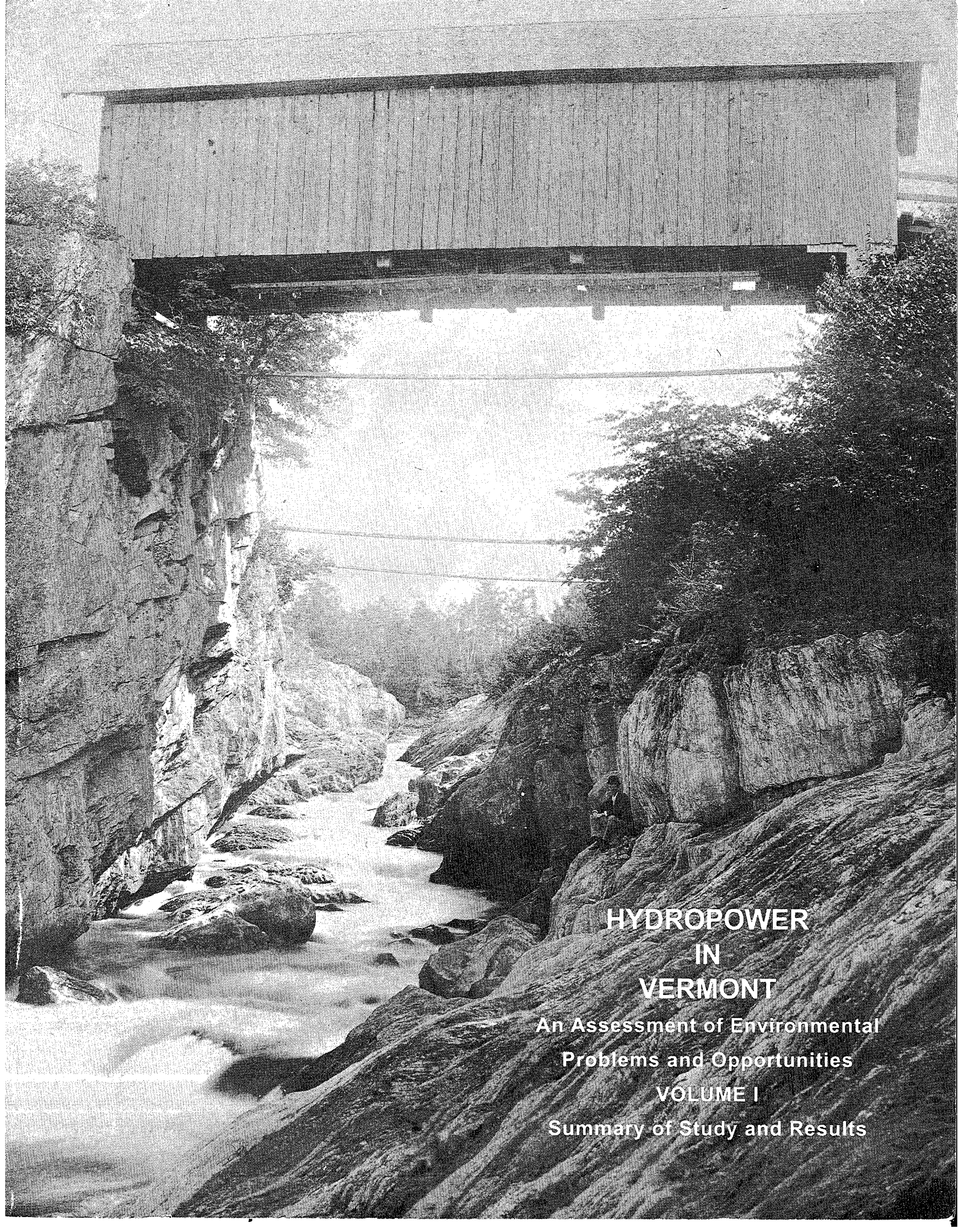

HYDROPOWER IN VERMONT

An Assessment of Environmental Problems and Opportunities

VOLUME I

Summary of Study and Results

HYDROPOWER IN VERMONT

AN ASSESSMENT OF ENVIRONMENTAL PROBLEMS AND OPPORTUNITIES

VOLUME I

SUMMARY OF STUDIES AND RESULTS

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Cover Photo - Middlesex Gorge, Winooski River, Circa 1890.
Looking upstream before flooding by 1895
construction of dam for Middlesex #2 Project.
(Photo from the collection of Jeffrey R. Cueto.)

ACKNOWLEDGEMENTS

Many individuals and organizations contributed to the Vermont Hydropower Study and this final report. While it is not possible to name them all, several persons deserve special recognition as follows: Thomas Willard for conceiving and bringing the study to fruition; Jeffrey Cueto for his expertise, editing and graphics; Brenda Clarkson for her technical assistance; the staff of the Vermont Department of Environmental Conservation biology and chemistry laboratories for the many hours of analyses; Angelo Incerpi, Director of Fisheries for the Vermont Fish and Wildlife Department, and his staff of fisheries biologists for their technical and field support; Leonard Gerardi for his invaluable assistance with the Fishery Flow Needs Assessment Methodology; Green Mountain Power Corporation and Central Vermont Public Service Corporation for releasing certain flows when requested for field work; Rosemary Hebert, Dede Scott, Debbie Corliss, and Ellen Hinman for typing this report; and Gary Durkee for his graphics work.

Special appreciation is expressed to six people who made this study a reality. They worked long hours with enthusiasm and dedication, enduring poison ivy, torrential streams, and broken equipment, always with a smile. These devoted individuals are: Debbie Lester, Lisa Terwilliger, Betsy Rosenbluth, Jon Wilkinson, Wendy Bell, and Rick Hopkins.

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GLOSSARY

assimilative capacity (ASCAP): a measure of the capacity of the receiving waters to assimilate wastes without lowering their quality below the applicable water quality criteria.

bypass: a section of stream bypassed by a hydroelectric project. These sections are usually located between a project's dam and the end of a project's tailrace. This section may vary in length from simply the width of a dam to a few miles. These stream sections are either completely or partially dewatered.

dissolved oxygen (D.O.): oxygen dissolved in water, measured in terms of mg/l or percent saturation. The concentration of dissolved oxygen present in a stream is an indicator of water quality.

flashboard: boards installed along the crest of a dam. These boards increase the available head for a given project and increase the size of an impoundment which in turn increases a project's storage capacity. These boards are frequently designed to fail under high stream flows.

impoundment: an impounded body of water located upstream of a dam.

invertebrates: refers to aquatic nymph or larval stages of insects, crustaceans, and worms which contribute to the aquatic biota of a stream and are indicators of water quality. Many invertebrates serve as fish food organisms (may also be referred to as macroinvertebrates or benthos).

leakage flow: that flow which leaks through a hydroelectric project. The source of this flow is usually leakage through or around a project's dam, flashboards, gates, bedrock or powerhouse. This flow is frequently less than the 7Q10 value for the stream on which the project is located.

lentic: of, relating to, or living in slow moving water.

lotic: of, relating to, or living in actively moving water.

peaking project: a project which operates to maximize power generation during periods of peak power demand. Natural stream flows below the project's powerhouse are artificially regulated as a result.

penstock: a conduit or pipe for conducting water from an impoundment to a project's powerhouse.

periphyton: organisms (such as algae or mosses) which live attached to the submerged substrate of a streambed. It is an important food source for some fish and many invertebrates.

reoxygenation: the process of oxygen entering and mixing with water.

rheophilic: preferring or living in flowing water.

riffle: a shallow section of stream characterized by a broken, turbulent water surface.

run: a deep, fast-moving section of stream where the water surface is non-turbulent.

run-of-the-river project:

a. true run-of-the-river: a project which does not operate out of storage and, therefore, does not artificially regulate natural stream flows below the project's powerhouse. Outflow from the project is equal to inflow to the project's impoundment on an instantaneous basis.

b. essentially run-of-the-river project: a project which does not utilize substantial storage, does not significantly fluctuate flows, and at all times releases adequate minimum flows. Project outflow is substantially equal to project inflow.

storage reservoir or storage natural lake: a manmade reservoir or natural lake used to augment natural stream flows for downstream generating facilities.

stratification: the distinct layering of reservoir water during the summer season. The warmer upper layer of the water is prevented from mixing with the cooler lower layer because of the large difference in their densities due to temperature differentials. Oxygen isolated in the lower water at the beginning of the stratification period, if used up, cannot be replenished. An oxygen deficit occurs in the deeper sections as a result.

tailrace: a canal located at the powerhouse discharge to divert flows back into the river channel.

useable area: the area of a section of stream having suitable depths, velocity and substrate for a specific fish species at a particular life stage or for invertebrates.

ABBREVIATIONS

ACOE: Army Corps of Engineers

cfs: cubic feet per second

csm: cubic feet per square mile of drainage area

D.O.: dissolved oxygen

FERC: Federal Energy Regulatory Commission

FFNA methodology: Fishery Flow Needs Assessment methodology

IFIM: Instream Flow Incremental Methodology

PSD: Vermont Public Service Department

7Q10: a statistical flow value representing the consecutive seven-day mean low flow with a recurrence interval of ten years.

STP: Sewage Treatment Plant

TNC: The Nature Conservancy

USFWS: U.S. Fish and Wildlife Service

VINS: Vermont Institute of Natural Science

EXECUTIVE SUMMARY

"Hydropower in Vermont: An Assessment of Environmental Problems and Opportunities" is the first comprehensive environmental study of older hydroelectric projects in Vermont. The study focused primarily on the identification of water quality and quantity problems which may occur at these facilities as a result of the artificial regulation of natural stream flow. The study does not attempt to evaluate or weigh the several environmental benefits of hydropower development nor does it make judgements about the value of electricity production against the environmental costs. By design, the study only includes those projects that predate the recent period of renewed interest in hydroelectric project development since the late 1970s.

The Department of Environmental Conservation has a responsibility to manage state waters to meet the goals of the Vermont Water Quality Standards and stream classifications. The Department recognizes from experience that hydropower development can conflict with these goals. The study commenced in 1982 to determine the actual extent of these conflicts and to identify solutions appropriate for individual project sites.

Study results indicate hydroelectric development has a tremendous impact on Vermont streams. Artificial regulation of natural stream flows and the lack of adequate minimum flows at these sites have reduced to a large extent the success of the state's initiatives to restore the beneficial values and uses for which the affected waters are managed. This flow regulation has a significant effect on water quality, fisheries and other aquatic biota, assimilative capacity, recreational use, aesthetics, wildlife habitat, and natural area values of the affected streams.

More than three-fourths of the projects studied were found to be adversely impacting the streams on which they are located. The 62 projects are located on 683 total miles of stream, measured from headwater to mouth. This encompasses most of our major rivers. Over one-third of these total stream miles are impounded, bypassed or flow-regulated as a result of hydroelectric project development. Artificial flow regulation and penstock bypasses result in about 77 miles of stream not supporting the uses designated in the Vermont Water Quality Standards and an equal number of miles only partially supporting their designated uses.

These facts contrast sharply with the efforts and progress made in the State's water pollution control program. Substantial public funds have been expended to improve the water quality of our streams through the elimination of water pollution discharges. As of November 1988, there were 90 public wastewater treatment plants and 45 industrial pretreatment plants in the state. These plants have improved the quality of approximately 55 rivers and streams and three lakes. A total of $290,000,000 of state, federal, and local funds have been spent to cover the capital construction of the public facilities. Annual operation and maintenance costs alone exceed $10,000,000 a year. No estimates are available for the industrial facilities.

This expenditure of public funds is necessary to meet the goals of both Federal and State water pollution control programs. However, the regulation of stream flows by hydroelectric projects threatens the attainment of these goals. While committing resources to improve the water quality of our streams through the elimination and control of water pollution discharges, we have yet to resolve the flow regulation problem.

This report includes many recommendations for mitigation and outlines areas of further study, especially in the area of stream flow management. But this is only a beginning process. Project owners must now become more directly involved as well as the Vermont Public Service Department and the Federal Energy Regulatory Commission. The Department's goal is to bring all 62 projects into compliance with the State Water Quality Standards and to improve the management of our water resource. With the cooperation of all parties and the active support of the public, we can achieve this goal for the benefit of this and future generations.

Patrick Parenteau

PATRICK PARENTEAU, COMMISSIONER
VERMONT DEPARTMENT OF ENVIRONMENTAL CONSERVATION

11-18-88

DATE

SECTION I

INTRODUCTION

"It is the policy of the state of Vermont to:

(1) protect and enhance the quality, character and usefulness of its surface waters and to assure the public health;

(2) maintain the purity of drinking water;

(3) control the discharge of wastes to the waters of the state, prevent degradation of high quality waters and prevent, abate or control all activities harmful to water quality;

(4) assure the maintenance of water quality necessary to sustain existing aquatic communities;

(5) provide clear, consistent and enforceable standards for the permitting and management of discharges;

(6) protect from risk and preserve in their natural state certain high quality waters including fragile high-altitude waters, and the ecosystems they sustain;

(7) manage the waters of the state to promote a healthy and prosperous agricultural community, to increase the opportunities for use of the state's forest, parks and recreational facilities, and to allow beneficial and environmentally sound development.

It is further the policy of the state to seek over the long term to upgrade the quality of waters and to reduce existing risks to water quality."

(from Vermont Water Quality Standards, Section 1-02, General Water Quality Policy, January 8, 1987)

For centuries, hydropower development has dramatically changed the character of Vermont's streams. Water quality has been degraded. The usefulness of the resource for purposes other than power production has been reduced and, in some cases, virtually eliminated. Aquatic communities have changed in composition or been lost entirely.

These power projects are usually located on very scenic and ecologically important sections of stream, such as cascades or waterfalls, and they artificially regulate natural stream flows. As a result, there is a potential for conflict with many of the uses and values for which our waters are managed:

1. Aesthetics and natural areas values
2. Aquatic biota
3. Fish and wildlife habitat
4. Recreation such as boating, fishing, and swimming
5. Irrigation and other agricultural uses
6. Water supply
7. Wastewater assimilation
8. Compatible industrial uses

The State has a legal mandate to "prevent, abate or control all activities harmful to water quality" (no.3 of the general policy quoted above). The Vermont Water Resources Board specifically addressed the problem of flow regulation when drafting the <u>Vermont Water Quality Standards</u>. Section 2-02 Hydrology states that "the flow of waters shall not be regulated in a manner which would result in an undue adverse effect on any existing use, beneficial value or use or result in a level of water quality which does not comply with these rules." The purpose of this study is to determine the changes necessary to bring Vermont hydroelectric projects into conformance with the Standards by thoroughly investigating the manner in which the projects operate and the uses and values impacted.

In 1982, the year the study was initiated, 62 hydroelectric projects existed in Vermont (Table 1). These projects were generating approximately 13% of the electricity used annually in the state. As a result of the Arab Oil Embargo and the evolution of the energy crisis in the late 1970's, new sources of domestic electrical energy production were being actively pursued. The Agency of Natural Resources (the Agency) received proposals for over 70 new projects. The Federal Energy Regulatory Commission (FERC) has licensed or exempted 51 of these projects. Of these 51 projects, 38 have been constructed and are now on line, and three are under construction (Table 2).

