

Report of the Instream Flow Pilot Program

(Submitted pursuant to RSA 483; Laws of 2009, Chapter 201; and Laws of 2013, Chapter 248)

Prepared by

**Watershed Management Bureau
NH Department of Environmental Services**

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December 1, 2015

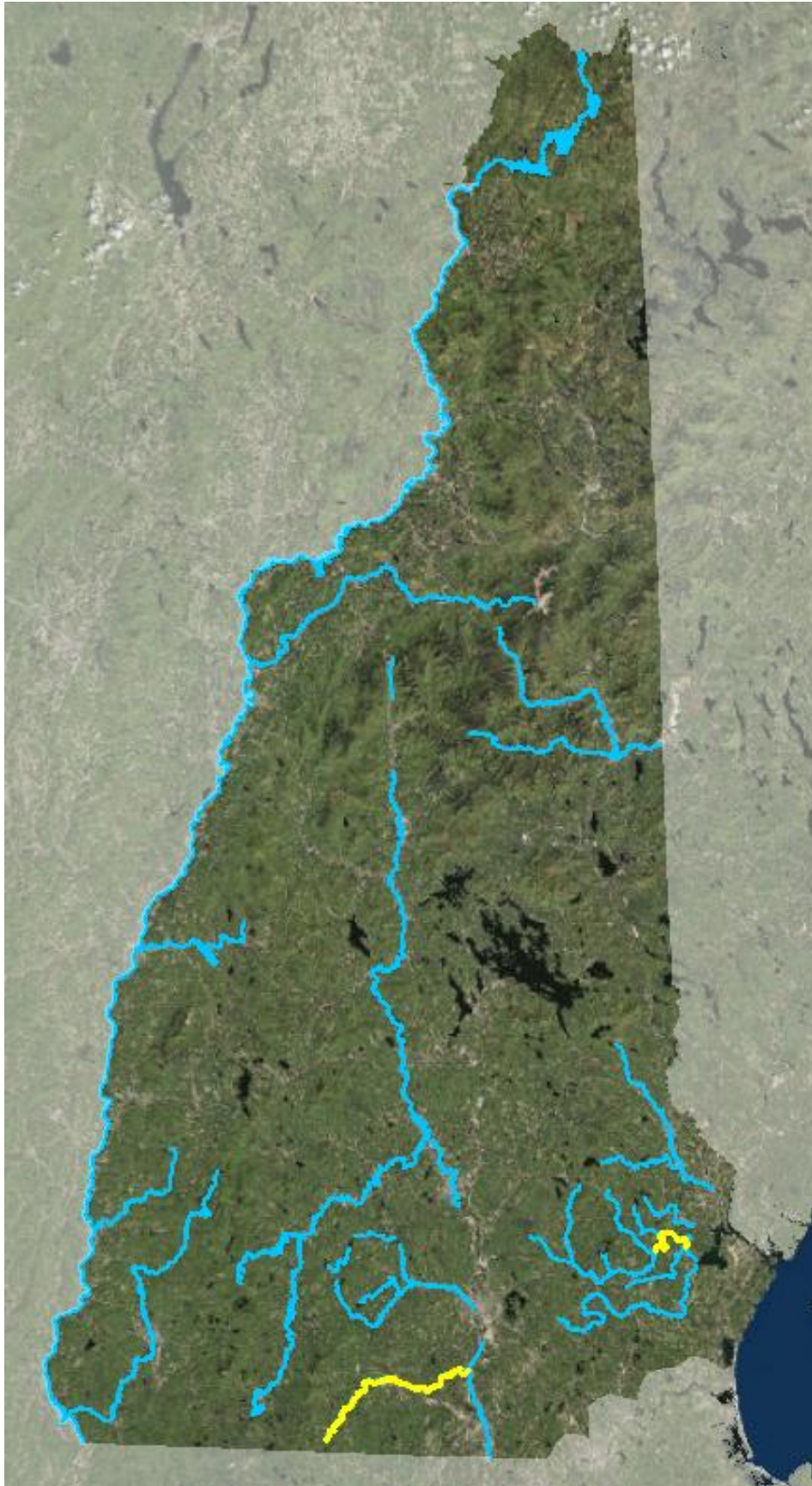


Figure 1 - Designated Rivers of New Hampshire 2015, showing the Souhegan and Lamprey Rivers (highlighted) as the two pilot rivers pursuant to Laws of 2002, Chapter 278.

Statutory Requirement for this report:

“III. The commissioner of the department of environmental services shall:

(c) By December 1, 2015, submit a final report that details the activities and results of the pilot program, including the impacts of the protected instream flows and water management plans on water users, wildlife, recreation, and other interests along the rivers, a plan for implementing protected instream flows and water management plans for other rivers designated under RSA 483:15, and any recommendations for proposed legislation. The report shall also include a summary of public comments received, the completed instream flow studies, and the adopted protected instream flow levels and water management plans and shall be submitted to the senate energy, environment and economic development committee, the house resources, recreation and development committee, the senate president, the speaker of the house of representatives, the governor, the committee to study the impact of water withdrawals on instream flows established under 2000, 242:1, and the state library.” Laws of 2013, Chapter 241

Previous Chapter law set out requirements for NHDES to provide a draft for public comment and schedule hearings prior to the final publication of the report on December 1, 2015. See Laws of 2009, Chapter 201.

Standards for Instream Flows

An instream flow standard should imply a formula that would incorporate biological and hydrological information to assign a range of instream flows for a stream.

Hal Beecher, Standards for Instream Flows, Rivers, Volume 1. Number 2, 1990.

The Importance Of Natural Flow Variability

Comprehensively addressing ecological flow needs requires recognizing the importance of natural flow variability, within and among years, to sustaining ecological processes in riverine systems. Although maintaining natural flow variability is only one component necessary to sustaining riverine systems (i.e., adequate water quality, channel maintenance and connectivity among parts of the river system are also essential), ecologists consider maintaining natural variability key to supporting ecosystem function (Poff et al. 1997).

from Some “Pros and Cons” of Alternative Methods of Defining Instream Flow Requirements, Mary C. Freeman, *Proceedings of the 2005 Georgia Water Resources Conference*, held April 25-27, 2005, at the University of Georgia. Kathryn J. Hatcher, editor, Institute of Ecology, The University of Georgia, Athens, Georgia.

http://www.gwri.gatech.edu/sites/default/files/files/docs/2005/freemanm_GWRCpaper2.pdf

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Glossary and Acronyms

anadromous fish – An anadromous fish is born in fresh water, spends most of its life in the sea and returns to fresh water to spawn. Salmon, smelt, shad, striped bass, and sturgeon are common examples.

biological integrity – In the NH Code of Administrative Rules Env-Wq 1702.07, “Biological integrity” means the ability of an aquatic ecosystem to support and maintain a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of similar natural habitats of a region. Biological integrity is required in all surface waters by the New Hampshire Surface Water Quality rules.

Env-Wq 1703.01 Water Use Classifications.

(b) All surface waters shall be restored¹ to meet the water quality criteria for their designated classification including existing and designated uses, and to maintain the chemical, physical, and biological integrity of surface waters.

consumptive water use – is water that is removed and is not returned either in the same quantity, in the same location or at the same time as the withdrawal.

cfs – means cubic feet per second. This applies to stream flow rates and represents the equivalent of a basketball-sized amount of water passing per second.

dam owner – for the purposes of instream flow means a dam owner affected by the Instream Flow Pilot Rules known as an affected dam owner. An affected dam owner is defined in the Instream Flow Pilot Rules as an owner of a dam with an impoundment having a surface area greater than 10 acres in the watershed area of a Designated River. See Env-Wq 1902.02.

de minimis amount - is an aggregate water use at any river location equal to 5 percent of 7Q10 at that location. 7Q10 is the lowest, seven-day average flow having a statistical recurrence interval of once in ten years.

See the Instream Flow Pilot Rules: Env-Wq 1902.07. The *de minimis* amount is always available for use.

Designated River – In the Instream Flow Pilot Rules, Env-Wq 1902.09, “Designated river” means a river or river segment that is designated under RSA 483:15. There are currently 18 rivers or segments thereof that have been determined by legislative action to be Designated Rivers.

RSA 483:4 Definitions. – In this chapter:

VIII. “Designated river” means that portion of a river which has been specifically designated by the general court pursuant to RSA 483:15.”

The current Designated Rivers are shown in Figure 1.

designated uses – are defined by Env-Wq 1702.17 in the Surface Water Quality Rules as those uses specified in water quality standards for each waterbody or segment whether or not such uses are occurring at present. The New Hampshire Consolidated Assessment and Listing Methodology describes designated

¹ Note the definition of ‘restore’ in RSA 483 is XVI-a. “Restore” means to return an ecosystem to a close approximation of its natural condition.

uses as the desirable uses that surface waters should support. Table 3.4 of that document lists and describes the seven New Hampshire designated uses and may be found at <http://des.nh.gov/organization/divisions/water/wmb/swqa/documents/calm.pdf>.

existing uses – are defined by Env-Wq 1702.23 as those uses, other than assimilation or waste transport, which actually occurred in the waterbody on or after November 28, 1975, whether or not they are included in the water quality standards.

FERC – Federal Energy Regulatory Commission is an agency that regulates the interstate transmission of electricity, natural gas, and oil. FERC reviews, authorizes and licenses hydropower projects.

flow deficit – is the difference between daily mean stream flow and the protected instream flow criteria as measured at an index location, usually a U.S. Geological Society stream flow gage.

flow-dependent protected entities – are the instream public uses described in RSA 483 that require a certain flow in order to persist including fish and other aquatic life, recreational uses, and riparian plant communities and wildlife species.

gage, stream gage, or stream flow gage – is a U.S. Geological Survey facility where stream data are collected to determine stream flows. For the purposes of this report, a gage is an active, continuously functioning measuring device for which a mean daily streamflow is computed or estimated and quality assured for at least 355 days of a water year or a complete set of unit values are computed or estimated and quality assured for at least 355 days of a water year.²

induced recharge – is the water collected by a groundwater well that comes from a stream or lake when pumping the well lowers the water table adjacent to or below the stream or lake.

Instream Flow Pilot Rules – Env-Wq 1900 - Rules For The Protection Of Instream Flow On Designated Rivers. These rules, first adopted in 2003, apply only to the Pilot Program on the Souhegan and Lamprey Designated Rivers as required by Laws of 2002, Chapter 278. They are interim rules in partial fulfillment of the requirements under RSA 483:9-c.

management - is used in this document to refer all actions taken before, during and after a low flow event as they are described in the Water Use Plans and Dam Management Plans for the Pilot rivers.

Natural Flow Paradigm – is a conceptual model for stream flow protection that recognizes that stream flow is comprised of more than magnitude, and also includes the timing, duration, frequency and rate of change as components of stream flow. Protection of stream flow requires retaining the natural variability of streams, which must be described using these components.³

NHDES – New Hampshire Department of Environmental Services.

² U.S. Geological Survey definition available at <http://water.usgs.gov/nsip/definition9.html>

³ Poff, N. L., J.D. Allan, M.B. Bain, J.R. Karr, K.L. Prestegard, B.D. Richter, R.E. Sparks, and J.C. Stromberg, 1997, *The Natural Flow Regime*. *BioScience* 47 (11): 769-784.

protected entities – are a river’s instream public uses, outstanding characteristics and resources as listed in RSA 483, and designated and existing uses. These include fish and other aquatic life, hydropower, recreational use, and stream bank plant communities and wildlife. See Appendix B for a listing of protected entities. See also **flow-dependent protected entities**.

protected instream flows – are a set of criteria that define the stream flows in a Designated River which maintain water for instream public uses and conserve and protect outstanding characteristics, with priority given to those characteristics that are necessary to meet state water quality standards.

relief pulse – is an intentional, two-day, release of water from a dam, which is designed to briefly increase stream flow in the Designated River to restore the natural stream flow pattern and as a relief for fish and other species of the aquatic ecosystem. Relief pulses are described in dam management plans and are part of the overall water management plan.

reporting threshold – refers to the Water Use Registration And Reporting Rules,⁴ which require reporting of water use by the owner of a facility that uses an average of 20,000 gallons of water or more per day in any 7-day period or 600,000 gallons in any 30-day period.

riparian – of, relating to, or situated on the banks of a river. Protection criteria are determined for riparian wildlife and plant communities during the instream flow study.

Rivers Act or New Hampshire Rivers Management and Protection Program Act – RSA 483 - Chapter 483 - New Hampshire Rivers Management And Protection Program. The Rivers Act contains the provisions adopted in 1990 for developing instream flow protection for the State’s Designated Rivers. The Rivers Act also identifies and describes each of the Designated Rivers.

USGS – means the United States Geological Survey.

Target Fish Community – is the distribution of species that would ideally live in a river. The distribution and relative abundance of target fish species are determined from fish collections in similar rivers having the least level of impairment. An existing community that matches the Target Fish Community is the goal of instream flow protection. The species identified are included in the flow-habitat model during the instream flow study to determine protection criteria.

water quality standards – are described by Env-Wq 1702.52 in the Surface Water Quality Rules as the combination of designated uses of surface waters, and the water quality criteria for such surface waters based upon such uses.

water user – for the purposes of instream flow means a water user affected by the Instream Flow Pilot Rules known as an affected water user. An affected water user is defined in these rules as a water user required to be registered because their water use exceeds the threshold defined in Env-Wq 2102 and having a withdrawal or return location within 500 feet of a Designated River or within 500 feet of a river or stream in its tributary drainage area. See Env-Wq 1902.03.

⁴ Env-Wq 2102 is available at <http://des.nh.gov/organization/commissioner/legal/rules/documents/env-wq2102toc.pdf>.

Organization of this report

This report documents the implementation of the Souhegan and Lamprey Water Management Plans since their adoption in August 2013. It describes the activities and results of the Pilot Program and what was learned. The report is required to detail the impacts of the protected instream flows and water management plans on water users, wildlife, recreation, and other interests along the rivers; and also to define a plan for protecting stream flow on other Designated Rivers in New Hampshire. It includes a summary of the comments heard on the draft report during the public hearings and comment period.

The report is organized into the following sections and appendices.

Report Sections

- Section I contains NHDES's legislative, programmatic and funding **recommendations** for applying the Instream Flow Program to the other Designated Rivers and for continuing the implementation on the Souhegan and Lamprey Designated Rivers.
- Section II outlines key concepts for understanding this report by reiterating earlier reports describing the **development of protected instream flows and water management plans**. See also appendices A, C, D, and E for more detailed descriptions and access to the original reports.
- Section III lists the **lessons learned** from the Pilot Program development and implementation that will be useful for applying instream flow protection on other rivers, as well as the benefits resulting from the development and application of instream flow protection.
- Section IV identifies the **impacts of protected instream flows and water management plans** on protected entities and the public.
- Section V contains the proposed **plan for applying instream flow protection** to other Designated Rivers.
- Section VI provides the **conclusions** of this report.

Report Appendices

- Appendix A expands the description of the protected instream flow studies and the water management plan development that are summarized in the next section below by including the guiding concepts and methods used by the Program.
- Appendix B contains links to the legislation and rules that define both the New Hampshire Instream Flow Program and the requirements for this report.
- The Protected Instream Flow Study Reports, Water Management Plan Reports and the NHDES Commissioner's Declarations of the Establishment of Protected Instream Flows are included by reference. Appendices C, D and E describe the physical and online locations where one may access these earlier reports. Appendix C describes access to the Protected Instream Flow Study Reports. Appendix D describes access to the rivers' Establishment of the Protected Instream Flows reports. Appendix E describes access to the Water Management Plans. The Instream Flow Program maintains a website where all Souhegan and Lamprey River documents can be found at <http://des.nh.gov/organization/divisions/water/wmb/rivers/instream/index.htm>.
- Appendix F contains a compilation of the protected entities that are described in RSA 483.
- Appendix G contains the 2013 guiding principles for water resource management developed by the Lakes Management Advisory Committee and the Rivers Management Advisory Committee as a mechanism for resolving competing interests in water resource management.
- Appendix H contains the comments received on the September 1, 2015 draft of this report along with a summary and discussion of those comments.

Report of the Instream Flow Pilot Program

Executive Summary

The New Hampshire Department of Environmental Services (NHDES) submits this Report of the Instream Flow Pilot Program to the General Court as part of the Instream Flow Pilot Program statutory requirements. The two purposes of the Instream Flow Pilot Program (Pilot) defined by statute are to develop a methodology to define and implement protected instream flows on Designated Rivers and to meet water quality standards. Two rivers, the Souhegan and Lamprey, were chosen as the pilot rivers. Protected instream flows were established that translate the narrative water quality standards to numerical criteria. The Pilot provided an appropriate way of protecting water quantity by establishing specific stream flows that represent the natural variability of flows. In short, the Program identified when the pattern of flows are abnormal and then created water management plans to restore natural flow patterns.

The report contains a summary of the decade-long development of protected instream flows and water management plans for the Souhegan and Lamprey Rivers, along with the lessons learned during that process. It also describes the next steps and recommendations for applying instream flow protection provisions to other Designated Rivers. These other rivers could enjoy the same benefits of the Instream Flow Pilot Program.

The Pilot Program ...

Protects fish and other aquatic life-- The protected instream flow levels that were determined during the Pilot reflect stream flows that mimic natural stream flow patterns, which best support fish. Fish are sensitive to changes in the stream flow pattern. By protecting the fish, other species, recreation and other uses are also protected.

Provides water for people-- The Program determined the water use needs for water users on the rivers and worked with those users to develop management plans. Water users include municipal suppliers, golf courses, plant nurseries, and agriculture. Each user has a customized water use plan that describes their actions to meet their water needs in times of drought and protect stream flows for other users and the environment.

Proactively plans for water use-- A key result of maintaining protected instream flows is a more robust water supply. Existing and new water users will develop supplies that are useable during drought. New users will also gravitate toward more plentiful sources and away from sensitive sources. This will both protect river ecology and help direct water-intensive businesses to ample supplies.

Levels the playing-field for all users-- Conservation plans and water use plans are required for all larger water users on and upstream of each Designated River, so these water users know, if they impact stream flow, that they will need to find alternative water sources during droughts. Any new user will not be able to drive the water levels lower than the protected flows. Applying the Program on all of the Designated Rivers would provide a level playing field for existing and new water users throughout most of the state because any new user ... would be subject to the same water management conditions as existing users.

Provides incentives for sustainable water infrastructure development-- The communities of the state invest significant amounts of tax-payer dollars on their water infrastructure. A key feature of the Instream Flow Program is that water management focuses on water uses that most impact stream flow. Water that

is returned to the same place on a river from which it is withdrawn is counted as a “net zero” use of water. As such, there are few restrictions placed on these types of uses during low flow periods. This provides an incentive for communities and businesses to design their water use infrastructure to be non-consumptive and to have less impact on stream flow. The value of infrastructure that already returns locally is enhanced by the Instream Flow Program.

Integrates management of lakes and rivers-- This Program recognizes that lakes and rivers are integrally connected and that they must be managed in concert. The water management plans include relief pulses from lakes to restore the natural stream flow pattern. Limits were applied to these releases to protect lake habitat and recreational uses. In one case, by virtue of taking a close look at the lake level and river flows, changes in management have resulted in improved water quality in a lake.

Improves the public outreach approach-- The Program recognized the need for public input from the outset, and included dozens of public meetings over the decade of its development. Moreover, the Pilot emphasized the need to specifically involve certain types of stakeholders, particularly lake-front property owners on lakes that will be used to create relief pulses, water users and dam owners.

Is a scientific and river-specific approach-- The Pilot Program applied a systematic approach to define protected instream flow criteria. Results of the Pilot confirmed the need for river-specific instream flow studies for each river, rather than generalizing protected flows. For example, the Lamprey and Souhegan watersheds are similarly sized, but given their respective unique geology and geography, it is not surprising that the same methods resulted in different flow protection criteria for the two rivers. In one case, this river-specific approach increased the amount of river flow that a water supplier could withdraw because the Instream Flow methods are much more precise than the generalized procedures employed by their earlier permitting processes.

The Instream Flow Program is an investment in the health and wellbeing of the people of New Hampshire. The Instream Flow Program is a proactive planning tool that not only addresses current river use but establishes a process for managing the demand for future water uses. Fully implemented, the Program will result in Designated Rivers that have healthy, balanced ecosystems and in robust water supplies for drinking water, business and other off-stream uses, which are capable of fully providing for water needs during low-flow conditions.

I. Summary of Program recommendations

Under current law, RSA 483:9-c, instream flow protection is required for all of the Designated Rivers. The following recommendations, if implemented would provide the authority and resources needed to meet this requirement. Revisions to the specified statutes would allow NHDES to apply the instream flow rules in the most efficient and effective way. Resources in the form of staff and funding would be needed to achieve these objectives. The current Program operates without any state funding. Without additional funding, instream flow protection on the remaining rivers could not be completed in a timely manner, if at all, and the implementation of management plans on the Souhegan and Lamprey Rivers would be less effective. Below is a summary of the legislative, programmatic and funding recommendations as described in greater detail later in the report.

I.A. Legislative Recommendations:

- Allow the expiration of Chapter 278 of the Laws of 2002 to remove the pilot status of the Instream Flow Program, which will promote the application of instream flow protection on all of the Designated Rivers in the state. NHDES, following Laws of 2013, Chapter 241, would, at some time after December 2015, revise the Instream Flow Pilot Rules to define the process for determining protected flows on all of the Designated Rivers.
- Revise RSA 483 to state that flow-dependent entities are the intended targets for instream flow protection. The only flow-dependent entities in the Pilot Program included fish and fish habitat, riparian wildlife and vegetation, and recreational boating. Currently, instream flow protection is applied to all of the features for which a river is designated, which includes many features that are not flow dependent.
- Revise RSA 483 to formalize the concept of the Natural Flow Paradigm developed by Poff and others⁵ and as applied by the Pilot as the conceptual framework for stream flow protection.
- Revise RSA 483, if necessary, to establish stakeholder advisory committees in order to ensure an inclusive, easily maintained, and effective public participation process. The Pilot Program showed that a single member of an interest group may not adequately represent all of the various interests within a watershed and that it is not reasonable to expect that member to relate technical information to all members of their constituency. NHDES intends to ensure that each potential management action is known and understood by all of those who may be affected. NHDES recommends forming instream flow subcommittees based on, but not limited to, the Local River Management Advisory Committees. These subcommittees would be formed for each Designated River at the outset of an instream flow study and water management plan development process in order to provide the framework for public participation that encourages broad and in-depth involvement.
- Revise a provision of the New Hampshire Safe Drinking Water Act, specifically RSA 485:61, Rules for Water Conservation, to broaden the applicability of the existing Water Conservation Rules to include water users in a Designated River watershed where an instream flow water management plan is being developed or has been adopted. Currently, some water users are subject

⁵ Poff, N. L., J.D. Allan, M.B. Bain, J.R. Karr, K.L. Prestegard, B.D. Richter, R.E. Sparks, and J.C. Stromberg, 1997, *The Natural Flow Regime*. *BioScience* 47 (11): 769-784.

to water conservation measures under either the Instream Flow Program, the Water Conservation Program, or both. This change would consolidate all water conservation practices within a single program.

I.B. Programmatic Recommendations:

- Relative to the process, the protected instream flow studies should continue to be conducted by consulting firms, however, NHDES should be responsible for facilitating public participation and for completing the water management plans. During the Pilot, the consultants were responsible for completing all aspects of the study and the water management plan. Given the iterative nature and need for extensive public participation in the development of water management plans, it is impractical for consultants to perform this phase of the work.
- Relative to the instream flow methods, the methods tested by the Pilot Program should be modified to reflect the lessons learned as outlined in this report, and be applied to all of the Designated Rivers.
- Public input on river-specific instream flow issues should be addressed by creating a subcommittee of the Local River Management Advisory Committee. This subcommittee should be focused on the effects of the water management plans and include stakeholder interests as well as Local River Management Advisory Committee members. Representation of state-wide stakeholder groups through the Rivers Management Advisory Committee and the Lakes Management Advisory Committee should continue advising NHDES on issues affecting all of the Designated Rivers.
- The long-term biological monitoring network could be augmented to fully assess the results of instream flow protections. The key elements of this monitoring include fish and riparian vegetation. Fish monitoring includes repeating the baseline fish collections at regular intervals, in this case, at least once every five years for each Designated River segment that receives its own protected instream flow. Riparian vegetation communities were identified and measured during the development of instream flow protections. Similar surveys should be conducted on all of the Designated Rivers followed by monitoring.
- Criteria should be developed for the application of adaptive management. Adaptive management would be applied if unintended or unexpected negative consequences are identified (through monitoring or other means) in order to correct for these consequences. Criteria should be developed to define a change significant enough to warrant revision of protected instream flows or water management plans.
- NHDES recommends that the application of the Instream Flow Program to the other Designated Rivers be prioritized. NHDES has begun developing criteria, as described in Section V, that could guide the prioritization process. Instream flow protection would be applied earliest to the rivers of highest priority.
- The maintenance of existing stream flow gages and the collection of new and additional stream flow data to support instream flow protection should be addressed on all Designated Rivers.

- Among other things, this would require protection of the existing stream gage network by providing an allowance to cover inflation of costs for the existing gages that NHDES already supports with general funds. (See funding recommendations below.)
 - There are Designated Rivers with no gages. Other Designated River gages are too few to describe stream flow and water use impacts adequately. NHDES and other interested parties should review the stream flow data needed for water management plans on the Designated Rivers. Review should include the recommendations of the 2006 Stream Gage Task Force Report⁶ to make new recommendations for additional gages, where necessary, specific to the Instream Flow Program needs.
 - Multi-year flow record estimates should be created at ungaged locations in order to conduct instream flow study modeling. (See funding recommendations below.) USGS and others are able to generate these stream flow data records, which are currently available for streams in Massachusetts.
- Data should be collected and analyzed to describe the Target Fish Communities in the state's Designated Rivers. Fish data can be most efficiently collected and assessed in a single, state-wide effort applied to all of the Designated Rivers. These data would complement monitoring that should be performed to identify existing conditions and trends. (See funding recommendation below.)
 - Long-term monitoring methods should be developed and applied on all of the Designated Rivers to assess baseline conditions and changes in fish population, riparian plants and wildlife, and recreational usage. Currently, there is no systematic monitoring to identify trends in the health of the fish, or riparian plant communities and wildlife on the Designated Rivers. (See funding recommendations below.)

