

**Instream Flow Studies and Water Management Plan
for the
Lamprey River Designated Reach**

by

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University of Massachusetts
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Table of Contents

List of Figures..... ii

I. Specialized Experience of the Project Team..... 1

II. Project Personnel..... 7

III. Project Approach..... 10

Protected Instream Flow Study

Background..... 10

1. Identification and Draft List of IPUOCR Entities..... 11

2. Assessment of Well Withdrawal Impacts on Surface Water... 13

3. On-Stream Survey for IPUOCR Entities..... 14

4. Reports Describing IPUOCR Entities and Proposed

PISF Methods..... 17

5. PISF Assessments and Proposed PISF Report..... 25

Selection of models..... 25

Wetland model..... 28

Impoundments..... 30

Development of PISF Recommendations..... 31

6. PISF Public Hearing..... 35

7. PISF Report for the Souhegan River..... 36

8. Assessment of Water Use with the Established PISF..... 36

9. Development of WMP Sub plans..... 37

a. Conservation Plan..... 41

b. Water Use Plan..... 42

c. Dam Management Plan..... 43

10. Proposed WMP..... 43

11. WMP Public Hearing..... 44

12. Water Management Plan for the Souhegan River..... 44

IV. Proposed Project Performance Schedule..... 45

V. Confidentiality Statements..... 46

VI. Conflict Of Interest Statements..... 46

VII. References.....	46
Appendix A Project Experience Descriptions.....	50
Appendix B Personnel Resumes.....	67
Appendix C Surveys and User Profiles.....	102
Well Information Questionnaire.....	103
Questionnaire for Souhegan River Affected Water Users.....	105
Generic Water User Profile.....	109
Consent Form.....	111

List of Figures

Figure 1. Project Personnel Organization Chart.....	9
Figure 2. In the two figures 1:12,000-scale, 1-meter resolution, black & white digital orthophotoquads taken April 11th 1998 and obtained from GRANIT and the US Geological Survey are compared to the increased resolution of our newly acquired high-resolution digital aerials photographed in fall 2004. One figure shows a portion of site 2 on the Souhegan River and the other shows a section of the Lamprey River along Route 152 and Campground Road.....	15
Figure 3. Schematics of proposed data collection.	16
Figure 4. (left to right) 1. Black and white aerial imagery, 2. An initial segmentation, 3. Iterations of the algorithm. 4. A “perfect” hand generated segmentation.....	27
Figure 5. Using aerial data and field surveys to delineate wetland vegetation (symbols in the legend refer to primary and secondary vegetation type). This method has been applied to evaluate wetland alteration as a consequence of the potential removal of Hatfield Dam on the Mill River in western Massachusetts.....	30
Figure 6. Results of scuba investigation of one impoundment on the Souhegan River	31
Figure 7. CUT curves from habitat time series (source: Capra et al., 1995).....	33
Figure 8. Continuous Under Threshold duration (CUT) curves for adult resident fish in the Quinebaug River during the summer season	34
Figure 9. Synthesis of multiple information sources, stakeholder perspectives, and decision criteria using multi-criteria decision analysis.....	38

List of Tables

Table 1. IHA statistics for the Lamprey and Souhegan Rivers for the period of 1934 to 1976.....	19
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I. Specialized Experience of the Project Team

The project team of the University of New Hampshire, Normandeau Associates, and the University of Massachusetts has worked together in the past and therefore possesses the ability to work in a unified and well-integrated manner to successfully meet project objectives. The team fields experience in: field data collection and computer simulation of instream flow and habitat relationships, water resources management strategies, involvement of the public and stakeholders during the performance of technical projects, state and federal permitting, stream restoration, hydrologic field methods and simulation, and biologic characterization of aquatic systems. The team is highly qualified to perform all aspects of the Lamprey River Instream Flow Study and Water Management Plan. Brief descriptions of relevant past projects of team members are found in the following paragraphs. More detailed descriptions of these projects appear in Appendix A.

Protected Instream Flow Studies and Water Management Plan for the Souhegan River Designated Reach: The project team is presently performing the instream flow study for the Souhegan River designated reach. Tasks completed to date include: IPUOCR delineation, on-stream IPUOCR survey, and the report describing IPUOCR entities and proposed PISF methods. Soon to be completed will be the assessment of groundwater withdrawals. Tasks in progress include: PISF assessments and proposed PISF report, development of WMP sub-plans, and stakeholder/public engagement. Input is being continually solicited from Affected Water Users (AWU's) and Affected Dam Owners (ADO's) and is viewed as critical to the success of the project. The Souhegan project tasks are very similar to the tasks required of the Lamprey River Instream Flow Study and Water Management Plan although we recognize that different methods may be employed on the Lamprey, if, and when, appropriate.

Minimum Flows and Levels for the lower Suwannee River, Florida: This instream flow plan addressed Florida Statutes, requiring that minimum surface water flows be set for water courses based on the premise that “the minimum flow for a given water course shall be the limit at which further withdrawals would be significantly harmful to the water resources or ecology of the area.” Through a series of projects, this multidisciplinary study created a framework to link flow regimes with ecological indices in the development of minimum flows and levels for the lower Suwannee River basin in Florida. The statistically robust framework identifies the volume and timing of water available for consumptive use while sustaining ecosystem integrity. Using HEC-RAS and MODFLOW models, recent studies have accounted for the impact of spatially distributed withdrawals on downstream ecosystems.

Ecohydrology Study on the Quinebaug River: The ecohydrology study on the Quinebaug River in Massachusetts and Connecticut evaluated the assessment of the river's bio-physical conditions, the identification of ecological water deficits, and the determination of potential improvement measures including determination of protected instream flows and potential flow augmentation methods. This was part of a multidisciplinary investigation required by the US Army Corps of Engineers Section 404 permit and by the Massachusetts Department of Environmental Protection Section 401 Water Quality Certification for the Millennium Power Project in Charlton, Massachusetts. The results of the study provided a basis for future decision-making processes and for the design of a long-term implementation plan.

Eightmile River Instream Flow Study: In 2001, Congress authorized a Wild and Scenic River Study for the Eightmile River, a tributary of the lower Connecticut River. In the study area, the Eightmile River is a second to fourth order river with the unusual characteristic of being largely undeveloped in a densely populated area of the country. It is rare for a watershed in coastal Connecticut to remain so highly forested, with few point and nonpoint pollutant discharge sources. Its baseline condition may serve as a benchmark for other rivers in the state. The Northeast Instream Habitat Program (NEIHP) sampled a variety of stream types including the main and East Branch of the Eightmile as well as the smaller headwater streams. The first phase of the project identified a number of outstanding characteristics of the Eightmile together with some detrimental characteristics, of which lack of large woody debris and high water temperature have the strongest influence on the fish and mussel fauna. Presently the project is in the habitat modeling phase that will provide tools for protection and management of the Eightmile River.

Developing a Sustainable Management Plan for the Pomperaug River Watershed: Because of its relatively high ecological integrity, the Pomperaug River serves as a model of a recovered river ecosystem that could be used as a reference river for other river systems in the region. However, rapid population growth in the region and higher per capita water use has caused an increase in water demand, putting considerable pressure on the Pomperaug aquifer. Thus, the growing water demand could jeopardize the quality of the Pomperaug ecosystem.

This pilot project (performed in collaboration with the local USGS) covered the concept development and the first stage of the habitat component of the comprehensive study of the river ecosystem. A watershed-wide instream habitat survey was conducted in order to develop a quantitative instream habitat model. This model provided a general overview of available fish habitat. Recently the Connecticut Senate allocated additional funding to continue the study.

Measuring River Ecosystem Health in Western Massachusetts: This study investigated the availability of suitable habitat for dwarf wedgemussel during low flow conditions. The primary tools used for this effort were the MesoHABSIM habitat simulation model and the target fish community developed specifically for the Mill River.

Feasibility Study of the Removal of Hatfield Dam (Mill River, Hatfield, MA): This project investigates the ecological benefits of the potential removal of a 300 year old dam on a tributary of the Connecticut River. Unique fish and mussel fauna as well as considerable wetland area could be impacted by dam removal. The project includes cost benefit analysis, engineering, hydraulic, hydrologic (surface and groundwater), as well as biological simulation components.

Fish Habitat Assessment on Stony Clove Creek, NY Using MesoHABSIM: From a physical standpoint, the Stony Clove Creek faces river management problems due to historic hydrologic alterations, impaired aquatic fauna and fisheries, and dramatic seasonal fluctuations in flow. The New York City Department of Environmental Protection (DEP), in partnership with the Greene County Soil and Water Conservation Districts, is restoring stream channel stability in priority sub-basins in order to improve water quality in city reservoirs. This study was therefore prompted by the need to develop a comprehensive, multi-objective Stream Management Plan.

Instream habitat evaluation of Santee River below Santee Dam, SC: This instream habitat evaluation study is developing a quantitative relationship between dam releases and spills and habitat composition in a 37 mile study reach of the Santee River. The study assesses the condition of the river habitat and will suggest methods for the protection, mitigation or enhancement of habitat via river flows. Study suggestions for flow regime management will be evaluated by FERC, federal, and state agencies and other watershed stakeholders to satisfy all interests in the river.

Merrimack River Watershed Assessment Study: This study is developing a watershed management plan that will guide investments to achieve conditions that support feasible beneficial uses. This will be accomplished by conducting a water resources and ecosystem restoration investigation of the Merrimack River.

Aziscohos Dam Minimum Flow Study: Computer simulation procedures of flow/habitat relationships within the Instream Flow Incremental Methodology (IFIM) were used to quantify the amount of habitat available for brook trout and landlocked Atlantic salmon over a range of alternative stream flows in the tailrace and bypass area for a proposed hydroelectric station. Habitat suitability curves were developed for landlocked salmon in cooperation with the Maine Department of Inland Fisheries and Wildlife. In addition, Habitat Evaluation Procedures (HEP), developed by the U.S. Fish and Wildlife Service, were used to determine the amount of habitat for the evaluation species in the bypass reach and in a compensation area. This was done to assist in the development of a plan to mitigate for losses in habitat associated with the project.

Farmington River IFIM: Instream flow needs for fisheries within the Connecticut section of the West Branch and mainstem of the Farmington River were assessed using the Instream Flow Incremental Methodology (IFIM). The effects of alternate flows on recreational opportunities and aesthetics were assessed based on: 1) a user survey of recreationists on the river during spring, summer, and fall, 2) a field evaluation of recreational conditions conducted by experts and local volunteers, and 3) an evaluation of how scenic conditions are affected by flows based on videotapes and panel review.

Snowmaking Needs vs. Headwater Instream Flow Requirements: Diversion of water from small, headwater streams for snowmaking purposes has resulted in serious concerns by state and federal fisheries and wildlife officials regarding potential impacts to aquatic biota. This project required the evaluation of minimum flows to sustain native coldwater fisheries in small headwater streams, negotiations with state fisheries and wildlife biologists, and presentation of expert testimony at Vermont Act 250 hearings. Winter minimum flows negotiated for two of these projects have yielded minimum flows substantially less than initial agency standards based on summer flow requirements. The third project, which is ongoing, involves the use of the U.S. Fish & Wildlife Service developed Instream Flow Incremental Methodology (IFIM) on Vermont's Ottauquechee River.

A Geographic Information System for Aquatic Resource Characterization and Management in the Upper Ohio River Basin, OH, PA, WV, KY: The study area covered approximately 110 miles of the Ohio, Allegheny, and Monongahela Rivers. The project was a joint venture of the Pennsylvania Department of Environmental Protection (PA DEP), the Pennsylvania Fish and Boat

Commission (PFBC), and the Ohio River Valley Water Sanitation Commission (ORSANCO). The objectives of the project were to: 1) characterize aquatic habitat and develop GIS-based representations of the habitat variables used in classification, and 2) develop and implement GIS-based resource inventory and management applications.

Modeling Instream Habitat and Water Temperature Regimes in Marsh Creek at the Eisenhower National Historic Site, Pennsylvania: Marsh Creek is one of only two permanent streams flowing through the Eisenhower National Historic Site (EISE). The ecological integrity of these streams, and particularly Marsh Creek, has been an ongoing concern of the National Park Service due to development and disturbance of the upper watershed. The largest and most direct threat to Marsh Creek was the issuance of a permit to the Gettysburg Municipal Authority (GMA) to withdraw surface water just upstream from the EISE boundary and augment withdrawals with well water (a novel permit situation within Pennsylvania). Water withdrawal and augmentation could comprise a significant fraction of the total stream flow in Marsh Creek through EISE, altering available habitat quantity or water quality. The proximity of the GMA activity (adjacent and just upstream of EISE), coupled with the relatively short length of stream within the Park boundary, are of great concern because the activity may substantially degrade the ecological integrity of a unique Park resource. To address these ecological concerns instream flow modeling and water temperature monitoring of the stream were employed. A detailed study map of instream habitat units was constructed using a GPS unit with sub-meter accuracy and then plotted using ArcView software which also served as a spatially explicit data library for project samples.

Feasibility of Main Stem Reservoir Developments - Powder River, Wyoming: The project objective was to determine the maximum sustainable water resources development of the Powder River Basin to meet the demands of mining, public supply, irrigation, recreation, and instream flow. The Powder River extends from the Bighorn Mountains eastward to the state boundary with Nebraska and northward to the state line with Montana. The river is characterized by very clear, cold water from the west, and salty, turbid, warm water from the south and east. Hydrologic characterization of the flow regimes on ungaged tributaries and the mainstem were performed by statistical methods reinforced by concurrent flow measurements. Water development strategies considered the effect of both removing fresh water and sediment. A very significant issue on the mainstem was sediment transport and sedimentation in any proposed mainstem dam. Results of this study were recently employed in the assessment of the coal-bed methane extraction in the same watershed.

Legal, Environmental, and Hydrological Consequences of Missouri River Diversions: A very large water withdrawal from the mainstem Missouri River was proposed by a private interest and approved by the federal government. The diversion would take water from the Missouri River at the Oahe Dam in South Dakota and pump it out of the basin to eastern Wyoming where it was to be used for coal slurry, and then pumped to Texas. . The objection by the downstream states to this proposal brought the matter before the US Supreme Court. To support the concerns of the downstream states required: developing long term flow statistics for the river (including flow duration curves and 7Q10), identifying critical stream reaches of habitat adversely affected by the withdrawals, reviewing system-wide reservoir operation strategies and how these strategies would be affected by the diversion, delineating how diversions would

impact existing users, preparation of the hydrology in the context of the governing water law, preparing legal briefs, and supplying deposition testimony.

Hydrogeology of the Spruce Hole Formation: The Spruce Hole formation is a stratified drift aquifer located in Lee and Durham, NH. The formation was under development pressure. The formation also included one of the few remaining undisturbed kettle-hole bogs in New England, and as such, it was classified as a unique ecological area by the US National Park Service and is a registered National Natural Landmark. The primary objectives of the study were: aquifer delineation; determination of the safe ground water yield; evaluation of water quality; location of water supply well(s); wellhead delineation, assessment of the potential for artificial recharge; determination of the baseline vegetation of the bog; and establishing permanent long-term vegetation monitoring plots. The performance of the study included well installation of the following types of wells: production well, monitoring wells, small diameter wells, and miniature piezometers. The small diameter wells and the miniature piezometers were instrumental in clearly delineating the connection between the bog and the aquifer below.

Ground Water Well Supply and Wellhead Delineation, Pembroke, NH: The stratified drift formation along the Soucook River, at the Concord/Pembroke town line, was investigated for its suitability as a water supply source for the town of Pembroke. Monitoring wells and a production well were located and constructed. The production well is within 250 feet of the Soucook River. A pumping test was performed to help identify the well head area as well as to define the fraction of water pumped from the well that was induced to infiltrate from the river. Miniature piezometers were used to assist defining the amount of river water pumped by the production well. This information was then built into the well head delineation.

Interaction of Surface and Ground Water, Fort Wainwright, AK: The large aquifer below Fairbanks AK was being studied with respect to water supply and contamination issues. A large part of this study was the computer simulation of the formation. This computer simulation relied on precipitation and surface water as boundary conditions to drive ground water flow in the aquifer. UNH used small diameter wells and miniature piezometers to determine river bed hydraulic conductivity in the Chena and Tanana Rivers. In addition, the miniature piezometers were used to define the ground water gradients used in the computer model during model calibration.

Movement of Contaminants and the Effects of Ground Water Pumping, Eielson Air Force Base, AK: Large volume ground water wells (> 4,000 gpm) were used for power plant cooling at Eielson AFB. Due to the very high transmissivity of the aquifer at the base (>100,000 ft²/day) the effects of this pumping were far reaching. The base had various sites of ground water contamination, and the movement of contaminants was affected by the ground water pumping. Some contamination was moving towards the base water supply wells. The objective of this project was to study the effects of ground water withdrawals and propose management strategies or water supply options. Part of the performance of this project included the use of miniature piezometers on cooling ponds near to the power plant wells, in order to define the extent of short-circuiting of water from ponds to wells.

The Effects of Cochiti Dam on Sedimentation and Erosion in the Mainstem Rio Grande, New Mexico: The construction and operation of Cochiti Dam created a sink for river-borne sediments. The clear water discharge of the dam resulted in 20 miles of river-bed degradation below the dam, and this degradation was continuing to propagate downstream. Degradation generally resulted in 4 to 10 feet of scour before the river bed would armor. The objective of this project was to model the river bed scour process and to recommend strategies to arrest its progression. To do this, first the system hydrology was developed, then hydraulics, then sediment transport. Since most of the tributaries were ungaged, yet the hydrologic task required the generation of tributary stream flows, on a daily basis, for a 100-year horizon. These tributary hydrograph time series were developed by using aerial weighting schemes, regression relations, stochastic modeling, and concurrent flow data collection.

Assessing Cocheco River Contaminated Sediment Management Alternatives from Multiple Stakeholder Perspectives: This study characterized the priorities of different stakeholder groups in relation to novel contaminated sediment management alternatives. Stakeholder values were elicited in an interview-questionnaire-verification interview format and combined with expert assessments of the performance of the technological alternatives in relation to the decision criteria identified by stakeholders. A multi-criteria decision analysis framework was employed to identify potential conflicts or opportunities for compromise among different stakeholder groups.

II. Project Personnel

To provide the best, scientifically defensible Instream Flow Study (IFS) and Water Management Plan (WMP), we have assembled a team of scientists and engineers who have significant experience in the evaluation of water resources issues. The team will be led by Dr. Tom Ballestero of the University of New Hampshire (UNH). Collaborating with Dr. Ballestero will be Dr. Piotr Parasiewicz of the University of Massachusetts (UMass) and Donald Kretchmer of Normandeau Associates, Inc. (Normandeau) in Bedford, New Hampshire. In addition to leading the team, Dr. Ballestero assumes the lead technical role in the preparation of the WMP. Dr. Parasiewicz assumes lead technical role for the IFS. Dr. Sean Werle is an invertebrate zoologist in Dr. Parasiewicz's lab who will provide expertise on freshwater mussels and other aquatic invertebrates. Normandeau will provide additional technical assistance with both the IFS and the WMP as well as field support for the IFS and the WMP through Dr. Matthew Chan (Normandeau) and Don Kretchmer. Mr. Kretchmer will lead the public participation portion of the project and all Normandeau efforts. Details and resumes for all project personnel appear in Appendix B. Brief descriptions of the three lead personnel follow. These lead personnel are committing a minimum of 20% of their time to this project for the duration of the project. An organization chart may be found in Figure 1.

Dr. Thomas P. Ballestero has been involved in water resources engineering projects for 24 years. He has managed multi-million dollar projects that included diverse teams of professionals. Dr. Ballestero is a hydrologist and water resources engineer presently on the Civil Engineering faculty at the University of New Hampshire, where he has been employed since 1983. For 13 years Dr. Ballestero was the Director of the NH Water Resources Research Center. This position required that he be knowledgeable of NH water resources issues/laws, interact with the legislature, and integrate the public into the water resources issues that faced the state. Dr. Ballestero has been involved in a number of projects that directly or indirectly involve instream flow issues, such as: water resources development of the Powder River Basin, WY; evaluation of the impacts of trans-basin diversions on the Missouri River from South Dakota to the confluence with the Mississippi River; waste load allocation study for the Contoocook River below Jaffrey, NH; ground water resources evaluations, and hydropower optimization along the lower Cochecho River, NH. In addition, Dr. Ballestero has had formal training in strategies for water resources allocation during times of deficit. His dissertation research developed stochastic strategies to forecast deficits, thereby providing reaction time for management strategies prior to the deficit. He has taught courses on water resources allocation strategies. Dr. Ballestero has experience in public forums, especially those involving complicated and controversial issues. His advice was sought during the development of the New Hampshire instream flow rules.

Dr. Piotr Parasiewicz is a civil and environmental engineer educated at the University of Agricultural Sciences in Vienna. He started his career in 1988 as a research associate on an interdisciplinary team of biologists, water engineers, and landscape ecologist in the Department of Hydrobiology, Fisheries, and Aquaculture of the same university. This position strongly influenced his professional development and provided him with expertise on riverine ecology, ecosystem management and restoration, river morphology, physical habitat assessment, statistical and numerical modelling, as well as remote sensing. From 1997 to 1999 Piotr was a member of the Austrian Network for Environmental Research, a governmental institution

actively participating in development of EU environmental and research policy. Since 1999 to 2004 Piotr has been leading the Instream Habitat Program at the Department of Natural Resources of Cornell University. He is also an adjunct assistant professor in the Department of Natural Resources Engineering of the University of Connecticut. One of the key tasks of the Instream Habitat Program is to develop methodologies for basin-wide assessment of flow needs as a tool for water use planning and regional legislation. Recently, the University of Massachusetts proposed to relocate the Instream Habitat Program to Amherst with the ambition of creating a national and international center of excellence in instream habitat studies. Consequently last March, Piotr took the position of Research Associate Professor in the Department of Natural Resources Conservation at the University of Massachusetts, Amherst. The Northeast Instream Habitat Program builds upon intensive collaboration with organizations such as the USGS (Conte Anadromous Fish Laboratory), US Army Corps of Engineers (Waterways Experimental Station), Iowa Institute of Hydraulic Research, regional state Universities as well as the International Aquatic Modelling Group. Development of state-wide instream flow rules is one of the key tasks of the program.

The team leader for Normandeau Associates will be Mr. Donald W. Kretchmer. He has over 20 years of experience in water resource investigations as a principal investigator and project manager. He is currently managing a long-term water quality monitoring project on the Yadkin River System in North Carolina as a part of re-licensing of four hydropower dams. The alternative licensing process employed on this project relies on extensive input from stakeholders during study scoping, data collection and data interpretation. The stakeholder group includes regulatory agency personnel, NGO's, residents, fishermen and watershed groups. He is also currently managing a variety of water quality studies on the Lower Merrimack River to support the development of a comprehensive model of nutrients, bacteria and metals for the system. He recently evaluated the water quality implications of alternative reservoir operating scenarios on the entire TVA system as a part of a programmatic environmental impact statement. He has managed water quality investigations for Normandeau on the Souhegan Middle and Lower Merrimack, the Pemigewasset, the Androscoggin, the Connecticut, the Salmon Falls, and the Piscataqua Rivers in New Hampshire which focused on flow, bathymetry, nutrients, temperature, dissolved oxygen and municipal and industrial withdrawals and discharges. Nationwide, he has participated in or managed water quality investigations at over 50 hydroelectric sites. He has assisted Manchester, New Hampshire and Portland, Maine in protecting their water supplies. Other areas of investigation during his career include lake restoration, natural resource damage assessment, water resource planning, groundwater, fisheries, food web interactions and watershed management.

Other Personnel

Resumes of all other team members may be found in Appendix B.

Organization Chart

Project Personnel and their efforts are organized in the following diagram.

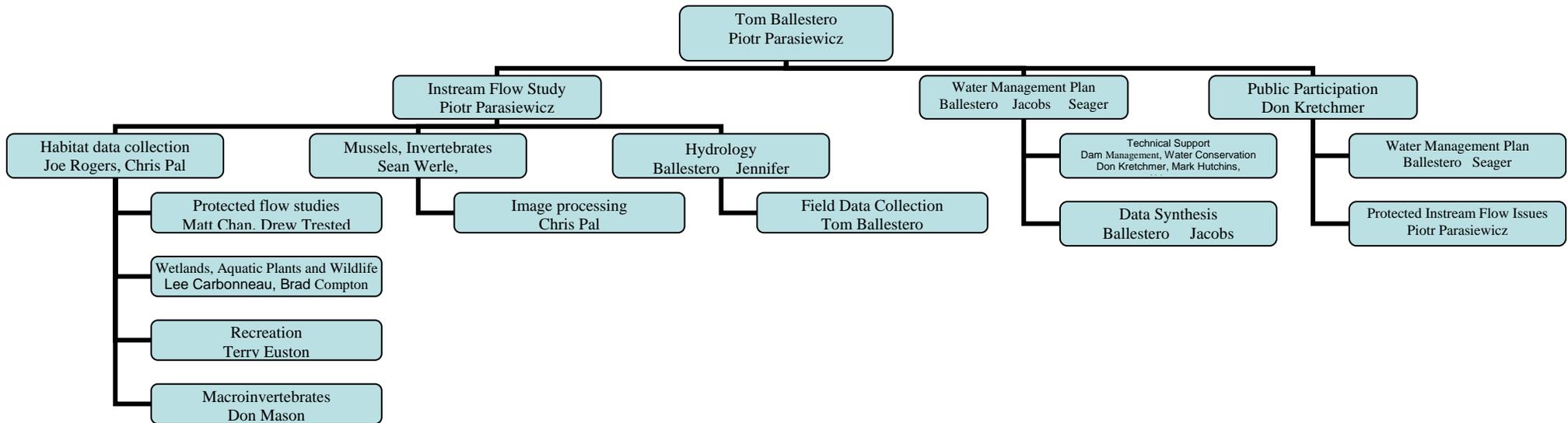


Figure 1. Project Personnel Organization Chart.

III. Project Approach

Protected Instream Flow Study

Background

A major goal of the Lamprey River instream flow assessment and Water Management Plan is the determination of Protected Instream Flow (PISF) values for individual reaches and strategies to achieve them. PISF values must be established that protect legislatively mandated Instream Public Uses, Outstanding Characteristics, and Resource (IPUOCR) entities, which may constrain water use by Affected Water Users (AWUs) or influence the operation of dams by Affected Dam Owners (ADOs) in the Lamprey River basin. Consideration of PISF levels in relation to current and projected water use patterns in the basin will be an integral component of the Water Management Plan (WMP), as discussed elsewhere in this proposal (Section 10).

In order to foster public understanding and acceptance of recommended PISF levels, it is critical that they be based on defensible scientific principles and methodologies. NHDES has established a series of tasks that will provide the technical background, fulfill legal mandates, and meet Public Trust responsibilities that are needed for the Agency to establish the PISF regulations that it deems necessary. Briefly, these tasks are as follows: 1) identify IPUOCR entities, 2) conduct a targeted field verification survey of IPUOCR entities, 3) develop and apply a method to assess well withdrawal impacts on surface water, 4) describe IPUOCR entities and propose methods that would be used to assess their flow needs, 5) apply selected PISF method(s) and develop quantified PISF values that protect IPUOCR entities and, within the context of applicable regulatory frameworks, promote compliance with water quality standards.

Following completion of these five primary technical tasks, two additional tasks must be accomplished in order to satisfy public participation mandates included in the legislation that establishes the pilot instream flow protection program. First, details of the study and recommendations from it must be made available to the public through a public hearing, delivery of draft reports to public outlets in the study area, and posting of documentation to the NHDES website. Second, feedback from public review of study reports and recommendations must be used to revise conclusions and recommendations, if necessary, and document how such comments were considered. Results of these tasks, in conjunction with the previous technical components, will be used to prepare a final PISF report for the Lamprey River.

Flow variability and dynamics in river ecosystems are critical drivers for river processes that support the viability of river ecosystem fauna and flora (Jowett and Duncan 1990; Poff and Allen 1995; Richter *et al.* 1997). Flow regimes are directly related to available habitat, including its amount (magnitude), quality, timing (frequency), and persistence (duration). Less altered ecosystem processes, such as flow regimes, maintain river ecosystems that are more resilient and can better withstand short-term stress than ecosystems with chronic or extensive changes to their physical processes (Niemi *et al.* 1990; Yount and Niemi 1990). Therefore, when evaluating river processes like flow regimes to identify its components which relate to important life processes of the river flora and fauna, it is essential to consider not only the magnitude of an impact, but also

its duration and frequency, especially when estimating the impacts to the fauna resulting from habitat and flow changes.

Regulated flow regimes may be characteristically different from unregulated systems depending on the type of watershed land use and flow regulation, and these different regulated flow regimes affect biota in both direct (habitat) and indirect ways (changes in competitors, prey sources, or predators). Frequent or persistent low flows modify the hydraulic character of a river ecosystem, lowering velocities and depths and creating habitat that is more suitable for pool-dwelling than fauna that prefer flowing water (Poff and Ward 1989, Kinsolving and Bain 1993). Low flows may also lead to increased temperatures and pollution levels, introducing additional stress for the entire aquatic community (Parasiewicz, 2005). Hydrological modifications are also caused by watershed land use; these changes are not always easily reversible at the source of alteration. Mitigating or reducing land use impacts usually requires pro-active, long-term planning and sometimes substantial limitations on human activities within the watershed.

Protecting natural and anthropomorphic resources through water resources planning requires a broad based approach, including using the presence of dams in a system as a unique tool to mitigate impacts to instream flow resources (via flow regulation) while sustaining human use of resources. One way to protect river resources is by adapting regulated and altered flow regimes to mimic patterns like those of an un-impacted watershed condition. Dams can play important roles in adapting flow regimes to protect and conserve river ecosystem resources.

The following narratives describe the processes and proposed activities to be accomplished for the PIFS phase that, in conjunction with the WMP, will enable NHDES to adopt rules for protected instream flows on the Lamprey River. These actions follow the basic strategy of first conducting studies to develop PISF standards that protect IPUOCR entities, and then planning water management strategies that will maintain those standards.

