrations in tailwaters below dams, (b) instream flow requirements for fisheries, and (c) the cumulative impacts of multiple-project development in river basins. The current status of these issues is reviewed and recommendations are made for addressing them.

Kondolf, G. M., and M. J. Sale, 1985, "Application of Historical Channel Stability Analysis to Instream Flow Studies," *Small Hydro and Fisheries, Symposium Proceedings, American Fisheries Society, Bethesda, Maryland,* edited by F. Olson et al., pp. 184–194.

Hydraulic simulation models used in the assessment of instream flow assume that channel morphology and bottom substrate do not vary over time. Ongoing, longterm channel adjustments may render this assumption invalid, especially if the "representativeness" of study reaches is affected. Consequently, channel stability should be evaluated as an integral part of instream flow assessment. Procedures are described for reconnaissance-level evaluation of river channel dynamics emphasizing the use of readily available historical records such as aerial and/or terrestrial photography, hydrologic records, old maps and channel survey data, gaging station records, narrative accounts, and other field evidence. If this examination suggests that the river channel being studied has been relatively stable over recent decades, then it is reasonable to assume that it is in equilibrium and that future changes will be caused by altered flow regimes. If the channel is not in equilibrium, then hydraulic simulation of aquatic habitat conditions must consider the naturally occurring channel dynamics. Guidance is provided on the collection and interpretation of data for historical channel stability analysis.

Loar, J. M., 1985, *Application of Habitat Evaluation Models in Southern Appalachian Trout Streams*, edited by Oak Ridge National Laboratory, Oak Ridge, Tennessee, 310 pp. Report No. ORNL/TM-9323.

This study evaluated the validity of physical habitat indices (e.g., weighted usable area) for predicting the response of trout populations to changes in stream flow. Because the use of habitat indices is based on the assumption that fish abundance or biomass is positively correlated with the value of the habitat index, the study focused on an analysis of fish-to-habitat relationships. Eight study sites on cold water streams with naturally reproducing populations of brown and rainbow trout were selected. The streams were situated in the southern Appalachian Mountains of eastern Tennessee and western North Carolina. Fish biomass, abundance, and production were estimated, using electrofishing and Petersen mark-recapture techniques. Physical habitat was quantified, using the IFIM's Physical Habitat Simulation (PHABSIM) system at each site. Water quality, water temperature, macroinvertebrate food resources, and average monthly flow regimes were also measured at each site. Based on our results, the validity of the assumption that fish abundance or biomass varies in direct proportion to physical habitat indices could not be rejected. Although physical habitat indices explained a significant proportion of the variability in brown trout populations between sites, habitat condition alone was not sufficient to explain differences in rainbow trout abundance. To predict the response of trout populations to flow alteration, it is recommended that (a) habitat variables be carefully chosen with respect to critical life stages and periods of the year, (b) site-specific interactions between target species be considered, and (c) management objectives be clearly defined. The most appropriate habitat indices are those based on minimum values calculated over the entire period that given life stage is present. When used properly, habitat variables can be useful in assessing changes in fishery resources resulting from flow alterations.

Sale, M. J., 1985, "Aquatic Ecosystem Response to Flow Modification: An Overview of the Issues," *Small Hydro and Fisheries, Symposium Proceedings, American Fisheries Society, Bethesda, Maryland*, edited by F. Olson et al., pp. 25–31.

This paper is an introduction to contributed papers in a session on "Biological Response to Flow Modification." Lotic ecosystems respond to modified flow regimes through changes in physical habitat availability, water chemistry and temperature, nutrient cycling, biomass/energy relationships, and the population and community dynamics of aquatic biota. A systems perspective is therefore essential in understanding flow-related impacts and in making water management decisions. More retrospective studies and experimental management are needed to provide the necessary design information for environmentally sound hydropower development. The responsibility for these studies must be shared among developers, regulators, and natural resource managers.

Taylor, R. E., and B. Kynard, 1985, "Mortality of Juvenile American Shad and Blueback Herring Passed Through a Low Head Kaplan Hydroelectric Turbine," *Transactions of the American Fisheries Society,* Vol. 114, pp. 430–435.

Immediate mortality of juvenile alosids [American shad (*Alosa sapidissima*) and blueback herring (*A. aestivalis*)] passed through the 17-MW Kaplan turbine at Holyoke Dam on the Connecticut River was estimated with mark-capture methods. Turbine-induced mortality of fish at full power output is thought to be related to greater turbine efficiency.

1984

Knapp, W. E., 1984, *SPLASH-Simulation Program for Low-Flow Analysis of Small-Scale Hydropower Projects: Test Applications*, U.S. Fish and Wildlife Service, Newton Corner, Massachusetts. Order report from Region 5, U.S. Fish and Wildlife Service, One Gateway, Newton Corner, Massachusetts 02150.

This report describes a computerized assessment method for rapidly evaluating the flow-related impacts of alternative hydrodesigns and operating modes. The SPLASH model is designed to represent branched stream networks with multiple hydroprojects and to give estimates of where, when, and to what degree conflicts in water use may occur. Input data are readily available for most project types. The Muskingum method is used to route stream flow through the specified channel and reservoir configuration. Case studies show the limitations of this routing method.

Olive, S. W., and B. L. Lamb, 1984, *Conducting a FERC Environmental Assessment: A Case Study and Recommendations from the Terror Lake Project*, Western Energy and Land Use Team, U.S. Fish and Wildlife Service, Ft. Collins, Colorado. NTIS No. PB84-209618 or FWS/OBS-84/08.

This report reviews the process of acquiring the license to operate the Terror Lake hydroelectric power project under the auspices of FERC. Terror River, the project site, is located on Kodiak Island in Alaska. The main controversy requiring negotiation stemmed from the fact that the intended development area was within the boundaries of the Kodiak National Wildlife Refuge. Conflicting views about potential project impacts, especially on fish, wildlife, and instream flows, were ultimately reconciled through interagency negotiations. Included is a detailed account of the negotiations and suggestions for strategies in future FERC licensing efforts.

1983

Cada, G. F., K. D. Kumar, J. A. Solomon, and S. G. Hildebrand, 1983, "An Analysis of Dissolved Oxygen Concentrations in Tailwaters of Hydroelectric Dams and the Implications for the Small-Scale Hydropower Development," *Water Resources Research*, Vol. 19, No. 4, pp. 1043–1048.

One of the environmental issues affecting small-scale hydropower development in the United States is water quality degradation. The extent of this potential problem, as exemplified by low dissolved oxygen concentrations in reservoir tailwaters, was analyzed by pairing operating hydroelectric sites with dissolved oxygen measurements from nearby downstream U.S. Geological Survey water quality stations. These data were used to calculate probabilities of noncompliance (PNCs), that is, the probabilities that dissolved oxygen concentrations in the discharge waters of operating hydroelectric dams will drop below 5 mg/L. The continental states were grouped into eight regions based on geographic and climatic similarities. Most regions had higher mean PNCs in summer than in winter, and summer PNCs were greater for large-scale than for small-scale hydropower facilities. Cumulative probability distributions of PNC also indicated that low dissolved oxygen concentrations in the tailwaters of operating hydroelectric dams are phenomena largely confined to sites with large-scale facilities.

Cada, G. F., et al., 1983, "Field Test of a Biological Assumption of Instream Flow Models," *Proceedings of Waterpower '83: An International Conference on Hydropower, Tennessee Valley Authority, Knoxville, Tennessee*, pp. 305–313.

A number of instream flow assessment methods rely on implicit biological assumptions about the relationships between aquatic biota and streamflow in order to make minimum flow recommendations. One such assumption, that the amount of benthic organisms available as food for stream fishes is directly proportional to the stream bottom area (wetted perimeter), was tested at four field sites in the southern Appalachian Mountains. For most of the sites and taxa examined, benthic densities did not show a consistent relationship with discharge/wetted perimeter dynamics. Our analysis indicates that simple physical habitat descriptors obtained from hydraulic-rating models do not provide sufficient information on the response of benthic organisms to decreased discharges and therefore may not be adequate to protect aquatic resources in water-use conflicts.

Cushman, R. M., 1983, "Biotic Effects of Rapidly Varying Flows from Hydroelectric Facilities," *Proceedings of Waterpower '83: An International Conference on Hydropower, Tennessee Valley Authority, Knoxville Tennessee* pp. 1274–1283.

Rapid changes in flow below hydroelectric facilities result from peaking operations. The potential impacts of these short-term disturbances of aquatic systems below dams are important considerations in hydro-power development. Reduced biotic abundance, diversity, and productivity in tailwaters may be caused by flow variations or a variety of related factors. This paper outlines information needs for site-specific evaluations, and presents options to reduce anticipated adverse effects.

Gloss, S. P., and J. R. Wahl, 1983, "Mortality of Juvenile Salmonids Passing Through Ossberger Cross-Flow Turbines at Small-Scale Hydroelectric Sites," *Transactions of the American Fisheries Society*, Vol. 112, No. 2A, pp. 194–200.

Experiments were conducted on Ossberger Cross-flow turbines to determine the amount of mortality that would be incurred by downstream-migrating juvenile salmonids passing though these turbines. Species tested were Atlantic salmon (*Salmo salar*), rainbow trout, and steelhead (*S. Gairdneri*). A highly significant (P 0.01) relationship was found between fish size and arc sine square root of mortality. Regression equations were calculated to predict mortality through 48 hours based upon fish size. Mortality ranged from 15% for 85-mm fish to over 70% for 280-mm fish. No significant difference in mortality was detected among similar size-groups of the three salmonids tested. Neither the output of the turbine nor its size (650 versus 850 kW) affected mortality. Temporal distribution of mortality after fish passed through the turbine was not different among species nor was it affected by the absolute rate of mortality in a given trial. Over 75% of the mortality was considered instantaneous.

Loar, J. M., and S. G. Hildebrand, 1983, "A Comparison of Environmental Issues Related to Development of Small Hydropower Resources at New Versus Existing Sites," *Alternate Energy Sources III, 9, Policy/Environment*, edited by T. N. Veziroglu, New York: Hemisphere Publishing Company, pp. 279–297.