I.C. Funding and staffing recommendations:

- Existing staff should continue the implementation of the water management plans on the Souhegan and Lamprey Rivers. In addition, over the next few years, existing NHDES staff would develop criteria for the application of adaptive management (as described below), rewrite administrative rules, create a long-term monitoring plan, and assist in the prioritization of the next Designated Rivers on which to develop and implement protected instream flow criteria. Existing staff costs total approximately \$106,000 per year. Existing staff is currently funded through Federal funds. That funding is subject to the whims of the United States Congress and the Federal budget process.
- Fund capital improvements to fully implement the water management plans on the Souhegan River by retrofitting the gates of three dams that are instrumental in providing relief pulses. These retrofits are to allow the state-owned Souhegan River flood control dams to be operated so that the Program can be fully implemented and the Souhegan River protected. A cost of \$151,200 is estimated to retrofit each dam for a total of \$453,600.

⁶ The Stream Gage Task Force's report is titled, "A strategy to implement and fund a long-term, multi-purpose New Hampshire Stream Gage Network" and dated September 15, 2006. It is available at http://des.nh.gov/organization/divisions/water/wmb/rivers/rmac/nh_sgtf.htm.

- Provide funding for an allowance to protect the stream gages that NHDES currently supports from losses due to inflation. New Hampshire loses gages when inflation increases costs for the USGS stream flow gages. Currently, as costs increase from year to year, these gages are threatened by stagnant or declining funding each budget cycle. NHDES's current budget from general funds for stream flow gage support is \$187,000. A five percent annual increase to cover inflation in costs may forestall further gage losses. These losses could be prevented by an allowance to account for rising costs starting at \$9,350.
- Provide funding for generating 30- to 50-year, daily flow record estimates for ungaged locations derived from flows measured at gaged locations. These flow records are required input to instream flow models, but are not available on ungaged or inadequately gaged rivers. NHDES estimates that all the rivers of the state may be analyzed for \$75,000 to \$125,000. These records would provide valuable data for assessing water resources and water quality for many programs and citizens' groups.
- Funding is needed to provide two additional staff for the Instream Flow Program. This would include a Hydrogeologist III to develop and implement water management plans and an aquatic biologist (Environmentalist IV or Biologist III) to monitor impacts on aquatic and riparian life and recreation. Salary and benefits for each additional position at LG 27-Step 1 would be \$51,772.50 + 51.5% for benefits = \$78,435 annually.⁷ These positions could be added over time as the Program ramps up to work on additional Designated Rivers. There are currently no General Funds being used for the Instream Flow Program or for existing staff.
- Provide adequate funding for instream flow studies on other Designated Rivers. An average of \$195,000⁸ annually would be needed to contract consulting services to conduct the two instream flow studies over two years. NHDES would initially focus on a prioritized set of Designated Rivers. Instream flow protection would be applied in order of priority relative the amount of funding available. If funding becomes available, instead, for a specific river then that river would be given priority. Without additional funding, instream flow protection on the remaining Designated Rivers cannot be completed.
- Provide \$250,000⁹ for a study to develop a regional statewide Target Fish Community that would identify the expected species distribution within each Designated River. Identification of biologic condition is lacking in much of the state, which this study would start to correct. Utilizing a defined target community, instream flow criteria would be assessed in the context of the expected conditions. Conducting this study in advance will "jump start" the development of protected instream flow criteria on the Designated Rivers when it occurs and streamline the Instream Flow Program process.

⁷ Effective 1/9/2015.

⁸ Determined from an average of the estimated, weighted, mileage-based costs of the eleven tributary Designated Rivers. Includes Contoocook and Piscataquog with all branches as one river. Management should be developed first on the tributary rivers to avoid duplication of effort. Table 6 is a list of all Designated Rivers and a cost estimate to complete each of their protected instream flow studies.

⁹ Estimate based on reported cost of \$200,000 by the Massachusetts Division of Fisheries & Wildlife to complete target fish community assessments on 11 mainstem rivers. There are 18 Designated Rivers in New Hampshire, some of which have a mainstem and one or more branches. The Souhegan and part of the Lamprey have been completed.

I.D. Proposed timeline for Instream Flow Program actions

The timeline below of anticipated NH Instream Flow activities assumes certain legislative actions affecting the Instream Flow Program and related programs occur during the 2016 legislative session.

Activity	2016	2017	2018	2019	2020
Continue implementation of Lamprey and Souhegan Rivers					
Replace Pilot Rules with new Instream Flow Rules					
Develop reference stream flow data					
Develop the process to identify the next river(s)					
Develop statewide Target Fish Communities					
Support stream flow gaging on Designated Rivers					
Hire instream flow staff person					
Begin hiring process for consultant conducting ISF study					
Hire second instream flow staff person					
Develop and conduct long-term biomonitoring program					
Public outreach regarding the next river(s) to be assessed					
Conduct Instream Flow Study and develop Water Management Plan on additional river/rivers.					

II. Introduction

This report is an evaluation of the Instream Flow Pilot Program required by statute. The Program protects the flow-dependent features of two rivers that the people of the state value. The Program also manages water use and resources to protect those public interests and to provide ways for water users to meet their needs. The Program provides incentives for the wise use of water resources, directing consumptive uses toward more robust supplies and guiding the future growth of infrastructure toward reuse as some of the long-term solutions to increasing water demand.

One of the objectives of the Program is to maintain stream flow conditions in order to protect the state's interests in surface waters and river resources. This objective is guided by the requirement to respect the interests of water users that are consistent with protecting the river. Instream flow protection is a two-step process, first to define flow protection criteria and second to apply the management necessary to meet those criteria. The flow protection criteria become the numerical translators of the State's narrative water quality standards for stream flow protection. The water management plans apply to the existing water uses and must be changed as water uses change.

New Hampshire's General Court created the Instream Flow Pilot Program by revising the instream flow requirements under the Rivers Management and Protection Act.¹⁰ The legislature in 2002 "established the Pilot Instream Program for the purpose of studying and establishing protected instream flows and water management plans for the Lamprey River and the Souhegan River, and their respective tributary drainage areas." The General Court directed NHDES to write administrative rules for pilot instream flow studies and developing water management plans on the Souhegan and Lamprey Designated Rivers. NHDES then contracted with ecologists and hydrologists to conduct the studies and develop the plans that are described in the previously published reports of the Instream Flow Pilot Program.

The Pilot Program legislation also requires this report to be a part of a review process. This report includes discussion of topics that were raised during public hearings on the protected instream flow studies and water management plans. It also includes discussions in response to both statutory requirements and to questions raised by the Rivers Management Advisory Committee and the Lamprey and Souhegan Water Management Planning Area Advisory Committees. After the water management plans were adopted, NHDES solicited these committees for topics that ought to be addressed in the final report. NHDES presented the draft report to the public for comment at three public hearings in September 2015 and considered those comments when formulating potential revisions to the Program and finalizing this Report.

II.A. Benefits of the Instream Flow Program

The Instream Flow Program was a pilot program designed to test methods for defining stream flow protection and management. The Pilot Program yielded several dividends that will not only form the foundations for protecting and managing stream flow on other Designated Rivers, but also provide benefits for other state programs, including:

1. **Stream flows that protect aquatic life and maintain biological integrity** – NHDES applied scientific methods that assessed river-specific flow needs for the river's aquatic species. The Pilot Program's methods were effective in defining critical flow thresholds on the pilot rivers. Flow

¹⁰ RSA 483 - New Hampshire Rivers Management and Protection Program. Available at <http://www.gencourt.state.nh.us/rsa/html/1/483/483-mrg.htm>.

protection criteria are defined which do not limit water use at arbitrary low-flows, but applies management when conditions exceed levels of defined biological stress.

2. **A process for ensuring water users have the water they need** – Assessments conducted during the Pilot Program showed that water for instream and off-stream uses is available most of the time. On rare occasions, stream flows will fall below critical thresholds and will not meet the needs of both instream and off-stream uses. Water Management Plans describe how water users will find the water supplies they need to maintain their operations. Water users with low levels of impact on river flows have the fewest management actions.

3. **Proactive planning for sustainable water resources** – Development of Water Management Plans will provide more resilient water supplies for water users and provide protection for aquatic species and habitat. These plans balance ecosystem and human needs. Water users will develop more robust, drought-resistant water supplies. New water users will be subject to the same management criteria as existing users and may decide to locate where water resources are plentiful.

4. **Conceptual model for flow protection** – The Program adopted the Natural Flow Paradigm¹¹ concept that stream flow protection requires protection of the pattern of seasonal flows. This paradigm states that effective stream flow protection criteria are defined in terms of magnitude, duration, frequency and timing.¹² This definition counters older ideas that streams can be protected by describing only a minimum flow rate. Use of the Natural Flow Paradigm definition profoundly enhances the effectiveness of flow protection measures and increases water availability for users.

5. **Coordination of lakes and rivers management principles** – Principles for the comprehensive management of water resources were developed and approved by both the Lakes Management Advisory Committee and Rivers Management Advisory Committee, which are two committees that were established by statute to advise the NHDES Commissioner with respect to lakes and rivers interests statewide. As a result of instream flow management discussions, in 2013 a joint subcommittee of the Lakes Management Advisory Committee and the Rivers Management Advisory Committee identified guiding principles for watershed management.¹³ Recognizing the potential for conflicting uses, principles were defined which advocate for water quality protection, management on a watershed-scale that includes all water uses, and management that imitates natural conditions. The principles recognized the need for evaluation of watershed-specific conditions, for infrastructure development focused on water use management, for water use based on public trust and riparian rights, and for effective emergency response management. NHDES now uses these principles as a lens through which to evaluate both new legislative proposals and existing programs.

6. **Expanded stream flow data collection and records** – The Stream Gage Task Force,¹⁴ convened by the Instream Flow Pilot Program, identified statewide stream flow gaging needs as determined by a variety of stream flow data users. The report pointed out the necessity of permanent funding for stream flow gages. Twelve stream flow gages were restored or newly

¹¹ Poff, N. L., J.D. Allan, M.B. Bain, J.R. Karr, K.L. Prestegard, B.D. Richter, R.E. Sparks, and J.C. Stromberg, 1997, *The Natural Flow Regime*. *BioScience* 47 (11): 769-784.

¹² Rate of change, the final component of the Natural Flow Paradigm, is managed by defining actions taken under the water management plans.

¹³ These principles are attached as Appendix G in a document called *Comprehensive Surface Water Resource Management - NH Lakes Management Advisory Committee and NH Rivers Management Advisory Committee - January 23, 2013*. Also available at <http://des.nh.gov/organization/divisions/water/wmb/rivers/instream/documents/20130123-l-and-r-final.pdf>.

¹⁴ See report called *A strategy to implement and fund a long-term, multi-purpose New Hampshire Stream Gage Network - 9/15/06* at NHDES website at http://des.nh.gov/organization/divisions/water/wmb/rivers/rmac/nh_sgtf.htm.

installed on Designated Rivers to provide site-specific flow data in 2008 and 2009 as a result of this study. However, funding remains an issue. Three of these gages were closed in 2011 due to lack of continuous funding. Another gage was threatened with closure in 2015 when the annual cost per gage increased while state funding remained level. The gage was saved only when a federal project fell through which freed up funding, however, this illustrates the tenuous nature of the New Hampshire stream gage network.

7. Tools to compare stream conditions to the protected instream flow criteria – Tracking tools, described later, were created to compare stream flow to the protected instream flow criteria. These tools are maintained on the NHDES website for the public to follow changing river conditions. Water users and dam owners that have management plans can use these tools to prepare for management events.

8. Lake management criteria – Releases from lakes are a component of instream flow management. Limits were set on lake level fluctuations as a result of management which were tied to key factors, including loon nesting, nutrient loading and export, ice condition, protection of seasonal docks, overwintering habitat, anadromous fish migration, and recreational use of lakes. These factors and associated limits were identified as part of the management criteria under this Program and will be considered when lake management considerations are applied to other lakes for the purpose of helping to meet surface water quality criteria in Designated Rivers. These criteria may also have benefits to other programs.

9. Study methods established and report outlines created – Study plans were created that define the methods for assessing protected instream flow criteria. A method for assessing the target fish community was applied during the Pilot to define a quantified goal for fish population distribution. The Instream Flow Study and Water Management Plan reports represent templates for reporting the instream flow protection criteria and for documenting the management plans.

10. Better understanding of lake drawdown impacts – The Instream Flow Pilot Program expanded an ongoing study of phosphorus into the fall, winter and spring that informed changes to lake drawdown management. These changes resulted in the increased export from the lake of hundreds of pounds of phosphorus and improved lake water quality without causing detrimental impacts to surface water quality in the Designated River. These changes to lake drawdown management are also expected to improve lake habitat for fish, amphibians and reptiles.

II.B. Program summary

The protected instream flow studies and water management plans are discussed below. These methods and concepts are the foundations for the discussion of impacts and the plan in this report. Key concepts included in Appendix A include: 1) the conceptual model of flow protection; 2) the flow protection goals; and 3) the components of the water management plans. It is important to understand these methods and concepts as they are fundamental to implementing the instream flows and water management plans, and also to understanding the proposed plan for moving forward with instream flow protection on other Designated Rivers. A fact sheet describing the New Hampshire Instream Flow Pilot Program is available on the NHDES website.¹⁵

II.B.1. Protected Instream Flow Studies

Instream flow studies were conducted on both the Lamprey and Souhegan rivers prior to setting the river-specific protected instream flow criteria. Flow protections were evaluated for the flow-dependent instream

¹⁵ Available at <http://des.nh.gov/organization/commissioner/pip/factsheets/rl/documents/rl-28.pdf>.

public uses found in the Designated Rivers. The studies used three assessment methods to evaluate the rivers' instream uses. Studies of the flow-habitat relationships are essential for identifying the flow thresholds that have the greatest effect on fish habitat. Protected instream flow criteria were set to maintain the frequency and duration of flows exceeding those thresholds.

Stream flows change over short and long time scales. Since fish and other river inhabitants vary in their life cycles and flow needs, the goal of the Program is to maintain the characteristic pattern of flows that supports aquatic life rather than prescribing any single flow. Protecting the stream flow pattern has been shown to be the only effective means of meeting the goal of protecting the biological integrity of streams and other water quality criteria. Protecting the natural flow variability has been recognized and adopted by instream flow practitioners around the world. The protected instream flow criteria describe this pattern of variability. The pattern of encompassing high and low flows allows species with different flow preferences to coexist. Maintaining a river's characteristic flow pattern also protects riparian plants and wildlife, as well as various recreational uses.

The studies were completed with input from technical and stakeholder advisory committees. Numerical protected flow criteria were defined. Flows were defined to protect fish and other aquatic life, and also recreational uses and stream bank species, collectively known as the flow-dependent protected entities. The protected instream flow criteria serve as the numerical translators of the narrative water quality standards for flow and aquatic life. These criteria are designed to restore surface waters to maintain their chemical, physical, and biological integrity and to protect existing and designated uses.

II.B.2. Water Management Plans

Water management plans were developed to document actions needed to meet the protected instream flow criteria. When stream flow approaches or no longer meets the protected flow criteria, then management is required to avoid water quality impairment. Actions by water users under the conservation and water use plans reduce the short-term stresses on streams by spreading, reducing or delaying impacts of water withdrawals. The water use plans also identify the means by which water users may fulfill their water demands during periods of low flows when management is applied. The dam management plan provides for relief pulses from dam storage to offset flow deficits. NHDES assessed the size of historical flow deficits to determine the magnitude and timing of management actions. Managing dam releases to create relief pulses is a key element of supporting biological integrity. Two-day relief pulses mimic historic flow patterns to provide relief to fish by resetting the flow pattern.

The Souhegan and Lamprey reports on the instream flow studies and the water management plans can be accessed through the information in appendices C and E for more detailed descriptions. They may be found online at <http://des.nh.gov/organization/divisions/water/wmb/rivers/instream/index.htm>.

III. Lessons learned from the Souhegan and Lamprey Rivers

This section describes the general and river-specific lessons learned during the development and implementation of the protected instream flow criteria and the water management plans. The development of the protected instream flow criteria and water management plans are described in separate reports. The implementation of the Souhegan and Lamprey water management plans began August 30, 2013 upon their adoption by the NHDES Commissioner. Included are the river-specific management actions taken by water users and dam owners and the actions NHDES is taking as a result of these experiences.

The Instream Flow Pilot Program achieved many of its objectives. The focus of the Pilot was on studying procedures and methods suitable to defining and implementing protected flow criteria. Numerical flow criteria were developed and management plans were adopted that will maintain those criteria. The Pilot shows that this process works and the methods can be applied on other rivers. Rivers with different conditions may be accommodated using the procedures developed under the Pilot.

III.A. River-specific lessons

III.A.1. Souhegan water management plan implementation status

There remains some work to complete the Souhegan River Water Management Plan implementation. The conservation plans are well under development. The water use plans are defined but in some cases are being modified to address the water users' desire for more water. The dam management plans are defined but not implementable, as is described below.

III.A.1.a. Souhegan management actions applied

This section describes Souhegan River management events that occurred in the last two years since August 2013 when the Pilot Program's implementation period began. The water management plan describes actions to be taken under certain protected instream flow conditions. NHDES compares Souhegan River stream flows to the protected flow criteria to determine these conditions and posts the results on the Instream Flow web page.¹⁶ The Souhegan River has two sets of instream flow criteria—one for the steeper, upper river and one for the flatter, lower river.

A variety of actions may occur under the Souhegan River water use plans depending on the time of year and stream flow, but the only action that is applied under a dam management plan is a relief pulse that would be applied to a Catastrophic condition. Catastrophic events include low-flow conditions that continue for extreme durations defined by the river and time of year, as well as multiple shorter-duration events during a specific period, called Persistent events. Persistent events may also have management associated. Catastrophic events require both water use plan actions and dam management plan actions.

i. Upper Souhegan management

Water use plan actions are applied before a relief pulse occurs for those affected users who have management responsibilities. Throughout the implementation period, no management was required.

ii. Lower Souhegan management

Two Persistent events occurred in successive years during the same October 1-November 14 bioperiod. In 2013, Persistent conditions lead into a Catastrophic condition lasting 28 days from October 14 to

¹⁶ <http://www2.des.state.nh.us/OneStopPub/Watershed/souhegan-upper-pisf-track.xls> and <http://www2.des.state.nh.us/OneStopPub/Watershed/souhegan-lower-pisf-track.xls>

November 10, 2013. In 2014, a four-day duration of Catastrophic conditions that would have resulted in a relief pulse occurred. However, no relief pulse was implemented because the flood control facilities identified in the dam management plans have not yet been retrofitted to allow releases of this kind. Because the October 1 through November 14 timeframe is outside the time of year when discretionary and outside water uses are common, and when stream flows are relatively large, no restrictions were applied to outside water use.

The deficit flow was 53 cubic feet per second (cfs) after 40 days below the Critical threshold of 96 cfs for this period. This deficit was so large that relief pulse flow of 22.3 cfs, as is outline in the water management plan, would not have met the instream flow criteria. A failure of a relief pulse is allowed and expected in one of ten years, but if failures are repeated more often, then adaptive management may be appropriate to ensure the designed rate of failure is not exceeded.

III.A.1.b. Souhegan dams not ready for management

The Souhegan dam management plan relies on releases from four dams. Three of these are flood control dams operated by NHDES. Implementation of the Souhegan dam management plan for relief pulses is stalled because NHDES lacks funding to retrofit the outlets at the state-owned dams. The existing outlets are passive release structures that require conversion to manageable outlets in order to conduct stream relief pulses. Reconstruction of the outlets is needed to allow storage and release of water. The NHDES Dam Bureau estimated in 2009 the cost for one dam outlet retrofit at \$136,000.¹⁷ An average inflation rate of 1.60% was applied over 7 years, resulting in an estimated 2015 cost of \$151,200.¹⁸ The resulting estimate to retrofit three dam outlets is \$453,600.

A fourth dam to be managed for relief pulses is a privately-owned, hydropower facility with operable outlet structures. The owner has expressed his willingness to be part of the management of releases. However, the conditions of the dam's FERC licensing exemption will need revision in order to accommodate the dam management plan.

III.A.1.c. Effects of dam removal on the Souhegan River¹⁹

The Merrimack Village Dam, near the mouth of the Souhegan River, was removed in 2008 in order to open fish passage between the Merrimack and Souhegan Rivers and to restore riverine habitat to the formerly impounded section. The effects on the fish population such as river herring and shad are as yet unknown, but New Hampshire Fish and Game Department is stocking the Merrimack River with these species and may stock the Souhegan River.²⁰

The dam removal does not change the protected flows. The protected flows were determined at study reaches unaffected by the dam and the protected instream flow criteria are not based on the fish distribution there. The study reaches were assessed to quantify the flow characteristics of magnitude, duration, frequency and timing that support the species of the Souhegan Target Fish Community at levels

¹⁷February 9, 2009 memo from Daniel Mattaini, P.E. , Senior Project Engineer, NHDES Dam Bureau to Wayne Ives, NHDES Watershed Bureau.

¹⁸<http://www.usinflationcalculator.com/inflation/current-inflation-rates/>

¹⁹ For the effects of dams and dam removals, see also: *Dams and Development: A New Framework for Decision-Making. The Report Of The World Commission On Dams*, Earthscan Publications Ltd, London and Sterling, VA at http://www.internationalrivers.org/files/attached-files/world_commission_on_dams_final_report.pdf.

²⁰ Personal communication from Matt Carpenter, NH F&G, March 2, 2015

equivalent to the historical or reference flow record. The Souhegan Target Fish Community is derived from fish collections on other rivers that the dam removal does not affect.

Neither did the dam removal reduce NHDES's ability to manage flows in the Designated River. The storage behind this dam was insufficient to provide a relief pulse and its location at the bottom of the watershed meant it would have had no effect on most of the Designated River. Removing the dam restored riverine habitat and flow conditions to the impounded segment. The river has benefited from the improvement of its physical integrity that has allowed the movement of fish, sediment, water and nutrients.

III.A.1.d. Souhegan management notification process

Water users and dam owners need to know the protected instream flow status and to be aware of impending management conditions. NHDES has created a website that includes an online tool where anyone can see the current status upper and lower Souhegan stream flow status and assess the upcoming conditions.²¹ The upper and lower Souhegan Designated River segments each have a Protected Instream Flow Tracking Tool on the Instream Flow Program's website. NHDES contacts water users directly when management is required. The website may at some point in the future eliminate the necessity of NHDES notifications, but NHDES will continue to make these notifications during the early years of implementation.

A notification plan will be developed more completely when Souhegan River dams are able to conduct relief pulses.²² In the initial years of Souhegan water management plan implementation, NHDES intends to notify individuals charged with actions under the Water Management Plans, and also the public officials and other individuals who have interests in the river management process, of the onset of required management activities. NHDES will initiate the notification plan based on the Souhegan's two online tracking tools. These notifications are likely to be in the form of emails and, in some cases, may include telephone calls to ensure that there is detailed coordination of activities such as dam releases. Notifications will summarize current conditions and describe actions being taken by NHDES. The particular actions required of water users and dam owners will be specified in their respective management plans.

III.A.2. Lamprey water management plan implementation status

The Lamprey water management plan is complete and implementation is ongoing. Conservation plans are well under development, water use plans are defined, and the dam management plans are ready for implementation, although Mendums Pond dam is undergoing reconstruction and will not be available in the next few years. The pond was drained in September 2015 to allow reconstruction that may take up to two years. Full implementation of the dam management plans, if needed, will be delayed until then.

III.A.2.a. Testing of relief pulses on the Lamprey

Before the water management plan was adopted, the dam management plan was tested. A series of releases were conducted to demonstrate the effects of a relief pulse on lake level, water quality, and flow change in the river.²³ These tests showed that the releases produced the expected increase in flow at a

²¹ <http://www2.des.state.nh.us/OneStopPub/Watershed/souhegan-upper-pisf-track.xls> and <http://www2.des.state.nh.us/OneStopPub/Watershed/souhegan-lower-pisf-track.xls>

²² See discussion of dam status under the section above called III.A.1. Souhegan water management plan implementation status.

²³ Unpublished NHDES report – 20130402 draft 2012 Pawtuckaway Release Test.

downstream USGS stream flow measurement station, did not violate water quality standards for turbidity or temperature, reduced conductivity, and had no significant effect on nutrient levels in the lake or downstream receiving waters. Two tests were conducted under winter conditions confirming the necessary winter lake level required to produce the stream flow pulse and that a lower lake level did not produce sufficient flow. Relief pulse tests are helpful and may be incorporated into future studies.

III.A.2.b. Lamprey management actions applied

This section describes Lamprey River management events that occurred in the two years since August 30, 2013 when the Pilot Program's implementation period began. The water management plan describes actions to be taken under certain protected instream flow conditions. NHDES compares Lamprey River stream flows to the protected flow criteria to determine these conditions and posts the results on the Instream Flow web page.²⁴

Water use plan actions are applied before a relief pulse occurs. Water use plans were activated in September 2014 before a Persistent event occurred. In September 2014, stream flow fell briefly below the protected threshold, initiating management by affected water users. The UNH/Durham Water System stopped pumping water from the Lamprey River and used its alternate sources. The low-flow condition lasted one day.²⁵ Coordination with the water systems in Epping and Raymond to notify their customers of NHDES's request for voluntary conservation was precluded by the brevity of the low-flow conditions.