Table 1

Licensing and Certification Status of Existing Hydropower Operations

Drainage Basin and Site	Owner/Utility[1]	License #	License Expiration Date	Water Quality Certification Date
Basin 1 (Batten Kill, Walloomsac R., Hoosic R.)				
No Projects				
Basin 2 (Poultney R.)				
Carvers Falls	CVPSC	Unlicensed	---	May 7, 1981[2]
Basin 3 (Otter Cr., East Cr.)				
Chittenden	CVPSC	Unlicensed	---	
Lefferts	CVPSC	Unlicensed	---	
Glen	CVPSC	Unlicensed	---	
Patch	CVPSC	Unlicensed	---	
Proctor	VMARCO	2558	March 31, 2012	July 21, 1981
Center Rutland	VMARCO	2445	December 31, 1993	
Middlebury Lower	CVPSC	2737	July 1, 2000	December 31, 1974
Beldens	VMARCO	2558	March 31, 2012	May 27, 1986
Huntington Falls	VMARCO	2558	March 31, 2012	May 27, 1986
Weybridge	CVPSC	2731	May 31, 2000	March 20, 1975
Vergennes	GMP	2674	May 31, 1999	

1. GMP - Green Mountain Power Corporation
   CVPSC - Central Vermont Public Service Corporation
   CUC - Citizens Utilities Company
   NEPCo - New England Power Company
   CRPCo - Coaticook River Power Company
   VMARCO - Vermont Marble Company

2. Certification issued for a desilting project only.

Table 1 (continued)

Drainage Basin and Site	Owner/Utility	License #	License Expiration Date	Water Quality Certification Date
Basin 3 (Otter Ck., East Ck.)				
Sugar Hill	CVPSC	Unlicensed	---	
Sucker Brook	CVPSC	Unlicensed	---	
Silver Lake	CVPSC	Unlicensed	---	
Lake Dunmore	CVPSC	Unlicensed	---	
Salisbury	CVPSC	Unlicensed	---	
Basin 4 (Lower Lake Champlain)				
No Projects				
Basin 5 (Upper Lake Champlain, LaPlatte R., Mallets Bay, St. Albans Bay, Rock R., Pike R.)				
No Projects				
Basin 6 (Missisquoi R.)				
Bakers Falls	CUC	Unlicensed	---	
Enosburg Falls	Village of Enosburg	2905	July 1, 2023	February 28, 1986
Sheldon Springs	Missisquoi Associates	7186[1]	September 30, 2024	March 19, 1984[2]
Highgate Falls	Village of Swanton	2547	April 30, 2024	November 25, 1983
Basin 7 (Lamoille R.)				
Hardwick Lake	Village of Hardwick	Unlicensed	---	
Wolcott	Village of Hardwick	Unlicensed	---	
East Long Pond	Village of Hardwick	Unlicensed	---	
Nichols Pond	Village of Hardwick	Unlicensed	---	
Caspian Lake	Village of Hardwick	Unlicensed	---	
Lake Elmore	Village of Morrisville	2629	August 15, 2015	
Morrisville	Village of Morrisville	2629	August 15, 2015	May 7, 1981

1. Formerly unlicensed

2. Amended October 18, 1984 and February 13, 1986

Table 1 (continued)

Drainage Basin and Site	Owner/Utility	License #	License Expiration Date	Water Quality Certification Date
Basin 7 (Lamoille R.)				
Cadys Falls	Village of Morrisville	2629	August 15, 2015	May 7, 1981
South Pond	CVPSC	Unlicensed	---	
Fairfax Falls	CVPSC	2205	December 31, 1987 (under review for relicensing)	
Clarks Falls	CVPSC	2205	December 31, 1987 (under review for relicensing)	
Milton	CVPSC	2205	December 31, 1987 (under review for relicensing)	
Peterson	CVPSC	2205	December 31, 1987 (under review for relicensing)	
Basin 8 (Winooski R.)				
Peacham Pond	GMP	Unlicensed[1]	---	
Mollys Falls	GMP	Unlicensed[1]	---	
Middlesex	GMP	Unlicensed[1]	---	
Little River #22	GMP	2090	September 1, 2001	
Essex #19	GMP	2513	December 31, 1993	
Gorge #18	GMP	Unlicensed[1]	---	
Basin 9 (White R.)				
No Projects				
Basin 10 (Black R., Ottauquechee R.)				
Lake Ninevah	CVPSC	Unlicensed	---	
Cavendish	CVPSC	2489	December 31, 1993	
Taftsville	CVPSC	2490	December 31, 1993	

1. License application dismissed August 24, 1979.

Table 1 (continued)

Drainage Basin and Site	Owner/Utility	License #	License Expiration Date	Water Quality Certification Date
Basin 11 (West R., Williams R., Saxtons R.)				
No Projects				
Basin 12 (Deerfield R.)				
Somerset	NEPCo	2323	December 31, 1993	
Searsburg	NEPCo	2323	December 31, 1993	
Harriman	NEPCo	2323	December 31, 1993	
Basin 13 (Lower Connecticut, Mill Brook)				
No Projects				
Basin 14 (Stevens R., Wells R., Waits R., Ompompanoosuc R.)				
No Projects				
Basin 15 (Passumpsic R.)				
Vail	Village of Lyndonville	3090	January 31, 2001	March 5, 1980
Great Falls	Village of Lyndonville	2839	June 1, 2019	February 26, 1984
Pierce Mills	CVPSC	2396	December 31, 1993	
Gage	CVPSC	2397	December 31, 1993	
Arnold Falls	CVPSC	2399	December 31, 1993	
Passumpsic	CVPSC	2400	December 31, 1993	
West Danville	GMP	Unlicensed[1]	---	

1. License application dismissed May 23, 1979

Table 1 (continued)

Drainage Basin and Site	Owner/Utility	License #	License Expiration Date	Water Quality Certification Date
Basin 16 (Upper Connecticut, Nulhegan R., Willard Stream, Paul Stream)				
No Projects				
Basin 17 (Coaticook R., Clyde R.)				
Great Averill Lake	CRPCo	Unlicensed	---	
Little Averill	CRPCo	Unlicensed	---	
Norton Pond	CRPCo	Unlicensed	---	
Pensioner Pond	Village of Barton	7725[1]	October 1, 2004	June 1, 1984
Seymour Lake	CUC	2306	December 31, 1993	
Echo Lake	CUC	2306	December 31, 1993	
West Charleston	CUC	2306	December 31, 1993	
Newport #1	CUC	2306	December 31, 1993	
Newport #11	CUC	2306	December 31, 1993	

1. Formerly unlicensed

Table 2
New Projects Under Construction or On Line

Basin Stream	Project	Utility/Owner	Status[1]
BASIN 1 Hoosic River	Pownal	Pownal Hydropower Corp.	OL
BASIN 2 Flower Brook	Flowerbrook	Flowerbrook Hydro, Inc.	OL
BASIN 6 Potter Brook	Warner Hydro	Mr. Arlon Warner	OL
BASIN 7 Baldin Brook	Baldin Brook Hydro	Mr. William B. Taylor	OL
Green River	Green River	Morrisville Water & Light Dept.	OL
Gihon River	Woodside	Mr. & Mrs. Robert M. Woodside	OL
BASIN 8 Winooski River	Bolton Falls	Green Mountain Power Corp.	OL
Winooski River	Winooski #8	Winooski Hydroelectric Co.	OL
Dog River	C.T.I.P.	Nantana Mill Dam Partnership	OL
North Branch - Winooski River	Ladds Mill	Worcester Hydro Co.	OL
North Branch - Winooski River	North Branch #3	Washington Electric Co-op	OL
North Branch - Winooski River	Lane Shops	Mr. David DuBrul	OL

[1]UC: Under Construction
OL: On Line

Table 2 (continued)

Basin Stream	Project	Utility/Owner	Status
BASIN 8 Kingsbury Branch - Winooski River	North Montpelier Pond	Dr. Thomas Stuwe Mr. William Porter	OL
Crossett Brook	Tourin Musica	Mr. Jack Tourin	OL
Mad River	Warren	Warren Hydro Co.	OL
Little River	Leveille	Leveille Inc.	OL
BASIN 9 Third Branch - White River	Bethel Mills	Bethel Mills Inc.	OL
BASIN 10 Black River	Fellows	Westinghouse Electric Corp. & Town of Springfield	UC
Black River	Gilman	Westinghouse Electric Corp. & Town of Springfield	UC
Black River	Comtu Falls	Comtu Falls Corp.	OL
Black River	Slack Dam	Sterling Enterprises	OL
Black River	Lovejoy	Westinghouse Electric Corp. & Town of Springfield	UC
Ottauquechee River	Downers Mill	Simon Pearce (U.S.) Inc.	OL
Ottauquechee River	Deweys Mills	Hydro Energies Corp.	OL
Ottauquechee River	North Hartland Dam	VT Electric Generation and Transmission Co-op, Inc.	OL
Ottauquechee River	White Current Corp.	White Current Corp.	OL
Kent Brook	Killington	Killington Hydroelectric Co.	OL

Table 2 (continued)

Basin Stream	Project	Utility/Owner	Status
BASIN 11			
Williams River	Brockways Mills	Williams River Electric Corp.	OL
BASIN 12			
Cold Brook	Cold Brook	Dr. & Mrs. Ruhl	OL
Green River	Harrisville Mill	Mr. Raymond C. Miller	OL
BASIN 13-16			
Halls Brook	Halls Brook	Mr. S.R. Thanhauser	OL
Lulls Brook	Martinsville	John L. Boeri	OL
BASIN 14			
Waits River	Bradford	Central Vermont Public Service Corp.	OL
Stevens River	Barnet	Barnet Hydro Co.	OL
Ompompanoosuc River	Shingle Mill	Howard E. Geer Jr.	OL
Wells River	Wells River	Essex Hydro Association	OL
Wells River	Newbury	Newbury Hydro Co.	OL
BASIN 15			
Passumpsic River	East Barnet	Central Vermont Public Service Corp.	OL
Sleepers River	Emerson Falls	Emerson Falls Hydro Associates	OL
Sleepers River	Fairbank's Mill	Robert F. Desrochers	OL
BASIN 17			
Coaticook River	Swanson-Eames	Norton Hydro Co.	OL

Figure 1 identifies the location of the 62 existing projects as well as the 41 new projects.*

The new project proposals quickly sensitized the Agency to the multiple impacts produced by hydroelectric development and the need to balance the development with other existing uses and values of the waters. Popularly considered a "clean and renewable" source of energy, hydropower was found not to be without its environmental cost. More aware of these costs, the Agency's Department of Environmental Conservation (the Department) researched and developed techniques for assessing the impacts of new projects and formulating mitigation. These same techniques have been applied to the existing projects under study.

Recognizing the need to evaluate and document impacts of the existing projects on a statewide basis and executing its mandate to manage State waters to meet the goals of the Vermont Water Quality Standards, the Department instituted the study "Hydropower in Vermont: An Assessment of Environmental Problems and Opportunities" in 1982. This study, funded by Section 208 of the Clean Water Act (P.L. 92-500), is the first comprehensive assessment of the adverse environmental impacts of hydroelectric projects in Vermont. This study evaluated the operation of the 62 existing projects for consistency with the Vermont Water Quality Standards and stream classifications.

The study has four primary objectives:

- The identification of water quality and quantity problems at the 62 existing projects.

- The formulation of recommendations to resolve or mitigate identified problems in order to improve resource management and enhance public use.

- The establishment of an extensive data base for all hydroelectric projects as a reference resource.

*The Fellows, Gilman, and Lovejoy projects on the Black River (Basin 10) and owned by the Westinghouse Corporation and the Town of Springfield went under construction in the summer of 1987 after Figure 1 was printed and, therefore, are not included on the map.

- The refinement of predictive models for projecting the water quality of new river impoundments and downstream impacts due to loss of reaeration and increased algal respiration.

The study involved an intensive data collection effort carried out by three two-member teams working under a study manager, Ms. Cynthia Parks. Site-specific data were collected for each of the 62 projects on hydrology, land use, recreation, aesthetics, fisheries, water quality, erosion, siltation, project operation and features, and license status. Information sources included the Department, the Department of Fish and Wildlife (Vermont Fish & Wildlife), the New England River Basin Commission, FERC, the Vermont Public Service Board, and the Vermont Department of Public Service. Site visits were made to each project to interview utility representatives and gather additional information. The information on project features and operation were summarized on questionnaires, which were sent to each utility to verify and supplement this data.

The Vermont Fishery Flow Needs Assessment Methodology, a means of quantifying the availability of fish habitat as a function of stream flow, was conducted at eight sites. The Vermont Fish & Wildlife had selected these sites as being among those most severely impacted by flow manipulation. The affected stream reaches were also judged as having the potential to sustain high quality fisheries with proper stream flow management.

Water quality sampling programs were conducted at ten sites to aid the Department in projecting the likely severity of water quality problems at proposed hydroelectric projects. Parameters included dissolved oxygen, total and dissolved phosphate, total kjeldahl nitrogen, ammonia, nitrite/nitrate and chlorophyll-a.

After analyzing the data and identifing the problems, the Department has made specific recommendations for mitigative measures in this report. This study is intended to initiate a process which the Department hopes will lead to the compliance of all these projects with State Water Quality Standards and result in the improved management of our water resources for the benefit of all.

This report is organized into two separate volumes:

<u>Volume I: Summary of Study and Results</u> - includes the executive summary, the introduction, a background

perspective on hydrodevelopment, and the study procedure, results, discussion, conclusions, and recommendations.

Volume II: Project Site Reports - includes individual site reports which contain specific information on each project studied.

SECTION 2

BACKGROUND ON HYDROELECTRIC DEVELOPMENT

Waterpower development has had a long and important history in Vermont, beginning soon after the first colonization by white settlers. By the mid 1800's, virtually every falls supported some form of mill development. The advent of hydroelectric development in the 1890's changed the character and magnitude of the demand on our water resource. In this section of the report, three items are explored--the known environmental impacts of hydroelectric projects, assessment and mitigation techniques that have been developed, and available regulations that are used to address the impacts.

ENVIRONMENTAL IMPACTS

The environmental impacts associated with hydropower development are numerous. The physical character of the stream is markedly changed upstream, downstream, and at the dam location. Water chemistry and biology are also altered.

Impoundment creation and use of natural lakes

The construction of a dam converts a free-flowing section of stream into a slow-moving, impounded body of water. A lotic environment is suddenly transformed into a lentic environment. Warming often occurs as a greater surface area of water is exposed to sunlight and cold water fish species such as salmonids may be replaced by warm water species. The species composition of invertebrates critical to support all fish species may be changed and the number reduced. Valuable salmonid spawning and wildlife habitat, as well as whitewater stream sections used for recreational activities such as kayaking and canoeing, may be flooded.

These whitewater areas, as well as riffle sections, are important sources of stream reoxygenation. Flooding reduces turbulence and increases depth, both of which lessen the potential for oxygen entrainment in the water. Lower velocities cause the deposition of sediment and organic material in the impoundment, favoring weed and algal growth.

The dam itself may create a physical barrier to upstream and downstream movement of fish. Spawning runs of migratory fish species, like Atlantic salmon and steelhead rainbow trout may be blocked, eliminating the use of reaches upstream of the dam for breeding.

If the impoundment fluctuates due to project operation, several problems may result. Shoreline erosion may occur. The severity of the erosion problem depends on the shoreline soils and the degree and frequency of the fluctuations. The impoundment's littoral zone, which normally provides important habitat for food production and spawning, becomes dewatered. Fluctuations may also cause an unsightly "bathtub ring" to develop along the impoundment shoreline as vegetation is unable to become established.

The impoundment may stratify, resulting in oxygen-depleted waters in the deeper sections of the impoundment. Heavy metals and nutrients which may have accumulated in the bottom sediments of the impoundment may be released back into the water column under these oxygen-depleted conditions. If a project operates with a bottom withdrawal structure and its impoundment is stratified, this water, sometimes containing heavy metals and nutrients, may be transported downstream.

Impoundments in Vermont range anywhere from a few hundred feet in length to several miles. On the Otter Creek alone, existing hydroelectric projects have resulted in the impounding of almost a quarter of the river. Statewide, existing projects have resulted in the impounding of over 100 miles of stream.

Storage reservoirs and natural lakes used for storage are managed by utilities to capture excess runoff during the spring and during storm events and to make this water available to downstream hydroelectric projects when natural river flows recede. A new host of conflicts result because these water bodies are generally not riverine impoundments and because drawdowns are frequently of greater magnitude than would occur naturally. Muskrats can become frozen in their winter dens during mid-winter drawdowns. In the spring, loon-nesting areas can become accessible to predators when ponds are drawn or flooded if the pond is raised. The aquatic ecosystem in the littoral zone cannot become well established. Recreational use, such as ice fishing and boating, can be negatively affected.

Artificial flow regulation

The operation of hydroelectric facilities often results in the artificial regulation of stream flows downstream of a dam. This regulation changes the flow regime differently in two reaches of the river--in the bypass and downstream of the bypass. Stream flows are diverted through an intake structure at the dam into a penstock which directs these flows to the project's powerhouse, where flows are released back into the stream. In most cases, these bypassed reaches of stream are completely or partially dewatered during the majority of the year. The reaches bypassed may range from a very short distance to several miles. For example, the Harriman Dam Project on the Deerfield River bypasses 4.5 miles of stream, the longest bypass in Vermont.

Certain projects operate to maximize power generation during periods of peak power demand. These facilities operate in a store-and-release mode, impounding water during periods of low demand and discharging during periods of generation. These peaking projects can result in "feast or famine" flow conditions downstream of the bypass--unnaturally high flows when generating from storage and unnaturally low flows when shut down and only passing leakage through the dam or flashboards. This leakage flow may be the only available flow in a stream for several minutes or even hours while the impoundment refills, and many miles of stream can be affected. During periods of impounding at the Cavendish Hydroelectric Project on the Black River, about 11 miles of stream below the project are impacted as a result of reduced stream flows. This scale of impact is not untypical in Vermont.

Similarly, storage reservoirs and natural lakes used for storage also regulate downstream flows by storing and releasing flows for downstream generating facilities. However, a seasonal cycle is often employed where storage is replenished only during spring runoff or other periods of unusually high flows. Because of the greater storage volumes involved, the periods of artificially low flows can be several weeks in duration.

In contrast with peaking facilities, true run-of-the-river projects are ones which do not operate out of storage and, therefore, do not artificially regulate natural flows below the powerhouse. Outflow from the project is maintained equal to inflow to the impoundment on an instantaneous basis.

Projects may also be categorized as essentially run-of-the-river. The Department considers a project "essentially run-of-the-river" if it does not use substantial storage, does not cause flows to fluctuate significantly, and at all times releases adequate minimum flows. Project outflow in such cases is substantially equal to project inflow.

Artificial regulation of natural stream flows can be devastating to a stream and its uses and values:

- Aesthetics and natural areas values. The aesthetics of a stream may be severely impaired when flows are diverted through a penstock or drastically reduced below a powerhouse during impounding. Often dams are constructed at the top of a cascade or waterfall to provide the head. These natural features are then bypassed by the project's penstock. Much of the aesthetic beauty of these features is lost as a result. For example, the dam for the Carvers Falls Project on the Poultney River in West Haven is constructed at the top of the highest and widest waterfall in the State. For most of the year, the only flow maintained over this falls is the small amount leaking through the dam and flashboards.

- Recreational use. Fluctuating flows below a project impair the recreational use of the affected stream section as well. Generation flows may be too high and impounding flows too low for people to enjoy the stream for recreational activities such as canoeing and whitewater kayaking, fishing, and swimming. Users often find it difficult if not impossible to predict the flow conditions they are likely to find at the site. Safety can also be a problem, especially when the projects release generation flows after a storage period without adequate warning to downstream recreationalists.

  It should be noted that artificially high generation flows can provide recreational opportunities like whitewater kayaking and canoeing, opportunities which would otherwise not be available.

- Ecological value. The ecology of a stream is also affected by regulated stream flows. As a result of evolutionary processes, many of the life cycle and habitat requirements of aquatic organisms are dependent on the natural seasonal and daily variations of stream flow. If these natural variations are interrupted or altered, the survival of a species can be threatened.