1. Identification and Draft List of IPUOCR Entities

A dramatic reality of the Lamprey River IPUOCRs versus those of the Souhegan is that the Souhegan designated reach is almost the entire river length whereas in the case of the Lamprey, the designated reach is a short length of the river. In the Souhegan study, all of the IPUOCRs, AWUs, and ADOs were in the designated reach. However for the Lamprey, there are a number of AWUs and ADOs outside of the designated reach. This may present a larger challenge to the ultimate Lamprey River management plan in that such remote entities may not feel as “connected” to the designated reach as in the Souhegan.

The primary objective of this task is to establish a comprehensive baseline of flow dependent IPUOCR entities for the designated reach of the Lamprey River. Based on their seasonal flow requirements, these entities will serve as a basis for designating protected instream flows. The IPUOCR to be evaluated and the preliminary list of entities for the Lamprey River that have already been defined by the NH DES in RFP Appendices A and B will provide a starting point for completing this task. Accordingly, the main focus for this work will be to evaluate the information in RFP Appendices A and B for appropriateness and to refine and augment it for the

designated reach. This will be accomplished by means of a comprehensive review of existing available data and information and by interviewing knowledgeable authorities, organizations, and individuals. Such information will include but not be limited to: designated river nomination reports, river corridor management plans, natural resources studies, natural heritage inventories and environmental assessments and impact statements.

There presently exists a variety of reports for the Lamprey River including a nomination report, watershed study, river corridor study and a water monitoring report. UNH has recently monitored and reported water quantity and quality throughout the basin (McDowell, 2004). Other available information includes NRCS soil maps, National Wetland Inventory maps, conservation lands maps, geologic resource maps, aerial photographs and fish community survey data. Many of these sources are available on the UNH GRANIT database as GIS layers. Agencies and organizations to be interviewed will include groups such as the Lamprey River Technical Review Committee and Water Management Planning Area Advisory Committee members, New Hampshire Natural Heritage, Strafford and Rockingham County Planning Commissions, NGOs associated with the Great Bay, representatives of the Seacoast groundwater study, Lamprey River Watershed Association, the Lamprey River Advisory Committee, National Park Service Wild and Scenic Rivers Program, Pawtuckaway Lake Improvement Association, Pawtuckaway Lake Advisory Committee, New Hampshire Fish and Game, and the relevant conservation commissions.

The reviews of available information and interviews will be structured so as to develop the information base necessary to prepare a list of IPUOCR entities for the designated reach and to annotate each entity on the basis of river location and dependence on flow conditions. This list will be confirmed to the extent possible and supplemented, if necessary, through the field survey to be conducted under Task III. The list and supporting information will be refined following review and comment by the advisory committee and general public and presented in a draft IPUOCR report. Ultimately, for each IPUOCR, there will be a database of primary contact information and contact person(s), contact information, and descriptions of relevance to the PIFS.

Concluding from the Lamprey River Baseline Fish Sampling Report (NH DES, 2005), we will select a set of species for PISF modeling. Using the fisheries data bases we will develop a list of critical river ecosystem processes that influence habitat for migratory and specific life stages of the river fauna, including the annual periods when the fauna is particularly dependent on appropriate river flows. Subsequently we will determine biological periods when migratory species and specific life stages of resident fauna are particularly dependent on appropriate flows. We will use the existing habitat data base and literature to establish habitat selection criteria for each of these species. The fish collection data obtained during Lamprey River Baseline Fish Sampling will be used for validation of habitat models later in the process.

Further, we will develop a list of fisheries management goals based on local, state, and federal management stakeholder values. Thus, using the identified fisheries management goals and values of all stakeholder levels and the key ecosystem processes driving the shape of the fish community, we will identify components of the flow regime that can be managed with the purpose of “pushing” the river community towards desirable states to meet user goals. An

important by-product of this process will be the identification of conflicting or incompatible user goals and gaps in management planning for the river ecosystem

2. Assessment of Well Withdrawal Impacts on Surface Water

Ground water supply wells in proximity to surface water bodies can often draw water directly from the surface water body into the well. This is known as induced infiltration or induced recharge. This constitutes a direct withdrawal from surface water that is masked as a withdrawal from an aquifer. In these scenarios, simple analytical techniques exist to estimate the fraction of water from the aquifer versus surface water. Some of these techniques are available in public domain computer models (WHPA and WhAEM, both supported by the US EPA). In order to use such models, some basic information about the well (construction specifications, pump, pumping rate, pumping schedule), the formation (transmissivity, saturated thickness, porosity, storage parameter, gradient) and the surface water (distance to well, depth, volume, flowrate) are necessary. There are also field techniques for estimating the fraction of surface water drawn into the well. These methods include fingerprinting water sources (using dissolved water chemistry, for example), pumping tests, and field monitoring of water levels and flows (for example a dilution study of the river to measure river flow with distance). A very inexpensive field technique is to use miniature piezometers (1/4-inch ID plastic wells) at the banks of the surface water body near the pumping well. The miniature piezometers clearly delineate the footprint of where surface water is drawn into the aquifer. Interpretation of the miniature piezometer data quantifies the amount of water drawn into the well.

The first step in the performance of this task is to investigate which of the subject wells (delineated in the RFP) have previously had a well head delineation study performed or aquifer test. It is quite likely that these well head studies have addressed this topic, for example see the well head protection report for the Pembroke, NH well by the Soucook River, on file at NHDES. In addition during this first step, each well owner is interviewed and surveyed to gather information pertinent to this study. The questionnaire used for the Souhegan study appears in Appendix C.

Next, in the cases of wells without a well head protection study, the USGS maps and studies of the New Hampshire stratified drift aquifers will be used to obtain the necessary information to use in an analytical model to estimate the fraction of surface water pumped by the wells. For two or three of these wells, in cooperation with the well owners and riparian landowners, miniature piezometers will be installed along the Lamprey River, and field measurements will be taken to validate the estimates from the analytical models. The detailed methodology employed here will be written into a guidance manual in the event that this method is to be employed in the future at other locations or in the event the method is to be employed in verification efforts.

If no well head protection study and no USGS data are available for the subject wells, static and dynamic well water levels will be measured. Aquifer hydraulic characteristics will be estimated for the sites, and analytical models again will be employed to estimate the amount of surface water pumped by each well.

The sites that are selected for field techniques will be preferentially those that appear to be in the more critical areas regarding instream flow needs.

The result of this task will be an estimate of the amount of induced Lamprey river infiltration by ground water wells within 500 feet of the river and its tributaries, as designated in the RFP.

3. On-Stream Survey for IPUOCR Entities

Within the designated reach an on-stream canoe/kayak survey will be conducted to verify the existence and occurrence of the IPUOCR entities identified in Task 1. This will be completed through an on-river, two day field survey of the designated reach and its watershed with stops at specific locations to document the presence of each entity or the presence of conditions or habitat suitable for each entity. To assemble the information for the WMA outside of the designated reach we will use remotely sensed data and visit selected locations by car. A pre-screening of likely locations will be conducted prior to the field survey. Data sources such as Landsat, GRANIT, high resolution low altitude photos of the Lamprey River corridor (already taken by the UNH team, see Figure 2), and stereo pairs of aerial photos will be reviewed for their utility in identifying IPUOCR locations; any entities located by those sources will be placed on GIS maps of the designated area reach segments. Stakeholders will be invited and encouraged to participate in the planning for this survey and, if circumstances allow, participate in the survey. Two groups that will be very important to involve will be white-water enthusiasts and anglers, among others. The last step in this process will divide the WMA into subwatersheds and the designated reach into segments with specific characteristics and IPUOCR mosaic and determine locations for collection of stage and temperature data. We will also determine the need for collection of more detailed habitat data from sections of the rivers adjacent to the designated reach, as those could have direct influence on the designated reach productivity.

Prior to the field survey, a Standard Operating Procedure (SOP) for conducting the survey will be prepared. This SOP will address the survey methods and schedule for the full range of IPUOCR entities developed in Task 1, and may include fisheries surveys, recreation surveys, rare plant surveys, spawning habitat evaluations, etc. Both the sampling locations and the SOP will be presented to DES (the Department) for review and finalized to incorporate comments. The Department's Photo Documentation Procedure will be followed in taking photos to document IPUOCR entities. Notes will be taken at each location that will include pertinent information to describe each entity and its condition. We believe that participation of representatives of the local watershed groups, stakeholders and the DES during the field survey task is critical to the success of the effort. This effort will be conducted as soon as possible after contract award and is anticipated to be primarily a float trip with stops at critical points. Depending on river flows, the float trip may need to be augmented with some walking or vehicle access surveys.

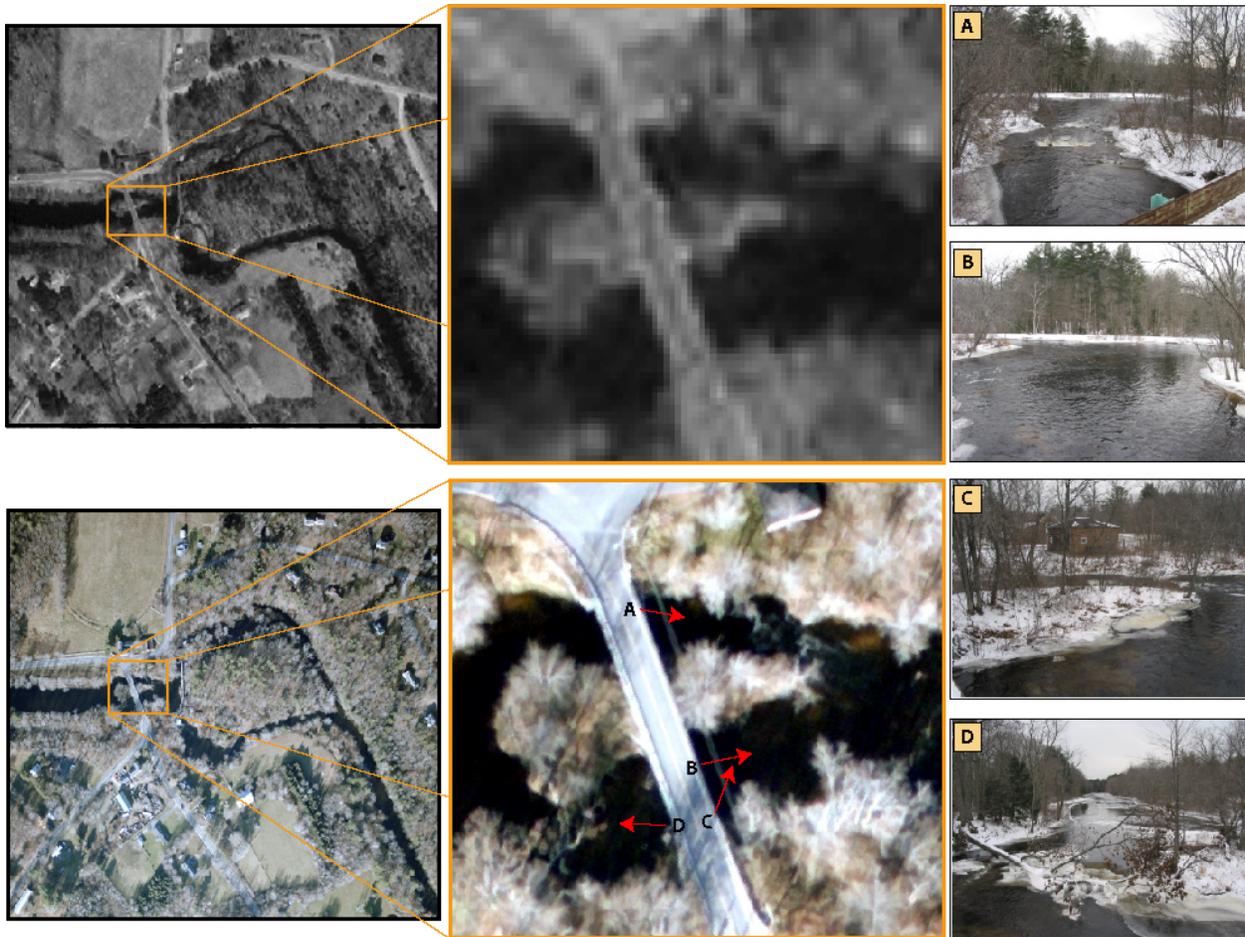


Figure 2. In the two pair of figures at 1:12,000-scale, 1-meter resolution, black & white digital orthophotoquads taken April 11th 1998 and obtained from GRANIT and the US Geological Survey (upper figures) are compared to the increased resolution of our newly acquired high-resolution digital aerials photographed in fall 2004 (lower figures). This is a section of the Lamprey River along Route 152 and Campground Road, upstream of Wadleigh Falls.

During the float trip along the designated reach we will also delineate the distribution of Hydromorphologic Units (HMU) and other habitat characteristics relevant to fish as described by Parasiewicz (2005). The distribution of habitat units will be entered as GIS layers in handheld or palmtop computers (PDAs) using georeferenced high resolution aerial photographs (2004) as a base layer. We will employ an Acoustic Doppler Current Profiler (ADCP) to collect hydraulic data from the designated reach. This equipment is integrated with a differential GPS system so the geographic coordinates of all locations measured are recorded. The survey will be accompanied by multispectral aerial photography to calibrate pictures with on-the-ground delineated features for subsequent data collection that will be based on image recognition. This technique is also to be applied for collection of habitat data on an 85 mile long stretch of the Delaware River in New York, New Jersey and Pennsylvania by NEIHP and the Army Corps of Engineers, and by employing the same technique on the Lamprey a degree of synergistic efficiency should be achieved that will benefit both studies. On the Lamprey River, it is

estimated that the field crew can cover 5 miles of river per day. The schematics of this approach are presented in Figure 3. Electronic data will be quality controlled and backed-up daily during data collection phases.

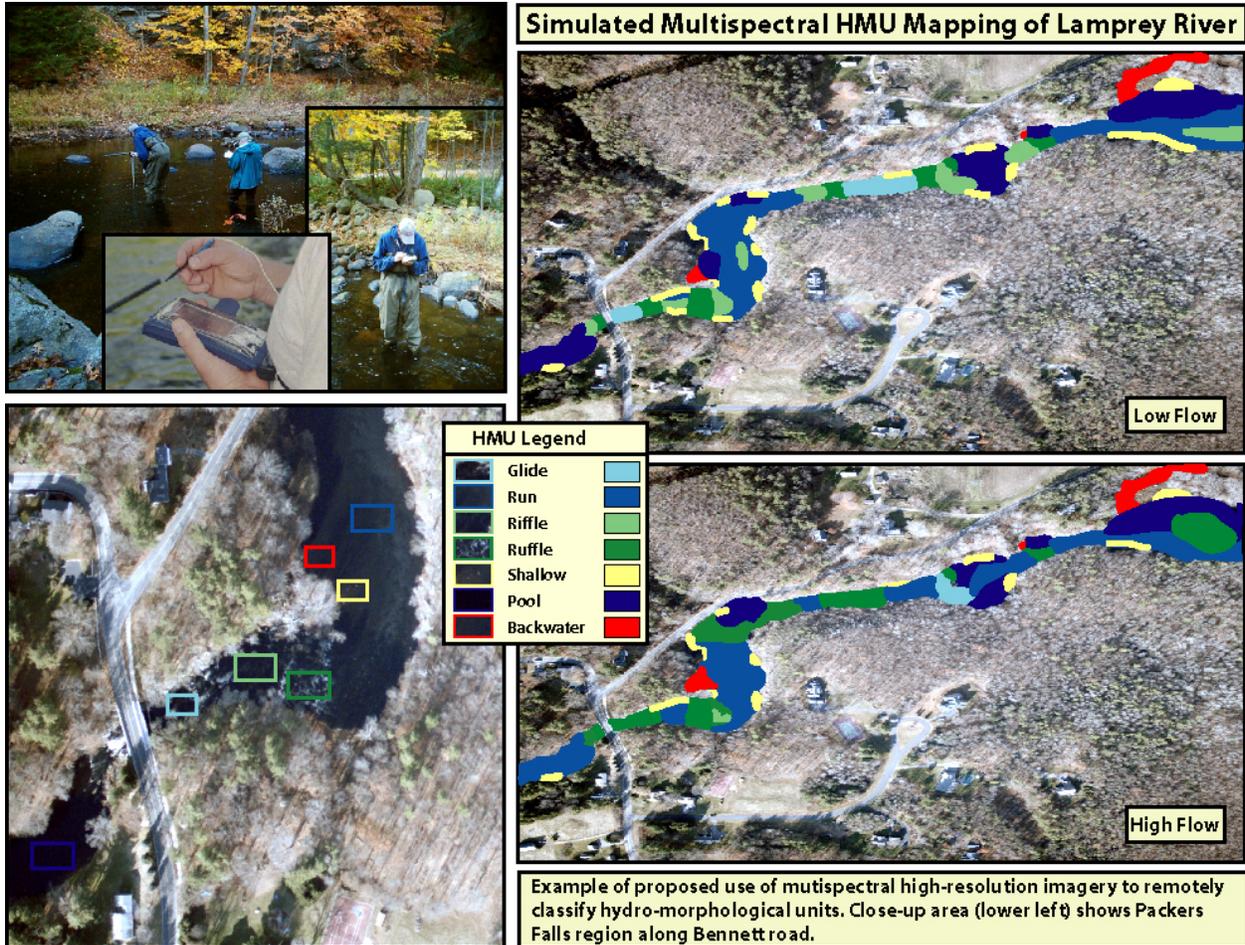


Figure 3. Schematics of proposed data collection.

Throughout this process, coordination will occur with the NHDES and with the advisory committees. Photo documentation together with supporting text will be presented for each representative IPUOCR entity visited in the field. The IPUOCR report will be centered on an IPUOCR matrix. Potential categories in the matrix will include but not be limited to: the resource, the reason for inclusion, the local, regional, and national importance of the resource, the flow requirement of the resource including seasonality and duration, the specific location of the resource in the study area and representative photos of the resource. The specific locations of resources that are rare, threatened, or endangered will be kept confidential; the Department and/or the advisory committee will make the ultimate decision on whether or not to publish these locations. The matrix of IPUOCR entities and accompanying report provides the organized, essential information to assist screening candidate methods for the determination of protected instream flow.

Prior to the survey we will prepare digital data entry forms that will include all information on IPUOCRs gathered in the Task 1 and habitat attributes expected to have importance for fish. The survey will be conducted in July- August 2005.

4. Report Describing IPUOCR Entities and Proposed PISF Methods

This task requires that IPUOCR entities be identified and results of field verification be documented in the form of an initial report that, among other things, locates those entities geographically. Some uses and characteristics in need of protection may apply to the whole system, such that operationalizing their needs (that is, identifying what they are and how they can be attained) becomes a focus of investigation that is less dependent on location, other than accounting for natural spatial variation in flow across the drainage network. Otherwise, geographic differentiation of PISF recommendations can be seen as an added component of any study that addresses the needs of IPUOCR entities having well-defined spatial attributes (that is, they relate to specific locations or stream reaches). The IPUOCR assessment thus defines the context and requirements for methods that will quantify attributes of the River's flow regime needed to protect those entities.

It is clear from the diversity of potential IPUOCR entities (listed in Attachment V of the RFP) that no single evaluation method is adequate to address all the questions that must be answered in order to arrive at defensible PISF recommendations. Indeed, the realization of this problem by DES is evident in the structure of the RFP, in that the report addressed by this task is intended to document the process by which assessment methods are proposed. Therefore, because specific IPUOCR entities (and initial evaluation of their flow needs) have yet to be identified, a firm commitment to any one method or set of methods at the proposal stage is premature. Methods should be viewed as tools for assessing instream flow needs; what is most important at this stage is the adoption of a sound conceptual framework to guide not only the selection of appropriate methods, but also to provide a basis for asking relevant questions, interpreting results, and developing recommendations. Lessons learned from the application of specific methodologies to the Souhegan River will be valuable in evaluating methods for the Lamprey. The combination of both projects will allow us to investigate transferability of the developed framework between the rivers and the utility for generalization of findings to be applied for development of state-wide instream flow considerations.

Early efforts to protect instream flow values arose primarily in the context of water-use allocation in western streams, many of which were already over-appropriated (i.e., demand often exceeded supply). As a result, early stream flow protection measures focused on the *minimum flow* that allowed for *maximum use* while preserving some (often only one or a few) critical aspect(s) of the stream system deemed necessary for survival of aquatic biota (often judged by relationships between flow, water temperature, and indices of suitable habitat for a few "indicator" species or species of management interest). Advances in understanding of relationships between stream flow and the biophysical structure and function of lotic systems led to the realization that stream ecosystem integrity depends on more than just the maintenance of a single, persistent low minimum flow. The "natural flow paradigm" (Poff et al. 1997) has

emerged as a widely accepted framework for describing the roles played by stream flow in shaping ecological characteristics of streams and understanding the consequences of modifications to natural stream flow patterns by human activity.

The natural flow paradigm (NFP) recognizes the importance of considering stream flow in terms of a *regime*, that is, a dynamic quantity that naturally varies over time in response to changes in many driving variables (precipitation, runoff, groundwater interactions, and evapotranspiration, to name a few) that occur over a broad range of spatial and temporal scales. Flow regimes can be described in terms of five general attributes that characterize temporal patterns and invoke conceptual linkages to other ecological variables. These include flow *magnitude* (which is used to distinguish between low, normal, and high flow conditions), the *timing* of high and low flow events (the predictability of which may select for or against various life history characteristics of resident biota), their *frequency* and *duration* (which interact to define disturbance intensity), and the *rate of change* in flow conditions (which interacts with organism mobility and availability of refuge from intolerable physical conditions to further characterize the intensity and consequences of disturbance).

We propose to adopt the NFP as an organizing framework for developing PISF recommendations for the Lamprey River. Note that the NFP is not a “method” in and of itself. Rather, it is an over-arching philosophy that will be used to assess and prioritize efforts to understand the instream flow needs of various IPUOCR entities and devise or select among methods needed to answer questions raised by that understanding when placed in a water management framework. For example, a “piece of the puzzle” that must be determined initially is to characterize the existing Lamprey River flow regime and estimate to what extent it may already deviate from “natural” conditions. Statistical tools such as the Indicators of Hydrologic Alteration (Richter et al. 1996) and related indices like those used by Poff and Ward (1989) can be used to characterize patterns of stream flow variation across temporal scales. As stream ecologists are challenged to choose appropriate and relevant indices from the available suit of indices, Olden and Poff’s (2003) comprehensive review of currently available hydrologic indices for characterizing streamflow regimes and their recommendation of non-redundant indices based on stream types will be used to guide index selection.

Preliminary results using six Indicators of Hydrologic Alteration (IHA, Richter et al., 1996) for the Lamprey River as compared the Souhegan are shown in Table 1. The values for the three low flow IHA statistics (7-day low, 30-day low, and low pulse duration) were compared with thresholds developed by the Massachusetts Water Resource Commission (WRC) for Massachusetts basins (Presented by R. Abele, U.S. EPA, 2004) and indicate the overall Basin Stress Index is high. The duration of high and low pulses in the Lamprey show a level of persistence indicative of flow regulation, heavy water withdrawals or generally low contributions from groundwater. A comparison of historical streamflow data (1935-1966) to more recent flows (1967-1990) showed that, while the duration of flooding events has remained relatively constant over the period of interest, the duration of drought periods has increased in the Lamprey. This increase in conjunction with moderate to high IHA indicators shows that the Lamprey basin is highly stressed (altered flow regime) likely due to human pressures resulting in increased water demand during annual low flow periods.

Table 1. IHA statistics for the Lamprey and Souhegan Rivers for the period of 1934 to 1976.

IHA	Median statistics for 1934-1976			
	Lamprey	Stress ¹	Souhegan	Stress ¹
7-day low flow (cfsm)	0.06	High	0.13	Medium
30-day low flow (cfsm)	0.10	Medium	0.18	Medium
Low pulse duration (days)	18.50	High	13.16	High
Overall basin stress index		High		Medium
7-day high flow (cfsm)	8.36		9.13	
30-day high flow (cfsm)	5.11		5.94	
High pulse duration (days)	12.40		9.88	

¹ MA Stress thresholds	Low-Med	Med-High
7-day low flow	0.22	0.09
30-day low flow	0.30	0.16
Low pulse duration	6.80	10.90

Due to geographic variation in IPUOCR entities and existing water use patterns, methods will likely be needed to estimate stream flow records for ungaged locations of interest in the watershed (see Richter et al. 1998). There could well be a need to compare flow regime attributes to those of a nearby reference stream, or between two time periods that bracket a significant change in water use within the basin. Consequences of such deviations, or of projected future water use scenarios, would then be evaluated with other methods specific to the nature of each IPUOCR entity, which could be grouped into classes or habitat guilds, reducing the number of methods ultimately required to address all pertinent issues (examples of such methods are given later in this section).

It is important to recognize that adoption of the NFP as a conceptual framework does not mean that PISF studies will automatically result in recommendations to restore a “pristine” hydrograph to the Lamprey River. For one thing, total restoration of an unaltered hydrograph allows for no water usage at all, and is generally technically impossible (due to human-induced changes in watershed characteristics) and socially infeasible (due to human demands on flowing water resources). The challenge is in devising water management strategies (including PISF levels) that effectively balance human needs for water with those of the natural systems which provide the water and other forms of “natural capital”.

Adding to this problem is the fact that the flow needs required to support multiple IPUOCR entities very often will conflict, raising issues of fairness human values, and inter-generational equity among present and future stakeholders. Noting that the draft list of IPUOCR “types” (listed after the references) includes a mix of both anthropocentric (human-oriented) and “natural” uses to be protected, the NFP leads one to conclude that the latter are best served by an

unaltered flow regime, inasmuch as the natural hydrology is a major component of the habitat template within which native biota evolved, often mediated through effects of stream flow on channel geometry, habitat diversity, and the timing and intensity of disturbance from droughts and floods. On the other hand, human demands on water resources are often continuous or display spatiotemporal patterns that do not correspond to the “natural delivery schedule”.

Thus, from a water management perspective, it is important to ask, “How far can flow regime deviate from natural pattern before a system degrades?” To answer this question, assessment methods must use appropriate indicator variables that link flow regime alteration to changes in the biophysical properties of stream systems and their watersheds. Although it is unlikely that evaluation methods for this study will incorporate direct study of systems other than the Lamprey, comparative information is likely available from watershed assessments for other New England rivers, instream flow studies, and ecological profiles associated with hydropower projects, and monitoring reports associated with other water resource development projects. Such analogs would contribute to the credibility of PISF recommendations by providing much-needed perspectives from which to judge the consequences of departures from natural flow patterns in the Lamprey River.

Even if much redundancy exists in the flow needs among IPUOCR entities, the set of issues to be considered remains diverse enough that no single methodology is likely to address all relevant questions. However, the IPUOCR entities can broadly be divided into those having natural or anthropocentric origins, and then further into sub-sets. Natural use categories for the Lamprey River have been identified by DES and include wildlife, conservation, maintenance, and enhancement of aquatic and fish life, fish and wildlife habitat, and aquatic life and wildlife uses designated under the federal Clean Water Act. Natural outstanding characteristics and resources requiring protection are categorized as wildlife, natural, hydrological, geological, environmental, and ecological. Some IPUOCR entities, including fishing, fisheries, protection of water quality and public health, pollution abatement, aesthetic beauty, scenic resources, scientific resources, and consumption of fish and shellfish, are defined in ways that blur the distinction between natural and anthropocentric uses. In fact the flow needed may vary broadly across IPUOCR categories. Finally, IPUOCR definitions for navigation, recreation and recreational resources, water storage, cultural and archaeological resources, significance of community resources, agriculture, and hydroelectric energy production are clearly anthropocentric. Natural and anthropocentric resources can vary widely with respect to their dependence on the natural flow regime. However, such dependence, as well as the impact of deviations, will often be similar among sub-sets, suggesting that methodological approaches for one entity will usually be applicable or contribute to understanding of the flows needed to protect several.

Furthermore, all flow assessment tools have assumptions and limitations, and variation in their application costs must be evaluated against finite budget and time constraints. Some tools, such as models of system hydrology and statistical analyses of flow regime attributes, are common to more than one “methodology”. The IPUOCR and methods evaluation report will identify such interrelationships and account for them when selecting particular approaches to address the various instream flow needs of specific entities.

Nevertheless, as all IPUOCRs are related to the same entity, a running water ecosystem that evolved over thousands of years of adaptation and evolution, which needs to be left functional and integer to sustainably support all IPUOCR. Even if short term economic benefits could create the appearance of some IPUOCR having contrary objectives (e.g. fisheries vs. water withdrawals), in the long run, maintenance of a self-sustaining, balanced system extends the longevity of all uses and is in the mutual interest of the entire society. Therefore, application of the PISF setting approach that balances anthropocentric water uses with maintenance of ecological integrity, as a measure of ecosystem sustainability, should address the objectives of the majority of uses and users.

Because analyzing all components of the aquatic ecosystem would be an enormous and overwhelming task, we propose to focus on fish and freshwater mussels as a primary indicator of ecological integrity. This decision is supported by the fact that fish are the primary animals of interest to the public in the river, and freshwater mussels are the most likely invertebrate group to be rare or endangered, and thus both are an important component of any PISF recommendation.

Within the Souhegan Project, a number of literature sources were consulted to provide insight into methods for surveying the Souhegan River. Each of the papers consulted discusses methods of surveying flowing water, and eventually modeling its outcome. One source is a paper entitled “Overseas Approaches to Setting River Flow Objectives” by M. J. Dunbar et al. from the Environmental Agency and the Institute of Hydrology in the United Kingdom. Another source is “A Global Perspective on Environmental Flow Assessment: Emerging Trends in the Development and Application of Environmental Flow Methodologies for Rivers”, by R. E. Tharme, of the Freshwater Research Institute at the University of Cape Town, South Africa. A third source consulted is “Instream Flows for Riverine Resource Stewardship”, by the Instream Flow Council (Annear, et. al., 2002). The fourth literature cited is “State-of-the-art in data sampling, modeling analysis and application of river habitat modeling,” a Cost Action 626 Report written by Atle Harby et al. Each approach, as described by this literature is individually determined, however, there is a definite theme which can be taken from their research, particularly concerning the assessment methods.