This paper discusses the ecological issues associated with the development of small hydropower resources at new (undeveloped) sites and those with existing dams that will be retrofitted for hydroelectric generation. Issues that could occur with both types of development are (a) blockage of fish migration routes, (b) water level fluctuations, (c) instream flows, (d) water quality, (e) dredging and dredged material disposal, and (f) threatened or endangered species. However, new site development projects require the alteration of existing aquatic and terrestrial ecosystems that will be, in most cases, significantly greater than the environmental changes associated with retrofitting of existing dams. Although project design and operation are important factors controlling the nature and magnitude of the environmental impacts of small hydropower resource development, the mitigation of adverse impacts (and the optimization of beneficial effects) is dependent, in large measure, on our ability to accurately predict physical, chemical, and biological changes. Predicting the impacts of new impoundments may be considerably more difficult than predicting the impacts that might occur if an existing dam/impoundment system is developed. A comparative approach at the ecosystem level can provide valuable insights into the structure and function of reservoir systems and significantly increase our predictive capability.

Loar, J. M., 1983, "Impacts of Hydropower Development on Downstream Fish Passage," *Proceedings of the 1982 Northeast Coldwater Workshop on Hydropower Development and Fisheries: Impacts and Opportunities, New York State Department of Environmental Conserva tion, Albany, New York*, edited by G. A. Barnhart, pp. 25–36.

Hydroelectric dams can have a significant impact on anadromous species (e.g., Atlantic salmon and American shad) that spend most of their adult life in the ocean but return to freshwater to spawn. This paper addresses the nature of the impacts on downstream migrants resulting from dam construction and operation, and the mitigation options available for reducing adverse impacts. Mortality can result from turbine passage and delays in downstream migration caused by flow regulation. Minimization and compensation are two general approaches that can be employed to reduce the adverse impacts of hydroelectric dams on downstream migrants. Mortality resulting from turbine passage can be minimized by (a) installation of intake diversion and bypass systems, (b) collection and transportation of downstream migrants around dams, and (c) controlled spills. Restoration of degraded spawning/nursery habitat, on the other hand, can be employed to compensate for losses in natural production resulting from the construction of new dams or the operation of existing hydroelectric dams.

Sale, M. J., 1983, "Assessing the Impacts of Regulated Flows at Hydropower Projects," *Proceedings of the 1982 Northeast Coldwater Workshop on Hydropower Development and Fisheries Impacts and Opportunities, New York State Department of Environmental Conservation*, Albany, New York, edited by G. A. Barnhart.

Hydropower development is frequently accompanied by streamflow regulation that can adversely affect upstream and downstream fisheries. This paper is a literature review and summary of the current capabilities for assessing the impacts of regulated flows both within and below hydropower reservoirs. Assessment of project impacts must begin within a definition of project design and operation variables. Three approaches are then available for assessing impacts below the dam and resultant instream flow needs: (a) discharge methods, (b) hydraulic-rating methods, and (c) habitat-rating methods. Fewer analytical assessment methods are available for assessing impacts within the reservoir, but a conceptual approach is proposed. The constructive use of these techniques to avoid adverse fisheries impacts is a major challenge to resource managers and hydrodevelopers.

Sale, M. J., S. F. Railsback, and E. E. Herricks, 1983, "Frequency Analysis of Aquatic Habitat," *Proceedings of the Symposium on Acquisition and Utilization of Aquatic Habitat Inventory Information, Western Division, American Fisheries Society, Portland, Oregon*, edited by B. Armantrout, pp. 340–346.

Minimum flow recommendations can be improved by analyzing the natural habitat variability in lotic environments. Habitat modeling techniques such as the Instream Flow Incremental Methodology can be combined with stream flow records to generate habitat frequency curves that are useful in determining instream flow needs.

1982

Bain, M. B., et al., 1982, *An Evaluation of Methodologies for Assessing the Effects of Flow Fluctuations on Stream Fish*, U.S. Fish and Wildlife Service, Newton Corner, Massachusetts. Report No. FWS/OBS-82/63. Order report from Region 5, U.S. Fish and Wildlife Service, One Gateway, Newton Corner, Massachusetts 02158.

Two reaches of the Deerfield River in Massachusetts were studied to test the applicability of the Instream Flow Incremental Methodology (IFIM) on an eastern river with daily fluctuating flows, to explore some of the biological assumptions of the IFIM, and to develop new methods for studying fish behavior in streams with fluctuating flow. Physical habitat simulations in the fluctuating-flow environment are basically acceptable. However, the biological portion of the IFIM is not as applicable to a river with daily fluctuating flow because fish do not consistently inhabit locations that were predicted to be the most suitable. Producing reliable habitat suitability curves is the major problem in applying the IFIM to fluctuating-flow streams. Basic research is needed to determine how fish behave in fluctuating flow and what variables they are responding to, in addition to velocity, depth, and substrate. Radio telemetry was seen as a potentially useful, but presently limited, tool for examining fish behavior during changing flow.

Cada, G. F., et al., 1982, *Analysis of Environmental Issues Related to Small-Scale Hydroelectric Development VI, Dissolved Oxygen Concentrations Below Operating Dams*, Oak Ridge National Laboratory. Report No. ORNL/TM-7887.

An analysis of the potential for small-scale hydropower development to create water quality problems (as exemplified by low dissolved oxygen concentrations) was performed by pairing operating hydroelectric sites with dissolved oxygen measurements from nearby downstream USGS water quality stations. Probabilities of Non-Compliance (PNCs) (i.e., the probabilities that dissolved oxygen concentrations in tailwaters will drop below 5 mg/L) were estimated for each site, season, and capacity category (>30 MW vs. <30 MW). During the winter months, all regions of the U.S. had low mean PNCs, regardless of hydroelectric capacity. Summer PNCs were greater for large-scale than for small-scale sites. Among regions, highest mean summer PNCs were found in the southeast, Ohio Valley, and the Great Basin. Cumulative probability distributions of PNC were developed, which indicated that low tailwater dissolved oxygen concentrations are a problem largely confined to large-scale facilities.

Knapp, W. E., B. Kynard, and S. P. Gloss, eds., 1982 *Potential Effects of Kaplan, Ossberger, and Bulb Turbines on Anadromous Fishes of the Northeast United States*, U.S. Fish and Wildlife Service, Newton Corner, Massachusetts. Report No. FWS/OBS-82/62. Order report from Region 5, U.S. Fish and Wildlife Service, One Gateway Center, Newton Corner, Massachusetts 02158.

The effects of turbine passage on anadromous fishes of the northeast United States were investigated in the field and laboratory. Kaplan, Ossberger, and bulb turbines were studied using Atlantic salmon smolts (*Salmo salar*), juvenile and adult American shad (*Alosa sapidissima*), juvenile blueback herring (*Alosa aestivalis*), striped bass (*Morone saxatilis*) and rainbow and steelhead trout (*Salmo gairdneri*). The effects of turbine size and electric power level on mortality were studied in the field. Laboratory investigations and other field studies focused attention on turbine-induced scale loss and its potential for sublethally affecting Atlantic salmon smolts, juvenile American shad, and blueback herring. The investigations provide valuable guidance for conducting turbine-passage studies in the future and furnish useful estimates of acute and delayed mortality.

Sale, M. J., E. D. Brill, Jr., and E. E. Herricks, 1982, "An Approach to Optimizing Reservoir Operation for Downstream Aquatic Resources," *Water Resources Research,* Vol. 18, No. 4, pp. 705–712.

This paper proposes a mathematical programming methodology to examine the relationship between biological instream flow needs (IFN) and more traditional water project objectives, such as water yield, flood control, reservoir recreation, or economic efficiency. This optimization approach combines the linear decision rule modeling technique with an objective function representing the value of reservoir releases to downstream fisheries. The IFN performance objective is based on an index of physical habitat conditions for fish. A case study is presented using data from a multipurpose reservoir in central Illinois.

Sale, M. J., and J. M. Loar, 1982, "Instream Flow and Hydropower Development: Methods and Strategies for Impact Assessment," *Proceedings of Waterpower '81: An International Conference on Hydropower, I*, U.S. Army Corps of Engineers, Washington, D.C.

The issues of instream flow maintenance in hydropower development is essentially a problem of evaluating the effects of planned modifications in hydrologic patterns. Both large- and small-scale hydropower projects can alter natural flow regimes on either spatial or temporal scales. This paper reviews the status of instream flow methodologies and identifies their role in the environmental assessment of hydroprojects. Strategies for selecting the best methods are discussed in terms of site-specific factors such as project design specifications, fluvial morphology, watershed hydrology, biological sensitivity, and extant local water usage.

1981

Cada, G. F., and F. Zadroga, 1981, *Environmental Issues and Site-Selection Criteria for Small Hydropower Projects in Developing Countries*, Oak Ridge National Laboratory. Report No. ORNL/TM-7620.

Because small hydropower projects are simple and versatile and use a renewable resource, they can effectively provide electric power to small, isolated rural communities in developing countries. However, construction and operation of even the smallest project can result in adverse environmental consequences and should be considered in the initial stages of site selection and development. The report discusses potential environmental impacts and provides guidance for factoring environmental concerns into the site selection process both at prefeasibility and feasibility stages. It includes a checklist of environmental data that should be collected and recommendations on the training of personnel involved in the environmental evaluation.

Gilliland, M. W., J. M. Klopatek, and S. G. Hildebrand, 1981, *Net Energy of Seven Small-Scale Hydroelectric Power Plants*, Oak Ridge National Laboratory. Report No. ORNL/TM-7694.

Net energy analysis evaluates the direct and indirect energy inputs involved in constructing and operating an energy supply technology and compares those inputs with the energy produced by the technology. This study performed a net energy analysis on seven small-scale hydroelectric plants, comparing them to conventional hydroelectric plants and other energy supply technologies. All seven small-scale plants represent some kind of retrofit to an existing dam. The results indicate that the energy output from these small hydroprojects is 8.6 to 32.9 times greater than the energy input when output is expressed as electricity, and 26.3 to 101.4 times greater than the energy input when output is expressed as fossil fuel equivalent. Based on the net energy criterion, small-scale plants are probably a better investment than conventional peak-load hydroelectric plants and similar to conventional base-load hydroelectric plants.

Hildebrand, S. G., and L. B. Gross, 1981, *Hydroelectric Operation at the River Basin Level: Research Needs to Include Ecological Issues in Basin-Level Hydropower Planning*, Electric Power Research Institute. Report No. EPRI WS-80-155. Order report from the Electric Power Research Institute, Research Reports Center, P.O. Box 50490, Palo Alto, California 94303, (415) 965-4081.

A workshop to recommend research needed to quantitatively integrate ecological issues in river basin level hydropower planning was held at Oak Ridge, Tennessee, on September 15–17, 1980. The 32 workshop participants identified 18 research topics that were responsive to the workshop objective. These topics were related to impacts of water level fluctuation, instream flow requirements, water quality alteration, and impacts on migratory fish. The report summarizes the development of these research topics and recommended research priorities.