  Spawning by salmonids, for example, involves depositing and fertilizing eggs in stream sections where the appropriate water quality, velocity, and depth requirements are met. Once these eggs are deposited and fertilized in the substrate, they may remain there for a few weeks to four or five months, depending on the species. If, during this period of incubation, natural stream flows are significantly reduced due to operation of a hydroelectric project, freezing or desiccation and consequent destruction of the eggs may occur. If natural stream flows are significantly increased on the other hand, scouring can occur, and the eggs may be dislodged. As a result of either regulated flow condition, a year class of fish may be lost. Even if spawning areas are not dewatered, changes in water velocity and depth that result from flow regulation can make the areas unsuitable for spawning.

Vermont Fish & Wildlife, for example, has found that the construction and operation of the West Charleston Project and the Newport and Newport #11 projects have significantly impaired fisheries of the Clyde River, particularly the famous Memphremagog strain of the landlocked salmon. Substantial fall spawning runs existed until the 1940's when the West Charleston and Newport projects began operating in peaking modes. Extreme water fluctuations resulted in the loss of natural reproduction and decreasing numbers of salmon entering the river to spawn. In addition, further encroachment and the loss of salmon habitat occurred in 1956 with the construction of the Newport #11 diversion dam which eliminated the upper spawning areas as well as creating reduced flows in a substantial portion of the normal river course.

Aside from spawning, flow regulation disrupts a fish's "everyday life". Many fishes, including salmonids, select specific sites in a stream to reside, and may stay at these locations for months or even years. These sites meet specific needs for feeding, hiding, and resting. Unnatural flow fluctuation changes the depth and velocity characteristics of these microhabitats and their suitability for fish, sometimes forcing fish to relocate. The result is increased predation and fewer fish and poorer growth.

- <u>Water quality</u>. Flow regulation and enhanced aquatic plant growth in an impoundment can both contribute to increased dissolved oxygen deficits in a stream. Two different mechanisms are involved. Entrainment of oxygen from the atmosphere is reduced when flows do not spill over the dam and cascade through the high-gradient bypass. Oxygen is consumed by algae and other aquatic plants when they respire. Hydroelectric projects' net effect on these two mechanisms can result in substandard dissolved oxygen levels.

During daylight hours, dissolved oxygen concentrations are often at or above saturation values--plants are producing more oxygen as a product of photosynthesis than they are consuming through respiration. However, during the non-daylight hours, the plants are only consuming oxygen. Daily swings in dissolved oxygen concentrations result with the most severe oxygen depletion occurring just before dawn.

Cycling hydroelectric projects commonly store water during the nighttime hours to meet customer demands during the morning peak usage. This can result in extreme low flows during the critical hours for oxygen depletion. Certain fish and other aquatic biota may be stressed or may be unable to reside in the affected reach of stream.

- <u>Wastewater assimilation</u>. The artificial regulation of stream flows may also affect the capacity of a stream to assimilate wastewater from treatment facilities and lower the stream's quality below the applicable water quality criteria. This capacity is referred to as the "assimilative capacity" of the stream. The water quality criteria are legally applied at a flow referred to as the 7Q10 flow, a statistical flow value representing the consecutive seven day mean low flow with a recurrence interval of ten years. Wastewater treatment plants are designed to comply with the minimum water quality criteria of the Vermont Water Quality Standards whenever the natural stream flow is equal to or greater than this low flow. Flows less than 7Q10 occur naturally, though infrequently, and Water Quality Standards violations may occur under these conditions. Peaking hydroelectric projects on streams that receive effluent from wastewater treatment plants are known to cause substandard D.O. concentrations and reduce the streams' assimilative capacity.

The Lower Winooski River receives waste loads from six municipal wastewater treatment plants and one industrial discharge. Green Mountain Power's (GMP) Essex #19 and Gorge #18 hydroelectric projects on the Lower Winooski in Essex and Winooski historically regulated flows to much less than the 7Q10 flow of 167 cfs. From 1977 to 1979, the Department conducted a wasteload allocation study on the Lower Winooski River, the results of which are published in two reports - Lower Winooski River Wasteload Allocation Study - Part A: Report of Data, December, 1980; and Lower Winooski River Wasteload Allocation Study - Part B: Mathematical Modeling Report, January, 1982.

According to the results of a flow sensitivity analysis presented in this study, violations of D.O. standards can be expected to occur in the Lower Winooski at stream flows less than 142 cfs, under conditions of high instream temperatures, treatment plants at projected design discharges and full reaeration of the river flow over the two GMP dams. The two hydro facilities reduced downstream flows to about 70 cfs during periods of impounding, and this resulted in standards violations at present waste loadings. (During the summer of 1987, GMP modified their operation at these two facilities to release 167 cfs as a minimum flow.)

ASSESSMENT AND MITIGATION TECHNIQUES

At the time many of the 62 existing projects were developed, knowledge of their potential environmental impacts was limited. It follows that few if any measures were taken to mitigate these impacts. Today we are better able to anticipate or project likely adverse impacts and to plan and implement remedial measures.

Flow management

Perhaps one of the more important developments with respect to mitigating environmental impacts of these projects has been the development of methodologies for determining flow regime requirements below projects which artificially regulate natural stream flows. These methodologies can be applied by both developers and regulators to determine how to manage flows below projects in order to protect downstream fisheries, water quality, recreation, and aesthetics. The State of Vermont, for example, has developed the Fishery Flow Needs Assessment Methodology (FFNA) as a tool to determine minimum stream flow requirements to support aquatic communities below projects which regulate natural flows. This methodology was applied at eight of the 62 sites studied and is described in greater detail in Section 3, pages 2-4.

The U.S. Fish and Wildlife Service (USFWS) National Ecology Center in Colorado pioneered a methodology considered the state of the art in flow studies--the Instream Flow Incremental Methodology (IFIM). IFIM requires intensive field data collection, computer modelling and analytical efforts, and as a result, is relatively expensive to apply. The FFNA was derived in large part from IFIM. IFIM has been utilized at four sites in Vermont (three operating and one proposed).

In 1980, the USFWS Region 5 office promolgated the USFWS Flow Recommendation Policy for the New England Area to encourage natural stream flows and perpetuate indigenous aquatic organisms in streams where natural flows are artificially regulated. This policy uses the estimated monthly median flow for months critical to resident species as a standard--0.5 cfs/sq. mi. for the summer period and 4.0 cfs/sq. mi. and 1.0 cfs/sq. mi. for the spring and fall spawning and incubation periods, respectively. It is simple to apply since it is hydrologically based and no field work is necessary.

Complementing the capability to determine flow standards is the present availability of technologically advanced hardware that can be installed at hydroelectric projects to continuously monitor and control plant operation. Solid-state level sensors can precisely measure changes in reservoir elevation and relay this information back to computers in the powerhouse. The computers in turn can react by adjusting turbine gate settings to maintain the pond at a constant level, guarantying run-of-river operation. At unmanned facilities the computers can also be interrogated remotely by the utility, allowing personnel to check station performance.

Water quality

Assessment techniques have also been developed to model water quality and provide a means of predicting the effect a particular activity will have on river water quality. The models are commonly used in setting effluent standards for wastewater treatment processes and have proved valuable for evaluating development and operation of hydroelectric projects. These models are powerful decision-making tools for water quality management at hydroelectric project sites. They enable the Department to set constraints on project operational characteristics, specify certain spillage flows, and investigate potential water quality improvements which may occur if a dam's height is reduced, a tailrace reaeration structure constructed, an intake modified to encourage mixing or prevent a hypolimnetic withdrawl, or watershed treatment facilities upgraded.

Fish passage

Substantial research has been done in the area of accomodating fish movement through dammed sections of river, both for resident and migratory species. Projects can be modified to provide upstream passage using fish ladders or trap-and-truck operations. In order to reduce turbine mortality and trashrack impingement, intakes and headraces can be screened. Trashracks can be realigned, increased in rack area to reduce approach velocities, and their bar spacing decreased. Downstream movement can be handled through the use of controlled dam spillage near the intake or more sophisticated approaches like floating gulpers, upstream collection systems, and penstock screening systems.

REGULATIONS

Even had people anticipated the impacts of these 62 projects when they were initially being developed, environmental regulations were not available with which to control them. Today, regulations governing this type of development are much more thorough.

Unfortunately, the way many of these projects are operated has changed markedly since they were first developed. Most projects were initially used for base-load power and operated continuously as run-of-the-river facilities. Now they are part of a more diverse mix of power sources and are, therefore, frequently managed to maximize output during peak demand periods by drawing from storage. As a result, the impact on stream ecology and use has become more severe. Had the present operating schemes of many of these projects been instituted originally, historic restrictions on hydroelectric projects may well have been greater. Further, we have to recognize that, in many cases, wastewater discharges had already severely degraded water quality and obviated many recreational uses.

The Federal Power Act of 1920 and its subsequent amendments (reference Section 23(b)) empower the Federal Energy Regulatory Commission (FERC), formerly the Federal Power Commission, to license and regulate hydroelectric projects on navigable waterways and projects not located on a navigable waterway but constructed or modified on or after August 26, 1935 and affecting the interests of interstate or foreign commerce. Generally, in the latter case, authority has only been exerted where post-1935 construction increases the project head, adds generating or water-storage capacity, or otherwise significantly changes the pre-1935 design or operation.

The Federal Power Act pre-empts several state statutory authorities which would normally be applied to river or commercial projects of this magnitude and scope. The Vermont Land Use and Development Law (Act 250), the Dam Statute (Title 10, Chapter 43), and the Stream Alteration Statute (Title 10, Chapter 41) are three important state processes which have been pre-empted by the Federal Power Act. This pre-emption effectively limits the State's role in the decision-making process to one of advising the FERC of the Vermont position or furnishing recommended conditions for the final license. Fortunately, there is one exception--the State's jurisdiction under Section 401 of the Federal Clean Water Act, P.L. 92-500.

Section 401 requires any applicant for a federal license or permit, where that applicant is proposing to construct and operate a facility which may result in a discharge into navigable waters, to obtain a certification that the discharge will comply with Federal and State Water Quality Standards. An applicant must, therefore, demonstrate that the project will not violate certain water quality criteria and will be compatible with the management objectives for a stream's classification. If this demonstration cannot be made, the project cannot be certified and proceed through the federal licensing process. The Department has been delegated the authority to issue and deny water quality certifications.

Projects reviewed under Section 401 must be found to be compatible with a stream's fish habitat designation as either cold water or warm water. The designation provides for the protection and management of fisheries using specific criteria for dissolved oxygen, temperature, and turbidity. General criteria further protect habitat from project-induced changes by limiting changes to flow regime, substrate and nutrients and aquatic plant growth. The general and class-specific water quality criteria are contained in Chapter 3 of the Water Quality Standards. The management objectives for a stream's classification are presented in Table 3.

Certifications are issued with specific conditions regulating project construction and operation. Conditions stipulating minimum flows for the project bypass reaches and downstream are routinely incorporated in the document.

Table 1 identifies the licensing and certification status of the 62 existing projects in Vermont. The overall status breaks down as follows:

- <u>Unlicensed and uncertified</u> <u>26 projects</u>
  Unlicensed projects are those projects not located on navigable waterways and those without post-1935 construction and no involvement in interstate commerce.

- <u>Licensed and uncertified</u> <u>23 projects</u>
  These projects have had no licensing activity subsequent to the passage of the Clean Water Act in 1972 and, therefore, were not subject to Section 401.

- <u>Licensed and certified</u> <u>13 projects</u>
  These are cases where relicensing activity has triggered Section 401.

Of the 62 existing projects, 49 are not regulated by water quality certifications. Each of these uncertified projects will be subject to Section 401 under one of the following circumstances:

1. Unlicensed projects where proposals for modification or expansion are made.

2. Licensed facilities where proposals for modification or expansion are made.

3. Licensed facilities where the license term is ending and the relicensing process is being

Table 3

Management Objectives for Class A, B, and C Waters

	CLASS A	CLASS B	CLASS C
	Shall be managed to achieve and maintain waters with a very high level of quality which is compatible with:	Shall be managed to achieve and maintain a high level of quality which is compatible with:	Shall be managed to achieve and maintain a good level of quality which is compatible with:
VALUES:	High quality waters which have significant ecological value and water quality of a uniformly excellent character.	Water which is of a quality which consistenlty exhibits good aesthetic value and provides high quality habitat for aquatic biota, fish, and wildlife.	Habitat suitable for aquatic biota, fish, and wildlife.
USES:	As a source of public water supply with disinfection when necessary and, when compatible, for the enjoyment of water in its natural condition.	Public water supply with filtration and disinfection; irrigation and other agricultural uses; swimming, and recreation.	Recreational boating and any recreational or other water uses in which contact with the water is minimal and where ingestion of the water is not probable; irrigation of crops not used for human consumption without cooking; and compatible industrial uses.

initiated. Many older licenses were written to expire after fifty years.

The Sheldon Springs Project is an example of a major project which, until recently, was unlicensed, uncertified, and incorporated few, if any, environmental safeguards. Located at a papermill on the Missisquoi River, the project provided power to generate electricity as well as to hydromechanically drive pulp grinders in the mill. For decades, the project was operated in a cycling mode to benefit the process schedule at the mill. During periods of moderate to low natural flows, the 2800 foot bypass often contained essentially no flow. Downstream of the project, flows were fluctuated from high generation flows to drought conditions.

Missisquoi Associates, the new owner, proposed project expansion in 1983. As a result, the project is now licensed and certified with flow requirements both in the bypass and downstream for water quality and fisheries habitat. Missisquoi Associates has also committed to provide spring spawning flow releases for a planned program by Vermont Fish & Wildlife to establish walleyed pike at Highgate Falls. Special whitewater flow releases for kayaking are also to be arranged. Construction of the expanded project commenced in 1986 and is scheduled to be completed in Spring, 1988. This project has demonstrated what opportunities for improved resource management can be achieved through the licensing and certification process when FERC, the State, the owner, and public interest groups like Northern Vermont Canoe Cruisers work cooperatively.

The older licenses for most of the existing projects developed prior to the Clean Water Act do not contain adequate environmental constraints. Instead of including specific flow requirements and other articles for mitigation in the license, FERC deferred the issues by using certain standard license articles. The passage of minimum flows would be required, for example, only after a demonstration of need by the State or the USFWS. Such a standard article is contained in the FERC license for the Cavendish Project:

> "Article 12. Licensee shall consult and cooperate with the United States Department of the Interior and the appropriate State conservation agencies for the purpose of conserving and developing the recreation, fish and wildlife resources of the project area, and shall make such reasonable modifications of project structures and operation, including construction, operation, and maintenance or

arranging for the construction, operation, and maintenance of Facilities, as may be ordered by the Commission upon its own motion or upon recommendation of the Secretary of the Interior or the State of Vermont, after notice, and opportunity for hearing and upon findings that such facilities and modifications are necessary, desirable and consistent with the provisions of the Act."

As is the case with most of these licensed projects, neither the State nor the USFWS has taken advantage of the opportunities for obtaining changes to the projects using this type of article. The primary reason is that the necessary resources have not been allocated to obtain adequate and defensible documentation of the environmental impacts of the project and recommend remedial measures. The Department is presently conducting a detailed environmental assessment of the Cavendish Project and anticipates completion of this study in 1988.

The Department has also found a lack of compliance with license articles and certification conditions to be a major problem with these newly developed projects. This noncompliance can be attributed in most cases to either equipment malfunction, negligence, or ignorance on the part of the project developer or owner.

Developers of almost half of the 41 new projects have been responsible for significant and serious violations of the conditions of the projects' water quality certifications. The majority of these cases have been either violations of flow standards or departures from the Departmentally approved erosion control plans for construction.

In an effort to monitor compliance with minimum-flow requirements at these sites, the Department is considering a streamflow monitoring program. Gages would be required below these projects to monitor flow releases for compliance. Project developers or owners would be responsible for maintaining these gages and providing the flow records to the Department. Such a compliance-monitoring scheme may also be desirable for some of the older existing projects as well.

SECTION 3

STUDY PROCEDURE

This environmental study was a two-phase process. The first phase consisted of the data collection and research. The second phase involved the analysis of the collected data and the development of recommendations.

DATA COLLECTION AND RESEARCH

This study phase was structured into three components and conducted by a study manager and six environmental technicians. The components were:

1. A comprehensive inventory to develop informational files on each project

2. Fisheries habitat studies at sites identified by Vermont Fish and Wildlife as being severely impacted by flow regulation

3. A chemical water quality sampling program

Inventory

In 1982, the Department conducted a thorough inventory of each of the 62 sites. Information was collected in the following areas:

- site identification
- maps, photographs, and sources of information
- hydrology
- site morphometry
- riparian land use
- recreational opportunities
- aesthetics
- water quality
- fisheries

- technical and operational data

- leakage flows

Data was obtained from several sources including Vermont Fish and Wildlife, the former New England River Basin Commission, FERC, the Vermont Public Service Department, the Vermont Public Service Board, the utilities, field investigations, and the Department's own files.

Specific project data was obtained directly from the utilities both through the use of on-site interviews and the use of questionnaires prepared by the study manager. Unfortunately, Vermont's largest utility, Central Vermont Public Service Corporation (CVPSC), did not choose to return the questionnaires. As a result, data relating to many of the CVPSC projects are incomplete or unconfirmed.

During the field visits, leakage flows were measured at the peaking sites when possible. Leakage flow is the rate of discharge of the combined flows passing through openings in the dam, flashboards, intake, gates, and turbines and through the dam foundation materials, when the project is drawn down and not operating. Leakage can be highly variable as it is dependent on the impoundment stage and the physical condition of the civil works and especially the flashboards. Therefore, the measurements made by the Department are not necessarily the lowest artificially imposed flows below the sites.