A report by the American Institute of Hydrology (see Dunbar, M.J., et. al., 1998) identified three types of methods applied world-wide for purpose of PISF determination.

“Look up” or standard-setting techniques, based upon simple hydrological indices such as percentage of the natural mean flow or an exceedance percentile on a natural flow duration curve are the most commonly applied. They generally aim to determine some sort of minimum ecological discharge, sometimes with seasonal considerations, sometimes with other thresholds (desirable, optimum). “Such methods require considerable resources to set up initially; but once developed require a relatively low level of resources per site. These standards can play an important monitoring and strategic role and provide interim objectives, where further investigation is justified. Good examples of look-up techniques include the Tennant and Texas methods, and the Basque method.”

The other set of methods is called “discussion-based approaches and hydrological analysis”. These methods use “structured consideration of expert opinion”. “The methods are able to consider broad ecological functioning, plus species requirements at an intermediate level of detail. They may include elements such as hydraulic modeling, but the key assessment is undertaken at an expert panel workshop. This would be of particular use for setting more specific interim flow objectives, especially in the absence of clear species-related management targets, and ensuring effective targeting of further study.”

The third category is “Biological response modeling”, that refers to the Instream Flow Incremental Methodology (IFIM), and variations thereof. “This type of approach is considered to be the most resource-intensive and defensible. Some countries have incorporated elements of the holistic approaches into their IFIM-equivalent framework. Another common approach is to incorporate multivariate classification of river sector types and their biotic communities.”

The IFIM uses habitat simulation models as a basis for an integrative decision making process. It is frequently misunderstood and falsely set equivalent with the Physical Habitat Simulation model (PHABSIM), which was the first modeling technique used for IFIM. The last twenty years have involved the application and further improvement of such models, along with heated discussion as to their validity (for a review see Gore and Nestler, 1988). Since the elaboration of the original PHABSIM habitat modeling software (Bovee, 1982) there have been a number of important developments, especially the incorporation of new remote-sensing techniques (e.g., LIDAR topographic surveying) and spatial analysis technology (e.g., GIS) in support of computer simulations (see Parasiewicz and Dunbar, 2001).

Physical habitat models quantitatively describe the functional relationship between the physical environment and aquatic fauna, and are capable of predicting habitat conditions during river flows that were not measured. These models are based on the observation that aquatic biota respond to physical habitat patterns within a stream (Wright et al., 1993). Spatial distributions of physical attributes (e.g., depth or velocity) in combination with observation of biological response to their patterns provide the basis for a predictive analysis of the consequences of ecosystem alteration (Milner et al., 1985; Stalnaker, 1995).

Computer river simulation methods use high precision measurements of physical conditions to predict flow-based alteration of habitat, together with habitat suitability data for fish. The underlying approach of these river simulations is to describe these changes with a deterministic hydraulic model (statistical relationships between flow, water velocity, and depth) as described above. Originally, one-dimensional hydrodynamic models provided the only basis for habitat analysis, but one dimensional models assume that all river flow is in one direction (downstream and parallel). Recently two-dimensional models such as River2D can estimate hydraulic characteristics of the physical habitat and do not assume water flows only in one direction. This new capability more accurately describes habitat conditions because it can model complex flowing habitat such as river eddies.

The biological component of the PHABSIM model builds upon univariate response functions that individually consider the suitability of each hydraulic (depth, velocity) and geomorphological attributes. Subsequently, *a priori* selected algorithms (e.g., average) are

applied to create composite suitability. In recent years, multivariate approaches, most notably logistic regression, have been developed that better take into account the interactive nature of habitat descriptors (Parasiewicz and Schmutz, 1999, Guay et al, 2000). A recent comparative study conducted on the Quinebaug River demonstrated substantial discrepancies between the results of multivariate and univariate models (Parasiewicz, 2005).

PHABSIM was originally designed for applications related to individual water use facilities. It was not intended to be used as a standard settings tool for entire rivers and watersheds. Attempts to apply the technique as a broad, planning tool have generated criticism (Williams, 1996) because of violation of the principle of scale. Application of precision measurements on only a few selected locations (i.e. cross-sections) and drawing conclusions at the river or watershed scale generates large extrapolation errors stripping the technique of its defensibility.

Instead, newer models such as River2D or watershed scale mapping techniques like MesoHABSIM (Parasiewicz, 2001) are an improvement over site specific PHABSIM models in addressing community based systems scale and integrative assessment of ecological status.

MesoHABSIM (Parasiewicz, 2001) is a recently developed habitat modeling technique in the northeastern United States which addresses the requirements of watershed-scale management of running waters. It is an improvement of PHABSIM developed in response to those concerns mentioned, and to address needs of community-based, system-scale, integrative assessment of ecological status. MesoHABSIM modifies the data acquisition technique and analytical approach of earlier efforts by changing the scale of resolution from micro- to meso-scales. Mesohabitats are described by hydro-morphological units (e.g., riffles, pools, and runs) as well as associated hydrologic and cover characteristics. When applying the MesoHABSIM survey approach, mesohabitats are mapped at different flows along extensive sections of a river. The suitability of each mesohabitat for a reference fish community is assessed using fishing surveys. These survey data are subsequently analyzed using multivariate statistics. The variation in cumulative area of suitable habitat is a measure of environmental quality associated with alterations in flow and channel structure.

River2D is freeware developed at the University of Alberta and taught by the U.S. Geological Survey (USGS). It has been applied to several watersheds in the west by the USGS and has been applied by Normandeau Associates to sites on the Santee Cooper watershed in support of flows that meet navigation requirements and describe flow-habitat relationships for the fish community. River2D is scalable which means that it can be applied to sites or watersheds and modeling results can be examined on a transect level, micro-scale, or meso-scale. River2D models create digital terrain models and then use these topographic descriptions of the river bed to solve complex hydraulic equations which estimate river stage, water velocity, flow direction, and water depth. For the biological modeling traditional IFIM habitat suitability criteria can be used or site specific information can be brought into the model from multivariate assessments of site specific habitat use.

The other two sources reviewed within the Souhegan River study “A Global Perspective on Environmental Flow Assessment: Emerging Trends in the Development and Application of Environmental Flow Methodologies for Rivers”, by Tharme and “Instream Flows for Riverine

Resource Stewardship”, by the Instream Flow Council provide a similar perspective. They both identify standard setting approaches and concur with the notion that these methods are adequate only for reconnaissance-level studies. Both sources also identify modeling techniques as effort intensive but precise techniques that are applicable for negotiations and detailed resource use planning. As a third category, Tharme identifies holistic methods that are in some sense similar to Dunbar et. al.’s discussion based techniques, however at higher level of sophistication. In Annear et. al. (2002) the third category is named “Monitoring and Diagnostic Methods that Assess the Conditions”. Those however are considered a tool of adaptive management.

“State-of-the-art in data sampling, modeling analysis and application of river habitat modeling,” is a report which has been created by the European Aquatic Modeling Network. The paper includes case studies from a variety of countries, and many examples of methods and equipment used to develop these surveys. This paper focuses on modeling techniques incorporating a wide scope of riverine habitat modeling that includes other taxonomic groups like pollution monitoring, etc.

One of the key conclusions is that identification of appropriate scales is a crucial element of instream habitat modeling. The authors emphasize the importance of a multi-scale approach to assessment to assure that analysis can be performed at the scales corresponding with the way biota utilize their environment and to allow for more comprehensive management. The report also states that frequently habitat assessment at some scales can be considered inefficient.

Scales can range from microscopic to macroscopic. At a microscopic scale, which deals with samples, it is ineffective to assume that a sample taken from one location could yield the same results over the entire area, which the sample is meant to represent. Two areas with similar characteristics could contain entirely different species on the microscopic scale. On the other hand, at a macroscopic scale, for example the entire river, shows that the function and species diversity is determined by the stability of the system. The problem with this scale is lack of the precision necessary for resource use decision-making.

“Mesohabitat scales are becoming more popular worldwide, and increasingly recognized as adequate scales for fish. Most commonly the size of mesohabitats correspond with the size of hydro-morphologic units, such as entire pools, riffles, runs or backwaters, They create a “functional habitat” pattern, identifiable for the entire river and allow the creation of a basis for multi-scale assessment” (Harby et al. 2004).

In summary, the following can be concluded from our literature review. The four cited publications describe their individual assessments on research of instream methods but have a common conclusion. The methods outlined in the literature indicate differences between approaches, ranging from surveys to creating entirely new data including expert panels and utilizing available data. However, each of these four publications has separate groupings of methods, as well as a desire to create a homogenous method, which is applicable over a wide spectrum.

In addition to the desire for a unified method, most papers discussed the development of IFIM and PHABSIM, with MesoHABSIM becoming the latest, and most intriguing method discussed

at this time. MesoHABSIM is an incremental method, as it is relatively easy to apply, and would deliver appropriate results. MesoHABSIM integrates the ideas of IFIM and PHABSIM, while studying rivers at a functional scale, which can be studied at a small scale, or included in a trend to create an overall model of the river. This method identifies the species and the influences affecting individual sections of the river, or hydro-morphological units (HMU's). Once each section of the river has been specifically cataloged, then an average inclusion can be made to consider the influences on species within these areas of similar characteristics. These areas can then be modeled, and the effects of outside influences can be determined with a management plan developed to determine the best situation possible for species within that reach.

For the Lamprey River project we propose to build upon results of the Souhegan River project effort and apply an adaptation of MeosHABSIM to the designated reach. We will focus the review of the methods on integration of the selected physical habitat model with larger-scale assessment techniques such as the Index of Hydrological Alteration (IHA) and macro scale habitat models (e.g. hydroecology and conservation mapping by Meixler et. al. 2003). This will allow us to better prepare for the application of the results from the Souhegan and Lamprey pilot-projects towards the development of the appropriate methods for evaluating instream flow needs on other designated reaches in the state. Furthermore such application will be necessary to roughly assess ecological conditions in the Water Management Area (WMA), upstream of the designated reach.

In this report we will determine the fish species that use the instream habitat of the Lamprey River and describe their habitat needs, life cycle, and seasons of particular dependence on adequate flows. For each season, we will also propose the indicator species to guide prescribed instream flows. In addition, the report will describe the outstanding morphological characteristics of the river corridor, instream public water uses, identified reaches, and reach types in the designated reach and subwatersheds in the WMA.

5. PISF Assessments and Proposed PISF Report

Selection of models

Our approach is to develop criteria for a flow regime that protects aquatic and riparian life within the designated reach and, by extension, throughout the watershed. Thorough understanding of biological flow needs should create a basis for a Water Management Plan. Methods for accomplishing this task are numerous and vary greatly in their appropriateness to specific situations. For this project they need to be applied at two different scales. The flow requirements of the designated reach need to be assessed at the river scale and the WPA upstream of the designated reach needs to be analyzed at the watershed scale. The need for the second model is given not only by flow management opportunities upstream of the designated reach but also by a necessity to protect this portion of the watershed from unintended damage. The primary approach for proposed application is to classify the streams in the watershed based on their ecological status and potential vulnerability to change as well as improvement opportunities that would reflect on the status of the fauna in the designated reach.

Because the developments in the WMA could have a strong influence on conditions in the designated reach we need to assess the conditions and potential impact sources upstream of the designated reach. Because of the size of the WMA, application of standard physical habitat modeling techniques is not feasible at this time and so here we will apply more generic techniques which use remotely sensed data while at the same time following the NFP principles. The primary task will be to reconstruct natural flow regimes in delineated sub-watersheds. In order to accomplish this we will collect continuous and concurrent flow data for at least one location per watershed. At the same time we will use remote sensed data to better describe the topographical characteristics and anthropogenic influences in sub-watersheds.

From the variety of approaches that have been developed for a similar purpose {e.g. Index of Hydrological Alteration (Richter et al, 1996), Hydroecology and Conservation Mapping (Meixler et al, 2003)) and Conservation Assessment and Prioritization System: An Interactive Decision-Support System (McGarigal and Marks, 1995)} we will select the most appropriate, modify it if necessary, and apply it to the watershed.

Land cover and land use change can have large influences on the chemical, physical, and biological characteristics of streams. Forested buffers are considered to be beneficial to streams by providing canopy shading and thereby regulating water temperature, contributing nutrients through leaf litter, and deterring erosion through interconnected root systems. Conversely, impervious surfaces speed water and pollutants into the system and increase erosion rates. We will remotely study all of the sub-watersheds to the Lamprey River in an attempt to classify the percent imperviousness and investigate the possibility of isolating specific regions where changes in policy or introduction of mitigation could have a large influence on river quality. Increasingly available access to high-resolution satellite imagery, such as the Space Imaging IKONOS and Digital Globe's Quickbird satellites (with 1m and 0.6 m pixel size, respectively) and advancements in computer hardware and software have made remote sensing an increasingly attractive option for the Lamprey project. The imagery from the two satellites mentioned above is composed of a high-resolution, black-and-white image and a multispectral (color plus near-infrared) image. The high resolution black-and-white image can be merged with the slightly lower resolution color data to create a new high-resolution multispectral image. The identification of impervious surfaces can then be preformed using GIS or similar programs. Comparison studies have indicated that the remote sensing technique has an accuracy of greater than 90% when compared to a traditional hand digitized map and can be processed in only 4% of the time (Rogers et al., 2004).

The use of impervious surface information is for a surrogate of land use. The present day gaging records are imprinted with modern land use. The early gaging records may be the closest estimate that we have of the "undeveloped" watershed hydrology. By taking concurrent flow measurements along the designated reach and correlating these to the USGS gage records, we can establish long term hydrographs along the designated reach. These hydrographs are then adjusted to account for any regulation or hydrologic modifications due to impoundments or land use.

Intensive analysis of the techniques applicable to the designated reach leads to the conclusion that meso-scale physical habitat simulations provide the most desirable base and the greatest

potential for application on the Lamprey River. Physical habitat models link a small number of hydraulic (depth, velocity) and habitat variables (cover, substrate) to models of suitability for target biota (habitat suitability criteria) and are useful for establishing criteria when a specific site or sites have high importance to an IPUOCR.

We propose to apply this method to all free flowing sections of the Lamprey River using high resolution- multispectral-aerial photography as a primary tool of data collection. These data will be accompanied by ground-truthing surveys, which together with the results of the reconnaissance survey from Task 1 will help to calibrate and validate the image recognition software results for habitat delineation.

We propose to conduct mesohabitat mapping of the designated reach with high-resolution aerial photographs at four flows in the range between 0.05 cfs and 2 cfs as the primary approach to describing flow-related habitat changes. At each flight a 3000ft wide corridor along the river will be captured from an elevation of 4000 ft providing a final horizontal resolution of 5 inches with 50% overlap.

In order to increase our efficiency in conducting large scale field surveys of habitat characteristics we will refine and employ software tools developed by Pal et al. (2001) for automating the classification of pixels in aerial imagery into categories relevant to habitat. They used a hierarchical, tree-structured Bayesian network probability model to integrate pixel color and intensity or texture (or wavelet) features in color aerial photography. This method was used in a software system for classifying pixels and larger regions into features relevant to landscape ecology and hydrologic modeling. In a related model (Pal et al, 2000) they used a Markov Random Field to classify black and white aerial imagery. Figure 4 illustrates iterations of the MRF based algorithm.

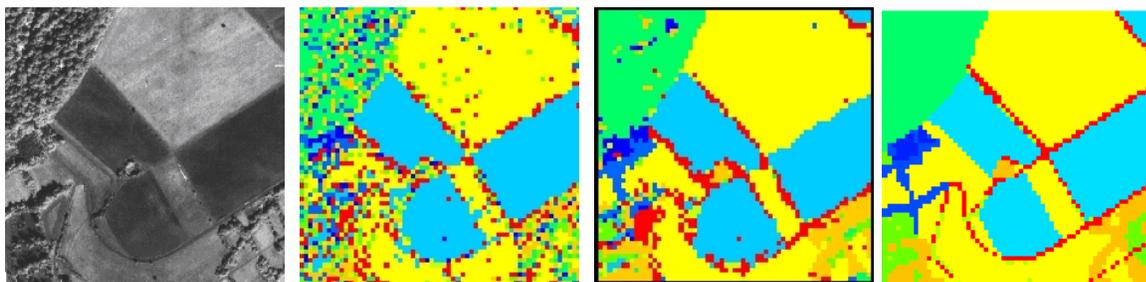


Figure 4. (left to right) 1. Black and white aerial imagery, 2. An initial segmentation, 3. Iterations of the algorithm. 4. A “perfect” hand generated segmentation.

We will adapt and build upon these approaches for automated recognition of habitat features and hydraulic patterns on the water surface. This system will also help us in delineation of wetlands.

Because of our experience working in the Northeast, we already have a well-developed habitat database on adult and early life stages of resident native fish for regional river systems (Souhegan River, Quinebaug River, Mill River, Fort River, Manhan River, Pomperaug River, Fenton River, Stony Clove Creek, Eightmile River etc.) collected from instream surveys; this database will provide a basis for determining fish-habitat relationships. For species which are

not included in our database we will develop habitat selection criteria using literature values, e.g. Parasiewicz (2005). To verify our habitat models we will compare habitat levels predicted for fishing sites with fish observations of the Baseline Fish Community survey performed by the Department.

We also propose to collect data describing habitat use by mussels and macro-invertebrates that will allow us to create an experimental model for these creatures. Based on a preliminary habitat survey we will select a number of HMU's that will represent a wide range of habitat conditions. In seven random locations within these units we will place 0.25m² quadrats and sample macro invertebrates (using a submerged drift net) and mussels, which will be identified and released where they were found. These quadrats will first be swept for non-bivalve invertebrates, and then will be searched for mussels. Mussel specimens will be identified and left in situ, while non-bivalve invertebrates will be preserved in ethanol for later processing by NH DES. A goal of approximately 300 quadrat samples equally divided across the representative HMU's will be set for the Lamprey River study. These data will be valuable in a number of ways, as they will provide quantitative knowledge about the habitat preference and distribution of freshwater mussels and other invertebrates, while also expanding the functionality of the computer simulation MesoHABSIM.

The physical habitat parameters at every quadrat will be recorded as a micro-scale attributes. Due to the limited mobility of these creatures, to define habitat suitability at the mesoscale we will not collect physical habitat characteristics at the time of the survey, but rather use the range of circumstances across the range of investigated flows occurring at these locations. The appropriate data will be extracted from habitat surveys described in the following sections.

These data will be integrated into a GIS database and habitat quality in the sites will be evaluated using criteria established as described previously. We will compute habitat flow rating curves for every hydro-morphologic unit and generalize the curves to the reach level according to the proportion of the units in the reach.

Wetland model

The floodplain of the Lamprey River includes floodplain forest and oxbows and backwater areas with emergent wetlands. Emergent wetlands range from seasonally to permanently flooded. Prolonged changes in depth or duration of water levels during the growing season could cause vegetation stress and changes and/or affect habitat functions of these wetlands. Numerous small fish, Painted Turtles (*Chrysemys p. picta*), and Green Frogs (*Rana clamitans melanota*) were observed in these marshes of the Lamprey River and are conceivable in the area . Changes in river water levels would affect primarily those wetlands with direct and unrestricted surface water connections to the river. The magnitude of the impact would depend, in part, on the elevation of the marsh relative to the river channel, the constriction of the surface water connection, and the frequency, regularity and duration of any flow changes.

Determination of minimum flow requirements will involve aerial and habitat surveys across the river floodplain and channel, with particular attention to emergent wetlands as was applied in the wetland community mapping procedure for the Hatfield Dam Removal project in the Mill River in Massachusetts (Figure 5).

- Photogrammetric survey of wetland and adjacent river channel along habitat polygons, including the lowest point of connection with the river channel and deepest point of marsh;
- Use Softcopy photogrammetry in combination with multiple flyovers at receding flow to develop a digital elevation model of wetland.
- Delineate wetland patches, creating a polygon coverage. If possible, use early-spring leaf-off photos, elevation data, or existing wetland delineations to define wetland/upland boundaries (Figure 5).
- In combination with site visits perform for each polygon
 - Wetland classification using National Wetland Inventory class level, giving primary and secondary type for each patch (e.g., em/ss is primarily emergent wetland, with secondary shrub-swamp).
 - Determine primary vegetation. Dominant plant species (>30% cover), up to five.
 - Determine secondary vegetation. Subdominant plant species (10-30% cover), up to four.
- Elevation of water recorded with flow recorders simultaneously in wetland and river at seasonal low flow (or as determined by historical data.).
- Use of a stage-discharge relationship and topography at each polygon to determine water levels along at each polygon at representative flows..
- In combination with hydrological time series develop inundation durations of polygons and vegetation types for wet and dry years.
- Habitat suitability value will be calculated for each patch and a total suitable area calculated for the wetland.

This methodology will be applied at selected sites in the designated reach. These sites will be chosen to overlap with the range of flow dependent species wherever possible.

The expected change in plant community boundaries associated with water level changes at each topographic position is identified on the elevation model and transferred to a baseline cover type map. For modeled flow scenarios the change in habitat suitability area will be calculated for a given segment of the river and extrapolated to other relevant reaches. The relative loss or gain of plant community types will serve as a measure of impact to the adapted flora and fauna. Where available, habitat suitability data will be integrated into the assessment.

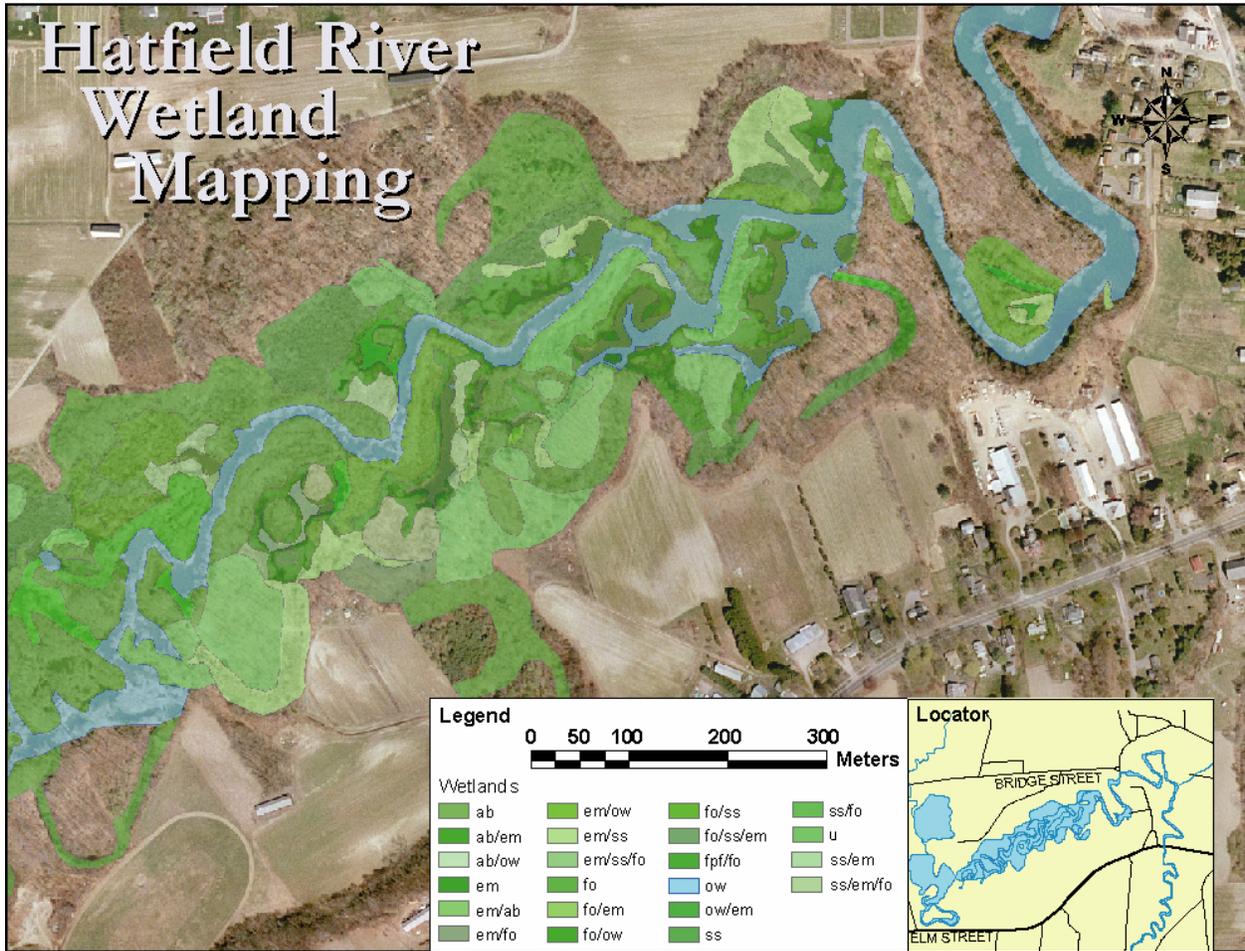


Figure 5. Using aerial data and field surveys to delineate wetland vegetation (symbols in the legend refer to primary and secondary vegetation type). This method has been applied to evaluate wetland alteration as a consequence of the potential removal of Hatfield Dam on the Mill River in western Massachusetts.

Impoundments

In addition, we propose to perform a reconnaissance level survey of the impoundments. The purpose of this survey is to identify the species that utilize impoundment habitats and roughly estimate the value of this habitat for the aquatic community. This will be accomplished by utilizing SCUBA divers trained in the recognition of fish and freshwater mussel species who will also roughly map the underwater topography. Figure 6 shows an example of the result of this approach as it was applied to the Souhegan River. This information, while somewhat crude, provides a useful addition to the study that could not be obtained through wading or electrofishing surveys and could be easily extended to develop a state-wide protocol for impoundment evaluation.

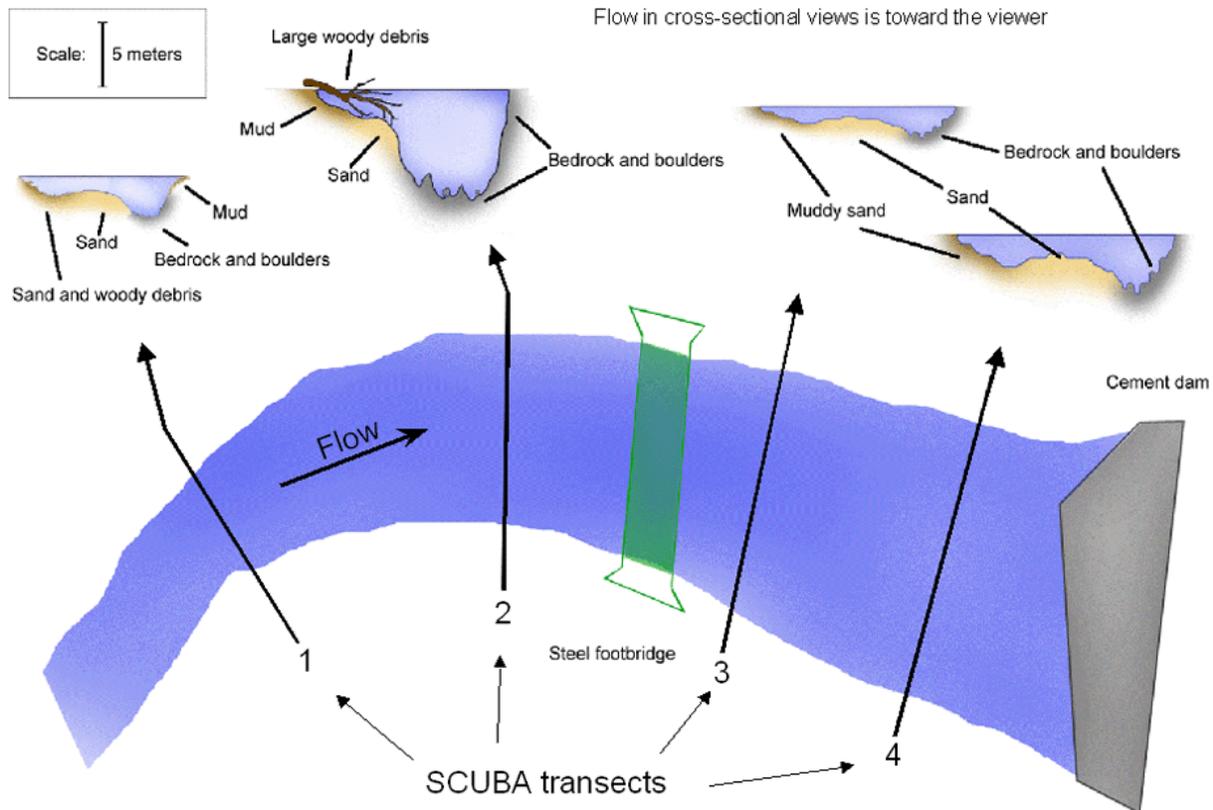


Figure 6. Results of scuba investigation of one impoundment on the Souhegan River.

Development of PISF recommendations

We propose to select the resident species to be modeled based on BFC developed by NH DES for the Lamprey River. The species or species groups that have highest flow needs in particular season (e.g. spawning salmon in the fall) will be selected as indicators for PISF needs and for habitat modeling. For species that are not included in our database, we will develop habitat selection criteria using literature values.

In general terms we will follow the approach developed during the Quinebaug and Souhegan River studies (Parasiewicz, 2005) as described in the following paragraphs.

The flow requirements of the fauna and of the flow regime itself vary through the course of a calendar year. When attempting to prescribe flows in a regulated river, it is necessary to take into consideration these flow and habitat fluctuations. To do this, we partitioned the calendar into seasons. These bio-periods reflect the special or critical times that a particular fauna or life stage may be particularly limited due to a lack in habitat.

The timing and duration of bio-periods are primarily based on upon species present and life history information found in the literature. During the Quinebaug River study we made refinements to the seasons using the simulated hydrograph as a guide, primarily lengthening or

shortening the period by a small percentage in order to have the biological requirements coincide with a consistent flow pattern, which is often associated with a particular bio-activity (such as high spring flows for spawning).