Loar, J. M., and M. J. Sale, 1981, *Analysis of Environmental Issues Related to Small-Scale Hydroelectric Development V, Instream Flow Needs for Fishery Resources*, Oak Ridge National, Laboratory. Report No. ORNL/TM-7861.

This document provides guidance to developers of small-scale hydroelectric projects on the assessment of instream flow needs. Whereas, numerous methods have been developed to assess the effects of stream flow regulation on aquatic biota in cold water streams in the West, no consensus has been reached regarding their general applicability, especially to streams in the eastern United States. The methods differ in their use of hydrologic records, hydraulic simulation techniques, and habitat rating criteria, and in their capability to provide seasonal or species-specific recommendations. Because of these differences in data requirements, application costs and the level of resolution associated with the instream flow recommendations vary greatly. Consequently, guidance is needed to ensure that the most appropriate methods are selected. To provide this guidance to developers of small hydropower projects, the methods were evaluated to determine their applicability in the assessment of instream flow needs for fishery resources at small hydropower sites. The methods were grouped into three categories based on (a) level of resolution associated with the instream flow recommendation, (b) data needs, and (c) costs of application. The categories correspond to different levels of assessment that might be required at a given hydropower site. To select the most appropriate level of analysis, criteria were identified relating to both the design and operation of the project, and the aquatic resources at the site.

Turbak, S. C., D. R. Reichle, and C. R. Shriner, 1981, *Analysis of Environmental Issues Related to Small-Scale Hydroelectric Development IV, Fish Mortality Resulting from Turbine Passage*; Oak Ridge National Laboratory. Report No. ORNL/TM-7521.

This document reviews state-of-the art literature concerning turbine-related fish mortality. The review discusses conventional and, to a lesser degree, pumped-storage (reversible) hydroelectric facilities. Much of the research on conventional facilities discussed in this report deals with studies performed in the Pacific Northwest and covers both prototype and model studies. Research conducted on Kaplan and Francis turbines during the 1950s and 1960s is extensively reviewed. Very little work on turbine-related fish mortality has been undertaken with newer turbine designs developed for more modern small-scale hydropower facilities; however, one study on a bulb unit (Kaplan runner) has recently been released. In discussing turbine-related fish mortality at pumped-storage facilities, much of the literature relates to the Ludington Pumped Storage Power Plant.

1980

Hildebrand, S. G., ed. 1980, "Small-Scale Hydroelectric Development and the Environment: Issues, Challenge, Opportunity," *Proceedings of the National Conference on Renewable Energy Technologies, Honolulu, Hawaii, December 6–11.*

This report reviews major environmental issues that could constrain small-scale hydroelectric development, including effects of dredging, interferences with fish passage, water level fluctuations, and minimum instream flow. It concludes that with adequate planning in the prefeasibility stage, communication with regulatory authorities and interested parties, appropriate site-specific environmental studies, and effective mitigation of anticipated impacts, environmental issues should not be an absolute barrier to small-scale hydroelectric development at many sites.

Hildebrand, S. G., ed. 1980, *Analysis of Environmental Issues Related to Small-Scale Hydroelectric Development III. Water Level Fluctuation,* Oak Ridge National Laboratory. Report No. ORNL/TM-7453.

This report identifies potential environmental impacts in reservoirs and downstream river reaches below dams that may be caused by water level fluctuation from development and operation of small-scale hydroelectric projects. It discusses impacts on physical and chemical characteristics in reservoirs, including resuspension and redistribution of sediments, leaching of soluble organic matter, and changes in water quality. It discusses the effect on reservoir biota by changes in habitat quality, which results in reduced standing crop and production of aquatic biota and possible shifts in species diversity, and discusses water quality problems that may occur below dams because of water level fluctuations. It discusses potential biological impacts on downstream ecosystems that result from changes in current velocity, habitat reduction, and alteration in food supply. And the report presents recommendations for site-specific evaluation of water level fluctuation at small-scale hydroelectric projects.

Hildebrand, S. G., ed. 1980, *Analysis of Environmental Issues Related to Small-Scale Hydroelectric Development II, Design Considerations for Upstream Fish Passage Facilities*, Oak Ridge National Laboratory. Report No. ORNL/TM-7396.

This report addresses basic design considerations that should be evaluated on a site-specific basis whenever upstream fish passage facilities are planned for small-scale hydroelectric projects. It presents information on general life history and geographic distribution of fish species that may require passage. It discusses biological factors such as gas bubble disease, fish swimming speed, oxygen consumption, diet, and photo behavior, which are important in the design of upstream fish passage facilities. It describes, with dimensions, three general types of facilities appropriate for upstream fish passage at small-scale hydroelectric projects (fishways, fishlocks, and fishlifts). It discusses general design criteria for these facilities (including fish swimming ability and behavior) and general location of facilities at a site. It indicates basic cost considerations for each type of passage facility including unit cost, operation and maintenance costs, and costs for supplying attraction water.

Loar, J. M., et al., 1980, *Analysis of Environmental Issues Related to Small-Scale Hydroelectric Development I, Dredging*, Oak Ridge National Laboratory. Report No. ORNL/TM-7228.

Development of hydropower resources at existing dams may require dredging in order to (a) reclaim reservoir storage capacity lost as a result of sediment accumulation; (b) clear intake structures; and (c) construct or repair power houses, trailraces, and headraces. This report includes a general introduction on dredging equipment and disposal practices, with emphasis on those practices applicable to small reservoirs.

It discusses the physical and chemical effects of dredging and disposal, their causes, and the biological effects engendered by these physical and chemical changes. Factors that could affect the severity (magnitude) of these effects (impacts) are emphasized for guidance to developers of potential sites. It discusses environmental constraints and mitigation, as well as guidelines, for the early evaluation of the environmental feasibility of dredging. It also discusses applicable regulations related to dredged material disposal and wetlands protection, and presents a preliminary analysis of the economic costs associated with dredging and disposal. Adequate mitigation capability exists for most of the environmental impacts of dredging, but the cost of this mitigation may place significant economic constraint on project development.

1979

Hildebrand, S. G., 1979, "Potential Environmental Impacts of Hydroelectric Development: An Overview," *Hydropower: A National Energy Resource*, pp. 322–392. Available from the U.S. Government Printing Office, Washington, D.C.

This report discusses environmental impacts resulting from (a) creation of a hydroelectric impoundment, (b) physical presence of a dam, (c) effects of turbine operation on the reservoir, and (d) effects of turbine operation on the tailwater ecosystem. It reviews environmental legislation, which requires a formal consideration of these impacts, including their prediction, minimization, or mitigation. Finally, some suggestions are offered on the role of ecologists and environmental scientists in the planning of environmentally sound hydropower development projects.

National Energy Strategy

U.S. DOE, 1990, *Interim Report-National Energy Strategy-A Compilation of Public Comments*, DOE/S-0066P.

The purpose of this Interim Report on the development of the National Energy Strategy is to convey the results of this public dialogue. The Interim Report presents a compilation of hearings and submitted testimony thus far received, containing more than 4,000 citations to individual documents or presentations—all of which are available for public review. The comments received are organized on the basis of presented public concerns, publicly identified goals, publicly identified obstacles to achieving those goals, and publicly suggested options for action to remove or overcome the obstacles.

Solar Energy Research Institute, 1990, *The Potential of Renewable Energy, An Interlaboratory White Paper*, Report SERI/TP-260-3674 (DE90000322).

This document is an evaluation of the present and projected performance status of the renewable energy technologies (RETs) and their potential contributions to the nation's energy requirements over the next four decades. It has been prepared for the National Energy Strategy Study by the U.S. DOE's national laboratories in response to a request from the Office of Policy, Planning and Analysis. Based on a consensus-forming approach to the assessment of many difficult questions, the paper attempts to convey a sense of what is and is not known about the range of technical and analytic issues surrounding RET deployment. The white paper identifies broadly the research, development, and demonstration (RD&D) thrusts which, if undertaken, would in our judgment remove the key technological constraints on the utilization of these energy resources and thereby enhance the institutional laws, that can be reduced or removed with appropriate action. It does not address the question of what is the appropriate national energy policy, nor does it suggest what policy actions might be undertaken to address the needs discussed here.

Engineering Research and Development

1997

*Alden Research Laboratory, Inc. and Northern Research and Engineering Corporation, 1997, *Development of a More Fish-Tolerant Turbine Runner, Advanced Hydropower Turbine Project*, ARL Report No. 13-97/M63F, DOE/ID-10571.

Alden Research Laboratory, Inc. and Northern Research and Engineering Corporation conducted a research program to develop a turbine runner which will minimize fish injury and mortality at hydroelectric projects. An existing pump impeller provided the starting point for developing the fish-tolerant turbine runner. The Hidrostal pump is a single-bladed combined screw/centrifugal pump which has been proven to transport fish with minimal injury. The focus of this research project was to develop a new runner geometry which is effective in downstream fish passage and hydroelectric power generation. A flow of 1,000 cfs and a head in the range of 75 ft to 100 ft were selected for conceptual design of a new runner.

Conceptual design of the new runner began with a reevaluation of studies which have been previously conducted to identify probable sources of injury to fish passing through hydraulic turbines. Criteria relative to hydraulic characteristics which are favorable for fish passage were prepared based on a reassessment of the available information. Important criteria used to develop the new runner design included low-pressure change rates, minimum absolute pressures, and minimum shear. Other criteria which are reflected in the runner design are a minimum number of blades (only two), minimum total length of leading edges, and large flow passages.

Flow characteristics of the new runner were analyzed using two-dimensional and three-dimensional Computational Fluid Dynamic models. The basic runner geometry was initially selected using the two-dimensional model. The three-dimensional model was used to investigate the flow characteristics in detail through the entire runner and to refine the design by eliminating potential problem areas at the leading and trailing edges. Results of the analyses indicated that the runner has characteristics which should provide safe fish passage with an overall power efficiency of approximately 90%.

*Franke, Gary F., Donald R. Webb, Richard K. Fisher, Jr., Dilip Mathur, Paul N. Hopping, Patrick A. March, Michael R. Headrick, Istvan T. Laczo, Yiannis Ventikos, Fotis Sotiropoulous, 1997, *Development of Environmentally Advanced Hydro Turbine Design Concepts,* Voith Hydro, Inc., Report 2677-0141, INEL/EXT-97-00639.