The original inventories have been updated to incorporate information from an Agency study entitled "The Waterfalls, Cascades and Gorges of Vermont" (September 1985). This study, hereinafter referred to as the "Waterfalls, Cascades and Gorges Study", was conducted in an effort to identify and prioritize the waterfalls, cascades and gorges of Vermont. Most existing hydroelectric projects were constructed at the site of either a waterfall, cascade or gorge to take advantage of the amount of head these features provide.

<u>Habitat studies</u>

In consultation with Vermont Fish & Wildlife, the Department chose eight sites for application of the Agency's Fishery Flow Needs Assessment Methodology (FFNA) based on current or potential high value for fisheries and the extent of plant impact on flow fluctuations:

1. Essex #19 - Winooski River
2. Middlesex - Winooski River
3. Little River - Little River
4. Pierce Mills - Passumpsic River
5. Wolcott - Lamoille River
6. Weybridge - Otter Creek
7. Beldens - Otter Creek
8. Taftsville - Ottauquechee River

The FFNA enables the Agency to assess fisheries flow needs and formulate streamflow maintenance recommendations. It is designed to measure hydraulic conditions (depths and velocities) in a stream along several transects in each of several stream sections over a range of stabilized flows. Hydraulic conditions are important determinants in biotic productivity and use. Individual fish species have been found to prefer particular depth and velocity characteristics for each life stage and for differing activities.

Sections studied typically encompass riffles, runs, and the heads or tails of pools, all of which are very sensitive to changes in flow. Sections with coarse substrates and fast water often provide essential habitat for various fish species in one or more of their life stages. These sections are also extremely important to benthic productivity.

The collected data are used to quantify the physical amount of bed area suitable for macroinvertebrate production and for the fish species for which the stream is managed. The actual available habitat, or useable area, is estimated at each of the different flows measured using the individual depth and velocity criteria contained in Table 4. The relationship between useable area and flow can then be analyzed in the context of plant operation and recommendations made for refinements in flow management in order to benefit the aquatic resource.

For a detailed discussion of the methodology, reference should be made to the Agency publication entitled "Vermont Streamflow Maintenance Study" (unedited version completed 1981).

Table 4

Depth and Velocity Criteria Employed in the Fishery Flow Needs Assessment Methodology

Computer Index	Habitat Need		Criteria* Depth (ft.)	Criteria* Velocity (ft/sec)
1	Wetted area		0^{+}-INF	0-INF
2	Food production		0.5-3.0	1.0-3.5
3	Rainbow trout	Spawning	0.5-1.4	0.9-2.7
4		Juveniles	0.5-1.5	0.4-2.2
5		Adults	1.4-INF	0.5-2.2
9	Brook trout	Spawning	0.2-1.0	0.1-1.5
6	Brown trout	Spawning	0.3-1.1	0.5-2.5
7		Juveniles	0.4-3.5	0-1.5
12	Atlantic salmon	Spawning	0.3-1.3	0.6-2.4
13		Juveniles	0.6-INF	0.6-2.4
15	Smallmouth bass	Spawning	1.7-INF	0-1.5
18		Fry	2.2-INF	0-0.8
16		Juveniles	1.0-INF	0-0.7
17		Adult	2.8-INF	0-0.8

* "INF", infinity

Water quality sampling program

An intensive water quality sampling program was planned to obtain data at three types of sites:

- Reservoirs. Existing large hydroelectric impoundments were studied for the purpose of refining available predictive water quality models. The refined models were desired for the evaluation of future proposed large-scale projects.

- Daily-peaking projects. Artificial flow regulation at cycling projects during summer low flow and its impact on the downstream oxygen and temperature regime was examined.

- Sequential projects. The effect of several river impoundments in a single reach of stream was studied to determine the impact of multiple projects and minimal reaeration.

Candidates for the reservoir study were screened on the basis of impoundment morphometric characteristics, head, and capacity. This screening produced a list of projects most likely to have significant dissolved oxygen problems due to reservoir volume and residence time. The list was reduced further to include only those reservoirs that were likely to become stratified. Three sites were chosen from this list for sampling:

Chittenden Reservoir - East Creek
Mollys Falls - Mollys Brook, Winooski River
Clarks Falls (Lake Arrowhead) - Lamoille River

Two sites representative of daily peaking operations were chosen for sampling:

Middlesex - Winooski River
Highgate Falls - Missisquoi River

The Lower Otter Creek was selected for sampling as a river system. Five projects, owned by three utility companies, impound most of the reach from Middlebury to Lake Champlain:

Middlebury Lower
Beldens
Huntington Falls
Weybridge
Vergennes

Each of the ten sites was sampled three or four times during the period June to September 1982. Sampling stations were located upstream of the impoundments to determine influent concentrations of chemical and biological parameters; longitudinally through the impoundments; and downstream in the bypassed reaches and below the tailraces. Table 5 lists the parameters sampled at the study sites.

DATA ANALYSIS AND RECOMMENDATION DEVELOPMENT

After completion of the data collection and research, the Department used the information to both develop recommendations for mitigation at individual sites and to perform a statewide assessment of the consistencies and inconsistencies of hydroelectric development with the values and uses protected under Vermont Water Quality Standards.

<u>Individual project site reports</u>

Individual project site reports were compiled from the study files and include the results of the fisheries habitat and water quality components of the study. These reports are in Volume II, and their format and contents are discussed in detail in Section 4 of this volume.

<u>Statewide assessment</u>

In order to complete a cumulative assessment of hydroelectric projects for a statewide perspective, the Department processed the data base taking two directions:

- <u>Categorizing projects as to impact</u>. Each project was subjectively placed in a category of stream impact defined as <u>significant</u>, <u>some</u> or <u>minor</u>. The rating system shown on Table 6 was developed for this purpose. The factors considered by the Department included how significantly a project regulates flows both in its bypass and downstream; the degree of impoundment fluctuation; and the length of the bypass. After rating a project's impact for each factor, a category determination was made of either significant, some, or minor.

Table 5

Water Quality Sampling Parameters

1. Dissolved Oxygen
2. Temperature
3. Total Phosphorus
4. Total Dissolved Phosphorus
5. Ammonia
6. Total Kjeldahl Nitrogen
7. Nitrates/Nitrites
8. Turbidity
9. Chlorophyll a
10. Secchi Disc

Table 6

Rating System to Categorize Projects as Having Significant, Some, or Minor Impacts

Factor	Minor Impact	Some Impact	Significant Impact
Minimum flow (Q_m) released below the project	$Q_m \geq 0.5$ csm	$1.5x(7Q10) < Q_m < 0.5$ csm	$Q_m \leq 1.5x(7Q10)$
Impoundment fluctuation (ΔS) (vertical feet)	$\Delta S < 1'$	$1' \leq \Delta S \leq 3'$	$\Delta S > 3'$
Bypass flow (Q_b)	$Q_b \geq 2.0x(7Q10)$	$7Q10 \leq Q_b < 2.0x(7Q10)$	$Q_b < 7Q10$
Bypass Distance (d)	$d < 100'$	$100' \leq d \leq 500'$	$d > 500'$

In some cases, other criteria have been used in assigning projects to impact categories under this system. For example, a project may operate with a drawdown of greater than three feet but no known or suspected problems are associated with the drawdown. As a result, it would have been rated as having some impact instead of significant impact for the impoundment fluctuation factor. A project which bypasses 400 feet of stream including an important waterfall may be assigned to the significant impact category even though the bypass length factor and other factors in the rating system infer the some impact category.

- Determination of length of Vermont streams with use impairments. The Department estimated the total mileage of streams that do not support, as a result of artificial flow regulation, the designated uses for which they are managed. To accomplish this, the operating mode for each project was reviewed to determine the degree of flow regulation. For those projects with significant flow regulation, the length of the affected reach was estimated based on the distance to large downstream tributaries and other hydroelectric projects.

Judgements were then made for each of the flow-regulating projects as to whether they partially support or do not support the designated water uses. The criteria used are in Table 7, which was obtained from the EPA publication Guidance, 1986 Water Quality Assessments (Section 305(b) Reports). The Department made these estimates from direct observations or using its best professional judgement when the data was limited.

Table 7

Criteria for Evaluating the Support of a Designated Use

SUPPORT OF DESIGNATED USE	BIOLOGICAL/ PHYSICAL INFORMATION	CHEMICAL INFORMATION	DIRECT OBSERVATION/ PROFESSIONAL JUDGEMENT
Waters support designated use Minor/no impairment of uses	Informations show that there is no impairment of the designated aquatic life community (in all respects described on previous page).	Standard is exceeded in 0 - 10% of the analyses and the mean measured value is less than the standard.	Direct observation shows that the designated use is supported, or professional judgement indicates that there is no reason for the use not to be supported.
Waters partially support designated use Moderate - some interference with designated uses	After evaluating information, there is some uncertainty that a balanced aquatic life community is fully supported. For instance, some species may not be able to propagate in the stream, although a put-and-take fishery may exist.	Standard is exceeded in 11 - 25% of the analyses and the mean measured value is less than the standard; or standard is exceeded in 0 - 10% of analyses and mean measured value exceeds the standard.	Direct observation shows that the use exists in the waterbody but professional judgement suggest the use is not supported at a maximum level (e.g. citizen complaints on record, fisherman success rates declining).
Waters do not support designated uses Severe - designated uses are precluded	Data show that the waterbody does not support the designated aquatic community. For example, the aquatic community is definitely imbalanced and or severely stressed; few or none of the expected species exist in the waterbody.	Standard is exceeded in more than 25% of analyses and mean measured value is less than the standard; or standard is exceeded in 11 -24% of analyses and mean measured value exceeds the standard.	Direct observations show overt signs of obvious use impairment (e.g. severe or frequent fish kills), or provide no evidence that the use exists. Professional judgment suggests that the use can not be supported due to known or suspected water quality impacts.
Unknown	Limited or no data are available.	No representative data are available for assessment.	Limited or no background information or direct obs.

SECTION 4

RESULTS AND DISCUSSION

The study resulted in comprehensive project files, the individual site reports and a statewide assessment, which is presented in the second portion of this section of the report.

PROJECT FILES

Comprehensive project files have been developed for each project. These files contain all of the information collected by the Department during the inventory phase of the study as well as the data and analyses from special habitat and water quality assessments. The files are available for review by contacting the Department at:

Agency of Natural Resources
Department of Environmental Conservation
Water Quality Division
103 South Main St.
Waterbury, VT 05676

Telephone (802) 244-6951

Any parties wishing to provide supplemental information for these files are encouraged to do so.

INDIVIDUAL PROJECT SITE REPORTS

Individual project site reports have been developed for inclusion in this study report, Volume II. Basin maps are provided in the second volume as an index for the site locations. The format and content of these site reports are as follows:

BASIN NUMBER: The number of the drainage basin in which the project is located.

STREAM: The stream(s) on which the project is located.

PROJECT: The project name.

UTILITY: The name of the utility which owns the project.

LICENSE STATUS: A summary of the license and Water Quality Certification status for the project.

CLASSIFICATION: The classification of the stream(s) as designated by the Vermont Water Resources Board.

FISH HABITAT DESIGNATION: The fish habitat designation for the stream(s) under Vermont Water Quality Standards--warm water or cold water.

IMPACT: The impact the project has on the water resource using the descriptors <u>significant</u>, <u>some</u>, and <u>minor</u> as defined on page 3-6 in the procedure section of this report.

PROJECT FEATURES: A summary of the major project features such as generating equipment, dam statistics, flashboard height, bypass length, and impoundment size.

OPERATING MODE: A discussion of how the project operates--whether it is a peaking facility, run-of-the-river, or a storage reservoir. Such information as the degree of flow regulation, leakage flows, and drawdown statistics are discussed.

ENVIRONMENTAL REVIEW: A review of the areas of environmental conflict believed to occur at the project site as they pertain to the categories below.

<u>Water Quality</u>: Includes a summary of any water quality data collected at the project site during the study.

<u>Fisheries</u>: Includes the results of the FFNA studies conducted as well as summaries from the fisheries survey questionnaires completed by Vermont Fish & Wildlife.

<u>Recreation/Aesthetics</u>: Summary of any apparent conflicts with recreation and aesthetics, including the need for additional recreational development.

<u>Natural Area/Wildlife Habitat</u>: Discussion of projects constructed at sites included in the Waterfalls, Cascades and Gorges Study, and projects identified as conflicting with loon nesting or wetland habitat.

<u>Erosion/Siltation</u>: Summary of erosion and siltation problems identified at sites.

RECOMMENDATIONS FOR FURTHER STUDY: Recommendations for areas of further study which may help define mitigation needs at the site.

RECOMMENDATIONS: Specific recommendations to mitigate the identified problems. Where appropriate, the Department will be reviewing its recommendations in terms of implementation cost.

STATEWIDE ASSESSMENT

Existing hydroelectric projects affect virtually every component of the river environment--from the river's ecological system to its public use and enjoyment. The data collection effort in 1982 revealed that many of the impacts could be reduced or eliminated through the passage of adequate flows. Without well-planned mitigation schemes for these projects, the beneficial uses and values of Vermont's streams cannot be restored.

The study assessment concentrated on the areas of water quality, fisheries, erosion and siltation, recreational use, aesthetic and natural area values, and wildlife habitat. The projects studied and the areas of apparent environmental conflict for each project are presented in Table 8. Table 9 indicates the number of projects by basin and statewide with conflicts in the environmental areas studied. Figure 2 displays the statewide data using a bar graph.

A discussion of the Department's findings with respect to the several conflict areas and case-specific examples follow. After that discussion, several other components of the statewide assessment are examined: the extent of the direct impact on streams as a result of impounding; the extent of the indirect impact attributed to flow regulation; the total extent of both direct and indirect impacts; and the categorization of individual projects in terms of significance of their impact on the resource.

<u>Areas of Conflict</u>

A. Water Quality

<u>Wastewater assimilation (ASCAP)</u>: Twenty-three (37%) of the sixty-two projects studied affect reaches of stream that receive wastewater discharges and are believed to be reducing the capacity of rivers to assimilate these wastes. The Essex #19 and the Gorge #18 projects located on the Winooski River severely reduced the Lower Winooski's assimilative capacity as discussed earlier on page 2-7.

FIGURE 2
PERCENTAGE OF PROJECTS STUDIED HAVING APPARENT ENVIRONMENTAL CONFLICTS

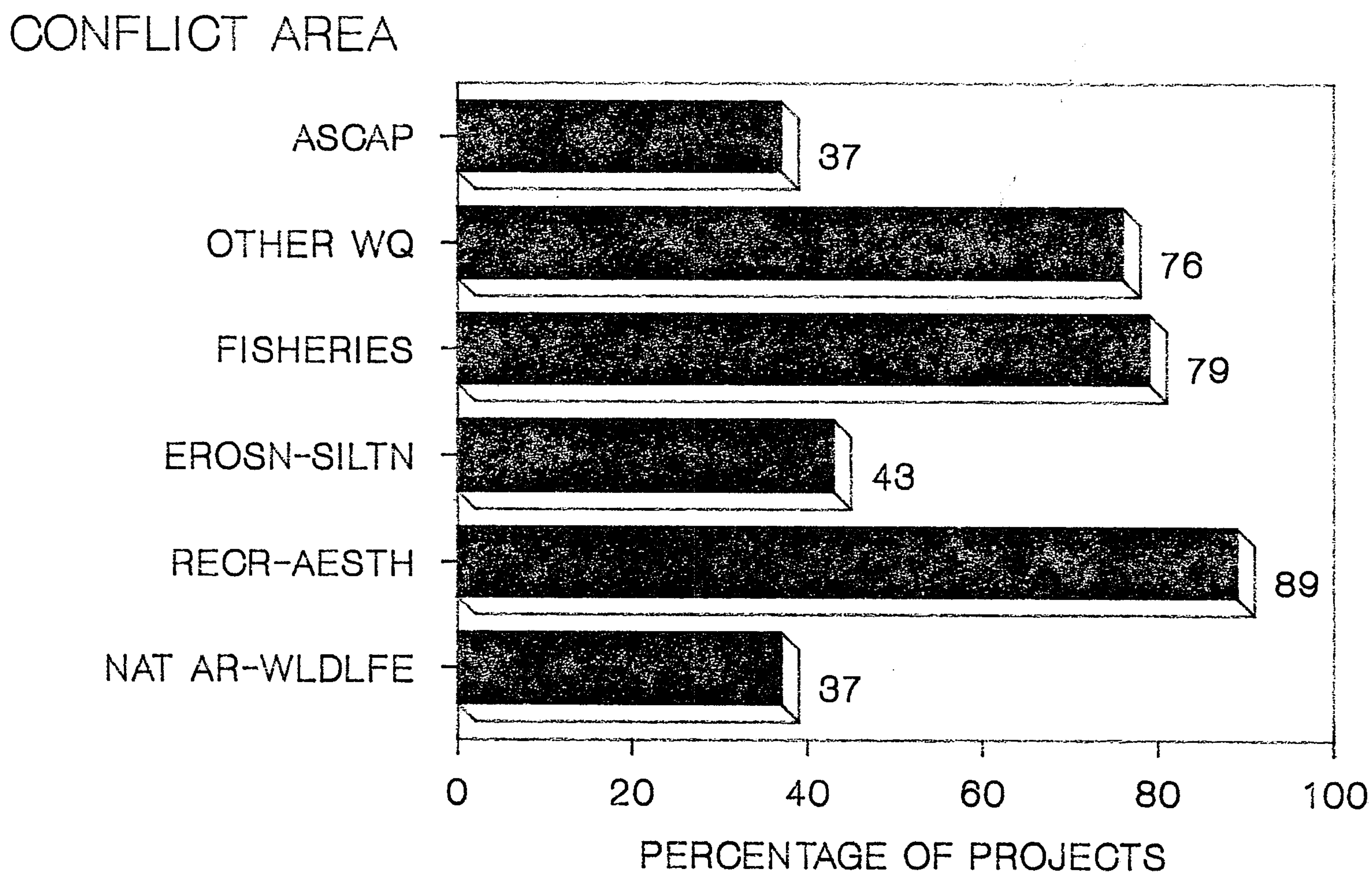


Table 8

Summary of Project Statistics and Apparent Environmental Conflicts

BASIN STREAM	PROJECT	OPERATING MODE[1]	DRAINAGE AREA (SQUARE MILES)	7Q10 (CFS)	LEAKAGE FLOW (CFS)	BYPASS LENGTH (feet)	IMPOUNDMENT LENGTH (feet)	AREAS OF APPARENT ENVIRONMENTAL CONFLICT[2]
BASIN 2								
Poultney River	Carvers Falls	CC	187	9	15-17	500	2100	WQ-O,F,E/S,R/A,NA/WH
BASIN 3								
East Creek	Lefferts Pond	SR	6	0.6	1.8			F
East Creek	Chittenden Reservoir and East Pittsford	DP/SR	17	5	0	21100	8400	WQ-A,WQ-O,F,R/A
East Creek	Glen Dam	DP	44	12	1.3	15800	500	WQ-A,WQ-O,F,E/S,R/A
East Creek	Patch Dam	CC	51				4000	WQ-A,WQ-O,F,E/S,R/A
Otter Creek	Center Rutland	CC	308			100	2500	WQ-A,WQ-O,F,R/A
Otter Creek	Proctor Dam	EROR	363			450	42200	R/A,NA/WH
Lower Otter Creek	Middlebury Lower	CC	630			400	5300	WQ-A,WQ-O,F,E/S,R/A
Lower Otter Creek	Beldens	TROR	632	156	2.3	500	4200	WQ-O,F,E/S,R/A,NA/WH
Lower Otter Creek	Huntington Falls	TROR	749	156	15	300	5300	WQ-O,F,E/S,R/A
Lower Otter Creek	Weybridge	CC	750	187	10		5300	WQ-A,WQ-O,F,E/S,R/A
Lower Otter Creek	Vergennes #9	CC	866			75	31700 - 42200	WQ-A,WQ-O,E/S,R/A
Sucker Brook	Sugar Hill Reservoir	SR	2.5				2000	WQ-O,F,R/A
Sucker Brook/Dutton Brook	Sucker Brook Dam	DD/SR	10.2			7900		F,R/A
Tributary of Sucker Brook & Sucker Brook	Silver Lake Dam	SR	1	0.1	2.1	6400	4800	WQ-O,F,R/A,NA/WH
Leicester River	Lake Dunmore	SNL	20.3				Natural Lake	WQ-O,F,R/A
Leicester River	Salisbury Dam	DP	22			2800	100	WQ-O,F,R/A