If biological data were unavailable or too sparse, we then developed periods based solely on consistent patterns (either relatively stable or relatively dynamic) in the simulated hydrograph. For example, the termination of the resident species' spawning period was adjusted slightly from general literature information to coincide with the inflection point of the receding limb of the hydrograph – the point where it is likely that the target fauna would cease spawning.

Spring/fall spawning and low flow summer survival/rearing and growth conditions were considered the primary biological periods of importance based on professional experience. Over-winter survival and the spring flood/storage periods are the other bio-periods and were evaluated solely by the simulated hydrograph since data for the targeted fauna are extremely sparse for these two periods.

We selected the spawning periods of the top five target resident species and those of the two selected extirpated anadromous species (Atlantic salmon and American shad) from published studies and literature sources, most of which provided data from outside the immediate Quinebaug area. Bio-period values for a given species were established by exercising professional judgment if the data obtainable were not from the Quinebaug region. For example, spawning data for fallfish was obtained (in part) from New York and Virginia sources in order to estimate the period of spawning for Connecticut and Massachusetts. If the data was limited to these two sources, we “interpolated” between the ranges of dates and consulted the hydrograph to select a season for the Quinebaug region.

Because of zoo-geographic proximity of the Quinebaug, Souhegan, and Lamprey Rivers the number and type of bio-periods selected for Lamprey River should not differ from those identified for Quinebaug River. However, it is conceivable that the timing and species driving habitat criteria for each season could be modified.

Using habitat rating curves developed from any method, in conjunction with flow time series for each river segment or IPUOCR site, we will create a time series of baseline habitat conditions which will be analyzed for flow levels critical to the protected use. We will apply continuous under threshold habitat duration curves (CUT-curves) using the technique described by Capra et al. (1995). The process is illustrated in Figure 7. Using this method we identify four habitat levels that correspond with different protection thresholds. These levels divide the flow regime characteristics along a gradient of potential impact and are named *absolute minimum*, *trigger*, *critical*, and *typical*.

Again we will build here upon the methodology developed during the Quinebaug River Study: A single set of CUT curves for a bioperiod are generated by analyzing negative run-time length (i.e. continuous durations of under threshold) characteristics of habitat time series (habitographs). Habitographs are computed by applying flow/habitat-rating curves developed for restored river conditions to a given season's flow time series. The magnitude and duration of habitat run-length characteristics relative to a series of thresholds is plotted as habitat duration curves on one chart. Thresholds are initially selected on an iterative basis until we were able to refine our evaluation

to target threshold “regions”. These target threshold “regions” demonstrated characteristics where trends depicting common and not-so-common occurrences could be discerned.

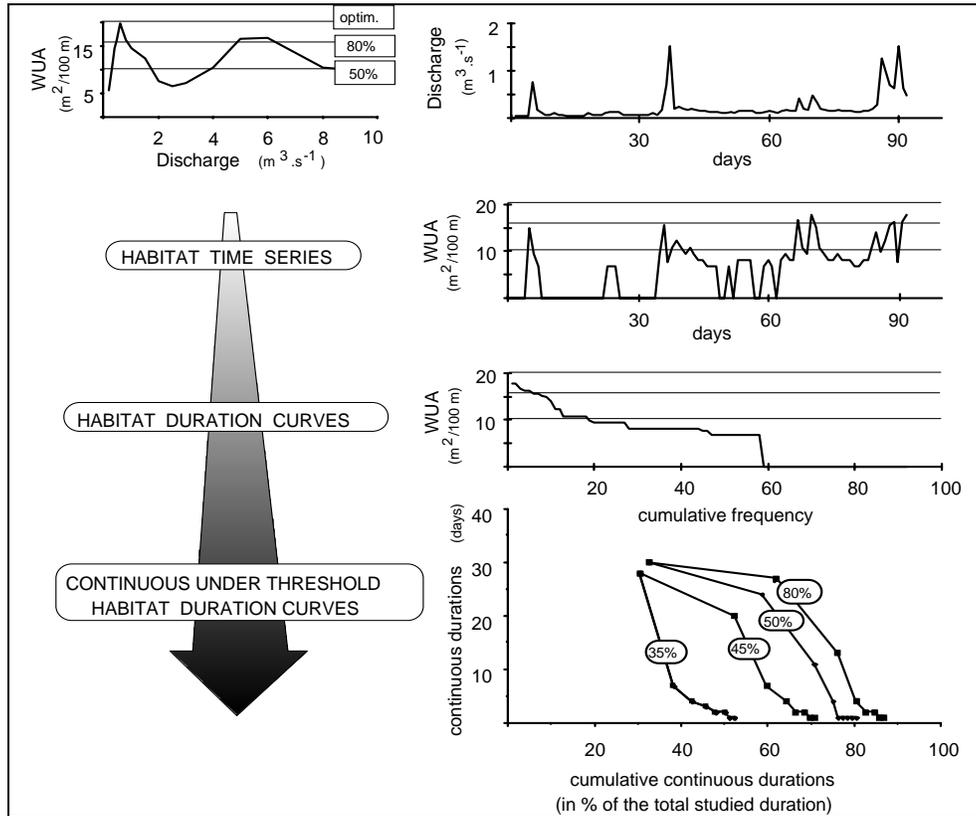


Figure 7. CUT curves from habitat time series (source: Capra et al., 1995).

For the low-flow conditions, we identified four habitat levels that corresponded with different levels of thresholds. These levels were named absolute minimum, minimum, critical, and typical. To define the absolute minimum (which is the lowest habitat level allowable), we select the lowest non-zero habitat level that occurred in the pre-development daily streamflow time series. To define the other three levels, we interpret the shape of the CUT curves and their location on the graph shown as Figure 8.

In Figure 8, the selected increment between habitat levels is 2% of the channel’s wetted area. The horizontal distance between the curves indicates the change in frequency of events associated with a habitat increase to the next level. The curve spacing increases constantly but in non-uniform increments thereby displaying a sudden shift in frequency. We assume that thresholds are associated with such a significant increase of spacing between the CUT curves. We observed that for minimum levels, which are exceeded very frequently and over long periods of time, the curves are steep and located in the lower left-hand corner of the graph. The curve representing the highest level of this group of curves has been chosen as a minimum habitat level. The first curve that stands out is identified as the critical (yellow curve) as it marks the lowest of events more common than minimum (red curve). After exceeding the critical level, the

lines begin to space out a little more. The next significant increase of the distances between the CUT-curves marks a first typical (green curve) event.

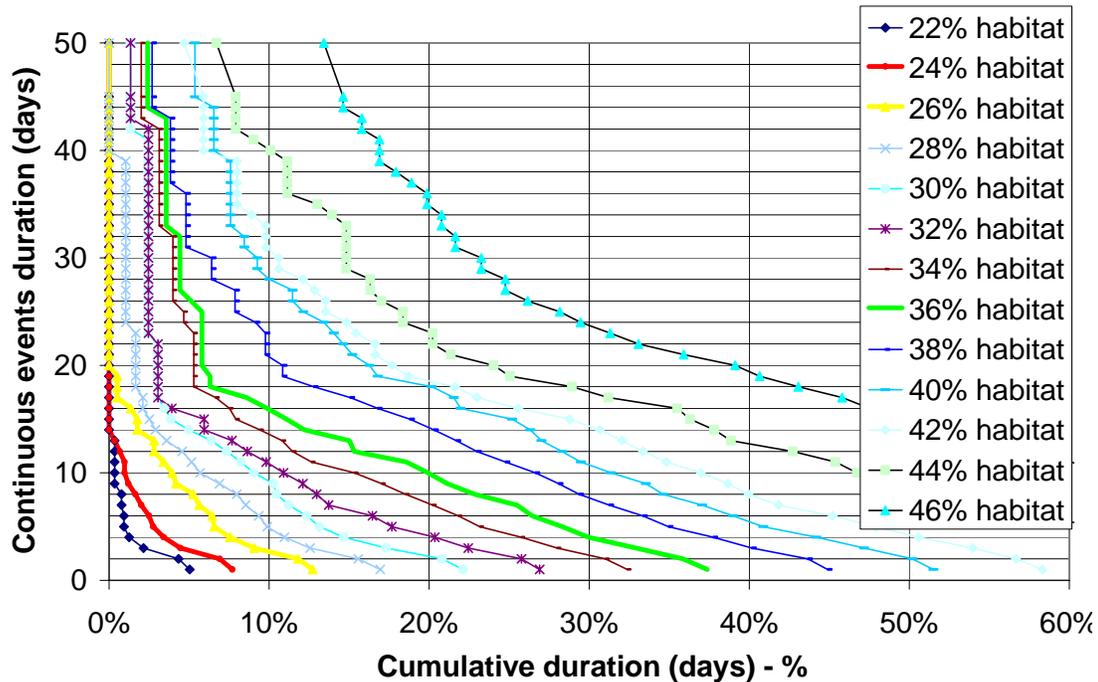


Figure 8. Continuous Under Threshold duration (CUT) curves for adult resident fish in the Quinebaug River during the summer season.

For each of these thresholds, we also identified significant changes in the shape of the curves to define the shortest common, longest common and catastrophic durations. We divided the duration of events into one of two categories: acute or catastrophic. The shortest common duration, the lowest inflection point on the CUT curve, is then used to determine the release pulse length. The longest common duration, the uppermost inflection point of the CUT curve, defined the maximum durations for which the habitat can fall under the threshold or duration between successive pulses as needed. The catastrophic length demarcates the duration that, if exceeded (e.g. for lack of water), would require additional mitigation actions in order to recover the fauna. In an operational sense, approaching catastrophic event duration should trigger an immediate pulse release.

The result of this analysis will be recommendations for seasonal habitat regimes consisting of allowable habitat quantity together with duration and frequencies of flow events with habitat under specific thresholds. In addition, the amount of water necessary to fulfill the above criteria will be defined for every season. We will develop a concept for the application of these criteria by introducing dynamic flow management rules. This will include flows that trigger protective actions, allowable durations of these flows, together with duration and magnitude of protective flow pulses. For each flow scenario we will also analyze change in wetland habitats as well as potential impact on stream miles in the WMA upstream of the designated reach. The above rules will be accompanied by boundary conditions protecting wetlands and upstream areas.

In subsequent steps, we will list river channel improvement opportunities by identifying areas where such measures could be more easily applied than on private property (e.g. public parks). The potential of these measures can be analyzed by simulation of the gain in fish habitat. This step will assist in the evaluation of potential water management vs. restoration trade-off options in the water management plan. This may be particularly applicable where water use conflicts cannot easily be mitigated. The water management plan will build upon simulation results and determine how water can be allocated in order to satisfy the above flow recommendations.

The report describing this phase will consist of the description of completed work, and conclusions with regard to PISF. It will be organized into following sections:

- Locations and the protection goals for IPUOCR entities,
- Description of PISF methods chosen to meet these goals,
- PISF results and their scientific basis:
 - Proposed PISFs will refer to the individual reaches and the study area as a whole.
 - Detailed habitat maps for all surveyed sites and all analyzed species
 - Results of habitat simulation.
 - Matrix of methods, sites, and prevailing criteria
- Discussion of how the proposed PISF values meet the criteria in RSA 483:1 and 483:2 and water quality standards
- Description of the factors for reviewing the PISF found under Env-Ws 1905.03(b) and the results of PUC's assessment.
- Preliminary determination of the designated reach

In the report we will also determine aggregate water use versus stream flow on a daily basis using the draft proposed PISF and the aggregate water use versus stream flow assessment as requested in RFP. We will present the draft proposed PISF values before the advisory committees for review and comment. After the consultation we will revise the report.

6. PISF Public Hearing

One of the unique aspects of the project team's approach is the engagement of stakeholder and public groups at multiple stages of the project, in addition to supporting NHDES in the preparation for and the presentation of the proposed PISF in a public hearing as specified in the RFP. Identification of IPUOCR entities, development of conservation, water use, and dam management plans, and final WMP recommendations will be drawn with stakeholder and public inputs in mind. The project team will deliver a draft report 30 days prior to the meeting and prepare presentation materials based on the draft report, including a multi-criteria decision analysis (MCDA) of alternatives from multiple stakeholder perspectives including identification of IPUOCR needs that may be in conflict, and the stakeholder or public groups that may be expected to express a preference for some IPUOCRs in comparison to others. (Please see further details on the MCDA in the Task 9 description). Team members will be present at the public hearing to present the proposed PISF as well as to answer questions. A copy of all presentation materials will be submitted to the NHDES prior to the meeting and will be available for posting to the DES instream flow website after the meeting. The public comments will be addressed and

potentially could alter the PISF recommendations due to consideration of factors not included in the draft assessment.

7. PISF Report for the Lamprey River

Following the comment period, we will revise the Proposed PISF report, in consultation with the Department, based on the comments received. We will prepare the final PISF Report from the Proposed PISF report with the addition of a section describing how the comments affected the final PISF values [Env-Ws 1905.04 (b)(5-6)].

8. Assessment of Water Use with the Established PISF

Fortunately there is a USGS streamgage on the Lamprey River, downstream of the designated reach, in Newmarket. The gage started recording daily flows in 1935 and continues today. The most recent modifications to the gage made it a real-time reporting station. In addition to flow records, there are 46 years of water quality data at this site. Another, much more recent USGS real-time gage exists on the North River near to Route 125. Both of these gages provide valuable information in assessing supply versus demand (water use and instream flow needs versus flow).

We will develop long term records of Lamprey River daily streamflow (30 years or longer), at five or more locations along the designated reach. This will be performed by using a weighted watershed area approach combined with concurrent flow measurements/observations. At the designated reach locations where we desire a long term flow record, staff gages will be installed. Selection of these locations is based on: watershed area, tributary locations, and specific IPUOCRs. At the staff gages during the low flow periods of the study, the staff gage reading will be recorded and stream flow measured using standard wading rod techniques. At these same monitoring events, the Lamprey River and North River gage flows will be recorded. This then creates a data set of flows at various locations along the designated reach from which rating curves are developed (river flow versus staff gage reading) at each staff gage and relationships are developed between the USGS gage flows and the staff gage flows (these are the concurrent flows). The longer record of concurrent flows of the two USGS gages will underscore the value of using the concurrent flows to derive long term hydrographs along the designated reach rather than by simply using watershed area ratios.

Long term hydrographs (daily flows) to be developed at each of the assigned locations along the designated reach, and for locations in subwatersheds upstream: the five preceding years (2000 – 2005), a three-year “wet” period, a three-year “dry” period, a three-year “mean streamflow” period, a >20-year hydrograph based on the gage flows, and a >20-year hydrograph without human-related effects. The three-year hydrographs will be selected by analyzing all three-year windows of the USGS gage in Newmarket and selecting the “wet” record from the highest 30% of the windows, the “dry” from the lowest 30% windows, and the “mean” from the central 10% windows. The two long term hydrographs are used in the CUT-curve method. The very last hydrograph is created by accounting for the effects of impoundments, withdrawals, and land use

changes, and is meant to assist in determining the ability of the reference fish community to survive in what is considered a “natural” system.

With these hydrographs in hand, we can then compare the locations of water use and the instream flow needs to the flow of water in the system. This occurs by conservatively assuming that the AWUs are using their maximum water allotment for the durations during the day when it is normally used. The net result is an identification of locations where the instream flow is not met, the magnitude of the deficit, the duration of the deficit, and the frequency of the deficit. Knowledge of the deficit characteristics then help guide the water management strategies.

9. Development of WMP Sub Plans

The water management sub-plans have been defined to describe: supply, demand, and management. Since none evolves in a vacuum, they are synthesized into the overall strategy to meet the needs of users and instream flow. It should be recognized that supply, demand, and system operation can work in concert to satisfy competing objectives. However when a system is oversubscribed (excessive demands) or undersupplied (extreme low river flow) or possesses insufficient storage, all needs cannot be met simultaneously. Moreover, the competing objectives or perspectives of different stakeholder groups make it likely that no single “best” alternative is likely to emerge that will satisfy all stakeholders. Therefore, the basic approach to analysis must accommodate multiple decision criteria, perspectives, and a variety of quantitative and qualitative scales. This study proposes to employ multi-criteria decision analysis (MCDA), which has been used successfully in previous watershed management problems in North America and Europe (e.g., Borsuk, et al., 2001; , Gregory and Failing 2002; and, McDaniels, et al., 1999). Several software packages, such as *Decision Lab* (Visual Decision 2000), are available to both speed calculations and clearly present results.

MCDA can help decision-makers understand how to assess different management strategies when IPUOCR needs must be prioritized. When combined with a stakeholder value elicitation process such as used in the Cocheco River contaminated sediments study (Rogers, Seager, and Gardner, 2004), MCDA can help establish a set of intercriteria weightings that represent the preferred prioritization schemes of different instream stakeholder groups. A partially or non-compensatory goal-aspiration method may be appropriate for most instances that call for meeting a PISF specification (such as a minimum or maximum), but places no additional value on exceeding the PISF standard. (Partially compensatory means that overperformance on one criterion might partially compensate for underperformance in another, whereas non-compensatory methods do not recognize any value in overperformance). In this case, a goal aspiration model in which in-stream ecological needs such as maintenance of fish habitat must be satisfied first, followed by mixed use needs such as water quality, and lastly in-stream anthropocentric needs satisfied last, may be an one appropriate approach to prioritizing among competing uses.

There are two areas in particular in which multi-criteria decision analysis (MCDA) could inform the project: development of the PISF specifications, and development of the Water Use and Water Management Plans. Figure 9 depicts the tiered approach proposed, in which information

gathered at the lowest levels (such as the in stream survey, stakeholder interviews, and stream flow data) are synthesized at increasing higher levels. MCDA is called for when contrasting objectives or stakeholder values must compete for scarce resources.

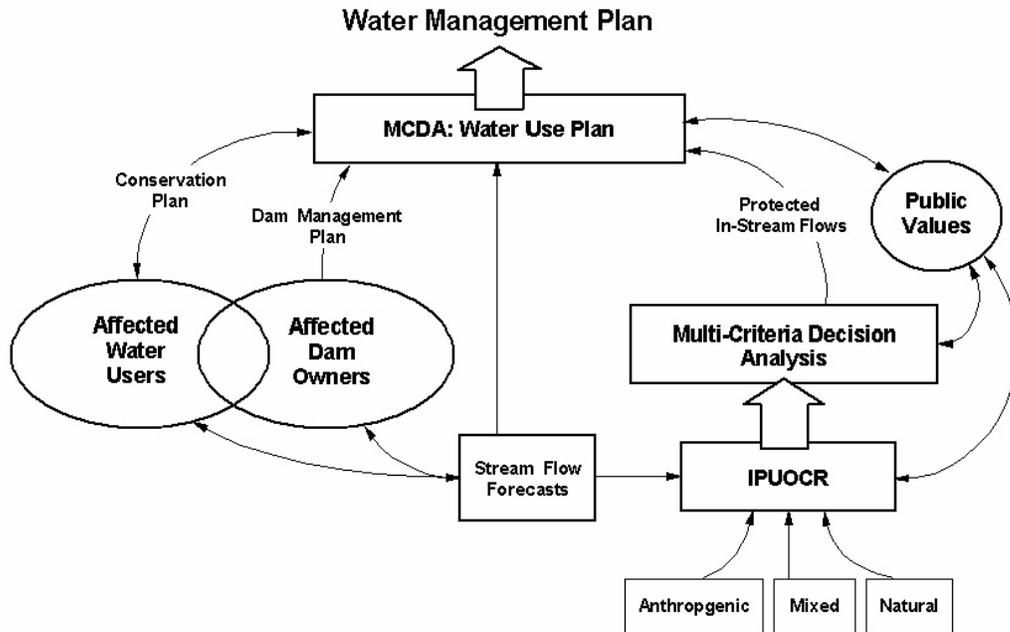


Figure 9. Synthesis of multiple information sources, stakeholder perspectives, and decision criteria using multi-criteria decision analysis.

The initial tasks of this PISF project will clearly delineate the water needs characteristics of the various entities in the system, including the instream flows. A silent but important aspect of management is forecast information. It is possible to avoid projected deficits or user needs going unmet if proper attention and reactions are made to forecasts (for example, see Anderberg, 1980 or Ballester, 1981). Forecasts and reactions to forecasts were not explicitly mentioned in the Request for Proposals, however, since there are near real-time stream gages on the Lamprey River and regionally, forecast information (trend in hydrograph recession, meteorological forecasts) can be employed to minimize or even prevent cutbacks to water users. The water management sub-plan strategies operate in concert to maximize the benefit to all needs while at the same time minimize negative consequences.

Normandeau Associates will take primary responsibility for meeting with each AWU and ADO to discuss the PISF and to query them about water use and management. All information obtained through these meetings will be held in strict confidence. Normandeau can accomplish this task very efficiently as most of the users are within 25 miles of the Normandeau office in Bedford. Don Kretchmer will lead this effort. The basis for the interviews will be a standard technical questionnaire and a value-based semi-structured interview. The questionnaire will be developed in cooperation with watershed advisory group members, including key AWU and ADO within the designated reach, and submitted to the DES for comment prior to conducting interviews. The questionnaire for the Souhegan River study may be found in Appendix C. As with all forms of interviews, surveys, and questionnaires, the UNH team uses a consent form so that individuals are completely aware of the project and the nature of the data collection, and the use of the data. The consent form may be found in Appendix C. Normandeau proposes to send the questionnaire to each user after an initial contact is made prior to the interview and then contact each user to discuss the questionnaire. This approach may reduce the amount of follow up that is required after the interview. The technical information requested from each water user will include but not be limited to the following:

- historical withdrawal records
- future plans for withdrawals
- configuration and location of intakes including depth
- estimated amount of return flow
- stream gaging in the vicinity of withdrawal points
- seasonal, weekly and diurnal variation in water needs
- current conservation measures employed
- potential conservation measures
- staffing related to water use (daytime, 24 hour, weekdays, weekends, seasonal)
- ability to store water and volume available
- ability to reuse water
- timing of planned shutdowns during water use season
- time required to respond to a change in water withdrawal and use
- known conflicts related to water use
- known sensitive IPUOCRs in vicinity of intakes or outflow areas
- estimated costs associated with changing water use

The interviewer will then discuss with each AWU the PISF in detail and have a two-way discussion on the universe of conservation measures that may be available to each AWU to meet the PISF, if any is required. If possible, the interviewer and the representative of the AWU will

then visit each facility in order to understand the relevant aspects of the operation. The site visit will be documented with photos. The result of this task will be a summary of the operation of each AWU and a description of the options available to meet the PISF. A typical user profile from the Souhegan project is presented in Appendix C.

Value-based aspects of the interview will focus on the relative importance of anthropocentric and ecological uses to the respondent. Three key questions are expected to guide the discussion:

- What is important to you (or your organization) about the Lamprey River?
- How do you know when the river is able to provide what is important to you (e.g., adequate flows to allow withdrawals, acceptable water quality or ecological habitat)?
- What do your customers (or constituents, or members) tell you about the river?

The responses will be paraphrased in concise single sentences and compiled into a single page summary of all interviews. Some statements culled from Souhegan interviews focus on ecological health, such as “The health of the River is essential to our operations.” or “We know that the river is healthy when we see big fish or birds of prey.” Others focus on water availability or quality. Taken as a whole, these statements represent multiple perspectives regarding the importance of different aspects or services that are represented in the IPUOCR entities. After completion of interviews with key AWU, ADO and other stakeholders, each a wider set of participants will then be asked to rank all of the written statements (including those paraphrased from others) in order of importance to them. Similar survey responses will be grouped together (partly to protect anonymity) and represented in the MCDA study by applying the greatest weightings to the criteria corresponding to the statements ranked highest.

The ADOs will be handled in a similar manner as AWUs. Owners who are also on the AWU list will be asked questions from both questionnaires. Again, Don Kretchmer will lead this effort. The technical information requested from each dam owner will include but not be limited to the following:

- FERC operating orders, if any
- Mode of operation by season (run of river, peaking, store/release)
- Estimated amount of storage under their control
- Routes of water past dam and capacities at different water levels (turbines, spillways, overflow sections, fishways)
- Existence of bypass reaches
- Ability to change flows
- Historical flow records and ability to gage flows
- Staffing related to flow management (automated vs. part time attendant vs. full time attendant)
- Time lags in implementing changes in flow at dams

- Projected changes in operation or upgrades to facilities
- Known conflicts related to dam operations
- Known IPUOCRs in vicinity of dams
- Estimated costs associated with changing operations

The interviewer will then discuss in detail, with each ADO, the PISF and have a two-way discussion on the universe of conservation and or operational measures that may be available to each ADO to meet the PISF. If possible, the interviewer and the representative of the ADO will then visit the dam and other relevant aspects of the operation. The site visit will be documented with photos. The team has worked on numerous dam and hydropower projects throughout the country and is intimately familiar with operations of such facilities. The team will draw this experience to interface with the users on this project. The result of this task will be a summary of the operation of each ADO and a description of the options available to meet the PISF. These will form the starting point for the development of the Dam Management Plan.

While it may be necessary to conduct the value-based and technical interviews separately, the advantage of parallel technical and value-based approaches is that it allows for direct participation in the value-based aspects by groups that are not engaged as AWUs, ADOs or already familiar to NHDES in an advisory capacity. This may include non-government organizations, recreational in-stream users, indirect users (such as bird watchers), or members of the public at large. Moreover, despite similarities shared by AWUs in the technical aspects (such as withdrawal rates or timing), the views expressed by AWUs with regard to IPUOCRs may be especially diverse, depending upon the purpose of the water use. For example, municipal water agencies may be more concerned about having adequate capacity for hydrant flows in the event of a fire than a group that is primarily concerned with water quality.

a. Conservation Plan

The conservation plan aims to determine, for each water user, how their needs can be met, altered, or reduced when instream flow needs prevail. The individual water use characteristics (average water use, temporal characteristics of water use, variability of water use, duration of water use, return flows for the water use) will be delineated along the river. Each user will define preferable options in the event that their full water Lamprey River need cannot be met. For example, using alternative water sources, ability to use less water, using water during off-peak water demand hours, maximizing use during periods of maximum return flows, capacity to store water (including aquifer storage and recovery), and/or alternative locations of Lamprey River withdrawal. These alternatives will not be undertaken in a vacuum but in concert with water use actions, forecasts, and reservoir management.

In addition, each AWU will be audited in its water use with the objective of identifying how their use may occur more efficiently. This can include: leak detection programs, metering, process modification, plumbing modifications, schedule modification, etc. Based on the audit, cost estimates to achieve more efficient water use, as well as the estimates of the water savings. The future projected water uses for each AWU will also be estimated, if records of past use exist, or

if data for projection is available. This will allow the water management plan to also address future critical developments with respect to the PISFs.

The river channel improvement measures (e.g. creating cover and habitat structure) will be listed indicating the most desirable locations and the areas of highest opportunity (e.g. public lands) associated with AWUs. These measures will be incorporated in the catalog of conservation measures for each AWU giving the opportunity for trade offs between water use and habitat restoration. The habitat simulation model and elaborated habitat rating curves computed during PISF determination phase will be used as a measure of ecological costs and benefits of proposed strategies.

Ultimately, conservation measures and strategies for all AWUs will be compiled into one data base, including: costs, timing, water savings, and payback period.

b. Water Use Plan

A water use plan will be developed according to the guidance developed in the RFP. The first stage in the development of the water use plan will be a comparison of the PISF proposed for each relevant IPUOCR and the flow regime of the river. The hydrologic model will be run under a scenario that includes all users withdrawing at the maximum rate and a minimum amount of natural rainfall and runoff. This will represent a worse case water use scenario for each IPUOCR. Similarly conservation will be minimized and a worst case scenario for dam operations will be developed. If there is insufficient water to meet the needs of the IPUOCRs and the AWU's and ADO's, a MCDA strategy will be developed to address the shortfall that satisfies the highest priority needs first. PISF values may vary in terms of timing of flow required, quantity of flow required and duration of the required flow. To address the conflicts between water required for instream flow and water use, proposed plans or scenarios will be developed to eliminate or reduce the conflict. Because there may be several ways to eliminate or reduce the conflict including elements of the conservation plan as discussed above and dam management as discussed below, the water use plan must incorporate elements of those plans. Examples of specific water use changes that might be considered for incorporation in the water management plan include:

- change in the timing or duration of withdrawals
- sharing or trading water (by agreement or by market forces)
- storage of water during high river flows (for example in aquifers)
- reductions in withdrawal shared among all users during critical times
- re-use of water or returning flow after use
- process changes
- temporary shutdowns

Whereas the Conservation and Dam Management Plans identify the *alternatives* (or decision variables) available, the Water Use Plan identifies the *merit* or criteria by which all the alternatives may be judged. Consequently, the WUP is required to balance the needs of AWU, ADO, and IPUOCR (as specified in the PISF) and will describe the pros and cons of each

scenario including the cost and the potential impact on the IPUOCRs if the required PISF cannot be met. Feasible water use scenarios which may include a number of changes in conservation, withdrawals, and dam operations will be run through the hydrologic model that forms the basis of the PISF to insure that they will meet the PISF throughout the designated reach. A mixed partially compensatory goal aspiration and utility maximization framework may be applicable. In the case of the AWUs and ADOs, utility maximization (of economic benefits) is most applicable. However, the *distribution* of benefits (and costs) may not be perceived as being fairly appropriated in a simple total utility maximization scheme. If some stakeholders are perceived to be disproportionately impacted, a partially compensatory or constrained compensatory utility maximization model may be most appropriate. On the other hand, the nature of the IPUOCR criteria are fundamentally different from the AWU and ADO criteria, and exceedances in IPUOCR criteria are unlikely to be tolerated by negatively impacted AWU or ADO users. Therefore, only partially or non- compensatory models interaction between IPUOCR and the AWU / ADO criteria shall be considered.

c. Dam Management Plan

If the comparison of the PISF and flow regime of the river as described above indicates a shortage of river flow in order to meet the PISF for each of the IPUOCRs, dam management will be evaluated along with conservation and changes in water use. Some of the dam management strategies that may be included are:

- change in the timing of releases from storage
- change in the mode of hydropower operations
- release of water through spill gates when insufficient flow is available to generate power
- coordinate the timing of releases to match the demands of water users and IPUOCRs
- change dams physically to gain better control of water releases
- dam removal
- temporary drawdown of impoundments

As described above for the Water Use Plan any dam management scenario considered should be integrated with conservation and water use alternatives and run through the hydrologic model to ensure the PISF requirements are met.