Persistent events occurred twice in the May 5-June 19 bioperiod of 2015 when flows fell below the protected-flow thresholds. These events lasted three days or less. The first ended as a result of natural rainfall and the second ended with the close of the bioperiod.

Persistent conditions also occurred in early August 2015 during the July 5 – October 6 bioperiod. These conditions exceeded the duration criteria for the lowest flow threshold, resulting in a Catastrophic condition. Water use plan actions and a relief pulse were conducted in July and August 2015 in response to that Persistent/Catastrophic event. Management actions began in July 2015, when stream flow fell below instream flow thresholds and the UNH/Durham Water System again stopped withdrawing from the Lamprey on July 24. NHDES provided Epping and Raymond with a press release requesting that those towns implement voluntary water conservation measures. At the time, Epping had already declared an outside water ban. On August 17, because stream flows had remained below the instream flow thresholds for an extended period, the imposition of outside water bans by all public water suppliers became mandatory per their water use plans. Also on that day, NHDES began a 48-hour relief pulse of 10.5 cfs from Dolloff Dam on Pawtuckaway Lake.²⁶ Due to necessary repairs, Mendums Pond was not available for the relief pulse. The resulting flow was about 2 cfs below the target flow: The Mendums Pond release would have been 4 cfs. Contingencies for addressing this type of problem with availability of relief pulse flows are addressed in Section III.A.2.d. To discourage juvenile alewives from migrating prematurely out

²⁴ http://www2.des.state.nh.us/onestoppub/watershed/lamprey_pisf_tracking.xls

²⁵ The event in real time was two or three days, but USGS corrected the provisional stream flow data using measurements made during the low flow and the corrections resulted in a reduced duration.

²⁶ Unrelated to the Instream Flow Program management, a reported fish kill in the Lamprey River prompted NHDES Dam Bureau to insert "a small stick between a pair of logs" in Pawtuckaway Lake's Dolloff Dam beginning August 7 and ending August 11. The Dam Bureau action provided some minimal flow to Pawtuckaway River from the lake, which stopped spilling water to the river after July 22, 2015.

of the lake during the relief pulse, NH Fish and Game Department assisted NHDES by setting up a net in front of the dam.

A Persistent event also occurred in September 2015 during the July 5-October 6 bioperiod. This event was the third consecutive event during this bioperiod resulting in a Catastrophic condition requiring management on the basis that continued and repeated chronic conditions exceed normal levels of stress. The outside water bans in Epping and Raymond were still in place at this time and the UNH/Durham Water System was not pumping from the Lamprey River. On September 16, NHDES began a 48-hour relief pulse of 10.5 cfs from Drowns Dam on Pawtuckaway Lake. Once again, NH Fish and Game Department assisted NHDES by setting up a net in front of the dam to discourage juvenile alewives from migrating prematurely out of the lake during the relief pulse.

III.A.2.c. Pawtuckaway Lake issues and solutions

In the process of identifying impounded water that could be used for instream flow protection in the Lamprey River, two lakes were large enough, Mendums Pond and Pawtuckaway Lake. The final selection of these lakes were identified relatively late in the process of developing management plans. As such, and due to a lack of direct contact, many lake residents were taken by surprise when they learned of the plans to conduct relief pulses from the lake. They were further distressed by plans to conduct winter releases.

Pawtuckaway Lake and Mendums Pond have both been subject to deep drawdowns, nominally of seven feet, each fall for decades. These drawdowns are historical artifacts that were continued by NHDES Dam Bureau and to which lakefront owners have become accustomed. Reasons cited for maintaining these deep drawdowns include protection of docks from ice, control of aquatic plant growth, and protection from spring floods. The water management plan called for changes in the deep fall drawdown historically conducted annually on Pawtuckaway Lake to hold water for winter relief pulse. As a result of input from the Pawtuckaway Lake Improvement Association (PLIA) and the Town of Nottingham, NHDES conducted a series of public meetings and hearings about the drawdown. The primary issues that were identified as concerns from the town and lake residents included: wildlife (loons and fish), water quality, invasive plants, damage to docks, and recreational impacts.

As a result of the interaction with the local residents, NHDES conducted several studies and investigations to ascertain the probable effects on the changed drawdown and relief pulses on those areas of concern. Below is a summary of the findings of these studies and the ways in which the water management plan was modified to address these concerns.

Wildlife -- A Lake Level Investigation report by the NHDES Dam Bureau concluded that the deep drawdown is likely having negative impacts on the fish, frog and turtle population of the lake as a result of loss of winter habitat. Fish populations were shown with significant gaps in year classes, particularly small forage fish, although the link to lake drawdowns was not directly addressed.²⁷ NHDES met with the Loon Preservation Committee to discuss ways to reduce risks to loons. As a result of those meetings, additional restrictions were placed on lake level changes during loon nesting season, specifically that relief pulses will not be conducted if they change the water level in the lake by more than six inches.

²⁷ Unpublished report - Review of Pawtuckaway Lake bass electrofishing data (1997) – by NHF&G, November 6, 2012. This report includes bass electrofishing data (1997) and bass tournament data (1996-2008) for Pawtuckaway Lake (Nottingham).

Fish – NHDES discussions with NH Fish and Game Department identified possible impacts to river herring residing in the lake. The migration cues of these fish might be triggered by the flows generated by a relief pulse. Premature outmigration could leave these fish stranded when the relief pulse ended after two days. NHDES and Fish and Game identified a barrier method to prevent these fish from accessing the outflow during a relief pulse. Ensuring that the alewives leave the lake during the migration season may require active steps by NHDES to ensure there is a viable outlet. If lake levels are too low in the fall to provide access to the spillways, NHDES must open a release from a dam outlet that the alewives can use.

Water quality -- NHDES determined from analysis of phosphorus samples and from measurements of lake outflow, that the deep fall drawdown is causing phosphorus to remain in the lake, and that a shallower drawdown is likely to reduce concentrations of phosphorus, especially in the northern section. Less water is released from the northern section when there is a deeper drawdown and, at the same time, most of the phosphorus load enters the northern section of the lake. The fall drawdown is now focused primarily through Drowns Dam, which is the northern-most outlet. NHDES estimates that this change alone will more than double the amount of phosphorous flushed from the lake. In addition, the new winter lake level will allow flushing of phosphorus throughout the year, which has a greater benefit than current management. NHDES consulted with biologists at UNH to determine that these phosphorous releases will not likely have detrimental impacts on the river system downstream.

Invasive plants -- One the reasons articulated for the historic deep drawdown was for control of aquatic plant growth. Previous conventional wisdom indicated that deep drawdowns may be beneficial to controlling underwater plants. Since that time, new research, including studies in New Hampshire, have shown that drawdowns may change the plant community structure but do not have a meaningful impact on aquatic plant growth or reducing the risk of invasive plants. To track plant growth and species changes related to the change in drawdown, NHDES initiated a study of the lake's vegetation. A baseline study includes both broad surveys and small-scale plots. NHDES has committed to conduct annual surveys for a number of years in order to identify any trends in aquatic plant growth. In 2015, invasive milfoil was identified for the first time by members of the local Volunteer Weed Watchers Program.²⁸ It was found in an area unaffected by the change in drawdown. NHDES hand harvested the infestation and will monitor in the years to come.

Damage to docks -- The reduction in the annual fall drawdown from 7 feet to 4.8 feet at Pawtuckaway Lake, in order to store water for the possibility of a winter relief pulse, may have an impact on some lakefront property owners' docks. About 25% of docks will now be in contact with the water in winter, where previously only a few were in water. Historically, many dock owners did not remove their seasonal docks because of the deep drawdown. Even so, ice damage was a hazard before the reduction in drawdown was carried out. Historically, refilling the lake in the late winter for spring recreation meant that the new drawdown level was reached in early March. Lake ice has been present for many of the past years well into April after the lake level was at or above the new drawdown level. NHDES delayed full implementation of the new winter level for four years and offered repair permitting assistance to dock owners who do not wish to remove their docks during the winter.

²⁸ http://des.nh.gov/organization/divisions/water/wmb/exoticspecies/weed_watcher.htm

Recreational impacts -- These concerns were reduced when NHDES clarified that a change in summer lake level due to a relief pulse would typically be less than one inch, and that a relief pulse would not be conducted if the cumulative sum of relief pulses and normal lake level declines would lower the lake more than 18 inches below full pond level.

Finally, in order to continue to ensure that instream flow management is protective of the lake and to ensure accountability to the lake residents, NHDES signed a first-of-its-kind Partnership Agreement with PLIA. Under the agreement NHDES continues to monitor water quality and plant communities, and both organizations commit to ongoing communication.

III.A.2.d. Mendums Pond dam outlet gate reconstruction demonstrates the need for redundancy in dam management

The Mendums Pond dam's outlet gates were out of commission and unavailable for stream flow management during 2014-2015. In the fall of 2014, the gates on Mendums Pond dam were found to be broken and leaking. Stoplogs were constructed temporarily into the dam to control the lake level. Divers were hired to make repairs to the dam between April and July 2015. There were no relief pulses required during this period.

During the gate repairs, the NHDES Dam Bureau identified other leaks in the dam that needed to be repaired. The Dam Bureau drained Mendums Pond beginning in September 2015 and plans to make repairs over the ensuing 18 to 24 months. An extended low-flow period beginning in July 2015 continued into August. The Lamprey water management plan calls for a relief pulse from Pawtuckaway Lake and Mendums Pond following extended low flows of this duration. However, the Dam Bureau recommended that Mendums Pond not be used for relief pulses because of the dam's condition.

Mendums Pond contributions represent 25% of the relief pulse volumes specified in the Lamprey River Water Management Plan. Relief pulses from Pawtuckaway Lake alone may still be effective in resetting the natural flow pattern during this period, but there is a greater likelihood of failure to meet the protected flow criteria.

This sudden loss of a significant portion of the relief pulse volume demonstrates the need for developing dam management plan contingencies that have greater flexibility and redundancy. Where possible, NHDES should identify contingency releases from other dams in future dam management plans. Contingency plans may be in the form of additional dams identified for releases, or alternative releases from the dams previously scheduled for dam releases.

III.A.2.e. Timing of dam relief pulses

The releases from Pawtuckaway Lake and Mendums Pond are designed to work together to provide an increase in stream flow. The releases will need to be coordinated to combine their pulses. During the annual fall drawdown of Pawtuckaway Lake in 2009, the first pulse required 23 hours to reach the USGS Lamprey River near Newmarket stream flow gage. In 2013, NHDES conducted a smaller test release of 10.5 cfs under somewhat lower flow conditions. The pulse arrived after 35 hours. During actual low-flow conditions requiring a release in August 2015, a release of 10.5 cfs required 55 hours to reach the stream flow gage. Clearly, the lower stream flow conditions result in longer travel times. Relief pulses from Mendums Pond have not been attempted. Releases from the two dams will need coordination to ensure their pulses arrive at the same time. Testing of relief pulse travel times will be continued as opportunities arise.

III.A.2.f. Effect of the removal of Bunker Pond Dam

In 2011, the Bunker Pond Dam in Epping was removed. The dam's impoundment was sufficiently large to provide some of the flow for Lamprey relief pulses and was located where pulses would have affected all of the Designated River. However, high yearly maintenance costs combined with the interest of conservation groups in restoring the river to its natural state prompted a 2009 Dam Bureau proposal to demolish the dam, and that demolition was completed in October of 2011.²⁹ One-time reconstruction costs were estimated at \$241,400, which exceeded actual removal costs of \$206,643, which also included preparation of required historical documentation, biomonitoring and installation of a dry hydrant.³⁰ Removal of the dam opened 27 miles of the Lamprey River to diadromous fish passage, reestablished riverine habitat, and avoided future maintenance and repair costs.

III.A.2.g. Effect of the Wiswall Dam retrofit on protected instream flow criteria and on fish population and distribution

Durham installed a fish ladder and a stop log bay outlet in 2011-2012³¹ at Wiswall Dam to facilitate migratory fish passage. These structures have the potential to change the fish distribution upstream and downstream of the dam. Neither has an effect on the determination of the protected instream flows.

The protected instream flows were assessed using the species identified by the Target Fish Community evaluation. The Target Fish Community evaluation identifies the species and population distribution that should be expected in the Lamprey Designated River based on fish found in other rivers with similar character that have low levels of impairment. The instream flow criteria for fish will not be affected by the newly installed fish passage. The instream flow criteria were determined for the Target Fish Community species that should be present in the riverine portions of the river. The flow criteria support the fish species that are supposed to be in the river, whether they are currently there or not.

The fish passage structures are likely to result in a better distribution of fish that more closely matches the Target Fish Community because the river, having more fish passage, will function better to support fish. Dams can have many ecological impacts on rivers. They can block fish and other aquatic species from moving throughout a river system to access spawning sites and other critical habitats.³² Fish populations were measured upstream and downstream of Wiswall Dam before the fish passage installation. The fish passage structures will improve the fish distribution by allowing species to migrate and occupy preferred habitat. Since their installation, the alewife population has risen significantly and the fish passage operation does not impact flow upon which management actions are based.

III.A.2.h. Lamprey notification process

Water users and dam owners need to know the protected instream flow status and to be aware of impending management conditions. NHDES has created a website that includes an online tracking tool where anyone can see the current Lamprey instream flow status and assess upcoming conditions. NHDES contacts water users directly when management is required. The website may at some point in the future eliminate the necessity of NHDES notifications, but NHDES will continue to make these notifications during the early years of implementation.

²⁹ http://www.lampreyriver.org/UploadedFiles/Files/Folsom_Mills_trail_signs.pdf

³⁰ Personal communication with Grace Levergood, NHDES Dam Bureau, May 19, 2015.

³¹ <http://www.lampreyriver.org/multi-media-slide-shows-wiswall>

³² <http://des.nh.gov/organization/divisions/water/wmb/coastal/restoration/projects/river.htm>

A notification plan has been developed to inform water users and the public of impending Lamprey River management actions. In the initial years of implementation, NHDES intends to notify people charged with taking action under the Water Management Plans, and also the public officials and other individuals who have interests in the river management process, of the onset of required management activities. NHDES will initiate the notification plan based on the Lamprey's online tracking tool. These notifications are likely to be in the form of emails, and in some cases, may include telephone calls to ensure that there is detailed coordination of activities such as dam releases. Notifications will summarize current conditions and describe actions being taken by NHDES. The particular actions required of water users and dam owners will be specified in their respective management plans.

NHDES's Lamprey River notification plan is to send a message to people interested in the management of Mendums Pond and Pawtuckaway Lake when a relief pulse is imminent.³³ NHDES will initiate the notification plan based on its online tracking tool describing daily stream flows relative to the protected instream flows.³⁴ The notifications will describe current conditions and upcoming management actions to be taken. The particular actions required of water users and dam owners will be specified in their respective management plans.

During the development of the Lamprey Water Management Plan, comments requested that the public be given access to the water level data being collected at the Wiswall Dam impoundment. The UNH/Durham Water System withdraws water from the Lamprey River at this impoundment and is allowed to use storage in the impoundment for water supply while releasing outflow equivalent to inflow during times of low flow. The impoundment level would be drawn down to accomplish the outflow goal. There are limits defined for the maximum daily drawdown and for the maximum total drawdown in the impoundment. UNH Complex Systems, UNH/Durham Water System, and NHDES coordinated the development of an online data stream that shows the impoundment levels and will soon³⁵ be available online through the University of New Hampshire's website.

III.B. General lessons learned from the development and implementation of instream flow protections

The process of developing the pilot instream flow criteria and water management plans, and subsequently implementing the plans, brought new understanding of the science and administration of instream flow protections. From the development and documentation of fundamental concepts, essential data and methods of data processing were developed.

III.B.1. Tracking tool to identify management conditions

The water management plans identify management actions to be taken when the protected flow criteria are not being met. To identify when to carry out management actions, NHDES created online tools³⁶ that compare daily stream flow records to the protected flow criteria for each Designated River. Each tool indicates when conditions requiring management are imminent. The water management plans for water users and dam owners describe their individual responsibilities at various low-flow conditions specified

³³ A partnership agreement signed in 2013 includes a formal statement of notification for Pawtuckaway Lake flow releases. This is on the Instream Flow Program's website at

<http://des.nh.gov/organization/divisions/water/wmb/rivers/instream/documents/20130925des-plia-pa.pdf>.

³⁴ http://www2.des.state.nh.us/onestoppub/watershed/lamprey_pisf_tracking.xls

³⁵ Perhaps before 2016.

³⁶ <http://des.nh.gov/organization/divisions/water/wmb/rivers/instream/index.htm>

by the online tracking tool. NHDES must manually update the tool for each river, and this process will become even more labor intensive if and when more rivers are included in the Instream Flow Program.

III.B.2. Duration of relief pulses for instream flow protection

Re-creating natural stream flow patterns is a major focus worldwide of protecting rivers. A relief pulse is used under dam management plans in New Hampshire to restore the pattern of flow variability and provide relief from extended durations of low flows. Pulses maintain the natural variability of stream flow and do not deplete the water in the lakes from which they are released as would a continuous release. The rarely-applied relief pulses of the dam management plans mimic a small storm event in size and duration.

Flow patterns must occasionally exceed the flow magnitudes defined in the protected instream flow criteria. These exceedences occur naturally as pulses from rainfall or may be created by a dam release. The Pilot Program examined the naturally-occurring pulses to define the duration of a relief pulse. The Lamprey River Water Management Plan describes the review of natural pulses that occurred as a result of rainfall. Summertime rain events were identified that raised stream flow above the instream flow threshold and these were seen to last one to three days. Figure 2 displays the cumulative probability distribution of the duration of natural pulses that occurred from June 20 to October 6 each year from 2000 – 2010. Analysis of flow data demonstrated that a substantial proportion (30%) of the natural pulse events lasted one or two days. Longer lasting events tend to result from larger rainfall pulses that far exceed the protected flow thresholds. Two-day relief pulses were selected because the natural flows demonstrate that releases of

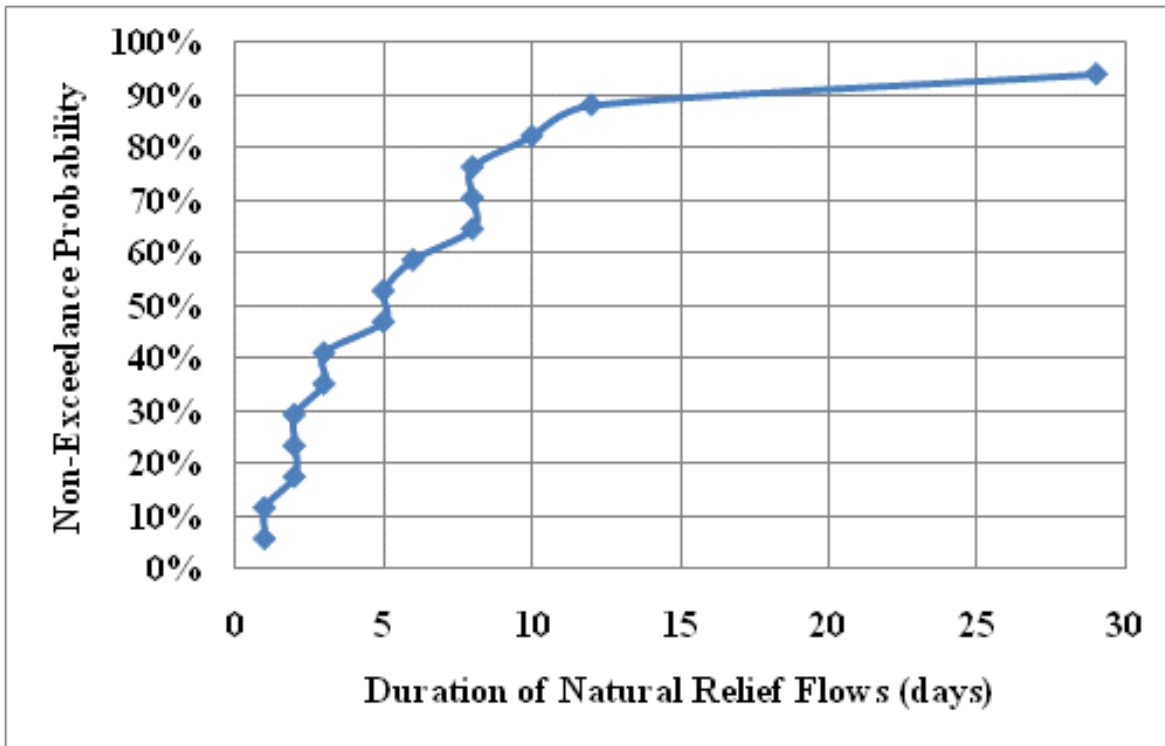


Figure 2 - Lamprey River natural flow pulse durations.

two days duration would be sufficient to restore the flow pattern and would also have limited impacts on lake levels. Longer relief pulse periods might be better at supporting flow-dependent fish, but would also remove more water from lake storage. Only relief pulses that are sufficient to exceed the protected instream flow

criteria are necessary, so releases of two days length were selected to recreate the natural flow pattern. Figure 3 is an example of a naturally-occurring pulse that exceeded the protected flow magnitude on the Lamprey River as a result of a small rain storm. It is this flow pattern that the relief pulses are mimicking.

III.B.3. Winter relief pulses and the need for winter habitat use data

Winter relief pulses are important management tools for maintaining the natural flow pattern of rivers. However, more research is needed on winter flows and their impacts on fish. Winter is an extremely stressful period for fish. Winter ice hazards are annual occurrences. Instream flow management should

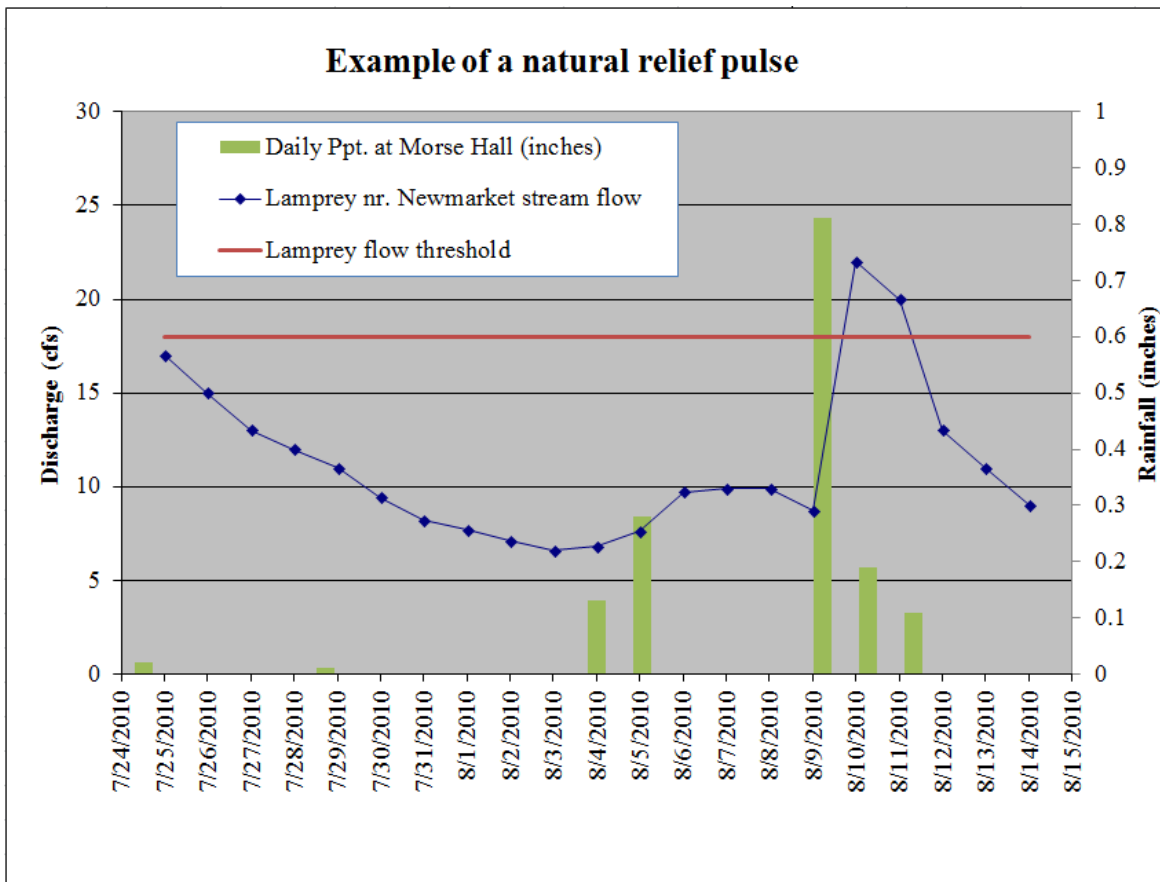


Figure 3 - A natural pulse on the Lamprey River as result of rain

strive to balance the stresses of low stream flows with those from the relief pulse relieving low stream flows. It may be appropriate to adjust relief pulses based on this research to be more protective of fish.

Riverine habitat use by fish and other aquatic species during the winter is poorly understood because few studies have been conducted during this time of year and fewer still have taken place in New Hampshire. Some researchers, however, suggest that survival rate is higher when the fish do not need to move. During winter, fish are required to expend energy to avoid ice jams, velocity increases, and predation that reduces their survivability.³⁷ However, continued low flows may result in ice formations that build up and crowd

³⁷ *Under the crystal ceiling*, by Lisa Densmore, Wyoming Wildlife, March 2014, http://www.instreamflowcouncil.org/instreamflowcouncil/wp-content/uploads/2014/04/Wyoming-Wildlife_Under-the-Crystal-Ceiling_Mar-2014.pdf.

fish out of their refuges or traps them within. When ice forms, the water flows through the ice at higher velocities that are often unsuitable for fish to maintain position.³⁸ The energy reserves of fish may not be sufficient to enable them to withstand disturbances such as frequent variation in river flows.³⁹ Relief pulses would increase velocity, but extended low flows may result in fish becoming trapped in ice and such conditions could be alleviated by a release that reopens flow channels and restores habitat space.