1. CC: Cannot Classify
   DP: Daily Peaking
   SNL: Storage Natural Lake
   TROR: True Run-of-River
   SR: Storage Reservoir
   EROR: Essentially Run-of-River
   DD: Diversion Dam

2. WQ-A: Water Quality ACSAP
   WQ-O: Water Quality Other
   F: Fisheries
   E/S: Erosion/Siltation
   R/A: Recreation/Aesthetics
   NA/WH: Natural Area/Wildlife Habitat

Table 8 (continued)

Summary of Project Statistics and Apparent Environmental Conflicts

BASIN STREAM	PROJECT	OPERATING MODE[1]	DRAINAGE AREA (SQUARE MILES)	7Q10 (CFS)	LEAKAGE FLOW (CFS)	BYPASS LENGTH (feet)	IMPOUNDMENT LENGTH (feet)	AREAS OF APPARENT ENVIRONMENTAL CONFLICT[2]
BASIN 6								
Missisquoi River	Bakers Falls	CC	100	16	0.1	250	5300	WQ-A,WQ-O,F,E/S,R/A,NA/WH
Missisquoi River	Enosburg Falls	EROR	585			120	2300	R/A
Missisquoi River	Sheldon Springs	DP	800			4700	18500	R/A,NA/WH
Missisquoi River	Highgate Falls	DP	815	100	35	750	5300(existing) 21100(proposed)	NA/WH
BASIN 7								
Greensboro Brook	Caspian Lake	SNL	8	0.8	7.9		Natural Lake	
Nichols Brook	East Long Pond	SNL	3	0.3	0.1		Natural Lake	F,NA/WH
Nichols Brook	Nichols Pond	SNL	4	0.4	0.1		Natural Lake	F,R/A
Lamoille River	Hardwick Lake	SR	118				10000	WQ-A,WQ-O,F,E/S,R/A,NA/WH
Lamoille River	Wolcott Dam	DP	144	30	0.4	100	5300	WQ-A,WQ-O,F,E/S,R/A
Elmore Pond Brook	Lake Elmore	SNL	7.5				Natural Lake	WQ-O,F
Lamoille River	Morrisville Dam	EROR	222			300	1300	E/S,R/A
Lamoille River	Cadys Falls	EROR	268	61	0.4	1800	7900	E/S,R/A
Tributary of Dark Branch, Gihon River	South Pond Dam	SNL	6				Natural Lake	WQ-O,F,R/A
Lamoille River	Fairfax Falls	CC	529	122	0.8	500	47500	WQ-O,F,R/A,NA/WH
Lamoille River	Clarks Falls	DP/SR	690	160	16	360	21100	WQ-O,F,R/A,NA/WH
Lamoille River	Milton	DP	690	160	3	500-550	1300	WQ-O,F,E/S,R/A,NA/WH
Lamoille River	Peterson	DP	700				13200	WQ-O,F,R/A
BASIN 8								
Sucker Brook	Peacham Pond	SNL	7				9000	WQ-O,F,NA/WH
Mollys Brook and Winooski River	Mollys Falls	DP/SR	23	2.3	0.7 0.8	10600	12900	WQ-A,WQ-O,F,E/S,R/A,NA/WH
Winooski River	Middlesex #2	DP	539	82	7.6	97	10600	WQ-O,E/S,R/A,NA/WH
Little River	Little River #22	DP/SR	110	1.8	11.2	400	31700	WQ-O,F,E/S,R/A
Winooski River	Essex #19	DP	1044	167	55	400	37000	WQ-A,WQ-O,F,R/A,NA/WH
Winooski River	Gorge #18	DP	1047	168	63	150	15800	WQ-A,WQ-O,F,E/S,R/A,NA/WH

Table 8 (continued)

Summary of Project Statistics and Apparent Environmental Conflicts

BASIN STREAM	PROJECT	OPERATING MODE[1]	DRAINAGE AREA (SQUARE MILES)	7Q10 (CFS)	LEAKAGE FLOW (CFS)	BYPASS LENGTH (feet)	IMPOUNDMENT LENGTH (feet)	AREAS OF APPARENT ENVIRONMENTAL CONFLICT[2]
BASIN 10								
Ottauquechee River	Taftsville	CC	200	20	4	50-100	500-600	WQ-A,WQ-O,F,E/S,R/A
Patch Brook	Lake Ninevah	SNL	2				Natural Lake	
Black River	Cavendish	CC	83			1100	600	WQ-A,WQ-O,F,R/A,NA/WH
BASIN 12								
East Branch-Deerfield River	Somerset Reservoir	SR	30				29600	WQ-O,F,R/A,NA/WH
Deerfield River	Searsburg Dam	DP	98			19000	4800	WQ-O,F,E/S,R/A,NA/WH
Deerfield River	Harriman Reservoir	DP/SR	184			23800	47500	WQ-A,WQ-O,F,R/A
BASIN 15								
Passumpsic River	Vail Station	TROR	210			30-40	15800	E/S,R/A
Passumpsic River	Great Falls	TROR	210	42	6.2	200	5800	E/S,R/A
Passumpsic River	Pierce Mills	CC	237			300	200	WQ-A,WQ-O,R,E/S,R/A
Passumpsic River	Arnold Falls	CC	245			100	?	WQ-A,WQ-O,F,R/A
Passumpsic River	Gage	CC	413			90	5300	WQ-A,WQ-O,F,R/A
Passumpsic River	Passumpsic	CC	428	86	14	500	100	WQ-A,WQ-O,F,E/S,R/A
Joes Brook	West Danville	DP/SR	29			2000	Natural Lake	WQ-O,F,R/A
BASIN 17								
Averill Creek	Little Averill	SNL	5	0.5	7.6		Natural Lake	WQ-O,F,R/A,NA/WH
Averill Creek	Great Averill	SNL	12	1.2	13.4		Natural Lake	WQ-O,F,R/A
Coaticook River	Norton Pond	SNL	17				Natural Lake	WQ-O,F,R/A,NA/WH
Tributary of Clyde River	Seymour Lake	SNL	21				Natural Lake	WQ-O,F,R/A
Tributary of Clyde River	Echo Lake	SNL	24				Natural Lake	WQ-O,F,R/A
Clyde River	Pensioner Pond Dam (Barton Village)	DP	108	21	1.4	660	Natural Lake	R/A,NA/WH
Clyde River	West Charleston	DP	109	21	2.8	1700	2640	WQ-A,WQ-O,F,E/S,R/A
Clyde River	Newport #I	DP	140	28	2	2500	5300	WQ-A,WQ-O,F,E/S,R/A
Clyde River	Newport #II	DP	141	28	12.2	2300	5300	WQ-A,WQ-O,F,E/S,R/A

Table 9

Summary of the Number of Projects in Each Basin Having Apparent Environmental Conflicts

		CONFLICTS					
		WATER QUALITY					
BASIN #	TOTAL # PROJECTS	ASCAP	OTHER	FISHERIES	EROSION/ SILTATION	RECREATION/ AESTHETICS	NATURAL AREA/ WILDLIFE HABITAT
2	1		1	1	1	1	1
3	16	7	13	14	7	15	3
6	4	1	1	1	1	3	3
7	13	2	8	10	5	10	5
8	6	3	6	5	4	5	5
10	3	2	2	2	1	2	1
12	3	1	3	3	1	3	2
15	7	4	5	5	4	7	
17	9	3	8	8	3	9	3
TOTAL:	62	23 37%	47 76%	49 79%	27 43%	55 89%	23 37%

Other examples include the Cavendish Project on the Black River; Hardwick Lake and Wolcott Dam on the Lamoille River in the towns of Hardwick and Wolcott, respectively; the Pierce Mills, Arnold Falls, and Gage Projects on the Passumpsic River in St. Johnsbury; and the Passumpsic Project on the Passumpsic River in Barnet. There are municipal wastewater treatment plant discharges on each of these streams, either upstream or downstream of the hydroelectric projects. Based on the data gathered, the Department finds that these projects maintain flows less than 7Q10 during periods of impounding following generation. On the Passumpsic River, the problem is compounded by the number of impoundments which reduce the atmospheric reaeration that would otherwise be available.

Other water quality impacts: Forty-seven of the projects were found or are believed to be causing general water quality problems. The most common problem is the reduction in dissolved oxygen concentrations as a result of several factors related to project design and operation. Operation out of storage during critical summer low-flow periods is significantly reducing spillage and bypass-reach reaeration at many sites. The problem is further confounded by the overall lack of flows to assimilate natural organic loads and to offset oxygen demands from plant respiration. Plant and algal growth is also often enhanced by the impounded condition of the stream.

Dissolved oxygen concentrations were measured at the ten sites included in the intensive sampling program and at several of the other sites. Sampling stations were located both in project impoundments and, in most cases, downstream. Measurements taken during the day often exhibited saturated or supersaturated conditions, indicating significant algal activity. Corresponding low unsaturated dissolved oxygen concentrations would be likely to occur during the nighttime and pre-dawn hours--especially with the lack of spillage and the artificial low-flow releases.

The Weybridge Project on the Otter Creek was one of the sites sampled. Supersaturated conditions were measured above and below the project during the daylight hours. One early morning (0638) dissolved oxygen sample collected below the project measured only 60% of saturation. The Otter Creek at the Weybridge Project is designated as warm water fish habitat. Under the Vermont Water Quality Standards, dissolved concentrations in stream sections designated as warm water are not to be less than 5 mg/l or 60% saturation at all times. The 60% saturation condition measured at

Weybridge was, therefore, just meeting standards. As this was just one random measurement, it is likely that there are periods when the river is substandard.

Dissolved oxygen deficits also occur below projects which have bottom withdrawal structures and impound reservoirs that stratify during the summer months. The oxygen-depleted water in the hypolimnion can be discharged downstream. Chittenden Reservoir on East Creek; Somerset Reservoir on the East Branch of the Deerfield in Stratton and Somerset; the Peterson and Clarks Falls Projects on the Lamoille River in Milton; and Little River #22 on the Little River in Waterbury are examples of facilities where the reservoirs stratify and the plants use bottom withdrawal structures.

Chittenden Reservoir has a maximum depth of 46 feet and a mean depth of 26 feet. The Department measured dissolved oxygen concentrations of less than 1% saturation at a depth of approximately 28 feet. These low dissolved oxygen concentrations are likely to be carried downstream through the discharge from the project's powerhouse. The Department did not collect samples downstream at this site.

The scope of the research-oriented water quality data collection program at the ten planned study sites was found to have been too broad and labor intensive for the human resources available. The data collection effort produced an excellent but limited data base. Although trends have been noted, additional data would be necessary in order to refine reservoir water quality models and to evaluate the effect of sequential projects on the water quality of a stream.

B. Fisheries

Forty-nine (79%) of the projects studied are believed to be impairing the fishery for which the streams are managed. The impairment has been attributed primarily to water quality degradation and reduced habitat availability caused by flow regulation. Fish passage obstruction, creation of impoundments, and water level fluctuations in impoundments and natural lakes used for storage have also been identified as impairing fisheries.

Artificial flow regulation: The Department's application of the Fisheries Flow Needs Assessment Methodology (FFNA) at seven of the sites revealed that artificial low flows at these sites are grossly inadequate to support self-reproducing, indigenous fisheries populations of the quality for which the streams are managed. (The FFNA study at Pierces Mill, the eighth site, was not completed.) Table 10 indicates the artificial low flow releases at the seven sites and the minimum flow recommendations from the FFNA studies. The projects are releasing, on the average, only 8% of the needed minimum flow.

A FFNA study was conducted at the Weybridge Project on the Otter Creek. This project provides a good example of how a facility's operating mode can affect a stream's fishery by altering the natural flow regime and how an improved operating mode has the potential for benefiting the resource.

On May 12, 1980, FERC licensed the Weybridge Project, incorporating a specific article in the license requiring the utility to complete a flow needs study within 18 months of the license's date of issuance. Even with this provision, flow negotiations have yet to be completed after eight years. From a special habitat study in 1986, the utility concluded that 100 cfs, or roughly half of 7Q10 would be an adequate minimum flow release--the U.S. Fish and Wildlife Service policy value is 375 cfs.

CVPSC operates the Weybridge Project in a variety of modes depending on stream flow conditions and the utility's needs. During low flow periods, the project generally operates as a peaking facility. While the impoundment is refilled following generation, there is essentially no flow in the Otter Creek immediately below the powerhouse other than leakage which occurs through openings in the limestone bedrock.

Leakage flow, which reaches a maximum of approximately 10 cfs as the impoundment approaches full head, may last for more than 10 hours at a time. This leakage flow represents only five percent of the 7Q10 value of 186 cfs at the site. Compounding the inadequate flow-release problem, on-peak generation on the same dates can result in discharges of up to 1625 cfs, resulting in wide fluctuations in downstream flows.

In a report entitled "Assessment of Fishery Flow Needs on Otter Creek at Weybridge" and dated July 1983, Vermont Fish & Wildlife found that the operation of the Weybridge Project affects the stream area below the project as follows:

- A large area of aquatic habitat is alternately wetted and dewatered daily.

Table 10
Recommended Flows from Fisheries Habitat Studies

BASIN STREAM	PROJECT	TOWN	DRAINAGE AREA (SQUARE MILES)	PROJECT-INDUCED LOW FLOW (CFS)	RECOMMENDED FLOW FROM HABITAT STUDY (CFS)
BASIN 3					
Otter Creek	Weybridge	Weybridge	750	<10	Being negotiated between ANR, CVPSC, and FERC
BASIN 7					
Lamoille River	Wolcott	Wolcott	144	7.4	80
BASIN 8					
Winooski River	Middlesex #2	Middlesex	539	7.6 (Prior to November 1986)	300 - 350 (228 required pursuant to April 16, 1985 agreement between ANR and GMP
Little River	Little River #22	Waterbury	110	3	55
Winooski River	Essex #19	Essex	1044	55 (Prior to August 1, 1987	340 (June to March) 1000 (April 1 to May 31)
BASIN 10					
Ottauquechee River	Taftsville	Woodstock	200	<8	110
BASIN 15					
Passumpsic River	Pierce Mills	St. Johnsbury	237	Not measured	Study incomplete

- Certain channel sections not fully dewatered during leakage flows are isolated from the active channel. Before becoming isolated they undergo a period of reverse-direction flow.

- Water temperatures and dissolved oxygen levels are probably limiting to certain managed species under low-flow conditions, particularly in the isolated pools and at night when algae and other aquatic plants are respiring and consuming oxygen.

- Proliferation of periphyton and abundance and production of macroinvertebrates in riffle and run areas are severely depressed.

- Abundance of managed species is severely depressed or precluded due to daily fluctuations in physical habitat availability.

- Reproduction and recruitment of several important species of forage fish (fallfish, common shiners, creek chubs, and white suckers) is limited by both instability of physical habitat and depressed food production.

- Development of a mixed fishery, including brown trout and rainbow trout originating from downstream drift and/or natural reproduction is limited by a combination of above-mentioned factors related to the prevailing instantaneous flow regime.

In the same report, Vermont Fish & Wildlife concluded an improved flow regime below the project would produce the following desired results:

<u>Physical</u>

- Maintenance of permanently wetted, active channels on all sides of the islands downstream of the dam at Weybridge.