10. Proposed WMP

The Conservation, Water Use, and Dam Management Plans will be synthesized into a Proposed Water Management Plan (WMP) that takes the form of a set of operating recommendations for different hydrologic conditions such as plentiful flows, normal flows, or drought. This synthesis will be a spatial and temporal delineation of critical instream flow as the Lamprey River hydrograph recedes. The implementation of strategies within the plan is first predicated on the

accuracy of forecast information: that is, rather than being reactive to real-time low flows that press AWUs and ecosystems into stressed status, forecast information (for example continued dry, hot weather) allows the river system some anticipated decision influence period when strategies can be employed to react to the potential for the stressed state yet minimize disruption to AWUs and ADOs. For example, reducing dam releases when water withdrawals are high, and increasing releases when withdrawals reduce, or maximizing water in off channel storage. The proposed WMP is a choreography of supply and demand to minimize impacts to all stakeholders. The WMP may highlight the most vulnerable stakeholders (the first to feel the pressure of low flows). In fact just the development of the WMP may prompt certain stakeholders to embark on proactive measures to make them less vulnerable in times of low flow, for example through habitat or stream restoration, or through conservation/use modifications.

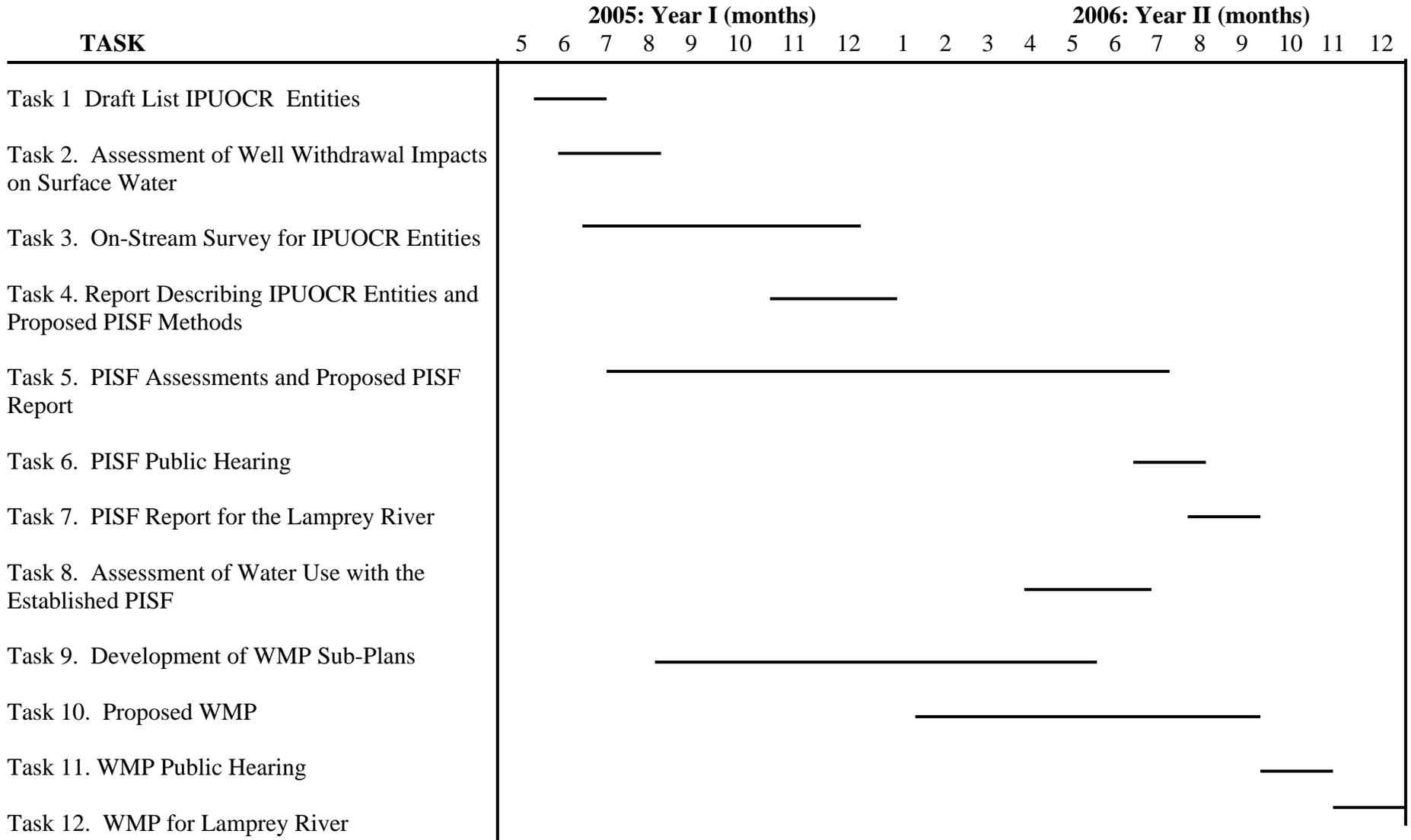
11. WMP Public Hearing

As with the PISF public hearing, the early and frequent engagement of stakeholder and public groups throughout the life of the project is expected to enhance support of NHDES in the preparation for and presentation of the proposed WMP in a public hearing. In addition to meeting the requirements specified in the RFP, including delivery of a draft report 30 days prior to the meeting and the preparation of presentation materials based on the draft report, the project team will incorporate the results of the MCDA identifying potential conflicts or opportunities for compromise among different affected groups. Team members will be present at the public hearing to present the proposed WMP as well as to answer questions. A copy of all presentation materials will be submitted to the NHDES prior to the meeting and will be available for posting to the DES instream flow website after the meeting. The public comments will be addressed and potentially could alter the WMP recommendations due to consideration of factors not included in the draft assessment.

12. Water Management Plan for the Lamprey River

Following the comment period, we will revise the Proposed WMP report based on the comments, in consultation with the Department. We will prepare the final WMP Report from the Proposed WMP report with the addition of a section describing how the comments affected the final WMP. We will submit the WMP Report to the Department to assist the Department meet the deadlines of Env-Ws 1906.07(a).

IV. Proposed Project Performance Schedule



V. Confidentiality Statement

Signed Confidentiality Statements by a representative of each team member may be found on the pages after the references.

VI. Conflict of Interest Statement

Signed Conflict of Interest Statements by a representative of each team member may be found on the pages after the Confidentiality Statements.

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Appendix A – Project Experience and Descriptions

On the following pages may be found short project description of the projects representing the most relevant experiences of the project team in reference to the Lamprey PIFS and WMP project.

Instream Flow Studies and Water Management Plan for the Souhegan River Designated Reach

New Hampshire Department of Environmental Services

The Lamprey River instream flow study and water management plan is modeled after the Souhegan River study, and both studies are the two pilot studies for the state of New Hampshire. The tasks in both studies are the same. The Souhegan study is in its tenth month, and at about 50% completion. The IPUOCR identification and survey were completed last summer, by employing the same methods proposed for the Lamprey study. The photo documentation report was completed and submitted to NHDES in August 2004. The IPUOCR report was submitted in October 2004. This report and other work products may be found at the project website - <http://www.unh.edu/erg/souhegan/> or at the NHDES website - <http://www.des.state.nh.us/rivers/instream/souhegan.asp> . We have met with both the TRC and the WMPAAC at various times as well as made public presentations on project status and progress.

In summer and fall 2004, field data collection for instream flow estimates was initiated and will be completed in spring and summer 2005. In fall 2004, high resolution low altitude photos were taken and are presently being used to define habitat characteristics in the riparian zone. The summer 2004 data was placed in GIS format and mapped in electronic form.

Staff gages were constructed at six locations in the designated reach. At these locations, streamflow is measured at low flow times and correlated to the flow at the downstream USGS gage. These correlations will be used to construct the long term hydrographs at each location, and ultimately to be used to compare the instream flow needs to discharge. The synthesis of this data will be used for development of the CUT curves as well as where and what types of management strategies are necessary.

Estimation of induced recharge is nearly completed. All large groundwater users within 500 feet of the designated reach and its tributaries have been contacted and given questionnaires. Their historic water use studied, wells located with GPS, and the distance to the river measured. USGS aquifer information was available for all wells and used to estimate induced recharge for each well.

The New Hampshire Natural Heritage Bureau cooperated with this study by providing the necessary information of rare, threatened, and endangered flora and fauna for the designated reach and its riparian zone.

Letters were sent to the planning boards, city planners, and select boards for each town in the watershed requesting notification of large water use proposals during the duration of the study. Whether or not the proposals are approved, they will be factored into the water management plan.

Presently each water user (AWU) and dam owner (ADO) are being interviewed in order to establish water needs and use characteristics. The questionnaire for this phase of the project may be found in Appendix C.

**Ecohydrology Study on the Quinebaug River
Massachusetts and Connecticut
Millennium Power**

(copy of the report previously provided on CD)

The Ecohydrology study on the Quinebaug River in Massachusetts and Connecticut focuses on the assessment of the river's bio-physical conditions, the identification of deficits, and the determination of potential improvement measures. It is part of a multidisciplinary investigation required by the US Army Corps of Engineers Section 404 permit and by the Massachusetts Department of Environmental Protection Section 401 Water Quality Certification for the Millennium Power Project in Charlton, Massachusetts. The study began in Fall 1999 and was conducted by the Instream Habitat Program of the Department of Natural Resources at Cornell University. The results of the study provide a basis for future decision-making processes and for the design of a long-term implementation plan.

The mesohabitat simulation model for the target fish community is one of the principal tools used in this investigation. In summer and fall 2000, 34 km of the river were mapped for their habitat distribution at low flow. A sensitivity analysis of the quantitative distribution of hydro-morphological units was used to identify the representative sites. The sites (combined length - 9.2 km) were then surveyed at three different flow situations ranging from 0.3cfs/m (cubic feet per second per square mile drainage) to 1cfs/m.

Fish community-specific habitat/flow rating curves provided an assessment tool for simulating various management options, such as temporal and spatial manipulation of flows and improvements to the riverbed structure. It also facilitated in defining seasonal recommendations for flow augmentation. Hydro-morphology, fish habitat, fish density, invertebrate samples, and temperature data were analyzed in every section to determine the present condition of the river and its restoration potential. The model has then been used to evaluate the remaining 30 miles of the Quinebaug River of the same stream order.

The Quinebaug River is a fourth-order river with multiple impoundments and a history of industrial use not too dissimilar than the Lamprey River. Within the study area, the different river sections demonstrate a wide range in condition, type, and degree of environmental impact. A number of deficits in fish habitat, river morphology, flow and thermal regime, as well as the presence of pollution, have been identified. Extended duration of low flow conditions combined with channel alteration have been identified as key sources of these deficits.

Comparison of habitat models

As a part of this study the use of different habitat models and their influence on the results of instream habitat assessment and therefore the conclusions for river management, was investigated. The experiment conducted for this purpose was to develop, for the same portion of the Quinebaug River, three types of models: a microhabitat model with univariate habitat suitability criteria (PHABSIM), a microhabitat model using multivariate criteria (HARPHA) and the mesohabitat model with multivariate criteria (MesoHABSIM). The following conclusions were drawn upon the results:

- Only MesoHABSIM passed the model validation test performed when using additional fish collections.

- Univariate habitat suitability criteria, as used in standard PHABSIM, are a major source of disagreements between the models.
- The second largest source of inaccuracy is an error introduced during the extrapolation of microhabitat observation (as in PHABSIM and HARPHA) from the site scale to the river scale.

Eightmile River Instream Flow Study

This initial biological and physical survey of the Eightmile River in southeastern Connecticut was performed as a component of the ongoing Wild and Scenic River study being conducted by the National Park Service (NPS). The Wild and Scenic study was authorized during a 2001 session of Congress for the Eightmile and its major tributary, the East Branch. The river was nominated for study mainly due to its preserved rural character, cultural resources, unique geology, and exemplary ecological communities. The study is also supported by the Eightmile River Watershed Advisory Committee and the Eightmile River Wild and Scenic Study Committee. The Northeast Instream Habitat Program (NEIHP) at the University of Massachusetts Amherst began work in spring, 2004 on a segment of the study focused on fish and freshwater mussel habitat in the river. NEIHP completed field work and initial analysis for Phase I of the study in late 2004. The information we collected contributes to the knowledge of the baseline status of the river and associated watershed. The completed portion of the NEIHP Eightmile study serves as a basis for future field work and analysis, as well as provides initial management and planning recommendations to the Committees involved in managing the river system. NEIHP anticipates completing a further phase of the study in the coming year.

As part of the work efforts, NEIHP developed a Reference Fish Community (RFC) for both the upper portions of the Eightmile and the East Branch as well as the main stem of the river below the confluence. This reference community is intended to approximate the assemblage of fish species, or the aquatic community which should be expected in a river similar to the Eightmile (based on size, ecoregion, and physical characteristics) with very limited anthropogenic influences (i.e. ecologically integer). Once the RFC was developed, the actual species assemblage (the eXisting Fish Community, or XFC) was surveyed and compared to the reference community. The existing species within the Eightmile were surveyed using the grid electrofishing technique during summer, 2004. At this time, observations of physical characteristics were also recorded in an attempt to determine associations between fish species and densities and physical habitat. Thermal recorders were placed throughout the watershed in April, 2004 and hourly water temperatures were documented through the summer. The watershed and survey locations were divided into sites based on general geography and similar features, and then hydromorphology, physical attributes, fish density, and temperature data were analyzed in each site to document the present status of the river. In order to further evaluate the river's existing aquatic community, we performed freshwater mussel surveys in several locations. We also performed a detailed literature review to supplement the information presented here.

In the study area, the Eightmile River is a second to fourth order river with the unusual characteristic of being largely undeveloped in a densely populated area of the country. It is rare

for a watershed in coastal Connecticut to remain so highly forested, with few point and nonpoint pollutant discharge sources. Its baseline condition may serve as a benchmark for other rivers in the state. The following list includes a number of basic observations regarding the aquatic community trends at the sites. Since the Eightmile retains high quality habitat throughout much of the watershed, it also seems appropriate to provide recommendations for areas to protect rather than restore.

The following observations were made during the evaluation of the study area:

- Eightmile River represents a functional ecosystem unique in a highly populated area of the country.
- Compared to the early 20th century, the magnitude, duration and frequency of low flows has significantly changed, creating more stable flow conditions.
- Compared to historical template, the river lacks larger woody debris and associated structure.
- Water temperature is raised by a number of impoundments and channel modifications on the Eightmile River and tributaries.
- Water temperatures in the East Branch were warmer than the upper mainstem.
- A relative lack of canopy shading in the East Branch may potentially add to the warmer temperatures there.
- The river system has a high species diversity overall but fish density and abundance is similar to the regional average.
- Species diversity decreases in sites where the river channel has been modified.
- The existing fish community is similar to the projected reference community but some species, such as longnose dace, brook trout, Atlantic salmon and American eel are in abundances lower than expected.
- Dominating species reproduce well in the river.
- High abundance of juvenile white suckers indicates stable flow conditions in the river during spawning and incubation season in the spring.
- High abundance of blacknose dace potentially suggests abundance of shallow margin/higher velocity habitat.
- Low abundance of longnose dace potentially suggests lack of flow concentration caused by structures (e.g. boulders or large woody debris).
- There is a significant correlation between fish community and habitat suite in the sampling sites.
- The sites in or immediately downstream of large alluvial deposits generally had high fish population densities and low species diversity.
- The Eightmile has a diverse freshwater mussel community with two state listed species.
- Hamburg Cove has a high level of boat traffic. The most abundant mollusk species here was the invasive Asian clam.

Hatfield Dam Removal project

The approximately 150 ft long, 16 ft high, 300 yr-old Hatfield Dam is located in Hatfield, Massachusetts near the mouth of the Mill River, a tributary to the Connecticut River. The dam is

located on a rock outcrop approximately 6 ft in height. The dam itself is approximately 10 ft high. This dam, the only one on the Mill River, blocks the movement of fish (Atlantic salmon, American shad, blueback herring and lamprey) and other aquatic organisms between the Connecticut River and the Mill River watershed. The tributaries to the Mill River, however, appear to contain ideal spawning and nursery habitat for Atlantic salmon. The discovery of a nesting salmon downstream of the dam further suggests that the fish might be available to establish a run at this system. A recent inspection of the dam by the Massachusetts Office of Dam Safety has rated this dam as at risk of failure, raising the possibility of dam removal for the sake of public safety as well as river restoration.

Dam removal at the site is complicated by a number of factors. The Mill River watershed is considered important due to the large diversity of freshwater mussels, including the federally endangered dwarf wedgemussel, that reside in the river and its tributaries. Removal of the dam could negatively impact that mussel population through the introduction of predatory species. It could also potentially impact the extensive upstream wetland system through a decrease in water levels. Therefore, a project team has been assembled to examine the feasibility and potential impact, of river restoration through removal of the Hatfield Dam or other design alternatives that help restore one or more ecological functions of the river.

The issues of dam removal and how it will impact river ecosystems are not confined to the Mill River. As part of a proactive effort to protect this valuable ecosystem and its many rare and endangered species, we are developing new approaches for evaluating the environmental costs and benefits of dam removal and for identifying ecologically-based stream flow requirements that can be used elsewhere in the Connecticut River watershed and throughout the state

Developing a sustainable management plan for the Pomperaug River watershed.

Connecticut

Connecticut State Department of Environmental Protection

Pomperaug River Watershed Coalition

The Pomperaug River watershed is a rural, 90 square mile area in west central Connecticut. The watershed includes the Pomperaug River and its tributaries, including the Nonnewaug River and the Weekepeemee River, which meet to form the Pomperaug, and Transylvania Brook and Hesseky Brook. This river system runs over the Pomperaug Aquifer, a highly productive aquifer that yields millions of gallons of water a day.

The Pomperaug watershed has a relatively low level of human-induced alterations compared to other rivers in the region. It has high quality groundwater and surface waters, and more than half of the basin remains in forest cover. Because of relatively high ecological integrity, the Pomperaug serves as a model of a healthy river ecosystem and could be used as a reference river for other river systems in the region. However, rapid population growth in the region and higher per capita water use has caused an increase in water demand, putting considerable pressure on the Pomperaug aquifer. Thus, the growing water demand could jeopardize the quality of the Pomperaug ecosystem.

In order to protect the river, the Pomperaug needs a well-defined, long-term watershed management plan that will assure the sustainable use of the resource and mitigate existing deficits. The plan should address both ecological and water management goals and follow a well-balanced concept for resource use that will maintain the ecological integrity of the river. It prompts a comprehensive study carried out by multidisciplinary team of scientists representing environmental and engineering perspectives.

This pilot project (performed in collaboration with local USGS) covered the concept development and the first stage of the habitat component of the comprehensive study outlined above. A watershed-wide instream habitat survey was conducted in order to develop a quantitative instream habitat model. This model will provide a general overview of available fish habitat, which will be used for the concept development process. Just last month the Connecticut Senate allocated additional funding to continue the study.

Measuring River Ecosystem Health in Western Massachusetts - Mill River, Hatfield, MA
Massachusetts Executive Office of Environmental Affairs
Massachusetts Environmental Trust
(copy of the reports previously provided on CD)

Located on the western edge of the Connecticut River valley, the Mill River is a tributary of the Connecticut River. The watershed is widely recognized as one of the state's most significant environmental attributes due to its exceptional wildlife habitat. At present, the river and its tributaries are known to support the greatest diversity of freshwater mussels in Massachusetts, including the state's only viable population of Federally Endangered dwarf wedgemussels. It also contains one of the Commonwealth's largest blocks of un-fragmented forest, an exemplary floodplain forest community, and habitat for over 20 state-listed plants and animals (most found in or adjacent to the Mill River and its tributaries). Nine native mussel species, four of which are classified as rare and endangered (one federally endangered), have been found in the river. However, due to a growing demand on water withdrawals from both major tributaries of the Mill River (Roaring Brook and West Brook), the unique fauna within the ecosystem could be irreparably damaged if protective measures are not taken.

From a physical standpoint, the Mill River is characterized by a 44 mi² drainage area and an average channel width of 24.6 ft. The study area encompasses a 12.6 mi stretch of river upstream of the confluence of the Connecticut River. The main stem of the Mill River is a low gradient, warm-water stream that winds through fairly flat topography. It is strongly influenced by its interaction with groundwater flow through the surrounding wetlands, as well as cold upland tributary streams that drain the hilly topography to the west.

The study investigated the availability of suitable fish habitat and dwarf wedgemussel under low flow conditions. The primary tools used for this effort were the MesoHABSIM habitat simulation model and the target fish community developed specifically for the Mill River.

The main conclusions of the study were:

1. Although the Mill River has relatively high abundances of fish habitat, the river is still greatly affected by human activity.

2. Chronic low flows cause habitat alteration and high water temperatures
3. The sporadic water quality problems and thermal stresses act as “environmental bottlenecks”
4. The flow patterns in the Mill River are stable due to complex interactions with adjacent wetlands and subsurface flows
5. Large and stable habitat clusters are necessary for sustainable dwarf wedgemussel colonies
6. The largest colony of dwarf wedgemussels can be strongly affected by present and future water withdrawals

Long-Term Impact Analysis of the University of Connecticut's Fenton River Water Supply Wells on the Habitat of the Fenton River
Connecticut
University of Connecticut

As part of a satisfactory finding by the State of Connecticut's Office of Policy and Management (OPM) (part of the University of Connecticut's (UConn) Environmental Impact Evaluation for the North Campus Master Plan), it is required that UConn conduct a study to evaluate water withdrawals from the University's Fenton River water supply wells. The study will focus on the impact of the wells and their effect on the aquatic habitat of the Fenton River. UConn withdraws water using water supply wells placed in a stratified drift aquifer located along a one-mile section of the Fenton River. The four Fenton River wells are registered by CTDEP for a maximum withdrawal rate of 0.8443 million gallons per day, MGD (1.31 cubic feet per second, cfs) (CTDEP Letter, June 21, 1991). As part of the impact assessment of UConn's water use, the University study team will investigate the relationships between fish habitat and instream flow for a section of the Fenton River from Old Turnpike Road to Mansfield Hollow Lake.

The overall goal of the study is to develop relationships between instream flow and habitat in the Fenton River for selected fish species and life stages using a physical habitat model such as the Physical Habitat Simulation System (PHABSIM). The project is led by a team of scientists from the Environmental Research Institute at the University of Connecticut. The Instream Habitat Program at Cornell University is subcontracted to provide scientific and logistic support for specific tasks related to the first objective.

Fish habitat assessment on Stony Clove Creek, NY using MesoHABSIM
New York
Greene County Soil and Water Conservation District
New York City Department of Environmental Protection

The Stony Clove Creek, located in Greene and Ulster counties, flows through the central Catskill Mountain region of eastern New York. In the town of Phoenicia, the Stony Clove joins the Esopus River, eventually emptying into the Ashokan Reservoir, which supplies New York City with nearly ten percent of its drinking water.

From a physical standpoint, the Stony Clove Creek faces river management problems due to historical hydrological alterations, impaired aquatic fauna and fisheries, and dramatic seasonal fluctuations in flow. The New York City Department of Environmental Protection (DEP), in partnership with the Greene County Soil and Water Conservation Districts, is restoring stream channel stability in priority sub-basins in order to improve water quality in city reservoirs. This study was therefore prompted by the need to develop a comprehensive, multi-objective Stream Management Plan.

To help accomplish this task, the Instream Habitat Program and the Greene County Soil and Water Conservation District conducted a detailed instream habitat study of the main stem of the Stony Clove. This project also served to demonstrate the applicability of a newly-developed instream habitat modeling technique (MesoHABSIM) in conjunction with the Target Fish Community approach in the integration of aquatic habitat management, flood protection and water quality protection. Using fish habitat as an indicator of ecological health, this study investigates the availability of suitable fish habitat under low-flow conditions.

The main conclusion of this project was the dramatic deficit of brook trout habitat associated with a lack of woody debris and pool structure. It also showed the utility of MesoHABSIM for river restoration. It led to Phase II of the project on the Westkill River with a purpose of evaluating individual measures of natural-channel-design approach to restoration.

Instream habitat evaluation of Santee River below Wilson Dam

South Carolina

Santee Cooper Public Service Authority

Presently, Santee Cooper is involved in a federal re-licensing process under the Federal Energy Regulatory Commission (FERC); the current license expires in 2006. FERC is required to evaluate and balance the competing interests of the project.

The construction of the Santee Dam in 1942 resulted in the diversion of a majority of the natural stream flow from the Santee River to the Cooper River. The diversion created sediment problems in Charleston Harbor at the mouth of the Cooper River. In 1985, U.S. Army Corps of Engineers re-directed most of the flow back to the Santee River. The diversion and re-diversion of water at Santee Dam created a 37 mile bypass reach.

As part of the FERC re-licensing process and per the recommendations of the US Fish and Wildlife Service (USFWS), South Carolina Department of Natural Resources (SCDNR), National Marine Fisheries Service (NMFS) and South Carolina Coastal Conservation League (SCCCL), Santee-Cooper is sponsoring an instream flow study to address :

1. Evaluate small boat navigation using River2D two-dimensional hydraulic modeling
2. Evaluate floodplain connectivity
3. Evaluate ecosystem integrity and function related to instream flows and flooding
4. Evaluate the existing fish community and habitat relationships relative to flow
5. Evaluate flow scenarios that are consistent with characteristics of the inflow regime to the reservoir.

6. Evaluate water quality, including temperature and oxygen levels during summer months

The goal of the instream flow study is to evaluate dam operations for habitat enhancement, protection or mitigation of impacts. These recommendations will then be evaluated by FERC, federal and state agencies, and other stakeholders and a course of action will be determined to balance competing interests on the river.

Merrimack River Watershed Assessment Study
Massachusetts and New Hampshire
U.S. Army Corps of Engineers (New England District)

As a subcontractor to CDM, Normandeau Associates in helping the New England District of the US Army Corps of Engineers develop a watershed management plan for the Merrimack River. The Merrimack River watershed has a total drainage of 5,010 square miles with about three-quarters of the watershed in New Hampshire and one-quarter in Massachusetts. The water quality in the river is impaired and the river does not fully support beneficial uses such as aquatic habitat recreation, water supply, and hydropower.

The study is developing a watershed management plan that will guide investments to achieve conditions that support feasible beneficial uses. This will be accomplished by conducting a water resources and ecosystem restoration investigation of the Merrimack River. The study will be used to answer the questions:

- What are the existing and potential future feasible uses of the river?
- What are the pollutant sources that may impact these uses?
- What is the relative contribution of pollutants from various sources?
- What project(s) will provide the most significant return on investment?
- Which projects have the highest priority?

The study is being conducted in several phases. Phase I efforts will identify current and potential future uses of the river, assessing the existing water quality conditions, identifying and quantifying pollutant loads to the river, developing models to evaluate the effects of all existing pollutant loads including non-point sources, evaluating various CSO and non-CSO abatement strategies, and completing an initial inventory of potential ecosystem restoration projects in the watershed. Phase II efforts will be determined following the results of Phase I and undertaken based on availability of non-Federal and Federal funding. At this time it is anticipated that Phase II efforts may focus on in-stream flow issues, possible testing for nonstandard water quality parameters, more detailed analysis of abatement alternatives, and providing for preliminary assessment of ecosystem restoration projects identified in Phase I.

The study will include an inventory of current and potential future uses, determining existing water quality conditions (dry and wet weather), analyses of river water quality using models to evaluate benefits of alternative abatement strategies, determining relative contribution of pollution from varying sources, and evaluating the benefits of alternative abatement plans.

Specifically the scope will include data and analysis needed to determine causes of water quality degradation in the Merrimack River and to assess the impact of CSO and other point and non-point contributions to the river.

Azischohos Dam Minimum Flow Study
Magalloway River, Wilsons Mills, Maine
Central Maine Power Company

Normandeau Associates used computer modeling procedures of the Instream Flow Incremental Methodology (IFIM) to quantify the amount of habitat available for brook trout and landlocked Atlantic salmon over a range of alternative stream flows in the tailrace and bypass area for a proposed hydroelectric station. Normandeau developed habitat suitability curves for landlocked salmon in cooperation with the Maine Department of Inland Fisheries and Wildlife. In addition, Habitat Evaluation Procedures (HEP), developed by the Western Energy and Land Use Team, were used to determine the amount of habitat for the evaluation species in the bypass reach and in a compensation area. This was done to assist in the development of a plan to mitigate for losses in habitat associated with the project.

Hiram Project Instream Minimum Flow Study
Saco River, Baldwin and Hiram, Maine
Central Maine Power Company

Normandeau Associates performed an instream minimum flow study for Central Maine Power's (CMP) Hiram Hydroelectric Plant on the Saco River. This study, the first of its kind in Maine, utilized the Instream Flow Incremental Methodology (IFIM), developed by the Western Energy and Land Use Team of the U.S. Fish and Wildlife Service (USFWS). The primary purpose of the study was to predict the impacts that various low flows would have upon the spawning habitat for sea-run Atlantic salmon and habitat to support their fry and juveniles below the hydroelectric plant. Normandeau developed habitat suitability curves from literature and unpublished data. The IFIM was supported by the Physical Habitat Simulation System (PHABSIM) library, which includes the computer programs WSP, IFG-4, and HABTAT, plus linking and support programs. The IFIM demonstrated an acceptable minimum flow of approximately half the New England Regional Aquatic Base Flow, which was approved by the Federal Energy Regulatory Commission.