To balance the hazards of low flows with those of relief pulses, changes to winter releases may be appropriate. More data are needed that demonstrate the use by fish of river habitat during the winter. Standard techniques are difficult or impossible to employ during the winter. Life cycle habits of fish during the winter are known to be different than during the other seasons. However, this understanding does not translate into quantifiable habitat values. As a result, the needs of aquatic species during the winter are largely extrapolations of their habitat use based on other times of the year. Given the unknowns of winter habitat conditions, Instream Flow Program staff intends to continue to follow the research concerning winter relief pulses and winter fish habitat use.

III.B.4. Long-term monitoring is necessary

It has been apparent since before the water management plan adoption that some means of evaluating the effects of management are appropriate and necessary for assessing the Program's effectiveness. The natural variability in biological populations, the fact that management measures are only rarely applied, and other non-flow factors make assessing the effects of instream flow management a study in long-term trends. Ideally, adequate monitoring would be conducted before the start of management to establish baseline conditions. Monitoring would then be continued to track changing biological and recreational conditions and to inform adaptive management decisions.

Given the relatively short implementation period of the Pilot Program, we would not yet expect to observe any ecosystem changes attributable to the Program. In addition, the current health of both the Souhegan and Lamprey Rivers is good and relatively stable. In other words, the protected instream flow criteria will lead to protecting the existing river ecology but the improvements will be incremental over time as low flow events are managed.

Long-term monitoring strategies for the Program are under development and will build upon existing trend monitoring activities to answer whether flow conditions are affecting biological integrity. Elements of a monitoring plan are likely to be focused around fish collections and surveys of riparian plant communities. Five-year monitoring cycles are recommended. Assessments of chemical or physical parameters such as specific conductance and temperature would provide clues to a cause if changes were observed.

Planning for implementation of a comprehensive monitoring plan is greatly complicated by the uncertain availability of staff. Each field season, NHDES already collects thousands of data points to fulfill its current obligations. Additional field work to assess fish communities and riparian habitat will require significant staff time above the present capacity. In order to fully assess the long-term ecological effects of the Instream Flow Program, additional resources for monitoring will be needed.

³⁸ *A Primer on Winter, Ice, and Fish: What Fisheries Biologists Should Know about Winter Ice Processes and Stream-dwelling Fish*, Fisheries • vol. 36, no. 1, January 2011. www.fisheries.org

³⁹ *Winter Habitat Use of Fishes in the Ohio River*, Benjamin Ernst Lenz, Thesis, West Virginia University, 2003. http://www.wvuforestry.com/sWelsh/Lenz_thesis_library.pdf

III.B.4.a. Natural hydrologic variability

In addition to meeting the protected instream flow criteria, maintaining the natural variability of stream flow is a key goal for maintaining stream functions. A river's variability can be affected by water withdrawals, by dam storage, and by watershed impacts such as excessive impervious surface or land use changes. The protected flow criteria defines the key flow thresholds under the assumption that these impacts have not significantly altered the natural pattern. In fact, existing water use and dam management effects are quantified and removed from stream flow data to create a near-natural flow history. However, increasing water use may harvest more of the water available at high flows, resulting in declining variability. Land use changes and river modifications affect timing and rate of runoff as well as the physical instream habitat, all in ways that may affect variability. NHDES is conducting assessments of the short-, intermediate- and long-term variability using the Ecologically Sustainable Water Management⁴⁰ tool to evaluate the stream flow variability. Ecologically Sustainable Water Management can be used to evaluate the distribution of flows over these timescales for changes in the natural variability. Ecologically Sustainable Water Management assessments, especially if applied to the conditions resulting from new water use, will provide key insights into the effects of that water use on flow variability.

III.B.4.b. Fish

Fish are the most sensitive indicator of flow alteration. Fish monitoring data will be compared to the target fish community using metrics of species types, relative abundance and abundance. Each fish collection shows a snapshot of a small portion of a river at an instant in time. It takes many collections to form a comprehensive picture of the fish community. A series of these pictures is needed to show whether changes represent a larger trend or the regular, periodic rise and fall of fish species.

The target fish community was compiled from fish collections from several similar rivers that have low levels of disturbance to represent the expected fish community. Fish collections were made on the Lamprey and Souhegan Rivers to define the existing fish community. If the Instream Flow Program is effective, the species and composition of the existing community will shift to be more closely aligned with the target community. The Lamprey Target Fish Community is described in the Lamprey Protected Instream Flow Report.⁴¹ The Souhegan Target Fish Communities⁴² are described in the Souhegan Protected Instream Flow Report.⁴³

III.B.4.c. Riparian habitats and wildlife

Riparian habitats and wildlife are less immediately sensitive to flow than fish because they respond more to mid-range and higher stream flows. The occurrence of floods at a frequency as rare as two to ten years apart determines the viability of some plant communities. Exemplary plant communities were surveyed and described during the Protected Instream Flow study.⁴⁴ Repeating these surveys periodically will show whether these species and habitats maintain their relative position and abundance over the long term.

⁴⁰ *Ecologically Sustainable Water Management: Managing River Flows for Ecological Integrity*, Brian D. Richter; Ruth Mathews; David L. Harrison; Robert Wigington, *Ecological Applications*, Vol. 13, No. 1. (Feb., 2003), pp. 206-224.

⁴¹ See Section D 5, pp. 85-95

http://des.nh.gov/organization/divisions/water/wmb/rivers/instream/lamprey/documents/task7_1_pisf_report_071309.pdf

⁴² There are two segments of the Souhegan River, each with its own Target Fish Community because of the different characters of each.

⁴³ See Section IX, pp. 42-53

http://des.nh.gov/organization/divisions/water/wmb/rivers/instream/souhegan/documents/main_report.pdf

⁴⁴ In the section on Wildlife, Vegetation, and Natural/Ecological Communities.

III.B.4.d. Recreational use

Recreational use was assessed by surveying the boaters and canoeists who were using the river for their preferred flows. These uses are less sensitive than fish or riparian species to flow changes. Many boaters have a sense of how many boating opportunities are likely to occur during certain times of the year, but recognize that some seasons and some years will offer either more or fewer opportunities. The management strategy considers boating flows in the context of preserving the frequency of its occurrence. The number of such opportunities over a range of time periods⁴⁵ will be counted to determine whether the timing and frequency of opportunities are being maintained. Ideally, NHDES should repeat the survey of boaters at periodic intervals in order to assess whether there are perceived changes in opportunities and whether preferences have changed.

III.B.5. Effectiveness of relief pulses

Despite the absence of long-term monitoring required to assess biological effectiveness,⁴⁶ one key question of instream flow protection can be answered— Do relief pulses have the desired effect on flow?

One element of the water management plans is to use water held behind dams to cause relief pulses when stream flows remain below thresholds. Relief pulses are intended to create a specified increase in flow that briefly exceeds the protected flow threshold. The relief pulses can be observed at a downstream gage. The protected instream flow criteria are indexed to these gages.

A relief pulse of sufficient size and duration restores the natural flow pattern of stream flows.⁴⁷ The assumption that fish will be supported by this management will be tested by long-term monitoring, but relief pulse tests have demonstrated the releases are effective in restoring the flow pattern.

Two releases from Pawtuckaway Lake in 2012 and 2013 tested the relief pulses described under the Lamprey River Water Management Plan. The releases were made in late summer and winter.⁴⁸ The target flow rates were observed at the downstream gage as a result of the release. An actual relief pulse may respond differently because these tests were not conducted under low flow management conditions. However, the tests showed clearly that a managed release will increase the flow downstream in the predetermined quantity and duration needed to exceed the protected flow threshold.

Figure 4 demonstrates the result of one of the test relief pulses. An upstream gage⁴⁹ above the effects of the relief pulse was unaffected by the release. The downstream gage⁵⁰ clearly showed the relief pulse starting almost a day after the release and lasting two days before flows returned to previous levels.

⁴⁵ Monthly and annually at a minimum.

⁴⁶ See the preceding section describing the need for monitoring of biological conditions over a management period of years to assess the effects of instream flow management.

⁴⁷ <http://www.americanrivers.org/initiative/water-supply/projects/protecting-flow-with-the-clean-water-act/>

⁴⁸ Unpublished NHDES reports – Report on the Pawtuckaway Lake Release Test of September 5-7, 2012 - April 2013 and Report on the Pawtuckaway Lake Release Test of December 3 - 5, 2012 – April 2013

⁴⁹ USGS 01073319 Lamprey River at Langford Road, at Raymond, NH

⁵⁰ USGS 01073500 Lamprey River Near Newmarket, NH

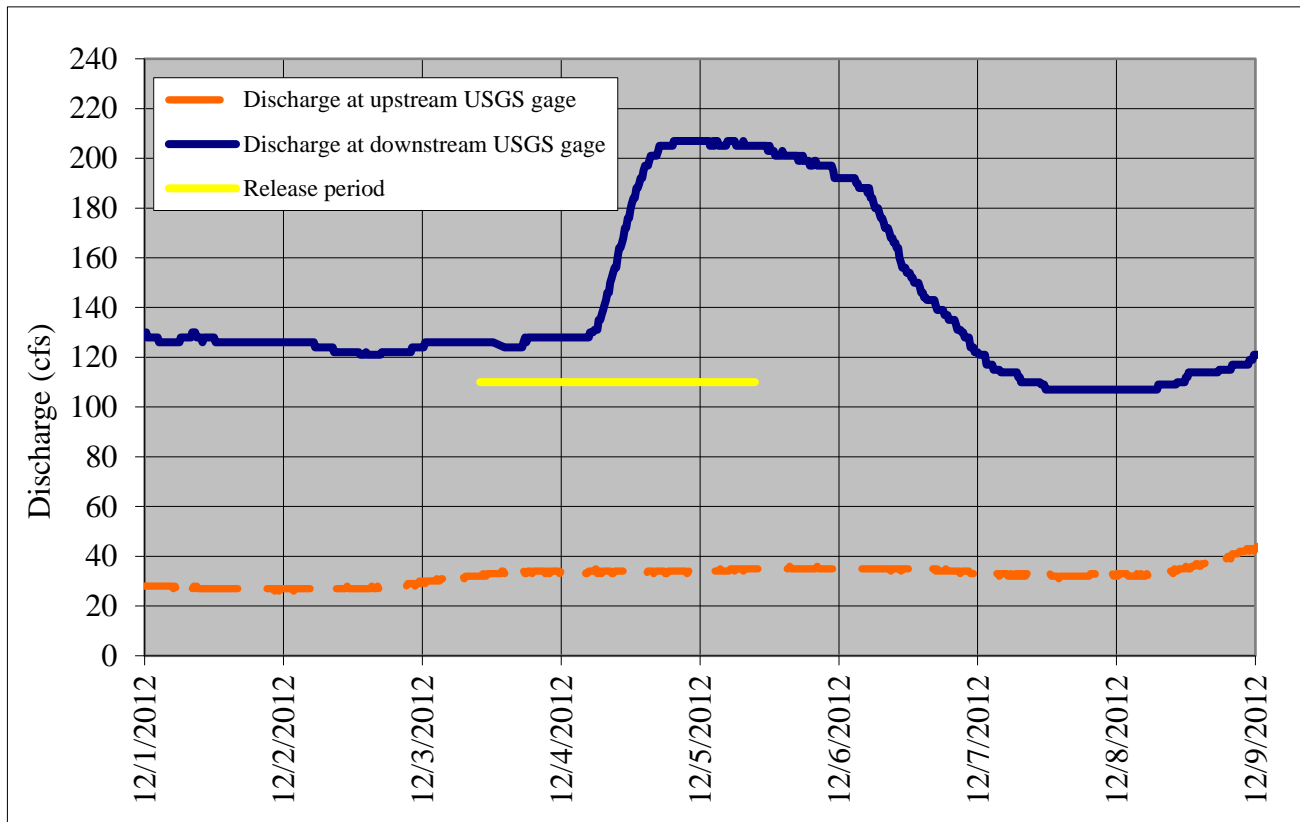


Figure 4 - Effects of a relief pulse demonstrated. Comparison of flow at upstream and downstream USGS gages on the Lamprey River during a 2012 Pawtuckaway Lake flow release test.

III.B.6. Work week restricts timing of relief pulses

At present, most of the dams for instream flow protection are operated by NHDES, whose work week is Monday through Friday. A relief pulse lasts 48 hours. Relief pulses can only start Monday through Wednesday without NHDES or other dam owners having to work weekends to either start or end the release. Relief pulses that begin between Thursday and Sunday would require dam operations over the weekend or flows to continue more than 48 hours.

III.B.7. Effect of the absence of dams on instream flow management

One of the key elements of a dam is its ability to store and release water. Dam management was made part of the Instream Flow Program’s strategy for meeting protected flows. The presence of dams creates options for instream flow protection by conducting relief pulses.

However, dams have a negative impact on stream flows, so NHDES is not recommending that new dams be installed for the purpose of instream flow protection. Changes to the natural flow pattern as a result of the presence of dams affect, to a greater or lesser extent, riparian wildlife and vegetation, and the fish in the river. Dams also replace the river with an impoundment, removing that segment’s riverine habitat, and changing water temperature, sediment transport, navigation and fish passage.

However, where there is an existing dam, relief pulses can be used to offset some of the changes to the river’s flow caused by the dam and by land use and development. Rivers that have a higher level of watershed development, and thus need more management, are also likely to also have more dams. The

changes to stream flow patterns resulting from factors like dams, existing impervious surfaces, floodplain development, channelization and water withdrawals may need management that can be accomplished by dam management unless other watershed-wide actions are applied to offset these factors.

NHDES may not be able to conduct a relief pulse to apply management to stream flow on rivers that have little development, including few or no dams, and there may not be a need to. Where there are few dams there are also fewer dam-related impacts on flow, and, perhaps, less need for dam management because existing flows will more closely mimic natural flows. On the other hand, the absence of dams removes one component of instream flow management options for stream flow protection. On rivers where there are either no dams, or at least no dams that affect most of the watershed, water resource management would need to rely heavily, if not exclusively, on conservation measures and water use management. Future development of the watershed should recognize the impacts of land development on stream flow in order to continue to avoid the need for dam management.

III.B.8. Hydropower dams as dams and water users

Hydropower dams are registered water users and, as such, are water users affected by the Instream Flow Pilot Rules. In some cases these dams also have impoundments large enough to be subject to the Instream Flow Pilot Rules as affected dams. Only Water Loom Pond dam in New Ipswich of the hydropower dams in the Souhegan and Lamprey watersheds met the definition of both an affected water user and an affected dam under the rules. Instream flow management in this case was addressed only by a dam management plan.

Smaller hydropower dams that do not qualify as affected dams, but are registered water users, are managed under conservation and water use plans. Since run-of-river hydropower water use is non-consumptive, there is no value in defining conservation measures.⁵¹ Their conservation plans simply follow Env-Wq 1906.02(d)(1) by stating that no conservation measures are to be implemented. Their water use plans state, where appropriate, that the dam will pass any water released as part of an upstream management action.

III.B.9. Limits on lake level changes for instream flow protection

The Instream Flow Program recognizes the need to avoid creating one problem in order to solve another. In the early development of water management plans, storage and release of water from dams over a range of up to 10 feet was proposed as a management tool. However, it was determined that a water level change of this magnitude would have a significant effect resulting in unacceptable social and environmental impacts. Such large changes of water level would negatively affect shoreline habitat and recreational interests of the affected lake. Accordingly, a limit was sought that would imitate natural lake level fluctuations.

As a general guideline, the Program determined that lake level changes should be limited. The Program applies a limit of two feet of lake level change to the effects of instream flow management, although in practice the change in water level will be much less. Lake level changes in some cases have been further

⁵¹ The Instream Flow Program leaves addressing appropriate stream flow protections within a dam's bypass reach, the segment between the dam intake and its return, to be addressed during dam license renewal.

reduced to protect sensitive lake environments or species.⁵² The Program sought to balance the impacts of water resource management between lakes and their downstream rivers

Management of water levels at dams for storage and release of relief pulses must also consider the structural integrity of the dams and the requirement to maintain capacity for flood storage. The dam structure may be required to hold permanently higher water levels in order to create relief pulses. Dams that are used for flood storage must be managed to retain the requisite flood storage volume or must otherwise be subject to operational mandates so that they safely release the stored water prior to a storm. The NHDES Dam Bureau already operates some dams to release water prior to a predicted large storm.

III.B.10. Use of privately owned dams in flow management

Under the current versions of the Lamprey and Souhegan water management plans, only one privately owned dam is included in the management actions that will be used to create a relief pulse. Watershed position and impoundment capacity may require privately-owned dams to be included in water management plans.

Private dams may be subject to instream flow management. New Hampshire holds in trust its lakes, large natural ponds, navigable rivers and tidal waters for the use and benefit of the people of the State. Under New Hampshire law, the legislature has the authority under its police powers to impose restrictions on the private use of water, as it has done under the Instream Flow Program. The legislature determined that the rules developed by NHDES will manage the quantity of water in certain rivers. Consistent with well-established legal principles, rules designed to protect public uses of a public body of water can be implemented without resulting in the taking of private property.

Privately-owned hydropower facilities operate under FERC licenses or under FERC-exemptions that define their management. These licenses are granted for decades and the exemptions are granted in perpetuity. Their operating conditions are defined for under these instruments. This situation vastly complicates the process of developing dam management plans in the Instream Flow Program.

NHDES has applied and would expect to continue to apply a standard of reasonable use to the dam management plans such that the owners, and the shorefront property owners, continue to enjoy the values and uses provided by the dam. To date NHDES has set limits on the water level changes in the impoundments of the dams being managed under the Pilot Program management plans. NHDES would expect to apply similar limits on the effects of management on any other dam used for water resource management should this Program be extended to other rivers in the future. Moreover, consistent with the Pilot rivers, management on other rivers would be limited to reasonable water level changes relative to the purpose of the dam and would protect water quality, including aquatic life habitat within a dam's impoundment.

III.B.11. Potential conflicts with other regulatory agencies

The application of water management through relief pulses has required changing current operations at some dams. The Instream Flow Program addressed issues of flood storage capacity with the U.S. Department of Agriculture's Natural Resources Conservation Service (NRCS) when assessing the storage of additional water for creating relief pulses. The relatively small changes in water level that the Instream

⁵² See the section titled 'Lakeshore environments and properties' in the 'Impacts of protected flows and water management plans' chapter.

Flow Program operates with to create pulses led the Natural Resources Conservation Service to allow NHDES to operate flood control dams funded by NRCS.

However, many other dams, and most of the dams that generate hydroelectric power, are regulated by FERC, often with input from the U.S. Fish and Wildlife Service (USFWS). These dams usually are required to maintain some form of minimum release or run-of-river conditions. These conditions may conflict with water management plans to support stream flow. Changing these conditions for small hydropower generators requires the dam owner to request a change from the FERC and to secure concurrence from the USFWS. At larger facilities, this process may require changes to the federal license. Relicensing generally occurs no more frequently than a 30-year cycle. There were no FERC-licensed dams on the Pilot rivers, but one dam on the Souhegan is a FERC-exempt facility that requires a change to its operating conditions in order to address the management needs of the Instream Flow Program.

III.B.12. Identifying and including new and existing water users in management

Every year, new water users are registered and existing water users add new sources in Designated River watersheds. Not only will the Instream Flow Program need to regularly incorporate new users into the management plans, but it will also need to adapt the management plans as existing water users change their operations. For example, during the implementation period, registered water systems were identified who were purchasing their water from another registered water user but continued to operate their own distribution system. These water users also require management plans since they are responsible for the effectiveness of their distribution systems as well. These water users will each have their own water conservation plan as defined under Env-Wq 2101, as other affected water users do, to meter water use and test for leaks, etc. Their individual water use plans will be tied to their water provider's plan since, other than owning their distribution systems, they would be covered under the larger system's management plan actions relative to the water source.

III.B.13. Application of the 500-foot rule

Affected water users, as defined by their water use and distance from the Designated River or its tributaries, are required to be part of a water management plan. Any water user facility required to register their water use but whose water sources and discharges were located more than 500 feet from the river or its tributaries were exempt from management under the Instream Flow Pilot rules.

The original purpose of the 500-foot rule was a simplification intended to exempt water users who were less likely to have an impact on stream flow as a result of the distance of their well from the stream. This simplification became unnecessary when NHDES incorporated an assessment of actual groundwater withdrawals as part of the instream flow studies. The use of the 500-foot rule to predict hydrogeologic connectivity is arbitrary, and since NHDES is conducting assessments of the hydrogeologic conditions associated with each water user, there is no reason for this rule to be continued.

III.B.14. Withdrawals from interstate waters

New Hampshire shares several waterbodies with its neighboring states. This condition may create an inequity to water users withdrawing from the New Hampshire side of interstate waters. The establishment of consistent authorities to regulate the withdrawal of water from interstate waters by users located in

neighboring states would require a coordinated response. This situation has been discussed in a report⁵³ to the Connecticut River Joint Commission and at the Commission's *Flow Policy Conference for the Upper Connecticut River Watershed* held on June 30, 1999. One suggestion proposed that the Connecticut River watershed be used as a pilot project for development of an interstate flow policy under the framework of the Clean Water Act (Water Quality Certification) and the New England Interstate Water Pollution Control Commission. Such a policy could develop watershed-specific flow standards which would be incorporated into each state's water quality standards.

III.B.15. Management plans apply only to water use

The water management plans are limited to management of the effects of withdrawals and returns of water. These effects were quantified during the Protected Instream Flow Studies. The studies did not address the effect on flows of watershed-scale factors (impervious cover, future development, etc.). While these factors have an effect on stream flow, it is not easy to quantify the effects of land use change on stream flow with great certainty. In addition, management of watershed-wide conditions is not yet part of the stream flow protection toolbox described in statute. Where the effects of watershed-wide factors exceed the ability of dam management to offset low flow conditions, other approaches that are beyond the scope of the Instream Flow Program, such as addressing reduction in impervious surfaces and other factors to manage these flows, may need to be considered.

III.B.16. Management plan changes on newly designated tributaries

Water management plans that are developed first in the upper Designated River watersheds are more likely to remain unchanged when a management plan is developed for a Designated River downstream. This is because not only do the management actions taken on tributaries serve to protect the aquatic resources within themselves, they also reduce the need for management downstream. Conversely, management plans on downstream Designated Rivers, which are less sensitive to instream flow issues, do not necessarily support protected flow criteria in the tributary Designated Rivers. As such, there is the need to recognize that any management plans that are written first for mainstem segments of Designated Rivers are likely to be altered for water users and dam owners in the upstream tributaries.

Water use on an upper watershed has a greater impact on that watershed than on the downstream river segment. For example, a municipal waste water treatment plant downstream of the community's water supply intake may only affect the river segment between where they occur. The return could occur at such a distance downstream that the water supply would be treated as a consumptive use in the tributary where it exists, but not to the mainstem below where the water has been returned. Similarly, a dam may not be part of a water management plan within the mainstem designated watershed, but it may be needed to affect flows specific to a tributary. Consequently, protected instream flow management that starts in the upstream Designated Rivers and expands downstream will be most efficient in developing and implementing management and avoiding future complications as more Designated Rivers become part of the Instream Flow Program.

⁵³ Instream Flow Uses, Values & Policies in the Upper Connecticut River Watershed - A report to the Connecticut River Joint Commissions Prepared by Kathy Fallon Lambert, Hanover, NH April, 1998. Available at <http://www.crjc.org/flowreport.htm#policies>

III.B.17. Initial and ongoing coordination with affected and interested parties is necessary

Ongoing interaction with all affected and interested parties is and will continue to be vital in order to develop and maintain water management plan effectiveness. Meetings with municipal managers to gather water use and operational data are not sufficient to notify the community decision makers of water management plan actions. Neither is it fair to burden a Designated River's local advisory committee members to carry detailed information and plans back to their constituencies. NHDES needs to have direct communications with groups affected by management plans. Meetings should be held with the governing bodies of the communities that own, operate or are affected by water sources, discharges or dams, and also with similarly situated private parties. These meetings should be held at the beginning of the instream flow process to emphasize to these groups that the instream flow process affects their interests in the water resources and to provide them an opportunity to voice their concerns. Recurring communications should be conducted to maintain continuity of management plan development and implementation through job changes and election cycles, and to get feedback on interim and final products. State senators, representatives, and executive councilors should also be notified and kept informed.

Recurrent interaction will also be necessary to ensure that management actions are carried out. Because the instream flow management actions are rarely invoked, the water users and dam owners affected under the rules are likely to forget that action is required, when to apply those actions, or the specific activity described to them in their plans. New personnel in public works and town engineer positions may not be informed of the responsibilities, nor is notification to NHDES instream flow staff likely when personnel changes occur in these positions. Consequently, NHDES staff will need to make frequent (at least annual) contact with water users and dam owners to ensure that there is a known and informed party prepared to act in the event that management becomes necessary. NHDES uses similar protocols in in some of its other programs in which management activities may be required only occasionally if at all during the course of several years.

Changes in water use are inevitable and will require NHDES to reassess and update the water management plans. Updates will also be necessary when there are changes in the representatives of dams or water use facilities. NHDES will need to coordinate with the water users and dam owners frequently enough to maintain good communications and working arrangements.