- Many-fold increase in the amount of wetted area in riffle type habitat.

- Reduction of the magnitude of change in discharge between generation flow and leakage flow from over 160 fold to slightly over eight fold.

Biological

- Large increase in development of the periphyton community.

- Large increase in abundance and production of invertebrates, especially rheophilic nymph and larval stages of many insect taxa.

- Large increase in abundance and production of several forage fish species, namely fallfish, creek chubs, common shiners, and white suckers, principally through juvenile stages.

- Improved smallmouth bass spawning success and survival of larval fish.

- More steady distribution, greater abundance, and accelerated growth rates of juvenile and adult smallmouth bass.

- More steady distribution, greater abundance, and accelerated growth rates of northern pike and muskellunge.

- More steady distribution and increased abundance of juvenile and adult brown trout and rainbow trout through downstream dispersion.

- Potential natural reproduction of brown trout and rainbow trout.

Social

- Improved fishing opportunity for smallmouth bass, northern pike, and muskellunge.

- Restored fishery management options, through the provision of habitat suitable for maintenance of a cold water/cool water fishery.

- Increased local opportunity for brown trout and rainbow trout fishing.

- Decreased hazard and more conducive fishing conditions for anglers through the reduction of the magnitude of flow changes.

Flow negotiations are continuing. This case well illustrates the needs, opportunities and difficulties involved with improved flow management.

Fish passage obstruction: None of the existing projects were found to have incorporated special facilities for the downstream movement of salmonids or walleye fry or for upstream passage of migratory species. New projects are typically required to make such provisions, if needed, either upon initial construction or when necessary to meet fisheries management goals at some point in the future. Three of the existing projects are currently making provisions for downstream fish movement: Enosburg Falls, Huntington Falls, and Beldens.

Some projects may accomodate downstream passage by providing adequate spillage and utilizing trashracks with bar spacings, alignment and surface area that would prevent impingement and exclude fish from entering the penstock and being subject to potential turbine mortality. Such favorable conditions would be coincidental as the issue of downstream fish movement has not been posed until relatively recently.

The Clyde River Projects, discussed earlier in Section 2, is an example of how hydroelectric development can impact fisheries both by artificial flow regulation and by interfering with the upstream migration of fish as the dams create physical barriers to this movement. The study inventory did not include a review of sites with regard to the need for fish passage provisions.

Water level fluctuations: Impoundment and lake fluctuations were found to have severely limited fisheries production by decreasing the amount of habitat available for residency and spawning and by reducing the establishment of littoral zone vegetation and fish cover.

Little Averill Lake and Great Averill Lake on Averill Creek in the towns of Averill and Norton are natural lakes used as storage reservoirs for downstream generating facilities on the Coaticook River. Vermont Fish & Wildlife suspects that extreme drawdowns of both lakes from the first part of October to late April reduces the spawning success of lake trout. Vermont Fish & Wildlife has recommended that Coaticook River Water Power Company maintain stable water levels during the period October 1 to April 30.

Creation of impoundments: The data indicate that impoundments change the water quality, thermal regime, substrate composition, and weed and algal productivity in our rivers.

Hardwick Lake, a storage reservoir located on the Lamoille River, is a good example of how the impounding of water and resultant increase in water temperatures can cause a drastic increase in warm water fish populations such as yellow perch, pickerel, and suckers downstream of the impoundment. These fish compete directly with salmonids such as brook, brown, and rainbow trout which are the primary fisheries of the river. Vermont Fish & Wildlife also reports that the fluctuating water levels both in the lake and downstream have contributed to this displacement of salmonids by warm water species.

C. Erosion/Siltation

Twenty-seven (43%) of the projects have been identified as causing or likely to be causing erosion and siltation problems. The problems occur principally in two areas--impoundment shoreline instability due to cycling pond levels and releases of silt during impoundment desilting operations. Another problem, not as well documented in this study, is the potential for streambank and bed erosion caused by high generation flow releases or by increasing the capacity of streams to erode stream channels after passing through an impoundment and becoming clarified. The latter is a recognized river morphologic property known as stream competence.

Shoreline erosion: Reservoir fluctuations due to project operation cause shoreline areas within the zone of fluctuation to become unstable. Certain types of soil are particularly susceptible to the alternate saturating and draining of the soil structure. In natural river and lake systems, the same erosional process may occur; however, there are important differences. In natural systems, the cycles are primarily seasonal, and vegetation is afforded an opportunity to become established, providing a root system that anchors the soils in place. The artificial system often inhibits plant growth, and the cycles are generally much more frequent.

Severe erosion occurs along the shoreline of the Waterbury Reservoir, the impoundment for the Little River #22 Project. Daily reservoir fluctuations are destabilizing the clay embankments. Erosion problems due to water level fluctuations were also identified at Hardwick Lake on the Lamoille River and several other sites.

Siltation: Several projects were identified as having siltation problems. Suspended sediment particles contained in water flowing into an impoundment settle out as the velocities are reduced. This silt accumulates in the impoundment over time. Many projects have wastegates located at the bottom of their dams for the purpose of drawing down the impoundment for repairs and for sluicing silt downstream.

Depending on the amount of silt accumulated behind a dam, the time of year, and the prevailing flows, a silt release through a project's wastegate can be devastating to aquatic life and habitat below. Suspended silt particles can abrade and clog gill membranes causing fish to feed less, to attempt to leave the affected stream reach, or even to die. Silt also resettles on the streambed, filling interstices in gravel and rubble and resulting in the loss of invertebrates, the suffocation of trout embryos, and the blockage of larval trout emergence.

The Department has developed a formal desilting policy which has been forwarded to dam owners but is not always adhered to. The Department also issues desilting orders in accordance with 10 V.S.A. Section 1272. These orders prescribe the exact procedure to be followed by the dam owner in desilting an impoundment. The Department works with the owner in defining a reasonable procedure which will minimize the discharge to State waters.

The Patch Dam Project on East Creek in Rutland has a chronic siltation problem, typical of many projects. Significant silt releases have occurred as a result of maintenance and desilting activities. According to a Vermont Fish & Wildlife memorandum dated December 5, 1979, "A few years ago, a project was undertaken to desilt this impoundment. The problem caused by the silt release downstream can be found even today."

In September of 1980, another silt release occurred below Patch Dam while the dam owner drew down the pond to facilitate making repairs to the dam. The release resulted from a phenomenon known as headcutting, where the river tries to reestablish its original channel by eroding the bed sediments beginning at the dam and proceeding upstream. There was a technical violation of Vermont Water Quality Standards in both East Creek and Otter Creek. Many fish were killed and redeposited sediment blanketed the streambed.

A similar desilting problem occurred at the Wolcott Dam on the Lamoille River in 1982. The owner of the Wolcott Dam proposed to hydraulically dredge the project's impoundment. A lagoon was constructed to contain the dredged material. In October, a substantial volume of the dredge material was released into Lamoille when the lagoon dam failed. To make matters worse, in December additional silt entered the river when the owner opened the wastegate at the dam, thinking that the impoundment could be slowly drained without a silt release. Unsuccessful in this endeavor, he attempted to close the gate. Unfortunately, an object had become lodged in the gate opening, and he was unable to shut the gate before discharging a substantial amount of silt downstream.

<u>Stream channel erosion</u>: Channel erosion can occur at the tailrace transition. Erosion can also occur downstream as the channel is forced to carry a disproportionate ammount of high flow due to peaking. Severe streambank erosion was observed at the outlet of the powerhouse of the Mollys Falls Project on the Winooski River.

D. Recreation/Aesthetics

Fifty-five (89%) of the projects conflict with recreation and stream aesthetic values. The Department found that the primary reason for these conflicts is fluctuating water levels both in project impoundments and downstream.

<u>Boating downstream</u>: Fluctuating flows downstream of projects are resulting in either too much or too little water to satisfy recreation needs for boating. Cycling of flows during the summer period creates the greatest conflict. For example, while conducting studies below the Middlesex #2 Project, the Department witnessed unfortunate canoeists who had become stranded when the project began to impound. Under natural flow conditions, recreational users would normally be able to judge the adequacy of flows ahead of time for their use and be assured that for a reasonable period of time the flow would support their boating. Artificial flow regulation confounds planning such uses.

<u>Fishing</u>: Use of the rivers, lakes and impoundments for sport fishing is generally optimized by natural flow regimes. Fluctuations have been found to be reducing fisheries production, impairing access and use, and endangering fishermen.

One conflict noted is the winter drawdown at the Mollys Falls Project on Mollys Brook. The water level in the reservoir is stable during the summer months but is drawn down up to 39 feet from December through early spring. Vermont Fish & Wildlife has reported that this drawdown creates hazardous ice conditions and that ice fishing on the reservoir would be enhanced if the levels were stabilized during the winter months.

Passive use: Many stream users are there for a more passive recreational use--to relax and enjoy the attractiveness of the river resource and the ecological diversity of the river environment. Flow manipulation and dewatering of falls and gorges has been found to degrade passive use experiences. This type of experience is, in most cases, a part of other recreational uses also--many fishermen enjoy using the rivers and lakes even when unsuccessful in their catch.

The aesthetic value of a stream is a topic often discussed in the context of user experience. Spillage of water over dams, cascades and falls and through gorges is especially important to the experience of a river user. In unaltered streams, the natural dynamics of river flow produce diverse visual and auditory sensory experiences. For much of the year, hydroprojects create a water on / water off condition downstream and a uniform off condition in the bypass. None of the projects studied release water for the express purpose of maintaining aesthetic values.

At Sucker Brook Dam in Salisbury, natural flows are diverted from Sucker Brook into a conduit which carries these flows to Silver Lake, from which a penstock carries flows to a powerhouse that discharges into Sucker Brook just upstream of Lake Dunmore. The Department found that a lack of water in 1.5 miles of Sucker Brook impairs the recreational use of the area, which has a high recreational value as a natural area for bird and wildlife watching. The dewatering of the stream is of particular concern since the site is located within the Green Mountain National Forest, and the affected reach includes the Falls of Lana. The Falls of Lana was considered to be very important by the authors of the Waterfalls, Cascades, and Gorges Study. They describe the site as moderately wild and secluded and much visited by hikers including campers from nearby Branbury State Park.

Swimming: Swimmers below hydroelectric facilities often suffer from too much or too little flow. Natural moderate to low summer flows are usually optimum for bathing use; however, some of the most desirable locations for bathing become essentially stagnant or dewatered during much of the summer. Bypassed sections are particularly adversely affected. Below the powerhouse, generation flow releases can creat a hazardous condition, especially for young and inexperienced swimmers.

General access: Due to potential liability, utilities understandably limit access to the dam sites and often to the associated falls and gorges. This can affect swimming, fishing, and other uses. The dams and access limitations also create lengthy portages. The Patch Dam impoundment, for example, is posted against trespassing.

E. Natural Areas/Wildlife Habitat

Twenty-three (37%) of the projects have been identified as impairing the natural area or wildlife habitat values of a stream. Habitat impairments have been attributed to flow fluctuations in project impoundments. Natural area losses have resulted from several causes:

- bypassing and resultant dewatering of what were once beautiful, free-flowing cascades and waterfalls.

- construction of dams directly on cascades and waterfalls or in gorges, including demolition of portions of these features.

- flooding of gorges.

- intrusion of dams and other project components such as penstocks, powerhouses, and power lines into areas which would otherwise be considered unspoiled natural areas.

<u>Natural areas values</u>: Fifteen (17%) of the 90 natural areas included in the Waterfalls, Cascades and Gorges Study have been impacted by existing hydroelectric projects. In addition, eleven new hydroelectric projects have been developed at sites included in the study, and another eleven have been proposed for development. Up to almost half of the sites studied are or may be altered by hydroelectric development.

Natural areas of this type are important public and ecological assets. Waterfalls, cascades and gorges are also extremely rare. Vermont has roughly 8,000 miles of streams. The authors of the Waterfalls, Cascades and Gorges Study were able to find twenty-two large falls and cascades in Vermont--"large" being those with a vertical drop exceeding twenty feet. That gives us one large waterfall or cascade for every 364 miles of stream. Large gorges (wall height of 40 feet or greater) are even rarer. Sixteen have been identified statewide--one for every 500 miles of stream.

- The Carvers Falls Project was constructed on the largest falls, both in height and width, in

- the state. It is probably the only horseshoe falls in the state. The falls and narrow, deep limestone gorge downstream are frequently dewatered.

- The Mollys Falls Project bypasses one of the two or three highest woodland falls in Vermont. According to the Waterfalls, Cascades and Gorges Study, Mollys Falls is probably the tallest continuous falls of any kind in the state. Before the project was built, it was said that you could hear the roar of the falls more than a mile away. The only water which flows over the falls now is leakage through the dam.

- The Pensioner Pond Project was constructed at the site of the "Great Falls of the Clyde". The dam is located at the top of the falls. Prior to the licensing and certification of the project in 1983-1984, the project's penstock diverted all but leakage flows from the falls. "It is an attractive place... but suffers from low summer flows which dry it out, and the clearing and blasting of the east side to install the penstock. (Which might have been averted if the engineers had been more sensitive to the natural beauty and willing to pay the price of a more indirect line for the penstock.) It must have been a very striking place before it was developed." (Waterfalls, Cascades and Gorges Study). Under the permit requirements for the project, a minimum flow is to be maintained at all times; however, this flow is not adequate to fully restore the natural beauty of the Falls.

<u>Wildlife habitat</u>: Wildlife habitat conflicts are not well documented in this report since limited information was collected during the 1982 inventory. Nevertheless, the Department did identify conflicts at eight of the sites. These conflicts were all related to impoundment water level fluctuations.

Water level fluctuations at five sites threaten the breeding success of loons, a waterfowl species with endangered status in Vermont. These sites are:

- Somerset Reservoir on the East Branch of the Deerfield River in Somerset and Stratton

- Peacham Pond on Sucker Brook in Peacham
- Little Averill Pond on Averill Creek in Averill

- Norton Pond on the Coaticook in Warren Gore

- East Long Pond on Nichols Brook in Woodbury

Loons have been known to nest along the shorelines or on islands at each of these sites in recent years. The loon nesting season normally begins in mid-May and ends in mid-July. Water level fluctuations on the order of six inches and greater during the nesting season have been found to cause loon nesting failure either due to flooding or stranding of the nest. Because loons walk with difficulty on land, stranded nests are virtually inaccessible.

For successful nesting and breeding, water levels must remain stable from early May through July. This allows for loon nest building in May, egg laying, incubation of the eggs, and late renesting. Artificial water level fluctuations must, therefore, be carefully monitored and limited through the nesting season.

Another wildlife habitat conflict was observed at Hardwick Lake. Daily lake drawdowns were exposing peripheral wetlands. A number of adverse wildlife impacts can occur, including the displacement of certain animal and plant species inhabiting the wetlands.

Waterfalls and cascades produce a special microclimate which favors colonization by diverse species of plantlife often including rare, threatened and endangered species. Loss of natural spillage can eliminate specific habitat that allowed the plants to become established and flourish. The botanists involved in the Waterfalls, Cascades and Gorges Study found several hydroelectric sites where rare plants had been discovered in the nineteenth or early twentieth century and had since vanished.

<u>Extent of Direct Impact (Impounded)</u>

The total length of streams (headwaters to mouth) on which the projects are located is 683 miles. Approximately 101 miles of once free-flowing stream are now impounded, directly impacting 15% of the total miles of stream

(Table 11). The most severely impacted river is the Deerfield, with over a third of the river impounded.

Impoundment lengths may range from a few hundred feet to several miles:

- Glen Dam on East Creek at 500 feet
- Pierce Mills on the Passumpsic at 200 feet

- Vergennes Dam on Otter Creek at 9 miles

- Somerset Reservoir on the East Branch of the Deerfield at 6 miles

<u>Extent of Indirect Impact (Bypasses and Downstream)</u>

Of the 683-mile total stream length, an estimated 155 miles of stream, or 23% of the total mileage, are impacted by artificial flow regulation such that use impairment results (Table 12). Half of these regulated river miles do not support their designated water uses, and the remaining half only partially support these uses. Reaches bypassed are extensive in some basins, totalling 25 miles statewide (Table 13). The Passumpsic River is the most severely affected by regulation as the designated uses are not fully supported for over half of the river length.

Determination of Operating Mode

The degree of artificial flow regulation imposed on a stream by a particular project depends on the operating mode of that facility. Peaking projects cause the greatest regulation. True run-of-the-river projects result in virtually no regulation of stream flow, except for bypassed sections of stream when involved.

An example of a peaking project and the degree of stream flow regulation this type of operation may impose on a stream is the Essex #19 Project on the Winooski River. Figure 3 graphically illustrates the degree of flow fluctuation as measured at the U.S.G.S. gage in Essex Junction (#04290500) just below the project for the period July 29 to August 7, 1985. Clearly, the project has had a drastic impact on the natural stream flow regime, cycling between a 1250 cfs generation flow and a 60 cfs leakage flow on a daily basis.

Figure 4 summarizes the number of projects operating in particular operating modes. Fifteen projects were identified as operating in daily peaking modes. Only four

Table 11

Miles of Stream Directly Impacted by Impounding

BASIN #	# PROJECTS	MILES OF STREAM IMPOUNDED	MILES OF STREAM*	% DIRECTLY IMPACTED BY IMPOUNDING
2	1	0.4	40.0	1
3	16	24.7	143.5	17
6	4	9.8	88.0	11
7	13	20.4	97.7	21
8	6	22.0	115.5	19
10	3	0.2	83.5	<1
12	3	15.5	45.0	34
15	7	5.2	43.0	12
17	9	2.5	40.5	6
TOTAL:	62	101	683	15

*Total miles of stream (headwater to mouth) on which the projects are located.