Farmington River IFIM
Farmington River, Connecticut
Connecticut Department of Environmental Protection

Normandeau Associates conducted an instream flow study on the West Branch and mainstem of the Farmington River in Connecticut (covering 81 miles). The study objectives were to determine the instream flow requirements needed to support fisheries habitat, recreational resources, and aesthetic qualities at a level sufficient to qualify the West Branch of the Farmington River for

Federal designation as Wild and Scenic. Additionally, Normandeau identified the quantity, quality, and timing of diverse river uses in relation to existing flows. An alternatives analysis was conducted: 1) to determine the level of additional consumptive withdrawals from the river system that was compatible with Wild and Scenic River designation, and 2) to examine the effects of various flow regimes (including those associated with a one hundred year drought) on competing stream uses.

Instream flow needs for fisheries within the Connecticut section of the West Branch and mainstem of the Farmington River were assessed using the Instream Flow Incremental Methodology (IFIM). The effects of alternate flows on recreational opportunities and aesthetics were assessed based on: 1) a user survey of recreationists on the river during spring, summer, and fall, 2) a field evaluation of recreational conditions conducted by experts and local volunteers, and 3) an evaluation of how scenic conditions are affected by flows based on videotapes and panel review.

The alternative analysis required the development of a hydrologic model that integrated existing watershed yield, water storage of three major reservoirs, flow rights of a downstream riparian user, and flow requirements to sustain historic recreation and fisheries resources.

Johns River Dwarf Wedge Mussel Survey
Dalton, NH
New Hampshire DOT

Normandeau Associates was contracted by the New Hampshire DOT to search for dwarf wedge mussels (*Alasmidonta heterodon*), a Federally listed endangered species, in the Johns River near its confluence with the Connecticut River. This study was conducted to determine whether reconstruction of the bridge that crosses the Johns River would adversely affect a resident dwarf wedge mussel population. The entire substrate of the Johns River that would be affected by construction activities was systematically searched by a Normandeau diver.

Prior to conducting the search, a dwarf wedge mussel expert with the US Fish and Wildlife Service asked the diver to locate specimens from an area of the Connecticut River where a known population existed to verify the diver's ability to identify specimens in situ. The diver successfully located several specimens within a 15 minute search and satisfied the USFWS concerns.

Snowmaking Needs vs. Minimum Flow Requirements
Killington, Vermont; Mt. Snow, Vermont
Killington Ltd.

Diversion of water from small, headwater streams for snowmaking purposes has resulted in serious concerns by state and federal fisheries and wildlife officials regarding potential impacts to aquatic biota. Normandeau has been involved with three minimum flow studies for Killington, Ltd.

These efforts included evaluation of minimum flows required to sustain native coldwater fisheries in small headwater streams, negotiations with state fisheries and wildlife biologists, and

presentation of expert testimony at Vermont Act 250 hearings. Winter minimum flows negotiated for two of these projects have yielded minimum flows substantially less than initial agency standards based on summer flow requirements. The third project, which is ongoing, involves the use of the U.S. Fish & Wildlife Service developed Instream Flow Incremental Methodology (IFIM) on Vermont's Ottauquechee River.

**Peshtigo River Instream Flow Studies
Caldron Falls, Johnson Falls and Peshtigo Dam; Northeastern Wisconsin
Wisconsin Public Service Corporation**

In response to a request from the Federal Energy Regulatory Commission for additional information regarding the effects of various flows on the Peshtigo River, Normandeau Associates conducted two instream flow studies.

An instream flow assessment for fisheries was conducted in the free-flowing sections of the river below three hydroelectric projects: the Caldron Falls Project, the Johnson Falls Project and the Peshtigo Project. Habitat conditions (depth, velocity, substrate and cover quality) were documented at representative transects at a series of five flows, including ones typically associated with project operations as well as run-of-river conditions. Rates of downramping associated with proposed project operations were also recorded at the study transects. Effects of project operations were evaluated for spawning walleye and for the fry, juvenile, adult and spawning stages of white sucker and smallmouth bass.

A second study focussed on the effects of various flow regimes on whitewater boating below the Johnson Falls Project. Normandeau Associates designed and conducted a systematic field evaluation of whitewater boating conditions under a series of seven flows. A group of expert boaters, using criteria and data sheets developed by Normandeau, ran the river at the various flows and evaluated the boating conditions. Results were later tabulated and analyzed. The effects on fisheries of whitewater boating recreational flows were also evaluated.

**A Geographic Information System for Aquatic
Resource Characterization and Management in the
Upper Ohio River Basin of Western Pennsylvania
Ohio River Valley Water Sanitation Commission (ORSANCO)**

Normandeau Associates completed a 5-year, \$1,000,000 effort to develop a geographic information system (GIS) for aquatic resources management in the Ohio River basin of western Pennsylvania. The study area covered approximately 110 miles of the Ohio, Allegheny, and Monongahela Rivers. The project was a joint venture of the Pennsylvania Department of Environmental Protection (PA DEP), the Pennsylvania Fish and Boat Commission (PFBC), and the Ohio River Valley Water Sanitation Commission (ORSANCO). The objectives of the project were 1) to create and apply a GIS in the characterization of aquatic habitat and use by fish and mollusks, and 2) to develop and implement GIS-based resource inventory and management applications.

ArcInfo and related software systems (products of Environmental Systems Research Institute, Inc.) were used to develop a sophisticated GIS application for the storage, retrieval, management and analysis of aquatic resources data. The GIS will be used to aid in the design of field studies to inventory physical habitat. Further analysis of the data acquired from these studies will be used to refine habitat characterizations and their representative coverages within the GIS.

Normandeau developed the basemap by photorevising existing 1:24,000 scale digital mapping using newly flown 1:8,400 scale true-color aerial photography. Coverages were developed for bathymetry (depth) and aquatic areas (large, relatively homogeneous sections defined on the basis of river morphology) where existing information was available and sufficient. Normandeau performed aerial and river-level videography in order to characterize near-shore cover and substrate conditions, which became another coverage within the GIS. Spatial analysis of this data, combined with extensive review of fisheries literature and previous field studies, resulted in the development of a preliminary habitat characterization system. Normandeau performed a detailed side-scan sonar survey of the study area to acquire substrate and bathymetric data in the off-shore areas. The digital sonar images were interpreted and incorporated into the GIS via on-screen digitization using image processing software. Spatial analysis of this information was used to refine habitat characterizations.

Supporting coverages in the GIS include features such as the lock and dam navigation system, water intake and discharge points, recreational sites, hydroelectric facilities, transportation routes, industrial sites and municipal boundaries. Digitized photographic images of areas representing different habitat categories, environmentally sensitive areas, and other features were integrated into the GIS to provide a visual reference medium.

The Ohio River Basin GIS is designed to interface with existing natural resources and environmental regulatory data storage and retrieval systems, such as U.S. Environmental Protection Agency STORET, IREACH, and NPDES files; U.S. Geological Survey gaging station records and water quality/biomonitoring networks; and natural resources databases maintained by PA DEP and PFBC.

Provisions have been made to conceptually link the Ohio River basin GIS with efforts by state and Federal environmental agencies to develop natural resource inventory and classification systems which are regional and national in scope. The GIS enables natural resources trustees to better comprehend the present status of natural resources in the basin, and the structure and function of a large navigation river ecosystem.

**Modeling Instream Habitat and Water Temperature
Regimes in Marsh Creek
Gettysburg, Pennsylvania
Eisenhower National Historic Site, National Park Service**

Marsh Creek is one of only two permanent streams flowing through Eisenhower National Historic Site (EISE). The ecological integrity of these streams, and particularly Marsh Creek,

has been an ongoing concern for many years due to increased human development and disturbance of the upper watershed. The largest and most direct threat to Marsh Creek was the recent issuance of a permit to Gettysburg Municipal Authority (GMA) to withdraw surface water just upstream from the EISE boundary and augment withdrawals with well water (a novel permit situation within Pennsylvania). Water withdrawal and augmentation could comprise a significant fraction of the total stream flow in Marsh Creek through EISE, altering available habitat quantity or water quality. The proximity of the GMA activity (adjacent and just upstream of EISE), coupled with the relatively short length of stream within the Park boundary, are of great concern because the activity may substantially degrade the ecological integrity of a unique Park resource.

To address the ecological concerns of the Park Service, Normandeau Associates has been providing instream flow modeling and water temperature monitoring of the stream. A detailed study map of instream habitat units was constructed using a GPS unit with sub-meter accuracy and then plotted using ArcView software which will also serve as a spatially explicit data library for project samples.

The fish community was sampled using a mesohabitat approach -- quadrat samples (3.05 m X 6.10 m) of habitat use taken by electrofishing. To capture spatial variability of important habitat features within mesohabitat units, microhabitat measurements were collected using 1 m² grid samples within quadrats. Within each grid, nine evenly-spaced substrate measurements were taken and at the center of each grid, mid-column water velocity, bottom water velocity, and water depth were measured. Cover within the four corners of the grid also were identified and enumerated. This sampling regime provides a spatially explicit, hierarchical habitat sample.

Next, a physical habitat model of the stream was constructed using transect-based descriptions of channel shape in RHABSIM. Available habitat for habitat guilds as determined from the quadrat sampling described above will be modeled, based on a combination of empirical measurements and available habitat literature. Physical habitat results will be integrated with water temperature monitoring at four sites to determine how water withdrawal activities are impacting the ecological integrity of the stream. Results also will serve to identify sensitive ecological components in need of continued monitoring and any areas in need of mitigation.

Contoocook River Waste Load Allocation Study Town of Jaffrey, NH

Dr. Ballestero performed this project that identified the relation between low flows and oxygen deficits in the Contoocook River due to effluent from the Jaffrey wastewater treatment plant and to recommend solution strategies to mitigate these deficits. The project included: construction of a stream gage and its calibration, stream gaging, river surveying, development of flow duration curves, computer hydraulic analyses (to delineate habitat) and calibration, sampling and monitoring of water quality (temperature, pH, BOD, dissolved oxygen, nitrogen species), computer simulation of dissolved oxygen and calibration, and development of mitigation strategies. The study included NHDES (water quality bureau) input throughout its performance.

Assessing Cocheco River Contaminated Sediment Management Alternatives from Multiple Stakeholder Perspectives: The planned dredging of the Cocheco River from Dover NH to Great Bay created an opportunity to study several novel contaminated sediment management technologies under development at the Center for Contaminated Sediments Research at the University of New Hampshire. This study identified several key stakeholders, including town officials, abutters, non-government organizations, and local business representatives. Preliminary interviews were conducted with each stakeholder to identify the key criteria that would be the basis for evaluating any option. Four areas were of primary concern: water quality, ecological habitat, human habitat, and economics. A follow-up questionnaire helped reinforce and quantify the responses logged in the initial interview, and results were reported to the technology developers. Verification interviews ensured that survey responses were interpreted correctly, and introduced the performance characteristics of each alternative to the stakeholders.

The technology experts rated the performance of each technological option with respect to the decision criteria identified. Because not all stakeholder criteria were amenable to quantitative scales, experts relied on semi-quantitative or qualitative scales such as “high, medium, or low” were appropriate. This precluded use of an optimization approach such as cost/benefit analysis, which requires that all performance measures be reducible to a single scale. Moreover, stakeholder expressed a strong opinion that all criteria were interconnected, suggesting that overperformance in a single area could not compensate for poor performance in others.

A multi-criteria decision analysis (MCDA) called *outranking* was employed to study the trade-offs available to contaminated sediment managers, identify potential conflicts between different stakeholder groups, and assess the potential for compromise or consensus. This approach simply determines the dominance of one alternative in comparison to another, with outranking scores weighted to reflect the relative importance of each criterion to different stakeholders, generating a unique preference ordering for each stakeholder. The planned alternative, dewatering and disposal at a compromised riparian site, performed well with most stakeholder groups, which was consistent with the fact that consensus had been achieved prior to initiation of the study. However, the MCDA model correctly predicted the first, second, third and fourth choices made by the majority of stakeholders, and in every instance predicted the top two choices correctly, suggesting that the model is consistent with stakeholders’ intuitive or heuristic reasoning processes, and may be informative in problems of greater complexity or size.

Feasibility of Main Stem Reservoir Developments - Powder River Wyoming Water Development Commission

Dr. Ballestero was a principal investigator of this project. The project objective was the water resources development of the Powder River Basin in Wyoming. The Powder River extends from the Bighorn Mountains eastward to the state boundary with Nebraska and northward to the state line with Montana. The river is characterized by very clear water from the west, and salty, turbid water from the south and east. Development strategies had to consider the effect of both removing fresh water and sediment. Many of the results of this study are now being employed in the assessment of the present coal-bed methane strategies in the same watershed. Dr. Ballestero was in charge of all hydrology and hydraulics on the project, as well

as public involvement (numerous public forums) and interactions with the Wyoming Water Development Commission.

Legal, Environmental, and Hydrological Consequences of Missouri River Diversions States of Iowa, Missouri, and Nebraska, also the Kansas City Southern Railroad

Dr. Ballesterio was the lead investigator on this project. A very large water withdrawal was proposed by a private interest and approved by the federal government. The diversion would take water from the Missouri River at the Oahe Dam in South Dakota and pump it to eastern Wyoming. The objection by the downstream states to this proposal brought the matter before the US Supreme Court. Dr. Ballesterio developed and produced the majority of the technical information to support the successful opposition to this project by the downstream states. Dr. Ballesterio: developed long term flow statistics for the river (including flow duration curves and 7Q10), identified critical stream reaches of habitat adversely affected by the withdrawals, reviewed system-wide reservoir operation strategies and how these strategies would be affected by the diversion, prepared the hydrology in the context of the governing water law, prepared legal briefs, and supplied depositions.

Expert System for Landfill Siting New Hampshire DES (Waste Management Bureau)

Dr. Ballesterio was the lead investigator on this project. Siting new landfills is one of the most controversial issues facing local populations. This project reviewed all federal, state, and local laws and built there quantitative requirements into a computer model. In addition, the computer included quantifiable and judgmental stakeholder factors in its algorithm. The computer model was an expert system: it could be queried by a user and given site specific information, from various sites, and then rank the sites from most acceptable to least acceptable. The model was meant as a screening tool, such that many sites could be prioritized without the need for extensive field work at each. The prioritized list from the expert system could then be used to determine how many of the top sites would then undergo further, more detailed field investigation. The model was compared to a concurrent study performed by traditional means. Of note: of the top 10 sites (out of 72) selected by the consultants, the expert system agreed with 8.

Appendix B – Personnel Resumes

On the following pages are brief resumes of all project personnel.

THOMAS P. BALLESTERO

Associate Professor of Civil Engineering
University of New Hampshire
Hydrology and Water Resources

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EDUCATION

Pennsylvania State University: B.S. in Civil Engineering, 1975
(Environmental Engineering)
Pennsylvania State University: M.S. in Civil Engineering, 1977
(Hydrology and Hydraulics)
Colorado State University: Ph.D. in Civil Engineering, 1981
(Hydrology & Water Resources)

REGISTRATION

Professional Engineering License in New Hampshire, Colorado, and Wyoming
Registered Professional Hydrologist (AIH)
Certified Ground Water Professional (NGWA)
Licensed Professional Geologist, New Hampshire

TECHNICAL SOCIETIES

American Geophysical Union, Member
American Institute of Hydrology, Member and Secretary of State Chapter
American Society of Civil Engineers, Member
American Water Resources Association, Member
American Water Works Association, Member
National Ground Water Association, Member
Universities Council on Water Resources

EXPERIENCE SUMMARY

1989-present	Associate Professor of Civil Engineering, UNH
1993-1999	Chairman, Department of Civil Engineering, UNH
1986-1999	Director, New Hampshire Water Resources Research Center, UNH
1983-1988	Assistant Professor of Civil Engineering, UNH
1982-1983	Division Manager, Water Resources, Simons, Li and Associates, Inc.
1980-1981	Senior Hydrologist, Simons, Li and Associates, Inc.

EXPERIENCE NARRATIVE

At the University of New Hampshire, Dr. Ballestero teaches eight different courses in hydrology and water resources engineering. His research interests are broadly in the field of water resources computer simulation and field measurement of parameters. Current research projects upon which he is working include: comparison of stormwater treatment technologies; urbanization effects on runoff and water quality, simulation of historic salt water reductions to New Hampshire salt water marshes; groundwater flow into coastal and estuarine systems; stream restoration; and constructed wetlands from contaminated sediments.

Dr. Ballestero has been nationally and internationally involved in water resources projects including: groundwater development in both northeast Brazil and Colombia, riverbank stabilization in Argentina, the effects of port construction in Brazil, testimony before the U.S. Congress regarding ground water contamination, measurement and development of landfill gas in Bermuda, monitoring of groundwater contamination in Colombia and South Korea, assessment of environmental hazards in northern Russia, estuarine monitoring in Puerto Rico, and an advisory/review capacity on the Boston Harbor clean-up program.

Dr. Ballestero has performed numerous consulting projects in the last 20 years. In the areas of river mechanics and sediment transport, these projects include: analysis of the Foster Pond earthen dam failure (Windham, NH), Hudson River sediment transport characteristics (Halfmoon, NY), analysis of coastal erosion and breakwater failure (Humboldt Bay, CA), Winnepesaukee River bank failure and channel scour (Laconia, NH), and Little River flooding and erosion (Hampton, NH).

Prior to his employment at UNH, Dr. Ballestero was employed by Simons, Li and Associates, Inc. The primary consulting efforts of this firm was sediment transport. Dr. Ballestero's position there was Senior Hydrologist and Division Manager of the Water Resources Engineering Division. His primary efforts in this position was the project management of water resources development proposals (ground water and surface water supplies), hydropower feasibility analyses, hydrologic analysis and simulation, evaluation of contaminant migration, water rights, and design and evaluation of water monitoring networks. At the time he left Colorado, western states were just beginning instream flow studies.

Selected PUBLICATIONS (* - refereed)

Ballestero, T. P., 1996, "Nonpoint Source Aspects of Land Disposal of Wastes", Invited Paper, in Proceedings of the NEIWPC Conference entitled "Residuals Management, Where Are We Going?", March 26 & 27, Westford, MA.

- * Ballestero, T. P. and Jason C. Clere, Modeling of Estuarine Sediment Transport on the Piscataqua River: Evaluation of In-Channel Disposal of Dredge Spoils, submitted to ASCE Journal of Hydraulics, in revision.
- * Ballestero, T. P., J. P. Marrone and D. M. Trottier, 1993, "Effects of Transportation Structures and Ice on Salt Water Marsh Hydrology and Hydraulics", in Hydraulic Engineering '93, V. 1, Hsieh Wen Shen, S.T. Su, and Fang Wen eds., ASCE, New York, NY, pp. 150-155.

Ballestero, T. P., June 10, 1992, Evaluation of Waste Load Allocation Strategies for Jaffrey, NH, University of New Hampshire, Durham, NH.

Celikkol, B., M. R. Swift, T. P. Ballestero, A. Bilgili, J. Clere, and J. Pavlos, 1992, Piscataqua River Dredging/Sediment Transport Program Final Report, Submitted to NH OSP, University of New Hampshire, Durham, NH.

Ballestero, Thomas P., October, 1988, Piscataqua River Dispersion Study in the Vicinity of the Proposed Dover WWTP Outfall, Final Report, submitted to City of Dover, Durham, NH.

Ballestero, Thomas P., October 1985, Final Report: Dead River Physical Model and Computer Simulations, for SEA, Inc., UNH, Durham, NH.

Ballestero, T. P., January, 1985, Assessment of Hydraulic Consequences Due to Remediation Measures for PCB Contamination in the Acushnet Harbor, MA, for Normandeau, Inc., Durham, NH.

Ballestero, T. P., May, 1984, Analysis and Design of Streambank Stabilization for the Rio Paraguay at Puerto Formosa, Argentina, for Raymond International, UNH, Durham, NH.

Saunders, M. P., L. Butikofer, F. J. Trelease, T. P. Ballestero, and B. A. Anderson, 1983, Water Resources Development of the Powder River Basin, Wyoming, Wyoming Water Development Commission.

LaGasse, P. F., M. R. Peterson, J. D. Schall, T. P. Ballestero, and B. A. Anderson, 1983, Analysis of Hydrology and Hydraulics Causing the Perkins Road Bridge Failure, Memphis, Tennessee, Simons, Li and Associates, Inc., CO.

Simons, D.B., T. P. Ballestero, B. A. Anderson, R. M. Summer, and Y. H. Chen, 1983, Analysis of the Hydrologic, Legal, and Environmental Effects of Surface Water Diversions from the Missouri River Basin, Simons, Li and Associates, Inc., CO.

Simons, D.B., R. M. Li, M. P. Conner, T. P. Ballestero, and W. T. Fullerton, 1983, Analysis and Design of a Low Weir on the Kansas River, Topeka, Kansas, Simons, Li and Associates, Inc., CO.

"Chapter III: Hydrologic Analysis" in Engineering Analysis of Fluvial Systems by Simons, Li and Associates, Inc., SLA, 1982.

Simons, D.B., R. M. Li, W. T. Fullerton, M. P. Conner, and T. P. Ballestero, Cowlitz Falls Hydropower Sedimentation Study, Simons, Li and Associates, Inc., CO, 1982.

Simons, D. B., R. M. Li, W. T. Fullerton, M. J. Ballantine, and T. P. Ballestero, 1981, Design of GCC Intake Structure on the Colorado River Near Debeque, CO, Simons, Li and Associates, Inc., CO.

Simons, D. B., K. G. Eggert, and T. P. Ballestero, 1981, Design and Evaluation of Water Monitoring Networks, US EPA, Washington, D.C.

Simons, D. B., R. M. Li, R. K. Simons, W. T. Fullerton, T. P. Ballestero, and M. P. Conner, 1981, Hydrologic Analysis of the Rio Grande River Basin, New Mexico, US COE, Albuquerque, NM.

Ballestero, T. P., 1981, Feasibility Analysis of Small Scale Hydropower Development on Meadow Lake Creek, Gilmore, Idaho, U.S. DOE, Washington, D.C.

Piotr Parasiewicz
Department of Natural Resources Conservation
University of Massachusetts
310 Hodsworth Hall
Amherst, MA01003
+ 413 577 1239 voice + 208 693 9330 fax
Email: piotrp@forwild.umass.edu

Education:

- 1998 - Ph. D. Natural Resources Management and Water Engineering, University of Agricultural Sciences in Vienna, Austria.
Advisors: Univ. Prof. Dr. Mathias Jungwirth and ao.Univ. Prof. Dr. Stefan Schmutz.
- 1993 - M.S., Environmental and Water Engineering, University of Agricultural sciences in Vienna, Austria.
Advisors: Univ. Prof. Dr. Mathias Jungwirth and Univ. Prof. Dr. Siegfried Radler.
- 1988 - B.S., Environmental and Water Engineering, Department of Hydrobiology, Fisheries and Aquaculture, University of Agricultural Sciences, Vienna, Austria.
- 1984 - Arabic, University of “Al Fateh”, Tripolis, Lybia.
- 1980 - Advanced Mathematics Program in “Klement Gottwald” High School, Warsaw, Poland.

Special training courses

- 1994 – Instream Flow Incremental Methodology (IFIM) - Stream Habitat Sampling Techniques” Colorado State University, Ft. Collins, CO.
- 1994 - “Using Computer-Based Physical Habitat Simulation (PHABSIM) System”, Utah State University, Logan, UT.

Research expertise and interests

Habitat modeling: Quantitative modeling of running water ecosystem with focus on system scale physical habitat assessment and modeling, Instream Flow/Habitat Models.
River restoration: Assessment and maintenance of ecological integrity, comprehensive river management concepts, river restoration planning, construction and evaluation.
Fish ecology and fisheries management: Fish community structure, diversity and population dynamics.
Fish passage: Development of innovative technologies for diadromous and freshwater fishpassage (design, planning, construction and evaluation).
River Survey and Instrumentation: physical and biological survey designs
Development and application of flow meters and multiplex sensors, ADP, GPS, Aerial Photography.
Computer Aided Design (CAD), Digital Terrain Models (DTM), Geographical Information Systems (GIS), Acoustic Doppler Profiling (ADV), environmental statistics, computer programming.

Academic and professional appointments

- 2004-present. University of Massachusetts, Amherst, MA .
Research Associate Professor, Department of Natural Resources Conservation.
- 2000-2004. Cornell University, Ithaca, NY.
Research Associate IV. Department of Natural Resources. Director, Instream Habitat Program.
- 2000-present. University of Massachusetts, Amherst, MA .
Adjunct Assistant Professor in Aquatic Ecology and Engineering, Department of Natural Resources Conservation.
- 2003-present. University of Connecticut, Storrs, CT.
Adjunct Assistant Professor in Aquatic Ecology and Engineering, Department of Natural Resources Management and Engineering,
- 1999-2000 Cornell University, Ithaca, NY.
Post Doctoral Fellow, Aquatic Ecological Engineering, New York Cooperative Fish and Wildlife Research Unit
- 1998-1999 University of Agricultural Sciences, Vienna, Austria.
University Lecturer, Institute of Water Provision, River Ecology and Waste Management Department of Hydrobiology, Fisheries and Aquaculture,
- 1994-1998 University of Agricultural Sciences, Vienna, Austria.
Research Associate, Institute of Water Provision, River Ecology and Waste Management. Department of Hydrobiology, Fisheries and Aquaculture,
- 1988-1994 Research Assistant, Department of Hydrobiology, Fisheries and Aquaculture, University of Agricultural Sciences, Vienna, Austria.

Select relevant publications in peer-reviewed journals

- Nestler, J., Parasiewicz P. & N. L. Poff (accepted for publication). First principles based attributes for describing a template to develop the reference river. *River Research and Application*
- Parasiewicz P. (2003): Upscaling: Integrating habitat model into river management. *Canadian Water Resources Journal*. Special Issue: State-of-the-Art in Habitat Modelling and Conservation of Flows **28** (2) p. 283-300.
- Jacobson, R. & Parasiewicz, P. (2002): Methods for Defining Instream Flow Standards: New developments in habitat modeling. In proceedings of Connecticut Instream Flow Conference. Berlin, CT 3/23/2001, p. 99 – 113. Yale University.
- Parasiewicz P. (2001): MesoHABSIM - a concept for application of instream flow models in river restoration planning. *Fisheries* **29** (9) p. 6-13.

- Parasiewicz P. & M. J. Dunbar (2001): Physical habitat modelling for fish – a developing approach - *Archiv für Hydrobiologie. Suppl. (Large Rivers Vol. 12)*, 135/2-4 p. 239-268.
- Parasiewicz P., Hofmann H. C. & B. Höglinger (1999): The DVP - Depth Velocity Position Bar - a multiplex instrument for physical habitat measurements in small riverine domains - *Regulated Rivers: Research and Management*, **15**, 77-86.
- Parasiewicz, P., S. Schmutz & O. Moog, (1998): The effects of managed hydropower peaking on the physical habitat, benthos and fish fauna in the Bregenzerach, a nival 6th order river in Austria, *Fisheries Management and Ecology*, 1998, **5**, 403-417.
- Parasiewicz, P. (1996): Estimation of physical habitat characteristics using automation and geodesic-based sampling. *Regulated Rivers: Research & Management*, Vol. 12, 575-583.

DONALD W. KRETCHMER
Senior Limnologist
Certified Lake Manager

Mr. Kretchmer has over 20 years of experience as a limnologist, specializing in freshwater aquatic ecology and fisheries. His experience involves aquatic ecosystem restoration and management, nutrient and dissolved oxygen modeling in lakes and streams, bioenergetics modeling of fishes, environmental impact assessment, permitting, natural resource damage assessment, and limnological, groundwater, surface water and fisheries fieldwork supervision, data interpretation and reporting.

EDUCATION

M.S. 1986, Water Resources Management, University of Wisconsin-Madison
B.S. 1982, Natural Resources, Cornell University

PROFESSIONAL EMPLOYMENT HISTORY

1987-Present Normandeau Associates, Inc.
1986-1987 Alliance Technologies Corp.
1985-1986 University of Wisconsin, Center for Limnology
1982, New York State, Cornell
1983-1984 Biological Field Station
1983 New York State Resource Information Laboratory

AFFILIATIONS

North American Lake Management Society
Lake Wentworth Association
Lakes Region Conservation Roundtable
NHDES Stormwater Recharge Advisory Subcommittee (1999-2000)
NHBIA Instream Flow Committee (1999-2002)

SELECTED PROJECT EXPERIENCE

Souhegan River Instream Flow Study (NH) (ongoing) – Responsible for Normandeau tasks related to the establishment of a protected instream flow for critical resources. Leading stakeholder interaction, interface with affected water users and dam owners and development of a dam management plan and a conservation plan. Directing studies related to the establishment of protective instream flows for terrestrial, recreation and riparian resources. Principal Investigator.

Tennessee Valley Authority (TN and 7 other states) (2002-2003) - Prepared water quality section of EIS for Reservoir Operating Study. Alternatives for the future management of water quality, transportation, flood control and recreation throughout the entire TVA system were evaluated. Task Manager.

U.S. Army Corps of Engineers (MA,NH) (On-Going) - Water Resource Evaluation of the Lower Merrimack River. Evaluating storm water, CSO inputs, background water quality, time of travel and bathymetry of the system as a part of a larger effort to understand the dynamics of nutrients, bacteria, and toxic substances throughout an 80-mile reach of the river. Includes all major tributaries between Concord, NH and seacoast. Project Manager.

Yadkin, Inc (NC) (On-Going) – Yadkin Water Quality Study. Evaluating the limnology of a river and reservoir system (four impoundments) as a part of a relicensing effort. Issues include nutrient enrichment, temperature, dissolved oxygen dynamics and mitigation of dissolved oxygen problems. Study design and results presented to large stakeholder group. Project Manager.

Tapoco Reservoir Water Quality Study (NC, TN) (1996-2004) - Evaluated limnology, fisheries, and wetlands of river reservoir system's four dams as a part of relicensing effort. Project Manager.

U.S. Army Corps of Engineers (1997-2001) - Snake River Productivity Study (WA); Documented limnology and primary productivity of Lower Snake River to support modeling of potential changes in primary and secondary productivity associated with removal of four hydropower dams. EIS evaluated anadromous fish movement throughout the system. Project Manager.