III.B.18. Timescale considerations

The instream flow process applies protections using stream flow in daily time-steps to evaluate the instream flow protection criteria. NHDES observations of stream flow data have demonstrated that average daily flow data can hide significant fluctuations in flow. During the Pilot Program, staff discovered that a hydropower generator's storage and release operations caused significant changes in flow that occurred over only a few hours, fluctuations not apparent in the daily average flow. Such short-term fluctuations indicate that stream flow management may need to be applied in shorter than daily time-steps to prevent no-flow conditions during part of a day. The U.S. Army Corps of Engineers and The Nature Conservancy are developing a flow optimization model on the Connecticut River. This model recognizes that hydropower operations may have significant impacts on flow on shorter than daily intervals.⁵⁴

⁵⁴ Zimmerman, J. K., Letcher, B. H., Nislow, K. H., Lutz, K. A., & Magilligan, F. J. (2009). *Determining the Effects of Dams on Subdaily Variation in River Flows at a Whole Basin Scale*. River Research and Applications, 1246-1260.

Further, water use data are currently collected on a monthly time-step. Registered water users report their water use quarterly or annually as monthly totals only. This monthly water use may have occurred entirely within one day or been spread across all the days of the month. NHDES assessed the impacts resulting from differences between using actual daily water use data versus using daily water use values derived from monthly reports.⁵⁵ NHDES and other investigators have concluded that reporting the average monthly water use may mask periodic low or even no flow events in a river.⁵⁶

III.B.19. Using reference rivers to assess the effects of management

A reference river is a river that represents a high quality river and thereby may be considered the standard against which other rivers should be assessed. The selection of a reference river is necessarily a compromise that must select the least altered, comparable river. Comparing the Lamprey and Souhegan to a reference river could provide a means of comparison that might demonstrate the positive or negative effects of management, but only if the reference river is changing only as a result of natural conditions. A problem with comparisons to a reference river is that no rivers are consistently affected by only natural conditions.

In addition, finding a suitable reference river is fairly difficult because it must be physically similar to the study river in terms of watershed area, mean elevation, stream order, latitude, and slope in order to be comparable. A reference river also must be similar in geological characteristics to the study river, relatively unimpaired, undammed, and undeveloped, and have few water withdrawals, good water quality and a natural temperature regime.⁵⁷ Unfortunately, while some rivers are better suited to serving as reference rivers than others, few rivers can be considered ideal reference rivers, so reference rivers must be selected from the best of those available.

Despite these limitations, several rivers in New England were identified as reference rivers for the Souhegan and Lamprey Rivers. These rivers were used to develop a target fish community as the goal for the Designated River segments. These rivers represent the best rivers available that also had fish data. These rivers were chosen because they were determined to be the least modified, but they are still subject to ongoing watershed development, water withdrawals or other flow modifications. Fish collections from several rivers were used to ensure that the appropriate group of dominant species were identified.

III.B.20. Climate change and instream flow management

Throughout the Instream Flow Pilot Project development and formal comment period, many people raised the issue of climate change. While the Program recognized the likely impacts of extended and deepened droughts due to climate change, it determined that incorporating climate change into the protected instream flow criteria was beyond the capabilities of the Program at this time. The challenge of incorporating climate change impacts directly into the instream flow calculations relates to the lack of specific forecasts regarding the frequency, magnitude and duration of low flows in the future. As

⁵⁵ Instream Flow Analysis within the Contoocook River Basin, Owre, R., January 2002, NHDES unpublished report.

⁵⁶ Tennant, D. L. 1976. *Instream flow regimens for fish, wildlife, recreation, and related environmental resources*. Pages 359-373 in J. F. Orsborn and C. H. Allman, editors. *Proceedings of the Symposium and Special Conference on Instream Flow Needs*. Vol. II, American Fisheries Society, Bethesda, Maryland. as cited in http://www.georgiawildlife.com/sites/default/files/uploads/wildlife/fishing/pdfs/studyReports/F24_InstreamFlow.pdf

⁵⁷ Kearns, M., T. Richards, A. Madden, R. Abele, V. Lang, R. Maietta, and D. Armstrong. 2005. *Development of a Target Fish Community for the Housatonic River, Massachusetts*. Draft Report. 18 p., as cited in http://des.nh.gov/organization/divisions/water/wmb/rivers/instream/lamprey/documents/tfc_report_legros_21june2007final.pdf and http://des.nh.gov/organization/divisions/water/wmb/rivers/instream/souhegan/documents/final_draft_fish.pdf.

described elsewhere, the protected instream levels were tied to thirty years of recent hydrologic data. To the extent that the climate has already begun to shift, those data may pick up some changes. In addition, if droughts worsen in the near future, more management actions will be necessary as a result of the Program, which will help to ameliorate the ecological impacts of climate change on the Designated Rivers.

The primary way in which the Instream Flow Pilot Program intends to incorporate changing climactic conditions is through assessments of flow variability⁵⁸ and the frequency of required water management actions. Over a number of years, these assessments, combined with analyses by others, can identify trend shifts in hydrologic conditions away from the baseline. NHDES would then need to determine whether the trends result from climate change, water use changes, or changes in watershed development, or some combination thereof. The Instream Flow Program intends to use the trend analysis to determine whether climate change has altered stream flow characteristics enough to warrant an adjustment to the protected instream flow criteria.

III.B.21. Adaptive management

Adaptive management is a process for assessing the effects of management and redirecting management to better meet Program goals. Incorporating adaptive management recognizes that the implementation of water management plans may not go as expected. An adaptive management plan creates a threshold for identifying and responding to unforeseen, negative results. Minimum thresholds for taking action should be part of the adaptive management plan in order to account for natural variation in conditions and to avoid haphazard changes to management.

One suggestion received from a commenter was to apply adaptive management to evaluations of fish mass, such that if fish mass declined as a result of management, then adaptive management might be applied in an attempt to reverse it. Since factors like fish mass will characteristically rise and fall, a minimum threshold of change would have to be set before changes in management were applied. Assessments of the cause or causes of a decline in fish mass would also have to be assessed to determine whether flow is a factor so that a changed management response would be effective. Moreover, this particular suggestion could not be implemented because fish mass was not measured during either the Lamprey or Souhegan studies due to the additional time and effort required, so there is no baseline for further comparison. Using any single criteria to apply adaptive management, including those using biomass, overlooks many important variables and thus oversimplifies exceedingly complex systems.⁵⁹ This suggests that more detailed criteria than fish mass alone need to be assessed before applying adaptive management.

At present, adaptive management is a concept under further development in the Program. Adaptive management is a resource-intensive management process. Details such as which criteria to assess and the minimum thresholds that warrant adaptive management must still be determined. These decisions rely on monitoring data, which would need to be systematically collected.

Applying adaptive management should not be considered as an option to compromise the assessment of protected flows. There is a process for changing the protected instream flow criteria in the pilot rules that

⁵⁸ Using the Ecologically Sustainable Water Management tool described earlier.

⁵⁹ *Assessment Of Biotic Integrity Using Fish Communities*, James R. Karr, Fisheries, Vol. 6, No. 6, November - December 1981.

NHDES recommends be continued in the new Instream Flow Rules. Major changes made to a water management plan would be deliberated at meetings in a public process. Public notice and a public hearing may be appropriate prior to NHDES making a decision.

III.B.22. No shortcuts have been identified

Program staff have evaluated alternative methods for defining protected flow criteria. Some methods applied by other states have already been scrapped and alternate methods are now being attempted. New Hampshire's Instream Flow Program rejected methods that do not address river-specific conditions. It is clear that rivers have unique characteristics that support different uses. A scientific method that addresses each river's unique characteristics was applied. New Hampshire also rejected methods that applied arbitrary or selected levels of protection because these would not provide the protections mandated by statute. Further, there is no single value or set of values that would support a uniform and fair level of protection and water use. The method used by the Instream Flow Pilot Program assessed each river's flow and habitat conditions to define the protected instream flow criteria, and in this manner appropriate and fair levels of protection and water use were established. The subject of alternative methods for defining protected flow criteria is covered in detail in Section V.

III.C. Conclusions from lessons learned

The Pilot Program was valuable in identifying the practical application of instream flow protections. Methods were successfully applied to quantify instream flow criteria that protect instream public uses. In addition, actions that will maintain the protected instream flow criteria were shown to be effective. Long-term monitoring and assessment are recommended to further evaluate the Program's effectiveness. The two pilot rivers demonstrate only a limited range of river conditions relative to size, water use, development, ecological region, and other factors affecting river ecosystems. Supporting hydrological and biological data must continue to be generated and should be expanded to support more comprehensive assessments of protected instream flow criteria.

IV. Impacts of protected flows and water management plans

The Instream Flow Pilot Program was intended to develop management actions that meet biological, hydrologic, social, and legal standards or goals. This section of the report describes the goals for protection as described in statute and then describes the impacts of the protected instream flows and water management plans on water users, wildlife, recreation, and other interests along the rivers.⁶⁰

The Instream Flow Program has several goals. These goals drive the actions that result in positive and negative impacts. Biologically, success means improving or maintaining aquatic habitat by providing the appropriate flow pattern: biological goals are defined in the water quality standards.⁶¹ Hydrologic goals are to mimic the natural pattern of stream flows. Socially, success means maintaining expectations for water availability for recreation, hydropower and for off-stream uses. Legally, success means meeting New Hampshire's Surface Water Quality Regulations and Instream Flow Pilot Rules, as well as the sections and paragraphs defining instream flow protection requirements and Program purpose and intent under the Rivers Act.

The Rivers Act is intended to complement and reinforce existing state and federal water quality laws. New Hampshire law specifically requires the protection of fish and wildlife and maintenance of flows adequate to protect them,⁶² and restoration of surface waters to maintain physical and biological integrity.⁶³ Biological integrity is the ability of an aquatic ecosystem to support and maintain a balanced, integrated, adaptive community of organisms having species composition, diversity, and functional organization comparable to that of similar natural habitats of a region.⁶⁴ In addition, the Rivers Act describes the instream flow protection goals. The Act's statement of intent concludes "if conflicts arise in the attempt to protect all valued characteristics within a river or stream, priority shall be given to those characteristics that are necessary to meet state water quality standards."⁶⁵

This report is required to describe the impacts of the protected instream flows and water management plans by answering whether the Instream Flow Program is having positive or negative effects. The instream flow criteria have no impact until they are implemented by applying the actions adopted under a water management plan. The first test of whether management is effective is to compare the hydrograph with the protected instream flow criteria to see whether these criteria are being met. If so, then the next questions are whether there is a biological response to maintaining the protected flows and whether societal needs can be met at the same time.

The prevailing view is that native species are adapted to, and thus supported by, the natural flow pattern. By maintaining the natural pattern, the flow needs of the river's ecosystem will be supported. Water management plans are intended to result in flows that mimic the natural flow pattern of the river.

⁶⁰ As required by Laws of 2013, Chapter 241 - <http://www.gencourt.state.nh.us/legislation/2013/HB0588.pdf>

⁶¹ See Appendix B - Statutory authority for Instream Flow and other statutory and rule references

⁶² Env-Wq 1703.01(d) and State Of New Hampshire 2012 Section 305(b) and 303(d) Consolidated Assessment and Listing Methodology [<http://des.nh.gov/organization/divisions/water/wmb/swqa/documents/calm.pdf>]

⁶³ Env-Wq 1703.01(b)

⁶⁴ Env-Wq 1702.07 "Biological integrity" means the ability of an aquatic ecosystem to support and maintain a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of similar natural habitats of a region.

⁶⁵ 483:1 Statement of Policy. <http://www.gencourt.state.nh.us/rsa/html/L/483/483-mrg.htm>

The river ecosystem is not a one dimensional system in which higher flows are always better. The stream flow pattern includes low flows that cause stress for some species, but provide habitat for those species that have low flow life cycle needs. The same is true for high flows. This variability from stressed to unstressed conditions complements the needs of species that have different flow needs and lets both live in the same environment.

The sections below address the effects of instream flow management. Included are the impacts on various types of water users as a result of water management plan actions. The impacts on fish and riparian species and recreational uses are described, as are the environmental and recreational impacts on lakeshore environments. A section is devoted to water quality effects and one section discusses the impacts on state agencies. During the short, two-year implementation period, some impacts have not yet been experienced, but expected effects can be identified.

IV.A. Are relief pulses from dams effective in supporting the river species?

Maintaining stream flows that mimic natural flow patterns will support and maintain the aquatic ecosystem. Most instream flow practitioners today wholly subscribe to this concept as the key to instream flow protection. Flow releases from dams to provide one or more key elements of stream flow are an outgrowth of this fundamental concept.⁶⁶ Elsewhere, flow releases are applied to create a variety of conditions including high flows at the Grand Canyon for channel restoration,⁶⁷ and recreational flow releases for white water rafting and boating.⁶⁸ In New Hampshire, relief pulses are defined for protecting aquatic species from abnormally long periods of low flow.

The New Hampshire Instream Flow Program identified instream flow criteria that avoid increased stress from low flows on the fish community. In the dam management plans, relief pulses to create relief pulses are described by flow rates designed to meet these criteria. Flow deficits from historical flow data were analyzed and flow rates for relief pulses were selected to exceed 90 percent of the deficit events because some low-flow conditions should occur as part of the natural pattern. NHDES defined relief pulses that would offset most of the historical deficits for two days. The two-day length of relief pulses was selected to recreate the natural flow pattern.

In 2014 a test relief pulse from one of the four dams in the Souhegan water management plan was conducted. NHDES, working with the dam owner, measured water level change in the lake and the resulting downstream flow. This test showed that a significant portion of the largest relief pulse's flow rate can be generated by a release from this one dam alone, suggesting that the relief pulses can be readily generated using the four dams in concert. Relief pulse tests in 2012 from one of the Lamprey dams also showed that two-day relief pulses can be applied and will cause the expected downstream flows. Water quality parameters were measured during one of the Lamprey relief pulse tests and showed no violations

⁶⁶ Richter, B. D., and G. A. Thomas. 2007. *Restoring environmental flows by modifying dam operations*. Ecology and Society 12(1): 12. [online] URL: <http://www.ecologyandsociety.org/vol12/iss1/art12/>

⁶⁷ National Park Service, November 2014 High-Flow Experiment <http://www.nps.gov/grca/naturescience/hfe.htm>

⁶⁸ "This dam-controlled river has limited releases a season with heart-pounding Class III, IV, and IV+ whitewater from below Grand Falls to the confluence of the [Kennebec](#) and Dead Rivers." <http://www.northernoutdoors.com/site/rafting/dead-river-rafting.html> and "Consistent flows are controlled by the upstream reservoirs in the summertime" American Rivers <http://www.american-rivers.com/flows.htm>

of water quality standards or other ill effects as a result of the relief pulses.⁶⁹ The Souhegan and Lamprey tests demonstrated that NHDES can effectively apply relief pulses to meet the protected flow criteria.⁷⁰ Long-term biological monitoring will be necessary to test whether there are net positive or negative effects from relief pulses. The need for long-term monitoring has been described in an earlier part of this report. The impacts on dam owners are described below.

IV.B. Water Users

Water users have dual roles in instream flow protection. They are both protected by and required to take part in the management during times of low flow. They benefit from the protections afforded by the clearly identified flow requirements and by a watershed-wide sharing of the available resource. The Instream Flow Pilot Rules create an even playing field for new and existing users. The rules also define a management structure that allows for sustainable water use without which water users might find themselves cut off by upstream users.

Water users affected by the Instream Flow Program are required to have a water use plan and a water conservation plan. Water conservation plans are already required of some of these water users under the state's water conservation program. There are several water users whose sole management action under the Instream Flow Program is the development and implementation of water conservation plan; they have no other actions to take as part of their water use plan because their water use does not have an impact on short-term stream flow conditions. The NHDES Drinking Water and Groundwater Protection Bureau administers the water conservation plans for both programs.⁷¹

Costs to develop and follow water conservation plans, if not already required, represent an additional expense for water users. Water conservation measures are defined by the type of water use. There may be costs for drafting the conservation plan, for equipment such as water meters, leak detection surveys, and a more frequent billing cycle. Costs for equipment and labor depend on the Best Management Practices for the specific types of water use. For community systems, other costs might include educational mailings and the testing and calibration of pump house meters. NHDES has not developed cost estimates for water conservation plans. Given the level of variability among water users' conservation requirements, NHDES has no estimates for how much it costs water users to write an approved water conservation plan or to conduct activities under the plan to remain in compliance.

Water users have actions in their water use plan that differ from others' depending on their withdrawal's impacts on stream flow. Management increases with higher levels of consumptive water use and with higher rates of induced recharge. Management of groundwater and surface water sources that directly affect streamflow will have the most immediate and pronounced effect on stream flows.

Withdrawals from the Designated River have the most immediate impact. Wells completely separated by distance and geology from the river have the least impact on flow. In between are wells that have immediate impacts because they induce some or all of their water from the river, and wells that do not induce recharge that would have delayed impacts as a result of withdrawing only groundwater that would have taken days or more to reach the river. These withdrawals have a long-term impact on stream flow,

⁶⁹ Water quality parameters measured during this test are described further in Section III.B.5.

⁷⁰ Lamprey River Water Management Plan – Appendix I – Response to Comments, p. 23.

⁷¹ Under Env-Wq 2101 Water Conservation - <http://des.nh.gov/organization/commissioner/legal/rules/documents/env-wq2101.pdf>

resulting in reducing stream flow volume,⁷² but even a complete cessation of withdrawal would have no effect on stream flows for many days. Water management plans eventually may need to consider management of withdrawals that have longer term effects on flow, but that is not currently necessary.

Water users that have direct impacts are developing alternate sources in order to maintain their surety of water during low flows. Those that withdraw directly from surface water have access to a portion of flow that is always available, called the *de minimis* amount. However, if more water is needed, alternate sources may be required, including the installation or use of ponds or wells away from the stream, or connections to water supplies such as bedrock wells, sources outside the watershed or sources that have much greater capacities. Costs for developing a new groundwater withdrawal as an alternate water supply would represent a large investment for exploration, testing, permitting and installation. Alternatively, a connection made to an existing local public or private supply that has adequate surplus is likely to be much less costly.

Water users that have direct impacts on stream flow often include irrigators who withdraw directly from the river or from a well that induces water from the river. The Program assists water users with identifying and linking up to replacement sources. Water from an alternate source may include wells, ponds, or water purchased from another source⁷³ that are hydrologically distant from the river. The availability of funding for the development of alternate sources through state or federal grants or loans has diminished in recent times.

Public water suppliers' management actions include summertime reductions in outside water use. Stepwise reduction in outside water use is aligned with municipality's water emergency plans. The initial action is a notice to water users that NHDES is concerned about the stream flow conditions. A municipally enforced outside water use ban would apply during the most extreme low-flow conditions. Public water suppliers can expect variable costs for notifying customers with conservation information or water use changes depending on whether email or paper mailings are used.

Nothing in the water management plans precludes a water user from implementing more restrictive water use actions on its own initiative. Due to a supply shortage in one community, the public water supplier may initiate an outside water ban well ahead of any actions required by the Instream Flow Program.

IV.B.1. Souhegan management examples

In the Souhegan watershed, a bottled water company is a consumptive use, but its water sources are wells that are hydrologically separated from the river and as such, there are no water use plan requirements for this water user. There is a public water supply that represents a partial consumptive use in that some lawn irrigation and other outside water uses are likely. Its water sources are groundwater wells that induce some recharge from out of the river, but the town returns the treated wastewater directly to the river, resulting in a near balance in inflow and outflow excepting for the consumptive loss that might occur as a result of lawn irrigation and other outside water uses. In this case, the water use plan requirements are limited to outside water use restrictions during the summer.

⁷² Groundwater withdrawals may also reduce cold, groundwater entering the stream affecting the availability of refuge from summer heat for some coldwater fish species.

⁷³ Note that water purchased from another source may be a stop gap measure if future instream flow protection measures apply to the alternative source.

IV.B.2. Lamprey management examples

In the Lamprey watershed, one of the public water systems represents a partial consumptive use. The water sources are groundwater wells that induce recharge, but the town returns water to groundwater by individual septic systems, resulting in a near balance in inflow and outflow except for consumptive losses due to outside uses. Therefore, that supplier's water use plan requirements are limited to outside water use restrictions during the summer. Where town boundaries cross outside of watershed boundaries, water use plans may be applied that affect customers who are outside the management area. Water use plans can be adapted to apply to all customers or to only those customers within the affected watershed so long as the effects of water use meet management goals. In another case a large public water supplier is required to cease withdrawals from the river during low flow conditions. This system has developed alternate sources of groundwater to use when stream flows are low, and outside water restrictions are only implemented if the total supply situation warrants.

IV.B.3. Reported impacts of management by water users

An online survey was sent to Souhegan and Lamprey water users February 3, 2015 asking for feedback on their actions since August 30, 2013 under the Water Management Plan. The survey asked water users to describe any actions they had made or costs they had incurred as a direct result of their part in the water management plan. Surveys were sent to all water users in the pilot river watersheds. Ten responses were received before March 31; two from the Lamprey watershed and eight from the Souhegan. Responses were received from a golf course, a commercial/industrial user, six public water supplies and two from an aquaculture facility.

Below is a summary of survey results.

- One public water supplier noted it had switched to alternate water sources [as described in their water management plan] in response to a low flow condition on the Lamprey River in September 2014.
- One public water supplier on the Souhegan made unspecified changes as a result of their water management plan.
- An aquaculture facility on the Souhegan stated they made changes by installing equipment to reduce water use. [However, this was not a requirement of their water management plan.]
- Comments about the management requirements included:
 - they have developed a robust alternate water supply and feel they can meet their flow needs,
 - that a less onerous and expensive process is needed, but noted that the pilot process may have required that level of effort and cost;
 - that it did not make sense to include only the lower Lamprey
 - that this Program is unjust because it only burdens water systems on two rivers that have to jump through hoops and expend extra money.

IV.B.4. Evaluation of impacts on business water users

The kinds of businesses likely to be most impacted are irrigators, such as golf courses and agricultural operations because of their consumptive use of water and the tendency of these businesses to draw water directly from a river. Other kinds of businesses that may be affected include bottled water or other food processing facilities where water is part of the commodity being produced. These may be affected less because they tend to get water from wells or from public water supplies, respectively, that are likely to have less direct impact on streamflow. Specific impacts from management on business water users, including irrigators, have not yet been apparent.

Businesses using direct withdrawals from the river for irrigation will be most affected by management for instream flow protection. New Hampshire produces about 5% of its own food.⁷⁴ There are many people who hope to see more locally produced agriculture. Unfortunately, irrigation is a consumptive use of water that is in heaviest use when river water is least available during the growing season. The commercial agricultural community is concerned about any constraint on irrigation especially for vegetables and higher value crops. Many irrigators have direct withdrawals from a river. During an extended low flow period when irrigation is most desired, water is also needed in the river to support the ecosystem.

River water is a public resource and a vital component of many business activities including especially agriculture. Protected flows represent an instream public use of water, in which the same water is used for multiple purposes. In contrast, consumptive business and agricultural water use is primarily for private benefit in which the water, when used to the advantage of one consumer, is not available for another. Ever-increasing consumptive uses cannot be sustained by a river without impacting other uses.

Water users' actions are covered in the water management plans in their conservation and water use plans. Under the water conservation plans, businesses are expected to operate their water use activities so as not to waste or lose water. The procedures for this are described in conservation plan rules that apply metering, leak detection and best management practices specific to the water use type. Water use plans describe the operational changes a business would make to reduce their impact on stream flow.

Water use plans describe management actions when stream flows are too low to support consumptive use. Where consumptive use is unavoidable, as in agriculture, water must be stored or drawn from other sources like deep wells, ponds and larger reservoirs when sufficient water from the river is not available. The use of an alternate water supply delays or spreads over time the impact relative to that of a direct surface water withdrawal. Alternate water supplies may include water from ponds, wells or from other suppliers. Costs may be substantial for a new groundwater supply requiring permitting. Or less so for a pump in a pond or for purchasing water from a local utility. Public comments on the Program suggest that the cost of installing an alternate water source may slow down the expansion of agricultural operations that need water for irrigation.

The Instream Flow Program has defined a *de minimis* amount, a small amount of water, that is available to be shared among water users that have direct surface water withdrawals. An irrigator in the Lamprey watershed uses water directly from the river. His water use needs are met by his portion of the *de minimis*, so under his water management plan he continues to withdraw water up to this amount.

It is difficult to know whether businesses have internally changed plans or decided not to use purchased equipment because of instream flow management. However, decisions to expand consumptive water processes will be reduced or relocated as a result of the Program. Water-consuming businesses will likely locate where supplies are most plentiful.

⁷⁴ *Community Gardening in New Hampshire from The Ground Up*, by Yvonne Beran, Tina Burr, Charlie French, And Nancy Friese - 2012 UNH Cooperative Extension https://extension.unh.edu/resources/files/Resource002173_Rep3203.pdf

The Instream Flow Program creates a management structure that supports sustainable water use without which water users might find themselves cut off by users whose points of water withdrawal are located higher in the watershed. Water use under the Instream Flow Program applies the principles of the northeastern United States in which the public trust requires regulators to apply only reasonable limits on water use, and also limits riparian water users to reasonable impacts on stream flow.

IV.B.5. New Water Users

Water is not always available for new users in states where allocations are used to manage water resources because all available water is allocated to existing users. New water uses are sometimes blocked for years until litigation determines a decision. Some states will close water bodies to new users based on a finding that water is not available.⁷⁵ The closures protect streams, as well as existing water users, from being affected by new uses. Unlike a Program that dispenses water allocations, the New Hampshire Instream Flow Program provides access for new water users. Under the riparian rights doctrine, new water users must be accommodated, because the water rights doctrine of reasonable use⁷⁶ provides for reciprocal limits on the impacts that any one water use can have on other water users. New users will be required to demonstrate how their water use will continue to meet instream flow criteria. Existing users may have to adjust their *de minimis* water use.