Table 12

Miles of Stream Where Water Uses are Partially Supported or Not Supported as a Result of Artificial Flow Regulation

BASIN #	MILES OF STREAM NOT SUPPORTING WATER USES	MILES OF STREAM PARTIALLY SUPPORTING WATER USES	MILES OF STREAM*	% INDIRECTLY IMPACTED
2	0.1	3	40	8
3	25	2	143.5	19
6	0.1	5	88	6
7	11	11	97.7	22
8	9.3	23	115.5	28
10	6.5	9	83.5	19
12	13	1	45	32
15	8.5	14	43	56
17	3.9	10	40.5	34
TOTAL	77	78	683	23

TOTAL: 155

* Total miles of stream (headwater to mouth) on which projects are located

NOTE: Bypassed stream sections are included in this tabulation.

Table 13

Miles of Stream Bypassed

BASIN #	# PROJECTS	MILES OF STREAM BYPASSED	MILES OF STREAM*	% BYPASSED
2	1	0.1	40.0	<1
3	16	10.6	143.5	7
6	4	1.1	88.0	1
7	13	0.7	97.7	1
8	6	2.1	115.5	2
10	3	0.2	83.5	<1
12	3	8.1	45.0	18
15	7	0.6	43.0	1
17	9	1.3	40.5	3
TOTAL:	62	25	683	4%

*Total miles of stream (headwater to mouth) on which the projects are located.

Figure 3

Winooski River Flow at USGS Gage, Essex Junction, July 29 to August 7, 1975

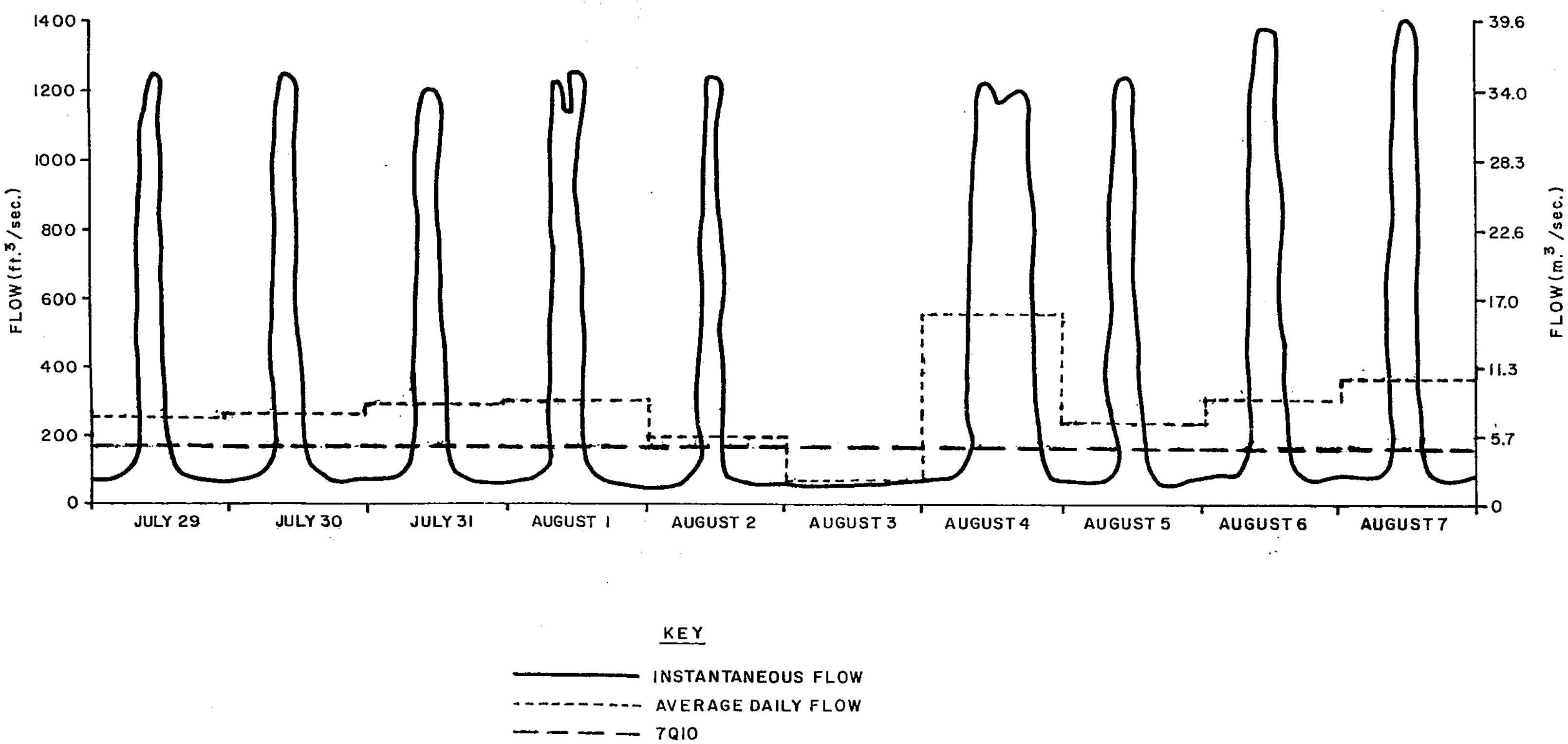
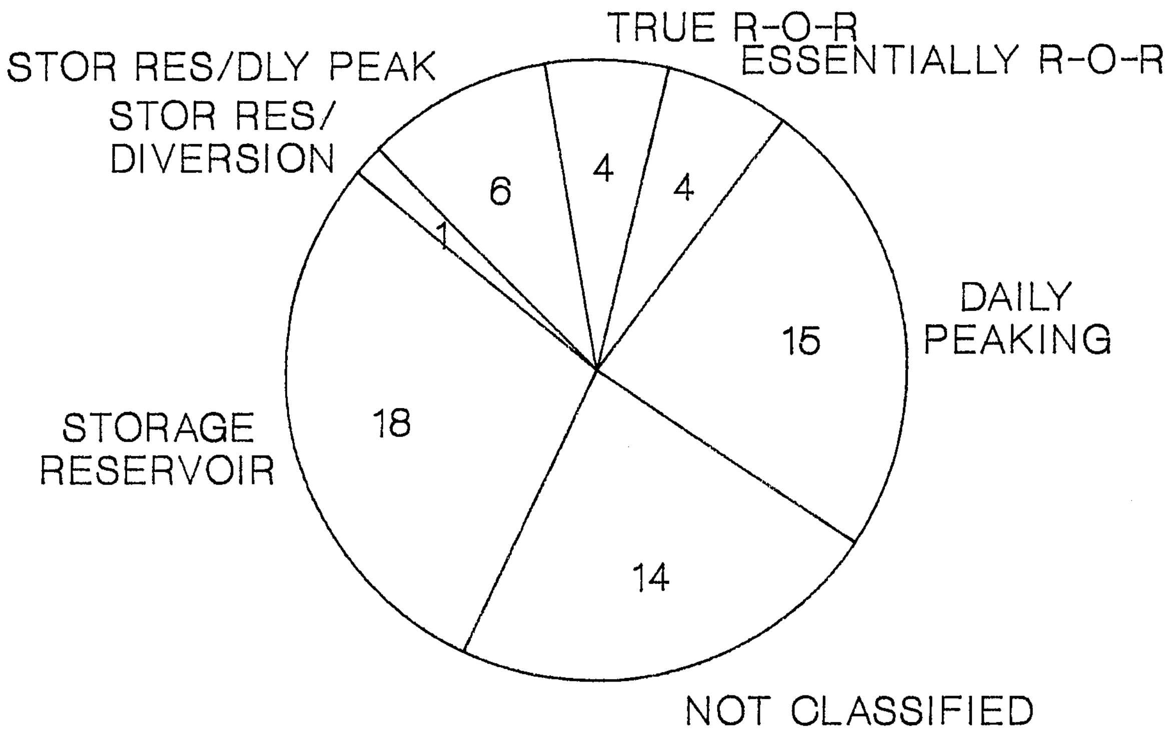


FIGURE 4

PROJECT OPERATING MODES



Values shown are the number of projects.

projects were operating as true run-of-the-river facilities and four as essentially run-of-the-river facilities. These run-of-the-river type operations have all been recently relicensed and issued Water Quality Certifications. Eighteen projects operate as storage facilities, augmenting stream flows for downstream generating plants. Thirteen of these projects are natural lakes and five are storage reservoirs.

Six projects were identified as daily peaking facilities which also operate as storage reservoirs. Another simply operates as a storage reservoir and diversion dam, diverting stream flows from one stream into a conduit which directs these flows to another stream with a downstream generating facility.

The operating mode of 14 projects could not be classified, usually for one of two reasons. Either sufficient information was not available to the Department to enable an identification of the project's operating mode or the project's operating mode varies based on the time of year and flow conditions. The Department was unable to classify the operating mode of many of the CVPSC projects as they did not respond to the Department's utility questionnaire. Frequently, the Department obtained information from the utilities that conflicted with field observations or file data.

Leakage Flow Measurements

Leakage flows were measured at 31 sites (Table 10). About three-quarters of the leakage flows were found to be less than the 7Q10 value for the stream. The majority of the time, leakage flow is all that is available to the bypassed reaches. In many cases, leakage flow is also the only flow downstream of these projects during periods of nongeneration. Leakage flow may be the prevailing flow below a project for up to over 24 hours at a time--note in Figure 6 where only leakage flows existed below the Essex #19 Project for over forty hours from August 2 to August 4, 1975.

The deviation of project leakage below the 7Q10 drought flow statistic is substantial:

- The 7Q10 flow at the Wolcott Dam on the Lamoille River is 30 cfs. The Department measured a leakage flow below the project tailrace of 7.5 cfs--only a quarter of 7Q10.

- At the Taftsville Project on the Ottauquechee River, a leakage flow of less than 8 cfs was measured by the Department in 1982. The 7Q10 value is 20 cfs. Since the 8 cfs measurement was taken, modifications have been made to the dam. These modifications have reduced the leakage flow to 4 cfs, as observed by the Department during the summer of 1985.

Bypasses

The effects of flow regulation are most dramatically apparent in the bypassed reaches. In terms of aquatic productivity, they are relatively sterile compared with similar stream sections containing natural flow regimes. In some cases, the bypasses may be short--a few projects discharge at or near the dam. More often, the reaches are long, up to several miles:

- Sugar Hill Reservoir on Sucker Brook discharges at the dam

- Harriman Reservoir on the Deerfield River discharges 4 miles downstream

- Middlesex #2 on the Winooski River discharges 100 feet downstream

- Sheldon Springs on the Missisquoi River discharges 4750 feet downstream

Bypasses may be either totally or partially dewatered much of the year. The amount of flow in the bypass depends on a number of factors, including dam leakage, tributaries discharging into the reach, natural flows exceeding the capacity of the project, and the operating mode of the project. Except for a leakage flow of about one-third of 7Q10, the Mollys Falls Project in Marshfield dewaters the lower two miles of Mollys Brook. The four mile long bypass for Chittenden Reservoir on East Creek is virtually dewatered, fed only by five minor tributaries.

<u>Summary of Extent of Impact</u>

Table 14 and Figure 5 summarize the number of river miles directly and indirectly impacted by existing hydroelectric projects. Approximately 256 miles, or 37% of the total river miles are impacted by the 62 projects:

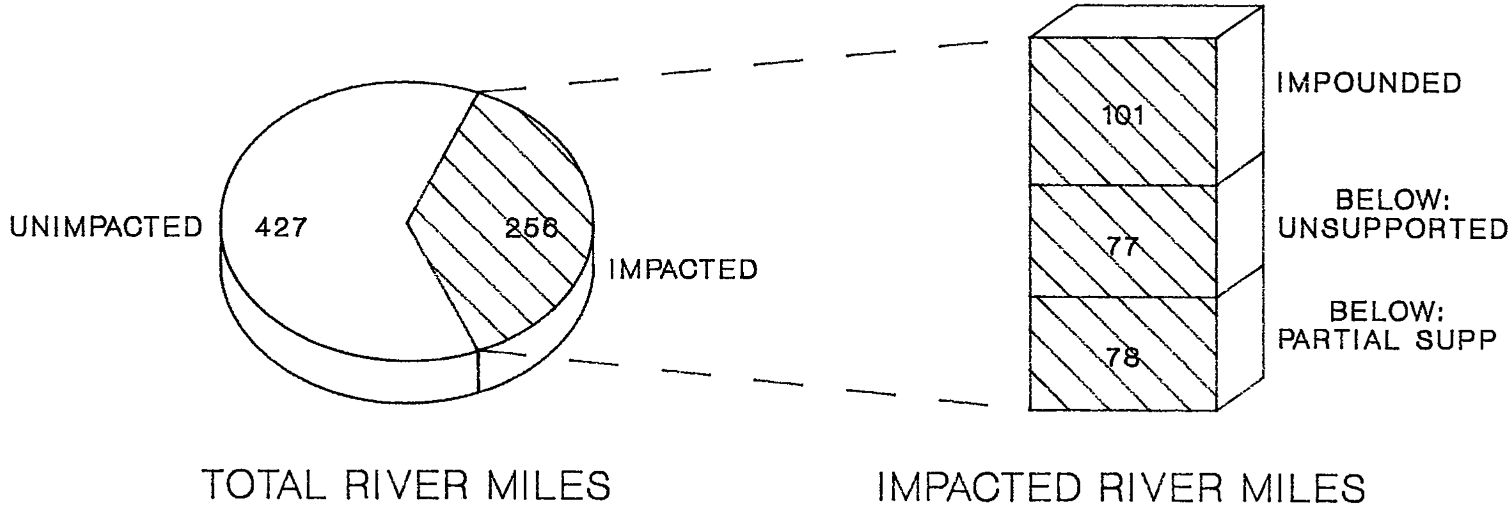
Table 14

Miles of Stream Impounded or Impacted by Artificial Flow Regulation

BASIN #	MILES OF STREAM IMPOUNDED	MILES OF STREAM IMPACTED BY ARTIFICIAL FLOW REGULATION		MILES OF STREAM*	% IMPACTED
		BYPASS	DOWNSTREAM		
2	0.4	0.1	3	40	9
3	24.7	10.6	27	143.5	36
6	9.8	2.2	4	88	17
7	20.4	0.8	21	97.7	43
8	22.0	2.1	30	115.5	47
10	0.2	0.2	16	83.5	19
12	15.5	8.1	6	45	66
15	5.2	0.6	21	43	64
17	2.5	1.3	13	40.5	41
TOTAL:	101	25	130	683	37
	TOTAL:	256			

*Total miles of stream on which projects are located.

FIGURE 5
SUMMARY OF RIVER MILES IMPACTED BY EXISTING HYDROELECTRIC PROJECTS



- 101 miles (40%) are impounded

- 155 miles (60%) are subject to significant flow regulation, with half not supporting their designated uses and half only partially supporting their designated uses

Categorizing Projects as to Impact Significance

An impact rating system was established to categorize each project as to the significance of its overall impact on the environment (Figures 6A and 6B). The intent of setting up this system was both to obtain a perspective on overall statewide impacts and potential benefits from remediation and to help prioritize projects for corrective action.

The categories were significant, some, and minor. The Department first evaluated each project in terms of impacts in the areas of minimum flow releases below the project, impoundment fluctuation, bypass flow regime, and bypass length. Based on that analysis and other relevant factors where appropriate, the Department then categorized the projects as to overall environmental impact. Tables 15-17 list the projects in each category.

Reviewing the results of the analysis for the four impact areas, the majority of the projects were found to significantly impact the resource due to insufficient bypass and downstream flow releases and adverse impoundment level management. Most projects did not fall into the significant category for bypass length impact.

When examining the overall impact, the Department found that 47 projects, about three-quarters of those studied, significantly impacted the environment. Ten (16%) were categorized as having some impact. Five (8%) were categorized as having a minor impact. Figure 7 displays the results of the overall categorization. Examples for each overall categorization follow.