Manchester WaterWorks (NH) (1999) – Lake Massabesic Watershed Management Plan. Prepared a comprehensive watershed management plan for the water supply for the City of Manchester, NH. Project incorporated transportation, GIS, water quality data, ground data and planning information. Project Manager.

New England Power (NH, VT) (1998-1999) – Fifteen Mile Falls Water Quality Study. Evaluated dissolved oxygen and water quality at a series of three major hydropower projects on the Connecticut River. Project Manager.

New York State Department of Environmental Conservation (1995-2003) - Onondaga Lake Natural Resource Damage Assessment Plan (NY); Prepared a plan to compensate the citizens of the Syracuse area and New York State for injury to the natural resources and recreational potential of Onondaga Lake attributable to releases of hazardous and non-hazardous substances over nearly a century. Project Manager.

SPECIAL TRAINING

USSCS, Short Course on TR-20 and TR-55; Computational Methods for Hydrology, 1988.

Maine DEP, Short Course on Phosphorus Allocation Methodology for Lakes, 1989.

New England Interstate Water Pollution Control Commission, Lakes Modeling Short Course, 1989.

University of New Hampshire, Working at a Watershed Level, 2000.

Utah State University, Basins 3.0 Training Workshop, 2001.

SELECTED PRESENTATIONS

Kretchmer, D.W., J. King, D. Ford and P. Massirer. 1998. Predictions Regarding the Aquatic System in the Lower Snake River after Dam Removal and Stabilization. Presented at the 18th Annual Meeting of The North American Lake Management Society November 10-13, 1998.

Juul S. and D.W. Kretchmer. 2000. Lateral and Vertical Total Dissolved Gas Concentrations within the Priest Rapids, Washington Hydroelectric Project. Presented at the 20th Annual Meeting of the North American Lake Management Society. November 2000.

LEE CARBONNEAU
Certified Wetland Scientist
Terrestrial and Wildlife Specialist

Ms. Carbonneau has twenty years of experience assessing terrestrial and wetland communities throughout the northeastern United States. She is involved in all aspects of wetland delineation, functional assessment, mitigation design, and wildlife inventory and habitat assessment. She is a manager of ecological support projects for hazardous waste site remediation, highway projects, and commercial and industrial developments.

EDUCATION

M.S. 1986, Wildlife Ecology, University of New Hampshire
B.S. 1981, Forest Biology, SUNY College of Environmental Science and Forestry, Magna cum laude

PROFESSIONAL EMPLOYMENT HISTORY

1989-Present Normandeau Associates, Inc.
1986-1989 The Smart Associates
1985-1986 Self Employed, Environmental Consultant
1983-1985 Institute of Natural and Environmental Resources, University of New Hampshire
1982 EIP Northeast and The Nature Conservancy-Long Island Chapter
1981 The Nature Conservancy-Lower Hudson Chapter

PROFESSIONAL AFFILIATIONS

Professional Wetland Scientist #882 - Society of Wetland Scientists
Certified Wetland Scientist #123 – New Hampshire Association of Natural Resource Scientists

SELECTED PROJECT EXPERIENCE

Souhegan River Instream Flow Study and Water Management Plan (on-going) – Identified important wildlife, vegetation and natural communities along the Souhegan River in NH and evaluated their potential flow dependence. Project Ecologist.

Tennessee Valley Authority (TN and 7 other states) (ongoing) - Prepared managed areas and ecologically significant sites section of EIS for Reservoir Operating Study. Alternatives for the future management of water quality, transportation, flood control and recreation throughout the entire TVA system were evaluated. Task Manager.

Yadkin, Inc (NC) (On-Going) – Evaluating the effects of reservoir management on wetlands, rare, threatened and endangered species, and wildlife habitat as a part of a relicensing effort. Tasks include air photo interpretation, field surveys, impact assessment. Project Ecologist.

PSNH – Merrimack River (2003) – Evaluated potential bald eagle winter perching and roosting habitat and nesting habitat along the Merrimack River from Concord to Manchester NH for dam relicensing study. Project Ecologist.

Sanborn Head Associates (2001-2003) Blackburn & Union Privileges Superfund Site, Walpole, MA. Wetland delineation, habitat assessment, ecorisk support and restoration design along the Neponset River. Project Manager.

Industrial Site Ecological Risk Assessment Projects (3 Sites in CT) (2000-2001) – Ecological inventory, conceptual site model development, exposure pathway and potential receptor evaluation for sites along the Connecticut and Quinnipiac Rivers. Senior Project Ecologist.

Fayscott Site, Dexter, Maine (1998-2001) -Wildlife habitat inventory for evaluation of remediation alternatives at a former manufacturing on East Branch of the Sebasticook River. Addressed Significant and Essential Wildlife Habitats, fisheries, reptile and amphibian habitat. Cover type mapping, wetland delineation, bird surveys, habitat evaluations. Project Manager.

PECO Energy Site Redevelopment Project (1998-1999) – Endangered species investigations and wildlife habitat evaluation on the shores of the Delaware River. Botanist/Wildlife Biologist.

NHDOT/Manchester Airport Access (1997-1998) – Wintering bald eagle survey and habitat assessment on the Merrimack River for major highway EIS. Principal Wildlife Investigator.

Coakley Landfill Superfund Site (1992-2000) - Wetland remediation and mitigation design, permit equivalency, construction management and long-term monitoring for North Hampshon NH site. Project Manager.

Newington-Dover Highway Improvement (1990-1991) – Environmental assessment and ecological constraints mapping for highway renovation. Project Manager.

Groundwood Pulp and Light Weight Coated Paper Mill Siting Project (ME) (1989-1990) – Resource inventory and mapping on remote sites in northern Maine. Wetland Scientist and Wildlife Biologist.

Research Natural Area Establishment (1986) –Establishment of 5 RNAs in the White Mountain National Forest, NH. Principal Investigator.

SPECIAL TRAINING

New England Freshwater Wetlands Invertebrate Biomonitoring Protocol – 2003

Design and Implementation of Treatment Wetlands (Water Environment Federation), 1996

Wetland Evaluation Technique Version 2.0 Certification (U.S. Army Corps of Engineers Course), 1988

Personnel Protection and Safety Training for Hazardous Waste Site Activities and Site Supervisor Certification (OSHA Course), 1989-Present

OSHA Hazardous Waste Site Supervisor Certification

NASDS SCUBA Certification, 1980

MATTHEW D. CHAN, Ph.D.
Senior Scientist

Dr. Chan's primary topic of research has been stream fish communities and their habitat requirements, particularly in relation to flow regimes. To date, his project experience includes stream/fish ecology, habitat assessments, regulated rivers/instream flow studies (IFIM/PHABSIM), fish ecomorphology (morphometrics), multivariate statistics, bioenergetics, and the use of surrogate species for determining habitat preferences of threatened and endangered fishes. His experience covers both southeastern and mid-Atlantic geographic regions, and includes small streams and large rivers. His current duties include performing instream flow studies and statistical analyses.

EDUCATION

Ph.D. 2001, Fisheries Science, Virginia Tech
M.S. 1995, Biology, University of Mississippi
B.A., 1992, Biology Major Computer Science Minor, Wittenburg University

PROFESSIONAL EMPLOYMENT HISTORY

2001-Present Normandeau Associates, Inc.
1996-2001 Virginia Tech
1995-1996 USCE Waterways Experiment Station
1992-1995 University of Mississippi
1988-1992 Wittenberg University

PROFESSIONAL AFFILIATIONS

Sigma Xi
American Fisheries Society
Virginia Tech Chapter of American Fisheries Society
American Society of Ichthyologists and Herpetologists
Virginia Tech Graduate Student Assembly

SELECTED PROJECT EXPERIENCE

Santee-Cooper Power (2002-2003) –
Investigate river habitat using Mesohabsim approach in 37 mi bypass reach, conduct hydrologic analysis using IHA and ROV methods for reach, and develop two-dimensional river models (R2D) of selected shoals to evaluate small-boat navigation capability and stream habitat. Principal Investigator.

Tennessee Valley Authority (2002-2003) – Preparation of a programmatic environmental impact statement for the TVA system. Section Leader for assessment of aquatic resources.

National Park Service (2002) – Investigation of fish and habitat relationships relative to water withdrawal from Marsh Creek, a stream flowing through the Dwight Eisenhower National Historic Site, Gettysburg, PA. Principal Investigator.

SSM Group, Inc. (2002) – Assessment of instream flow needs to protect aquatic biological resources in preparation of an integrated resource plan for water for Montgomery County, PA. Principal Investigator.

Virginia Tech (1997-2001) – Physical habitat study (PHABSIM) and water temperature measurements of North Fork Shenandoah River, VA. Constructed a physical habitat simulation model for helping decision makers allocate flow for aquatic fauna in a river valley with an expanding population and frequent droughts. Research Associate.

Virginia Tech (1999-2001) – Ecological studies of the Smith River, VA. Multiple studies on the effects of daily hydro-peaking operations on river fishes, specifically impacts on a naturalized brown trout population. Research Team Member.

Virginia Tech (1996-2001) - Watershed model of the upper Roanoke River, VA. Study impacts of urbanization on fish communities. Research Team Member.

SELECTED PRESENTATIONS AND PUBLICATIONS

Killgore, K. J., S. T. Maynard, M. D. Chan, and R. P. Morgan II. 2001. Evaluation of Propeller - Induced Mortality on Early Life Stages of Selected Fish Species. *North American Journal of Fisheries Management*. In press.

Chan, M. D., and E. D. Dibble. 1997. A laboratory examination of velocity and substrate preferences by age-0 Gulf sturgeon, *Acipenser oxyrinchus desotoi*. *Transactions of the American Fisheries Society* 126:330-333.

Killgore, K. J., and M. D. Chan. 1996. U.S. Army Corps of Engineers, Waterways Experiment Station. North American Sturgeon: Implications for the Corps of Engineers. *EIRP Bulletin* 96-1, 7 pp.

Chan, M. D. and D. J. Orth. 2001. Using complex hydraulic variables and fish morphology to predict habitat preference of river fishes. *Northeast Fish and Wildlife Conference: Instream Flow Symposium*.

Chan, M. D. and D. J. Orth. 2001. Prediction of stream fish microhabitat with complex hydraulic variables, an ecomorphological approach. Mid-year meeting of the Southern Division of American Fisheries Society.

Chan, M. D., D. C. H., D. J. Orth, and T. Newcomb. 2000. Water Quality in the North Fork Shenandoah River during the Drought of 1999: Implications for Minimum Instream Flow. *Tri-State Fisheries Conference/ Virginia AFS Meeting and as Poster at Graduate Student Assembly Research Symposium*.

| [Bradley Compton](#)

E. TERRY EUSTON
Principal Biologist

E. Terry Euston is a senior fisheries biologist with 31 years of experience in designing, managing, and conducting environmental monitoring, impact, and fisheries management related studies for hydroelectric, fossil, and nuclear power stations on waterways in the Northeast, mid-Atlantic, upper Midwest, and Pacific Northwest regions. Mr. Euston has investigated abundance, distribution, species composition, sport harvest, feeding ecology, and seasonal movement of fishes in a variety of lotic and lentic ecosystems influenced by these operations. He is trained to conduct and analyze instream flow studies using IFIM. Mr. Euston is also trained to evaluate hydro turbine entrainment and mortality with specific training in the application of HI-Z Turb'n Tag technology.

EDUCATION

B.S., 1970, Fisheries Science, Cornell University

PROFESSIONAL EMPLOYMENT HISTORY

1977-Present Normandeau Associates
1972-1977 Ichthyological Associates, Inc.
1968-1970 New York State Department of Environmental Conservation

PROFESSIONAL AFFILIATIONS AND SPECIAL TRAINING

American Fisheries Society
Mid-Atlantic Chapter, AFS
IF200 Designing and negotiating studies using IFIM
IF305 Field techniques for stream habitat analysis

SELECTED PROJECT EXPERIENCE

New York Power Authority (2003-Present) - Sport fishing survey of Upper Niagara River for Niagara Power Project. Project Manager.

New York State DEC (2000-Present) – Sport fishing survey of Hudson River estuary. Project Manager.

Reliant Energy (1997-Present) - managed environmental studies, prepared APEA materials in support of alternative relicensing of Piney Generation Station, Clarion River, PA.

Allegheny Energy (2000-2001) – Relicensing Environmental Studies. Project Manager.

U.S. Army Corps of Engineers (1998-1999) - Preparation of Resident Fish Appendix, a supplement to the Lower Snake River Juvenile Salmon Feasibility Study EIS evaluating dam removal effects on endangered chinook salmon. Project Manager/Co-author.

U.S. Army Corps of Engineers (1997-1999) - Aerial and ground creel surveys of 170 miles of the Snake River in WA and ID to support economic valuation studies of sport fishing and general recreation in impounded and free-flowing river sections. Project Manager.

U.S. Army Corps of Engineers (1995, 1997) - Assessed juvenile chinook salmon and steelhead injury and mortality utilizing HI-Z Turb'N Tag technology during spill and sluiceway passage at dams on the Columbia and Snake Rivers. Field Coordinator.

New England Power (1994-1995) - Evaluated turbine passage and bypass survival of Atlantic salmon smolts with HI-Z Turb'N Tag technology at Wilder and Vernon Hydroelectric Stations, Connecticut River, Vermont and New Hampshire. Principal Investigator.

Allegheny Power Service (1993-1995) - Responsible for the design, conduct and reporting of post-relicensing studies on the cumulative effects of four hydro stations on American eel passage. Full entrainment netting and radio telemetry were used to acquire data. Project Manager.

Allegheny Power Service (1990-1994) - Responsible for the final design, conduct and preparation of Exhibit E for FERC relicensing of five hydro stations in Virginia and West Virginia including studies of peaking power effects on fish and water quality utilizing IFIM on a river reach heavily impacted by acid mine drainage. Proj. Mgr.

Carolina Power & Light (1992) - Instream flow studies utilizing IFIM for a 12-mile bypass reach of the Pigeon River below Walters Dam, North Carolina and Tennessee. Co-field Leader.

SELECTED PRESENTATIONS AND PUBLICATIONS

Euston, E.T., S. Haney, K. Hattala, A. Kahnle. 2003. Hudson River Creel Survey-Recreational use of Hudson River fisheries resources. Presented at Hudson River Environmental Society conference, Poughkeepsie, NY.

Euston, E.T., D.D. Royer, and C.L. Simons. 1998. American eels and hydroplants: clues to eel passage. *Hydro Review* 17(4):94-103.

Relationship of emigration of silver American eels (*Anguilla rostrata*) to environmental variables at a low-head hydro station. *WATERPOWER '97*, ASCE, Atlanta, GA.

Euston, E.T., C.E. Denoncourt, K.J. McGrath, and J.D. Gerlach. 1996. Results of 1995 sports fishing surveys on the St. Lawrence River in the vicinity of the St. Lawrence-FDR Power Project. Presented at International Conference on the St. Lawrence Ecosystem, Cornwall, Ontario, Canada.

MARK L. HUTCHINS
Water Resource Engineer

Mr. Hutchins has been involved with water resource issues for more than 30 years. His expertise focuses on surface waters - lakes, rivers, streams, estuaries - and includes most aspects of water quality and quantity. Project experience includes input/output modeling to predict lake trophic state, DO/BOD modeling in rivers and streams, waste discharge plume modeling in estuaries and assessment of water quality impacts from various types of commercial, industrial and residential development. Mr. Hutchins has particular expertise in hydroelectric licensing/relicensing efforts, having been involved with water quality and quality studies for more than a dozen hydroelectric projects. Mr. Hutchins has been involved with the ski industry for more than 15 years. Activities have included wastewater discharge permitting, water quality impact assessments, water supply studies for snowmaking and minimum flow issues. Most recently, Mr. Hutchins has managed broad-based environmental documentation efforts to comply with NEPA regulations (EISs/EAs) and state permitting requirements associated with the ski industry, most of which has been related to snowmaking/minimum streamflow issues.

EDUCATION

M.S. 1977, Engineering/Water Resources, University of Maine
B.S. 1968, Geological Sciences, University of Maine

PROFESSIONAL EMPLOYMENT HISTORY

2002-present Hutchins Consulting Services, Normandeau Associates, Inc.
1997-2002 Sno.engineering, Inc., SE GROUP
1985-1997 Normandeau Associates, Inc.
1982-1985 Maine Department of Environmental Protection
1973-1982 University of Maine, Environmental Studies Center, Land and Water Resources Center

SELECTED PROJECT EXPERIENCE

Vermont Yankee, VT (2002-present) - Participating in the preparation of a 316a document that evaluates potential impacts to the Connecticut River from an increase thermal discharge resulting from a proposed power upgrade at Vermont Yankee. Principal Investigator.

Attitash/Bear Peak, NH (2000-present) - Representing Attitash/Bear Peak's interests in proposed minimum flow regulation before the NH Department of Environmental Services and Legislative Committee hearings. Prepared formal responses to proposed regulations and proposed alternative minimum flow regulations. Project Manager.

Wildcat, NH (3rd party contractor to the U.S. Forest Service) (1999-2001) - Coordinated environmental and archaeological work to support the preparation of an Environmental Assessment for a variety of proposed actions at Wildcat Ski Area. Project Manager.

Great Northern Paper Company, ME (1998-present) - Providing water quality consulting services to GNP relative to water quality modeling of the Penobscot River. Project Manager.

Killington Ltd., VT (1996-1999) - Hydrologic analyses and biological evaluation of Woodward Reservoir in support of proposed snowmaking withdrawals; Act 250 compliance. Project Manager.

Pease Development Authority, NH (subconsultant to Underwood Engineers) (1996-1997) - Plume modeling using CORMIX to support a new wastewater outfall design. Project Manager.

Waterville Valley, NH (subconsultant to Sno. Engineering, 3rd party contractor to the U.S. Forest Services) (1995-1998) - Waterville Valley snowmaking ponds EIS. Project Manager.

Town of Dartmouth, MA (subconsultant to Woodard and Curran, Inc.) (1995-1996) - Paskamanset River minimum flows. Project Manager.

Sugarbush, VT (subconsultant to Sno.engineering, 3rd party contractor to the U.S. Forest Service) (1994-1995) - Sugarbush snowmaking EIS. Project Manager.

Public Service Company of New Hampshire, NH (1994-1997) - Merrimack Station thermal impact evaluation. Project Manager.

City of Saco, ME (subconsultant to DeLuca Hoffman) (1994-1996) - Municipal tidewater wastewater outfall evaluation. Project Manager.

City of Saco, ME (subconsultant to DeLuca Hoffman) (1992-1996) - Saco River wasteload allocation. Project Manager.

Connecticut Department of Environmental Protection, CT (1992-1993) - Farmington River minimum flow. Principal Investigator.

Killington, Ltd., VT (1992) - Ottauquechee River minimum flow. Principal Investigator.

New England Power Co., MA, VT, NH (1991-1992) - Preparation of NPDES permit applications for 15 hydroelectric stations. Project Manager.

Central Maine Power Co., ME (1990-1991) - Moxie Stream minimum flow. Principal Investigator.

JENNIFER M. JACOBS

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EDUCATION

Cornell University, Ithaca, NY	Ph.D., Civil Engineering, August 1997
Tufts University, Medford, MA	M.S., Civil Engineering, May 1993
Brown University, Providence, RI	B.S., Electrical Engineering, May 1987

PROFESSIONAL EXPERIENCE

2003 – present *Assistant Professor*. University of New Hampshire, Dept. of Civil Engineering
1997- 2003 *Assistant Professor*. University of Florida, Dept. of Civil and Coastal Engineering
2000 - 2003 *Affiliate Faculty Member*. University of Florida, College of Natural Resources
1989 - 1993 *Environmental Consultant*. Eastern Research Group, Lexington, MA
1987 - 1989 *Consultant*. Boston Systems Group, Boston, MA

PROFESSIONAL SOCIETIES

- American Geophysical Union, 1993 to present
- American Society of Civil Engineering, 1992 to present
- American Society for Engineering Education, 1996 to present
- International Association of Hydrological Sciences, 2000 to present
- American Meteorological Society (AMS), 2002 to present

RELEVANT PROJECTS

- NASA, 2004-2006: “*Multi-Scale Remote Assessment of Land-Surface Hydrological Response to Natural and Anthropogenic Stressors: A Case Study in the Florida Everglades Protection Area*”.
- NASA NIP Award, 2001-2004: “*Characterization and Simulation of Remotely Sensed Soil Moisture for Rainfall-Runoff Modeling*”.
- SERDP, 1999-2004: “*Ecological Indicators of Environmental Change*”.
- Florida Department of Transportation, 2002-2004: “*Seasonal Variability of Near Surface Soil Water and Groundwater Tables in Florida*”.
- Florida Space Grant Consortium, 2001-2002: “*Characterization and Simulation of Remotely Sensed Soil Moisture for Rainfall-Runoff Modeling – Undergraduate Scholar*”.
- Suwannee River Water Management District, 2001-2002: “*Minimum Flows and Levels for the Lower Suwannee River Implementation Methodology*”.
- USGS, 2001-2002: “*Flow Duration Curves to Advance Ecologically Sustainable Water Management*”

RELEVANT PUBLICATIONS AND TECHNICAL REPORTS

- Satti, S.R. and J.M. Jacobs. GWRAPPS: A GIS-based Decision Support System for drought water requirement. to appear in *Agricultural Water Management*, 2004.
- Jacobs, J.M. 2003. Review of *Ecohydrology: Darwinian Expression of Vegetation Form and Function*, P.S. Eagleson, Cambridge University Press, Cambridge, United Kingdom to appear in *EOS Transaction, American Geophysical Union*. 2003.
- Bryant, M.L., Bhat, S., and J.M. Jacobs. Throughfall characterization of heterogeneous forest communities in the southeastern U.S., *Journal of Hydrology*. Accepted September 2003.
- Ripo, G.R., J.M. Jacobs, and J.C. Good, An Algorithm To Integrate Ecological Indicators With Streamflow Withdrawals, Proceedings of the EWRI World Water and Environmental Resources Congress, Philadelphia, PA, June 2003.
- Jacobs, J.M., G.R. Ripo, J.C. Good, and S.R. Satti*, Sustainable Watershed Ecohydrology And Optimized Water Management Using A Flow Duration Curve Framework, Supplement to European Geophysical Society/American Geophysical Union/EUG Joint Meeting, Nice, France, April 2003.
- Satti, S.R. and J.M. Jacobs. GIS-based Water Resources and Agricultural Permitting and Planning System (GWRAPPS) - An ArcGIS Decision Support System for St. Johns River Water Management District (SJRWMD), 2002.
- Tkaczyk, M*, J.W. Jawitz, J.M. Jacobs, S. Bhat*, P.S. Rao, and N. Haws, Rainfall/Runoff Analysis to Investigate the Effects of Soil Heterogeneity on Watershed Response Utilizing Topmodel, Supplement to AGU Spring Meeting, Washington, DC, May 2002.
- Satti*, S.R. and J.M. Jacobs. GWRAPPS: A GIS-based Decision Support System for Florida 1-in-10 Drought Water Requirements, Proceedings of the ASCE World Water and Environmental Resources Conference, Roanoke, Va, May 2002.
- Jacobs, J.M. and G. Ripo. Minimum Flows and Levels for the Lower Suwannee River - Implementation and Methodology. University of Florida, *Final Report to SRWMD*, Gainesville, Florida, June 2001. 129 pages.
- Good, J.C. and J.M. Jacobs. Ecologically Sustainable Watershed Management using Annualized Flow Duration Curves, Proceedings of the ASCE World Water and Environmental Resources Congress, Orlando, FL, May 2001.
- Bhat, S., J.M. Jacobs, W. Graham, P.S. Rao, N. Haws*, W.F. DeBusk, J.W. Jawitz, Identification of Eco-Hydrologic Indicators of Ecological Impact: Phase I Results from Fort Benning, Georgia Watersheds, Supplement to AGU Spring Meeting, Boston, MA, May 2001.
- Jacobs, J.M. and J.C. Good. Application of Annualized Flow Duration Curves to Minimum Water Flows and Levels, Supplement to AGU Spring Meeting, Boston, MA, May 2001.
- Good J.C. and J.M. Jacobs, Use of Annualized Flow Duration Curves for Minimum Flows and Levels. Florida Section ASAE Annual Conference, Orlando Florida, Cocoa Beach, FL, May 2001.
- Jacobs, J.M. and R.M. Vogel. Allocation of Water Withdrawals in a River Basin, Proceedings of the 25th Annual Conference on Water Resources Planning and Management, Chicago, IL, June 1998.
- Jacobs, J.M. and R.M. Vogel. 1998. The optimal allocation of water withdrawals in a river basin, *Journal of Water Resources Planning and Management*, ASCE, 124(6), 357-363.

AL LARSON P.G.
Principal Geoscientist

Mr. Larson has 20 years of professional experience in environmental geology and hydrology. His experience includes numerous Environmental Impact Statements, Environmental Assessments and FERC Relicensing Studies. He has been responsible for the development and implementation of surface and ground water flow and quality monitoring networks, fluvial geomorphic assessments and hydrologic/hydraulic modeling and wetland restoration. His experience includes projects in the Pacific Northwest, Rocky Mountain, Central and New England Regions.

EDUCATION

M.S. 1983, Earth Science, University of New Hampshire
B.S. 1978, Geology, SUNY Cortland, NY
A.S. 1976, Geology, Orange County Community College, NY

PROFESSIONAL EMPLOYMENT HISTORY

1986-Present Normandeau Associates, Inc.
1985-1986 Wehran Engineering
1981-1985 Camp, Dresser and McKee

PROFESSIONAL AFFILIATIONS And REGISTRATIONS

American Geophysical Union
American Water Resource Association
Geological Society of America
National Ground Water Association
Professional Geologist, PA (PG-002373-G)
Professional Geologist, NH (#137)

SELECTED PROJECT EXPERIENCE

Ameren UE, MO (2001-Present). Member of Erosion Advisory Team for the Bagnell Dam FERC relicensing project. Reviewed historical studies of channel and bank erosion on the Osage River and recently completed Erosion Study Summary Report to be submitted with FERC relicensing documentation. Project Geomorphologist.

Tuckahoe Turf Farm, ME (2001-Present). Supervised hydrologic investigation of proposed turf farm and its impacts on wetland hydrology. Included installation of a network of piezometers and continuous water level monitoring. Project documented re-establishment of ground water flow system following elimination of subsurface drain system.

Portland General Electric, OR (2000-2001) – Performed an evaluation of sedimentation related to the operation of the Willamette Falls Hydroelectric Project. As part of the FERC relicensing process the accumulation of sediments in the Willamette River upstream of the dam was evaluated

based upon a review of existing environmental, geomorphic and hydrologic information. Project Geomorphologist.

FPL Energy Maine Hydro LLC, ME (2000-2001) – Assisted in fluvial geomorphic assessment of impacts associated with the operation of the Indian Pond (Harris Dam) Hydroelectric Project, including initial assessment of the impacts to aquatic habitat from hydroelectric peaking operations and white water boating flow releases. Assessment included preliminary geomorphic evaluation of the upper Kennebec River focusing on sediment transport and channel morphology. Project Geomorphologist.

Tapoco, Inc., TN and NC (2000-2001) – Performed an investigation of the impacts of the Tapoco Hydroelectric Project on the hydrologic regime of the Cheoah and Little Tennessee Rivers as part of a FERC relicensing study. This investigation involved the statistical analysis of stream flows and reservoir surface water elevation data. The objective of this analysis was to determine the range and duration of stream flows and the variability of reservoir surface elevations relative to their impacts on aquatic habitat. Project Hydrologist.

Maine Turnpike Authority, ME (1999). Performed hydrologic assessment of a former sand and gravel pit for a wetland creation design project. Installed a network of piezometers to evaluate depth to ground water and direction of ground water flow. Also investigated potential recharge and water quality impacts to a local municipal water supply well. Project Hydrologist.

Massachusetts Water Resource Authority, MA (1998) – Performed analysis of potential impacts of relief sewer on water resources in the Weymouth-Fore Drainage Basin as part of an Interbasin Transfer Permit Application. Evaluated impact of inflow/infiltration losses on surface and ground water resources. Project Hydrologist.

U.S. Army Corps of Engineers, WA (1997-1999) – Responsible for the development and design of a sediment quality database for the Lower Snake River. Interpreted sediment quality to evaluate potential impacts associated with the alternatives analysis in the Environmental Impact Statement for the Lower Snake River. Project Geologist.

SPECIAL TRAINING

Designing Stream Restoration Works, The Waterloo Stream Course, 2001.

Design of Surface and Ground Water Monitoring Networks, Colorado State University, 1981.

Wildland Hydrology, Research and Educational Center for River Studies:

Fluvial Geomorphology for Engineers, 2000.

River Morphology and Applications, 2001.

River Assessment and Monitoring, 2001.

DONALD P. MASON
Aquatic Ecologist

Mr. Mason has over 17 years' experience assessing the effects of habitat alteration on aquatic ecosystems. His specialties include evaluating the effects of hazardous substances, hydropower, and commercial development on fish and benthic macroinvertebrate communities. Mr. Mason has conducted and managed several studies using freshwater macroinvertebrates as pollution indicators, assessing the impacts of road and highway construction on aquatic communities and searching for rare, threatened, or endangered aquatic species.

EDUCATION

M.S. 1982, Entomology, University of New Hampshire
B.A. 1976, Biology, Plymouth State College

PROFESSIONAL EMPLOYMENT HISTORY

1985-Present Normandeau Associates, Inc.
1983-1985 Battelle New England Marine Research Laboratory
1982-1983 Normandeau Associates, Inc.
1982 Charles T. Main, Inc.

PROFESSIONAL AFFILIATIONS AND SPECIAL TRAINING

North American Benthological Society
New England Association of Environmental Biologists
Freshwater Mollusk Conservation Society
Rapid Bioassessment Protocols (RBP)
Habitat Evaluation Procedures (HEP)

SELECTED PROJECT EXPERIENCE

Tri-Town Wildlife Surveys (2001-Present) - Survey for three species on the MA Natural Heritage and Endangered Species Program list in the west branch of French's Stream on the former South Weymouth Naval Air Station property (MA). Principal Investigator.