The conceptual design team brought together a turbine design and manufacturing company, biologists, a utility, a consulting engineering firm and a university research facility, in order to benefit from the synergy of diverse disciplines. Through a combination of advanced technology and engineering analyses, innovative design concepts adaptable to both new and existing hydro facilities were developed.

The project was divided into tasks. Task 1 investigated a broad range of environmental issues and how the issues differed throughout the country. Three families of design concepts were chosen for further investigation addressing the most significant problem elements. Task 2 addressed fish physiology and turbine physics. During this task, the team studied the state of available information, the mechanisms for injury and methods to predict injury, and defined which design elements to address to improve fish survival at hydro sites. In the report, additional controlled experiments needed to further clarify the effect of turbine geometry and the associated flow conditions on injury mechanisms are defined. Task 3 investigated individual design elements needed for the refinement of the three concept families defined in Task 1. Advanced numerical

* An asterisk (*) before the title indicates the publication has been added to the Bibliography in this biennial report.

tools for simulation in turbines are used to quantify characteristics of flow and pressure fields within turbine water passageways. The issues associated with dissolved oxygen enhancement using turbine aeration are presented. The state of the art and recent advancements of this technology are reviewed. Key elements for applying turbine aeration to improve aquatic habitat are discussed and a review of the procedures for testing of aerating turbines is presented.

The results of the Tasks are assembled into three families of design concepts to address the most significant issues defined in Task 1. Significantly, improvements in fish passage survival are achievable and design concepts can be implemented immediately at existing hydro projects. While the fundamental focus of the solutions developed is in the environmental arena, many of the issues can also improve plant efficiency thereby improving project economics and reducing the need for replacement energy generation from nonrenewable sources. In addition, improvements reducing cavitation and vibration will result in lowered maintenance requirements for operating utilities implementing the designs.

*U.S. DOE, 1997, *Hydropower Research and Development*, March, DOE/ID–10575.

This report represents the first attempt at developing a single point source for information on current and proposed hydropower research and development (R&D), environmental as well as engineering, being conducted by government agencies (Federal, State, local), utilities, and other private companies. It is hoped that this report will be useful to those conducting hydropower R&D, particularly during these times of declining R&D funding.

1992

Chappell, J. R., 1992, *Department of Energy Small-Scale Hydropower Program Engineering Research and Development 1977–1991 Summary Report*, Idaho National Engineering Laboratory, NTIS No. DOE/ID-10376.

The purpose of this report is to present an overview of the Engineering Research and Development subprogram of the U.S. DOE Small-Scale Hydroelectric Power Program. The purpose of the Engineering and Development program was to promote, encourage, and support the development of hydropower. DOE provided funds to develop new technologies and adapt novel applications of existing related technologies to the hydropower field. This report summarizes the lessons learned as well as some of the successes and failures of the individual projects. The purpose of this report is to document not only the successful projects that were explored but also to delineate the deficiencies of the projects that were not found to be viable for the intended application to hydropower. Some of the concepts explored were found to be more suitable to other applications than the proposed use for hydropower at the time the project was investigated. As a result, a few concepts explored were found to be commercially viable and were continued in the private sector.

Fontaine, T. A, 1992, "The Accuracy of Rainfall-Runoff Model Simulations of Extreme Floods," ASCE *Journal of Hydraulic Engineering*.

The accuracy of rainfall-runoff model simulations of extreme floods is evaluated using two models, two catchments, and two storms. HEC-1 and HSPF (a modified version of the Stanford Watershed Model) of the 100-year flood of July 1, 1978, on the Kickapoo River (drainage area = 690 sq. km) in southwest Wisconsin are compared for accuracy. The two models are also compared for hypothetical floods (0.5, 1.0, 2.5, and 5.0 times the 100-year flood) on the Whiteoak Creek catchment (drainage area = 9.3 sq. km) in eastern Tennessee. Error in peak discharge and runoff volume were significant, as were the differences between the two modeling approaches. Error in areal mean rainfall was considered to be a major source of uncertainty in the calibration of HSPF. The results indicate that

* An asterisk (*) before the title indicates the publication has been added to the Bibliography in this biennial report.

additional research is needed to determine the role of model selection, calibration data and the experience of the modeler in runoff model error.

1989

The University of Minnesota, 1989, *Performance Tests and Calibrations of the St. Anthony Falls Independent Turbine Test Facility, Project Report No. 288*, St. Anthony Falls Hydraulic Laboratory, Minneapolis, Minnesota, NTIS No. DOE/ID-12617.

The results of several tests to determine the performance characteristics of the independent test facility for testing hydraulic pump and turbine models are included in the report. The instrumentation is described and the measurement uncertainties documented and analyzed. Data collection equipment and software programs are also discussed.

Acres International Corporation, 1989, *Report on Siphon Penstocks for Hydroelectric Projects*, Amherst, New York, NTIS No. DOE/ID-12356.

The report contains the descriptions of 11 hydropower plants that use siphon penstocks. The design, construction, operation, and maintenance are considered and the benefits of siphon penstocks are summarized. Data, drawings and photographs of the 11 projects are included.

Ott Engineers, Inc., 1989, *Inexpensive Cross-Flow Hydropower Turbine at Arbuckle Mountain Hydroelectric Project-Field Test Report*, Bellevue, Washington, NTIS No. DOE/ID-12481-2.

The Arbuckle Mountain Plant was tested during two separate testing periods. The first tests were performed in January of 1988 and utilized the dye dilution method of flow measurement. The analysis of the first test data indicated some problems with the flow measurements and a second series of tests were performed in March 1989 using dye tagging and a velocity head probe to measure the flow. The report includes the data and analyses from both series of tests.

1988

Ott Water Engineers, Inc., 1988, *Inexpensive Cross-Flow Hydropower Turbine at Arbuckle Mountain Hydroelectric Project—Final Construction and Cost Report,* Redding, California, NTIS No. DOE/ID-12481-1.

This report documents the construction details as built and the final cost of the Arbuckle Mountain Cross-Flow Hydro Plant built near Redding, California.

1984

Chappell, J. R., 1984, "Future of Hydropower," Idaho National Engineering Laboratory, EG&G Idaho, Inc., Idaho Falls, Idaho, April 1984. Presented at the *Small Hydropower Workshop, University of Missouri-Columbia, April,* NTIS No. DE-84011452 or EGG-M-09284.

This paper discusses the history, current status, and resource potential, as well as impediments and factors, favoring hydropower development in the United States. Future hydroelectric capacity is estimated from FERC permit and license applications, and from several private and government agency projections.

Chappell, J. R., 1984, *Hydropower Hardware Descriptions*, EG&G Idaho, Inc., Idaho Falls, Idaho, Presented at *Small Hydropower Workshop, University of Missouri-Columbia, April,* NTIS No. DE-84011614 or EGG-M-09384.

This report discusses the differences in 11 types of turbines. Their characteristics are tabulated, and their operating ranges and geometry are illustrated by use of graphs and drawings. The primary conventional types are discussed, as well as the new or nonconventional types researched by DOE.

Chappell, J. R., 1984, *New Technology for Small Hydropower Installations*, Idaho National

Engineering Laboratory, EG&G Idaho, Inc., Idaho Falls, Idaho, NTIS No. DE-84011180 or EGG-M-09184.

This paper is a general discussion of new technologies, including hardware and methodologies, that may be used in developing small hydropower installations. The primary source of information is the results of the R&D projects funded under the DOE Small Hydropower Program. The paper is divided into the following categories: turbine/generator, head augmentation, nonconventional concepts, structure and construction, system management, controls, and reconnaissance and feasibility.

Energy Research and Applications, Inc., 1984, *Application of Marine Thrusters as Ultra-Low Head Hydroturbines—Test Report*, Santa Monica, California, NTIS No. DE-84013096 or DOE/ID-12201-T3.

This report presents the results of the field test of a hydropower plant utilizing a marine thruster for a turbine at the Modesto Irrigation District. The unit used 386 cfs of water at 13 ft of head to produce 235 kW. The cost of the thruster package was $343/kW of installed capacity.

1983

Energy Research and Applications, Inc., 1983, *Field Test of Ultra-Low Head Hydropower Package Based On Marine Thrusters—Final Report*, Santa Monica, California, NTIS No. DE-84013685 or DOE/ID-12201-T2.

The report is the final report on the design, construction, equipment procurement, installation, and site modeling for a hydropower plant using a marine thruster as a turbine. The installation was the Stonedrop site in the Modesto Irrigation District canal system. Also included is a breakdown of the costs and the results of a hydraulic model test that was performed to resolve flow problems.

F.W.E. Stapeshorst, Inc., 1983, *Test of Ossberger Cross-Flow Turbine of Bradford Hydroelectric Station*, Bradford, Vermont, NTIS No. DE-84007079 or DOE/ID-12314-T3.

This report covers the analysis of the efficiency test data of the 708 Shaft HP Ossberger cross-flow turbine at Central Vermont Public Service Company's Bradford Station.

Chappell, J. R., 1983, *Recent DOE-Sponsored Hydropower Engineering Research, Idaho National Engineering Laboratory, EG&G Idaho, Inc., Idaho Falls, Idaho. Presented at the Waterpower 1983 International Conference on Hydropower, Knoxville, Tennessee, September*, NTIS No. DE-84000809 or EGG-M-02983.

This paper provides an overview of U.S. DOE Engineering Development Research activity since Waterpower 1981. General results of 11 projects that have been completed since Waterpower 1981 are presented and compared. Continuing efforts are also described briefly. DOE has sponsored four projects dealing with the use of pumps as turbines. This approach results in capital cost savings, shorter time for completing a hydropower plant, wider variety of off-the-shelf equipment available, and better maintenance services. Results are summarized for feasibility studies, laboratory tests, and in-the-field experience surveys of the use of pumps as turbines. Other projects discussed include microhydropower plants (less than 100 kW in capacity), head augmentation devices, Schneider engines, the use of marine thrusters as turbines, low cost cross-flow turbines made of plastic, variable speed constant frequency generators, hydraulic air compressors, scroll motor turbines and modular float-in powerhouses. The paper also discusses some of the technologies where future research may prove fruitful.

Chappell, J. R., and M. J. McLatchy, 1983, *DOE Small-Hydropower Engineering Development Program Overview*, Idaho National Engineering Laboratory, EG&G Idaho, Inc., Idaho Falls, Idaho, and U.S. DOE Idaho Operations Office, Idaho Falls, Idaho, Presented at American Nuclear Society Annual Meeting, Detroit, Michigan, June, NTIS No. DE-83015127 or EGG-M-01983.