Significant impact: The West Charleston Project on the Clyde River operates in a daily peaking mode with insufficient flow releases to support the downstream biologic community. The project impoundment, Lubber Lake, fluctuates in excess of five feet, causing shoreline erosion, creating a "bathtub ring", and conflicting with recreational use. The bypass is 1650 feet long and receives a leakage flow of only 2.8 cfs, or 14% of 7Q10. During impounding periods, leakage is essentially all that is

FIGURE 6A
RESULTS OF RATING SYSTEM TO CATEGORIZE PROJECTS AS TO OVERALL IMPACT

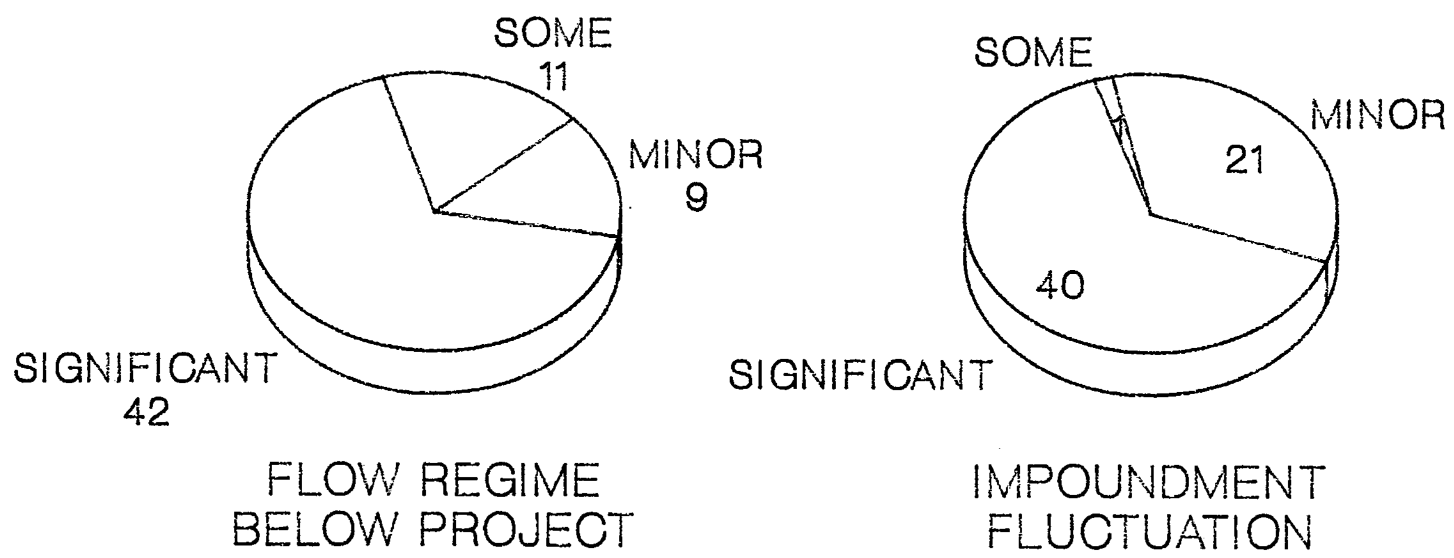
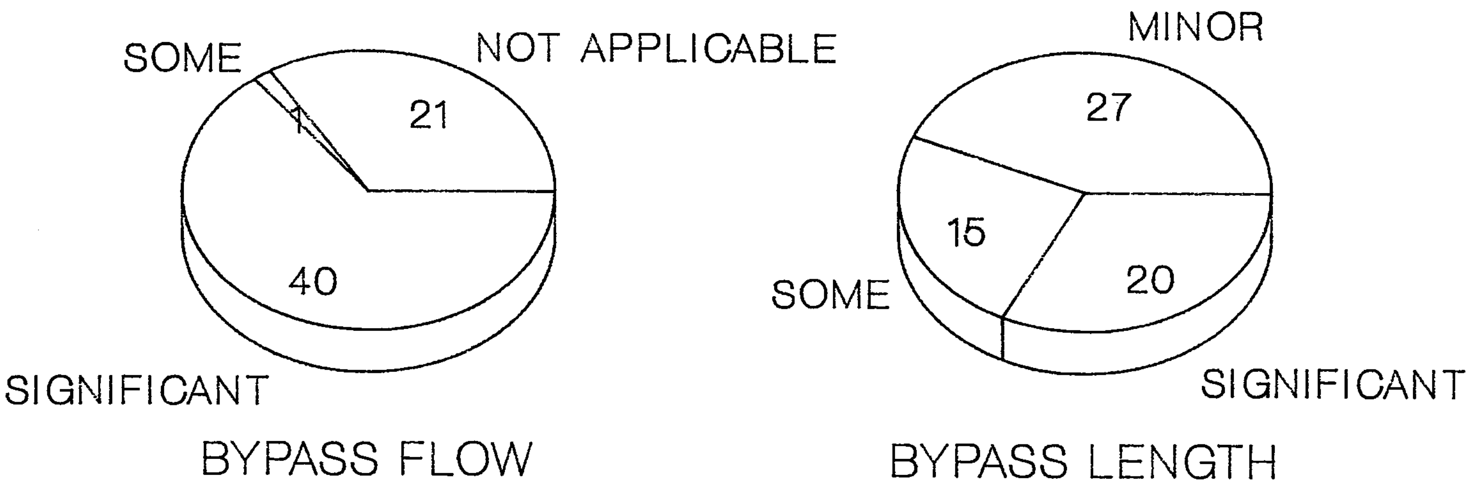


FIGURE 6B
RESULTS OF RATING SYSTEM TO CATEGORIZE PROJECTS AS TO OVERALL IMPACT



Bypass flows are not an issue where generating facilities are at dam.

Table 15

Projects Having a Significant Impact

Drainage Basin and Site	Owner/Utility[1]
Basin 2 (Poultney R.)	
Carvers Falls	CVPSC
Basin 3 (Otter Cr., East Cr.)	
Chittenden	CVPSC
Glen	CVPSC
Patch	CVPSC
Center Rutland	VMARCO
Weybridge	CVPSC
Sugar Hill	CVPSC
Sucker Brook	CVPSC
Silver Lake	CVPSC
Lake Dunmore	CVPSC
Salisbury	CVPSC
Basin 6 (Missisquoi R.)	
Bakers Falls	CUC
Sheldon Springs	Missisquoi Associates
Highgate Falls	Village of Swanton
Basin 7 (Lamoille R.)	
Hardwick Lake	Village of Hardwick
Wolcott	Village of Hardwick
East Long Pond	Village of Hardwick
Nichols Pond	Village of Hardwick
Lake Elmore	Village of Morrisville
Cadys Falls	Village of Morrisville
South Pond	CVPSC
Fairfax Falls	CVPSC
Clarks Falls	CVPSC
Milton	CVPSC
Peterson	CVPSC
Basin 8 (Winooski R.)	
Peacham Pond	GMP
Mollys Falls	GMP
Little River #22	GMP
Essex #19	GMP
Gorge #18	GMP

1. CVPSC - Central Vermont Public Service Corporation
   CUC - Citizens Utilities Company
   VMARCO - Vermont Marble Company
   GMP - Green Mountain Power Corporation

Table 15 (continued)

Drainage Basin and Site	Owner/Utility[1]
Basin 10 (Black R., Ottauquechee R.)	
Cavendish	CVPSC
Taftsville	CVPSC
Basin 12 (Deerfield R.)	
Somerset	NEPCo
Searsburg	NEPCo
Harriman	NEPCo
Basin 15 (Passumpsic R.)	
Pierce Mills	CVPSC
Gage	CVPSC
Arnold Falls	CVPSC
Passumpsic	CVPSC
West Danville	GMP
Basin 17 (Coaticook R., Clyde R.)	
Great Averill Lake	CRPCo
Little Averill	CRPCo
Norton Pond	CRPCo
Pensioner Pond (Barton Village)	Village of Barton
West Charleston	CUC
Newport	CUC
Newport #11	CUC

1. GMP - Green Mountain Power Corporation
   CVPSC - Central Vermont Public Service Corporation
   NEPCo - New England Power Company
   CRPCo - Coaticook River Power Company

Table 16

Projects Having Some Impact

Drainage Basin and Site	Owner/Utility[1]
Basin 3 (Otter Cr., East Cr.)	
Proctor	VMARCO
Middlebury Lower	CVPSC
Beldens	VMARCO
Huntington Falls	VMARCO
Vergennes #19	GMP
Basin 7 (Lamoille R.)	
Morrisville	Village of Morrisville
Basin 8 (Winooski R.)	
Middlesex #2	GMP
Basin 15 (Passumpsic R.)	
Great Falls	Village of Lyndonville
Basin 17 (Coaticook R., Clyde R.)	
Seymour Lake	CUC
Echo Lake	CUC

1. GMP - Green Mountain Power Corporation
   CVPSC - Central Vermont Public Service Corporation
   CUC - Citizens Utilities Company
   VMARCO - Vermont Marble Company

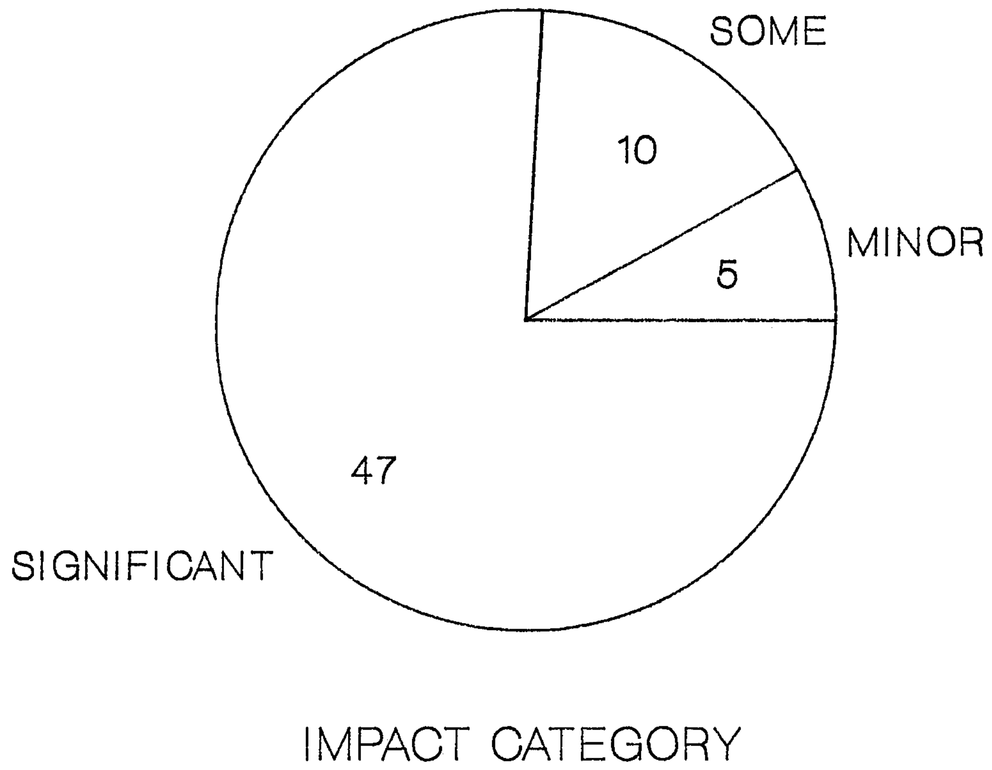
Table 17

Projects Having a Minor Impact

Drainage Basin and Site	Owner/Utility[1]
Basin 3 (Otter Cr., East Cr.)	
Lefferts	CVPSC
Basin 6 (Missisquoi R.)	
Enosburg Falls	Village of Enosburg
Basin 7 (Lamoille R.)	
Caspian Lake	Village of Hardwick
Basin 10 (Black R., Ottauquechee R.)	
Lake Ninevah	CVPSC
Basin 15 (Passumpsic R.)	
Vail	Village of Lyndonville

1. CVPSC - Central Vermont Public Service Corporation

FIGURE 7
NUMBER OF PROJECTS IN EACH CATEGORY OF OVERALL IMPACT



available to maintain downstream uses and values. The fishery is significantly impaired as a result.

Some impact: The Beldens Project on Otter Creek was certified as a run-of-the-river project by the Department in 1986. When operated in conformance with license articles and certification conditions, the project does not significantly modify the downstream flow regime and the impoundment level is held relatively constant. The project, however, does bypass a large waterfall through which the owner maintains a minimum flow of only 5 cfs, which is about 3% of 7Q10. This flow is not adequate to protect the visual qualities of the falls.

Minor impact: The Vail Project on the Passumpsic River in Lyndonville has been certified as an essentially run-of-the-river facility. Although no minimum flow is released at the dam, the bypass length is only 30-40 feet.

SECTION 5

CONCLUSIONS AND RECOMMENDATIONS

Hydroelectric projects are having numerous adverse effects on Vermont's river environments. The most severe impacts are attributable to the artificial regulation of natural stream flow and the consequent lack of adequate flow regimes to support the beneficial values and uses for which the affected waters are managed under the Water Quality Standards. The Department has estimated that about a quarter of the miles of streams upon which these projects are located are having their designated uses impaired by flow regulation--155 miles out of 683 miles. Half of these impaired miles of stream do not support their designated uses, and the other half only partially support their designated uses.

The degree of flow regulation with its resultant use impairment is a significant state environmental problem. This is particularly true when consideration is given to the fact that the regulation is occurring on Vermont's largest and most-used rivers. The Passumpsic River, for example, is Vermont's sixth largest river and passes through the population centers of St. Johnsbury and Lyndonville. As a result of flow regulation, less than half of the river fully supports its designated uses.

The institution of improved project flow regimes more closely resembling natural variations in stream flow would restore to a large degree the impaired uses and values of these affected streams. Adequate minimum flow releases in bypass sections and downstream would bring the majority of projects into compliance with State Water Quality Standards, and tremendous public and environmental benefits would be derived. A careful balancing act will be necessary to assure that both the state's environmental needs and its power needs are met in the process.

Although much emphasis has been placed on flow concerns, there are many other areas of impact where opportunities exist to improve management. In some cases, the costs to the utility would be negligible. Restoring and facilitating public access to the waters at several of the sites would be an important enhancement at slight expense. Provision of fish screening devices at the intake can reduce impingement and turbine mortality. Simple redesign of the trashracks is sufficient in many cases. Following are several of the known areas of adverse impact, observed conflicts and damages, and available approaches for mitigation.

- Impoundment fluctuation: shoreline erosion; recreational conflicts; fish residency and propagation impacts; wildlife habitat impairment including endangered species; aesthetic degradation

  Mitigation: controls or limits on water level fluctuations in impoundments

- Natural areas: defacing or destruction of cascades and waterfalls and flooding of gorges by project development; intrusion of project civil works into natural areas

  Mitigation: restore site after project has served its useful life (possible funding through establishment of an escrow account); relocate, bury or screen certain project features

- Recreational development: lack of development to enhance recreational opportunities; project design or layout preventing or discouraging access to waters

  Mitigation: provision of public access and parking; scenic overlooks; pathways; day use areas with picnic facilities; portages; signs; landscaping

- Fish movement: lack of adequate facilities to provide safe upstream and downstream passage of resident and migratory fish species

  Mitigation: upstream and downstream passage facilities; redesigned trashracks and intake screening systems; screening of headraces

- Water quality: stratified impoundments with hypolimnetic withdrawls of oxygen-deficient water; loss of reaeration at dams and through impounded sections

  Mitigation: installation of reaeration structures; modification of intake structures; dam spillage

- Erosion and sedimentation: streambed and bank scour from high generation flow releases; shoreline slumping and erosion from wave action or cycling; desilting releases

Mitigation: reduce amount and duration of high generation flows; shoreline stabilization or control of levels; proper safeguards when desilting

The Agency is now at a crossroads. The identification of environmental impacts at each of the 62 sites has been completed and measures to mitigate these impacts are being recommended. The next step is to develop a strategy for implementing these recommendations in a timely and manageable manner.

The FERC relicensing process will play a key role in this strategy as just over a quarter of the projects have licenses which expire in 1993. The utilities and their consultants have already begun to file information with the Agency as part of the FERC requirements in the prefiling consultation process. These projects will be subject to the certification under the Clean Water Act as well.

Through this relicensing and certification process, the Agency will require, where necessary, modifications to the design and operation of these projects. Where desireable and feasible, the Agency will seek implementation of the recommended mitigative measures in advance of the completion of the relicensing process. In deciding where first to implement its recommendations, the Agency will consider the magnitude of the impacts identified at a particular site; the relationship of the project to others in the basin; the public benefits to accrue; and administrative and legal capabilities.

In 1987 the state legislature passed into law H.339 - "An Act Relating To Establishing a Comprehensive Rivers Policy". The Act amended 10 V.S.A. s 1003. Conference; Recommendations, empowering the Department to "require action be taken by the person owning the dam with respect to the release of water as it may consider necessary and proper in the public interest..." A conference with the owner and other interested parties would be used to develop the final required actions. Section 1003 may prove to be a valuable tool for obtaining mitigation especially at unlicensed facilities, where federal pre-emption is not a factor. For federally licensed projects, the Act affirms the state's right to petition FERC for license amendments.

Implementation of the recommendations contained in this report will help insure that, to the extent feasible, hydroelectric generation is a compatible use of our water resource. The Department recognizes the importance of hydropower as an energy source for Vermont now and in the future. However the cases of monopoly of use must not continue at the expense of the public use and enjoyment of the waters and the preservation and enhancement of the aquatic community.

The Clean Water Act presents certain benchmarks and goals for the Nation's waters:

1. protect and enhance the quality, character, and usefulness of its surface waters;

2. prevent degradation of high quality waters and prevent, abate, or control all activities harmful to water quality;

3. assure the maintenance of water quality necessary to sustain existing aquatic communities;

4. seek over the long term to upgrade the quality of waters and to reduce the existing risks to water quality;

5. achieve water quality which provides for the protection and propagation of fish and wildlife and provides for recreation in and on the water;

6. restore and maintain the chemical, physical, and biological integrity of the Nation's waters; and

7. to plan the development and use (including restoration, preservation, and enhancement) of land and water resources.

Clearly, these goals will not be met in Vermont without an earnest and well planned effort on the part of both the State and the utilities. Improving the management and use of the resource is perhaps more timely now than ever with today's advanced technologic capabilities; improved environmental assessment and mitigation techniques; more comprehensive regulations at both the state and federal level; and the increased need due to the pressures of economic and population expansion.

A few of the benefits the Department believes will be derived are:

- Recapturing the natural beauty of at least 15 of Vermont's finest waterfalls and cascades.

- Protecting five critical nesting sites for the loon, an endangered waterfowl species.

- Restoring the beneficial uses and values of approximately 155 miles of Vermont streams.

- Provision of safe and effective upstream and downstream passage of fish at many sites for both resident and migratory species.

- Development of improved public access and recreational opportunities at a majority of sites to enhance public use and enjoyment of their waters.

- Improvement of portage routes at all projects where needed to facilitate public boating on our river corridors.

After a series of statewide public hearings and exhaustive research, the Governor's Commission on Vermont's Future found in its publication Report on the Governor's Commission on Vermont's Future: Guidelines for Growth (January 1988):

> "Outdoor recreation is important to Vermont's economy and its residents. People are attracted to our pristine trout streams, our free-running rivers, our wilderness lakes and ponds and the magnificence of Lake Champlain. The value of these resources must continue to be strongly protected in the planning and regulatory process."