Pond Eddy Bridge (PA) Mussel Survey (2001-2002) - Conducted a mussel survey near the Pond Eddy Bridge, Delaware River. Project Manager.

Centredale Manor (RI) Restoration Project Superfund Site Human Health and Ecological Risk Assessment (2001) - Analyses of benthic macro-invertebrates, fish, emerging aquatic insects, ichthyoplankton, and soil earthworms community and bioaccumulation at a multi-unit apartment complex on the property of a former chemical manufacturer contaminated with dioxin and PCBs. Project Manager.

Elizabeth Mine (VT) Superfund Site Bioassessment (2000-2002) – habitat and benthic community

assessment along Copperas Brook, heavily contaminated with acid mine drainage and metals from an abandoned mine. Project Manager

Tenney Brook Tributary (VT) Expert Witness Testimony (2000-2001) - Testified before Vermont's Act 250 Board regarding habitat quality of an unnamed tributary that was proposed for relocation. Project Manager.

Natick SSCOM Tier II Ecological Risk Assessment (1998-2001) - Assessed benthic macroinvertebrate and fish communities near two stormwater outfalls suspected of discharging SVOCs, PAHs, and pesticides using a recently developed biomonitoring protocol designed for lentic environments (Hicks 1997). Project Manager.

Paulins Kill (NJ) River Dwarf Wedge Mussel Survey (1999) - Surveyed 8 miles of the river for Dwarf Wedge Mussels and characterized mussel habitat. Field Supervisor.

East Branch of Sebasticook River (ME) Habitat Inventory (1998) - Evaluated impacts to benthic macroinvertebrate and fishery habitats in areas where sediment levels of heavy metals and PCBs were elevated. Project Biologist.

City of Manchester (CT) (1994, 1996, 1998) - Assessment of the fish and benthic macroinvertebrate communities in the Hockanum River for discharge permit application for municipal Sanitary Landfill and sewage treatment plant. Sr. Ecologist.

Dexter Corporation (CT) (1997) - Surveyed of streambed in Stony Brook (CT), near an aqueduct proposed for reconstruction, to look for Dwarf Wedge Mussel. Project Manager.

New Hampshire DOT (1997) – Diver survey in the Johns River (NH) at a bridge reconstruction site, to look for Dwarf Wedge Mussels. Project Manager.

Paradise Pond (MA) Dredging Mitigation Project (1997) - Mitigation for dredging impacts on a downstream population of Dwarf Wedge Mussel. Technical Director.

City of Brockton (MA) (1997) - Shoreline survey (Silver Lake) for two freshwater mussels included in the Massachusetts list of species of special concern. Project Manager.

Maritimes & Northeast Pipeline (ME) (1997) - Conducted a freshwater mussel search and evaluated mussel habitats in several stream crossings. Project Biologist.

SE Technologies, Inc. (CT) (1997) – Assessment of benthic macroinvertebrate community using EPA's RBP II and endangered aquatic species search near a closed electroplating facility in Fivemile River (CT). Project Manager.

Deschutes River Natural Resource Damage Assessment (OR) (1996-1997) – Assessment of short and long term effects of a diesel spill on the benthic macroinvertebrate community with on-site approval by State, Federal, and Tribal trustees. Principal Investigator.

Joseph N. Rogers
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EDUCATION

University of Massachusetts, Amherst, MA	M.S., Geoscience, 2003
Plymouth State University, Plymouth, NH	B.S., Physical Geography, 1999

RESEARCH EXPERIENCE

Souhegan River, NH

Involved in many aspects of Souhegan River HMU mapping, data collection, processing, and analysis. October 2004 – current.

Profile Lake, Franconia Notch State Park, White Mountains, NH.

Masters Thesis research on debris flows recorded by Profile Lake. Fieldwork centered on recovering lake sediment using Livingstone Sq.-rod and Glew coring devices. Multi-proxy lab analysis to document debris flow signals and compare to historical literature of events, developing recurrence intervals. 2000 - 2002

Lake Tuborg, Ellesmere Island, Nunavut, Canada. 81°N; 72°W

Field assistant for University of Massachusetts doctoral candidate, Ted Lewis. High Arctic lake sedimentation project. Fieldwork involved recovering Glew cores, installing and recovering sediment traps, sea-cat casts, lake current measurements, lake water collection, filtering lake samples, installing and monitoring: river gauging station, temperature, lake level and precipitation gauges. (lewist@geo.umass.edu) Summer 2001

Yukon Territory, Canada

Field assistant for University of Massachusetts doctoral candidate, Lesleigh Anderson. Holocene lake level re-construction and paleo-climate project. Fieldwork took place at several sites in Alaska, but mostly in the Yukon Territory. Fieldwork involved recovering water samples from nearly 70 lakes, recovering lake sediment using Livingstone Sq.-rod, Glew, and box coring devices. Collecting vegetation samples, bathymetric profiling, and hydro-lab casts. (land@geo.umass.edu) Summer 2000

Sheep Mountain Anticline, Greybull, WY

Field assistant for University of Massachusetts masters student, Heather Savage. Fracture mapping project. Fieldwork involved taking strike and dip measurements on fracture sets around several large surface features. Topographic map location and Brunton skills. (hsavage@geosc.psu.edu) Summer 2000

LEADERSHIP EXPERIENCE

Adjunct Professor, Westfield State College, Westfield, MA. 01086-1630

Developed and taught GARP 103/104 Physical Geography (Spring 2003, Fall 2004) and GARP 101 World & Regional Geography. (Spring 2003)

Holyoke Community College, Holyoke, MA. 01040

Developed and taught GEO 110(B) World Regional Geography. Spring 2003

Amherst Regional High School, Amherst, MA. 01002, Substitute Teacher. Spring 2003

Teaching Assistant, University of Massachusetts, Amherst, MA. 01002

Global Environmental Change, (Spring 2000, 2001, 2002)

Natural Disasters, (Fall 1999, 2001)

Earth Systems Science Seminar, (Fall 2000)

LAB AND PRACTICAL SKILLS

Magnetic Susceptibility, Loss on Ignition, Grain-Size Analysis, Munsell, Livingstone, Glew, and box coring experience, Brunton use, GPS, Sea-cat, Hydro-lab, Hydro-station, water sampling, word processing, Adobe Photoshop, Illustrator, GIS, Delta-Graph, Sigma-Plot, Power Point, End Note, Excell, Stella, Revolution.

RESEARCH INTERESTS

Global climate change, Quaternary stratigraphy and climatic change, geomorphology, lacustrine sedimentology, climatology, meteorology, glacial geology, natural hazards

GRANTS AND AWARDS

Research proposal titled "An 11,000-year Record of Debris Avalanching in Franconia Notch, NH." Funded by the Geological Society of America, Spring 2001

Research proposal titled "An 11,000-year Record of Debris Avalanching in Franconia Notch, NH based on Lake Sediment Analysis." Funded by Geography Alumni Award Fund, Spring 2001

Research proposal titled "Predicting the Reoccurrence Intervals of Major Landslides in the Franconia Notch Region Based on Lake Sediment Cores from Profile Lake, New Hampshire. "Funded by Geography Alumni Award Fund, Spring 2000

The John T. Ozgog award for excellence in geography, Spring 1998

PUBLICATIONS

Rogers, J.N., McCoy, W.D., and Davis, P.T., (in prep), *Holocene debris flows recorded by Profile Lake, Franconia Notch, New Hampshire: Geology?*

Johnson, S., Rogers, J.N., and Klekowski, E. (in prep), *Soil Characteristics of Bank Swallow Colony Sites on the Connecticut River. Conservation Biology?*

Rogers, J.N., 2003, *Major Holocene debris flows of Franconia Notch (White Mountains, New Hampshire) recorded in Profile Lake. Masters Thesis, University of Massachusetts, Amherst, 182 pp.*

Dr. Thomas P. Seager
 School of Civil Engineering
 Purdue University
 West Lafayette IN 47907
 tseager@purdue.edu

Professional Appointments

Jan 2005 – present	Visiting Research Fellow, Social & Environmental Research Institute
Nov 2004 – present	Assistant Professor, Civil Engineering, Purdue Univ.
Aug 2004 – Nov 2004	Assistant Research Professor, Civil Engineering, UNH
Aug 2002 – Aug 2004	Research Project Engineer, Environmental Research Group University of New Hampshire
Jan 2002 – Jun 2002	Visiting Assistant Research Professor Civil and Environmental Engineering, Clarkson University
1998-2001	Environmental Manufacturing Management IGERT Fellow Civil and Environmental Engineering, Clarkson University
1999-2001	Lucent Technologies/NSF Industrial Ecology Research Fellow Civil and Environmental Engineering, Clarkson University
1999 (summer)	Doctoral Resident, Environmental Health and Safety Eastman Kodak Corp, Kodak Park, Rochester NY.
1997-1998	Instructor and Teaching Assistant Civil and Environmental Engineering, Clarkson University
1996-1997	Adjunct Assistant Professor Civil Engineering, Union College
1993-1997	Tenure-track Instructor Civil Eng. & Construction Mgt. Tech., Hudson Valley CC
1991-1993	Teaching & Research Assistant Civil and Environmental Engineering, Clarkson University
1990-1992	Self-employed construction management consultant offering owner's representation, project management, inspection and on-site construction engineering and supervision services
1987-1992	Junior Surveying and Engineer and Consulting Surveying Engineer

Education

Clarkson University	Civil and Environmental Engineering	Ph.D.	2001
	Principal advisor: Dr. Thomas L. Theis		
Clarkson University	Civil and Environmental Engineering	M.S.	1994
Clarkson University	Civil and Environmental Engineering	B.S.	1987

Biographical Sketch

Dr. Thomas P. Seager conducts research and consulting related to sustainability of natural and industrial systems. His expertise is in civil and environmental engineering, with emphasis on multi-criteria-decision analysis (MCDA) and public participation for environmental decision-making and design. In addition to the work related to MCDA and characterization of community concerns and objectives in the Souhegan Instream Flow study, Dr. Seager is studying oil spill response, recovery and restoration efforts through the Social and Environmental Research Institute (Greenfield MA).

This study, which is funded by the National Oceanic and Atmospheric Administration and relies on MCDA, will determine whether the measures employed by technical experts and spill managers are those that also relate to public concerns. Prior to beginning his present position at Purdue University, Dr. Seager served as an Assistant Research Professor at the University of New Hampshire, where he led a study on stakeholder involvement to determine potential conflicts regarding the application of innovative technologies for management of contaminated materials dredged from the Cochecho River in Dover NH. In addition to publishing a number of articles on sustainability and environmental decision-making and design, Dr. Seager has served as a consultant to USEPA on alternatives to cost-benefit analysis in environmental decision-making.

Peer-Reviewed Journal Publications

- Linkov I, Sahay S, Kiker G, Bridges T, Seager TP, Belluck DA, Meyer A. 2005. Multi-criteria decision analysis: A comprehensive decision analysis tool for risk management of contaminated sediments. *Risk Analysis*. Under review.
- Seager TP, Lambert JH, Gardner KH. 2005. Fostering innovation in contaminated sediments management through multi-criteria technology assessment and public participation. *Risk Analysis*. Under review.
- Seager TP, Rogers SH, Gardner KH. 2005. Multicriteria decision analysis as a framework for combining expert knowledge and public values: A case study in contaminated sediments management. *Risk Analysis*. Under review.
- Kiker G, Bridges T, Varghese A, Seager TP, Linkov I. 2005. Multi-criteria decision analysis at contaminated sites and related areas: A review of applications and synthesis for future challenges. *Integrated Environmental Assessment and Management*. In press.
- Grimes HG, Seager TP, Theis TL, Powers SE. 2005. A game theory framework for cooperative management of the bottle life cycle. *J. Cleaner Production*. In press.
- Seager TP, Eighmy TT, Melton J. 2004. Working towards sustainable science and engineering: Introduction to the special issue on highway infrastructure. *Resources, Conservation, and Recycling*. 42(3):205-207.
- Seager TP, Theis TL. 2004. A taxonomy of metrics for testing the industrial ecology hypotheses and application to design of freezer insulation. *J. Cleaner Production*. 12(8-10):865-875.
- Dalton JL, Gardner KH, Seager TP, Weimer ML, Spear JCM, Magee BJ. 2004. Properties of portland cement made from contaminated sediments. *Resources, Conservation, and Recycling*. 41(3):227-241.
- Seager TP, Theis TL. 2002. Exergetic pollution potential: Estimating the revocability of chemical pollution. *Exergy, An International Journal*. 2:273-282.
- Seager TP, Theis TL. 2002. A uniform definition and quantitative basis for industrial ecology. *J. Cleaner Production*. 10(3):225-235.
- Seager TP, Theis TL. 2002. A thermodynamic basis for assessing GWP & ODP policy trade-offs. *Clean Technologies and Environmental Policy*. 4:217-226.

Book Chapters

- Seager TP, Linkov I, Cooper C. 2005. Performance metrics for oil spill response, recovery, and restoration: A critical review and agenda for research. In *Strategic Management of Marine Ecosystems* edited by Proth JM, Levner E, Linkov I. Kluwer: Amsterdam. In press.
- Seager TP, Gardner KH. 2005. Barriers to adoption of novel environmental technologies: Contaminated sediments. In *Strategic Management of Marine Ecosystems* edited by Proth JM, Levner E, Linkov I. Kluwer: Amsterdam. In press.
- Linkov I, Sahay S, Kiker G, Bridges T, Seager TP. 2005. Multi-criteria decision analysis: a framework for managing contaminated sediments. In *Strategic Management of Marine Ecosystems* edited by Proth JM, Levner E, Linkov I. Kluwer: Amsterdam. In press.
- Seager TP. 2004. Understanding industrial ecology and the multiple dimensions of sustainability. In *Strategic Environmental Management* by O'Brien and Gere Engineers. John Wiley & Sons: New York NY. ISBN: 0-471-09221-5.
- Seager TP, Theis TL. 2004. Pollution potential approach to environmental optimization – the case of CFC replacements. In *Strategic Environmental Management* by O'Brien and Gere Engineers. John Wiley & Sons: New York NY. ISBN: 0-471-09221-5.
- Rogers SH, Seager TP, Gardner KH. 2004. Combining expert judgment and stakeholder values with PROMETHEE: A case study in contaminated sediments management. In *Comparative Risk Assessment and Environmental Decision-Making* edited by I Linkov and AB Ramadan. Kluwer Academic Press: Boston MA. ISBN 1-4020-1895-9.
- Kiker G, Bridges T, Varghese A, Linkov I, Seager TP. 2004. Multi-criteria decision analysis: A framework for structuring remedial decisions at contaminated sites. In *Comparative Risk Assessment and Environmental Decision-Making* edited by I Linkov and AB Ramadan. Kluwer Academic Press: Boston MA. ISBN 1-4020-1895-9.

Selected Other Publications

- Seager TP. 2003. Bringing Sustainability Home: Tools for Integrated LCC and LCA in Building Design and Construction. *NH Forum*. December.

DREW TRESTED
Fisheries Biologist

Mr. Trested is a trained fisheries biologist. After spending two years working in a state agency he received a master's degree at Clemson University. While there he gained extensive experience in fisheries work, specifically with radio and acoustic telemetry with fish in a large river system. Mr. Trested is highly proficient in surgical and non-surgical tagging procedures, including internal radio transmitters (shortnose and gulf sturgeon, largemouth bass, and robust redhorse), VIAAlpha tags (rainbow trout), Floy tags (American Shad) and PIT tags (shortnose sturgeon and robust redhorse). Mr. Trested has extensive experience operating boats in riverine and reservoir systems. Since joining Normandeau, Mr. Trested has gained experience and knowledge in a wide variety of fisheries sampling techniques.

EDUCATION

M.S., 2003; Aquaculture, Fisheries and Wildlife, Clemson University
B.S., 1999, Zoology, University of New Hampshire

PROFESSIONAL EMPLOYMENT HISTORY

2003-Present Normandeau Associates, Inc.
2001-2003 Clemson University
1999-2001 New Hampshire Fish and Game Department
1999-1999 New Hampshire Audubon Society

PROFESSIONAL AFFILIATIONS

National American Fisheries Society

SELECTED PROJECT EXPERIENCE

Santee Cooper Power (SC) (2004) – Assessment and monitoring of Bendix hydroacoustic system used to monitor anadromous fish passage. Field Biologist

Amoskeag Dam (PSNH) (2004) – IFIM flow study in dam bypass reach. Field Biologist

Merrimack Generating Station (PSNH) (2004) – Fyke net and electrofishing surveys. Field Biologist

South Berwick Clupeid Study (ENEL) (2004) Downstream bypass efficiency study for movement of juvenile clupeids. Field Biologist.

Souhegan River Instream Flow Study (NH) (2004) – Collection of field data: microhabitat mapping and classification. Invertebrate sampling. Field Biologist.

Massachusetts Department of Environmental Protection (2003/2004) – Collection of tissue for use in mercury and pollutants assessment. Field Biologist.

Hudson River (NY) (2003-2004) – Laboratory taxonomic sorting of ichthyoplankton trawls. Laboratory Biologist.

Alcoa (NC) (2003/2004) – Tailwater fisheries survey (gillnet and electrofishing) as part of FERC relicensing. Field Biologist.

Public Service of New Hampshire (PSNH) (2003) – Radio telemetry studies at Amoskeag Hydro (Atlantic Salmon smolt downstream passage). Field Biologist.

CHI Energy, Inc. (MA) (2003) – Assessment of Canavac pump system for moving American Shad out of fish lift system. Field Biologist.

Public Service of New Hampshire (PSNH) (2003) – Garvins Falls downstream bypass efficiency for juvenile clupeids. Field Biologist

SPECIAL TRAINING

Dept. of Interior Motorboat Certification (2001)

State of NH – Safe Boater Certified (2003)

Live animal handling protocol, Clemson University

SELECTED PRESENTATIONS AND PUBLICATIONS

Trested, D.G., A behavioral comparison of hatchery-reared and wild shortnose sturgeon in the Savannah River: preliminary results. Annual Meeting of the Georgia Chapter of the American Fisheries Society, Augusta Georgia, 01-02.

Trested, D.G., A behavioral comparison of hatchery-reared and wild shortnose sturgeon in the Savannah River: preliminary results. Annual Meeting of the South Carolina Chapter of the American Fisheries Society, Johns Island, South Carolina, 02-02.

Trested, D.G., A behavioral comparison of hatchery-reared and wild shortnose sturgeon in the Savannah River: preliminary results. Southern Division American Fisheries Society 2002 Midyear Meeting, Little Rock, Arkansas, 02-02.

Trested, D.G., A behavioral comparison of hatchery-reared and wild shortnose sturgeon in the Savannah River: preliminary results. American Fisheries Society 132nd Annual Meeting, Baltimore, Maryland, 08-02.

Isely, J.J., D.G. Trested, T. Grabowski. 2004. Tag Retention and Survivorship of Hatchery Rainbow Trout Marked with Large-Format Visible Implant Alphanumeric Tags. North American Journal of Aquaculture. 66:73-74.

Trested, D.G., J.J. Isely, K.Ware, R.Bakal. 2004. A behavioral comparison of hatchery-reared and wild shortnose sturgeon in the Savannah River, South Carolina-Georgia. Transactions of the American Fisheries Society. Manuscript in Review.

Sean F. Werle
Northeast Instream Habitat Program
and Department of Biology
University of Massachusetts
331 Holdsworth Hall
Amherst, MA 01003

Education:

2004 - Ph. D., Organismic and Evolutionary Biology, University of Massachusetts, Amherst, MA
2000 - M. Sc., Entomology, University of Massachusetts, Amherst, MA
1995 - B. Sc., Zoology, Graduated with distinction, University of Rhode Island, Kingston, RI
1993 - Associate in Arts, Graduated with highest honors, Community College of Rhode Island,
Warwick, RI

Employment History:

2005 - present: Adjunct Lecturer, Department of Biology, University of Massachusetts, Amherst.
August 2004 - present: Post-doctoral research associate, Northeast Instream Habitat Program
(www.neihp.org)
June 1995 - 2004: Teaching and research assistant, various departments, University of Massachusetts,
Amherst.
1993 - 1995: Computer programming assistant, University of Rhode Island, South Kingston, RI

Awards:

1995 - Alumni Excellence Scholarship, University of Rhode Island Alumni Association.
2002 - OEB Teaching Award (for BIOL 497h Tropical Field Biology)

Computer Skills:

Familiar with MS-DOS, Microsoft Windows®, UNIX, LINUX, and Apple Macintosh operating systems and also with Microsoft Office®, and Adobe Photoshop® software. Also familiar with ERSI ArcGIS® software.

Community Activities:

RI Higher Education Assistance Authority Community Service Initiative Program, 1993 and 1994
Neighborhood of Orchard Valley, Fair Housing Committee, 2000-2005

Other Experience:

United States Coast Guard, Shipboard electronics technician, 1982-1986.
Commercial and residential electrical construction, 1986-1991

Publications:

- S. F. Werle. 2005. Populations of a Connecticut River Midge Structured by Geological History and Downstream Gene Flow. *Chromosome Research* 13: 97-106
- S. F. Werle, E. J. Klekowski, and D. J. Smith. 2004. Inversion polymorphism in a Connecticut River *Axarus* species (Diptera: Chironomidae) biometric effects of triple inversion heterozygote. *Canadian Journal of Zoology* 82: 118-129
- S. F. Werle, D. J. Smith, and E. Klekowski. 2004. Life in Crumbling Clay: The Biology of *Axarus* Species (Diptera: Chironomidae) in the Connecticut River. *Northeastern Naturalist* 11: 443-458.
- D. J. Smith, S. F. Werle, and E. Klekowski. 2002. The anatomy and brooding of *Pottsiella erecta* (Potts 1884) (Ectoprocta: Gymnolaemata: Ctenostomata), with an expanded diagnosis of Pottsiellidae. *Hydrobiologia* 490: 135-145.
- D. J. Smith, S. F. Werle, and E. Klekowski. 2002. The rapid colonization and emerging biology of *Cordylophora caspia* (Pallas, 1771) (Cnidaria: Clavidae) in the Connecticut River. *Journal of Freshwater Ecology* 17: 423-430.
- S. F. Werle and P. J. Vittum. 1999. The turfgrass ant: a necessary nuisance? *Golf Course Management*. January 1999
- S. F. Werle. 1995. United States Patent #5,388,840 "Throwing Dart Flight with Stepped Configuration".

Appendix C – Surveys and User Profiles

On the following pages are examples of surveys and questionnaires used in the Souhegan River PISF study as well as a typical user profile. Also included is the Consent Form that we employ for our interviews.

Souhegan River Instream Flow Study

Well Information Questionnaire

1. Well Owner _____
2. Contact Person _____
3. Phone Number _____
4. Mailing Address (owner) _____
_____ Well name, address, and street name

5. Is there a large groundwater withdrawal permit? Yes No (if yes, permit no. _____)
6. What is the typical summer pumping rate? _____ gallons per minute
7. What is the pumping frequency in the summer (on constantly, every other day, etc.)?
8. What are the pump details? (depth of intake, type of pump, horsepower, size, etc.)
depth _____ feet Intake depth _____ feet Diameter _____ inches
horsepower _____ hp pump type _____
9. What are the well construction details?
Casing depth _____ feet Casing diameter _____ inches
Well screen length _____ feet Well screen diameter _____ inches
Gravel pack thickness _____ inches
10. What are the formation details?
Overburden (grain size distribution)
Bedrock (depth of water producing fractures)
11. Are there monitoring wells? Yes No (If yes, how many? _____)

12. Have any studies been performed on the well (pumping tests, slug tests, performance tests, step drawdown tests, etc.)? Yes No (If yes, please identify who did the studies, a contact name, and address)

13. Who constructed the well, and when?

Questionnaire for Souhegan River Affected Water Users

The University of New Hampshire in conjunction with Normandeau Associates and the University of Massachusetts has a contract with NH Dept. of Environmental Services (NHDES) to develop a water management plan to protect flows in the designated section of the Souhegan River and sustain offstream water use. Your facility has been identified as a water user potentially affected by this water management plan. In order to choose the best alternatives, we request your help in describing your water usage and needs. This questionnaire will be used to develop the management alternatives closest to your current operating parameters. You will be a part of the decision making process. Thank you for your time and cooperation.

Please contact Don Kretchmer at 472-5191 or via email at dkretchmer@normandeau.com with any questions you may have. Use the additional space on page 4 if there is insufficient room for your response. Please return the completed questionnaire to:

Don Kretchmer
Normandeau Associates
25 Nashua Road
Bedford, NH 03110

1) *Do you currently use water from the Souhegan River or from adjacent wells?*

_____ Yes _____ No

2) *Briefly describe how water from the Souhegan River or adjacent wells is used at your facility?*

3) *When do you use this water? (Check all that apply)*

Seasons: _____ Fall _____ Winter _____ Spring _____ Summer

Days of the week: _____ Weekdays only _____ Every day _____ Weekends only _____ Other, explain below

_____ At all times _____ During dry periods _____ Not weather dependent.

Hours of water use during typical day: _____ start time _____ end time.

4) *How is your facility staffed when water is being used? _____ 24 hours a day/7 days a week, _____ 24 hours a day, weekdays only _____, day shift only during the week, _____ Other, please explain below.*

5) **How is your water use measured?**

_____ weir _____ meter _____ pump run time _____ other (explain)

6) **How much water does your facility return/introduce to the river?**

_____ % of withdrawal _____ a small amount, _____ unquantified _____, most of the water _____ all of the water withdrawn _____ other

(explain).

If you have return flow, where does it reenter the river and how is it measured?

7) **Do you have historic water use records for your facility?**

_____ Yes _____ No

What is the frequency of your observations? Check one.

_____ instantaneous, _____ daily, _____ weekly, _____ monthly, _____ other

(explain below)

How are the records kept?

_____ electronically _____ on data sheets

8) *Do you have plans to modify your water use in the future?*
_____ no plans _____ increase _____ decrease _____ change timing

If a change is anticipated, explain below _____

9) *Can you describe the depth and configuration of your intakes, if applicable? Attach a drawing if available?*

10) *Do you maintain a stream gage or are you aware of stream gaging data in the vicinity of your facility?*

11) *Briefly describe any water conservation measures that you currently employ or have considered but not employed and why.*

12) *How much water can you currently store? _____ gallons.*

13) *Do you reuse water or have the ability to reuse water? _____yes, currently do reuse, _____ could reuse but do not at present _____ cannot reuse water.*

14) *Do you typically have planned shutdowns during your water use season? _____ start date _____ end date.*

Generic Water User Profile

User: Acme Water Use Company
Address: 10 River Street
 Anytown, NH 11111

Reg Number: NH12345678

Contact: John Doe
Phone: 603-555-5555
Email: jdoe@acme.com



Intake structure for Acme Water Use Company: (see photo above) GPS coordinates: Latitude: 43 12' 46.19698" N; Longitude: 71 31' 11.47504" W

Water intake: 6 inch intake pipe in center of channel in 4 feet of water. Maximum pumping capacity equals 200 gallons per minute.

Water storage: 1- pond, capacity 1 million gallons. Storage is sufficient for 5 days of operation during peak water use period without refilling.

Average Water Use by month (thousand gallons/day):

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
				12	22	130	150	130	45		

Period of record 1990-2004

Days of water use: Monday to Friday

Hours of water use (when using water): 5PM through 7AM.

Description of use: Water is pumped to pond and pond is drawn down during the day for operations. Pond is refilled at night. Pump stops automatically with float switch once pond is full. Pond is refilled Friday night and remains full through weekend.

Staff Hours: 8AM to 5PM, water use at night is automatically controlled

Water use measured: With flow meter at pump. Meter is read every weekday morning

Water use records: Daily records kept on data sheets, monthly summaries submitted to NHDES.

Return Flow: Approximately 75% of the water used is returned via the Anytown wastewater treatment facility. The remainder is lost through the process.

Water reuse: Facility does not currently have the ability to reuse water.

Conservation Measures Used: Pipes visually inspected for leaks weekly. Pond checked for leaks every 5 years. Pond covered to minimize evaporation in summer. Process will be computer controlled for optimal water use by 2007. Expect water use to drop by 20%.

River gage: Facility uses USGS gage at Riverbend to determine river flow. Gage checked daily and recorded with daily pump totals on data sheet. Facility cannot physically use intakes if river flow at Riverbend is below 25 cfs.

Planned shutdowns: The facility shuts down for 1 week during the first full week of August. There is no water use during that week.

Other information: The facility is planning an expansion in 2008 that will double the plant output. Water conservation measures will allow this to happen with a 50% increase in water use.

Water Use Management Possibilities:

- 1) Change in timing of pumping each day.
- 2) Pump at a lower rate for a longer period of time each day.
- 3) Draw pond down during week and refill over weekend.
- 4) Accelerate implementation of computer process control to conserve water.
- 5) Increase storage capacity.
- 6) Treat and reuse water.

Souhegan Instream Flow Study and Water Management Plan

Consent Form

The study you are in which you are partaking involves research conducted through the University of New Hampshire. The purpose of the Souhegan Instream Flow Study is to develop a reliable process for investigating both technical and community aspects to river management and test the process for the Souhegan River to create recommendations for a Water Management Plan to be implemented by the State of New Hampshire Department of Environmental Services (NHDES).

Depending on your level of involvement, your participation in the study could take from 1-6 hours of time over the next few months. You will be assisting the research by sharing your values about the river, filling out a written survey, and partaking in a follow-up interview to verify your responses to the written survey.

If you have questions about the research, please call the project director, Tom Ballestero at 603-862-1405. The UNH Office of Sponsored Research can answer any questions about the rights of research subjects at 603-862-2003 (Julie Simpson).

To protect the anonymity of respondents, written survey results will only be reported in summary or aggregated forms, without individual identifying information. Original surveys, transcripts, or other responses shall be stored at UNH. All of the research products (such as reports and recommendations) deliverable to NHDES shall be open to the public and subject to comment and revision on the basis of public input

Your participation is voluntary; refusal to participate will involve no penalty or loss of benefits to which the subject is entitled. You may discontinue participation in the study at any point without penalty.

Thank you for your participation.