This paper discusses the 35 small hydropower engineering development projects funded by U.S. DOE. Results to date indicate that some of the concepts will significantly reduce the capital cost, and will reduce the time to get a plant on-line by nearly a factor of two.

Rice, W., 1983, *Hydraulic Air Compressor as Part of an Ultra-Low Head Hydropower System, Final Report*, January 1, 1981-December 31, 1981. Arizona State University, NTIS No. DE-82018428 or DOE/ID-12198-13.

Analytical and experimental research was conducted to advance design and application tools, and to gather information concerning the hydraulic air compressor (HAC) for use in ultra-low head hydropower systems. An existing analytical model was significantly improved and an experimental HAC was constructed, instrumented, and tested. A computer program was used to calculate and tabulate the applied head, water and air flow rate, depth, pressure, compressor size, and geometrical relationships. A preliminary design of a HAC hydropower plant was made and the cost study of a typical site is presented.

Moses, H. L., et al., 1983, *Optimization of a Diffuser/Ejector for Ultra-Low Head Hydroelectric Systems, Final Report*, Virginia Polytechnic Institute and State University, NTIS No. DE-83011251 or DOE/ID-12208-T1.

This study investigated head augmentation for ultra-low head hydroelectric systems by use of an ejector in the draft tube. A detailed analytical and experimental study was conducted of the flow in a conical diffuser with a peripheral wall jet. The results were then used to design and test a small laboratory model of an axial-flow turbine. The tests indicated an appreciable increase in head could be achieved and predicted by the analysis. Under certain circumstances with excess flow available, the increase in head would result in a significant decrease in turbine size and cost for a fixed power. However, for limited flow, the head increase would decrease the output power and give no economic advantage.

Liu, H., and M. Fessehaye, 1983, *Theoretical and Experimental Investigation of the Cherepnov Water Lifter*, University of Missouri-Columbia, NTIS No. DE-83007673 or DOE/ID-12206-1.

The Cherepnov lifter is a device that extracts energy from the flow of water at one head and uses the energy to lift a portion of the water to a higher head. Such a lifter can be used in hydroelectric power generation to increase the head and allow the use of smaller, less expensive turbines and powerhouses. The research reported consists of a theoretical analysis, including the derivation of equations and setting up computer models, and later experimental tests verifying the derived equations and computer models, as well as providing information that could not be obtained from theory. A later phase of the project is reported in The Economics of Cherepnov Water Lifter, DOE Report No. DOE/ID-12206-2.

Liu, H., and R. Geekie, 1983, *Economics of Cherepnov Water Lifter for Low Head Hydropower*, University of Missouri-Columbia, NTIS No. DE-83007639 or DOE/ID-12206-2.

This report documents an economic analysis of the use of the Cherepnov water lifter to increase the head and decrease the flow, allowing the use of low-cost turbines and powerhouses in low head hydropower plants. The economics of the Cherepnov lifter for use as a pump to supply water is very good for both small and large systems, even in places where electricity is available for pumps. However, the economics of using the lifter for hydroelectric power generation is not good, especially for large and high head systems. The lifter may still be economically viable in micro hydro-power low head systems where low-cost tanks are available and PVC pipes can be used. Earlier technical studies of the Cherepnov lifter are documented in *A Theoretical and Experimental Investigation of the Cherepnov Lifter*, DOE Report DOE/ID-12206-1.

EG&G Idaho, Inc., 1983, *Microhydropower Handbook*. Volume 1, NTIS No. DE-83006697 or IDO-10107(V.1).

Microhydropower Handbook, Volume 2, NTIS No. DE-83006698 or IDO-10107(V.2).

This handbook defines microhydropower as hydropower produced in quantities of 100 kW or less. The handbook is written so that a lay person with mechanical aptitude will have sufficient information to evaluate site potential, lay out a site, select and install equipment, and operate and maintain the completed system. Volume 1 establishes a foundation for the engineering principles, leads the individual through design, construction, and operation, and provides information on obtaining financing and licensing. Volume 2 is the appendix volume containing supplementary information, Federal and State agencies and their addresses, a glossary, and useful forms.

1982

Chappell, J. R., et al., 1982, *Pumps-as-Turbines Experience Profile*, EG&G Idaho, Inc., NTIS No. DE-83001143 or IDO-10109.

The report presents the results of a survey of owners, operators, consultants, engineering firms, and manufacturers to collect information on their experience in the use of pumps operating in reverse as turbines. The survey consisted of literature searches, telephone calls, questionnaires to selected individuals, conferences with consultants, and site visits. Information is presented on the types of pumps used, the methods of estimating their performance, modifications required, actual results of field tests if available, economics, operation and maintenance, methods used for control, and sources for hardware and engineering assistance.

Rothbart, G., and R. Fullwood, 1982, *Development of a Variable Shaft Speed Alternator*, Science Applications, Inc., NTIS No. DE-82012334 or DOE/ID-12203-T1.

The development of a variable speed alternator, with output voltage and current synchronized and phase-locked to the power grid, is reported. The variable shaft speed alternator consists of an ordinary unmodified wound-rotor motor, with polyphase excitation controlled by solid state switching and a hybrid of analog and digital circuitry. This circuitry senses both shaft speed and line phase, resulting in logic levels that control the current flow in each rotor coil. The laboratory unit was tested under no load, nearly-resistive passive load, and power and power grid load conditions. Efficiencies were measured for converting mechanical power to electrical over a wide range of shaft speeds. The unit was found to be capable of producing power at speeds down to 37% of synchronous speeds.

McCullough, J. E., and J. T. Dieckmann, 1982, *Demonstration of Scroll Motor Advantages for Ultra-Low Head Hydroelectric Power Generation, September 1980-November 1981 Final Report*, Arthur D. Little, Inc., NTIS No. DE-82009792 or DOE/ID-12202-T1.

This effort consisted of analytical and hardware development leading to the design, fabrication, and testing of a laboratory model scroll hydraulic motor. The purpose was to investigate the potential advantages of this scroll motor as a turbine in an ultra-low head hydroelectric power plant. The model scroll motor was designed, built, and tested at heads up to 10 ft and speeds up to 270 rpm. The maximum model output shaft power was 400 W. The maximum efficiency obtained was between 30 and 40%. The low efficiency was attributed to internal leakage and friction in the speed increasing gear box.

Albert H. Halff Associates, Inc., 1982, *Float-In Module for Retrofitting Navigation Dams for Power Generation. Volume I. Feasibility Report*, NTIS No. DE-82010719 or DOE/ID-12161-T2(V.1).

Float-In Module for Retrofitting Navigation Dams for Power Generation. Volume II. Structural Drawings. NTIS No. DE-82010936 or DOE/ID-12161-T1(V.2).

This feasibility study investigated the concept of retrofitting navigation dams on inland waterways with powerhouses by use of prefabricated, standardized powerhouse modules that could be constructed elsewhere and floated into place.

Twelve navigation dams in the Arkansas River Navigation System were used to evaluate the concept. Economic analyses based on the preliminary designs of the float-in plants showed the main benefit from the technique to be reduced construction time and associated costs.

Cooper, P., and R. Worthen, 1982, *Feasibility of Using Large Vertical Pumps as Turbines for Small-Scale Hydropower, Final Technical Report*, Ingersoll Rand Research, Inc., NTIS No. DE-82004267 or DOE/ID-12160-T1.

The object of the project was to establish the economic and technical feasibility of operating pumps as turbines in small-scale hydropower plants. The economics were shown to be competitive; 87% turbine efficiencies were obtained in actual tests.

Truebe, J., and M. Prooker, 1982, *Modular Innovations in Upstream Fish Passage*, Lakeside Engineering, 1982. NTIS No. DE-82010268 or DOE/ID-12207-T2.

This study examines two specific aspects of upstream fish passage design and operation: (a) the incorporation of modular components and structural elements into historically proven passage designs, and (b) the appropriate integration of water saving (and hence energy saving) techniques and hardware into the fish passage designs.

1981

Radkey, R. L., and B. D. Hibbs, 1981, *Definition of Cost-Effective River-Turbine Designs Final Report, September 30, 1980-December 31,* AeroVironment Inc., NTIS No. DE-82010972 or AV-FR-81/595.

Two system concepts were evaluated in this study: (a) a ducted turbine system and (b) a free-rotor system. The ducted turbine uses an augmenter duct to increase flow through the turbine rotor, and the free-rotor system is essentially an underwater windmill. It was concluded that both ducted and free-rotor turbine systems can produce cost-effective electricity. Energy cost estimates for both systems (10-ft diameter) indicate that either could produce energy at less than 50 mill/kWh.

Mayo, Jr., H. A., 1981, *Powerhouse Gate: Concept Definition Study*, Allis-Chalmers Corp., NTIS No. DE-82006226 or DOE/ID-12200-T1.

A study was made of the dual use of flood gate spaces for both power plants and flood flow passages. A powerhouse gate was designed that would fit in the space of an existing dam floodgate. The unit would be used to generate power during periods of normal flow but be hoisted to permit water flow beneath it during floods. The report addresses structural design, cost estimates, and applicability of the concept.

Energy Research and Applications, Inc., 1981, *Design of Low Cost, Ultra-Low Head Hydropower Package Based on Marine Thrusters Final Report*, Santa Monica, California, NTIS No. DE-82004813 or DOE/ID-12201-T1.

The use of marine thrusters operated as turbines is examined as a means to reduce the cost of low head hydroplants. Equipment costs were estimated at approximately $260/kW for units between 40 kW and 630 kW capacity, operating at 6 to 15 ft of head. Comparative concept designs at the feasibility study level of detail, using marine thruster packages or conventional hydropower equipment, indicate installed cost savings of 50 to 60% for the thrusters.

James Hansen and Associates, 1981, *Feasibility of a Small Scale Pumped Storage Demonstration Project, Hibbing, Minnesota*, Springfield, Vermont, for Hibbing Public Utilities Commission, NTIS No. DE-81028678 or DOE/TIC-1028678.

This feasibility study is of a small-pumped-storage hydropower plant that would utilize abandoned iron mine pits for the water storage reservoirs. Six alternatives were studied, which include gas turbine and diesel plants, as well as pumped storage hydro. Both economic and environmental benefits are considered after the technical evaluation is completed.

Gilbert Associates, Inc., 1981, *Modular Hydro-Dam Concept Definition Study*, NTIS No. DE-82000113 or DOE/ID-12207-T1.

This study explored the potential for developing economical new ultra-low head sites using the modular hydro-dam concept. The concept would use truck-transportable power modules and cable-supported fabric dams.