New and existing water users can avoid management activities by choosing processes and infrastructure that are low or non-consumptive. This may include changing operations to low-water use or waterless equipment, or developing their infrastructure to use and return water locally. Consumptive users are likely to seek out locations where stream flows commonly meet the protected flows, where water use is always insignificantly small relative to stream flow, or to develop water supplies that are hydraulically separate from the river water, such as some bedrock wells. The Program's presence will thus have a positive effect on stream flows and also make future management plans easier to design.

IV.B.6. Management of large water users purchasing from a water supplier

New large water users purchasing from an existing Affected Water User are unregulated since they are exempt from 401 Water Quality Certification or groundwater permitting. However, a new public water supply customer requires neither of these. Given the cost of developing their own water supply, new water users may opt to obtain water from an existing water supplier.

A water user, regardless of their water supply source, is required by Env-Wq 2102 to report their water use if their water use exceeds the reporting threshold of 140,000 gallons per week. Any water user who is required to register is subject to instream flow regulations, resulting in the application of a conservation plan and a water use plan to their use. In the long run, public water supplies are likely to become increasingly watchful when deciding to provide water to a new large user that may force them to manage their system differently during low flow conditions. Public water suppliers are also more likely to develop more flexible and diverse water supplies⁷⁷ that use surface water when plentiful and turn to groundwater when surface waters decline.

⁷⁵<http://www.ecy.wa.gov/programs/wr/instream-flows/isf-glossary.html>

⁷⁶<http://des.nh.gov/organization/commissioner/pip/factsheets/dwgb/documents/dwgb-22-13.pdf>

⁷⁷ The UNH/Durham Water Supply has developed two river withdrawals and two well fields, providing it with the capacity to rest its wells under most conditions and to use them when stream flows remain low.

IV.B.7. Costs to develop groundwater as an alternate supply

An alternate water supply may be desired to replace or augment a surface water withdrawal. Groundwater supplies can reduce or delay the impacts of withdrawals on stream flow relative to surface water withdrawals. The costs for developing a new groundwater supply are wide-ranging and depend on many factors.⁷⁸ A well that pumps less than 40 gallons per minute requires no permit, so the costs include only well installation and connection. Finding and using a well greater than 40 gallons per minute are likely to require hydrogeologic consultants for locating, testing and permitting the well. Costs for siting such a well may include fees for hydrogeologic services, property purchase or easements, well construction, length of pipeline and electrical lines, pump and pump house equipment. Costs for permitting a well can increase the costs of development significantly, but groundwater permitting is necessary to protect the water resource and other water users.

IV.C. Fish and riparian plant and wildlife communities

Fish are the most sensitive to stream flow conditions in the aquatic community. If the fish are doing well, then generally other instream resources are also usually thriving.⁷⁹ Flows that support riparian plants and wildlife communities may not be directly beneficial to fish, but are necessary for the long-term support of fish.

IV.C.1. FISH

The application of water management supports fish by meeting their habitat maintenance and survival needs. A key assumption is that the aquatic community is adapted to the historical stream flows and, therefore, have survived the duration and strength of historical low-flow stresses. Increasing those stresses by changing the duration, frequency, strength or timing of flows will weaken or eliminate some part of the ecosystem. Therefore, fish are supported by maintaining the natural flow patterns⁸⁰ and harmed by artificially altered stream flows.⁸¹

The assessment of impacts on fish or other aquatic life, such as mussels and periphyton, will require long-term monitoring to assess trends. Neither the Lamprey nor the Souhegan flows were so vastly divergent from their natural conditions such that a dramatic change in fish population, attributable solely to flow modifications, would be easily observed. Fish surveys on the Designated Rivers were completed on the Lamprey in 2003 and on the Souhegan in 2005. These surveys have not been repeated.

The Instream Flow Program's biological objective for fish is for the existing river community to match its target fish community.⁸² Fish surveys will be compared to the target fish community developed during the

⁷⁸ Personal communication from Christine Bowman, NHDES Drinking Water & Groundwater Bureau, July 31, 2014

⁷⁹ <https://fortress.wa.gov/ecy/publications/publications/qwr95104.pdf>

⁸⁰ *Effects of Flow Regime on Fish Assemblages in a Regulated California Stream*, Marchetti, M.P. and Moyle, P.B., Ecological Applications, 11(2), 2001, pp. 503-539. Available at http://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/bay_delta_plan/water_quality_control_planning/docs/sjrf_sprinfo/marchettiandmoyle_2001.pdf

⁸¹ *Alteration of streamflow magnitudes and potential ecological consequences: a multiregional assessment*, Carlisle, D.M. et al., Front Ecol Environ 2010; doi:10.1890/100053. Available at http://water.usgs.gov/nawqa/pubs/Carlisleetal_FLOWAlterationUS.pdf

⁸² See Souhegan Target Fish Community Report at <http://des.nh.gov/organization/divisions/water/wmb/rivers/instream/souhegan/documents/task5appendix6.pdf> and Lamprey Target Fish Community Report at http://des.nh.gov/organization/divisions/water/wmb/rivers/instream/lamprey/documents/tfc_report_legros_21june2007final.pdf

instream flow studies. The target fish community represents the expected species and composition for the river. The existing fish community would be assessed by repeating fish collections over time. The expected results are species numbers and compositions that more closely match the target community. If the management activities are successful, the existing fish population will shift to more closely resemble the target community defined in the protected instream flow studies. Comparisons to the baseline surveys also may be conducted to evaluate station-specific changes in numbers and species distribution. Mussels were assessed in the Lamprey by other investigators who concluded that most species are now too few to accurately quantify.⁸³

IV.C.2. ANADROMOUS FISH

Relief pulses from Pawtuckaway Lake may affect alewives, which are an anadromous fish species, stocked in Pawtuckaway Lake. A relief pulse from Pawtuckaway Lake may stimulate outmigration of alewives. Alewives respond to lower temperatures and higher outflows that happen naturally in the fall as cues to migrate to the ocean, so they also may be drawn to migrate if they identify a relief pulse as a trigger, especially in the late summer and fall when migration is imminent. The Instream Flow Program's relief pulses are a compromise for meeting water resource management goals, but they are not natural flows. Therefore, the relief pulse volumes may not fully support the outmigration of alewives to the sea, so additional protection measures are necessary.

Actions will be needed to prevent premature outmigration during a relief pulse. Alewives may mistake a relief pulse for migration flows. Relief pulses are conducted for 48 hours after long periods of dry weather. Outflow is increased and then relatively quickly reduced in a matter of hours. This is unlike a natural rainfall event which tapers off slowly over many days. Those fish that out-migrate during a relief pulse may die if they are stranded by low flows when the relief pulse is over.

NHDES and Fish and Game Department have determined that a physical barrier should be deployed in front of a dam from which a relief pulse is occurring in order to prevent an untimely outmigration from Pawtuckaway Lake. This is likely to be in the form of a fine-meshed, fish net suspended in the lake in front of the outlet as a barrier to discourage migration. Initial deployment may be made by Fish and Game Department using its equipment, but NHDES Watershed Management Bureau will take over these operations and will have to purchase equipment and supplies for the deployment.

Anadromous species have not been assessed in the Souhegan River to determine the effect of the 2008 removal of the Merrimack Village Dam that was near the mouth of the river. At this time, anadromous species are not known to be in the watershed and so would not be affected by dam management on this river. The protected flows would support the conditions these species need to reestablish themselves in this watershed.

IV.C.3. WILDLIFE

Little is documented in New Hampshire about the specific occurrence of wildlife in the shoreland areas affected by river flow. The presence or absence of Rare, Threatened, or Endangered species relative to historic sightings may give some indication of changing conditions, but this type of monitoring is sporadic and unevenly applied around the state. There are no defined target species, or baseline data, collected for wildlife, and thus the Program has no biological objective for wildlife other than to maintain

⁸³ Freshwater Mussel Survey in the Lamprey River and Exeter River Watersheds in Southeastern New Hampshire, Prepared by Biodiversity, April 2011. Summary available at <http://www.lampreyriver.org/about-the-river-lrac-studies-mussel-survey>.

existing habitat and to attempt to do no harm when applying management. The flow protections are defined to avoid management that would cause hazardous conditions for turtle nesting locations, and to ensure wetlands are maintained during amphibian spawning periods.

High and low flows are needed to support wildlife on the river banks. Low flow conditions for natural durations need to continue in order to maintain habitat for species that occupy the shallow margins of rivers. Turtle nests may be damaged by untimely flooding, an increased frequency of which may cause the loss of multiple year classes and threaten the species' survival. Other species occupying stream banks and adjacent wetlands need these areas to be flooded at various times of year. The high flows that flood these sites need to continue at naturally occurring times, frequency and durations. The times and flow rates affecting these species have been identified and stream flow data will be tracked to identify shifts in these flows.

IV.C.4. PLANT COMMUNITIES

Application of management plan activities are intended to support river bank plants including Rare, Threatened and Endangered Species.⁸⁴ Surveys were conducted to identify these plants and their communities. The biological objective is to maintain the species types and quantities similar to their distribution mapped during the protected flow studies. This objective is limited to maintaining the existing conditions because data describing their distribution, species types and the elevations at which they exist on the river banks are rarely compiled to provide a baseline condition. Appropriate timing and magnitude of flows will support these plants to maintain their presence, abundance and positions on the river banks.

These species are less immediately sensitive to flow conditions than fish. Plant communities rely on moderate and high stream flow conditions to maintain their habitat. Flow protections were defined to maintain flow conditions that support the life cycles of plants found in these communities. Higher flows defined for riparian plant protection also support fish by rejuvenating the river structure and bottom conditions vital to the long-term sustainability of the fish community.

The times and flow rates affecting these species have been identified and stream flow data will be tracked to identify shifts in the recurrence of these flows. The key assessment element would be whether the populations are stable. Changes to these communities are likely to require many years unless catastrophic flooding happens. A monitoring plan to repeat the original surveys by wetlands scientists on a multi-year cycle will be needed to determine changes.

IV.D. Dam owners

Most dam owners have no responsibilities under the current water management plans. In the aggregate across the Lamprey and Souhegan Designated Rivers there are six dams operated by the state and one privately-owned hydropower dam that would require management to create a relief pulse. In addition, two dam owners in the Lamprey watershed are prohibited from taking any action that would impede the passage of a relief pulse. They are required to actively manage the gate or stoplogs controlling flow if their hydropower or water supply withdrawals result in reduced outflow during a relief pulse or during low flow conditions.

⁸⁴ NH's rare species are listed at: Rare Animal List for New Hampshire

<http://www.nhdf.org/library/pdf/Natural%20Heritage/TrackingList-AnimalGeneral.pdf> and

Rare Plant List for New Hampshire <http://www.nhdf.org/library/pdf/Natural%20Heritage/TrackingList-PlantGeneral.pdf>

IV.E. Lakeshore environments and properties

Lakes and impoundments used for relief pulses also are habitat for plants and wildlife. Lake levels are important for wildlife, aquatic plants and recreation on the lake. Relief pulses require water from either increased storage or existing storage or both, all of which will affect lake water levels.

NHDES considered the impacts of lake level changes required by the dam management plans. Storage of water, relief pulses and the annual lake drawdowns may affect lake uses, including:

- plant life in and around the lake;
- riparian wildlife habitat;
- loon nesting;
- uses by lakefront property owners.

The draft dam management plans were revised to address shorefront property interests and lake habitat. The Instream Flow Program applied limits to the maximum lake level change that could result from management. In developing the final management plans, a balance was sought between river and lake interests that would not compromise either's habitat or uses.

The Lamprey management plan identifies Pawtuckaway Lake and Mendums Pond as the two impoundments capable of generating an adequate relief pulse during low flow conditions in the river. The plan raised concerns among people living on Pawtuckaway Lake. NHDES's assessment and studies of Pawtuckaway are described in detail above in the are described in detail above in the called section called "Pawtuckaway Lake Issues and Solutions."

Similarly, the Souhegan management plan raised concerns of people living around the impoundments created by two of the state-owned flood control dams, identified as the Site 19 and Site 35 dams. The draft dam management plan called for the storage of several feet of water to be maintained in these two impoundments for relief pulses. A report assessing the water level changes proposed in the two upper Souhegan impoundments concluded that wetlands and trees would be adversely affected by raising the water level that much. The property owners' use of the shoreline would have been changed by higher water levels affecting existing trails, beaches and docks.

As a result of local feedback, the maximum increase in storage was reduced in the final plan to avoid adverse impacts on shoreland trees and other habitat, and on shorefront property uses. NHDES responded by changing the plan to use the combination of a small increase in storage and drawdown from historical impoundment levels, and relief pulses from two additional impoundments in the watershed to generate the same relief pulse volume. While the final approval of these changes to the dam management plans are waiting on the required dam outlet modifications that will allow flow control from Sites 19 and 35, NHDES feels that the modified plans better meet the needs of local stakeholders.

A set of guiding principles was adopted in 2013 by the State's rivers and lakes advisory committees to balance lakes' and rivers' competing demands for water.⁸⁵ These principles establish an important

⁸⁵ These guiding principles for comprehensive lake and river management can be found in Appendix I of this report in a document called *Comprehensive Surface Water Resource Management - NH Lakes Management Advisory Committee and NH Rivers Management Advisory Committee -January 23, 2013*. Also available at <http://des.nh.gov/organization/divisions/water/wmb/rivers/instream/documents/20130123-l-and-r-final.pdf>.

framework for managing water resources. One of these principles is to balance the impacts to the lake and the benefits to stream flow.

IV.F. Recreational uses

The middle and higher range of river flows that support the riparian plants and wildlife also lend support to human recreational uses of a river. Flows were initially considered for swimming. However, because swimming preferences were wide ranging, but avoided higher flows and had no defined lower end, no swimming criteria or management actions were defined.

Flow criteria were defined for protecting boating or whitewater canoeing on the Souhegan and Lamprey Designated Rivers based on surveys of boater preferences. To provide continued opportunities for boating, flows in the preferred range must be maintained at the expected timing, frequency and duration. Higher flows are preferred, but they are not always available. Recreational boating is opportunistic in that users take advantage of occasions when flows are suitable and boaters do not expect these conditions to be continuous. Successfully applied management for natural flow patterns will maintain the expected flows for recreational opportunities within their historical range.

NHDES is tracking the occurrences of daily flows that meet or exceed the boating criteria within monthly and annual time periods to ensure they remain within the normal range. Management will be applied to avoid curtailing these flows. However, because the flows boaters tend to prefer are usually high and beyond the scale of management, the response to declining frequency or durations of the boating protected flow magnitudes may eventually require changes to watershed characteristics like storm water management and impervious surface impacts.

Some lakes and impoundments affected by management are also used for recreation. The management plans address how NHDES will minimize any impacts. Lake levels are the key parameter affected by relief pulses. Relief pulses were distributed to more than one lake in order to reduce the effects of relief pulses on any one lake. Limits were set on maximum change in lake level as a result of recognizing that lake levels change due to other reasons, such as evaporation.

IV.G. Hydropower

Instream flow criteria currently are not applied to hydropower in the stream segments between the dam and the end of the penstock where water is released. These issues are addressed in a separate process during FERC relicensing every 30-50 years. In order to ensure the economic viability of hydropower, the historical pattern of flows should continue.

Hydropower dam owners can expect to continue to see conditions that support their power production needs because flows will be maintained similar to the natural conditions under which the dam was constructed. Generally, water use by hydropower operators is supported by the most common flow range that occurs between the extreme highs and lows. Relief pulses for instream flow management may briefly provide flow generation opportunities for downstream hydropower generators, which may be a benefit to them without detracting from the management goals.

IV.H. Hydrologic changes

The Souhegan and Lamprey instream flow protections are defined under relatively low levels of water withdrawals. The protected flow criteria and water management plans will protect key elements of the river hydrology. However, river flows will be under increasing pressure from climate change, growing

demand, and land use changes. Unnatural flow conditions will develop as a consequence of increased withdrawals of surface water. Increasing use will absorb more and more of the unmanaged portions of stream flows, potentially resulting in overly managed conditions characterized by unnatural flat-lined or irregular flows.

Instream flow protection will help redirect increased consumptive uses to those river segments that have available capacity or that lack instream flow protection. Water use on rivers that are subject to instream flow protection will attract non-consumptive water uses that more easily meet water management plan actions. Consumptive uses will be attracted to locations where water is plentiful, such as near larger rivers.

NHDES will assess flow variability over short, medium and long durations and compare these with historical conditions to ensure that stream flows retain their dynamic variability over time using components of the Ecologically Sustainable Water Management tool.⁸⁶ This is a statistical tool that will require years of the collection of stream flow data in order to distinguish water use trends from natural variability unless streams are dramatically impacted by abrupt and massive changes in withdrawals, nearby land uses, or watershed conditions.

Downstream flooding is not a likely result of dam management for instream flow protection. Relief pulses are conducted during low flow periods and the releases are at rates similar to a small rainstorm event. Also, while the size of relief pulses varies with the season, they represent only enough flow to offset low flow conditions. The releases are much less than flows routinely experienced on the river. Changes in stream flow at these rates do not cause large changes in a stream's water level. In most cases riparian land owners will not notice any significant change.

Releases require storage behind dams. The NHDES Dam Bureau and other dam owners will always be permitted to manage storage in the event of an impending large rainfall. Public health and safety is the highest priority. The NHDES Dam Bureau has historically released water from impoundments prior to storm events in order to offset projected inflows and prevent flooding. This practice is not changed under the Instream Flow Program.

IV.I. Water quality

The effects of flow management on water quality are difficult to separate from effects from other processes. The key water quality parameters other than flow that may be affected by water management plan actions are phosphorus, temperature, conductivity, and turbidity. The effects of management on each are discussed below.

IV.I.1. PHOSPHORUS

As a result of the Lamprey River instream flow management plans, NHDES changed several management practices on Pawtuckaway Lake that will reduce phosphorus in the lake. By redirecting the majority of the lake's fall drawdown to the end of the lake that has higher phosphorus input, and then maintaining a higher winter lake level such that phosphorus-laden water can continue flowing out via this outlet rather

⁸⁶ Richter et al., *Ecologically Sustainable Water Management: Managing River Flows For Ecological Integrity*, Ecological Applications, 13(1), 2003, pp. 206–224, by the Ecological Society of America. Available at <http://www.esajournals.org/doi/abs/10.1890/1051-0761%282003%29013%5B0206%3AESWMMR%5D2.0.CO%3B2?journalCode=ecap>

than settling in the deep portion of the lake, the export of phosphorus has increased significantly. Phosphorus concentration and outflow measurements were collected from October 10 through December 3, 2014. The export of phosphorus for the period increased from 350 pounds using historical practices to 1070 pounds as a result of management changes. See Table 1. Higher phosphorus removal should reduce algae blooms in the lake and increase invertebrate production in the stream.

Table 1 – Total phosphorus (TP) export from Pawtuckaway Lake Dams during 2014 fall lake drawdown (Oct 10-Dec 4, 2014) compared to historical drawdown practices

	TP exported from Drowns (in pounds)	TP exported from Dolloff (in pounds)	Sum of TP exported (in pounds)
2014 TP export	1,049	17	1,066
TP export using historical drawdown practices	85	265	350
Difference in TP export	964	-248	716

IV.I.2. TEMPERATURE

Temperature effects as a result of relief pulses or increased groundwater withdrawals have the potential to negatively affect river species. Studies by the Instream Flow Pilot Program have indicated that, under some circumstances, releases may not exceed daily temperature changes and that some habitats that would be affected were already of low quality. NHDES will continue to assess temperature impacts to determine the magnitude of change, how far downstream the effects are felt, and whether the change affects the species in the river.

The relatively shallow, exposed impoundments of New Hampshire collect heat from the sun. The increased flow volumes released from an impoundment by a relief pulse can provide relief for some species; however, increased water temperatures may also cause harm.⁸⁷ Water released from a lake will shift the temperature of the downstream river to more closely approximate that of the lake. Generally there is very little water leaving an impoundment during low flow conditions and, what stream flow there is, is chiefly made up of cooler groundwater. Water, heated in the lake and then released, is warmer than groundwater. Downstream temperatures in a river during a relief pulse will depend on the relative volumes in the river's flow of released water and groundwater.

NHDES has deployed water temperature loggers upstream and downstream of lakes in the Souhegan and Lamprey watersheds for several years. Temperature increases were identified in the receiving waters downstream of Pawtuckaway Lake in the Lamprey watershed during a late summer test release. Evaluation of the temperature effect showed that, during the test, the temperature increase downstream was within the 3 degree centigrade range of diurnal fluctuations of the streams flowing into the lake. Downstream aquatic species would be accustomed to this range of fluctuation.

⁸⁷ Lessard, J. L. and Hayes, D. B. (2003), *Effects of elevated water temperature on fish and macroinvertebrate communities below small dams*. River Res. Applic., 19: 721–732. doi: 10.1002/rra.713. Available at <http://www.msu.edu/~hayesdan/PDF/lessard.pdf>.

New Hampshire Fish and Game Department sampled fish in the streams below two Souhegan flood control dams. Fish collections in the Souhegan watershed showed the population below these impoundments was comprised of only a few fish and those were heat tolerant species, suggesting that the habitat below these dams is already of very low quality. This may be a result of the impoundments' increased water temperature, and the dams' alteration of the natural flow regime, sediment transport and habitat.

Finally, groundwater is an important source of cool water to a river. Water users may increase their use of groundwater wells during low flow periods as an alternative to surface water withdrawals. Increased reliance on groundwater supplies have a temperature effect on streams if the withdrawal volumes are large relative to stream flow. The flow of cool water is reduced when wells intercept the groundwater that otherwise would end up in the river. Quantification of this impact is site-specific, depending on the stream flow magnitude, distance of the well from the river, the water withdrawal magnitude, and the hydrogeologic characteristics of the aquifer. In general, more hydraulic distance between the withdrawal and the surface water reduces the impacts of groundwater withdrawal on surface water temperatures. Bedrock wells are generally more hydraulically separated from a river than wells developed in sand and gravel aquifers. Diversified and well-managed water supplies, such as systems that use surface water when it is plentiful and groundwater at other times, can limit the temperature effects of groundwater withdrawals on streams.

IV.I.3. SPECIFIC CONDUCTIVITY

Specific conductivity is a measure of the ability of water to conduct an electrical current. It reflects the amount of dissolved solids (such as salt) in the water. As such, it is a useful measure of stream water quality.⁸⁸ Increasing conductivity is a general indicator of added pollution loading. Conductivity generally increases from upstream to downstream.

Conductivity measurements were made during a September 2012 test release from Dolloff Dam on Pawtuckaway Lake. Conductivity measurements made in the lake and downstream of the release were both low. The release diluted the conductivity level in the stream, marking a slight improvement in stream water quality.

IV.I.4. TURBIDITY

Water released from impoundments has the potential to increase turbidity as a result of mobilizing sediment. Increased turbidity can harm aquatic species and degrade habitat. Stream turbidity was measured downstream during a September 2012 test release from Dolloff Dam that showed the same levels of background turbidity prior to the test. All measured values easily met water quality standards.

The likelihood of increased turbidity was checked by looking at the highest relief pulse rates. The flow per square mile of watershed for the highest release rates was compared to the historical stream flow record. The release rates were less than about 20 percent of the historical flows, demonstrating that the river has routinely experienced greater rates of flow than those represented by the relief pulses. The relief pulses should cause no increase in turbidity.

⁸⁸<http://water.epa.gov/type/rs/monitoring/vms59.cfm>

IV.J. State agencies

The NHDES Watershed Management Bureau will be responsible for tracking hydrologic conditions, assessing biological conditions resulting from management and notifying water users and dam owners of stream flow conditions that may require management. Instream flow management will result in additional work by state agencies other than the Instream Flow Program. The NHDES Dam Bureau will have to operate the dams for relief pulses and to maintain necessary water levels. The NHDES Drinking Water & Groundwater Bureau will be responsible for reviewing, approving and enforcing the water conservation plans required by the Instream Flow Program. The Water Use Registration and Reporting Program of the NHDES Drinking Water and Groundwater Bureau will need to coordinate with the Instream Flow Program when new water users register to ensure that a water management plan is developed. The Instream Flow Program water management requirements are discussed in Part II of this report.

IV.J.1. NHDES DAM BUREAU

The water management plans for the Souhegan and Lamprey rivers include management to create relief pulses. Of the dams that will be managed, most are owned and operated by NHDES. The NHDES Dam Bureau will be responsible for maintaining reservoir storage, starting and stopping release flow management events, and generating and reviewing reservoir level data. Dam Bureau staff will expend additional time and expense to travel to the dam sites to change the stoplog configurations or adjust outlet gates, first to begin releases and then to end them. Where stoplogs control the outflow, specially-sized stoplogs may need to be cut to release enough water without drawing the lake down more than expected. Dam Bureau's experience on the August 2015 relief pulse demonstrated their costs for materials and personnel were approximately \$1000.

On the Souhegan, three of the dams are flood control dams that do not have active outlet structures that can be managed. Reconstruction of the outlets will be required in order to enable operation of these dams. Reconstruction of each dam outlet is estimated at \$151,232 in 2015 dollars.⁸⁹ This represents a capital budget expense.

The Instream Flow Program will reduce one aspect of The NHDES Dam Bureau's workload. The Lamprey water management plan lessened the annual drawdown at the Pawtuckaway Lake. Because of the reduced drawdown, the Dam Bureau will require fewer trips to confirm that the lake level reaches its winter drawdown level. Similarly, refilling the lake in the spring will require fewer trips to manage the dams.

IV.J.2. NHDES WATER USE REGISTRATION AND REPORTING PROGRAM

The Water Use Registration and Reporting program⁹⁰ administers the registration and reporting of water uses exceeding an average of 20,000 gallons per day in any 7-day period.⁹¹ The Instream Flow Pilot Program included water users meeting this criteria as being affected by the Instream Flow Pilot Rules and thus needing a water management plan. The Registration Program will need to notify new water users in the Lamprey and Souhegan watersheds of the Instream Flow Program requirements to have their own

⁸⁹ Based on 2009 estimate of costs by Dan Mattaini, NHDES Dam Bureau. Estimated costs adjusted to 2015 dollars using an average 1.60% inflation rate (2009-2014) derived from <http://www.usinflationcalculator.com/inflation/current-inflation-rates/>.