Haroldsen, R. D., and F. B. Simpson, 1981, *Micro Hydropower in the United States*, Idaho National Engineering Laboratory, EG&G Idaho, Inc., Idaho Falls, Idaho, *Waterpower 1981 Conference Washington, D.C.*, NTIS No. DE-81028271 or EGG-M-02701.

An assessment study of the interest and problems relating to the development of micro hydropower, i.e., capacities of less than 100 kW, was completed in December 1980 under DOE sponsorship. A total of 62 individuals from 10 states and four groups, i.e., developers, A/E firms, equipment manufacturers, and State and Federal agencies, were polled to determine their perceptions of the advantages and disadvantages of micro-hydro developments and the needs for such developments. Financing, technical assistance, and help with the economic analysis and regulatory aspects of micro-hydro development appeared to be the paramount needs. Whether or not a specific site can be successfully developed depends on site conditions. A micro-hydro plant discussed as an example is shown to be a poor investment (e.g., maximum $200 per month return on $60,000 investment).

1980

Chas T, Main, Inc., 1980, *Half Moon Cove Tidal Project, Feasibility Report*, Boston, Massachusetts, NTIS No. DOE/ID-12089-T1.

This is the feasibility study of the Half Moon Cove Tidal Power Project proposed for a small cove in the northern part of Cobscook Bay in the vicinity of Eastport, Maine. The study addresses technical, economic, legal, and environmental aspects of the proposal. Tides at Half Moon Cove range from a maximum spring of 26.2 ft to a near tide of 12.8 ft. Using these tides, it was determined that two 6 MW units could produce an annual energy of 37 million kWh at a cost of 78 mill/kWh.

Acres American, Inc., 1980, *Small Hydro Plant Development Program*, Vol. 1. Text, NTIS No. DE-81023052 or DOE/ID-01570-T21(V.1).

Small Hydro Plant Development Program, Vol. 2. NTIS No. DOE/ID-01570-T21(V.2) App. A-K or ID0-110094V2 App. A-K.

Small Hydro Plant Development Program, Vol. 3. NTIS No. DE-81023060 or DOE/ID-01570-T21(V.3) App.L.

This study investigated the feasibility of using off-the-shelf design pumps in the turbine mode and induction motors as generators in a representative range of small hydroplant projects. A survey of available pumps revealed that on a single-unit basis, and under the most efficient operating conditions, equipment is available for plants with capacities from 180 to 6800 kW and heads in the range of 20 to 370 ft. Capital cost savings of up to 50% may be achieved over conventional units. However, the efficiencies are generally lower, requiring a life-cycle cost analysis to get the true economic viability.

Beckwith, R. W., 1980, *Suggested Performance Specifications of Standard Modular Controls for the Automation of Small Hydroelectric Facilities*, NTIS No. DOE/ID/01570-2.

This report discusses the automation of a typical small hydroelectric site. It provides recommended guidelines for automation of such a facility, including the use of microprocessors, fiber optics, distributed station batteries, and the use of Pascal computer language.

1979

J. S. Gladwell and C. C. Warnick, 1979, *Low Head Hydro—An Examination of an Alternative Energy Source*, University of Idaho, NTIS No. ID0-1735-1.

This is a compilation of the papers delivered at a seminar, "Low Head Hydroelectric Technology—Problems and Opportunities of an Alternative Energy Source," held at the University of Idaho on June 6 and 7, 1978. The papers were divided into six categories: (a) An Overview, (b) Economics, (c) Low Head Turbines, (d) The Government Presence, (e) The Environment, and (f) Surveys of Energy Potential.

Fouad, A. A. et al., 1979, *Effect of Reduced Inertia on the Transient Stability of a Power System, Final Report*, 2 vols., Engineering Research Institute, Iowa State University, NTIS No. PB-300 912/3 or Report No. ISU-ERI-AMES-80026.

This report examines the influence of significant amounts of low head hydro generation (low inertia machines) on the transient stability of an existing power system. A simplified power system was selected for this computer study, consisting of three generators, nine buses, three loads, and the transmission network connecting them. A fourth generator represented the remote low-inertia generation. The study was performed for the U.S. Department of Interior, Bureau of Reclamation contract No. 9-07-83-V0711 and U.S. Department of Energy Agreement EG-77-36-1024.

Mueller, B. L., 1979, *Feasibility Determination for Hydroelectric Development at Thermalito Afterbay with STRAFLOW Turbine Generators, Final Report*, Aerojet Manufacturing Company, Fullerton, California, NTIS No. DOE/ID-01817-2.

The report summarizes the results of an independent study conducted under a cost-sharing contract with the U.S. DOE by Aerojet Manufacturing Company, International Engineering Company, Inc., and Sulzer Brothers, Inc., to determine the technical and economic feasibility of developing the hydroelectric potential of the Thermalito Afterbay discharge. The study shows the site to have a flow rate of from 0 to 18,000 cfs with an average of 3,934 cfs, and a head of approximately 27 ft. The proposed hydroplant would consist of two American-built Straflow turbines, using 6500 cfs of flow at 27.3 ft of head, with 13,250 kW of capacity. The annual energy would be 48.82 GW at a cost of approximately 42 mill/kWh.

Small/Low Head Hydropower PRDA-1706 Contractors' Symposium, Albany, New York, May 8-10, 1979, NTIS No. CONF-7905154.

The proceedings covers both the remaining five of 54 feasibility assessments performed under DOE's Program Research and Development Announcement (PRDA-ET-78-D-07-1706) and the presentations of the symposium. Papers are on regional planning, FERC licensing and status, feasibility studies and their costs, and specific sites.

EG&G Idaho, 1979, *Small/Low Head Hydropower PRDA-1 706 Feasibility Assessments, Executive Summaries*, Idaho National Engineering Laboratory, Idaho Falls, Idaho, NTIS No. DOE/ID-01570-1.

These executive summaries are 54 of the 59 feasibility assessments performed under U.S. DOE's Program Research and Development Announcement (PRDA-ET-78-D-07-1706).

Schneider, D. J., et al., 1979, *Schneider Lift Translator System, Low Head Hydro Feasibility Study Final Report*, Schneider Lift Translator Co., NTIS No. DOE/RA/01693-T1.

This report covers the results of three tasks performed on the Schneider engine to demonstrate technical feasibility. Task 1 established basic design criteria for a prototype and probable costs of the engine when placed in production. Task 2 tested a state-of-the-art model to evaluate designs of guide vanes, establish efficiencies, and refine cost projections. Task 3 resulted in the construction and testing of a prototype model based on a design to be installed at a canal drop.

Fric, P. A., and G. C. Alexander, 1979, *Cost of Controls for Small Hydroelectric Plants or River Systems, Final Report*, Department of Electrical and Computer Engineering, Oregon State University, NTIS No. DOE/ET/28310-1.

This technical paper is written for engineers and system scientists familiar with hydroelectric plants and control theory. It addresses the following topics mathematically: dam dynamics, flow control through propeller turbines, onsite head-generation control, and complete mathematical dam models.

Alward, R., S. Eisenbart, and J. Volkman, 1979, *Micro/Hydropower, Reviewing an Old Concept*, National Center for Appropriate Technology, Butte, Montana, NTIS No. DOE/ET/01752-1.

This is a simple introduction to all aspects of micro/hydropower, defined here as less than 100-kW output. It describes a variety of unit types and discusses many considerations, for example, economics, financing, legal, and institutional requirements. A resource directory of additional information is included.

1978

VerPlanck, W. K. and W. W. Wayne, Jr., 1978, *Report on Turbogenerating Equipment for Low Head Hydroelectric Developments*, Stone and Webster Engineering Corporation, Boston, Massachusetts, NTIS No. IDO-1962-1.

This report summarizes the selected turbogeneration equipment suitable for low head hydroelectric plants, using information from the Stone and Webster Corporation files (particularly for the Rock Island Hydroelectric Project) and from visits to manufacturers' laboratories and to other hydroelectric plants. The following types of hydraulic turbogenerator systems are discussed: Alstom-Neyrpic bulb turbines, Ossberger crossflow turbines, Escher Wyss Straflow Turbines, Barber Mini-Hydel turbines, and the Allis-Chalmers series of standard tube turbines.

1977

Wayne, W. W., Jr., 1977, *Tidal-Power Study for the United States Energy Research and Development Administration*, 2 vols., Stone & Webster Engineering Corporation, Boston, Massachusetts, NTIS No. DGE-2293-3 V.1 and DGE/2293-3 V.2.

This report discusses the potential of tidal energy as a world power source, especially two sites in the United States where tidal power could be utilized. It considers research opportunities that could reduce the costs of tidal power stations, making them more competitive as a national energy source. It also lists environmental, societal, and legal consequences (both positive and negative) of building a major power plant.

Technology Transfer

1995

Rinehart, B. N., et al., 1995, *DOE Hydropower Program Biennial Report 1994–1995 (with updated annotated bibliography)* Lockheed Martin Idaho Technologies, NTIS DOE/ID-10424.

This report summarizes the research and development and technology transfer activities of the U.S. DOE's Hydropower Program for FY 1994 and 1995, and provides an annotated bibliography of research, engineering, operations, regulations, and costs of projects pertinent to hydropower development. The Hydropower Program is reported in four sections:

- Resource Assessment
- Environmental Research
- Cost Shared Research with Industry
- Technology Transfer.

1993

Rinehart, B. N., et al., 1993, *DOE Hydropower Program Biennial Report 1992–1993 (with updated annotated bibliography)* EG&G Idaho, Inc., NTIS DOE/ID-10424.

This report summarizes the research and development and technology transfer activities of the U.S. DOE's Hydropower Program for FY 1992 and 1993, and provides an annotated bibliography of research, engineering, operations, regulations, and costs of projects pertinent to hydropower development. The Hydropower Program is reported in four sections:

- Resource Assessment
- Environmental Research
- Cost Shared Research with Industry
- Technology Transfer.

1991

EG&G Idaho, Inc., 1991, *DOE Hydropower Program Biennial Report 1990–1991 (with updated annotated bibliography)*, NTIS DOE/ID-10237.

This report summarizes the research and development and technology transfer activities of the U.S. Department of Energy's (DOE's) Hydropower Program for FY 1990 and 1991, and provides an annotated bibliography of research, engineering, operations, regulations, and costs of projects pertinent to hydropower development. The Hydropower Program is reported in six sections:

- Technology Development
- Engineering Research and Development
- Resource Assessment
- National Energy Strategy
- Technology Transfer
- Environmental Research.