⁹⁰ NHDES Water Use Registration and Reporting Program website at <http://des.nh.gov/organization/divisions/water/dwgb/dwspp/wurrrp/index.htm>.

⁹¹ PART Env-Wq 2102 WATER USE REGISTRATION AND REPORTING <http://des.nh.gov/organization/commissioner/legal/rules/documents/env-wq2102toc.pdf>

water management plans. The Instream Flow Program should also be notified when new water users register in these watersheds.

IV.J.3. NHDES WATER CONSERVATION PROGRAM

The Water Conservation Rules requiring water conservation plans are applicable to all new water withdrawal permits.⁹² The Instream Flow Pilot Rules also require conservation plans for water users if they meet the water use registration criteria. The Water Conservation Program⁹³ manages conservation plans required by either the Water Conservation Program or the Instream Flow Program, or both. The staff in the Water Conservation program will spend additional time reviewing and approving the water users' plans and in tracking compliance with the adopted plans.

⁹² PART Env-Wq 2101 WATER CONSERVATION <http://des.nh.gov/organization/commissioner/legal/rules/documents/env-wq2101.pdf>

⁹³ NHDES Water Conservation website at http://des.nh.gov/organization/divisions/water/dwgb/water_conservation/index.htm

V. Proposed plan for implementing protected instream flow protection on other Designated Rivers

This section describes NHDES's proposed plan for applying instream flow protection to all of the Designated Rivers in the state as required under the Rivers Act.⁹⁴ This plan, as required by the legislation that created the Pilot Program,⁹⁵ outlines the process and methods recommended for applying instream flow protection and water management plans to additional Designated Rivers, including changes that should be made to the approach used in the Pilot Program. The plan also identifies data needs, a river prioritization process, and the resources and funds needed to both maintain the Souhegan and Lamprey Designated Rivers instream flow management and to establish and manage instream flow protection on other Designated Rivers.

One of the goals of the New Hampshire Instream Flow Pilot Program was to ensure that adequate information is available to develop the necessary protected instream flow criteria and water management plans. The approach uses existing information or information that can be developed during an instream flow study. The pilot demonstrated that the instream flow study approach, applying methods that addressed the needs of the flow-dependent, instream uses, can successfully define numerical instream flow protections. The approach can be applied to other Designated Rivers. Water management plans use information from water users and from database records to develop management actions that will maintain the protected flow criteria. Water use evolves as users change their water sources and the purposes for which they use the water. The water management plans are developed interactively with water users, dam owners and other interested parties to ensure that site-specific conditions and interests are considered. The key goals of the water management plans are to spread, reduce, or delay the impacts of water use on stream flow and assist water users with identifying water sources that meet their long-term water needs.

The demand for water in the state will only increase. The sole long-term response that will address the impacts on rivers from increasing water use/demand is to reduce consumptive impacts on rivers. Consumptive use can be reduced by developing water infrastructure that promotes the local use and local return of water. In this way, fresh water may be used many times, providing its benefits again and again to accommodate demand. A water user's requirements for management actions under the Program vary with the impact the water user has on low flows. Higher levels of management are applied to larger consumptive uses. Without the Instream Flow Program to provide the incentives for conservation and practical management during droughts, the over use of water resources could expand inexorably.

Land use changes and river channel modifications also affect flow, but their impacts are more difficult to quantify than are the impacts of withdrawals. Impervious surfaces (such as pavement) reduce the infiltration of precipitation into the ground, which results in changes to a river's overall flow pattern. Culverts, dams and riprap also change stream flow patterns, thereby degrading habitat. Land use changes and channel modification impacts were not addressed in the Pilot and this report does not make any recommendations on those topics.

⁹⁴ RSA 483:9-c,I - <http://www.gencourt.state.nh.us/rsa/html/1/483/483-mrg.htm>

⁹⁵ Laws of 2013; Chapter 241:2(c) - <http://www.gencourt.state.nh.us/legislation/2013/HB0588.pdf>

Flow variability is inherent in all river systems. The Instream Flow Program assesses and detects when the normal range of flow variability is exceeded. The Program then defines management actions which will prevent and mitigate the ecological impacts of consumptive water use. It should be noted that the Pilot Program protections and management were developed under the relatively low water use stress conditions affecting the Souhegan and Lamprey Designated Rivers. Water use on these rivers affects flow significantly only during certain conditions and at certain times of the year. Initially, much of the flow pattern that defines a river will stay within normal ranges of variability without management. However, as demand increases, water users will seek to make more use of the flows under other conditions and other times of the year.

The recommended process for applying instream flow protections to the remaining Designated Rivers is similar to the pilot process, but with some changes that will make the process quicker. Similarly, the report describes efficiencies that can be achieved by developing data for all of the remaining Designated Rivers on a state-wide basis. In addition, the instream flow process does not end with the adoption of a water management plan. Therefore, ongoing Program maintenance and associated cost estimates are provided for the tracking of river conditions, monitoring, and ongoing coordination with affected parties.

V.A. Process for applying protected flow to the remaining Designated Rivers

The Instream Flow Pilot Program's process was conceptually simple. The river was assessed and the protected flows were calculated. Next, historical low flow conditions were assessed using the protected instream flow criteria, and then management plans were developed to address flow deficits.⁹⁶ In practice, it was much more complicated and there are details of the process that could be simplified and streamlined.

On the remaining Designated Rivers, NHDES recommends that the process be fundamentally the same, but with some modifications as discussed below. Following this plan, NHDES anticipates a two-year process for each river with the staggered development of two rivers at a time. One year of the process will be spent developing the instream flow protection criteria, and at the same time, NHDES would begin intense public participation in the development of the water management plans (describing the water conservation, water use and dam management plans). The development of water management plans would begin in the first year and continue through the second year.

V.A.1. PILOT PROCESS

The process applied during the Pilot Program was guided first by the Pilot Program's legislation and then by Env-Wq 1900, also known as the Instream Flow Pilot Rules. A flow chart and summary describing the generalized elements applied during the Pilot Program can also be found in Appendix A. The legislation defining the Pilot Program required each river to have technical and local interest committees to advise and assist NHDES. It also required that a protected instream flow study be conducted prior to adopting a protected instream flow level and a water management plan. The Instream Flow Pilot Rules required that scientifically-supported protected instream flow criteria be

⁹⁶ The Pilot Program is summarized in Appendix A - Simplified description of the Pilot Protected Instream Flow and Water Management Plan process.

established prior to adoption of the water management plan,⁹⁷ with the intent of developing appropriate protected flows without influence from the management actions that they might require. The process of writing the water management plans used the results of the protected instream flow study to define management actions to maintain those conditions.

V.A.2. CHANGES TO THE PILOT PROCESS MOVING FORWARD

In order to implement the provisions of RSA 483:9-c, which require the establishment of the protected instream flow for each Designated River, new Instream Flow Rules would be necessary to replace the pilot rules, which apply only to the Souhegan and Lamprey Rivers. The new rules would also need to detail the process for applying protected instream flow studies and developing the water management plans.⁹⁸ NHDES proposes that the Instream Flow process on the remaining Designated Rivers will be fundamentally the same as on the pilot rivers. The rules would therefore be similar to the Pilot Rules in most ways. The technical process for applying instream flow protection to other Designated Rivers is shown below. This process is modified from the original Pilot Program's scope of work. The tasks making up this approach will be applied to each of the Designated Rivers to define protected instream flow criteria which support the protected entities and to develop water management plans. The protected entities are the river uses, characteristics and resources described for protection in the Rivers Act. The protected entities are discussed in more detail in Appendix A. At the onset of each instream flow project, NHDES will create a public participation plan that is customized to the river and watershed that extends throughout the entire instream flow process.

Task I. Protected Entity Identification -- Identify and field-locate the river-specific, flow-dependent entities to be evaluated and protected.

Task II. Groundwater Impacts Analysis – Determine whether groundwater wells affected by the Instream Flow Pilot Rules are inducing recharge from the Designated River. The results will determine water management plan actions.

Task III. Protected Instream Flow Criteria Development – Evaluate the protected flow needs for the flow-dependent entities and integrate the flow needs into protected flow criteria that define the natural pattern of stream flows. Document the findings in I and II above.

Task IV. Protected Instream Flow Public Hearing and Final Report – Conduct a public hearing to present a summary of and receive comments on the protected instream flow criteria and findings of the Instream Flow Study. Finalize the Protected Instream Flow report and provide a “Declaration of the Establishment of Protected Instream Flows” for the river.

Task V. Water Use, Flow Deficit and Flow Augmentation Analysis – Identify the historical flow deficits using the established Protected Instream Flow criteria, and evaluate the capacity for relief pulses and water use changes to offset these deficits.

Task VI. Water Management Plan Development – Determine and document the combination of management actions required to meet the protected instream flow criteria for each water user and dam owner affected under the rules; develop protected instream flow management plans.

⁹⁷ Env-Wq 1904.02 Sequence. The department shall establish scientifically-supported protected instream flows prior to adoption of the water management plan for a [water management planning area]. This follows Laws of 2002, Chapter 278:2, II.

⁹⁸ Description of proposed changes to the rules are included in Appendix J – Discussion concerning the development of new instream flow rules

Task VII. Water Management Plan Public Hearing and Final Report – Conduct a public hearing to present a summary of and receive comments on the findings of the draft water management plan. Finalize the Water Management Plan report.

In concert with the technical tasks, NHDES proposes to both continue and expand upon the outreach and public participation activities that were part of the Pilot Program. NHDES would notify interested and affected parties within the watershed before beginning the technical work. Advisory committees made up of people with watershed interests were defined in the Pilot Program legislation. Assuming advisory committees will also be convened for the next Designated Rivers, these committees will be asked to provide their knowledge of local conditions, interests and concerns to help inform the development of the protected instream flow criteria and water management plans. NHDES recommends that the form of these committees be changed. Meetings of the advisory groups should continue to be open to the public. Public hearings for both the proposed instream flow criteria and the water management plans should provide for official public review questions and comment. A key lesson from the Pilot Program is that other opportunities, especially for unofficial, informational meetings, are needed to provide meaningful input and dialogue with local interested parties. A public participation strategy should be developed at the beginning of the work on each Designated River.

The review of the Pilot Program described in this report evaluated the regulatory requirements and the processes used to develop the instream flow criteria and the management plans for the Souhegan and Lamprey Rivers. Instream flow science had progressed significantly between 1990, when the Instream Flow Program's defining legislation was passed, and 2002, when the chapter law was passed that marked the beginning of the Pilot Program. The Pilot showed that some processes could be streamlined without reducing the quality of the results. The chief cost drivers in both time and money were the field work to assess flow criteria, the public process defining and reviewing the methodology and other public participation events, and the development of the water management plans with the affected water users, dam owners and other stakeholders. These are necessary components, but the pilot identified ways to reduce costs. The following changes are proposed for the instream flow process:

- a. Assess protected flows for only the flow-dependent instream public uses.
- b. Hire consultants to develop the river-specific protected instream flow criteria; NHDES would complete the water management plans.
- c. Develop the water management plan in parallel with the instream flow study.
- d. Simplify the Instream Flow Pilot Rules for conservation plans and water use plans.
- e. Improve and change the review and public input processes.

These changes are discussed below.

V.A.2.a. Assess protected flows for only the flow-dependent instream public uses

The Instream Flow Program should focus its assessments on the flow-dependent, instream public uses that were identified during the pilot. The list of entities assessed during the pilot followed statutory requirements and the rules generated from those statutes. The Rivers Act lists the river features for which a river may become designated; this legislation applies instream flow protection variously to conserve and protect, or to restore and maintain the river feature types listed. But the specific injunction is to “maintain water for instream public uses and to protect outstanding characteristics... and the resources for which the river or segment is designated.” Collectively, these became known in the Pilot Program as the protected entities. A table listing and defining the protected entities is included as

Appendix F. The Instream Flow Pilot Rules require⁹⁹ that all of these entities are identified and catalogued, that a survey of the river be conducted for them, and that methods be identified for defining a protected instream flow for them.

The Pilot Program showed that the identification and assessment of entities that are clearly not flow-dependent is unnecessary. The protected entities described above consist of dozens of river feature types, many of which are not flow-dependent, such as geology and open space. In addition, some of these protected entities are consumptive users of water that compete with instream public uses. The Pilot Program assessed all of the protected entities, as required under the Rivers Act, but determined protected instream flow criteria for only the flow-dependent, instream public uses. That list of flow-dependent entities is short and includes: aquatic and fish life and their habitats; riparian habitat for plants and wildlife; and recreation. When flow protection is developed for these critical entities, protection for the other entities is provided. Future protected instream flow studies should focus on criteria for flow-dependent, protected entities, which would have the benefit of saving both time and money while ensuring that flow-sensitive needs are met. Legislative changes may be necessary to clearly indicate that the flow-dependent entities are the targets for instream flow protection.

V.A.2.b. Contract for the instream flow study, NHDES will complete the management plans

The division of labor between consulting firms and NHDES should be different in the future than in the Pilot Program. During the Pilot Program, the consultants were responsible for every phase of the work. NHDES was closely involved with the project and provided considerable assistance, direction and oversight. NHDES found that the final drafts of the water management plans required staff to work on an iterative basis with the water users and dam owners in each watershed, requiring the water management plans to be rewritten by NHDES staff. Because of the close coordination required between water users and NHDES staff, future water management plans should be developed directly by NHDES and the water users.

Consultants should continue to be responsible for the instream flow study because they have the range of training, computer models and dedicated equipment to carry out the studies. By hiring consultants, the development of protected instream flow criteria will be insulated from the influence of requirements for water management plan actions that the criteria will drive. A commenter suggested that NHDES staff might be hired to conduct the instream flow studies instead of consultants to save money and retain the historical knowledge from developing the protected instream flow criteria. However, costs are similar for in-house staff and consultants. The chief benefits of hiring consultants are fixed costs and application of expert staff to each component of the study. Disadvantages are the state contracting process and inflexibility of a defined contract. The chief benefits of hiring NHDES staff are the retention of institutional knowledge of the development of the flow criteria. Disadvantages are the limited availability of qualified applicants and need to develop the study procedures and in-house costs for administration and to buy supplies and equipment. The recommendation is explored in greater detail in Appendix H – Public Comments.

Depending on the length of the river and the number of water users, the protected instream flow study and the water management plan development will each be about half of the total cost. The data necessary for developing the water management plan will come from NHDES' databases and from

⁹⁹ Refer to the requirements in RSA 483:9-c,II.

water user reports submitted to NHDES. Ultimately, NHDES will be responsible for coordinating the implementation of these plans with the dam owners, water users and stakeholders, and so NHDES should be involved in their development. NHDES staff have experience with developing water management plans and would develop working relations with dam owners and water users while preparing their plans.

V.A.2.c. Develop the water management plan in parallel with the instream flow study

The Pilot process was conducted purposely in a linear manner. The Pilot took a step-wise approach to the tasks to first define the protected flow criteria before addressing the water management plan. It appeared that the legislature wished the protected flow criteria to be defined before addressing management in order to avoid mixing the scientific process of the instream flow study with the management alternatives of the water management plan. Most tasks in the Pilot Program were also dependent on the results of a previous task, such as river assessments before flow criteria, then flow criteria to define flow problems, and flow problems before identifying management actions. The step-wise progress was also a simpler approach which helped when explaining the plans as they were presented to the advisory committees, the public, and the affected parties.

Moving forward, there are some steps that can be developed earlier in the process. Now that the Pilot Program has demonstrated how management actions will be applied under actual circumstances, it is clear that some parts of the water management plan development can be conducted before the protected flows are established and without compromising the scientific integrity of the protected instream flow.

First, notification to water users of the requirement to develop conservation plans can begin early during the project. The Pilot Program changed its conservation plan process to be subject to the rules developed later under the Drinking Water and Groundwater Bureau's Water Conservation Program.¹⁰⁰ These plans are independent of the protected flow criteria.

Next, documentation of each water users' situation and preliminary development of the water use plans can also begin at the start of the Program. The Pilot Program has shown NHDES the likely management actions required by various water users that will feed into a general plan. In the end, the needs of the water user in relation to the established flow criteria will determine the final management actions.

The Pilot Program also demonstrated the critical factors in determining how dam management would be applied. Early assessments of these factors can estimate likely management scenarios, and an array of dam management responses can then be developed. Identifying potentially suitable dams for management earlier in the process will also alert interested parties, allowing more time for them to provide their input and express concerns that may affect management plans. Parties other than the dam owners, particularly the lakefront property owners, also have interests in the dam management plans. As discovered in the Pilot process, there is keen interest around lakes to ensure that both the ecology and recreational values of the lake are seriously considered. Failure to open an early dialogue with lake property owners extended the endpoint of the Pilot water management plan for more than a year. NHDES continues to meet with the stakeholders around one lake to address their interests and concerns. The specific actions under the dam management plans would be entirely dependent on flow

¹⁰⁰ The Water Conservation Program's website can be found at http://des.nh.gov/organization/divisions/water/dwgb/water_conservation/index.htm

deficits determined using the established protected instream flow criteria. After the protected flows are established and deficit conditions have been defined, the best suited options for managing the flow deficits can be selected.

The final determination of the specific actions under both the water use plan and the dam management plan requires the established protected flow criteria as the basis for calculations. However, as noted above, elements of the water management plan can be addressed, in part or as a whole, earlier in the Program, thereby reducing the amount of time necessary to complete the plan.

V.A.2.d. Simplify the rule requirements for conservation plans and water use plans

Conservation plans described in the Instream Flow Pilot Rules (Env-Wq 1905) contain requirements for documentation that are similar to those found in the water use plans. Instream Flow Rules for other Designated Rivers would be changed to apply the Water Conservation Rules under Env-Wq 2101. The Water Conservation Rules were adopted after the Instream Flow Pilot Rules, resulting in two programs with different water conservation requirements. The rules under Env-Wq 2101 should be applied to the instream flow water users instead of the conservation rules under the Instream Flow Program. This approach would have the added benefit of applying only one form of NHDES-defined conservation plan to New Hampshire water users. Another advantage is that the plans are reviewed by personnel who have expertise in water conservation.

A water conservation plan that is approved under the Water Conservation Rules would suffice for the Instream Flow Program. Watershed Management Bureau would notify water users that an Env-Wq 2101 water conservation plan would be required during the initial stages of the discussions about conducting the Instream Flow Program in that watershed. However, currently only some water users affected by the Instream Flow Program are required to have water conservation plans under the Water Conservation Rules. Therefore, an amendment to existing law would be required to apply the Water Conservation Rule requirements to all water users when they are affected by the Instream Flow Program.

V.A.2.e. Change the review and public participation processes

The role of public participation should change when the Program is applied to other Designated Rivers. One of the primary reasons why the Pilot took so many years to complete was the time spent developing the process. As has been noted in the evaluation of the Program, the process for determining the protected instream flow and water management plans appears to function well and can be replicated. Therefore, the focus of future public participation should be on the results of the work rather than on the methodology itself. This will quicken the pace of the process.

The instream flow study results are very technical. Therefore, in addition to public review, NHDES proposes that the protected instream flow assessment results be reviewed by experts in this field. The more intensive public review would be requested on the water management plans and their implications to water users, dam owners and other stakeholders as an effective way of applying local interests and knowledge while shortening the project duration.

Public information was provided and public input was sought from the beginning to the end of the Pilot process. The Pilot Program included a technical and a stakeholder advisory committee for each river. NHDES held public meetings during the projects to propose and approve plans, present results and solicit feedback. The public meetings presented instream flow protection concepts, assessment methods

and results. A wide range of interested parties were invited to these meetings, starting with the people directly affected by the rules, the town officials in the watershed, members of the state's rivers and lakes advisory committees and the Water Council, members of the legislative oversight committee, and others who had requested notifications. The advisory committee representing local interests was open to the public and was made up of representatives of watershed interests. Public postings to the Instream Flow webpage and public bulletin boards, email and mail were used to notify the parties. NHDES met individually with each of the water users and with the dam owners at the beginning and during the process. NHDES also made numerous presentations at conferences and symposia. NHDES held a public hearing and comment period for each of the protected instream flow reports and water management plan reports.¹⁰¹

Despite these efforts at outreach, some entities did not recognize their interests in the proceedings and did not participate until very late in the water management planning process. This resulted in time spent in additional education and contentious discussion that might have been avoided by earlier involvement with the process. The weakness of the stakeholder committee was twofold: 1) committee members included representatives from the various types of interest groups, but not necessarily from each of the individual affected interests; and 2) the members cannot be expected to relay all of the important information back to their respective constituencies, especially over a long period of time.

The Pilot helped NHDES recognize who the likely stakeholders will be outside the circle of water users and dam owners. In the future, NHDES will create a public participation strategy that identifies these stakeholders early in the project and will directly contact anyone whose participation may be helpful in the evaluation of protected flows and management plans. The strategy will include timeframes and meeting schedules. A committee is recommended that is specific to each Designated River that would commence at the start of that river's instream flow process. In addition, continued involvement of both the Rivers Management Advisory Committee and the Lakes Management Advisory Committee is recommended.

These measures should improve public interaction with the Program and create a common expectation of how that interaction will occur. The elements of the technical review and public participation processes are described in more detail below.

i. Expert input

The science behind the instream flow criteria is multifaceted and takes time to comprehend. The key elements of instream flow protection are a combination of statistics, fisheries biology, river hydrology and incremental modeling methods. It is rare for any one person to be an expert in all of these fields and those who are, are very busy. As such, it is difficult to have a thorough expert review.

The advisory committees were presented with the descriptions of protected entities and the recommended methods for determining flow criteria for those that were flow-dependent. NHDES sought the committees' approval in order to ensure that there was concurrence with the consultants' conclusions about the flow-dependent list, the need to assess only the flow-dependent entities, and the

¹⁰¹ Consistent with RSA 483:9-c Establishment of Protected Instream Flows. "II. One public hearing shall be held in at least one municipality along the Designated River or segment to receive public comment on the establishment of a proposed protected instream flow."

proposed assessment methods. These flow-dependent entity lists and assessment methods were reviewed and approved in public meetings before being applied. There were no changes to the methods applied during the Pilot as a result of these meetings.

NHDES hired two natural resource companies and a university staff member in order to have sufficient staff with expertise in these fields to conduct the instream flow studies. To assess the preliminary results of the protected instream flow studies, NHDES requested a review by an *ad hoc* committee from the Instream Flow Council, an international collection of fish and wildlife agency staff with interest or experience in protected instream flow criteria. The technical aspects of the Program need to be reviewed during the instream flow study by experts in this field who possess at least this level of expertise. Obtaining peer reviews of instream flow applications is a pressing issue everywhere in stream flow protection. NHDES should replicate its expert review process by soliciting technical reviews from qualified experts.

ii. Public input

A number of important changes were made to the water management plans as a result of public input. Most people were clear about the implications of actions under the management plans. The key public inputs to the pilot plans were the watershed residents' knowledge specific to the subject river and associated lakes, and of their interests that might be affected by management. In the Lamprey and Souhegan Rivers, these interests and topics of information included recreational uses, loon nesting, water quality concerns and historical practices, to name a few.

NHDES made many changes to the pilot management plans and conducted additional studies as a result of public input. This shows that public participation produces an important review component, but at the same time, it also added time and cost to the process. During the Pilot process, the additional time spent to thoroughly explain project details and to explore management options with the public was valuable.

As noted above, NHDES believes that some parts of the Program demonstrated during the Pilot can now be conducted routinely. More time spent on outreach for water management plans and less on open-ended technical review process will reduce project cost and duration. For water management plans, NHDES now knows the interested parties who are more likely to be most affected based on the experience gained during the Pilot Program. NHDES would create a public participation strategy for each river in order to identify and notify these parties early in the process. Early involvement by affected parties is likely to provide valuable input focused on river-specific and lake-specific concerns. The Pilot Program's legislatively-created advisory committee for advising on the development and impacts of water management plans required a complex process for membership. An alternative that would be more inclusive and easier to maintain would be to form subcommittees under the aegis of the existing Local River Management Advisory Committees. These subcommittees would be formed within each Designated River watershed. Membership would be informal and open to any watershed interests. Each subcommittee would advise on the development that watershed's water management plans. The subcommittee would continue for at least one year into the implementation of the water management plan. At that time, the Local River Management Advisory Committee would decide whether to continue to support this subcommittee.

To inaugurate each subcommittee, NHDES will devise a public input plan to identify, document and contact interested people and groups early in the process. Thorough public input will be sought by

contacting all dam owners and also the lake associations on any dam impoundment that might be used for water management. If no lake associations exist, then NHDES will make a general notification to lakefront property owners. NHDES would continue to actively solicit watershed interests to attend.

Public meetings of the subcommittees will lay out the results of the Pilot Program as an example and indicate the likely management plans applicable to the watershed being studied. NHDES will contact the governing bodies of towns where public water supplies are affected and area legislators to ensure they are informed, as well as the municipal operations staff who will carry out the water management plan actions.

Wider public input will be provided by continuing to present the progress of the Instream Flow Program to the Rivers Management Advisory Committee and the Lakes Management Advisory Committee. These committees represent statewide stakeholder groups who may advise NHDES on the broader effects of the Program. If a question affecting the interaction of rivers and lakes arise, NHDES will request that the Rivers Management Advisory Committee and Lakes Management Advisory Committee reconvene its joint Instream Flow subcommittee made up of members of both advisory committees to address its resolution.