1989

EG&G Idaho, Inc., 1989, *DOE Hydropower Program Biennial Report 1988-1989 (with updated annotated bibliography)* NTIS DOE/ID 10237.

This report summarizes the research and development and technology transfer activities of the U.S. DOE's Hydropower Program for FY 1988 and 1989, and provides an annotated bibliography of research, engineering, operations, regulations, and costs of projects pertinent to hydropower development. The Hydropower Program is reported in five sections:

- Technology Development
- Engineering Research and Development
- Technology Transfer
- Environmental Research
- Legal and Institutional Aspects.

The bibliography discusses reports written by both private and non-Federal Governmental sectors. Most reports are available from the National Technical Information Service.

1987

EG&G Idaho, Inc., 1987, *DOE Small-Scale Hydropower Program Annual Report 1987* NTIS DOE/ID-10158.

This report summarizes the research and development and technology transfer activities of the U.S. DOE's Small-Scale Hydropower Program for FY 1986 and 1987, and provides an annotated bibliography of research, engineering, operations, regulations, and costs of projects pertinent to hydropower development. The Small-Scale Hydropower Program is reported in five sections:

- Technology Development
- Engineering Research and Development
- Technology Transfer
- Environmental Research
- Legal and Institutional Aspects.

The bibliography discusses reports written by both private and non-Federal Government

sectors. Most reports are available from the National Technical Information Service.

1986

Morrison-Knudsen Engineers, Inc., 1986, *Small-Hydropower Development: The Process, Pitfalls, and Experience, Volume III: Technology Development Projects Summary and Analysis*, NTIS No. DOE/ID-12254-1(V.3).

This report summarizes information from 23 projects, of which 19 have received financial assistance from DOE as part of the Small-Scale Hydropower Program and four have been developed independently. As of July 1986, 22 of the projects are complete and one is still in design. The completed projects range in generating capacity from 660 to 24,000 kW and in gross hydraulic head from 10 to 470 ft.

1985

Morrison-Knudsen Engineers, Inc., 1985, *Small-Hydropower Development: The Process, Pitfalls, and Experience, Volume IV: Guide for Developers*, NTIS No. DOE/ID-12254-1(V.4).

This manual is designed to assist developers in improving the planning and execution of their projects by learning from the experience of others. For those who are new to small hydropower development, it also provides an overview of the present developmental environment and a basic understanding of what to expect in developing a small hydropower project.

EG&G Idaho, Inc., 1985, *DOE Small-scale Hydropower Program Annual Report 1985*, NTIS DOE/ID-10132.

This report summarizes the research and development and technology transfer activities of the U.S. DOE's Small-Scale Hydropower Program for FY 1985, and provides an annotated bibliography of research, engineering, operations, regulations, and costs of projects pertinent to hydropower development. The Small-Scale Hydropower Program is reported in five sections:

EG&G Services, Inc., 1985, *Hydropower Computerized Reconnaissance Package*, Version 3.0, NTIS No. DOE/ID-10092-1.

This report is the technical manual for the Hydropower Computerized Reconnaissance Package, which is a set of routines designed to make a preliminary engineering and economic evaluation of producing hydroelectric power at existing dam sites. The package includes two main programs, HYD-CALC and HYD-ECON, which are used for engineering and economic analyses, respectively. A version of the package is available for the Apple II series and IBM/PC microcomputers.

Morrison-Knudsen Engineers, Inc., 1985, *Small-Hydropower Development: The Process, Pitfalls, and Experience, Volume II: Licensing Activities Summary and Analysis*, NTIS No. DOE/ID-12254-1(V.2).

This report summarizes the study of 41 license and exemption applications to the FERC for small hydropower projects conducted under the DOE Small-Scale Hydropower Program. These applications were analyzed in detail for significant information that will assist future developers of small hydropower projects in successfully and expeditiously obtaining licenses, or exemption from licensing.

- Technology Development
- Engineering Research and Development
- Technology Transfer
- Environmental Research
- Legal and Institutional Aspects.

The bibliography discusses reports written by both private and non-Federal Government sectors. Most reports are available from the National Technical Information Service.

1984

International Engineering Company, Inc., 1984, *Program Small Hydropower Technology Transfer Project: Task A—Feasibility Studies*, Vol. 1, NTIS No. DOE-ID-12254-1(V.1).

This report summarizes 240 feasibility studies of small hydropower projects conducted under the U.S. Department of Energy's Small-Scale Hydropower Program. It presents a detailed analysis of the studies and presents information significant to future developers.

Legal and Institutional Aspects

Hydroelectric Regulatory Studies. This series of reports and report summaries describes and analyzes the hydroelectric regulatory process of various states. They include a discussion of state water law, environmental regulation, hydroelectric construction regulation, state tax, and finance issues. An introductory section explains the relationship of state and Federal hydroelectric regulation. The Federal report provides similar analysis of the role of the Federal Government in the regulation and development of hydroelectric projects. These reports were presented at regional conferences. The conference reports contain the proceedings of the conference.

1980

Franklin Pierce Law Center, 1980, *Legal Obstacles and Incentives to the Development of Small-Scale Hydroelectric Potential*. NTIS Identification Numbers:

DOE/RA/04934-09	Illinois
DOE/RA/04934-10	Kentucky
DOE/RA/04934-11	Rhode Island
DOE/RA/04934-12	New Hampshire
DOE/RA/04934-13	Delaware
DOE/RA/04934-14	New York
DOE/RA/04934-15	Virginia
DOE/RA/04934-16	New Jersey
DOE/RA/04934-17	Pennsylvania
DOE/RA/04934-18	Maryland
DOE/RA/04934-19	Wisconsin
DOE/RA/04934-20	Maine
DOE/RA/04934-21	Vermont
DOE/RA/04934-22	West Virginia
DOE/RA/04934-23	Connecticut
DOE/RA/04934-24	Massachusetts
DOE/RA/04934-25	Michigan
DOE/RA/04934-26	Ohio
DOE/RA/04934-27	Indiana.

Franklin Pierce Law Center, 1980, *Federal Legal Obstacles and Incentives to the Development of the Small-Scale Hydroelectric Potential in the Nineteen Northeastern States*, NTIS No. DOE/RA/04934-29.

Franklin Pierce Law Center, 1980, *Executive Summary: Legal Obstacles and Incentives to Small-Scale Hydroelectric Development in the Six Middle Atlantic States*, NTIS No. DOE/RA/04934-06.

Franklin Pierce Law Center, 1980, *Executive Summary: Legal Obstacles and Incentives to the Development of Small-Scale Hydroelectric Potential in the Seven Mid-Western States*, NTIS No. DOE/RA/04934-08.

Franklin Pierce Law Center, 1980, *Executive Summary: Legal Obstacles and Incentives to the Development of Small-Scale Hydroelectric Potential in the Six New England States*, NTIS No. DOE/RA/04934-08.

1979

Franklin Pierce Law Center, 1979, *Summary of the New England Conference on Legal and Institutional Incentives to Small-Scale Hydroelectric Development*, NTIS No. DOE/RA/04934-03.

Franklin Pierce Law Center, 1979, *Preliminary Analysis of Legal Obstacles and Incentives to the Development of Low Head Hydroelectric Power in the Northeastern United States*, Energy Law Institute, Concord, New Hampshire, NTIS No. DOE/RA/04924-01.

Franklin Pierce Law Center, 1979, *Summary of the Midwest Conference on Small-Scale Hydropower in the Midwest: An Old Technology Whose Time Has Come*, NTIC No. DOE/RA/04934-05.

Franklin Pierce Law Center, 1979, *Summary of the Mid-Atlantic Conference on Small-Scale Hydropower in the Mid-Atlantic States: Resolution of the Barriers Impeding its Development*, NTIS No. DOE/RI/04934-04.

1978

Franklin Pierce Law Center, 1978, *Federal Legal Obstacles and Incentives to the Development of the Small-Scale Hydroelectric Potential in the Nineteen Northeastern States: Executive Summary*, NTIS No. DOE/RA/04934-41.

Case Study Reports. These case study reports examine the process of development at a particular hydropower site from a regulatory, economic, tax, and finance perspective. The studies examine development by various entities, including private development, municipal development, development at an Army Corps dam, and utility development. A summary report of all five case studies highlights the findings of each report.

Franklin Pierce Law Center, 1980, *A Case Study Analysis of Legal and Institutional Obstacles and Incentives to the Potential Hydroelectric Development of High Falls State Park, Georgia*, NTIS No. DOE/RA/04934-34.

Franklin Pierce Law Center, 1980, *A Case Study Analysis of Legal and Institutional Obstacles and Incentives to the Development of the Hydroelectric Development at the Maxwell Locks and Dam, Pennsylvania*, NTIS No. DOE/RA/04934-36.

Franklin Pierce Law Center, 1980, *A Case Study Analysis of Legal and Institutional Obstacles and Incentives to the Development of the Hydroelectric Potential at Goose River, Maine*, NTIS No. DOE/RA/04934-32.

Franklin Pierce Law Center, 1980, *A Case Study Analysis of Legal and Institutional Obstacles and Incentives to the Development of the Cornell Hydro Project at Cornell, Wisconsin*, NTIS No. DOE/RA/04934-35.

Franklin Pierce Law Center, 1980, *A Case Study Analysis of Legal and Institutional Obstacles and Incentives to the Development of the Hydroelectric Power of the Boardman River at Traverse City, Michigan*, NTIS No. DOE/RA/04934-33.

National Conference of State Legislatures, Denver, Colorado, and Franklin Pierce Law Center, 1979, *Case Studies of the Legal and Institutional Obstacles and Incentives to the Development of Small-Scale Hydroelectric Power: Executive Summary*, NTIS No. DOE/RA/23220-01.

Finance, Tax, and Economic Reports. These reports examine the tax and financing issues associated with small-scale hydropower development, including energy tax credit availability and rules, structures for transferring tax benefits, and tax exempt financing. The reports examine these issues for private and municipal development.

A state tax report surveys the hydroelectric and business tax provisions of various states.

Two economic papers survey the development issues of hydropower and examine the theory of monopsony and how it acts to constrain purchase prices for power.

Energy Law Institute, 1981, *The Financing of Private Small-Scale Hydroelectric Projects*, prepared by the U.S. Department of Energy, NTIS No. DOE/CE/04934-45.

Energy Law Institute, 1981, *A Manual for Development of Small-Scale Hydroelectric Projects*

by Public Entities, Prepared by the Energy Law Institute U.S. Department of Energy, NTIS No. DOE/CE/04934-45.

Franklin Pierce Law Center, 1980, *State Taxation of Small-Scale Hydroelectric Facilities in the Nineteen Northeastern United States*, NTIS No. DOE/RA/04934-30.

Franklin Pierce Law Center, 1980, *Two Economic Papers: (1) Monopsony Power and the Supply of Power From Small Generating Stations (2) A Preliminary Economic Analysis of the Value of Contributions by Small Dams to System Generation Reliability*, NTIS No. DOE/RA/04934-42.

Franklin Pierce Law Center, 1978, *Fundamental Economic Issues in the Development of Small-Scale Hydro*, Franklin Pierce Law Center, 1979. NTIS No. DOE/RA/04934-02.

Reports on Avoided Cost Ratemaking. This series of reports examines the initial implementation of Section 210 of the Public Utility Regulatory Policies Act of 1978 (PURPA) by various state public utility commissions. The reports highlight the various legal, policy, and economic issues addressed by the particular regulatory commission. The reports also examine any state laws modeled after PURPA and their relationship to the Federal law. Each report contains annotations of the PURPA rulemaking, which highlight the various interpretations of the rule by state commissions. Developer handbooks contain this information as well as information on the various electric utilities within the state.

Energy Law Institute, Franklin Pierce Law Center, 1982, *Developer Handbook for Section 210 of PURPA*. NTIS Nos.:

DOE/RA/04934-T2	Montana
DOE/RA/04934-T11	Georgia
DOE/RA/04934-T12	New Hampshire
DOE/RA/04934-T17	New York
DOE/RA/04934-T18	Arkansas
DOE/RA/04934-T19	Oregon
DOE/RA/04934-T21	Vermont
DOE/RA/04934-T23	Massachusetts
DOE/RA/04934-T24	North Carolina
DOE/RA/04934-T25	TVA
DOE/RA/04934-T26	Maine
DOE/RA/04934-T27	Connecticut
DOE/RA/04934-T28	Pennsylvania
DOE/RA/04934-T29	Virginia
DOE/RA/04934-T31	Colorado
DOE/RA/04934-T33	Rhode Island.

Energy Law Institute, Franklin Pierce Law Center, 1982, *Public Utility Commission Manuals for Section 210 of PURPA*. NTIS Numbers:

DOE/RA/04934-T3	New York
DOE/RA/04934-T4	Vermont
DOE/RA/04934-T5	Rhode Island
DOE/RA/04934-T6	Pennsylvania
DOE/RA/05934-T7	Arkansas
DOE/RA/04934-T8	Virginia
DOE/RA/04934-T10	Georgia
DOE/RA/04934-T13	Oregon
DOE/RA/04934-T14	North Carolina
DOE/RA/04934-T15	Massachusetts
DOE/RA/04934-T16	Colorado
DOE/RA/04934-T20	Maine
DOE/RA/04934-T22	Connecticut
DOE/RA/05934-T30	Montana
DOE/RA/04934-T32	New Hampshire.

Project Monitor Reports. This series of reports reviews on a regular basis the recent

developments in the area of small scale hydropower development. The topic areas include FERC activities, Environmental Regulation Federal Resource Agencies, State Electric Utility Regulatory Agencies, and Tax and Finance Issues.

ELI Corporation, 1986, *Small Scale Hydropower Program Legal and Institutional Aspects, Project Monitor Report,* NTIS No. DOE/ID-10133-3.

ELI Corporation, 1986, *Small Scale Hydropower Program Legal and Institutional Aspects, Project Monitor Report,* NTIS No. DOE/ID-10133-2.

ELI Corporation, 1986, *Small Scale Hydropower Program Legal and Institutional Aspects, Project Monitor Report,* NTIS No. DOE/ID-10133-1.

ELI Corporation, 1985, *Small Scale Hydropower Program Legal and Institutional Aspects, Project Monitor Report,* NTIS No. DOE/ID-10133.

Energy Law Institute, 1985, *Small Scale Hydropower Program Legal and Institutional Aspects, Project Monitor Report,* NTIS No. DOE/RA/04934-2.

Energy Law Institute, Franklin Pierce Law Center, January 1985, *Small Scale Hydropower Program Legal and Institutional Aspects, Project Monitor Reports,* NTIS No. DOE/RA 04934-1.

General

International Renewable Energy Conference—Conference Proceedings. May be obtained by writing to: IREC Proceedings Code 4, 73 DBEB Energy Division, 335 Merchant Street, Room 110, Honolulu, Hawaii 96813.

1988

Small Hydro '88—An International Conference and Trade Show—Conference Proceedings. Volume I: Plenary Session; Policy, Planning and Utility Issues. Volume II: Engineering and Technology; Markets and Financing.

The Qualifying Facilities Report—A cumulative list of filings made for small-power production and cogeneration facilities FY 1980 through FY 1988. FERC, Office of Electric Power Regulation, Washington, D.C. 20426, October 1, 1988.

1983

Waterpower '83—International Conference on Hydropower—Conference Proceedings, Knoxville, Tennessee: Volume I: Small and Micro/Min Hydro;/and Financing, Licensing, and Legal Issues. NTIS No. DE-84000808. Volume II—Conventional Hydro and Pumped Storage and Operation of Existing Conventional Hydro Operations, NTIS No. DE-84000809.

Volume III—Environmental Impacts; Research and Development; Dam Safety; NTIS No. DE-84000810.

U.S. DOE Energy Information Administration, 1983, *Hydroelectric Plant Construction Cost and Annual Production*, NTIS No. DE-84000243 or DOE/EIA-0171.

U.S. Army Corps of Engineers, 1983, *National Hydroelectric Power Resources Study,* For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (202) 783-3238 or -3311.

This plan identifies a set of best-candidate sites for future study of hydroelectric power potential. The plan includes both Federal and non-Federal sites. The final report comprises the following 23 volumes:

National Conference of State Legislatures, Denver, Colorado, 1983, *Legislation's Guide to Small-Scale Hydroelectric Development,* NTIS No. DE-83007370 or DOE/RA/23220.

Goerz, J. W., 1983, *Improved Generator for Use with Low-Speed Rotating Machines, Final Report,* Lexington, Kentucky, NTIS No. DOE/RA/10249-T1.

Tennessee Technological University, 1983, *Design and Evaluation of Small Water Turbines, Final Report,* NTIS No. DOE/RA/10243-T1.

Rehder, J. B., 1983, *Design and Applications for Floating Hydropower Systems in Small Streams*, Knoxville, Tennessee, NTIS No. DOE/RA/10415-T1.

1982

Kennedy, B. W., 1982, *Small Hydropower Turbine Generating System, Final Report*, Guntersville, Alabama, NTIS No. DOE/RA/10478-T1.

1981

Association of Bay Area Governments, 1981, *Renewable Energy for the Future, Local Government Options for Promoting Development of Renewable Energy Resources*, Berkeley, California, NTIS No. DE-82014945 or DOE/NBM-2014945.

INEL, 1981, *Hydropower Computerized Reconnaissance Package—Version 2.0*, Idaho National Engineering Laboratory, NTIS No. IDO-10092.

California State Cooperative Outreach Program for Small-Hydro Development, 1981, *Accomplishments of the Small-Hydro Outreach Program, Final Report*, NTIS No. DE-82016247 or DOE/R9/10034-T1.

1980

Tudor Engineering, 1980, *Reconnaissance Evaluation of Small, Low Head HydroelectricInstallations*, NTIS No. PB81-188294.

This is a methodology for assessing projects under both 15,000 kW and 65-foot heads, for reviewing cost data, determining available energy, and financing. Three examples of applying the methodology are presented.

National Conference of State Legislatures, 1980, *Small-Scale Hydroelectric Power in the Southeast, New Impetus for an Old Energy Source*, NTIS No. DOE/RA/23220-05.

National Conference of State Legislatures, 1980, *Small-Scale Hydroelectric Power in the Pacific Northwest: New Impetus for an Old Energy Source*, NTIS No. DOE/RA/23220-04.

1979

Gladwell, J. S., L. F. Heitz, and C. C. Warnick, 1979, *A Resource Survey of Low Head Hydroelectric Potential, Pacific Northwest Region, Completion Report, Phase I, Volume A*, NTIS No. DOE/RA/01691.

U.S. Army Corps of Engineers, 1979, *Feasibility Studies for Small Scale Hydropower Additions—A Guide Manual*. NTIS No. DOE/RA/0048.

This is a manual for performing hydropower feasibility assessments, prepared primarily with the practicing engineer in mind. It consists of the following subsections: technical guide, civil features, hydrologic studies, economic and financial analysis, electromechanical features, and existing facility integrity.

Gladwell, J. S., L. F. Heitz, C. C. Warwick, 1979, *A Resource Survey of Low Head Hydroelectric Potential at Existing Dams and Proposed Sites in the Pacific Northwest Region: Phase II*, September 1979. NTIS No. DOE/RA/01691-2.

1978

College of Engineering, 1978, *Small Low Head Hydroelectric Power, Proceedings from the Midwest Regional Conference, May 1978. Michigan State University*, East Lansing, Michigan, August 1978. NTIS No. IDO/10076.

Undated

Simplified Methodology for Economic Screening of Potential Low Head Small-Capacity Hydroelectric Sites (EM-1679), published by the Electric Power Research Institute. This technical report may be ordered from the Research Reports Center, P.O. Box 50490, Palo Alto, California 94303, (415) 965-4081. Please specify publication number.

Hydropower Sites of the United States Developed and Undeveloped; this FERC atlas may be purchased from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. GPO Stock No. 429-V-5.

Rivers of Energy; The Hydropower Potential, Daniel Deudney, Worldwatch Institute, 1776 Massachusetts Avenue, N.W., Washington, D.C. 20036. Copies may be ordered from this address.

Small and Micro Hydroelectric Power Plant—Technology and Feasibility, edited by R. Noyes. Available from Noyes Data Corporation, Mill Road at Grand Avenue, Park Ridge, New Jersey 07656.

Report on Assessment of Small Hydroelectric Development at Existing Facilities, Water and Power Resources Service, U.S. Department of Interior. NTIS No. PB81-104663.

Western States Inventory of Low Head Hydroelectric Sites, Water and Power Resources Service, U.S. Department of Interior, NTIS Nos. Volume I-PB81-134942, Volume II-PB81-134959.

Staff Report on Retired Hydropower Plants in the United States, FERC. This FERC report is available upon request by writing to Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. Request Document No. GPO 061-002-0069-3.