V.B. Methods for applying protected flow to the remaining Designated Rivers

During the development of the Instream Flow Program, the overwhelming sentiment of the public was that: 1) the methods should be tied to scientific approaches rather than negotiated, and 2) the results should be specific to unique attributes of each river. This section describes the methods applied during the Pilot to identify the protected instream flow criteria, and later those used for the water management plan. This section also describes the statewide data that will support these methods. Key to these methods are continuous stream flow data and a description of the expected fish population. Stream flow data are vital to assessing protected instream flow criteria. The expected fish population is used to define the model parameter for defining protected flows for fish. This section also addresses questions which have been raised regarding other possible methods for simplifying the instream flow assessments.

NHDES reviewed the Pilot methods and alternatives for the remaining Designated Rivers. The Pilot was effective in applying scientific methods to defining stream flow protections for fish, shoreline species and recreation. These methods produced appropriate numerical instream flow criteria that can be implemented effectively by water management plans. The pilot applied three methods to determine protected instream flow criteria that were then implemented by water management plans by addressing conservation, water use and dam management.

V.B.1. INSTREAM FLOW STUDY ASSESSMENT METHODS

The methods used during the Pilot addressed fish and aquatic life, riparian wildlife and plant communities, and recreation. Information on fish, riparian species and recreational preferences were collected during the instream flow studies as the data inputs for these methods. Defining flow protections for these three river uses provides a more complete protection of flow than any one assessment method alone. These methods, described below, assess site-specific conditions and apply biological habitat criteria that avoid the imposition of arbitrary or generalized standards that have poor links to life cycle needs and site-specific conditions sometimes found in other methods.

V.B.1.a. Fish community and life cycle needs

An incremental flow model is used to characterize the relationship between the change in fish habitat versus the change in flow. Fish communities were assessed using the most abundant species of fish expected to be present in the Designated River. These species were identified by developing a compilation of fish found in similar reference rivers. The result is a target fish community. Fish in the Designated River are also assessed to define their habitat use preferences. The river is surveyed to identify the areas where fish use preferences are met. Measurements are repeated at different flows. Historical flows are input to show the daily changes in habitat that have occurred over decades. Frequency analysis is then applied to identify the flow conditions that represent a major change in habitat availability. These points are defined in terms of flow magnitudes and their durations for different parts of the year. These key flow conditions are the protected instream flow for fish.

Several incremental flow models are available for assessing fish flow needs and may be applied under this method. The key element is computing seasonal flow conditions by means of frequency analysis of the relationship between and among flow, habitat and the historical stream flows.

V.B.1.b. Stream bank plant communities and wildlife

Plant communities and wildlife occupy positions on the stream bank. The flow of water can be determined for the height of water needed to reach these positions. Surveys are conducted to find the elevation of plant communities on the stream bank. Literature values for the plant communities are examined to determine the timing and flow conditions needed to maintain their life cycles. Flows and timing are determined and durations applied to define the protected flows for plants. Wildlife may need to avoid high flows at some times of the year. Limits are identified to avoid unnatural occurrences of flow at these elevations during those parts of the year.

V.B.1.c. Recreational preferences

Opinion surveys on the pilot rivers were conducted to determine preferences for recreational uses of the rivers. Because there were no clear preferences for swimming flows, no swimming flow condition value was identified. Preferences for boating were identified, however. The protected flow was determined by assessing the river at various flows and surveying boaters. Whitewater boating guides had identified certain minimum flows which were confirmed by the user surveys. This flow was set for whitewater boating. Surveys indicated that flat water boating was ideal at flows above the flow needed to float the whole river without dragging.

V.B.2. PLAN FOR STATEWIDE DEVELOPMENT OF KEY DATA

Key data should continue to be developed. The instream flow studies rely on hydrologic, biologic and use preference data for defining the flow criteria. Key information includes data describing stream flow hydrology, fish communities, and shoreline plant communities and wildlife. Information about boating preferences is also important for setting recreational boating criteria. Most of these data can be collected at the time of the instream flow study, but the Program would benefit from state-wide development of certain elements of this data in order to increase Program efficiency and timeliness.

The data that should be collected in advance are those that require long periods of data, or those that would provide the additional benefit of local and state-wide datasets with myriad uses. Stream flow data and fish species distributions are two data sets that meet those conditions.

V.B.2.a. Fish data

Two types of fish data are used in an instream flow assessment: 1) a target community comprised of the expected fish, derived from fish collections on other rivers; and 2) the existing community of fish within the Designated River. The target fish community¹⁰² defines a goal for meeting biological integrity requirements in water quality rules. The existing community is used to determine fish preferences for flow conditions and is compared to the target community.

The target fish community¹⁰³ represents the fish species distribution that is expected to occur in the river. Target fish community data identify a river's expected fish species distribution and represents a measurable goal for flow protection. The target community also defines the indicator fish species that will be modeled during the instream flow study, and is compiled from fish data from several ecologically healthy reference rivers that are physically similar to the Designated River segment. Target fish communities could be developed for New Hampshire rivers in each of the state's ecological sub-regions as has been done in Massachusetts watersheds. Massachusetts agencies have defined target fish communities for the major rivers of the state, comparing this information to data from their Statewide Fisheries Survey and Inventory.¹⁰⁴

Box V.1 -The need for adequate fish data

An example of the need for comprehensive fish data occurred in the Lamprey watershed. A number of historical fish samples had been collected in the river's upper reaches and tributaries. These collections described a cool to coldwater fish community. Before the Pilot Program began, some people thought that this collection represented the existing fish community in the lower Lamprey as well. However, only one of the stations was within the 13-mile Lamprey Designated River, the rest were located in the upper watershed. Recognizing that these fish might not represent the species in the Designated River, NHDES collected fish in the designated segment. In 2003, fisheries staff from five state and federal agencies conducted fish sampling at 43 stations on the Designated River, creating a comprehensive data set and a new understanding of the fish population in the lower Lamprey. The fish samples previously collected in smaller, colder, upstream tributaries showed a significantly different population of fish compared to the collection in the Designated River. Had the historical data been used, instream flow assessments would have been applied to species that are not generally present in the Designated River. As discussed below in the section discussing transferring protected flow criteria, the protected flows that apply to the lower Lamprey will apply upstream for some distance, but different flow criteria will be applied where species with different life cycle flow needs exist. Data are needed that show changes in fish community distribution. The Lamprey fish data collected in 2003 were available for application within the instream flow habitat modeling. In contrast, there was little pre-existing fish data available in the Souhegan Designated River, so fish collection was an additional task conducted by the consultants in order to develop data for model inputs.

¹⁰² A presentation discussing the Lamprey Target Fish Community is available at http://des.nh.gov/organization/divisions/water/wmb/rivers/instream/lamprey/documents/tfc_presentation.pdf. The Souhegan Target Fish Community report is available at http://des.nh.gov/organization/divisions/water/wmb/rivers/instream/souhegan/documents/final_draft_fish.pdf. The Lamprey Target Fish Community report is available at http://des.nh.gov/organization/divisions/water/wmb/rivers/instream/lamprey/documents/tfc_report_legros_21june2007final.pdf

¹⁰³ Bain, M. B. and Meixler, M. S. (2008). *A target fish community to guide river restoration*. River Res. Applic., 24: 453–458. doi: 10.1002/rra.1065 -

http://des.nh.gov/organization/divisions/water/wmb/rivers/instream/souhegan/documents/mar2204_fish_report.pdf

¹⁰⁴ <http://www.mass.gov/eea/agencies/dfg/dfw/wildlife-habitat-conservation/target-fish-community.html>

Collections of existing fish from the Designated River are another of the critical data sets for developing the protected instream flow criteria. Fish species will selectively occupy areas of a river with certain combinations of habitat parameters such as depth, velocity, shelter and stream bed material during various stages of their life cycle. Fish collections show which species are present, while measurements of habitat parameters show the habitat parameters those species are using. As flow changes, those parameters change and as a consequence, fish habitat becomes more or less suitable. The measurements of flow parameters link fish habitat use to flow levels. Analysis of historical flow data then identifies when the parameters most suitable for a species will be present or absent. The distribution of habitat suitability over time is used to define the protected flow criteria.

The existing fish community is also compared to the target fish community to determine how well the existing community compares to the expected community. After the instream flow management plans have been applied, the existing fish community over time should become more like the target community. Periodic fish collections will be needed to monitor the existing fish community.

Fish communities will change from the top to the bottom of a watershed as the river's flows, landscape and human uses change. Alterations in the distribution of fish species provide a means of determining the points where separate flow criteria may be needed. Differences in river slope, size or ecoregion,¹⁰⁵ and the presence of dams, represent locations where fish population changes are likely. Target fish communities for the Designated Rivers may be most efficiently and uniformly developed by a state-wide effort applied to the existing Designated Rivers.

V.B.2.b. Stream flow data

Stream flow data are needed both for assessing protected flow criteria and for applying flow management. Real time data from stream flow gages on all of the Designated Rivers are fundamental to water resource management. Many of New Hampshire's stream gages have been discontinued, or have gaps in their record that make assessments difficult. For example, the Merrimack River gage at Franklin Junction was closed for 23 years from 1978 through 2001. Similarly, the Swift River had a gage installed in August 2009 with funding from the New Hampshire General Court. However, this gage was removed in July 2011 when no maintenance funding could be found. Stream flow gages will be in ever greater need as water resources require more careful management, so permanent funding is needed to maintain gages on all of the Designated Rivers.

The USGS stream flow gages provide the hydrologic data used in assessing protected instream flow criteria. These data are trusted by the public, and data from USGS gages are available online. Thirty years of continuous hydrologic data are used to define the protected instream flow criteria. Even with

¹⁰⁵Ecoregions denote areas of general similarity in ecosystems and in the type, quality, and quantity of environmental resources. Regional divisions of New Hampshire may be appropriate applying either Omernik's Level IV delineations <https://catalog.data.gov/dataset/level-iv-ecoregions-of-new-hampshire> or The Nature Conservancy's ecological drainage basins http://www.2c1forest.org/atlas/metadata/edu_metadata.htm. The Nature Conservancy's divisions are a breakdown that are stratified for New Hampshire's rivers and lakes, based on geology, topographic features (elevation, gradient and landform), connectivity, and local climate patterns that effect watersheds over long time periods. The EPA version is well accepted and widely used. It was based on land formations, geology, topography, regional climate, and dominant natural vegetation. The boundaries were refined based on how natural communities occur. The selected ecoregion set may need to be subdivided using variables that affect temperature like size, elevation, position and gradient since this is a key factor in habitat use by fish.

gages in place, however, the historic record may not provide sufficient length of record to assess the protected flows without a separate estimate of daily flows.

While it is too late to install new gages to accumulate the 25-30 years of stream flow data records necessary to conduct instream flow studies, it may still be useful to reoccupy historical gages. First, for management purposes, a reliable source of current daily stream flow measurements is needed. Second, shorter records can be used to verify simulated historical records. Where a thirty-year period of data is not available, it may be created through various estimation methods, especially if some historical data has been collected. While estimated flow data is not ideal, there may be no alternative given the gaps in the records resulting from inconsistent funding and the lack of complete gage coverage. A technical committee may be helpful to advise NHDES on the development of simulated hydrologic records for the Designated Rivers that need additional stream flow data. Options for providing simulated hydrologic records for the state are included in a proposal from the New Hampshire-Vermont office of USGS. They propose creating a tool that would generate a 50-year, daily stream flow record at any stream location derived from flows measured at gaged locations. USGS has developed this tool in Massachusetts and it is currently available and in use.¹⁰⁶ The daily flow records are generated using an approach developed by Dr. Neil Fennessey of the University of Massachusetts Dartmouth, who may also be available to develop flow records.

V.B.3. CONSIDERATIONS OF INSTREAM FLOW METHODS

There are many methods for identifying protected instream flow criteria depending on the goals of a given program. Around the world, hundreds¹⁰⁷ of instream flow methods are in use—it is not possible or necessary to test them all. Each method was developed to answer a certain flow protection question, is based on certain assumptions, and has specific strengths. As such, it is possible that other methods that were not applied or assessed during the pilot may also meet New Hampshire's goals and preferences. For example, other site-specific, incremental methods are available that could also be applied to define protected flows for fish which result in similar detailed information about the river and fish as the model applied by the pilot. NHDES applied three methods similarly on the Lamprey and Souhegan Rivers. The pilot showed these methods were effective in quantifying the narrative criteria in the water quality standards. The pilot methods meet the requirements for scientific methods and the stated preference for site-specific studies. NHDES recommends that New Hampshire apply the same methods tested by the Pilot to the other Designated Rivers, incorporating the lessons learned as process modifications.

The instream flow pilot rules require a scientific process for determining protected flows.¹⁰⁸ Earlier attempts at rule writing that set fixed standards for all the Designated Rivers were rejected by

¹⁰⁶ The Massachusetts Safe Yield Estimator tool is a hindcasting tool that estimates unregulated, daily mean stream flow over a 44-year period from October 1, 1960 through September 30, 2004. *The Massachusetts Sustainable-Yield Estimator: A decision-support tool to assess water availability at ungaged stream locations in Massachusetts*, by Stacey A. Archfield and others, Scientific Investigations Report 2009–5227.

¹⁰⁷ Tharme, R. E. 2003. *A global perspective on environmental flow assessment: emerging trends in the development and application of environmental flow methodologies for rivers*. *River Research and Applications* 19:397-441.

¹⁰⁸ Env-W q 1904.02 Sequence. The department shall establish scientifically-supported protected instream flows prior to adoption of the water management plan for a [Designated River watershed.]

PART Env-Wq 1905 Procedure for Establishment of Protected Instream Flows

Env-Wq 1905.01 Elements. To establish protected instream flows:

(a) The department shall:

stakeholders and the legislature. NHDES determined from hearings, comments, and public discussions that a method that both assessed site-specific river characteristics, and relied as little as possible on best professional judgment, was desired. NHDES responded by selecting methods that used an incremental flow model to assess river-specific fish habitat. Other assessments determined the flow needs for river-specific distributions of stream bank plant communities and wildlife, and for river-specific boating practices.

The methods applied in the Pilot represent the necessary components for defining adequate protected instream flows. NHDES chose the pilot methods used because they were site-specific, scientific methods that defined flows that meet the water quality rules' biological integrity requirements or assessed human use preferences. These stream flow protections are strongly tied to the key concept of maintaining a stream's natural variability. Effective protection requires defining the components of the natural stream flow pattern, namely magnitude, duration, frequency, and timing.¹⁰⁹ In addition, the methods applied meet the Rivers Act requirements of complementing and reinforcing state and federal water quality laws. Key among these is the water quality standard requiring that surface waters be restored to maintain biological integrity.¹¹⁰

Below is a discussion of three alternative approaches and why they are not being recommended for New Hampshire's Instream Flow Program.

V.B.3.a. Transferring protected instream flow criteria within a watershed or to other watersheds

Instream flow criteria, defined for one designated segment, can apply to the adjacent segments upstream and downstream if those segments have similar regional, geomorphological, flow and biological conditions. For example, the thirteen miles segment of the Lamprey River in Lee and Durham¹¹¹ is very similar to the Lamprey River segments just above and below it which were designated later.¹¹² The protected flows established in the Pilot can be applied for some, as yet undetermined, distance upstream and downstream in the future. At some point, however, the river changes character enough to require a change in the flow protection. This may be a gradual change, but likely will occur at the confluence of significant tributaries where the river changes size. "Research applying hydraulic and habitat methods to a range of river sizes has suggested that small rivers require a larger proportion of the average flow to maintain similar levels of environmental protection."¹¹³ This research suggests that protected flows identified for a smaller river cannot be directly applied to a larger river.

For example, fish collections in the Lamprey watershed show that the river's tributaries contain cold water species, but that these species are rare downstream in the larger mainstem. Therefore, instream

(1) Conduct a protected in stream flow study and propose protected in stream flows based on scientifically-accepted ecological methods as provided in Env-Wq 1905.02;

¹⁰⁹ The final component, rate of change of stream flow, is addressed in management by applying limits to the rate of change.

¹¹⁰ Env-Wq 1702.07 "Biological integrity" means the ability of an aquatic ecosystem to support and maintain a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of similar natural habitats of a region.

¹¹¹ This segment was designated in 1990 and was the subject of the Pilot Program

¹¹² Many miles of the Lamprey and its tributaries were also designated in 2011.

¹¹³ Jowett I.G. 1997. *Instream Flow Methods: A Comparison of Approaches*. Regulated Rivers: Research and Management. 13 (2) 115-128.

flow criteria will differ between the headwaters and the lower reaches of the river, in part because of the different fish communities occurring in these areas of the watershed.

A river may also change character across the boundary of an ecological region. Ecoregions denote areas of general similarity in ecosystems and in the type, quality, and quantity of environmental resources.¹¹⁴ New Hampshire has been divided into nine distinct sub-ecoregions.¹¹⁵ Several Designated Rivers cross ecoregion boundaries. For example, a major change in river size and ecoregion was observed between the upper and lower Souhegan river segments. NHDES applied separate protected instream flow criteria at the coincident locations of a change in stream order, a break in river slope and a change in the underlying geology, and the related major ecoregion boundary. The methods used to determine the protected instream flows were the same in each segment, however the resulting flow criteria were different.

V.B.3.b. Simpler methods

A number of simpler methods, called standard-setting methods, exist that rely on computations of hydrology, or on assessments of one or more components of fish or river conditions. Standard-setting methods range from simple to complex. The simpler methods gain simplicity of computation at the cost of their ability to define the stream flow pattern and their connection to the biology on a specific river. As more complex methods are applied to incorporate more of the necessary components of flow protection, the computations become more detailed, and the chief benefits of these methods, speed and simplicity, are lost.

Simpler standard-setting methods are used because they can be easily computed. Simpler methods generally result in assigning flow criteria with little resemblance to the natural pattern of stream flows and are thus not as effective for flow protection that support fish. Commonly, the resulting criteria are a minimum flow or set of minimum flows applied at different times of the year. A common example is the Montana Method. This method was intended as a reconnaissance tool, but has sometimes been used to set protected instream flow criteria. This method applies a multiplier of the average annual flow to two periods of the year. The multipliers were based on an expert's assessment of the effects of width, average depth and average velocity on fish habitat in 11 streams in Montana. Reviewers in Oklahoma, however, recommended applying different multipliers and different times of the year¹¹⁶ indicating even this simple method must be tailored to the rivers and location where it is applied. Other methods describe protection criteria based on either the change in wetted river width in relation to flow, or the flow needed to maintain depths and velocities in critical habitat areas. None of the flows resulting from these methods provide for flow variability, however. Further, the association with river biology for these methods is tenuous, generally based on best professional judgment along with fish and river conditions in other parts of the country.

Hydrologic methods could be used to evaluate riverine flow characteristics, however these methods remain inadequate for defining protected instream flow criteria. Hydrologic methods are a type of statistical assessment of stream flow magnitudes resulting in either a single value or suite of river flow

¹¹⁴ <https://catalog.data.gov/dataset/level-iv-ecoregions-of-new-hampshire>

¹¹⁵ http://www.epa.gov/wed/pages/ecoregions/level_iii_iv.htm

¹¹⁶ *Evaluation of the "Montana Method" for Recommending Instream Flows in Oklahoma Streams*, Donald J. Orth and O. Eugene Maughan, Proc. Okla. Acad. Sci. 61:62-66 (1981)

<http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.500.9949&rep=rep1&type=pdf>

Box V.2 - Site-specific incremental method provide a greater benefit to the river and to water users

Standard setting flow protection techniques were applied to a water user on the Lamprey River before the instream flow protections. Without instream flow criteria to quantify the narrative standards, water withdrawals requiring federal permits are reviewed under the Clean Water Act's Section 401 Water Quality Certification program administered by the state. This program applies standard setting criteria to water withdrawals with the intention of meeting biological integrity and other water quality standards.

The standard setting technique's lack of biological information, frequently inadequate stream flow data, and structured nature means it must be applied very conservatively to have any useful effect. This leaves less water available for off-stream use.

A standard-setting technique was applied to protect stream flow under a Water Quality Certification for the UNH/Durham Water System in the Lamprey River in 2001, before incremental methods had been applied to define instream flow protections. The standard setting produced a requirement that the System stop using Lamprey River flow when river flows fell below 45 cfs. The incremental method piloted on the Lamprey as applied for July 5 through October 6 requires no management or reduction in water use until stream flow falls below 16 cfs for 15 days—a much rarer condition. The conditions for UNH/Durham at all other times of the year are also less stringent under the Instream Flow Program. The result of applying more detailed assessment methods is both more beneficial use of the river and greater flexibility for the town to manage its drinking water resources without ecological harm.

statistics. A common example is the selection of a stream flow statistic as the flow criteria, such as Q95 or 7Q10 values.¹¹⁷ These flow criteria describe only flow magnitude, perhaps with an element of timing, but ignore the key elements of duration and frequency of flows that provide flow variability. The flow criteria thus defined are a poor approximation of the stream flow pattern. This approach was summarily dismissed by the public and legislature early in the instream flow development debate.

The Indicators of Hydrologic Alteration method is a well-respected example of calculating hydrologic statistics. The chief use of this method is to assess the change in riverine flow conditions resulting from a proposed withdrawal from the existing flow conditions. On the plus side, the results provide statistics that describe stream flow using magnitude, timing, frequency, duration and rate of change. However, there are no guidelines identifying whether or not the statistics represent flows that support river uses. There is no link between the hydrologic conditions and the river biology. The effects on fish from the existing flow are not understood, so all that can be determined is that there is a greater or lesser percent change in riverine flow conditions when a new stress is applied. A limit can be applied to the variability in one or more riverine flow conditions. Who picks that limit, which riverine flow condition is limited, and by how much, would stimulate an ongoing and potentially contentious debate.

The assumption of incremental flow methods is that by maintaining the site-specific flow conditions that fish are known to use, that these fish will be supported. The Pilot Program applied this with the key components of flow to protect stream flow variability. The assumption of standard-setting methods is that flow can be defined by as few as one of the key components of flow—usually magnitude. This

¹¹⁷ Q95 means the flow representing the lowest 95th percentile of stream flow. 7Q10 means the lowest average, 7-day flow that occurs once in 10 years.

results in a loss of flow variability. The assumption in hydrologic methods is that defining the change in flow is sufficient to define flow protections. Each of these assumptions ignores the connection to biology and relies on human interpretation of the significant flow parameters and the limits to which they can be altered before fish are harmed.

Site-specific, incremental methods are the acme of setting instream flow protection for fish. They are costly and time consuming, but effective at defining flow protection determined through biological criteria. Application of site-specific methods provides scientific quantification of the protected flows. Other methods may be quicker or less expensive, but the trade-off is in effectiveness of the flow protection. In addition, as the UNH/Durham Water System example shows, standard setting methods may be over protective. These alternate methods apply thresholds or limits that were chosen with little scientific support.

NHDES has not identified a non-arbitrary, standard-setting method for defining protected instream flow criteria. While more complex to evaluate, the Pilot methods are more effective in allowing water use and protecting the aquatic habitat environment.

V.B.3.c. Could the Lamprey and Souhegan results be reverse engineered into a simpler desk top approach?

This is really two questions: 1) Can simpler desk top methods be applied to other rivers; and 2) can a method be derived from the two rivers assessed so far? The latter question assumes that the Lamprey and Souhegan rivers are enough alike each other and to the other Designated Rivers to generalize a single response for them all. The Pilot Program demonstrated the individual nature of rivers. The Souhegan River was divided into two segments with distinct flow criteria when the separate characteristics of the upper and lower river segments were identified. “Every river system has an individual or ‘signature’ flow regime with particular characteristics relating to flow quantity and temporal attributes such as seasonal pattern of flows, the timing, frequency, predictability and duration of extreme events (e.g., floods and droughts), rates of change and other aspects of flow variability.”¹¹⁸ These two points indicate with that the flow protections derived for one river will not match another.

One should also consider whether the Lamprey and Souhegan studies represent a sufficient sample size to be applied to the larger Designated River population. The Pilot Program so far has studied only two rivers, and these were in watersheds of similar size. Both rivers are in watersheds less than 200 square miles and located in the southern part of New Hampshire. That they have different flow criteria and different management demonstrates that one size does not fit all.

Two examples do not provide sufficient experience for creating a generalization that could be reliably applied on all the Designated Rivers. The watersheds do not represent a broad spectrum of the Designated Rivers of New Hampshire. Application of flow criteria from these rivers to watersheds in different climate regimes or to different watershed sizes would rightly draw criticism.

Simple descriptions of stream flow are limited because the environmental response to flow, and to flow alteration, is not linear. Instream flow expert Hal Beecher notes, “Other hydrological statistics are often proposed as protection statistics. However, hydrological statistics will yield inconsistent results relative

¹¹⁸ Citing Richter and others. 1996; Poff and others. 1997; and Olden and Poff 2002 in Jowett I.G. 1997. *Instream Flow Methods: A Comparison of Approaches*. Regulated Rivers: Research and Management. 13(2) 115-128.

to the goal because habitat is a function of flow and channel shape, not frequency of flow.”¹¹⁹ Desk top methods can be applied, but only at a cost: each simplification has a cost in either defining adequate stream flow protection or in defining the water available for water users. The simpler the method, the less it can approximate the river flows. Simplifications, such as the minimum flow requirements used in the past, resulted in overly prescriptive limits on withdrawals and ineffective protections that favored invasive and non-native species. A river’s dynamic flow pattern is what creates the conditions that support native species and discourage non-native species. Overly prescriptive flow limits result in unnaturally enhanced, higher than natural, flow protection criteria that result in negative ecological consequences and reduce the water available for withdrawal. A pattern of periodic low flows provide necessary services in the ecosystem, similar to the services provided by floods, and these patterns need to be preserved. This pattern is not easily or simply described.

One of the more promising methods for simplification is a process known as the Ecological Limits of Hydrologic Alteration, or ELOHA.¹²⁰ This process would allow for the determination of protected instream flow criteria for streams within a region or with certain hydrologic properties based comparisons with data from many similar streams. According to Oak Ridge National Laboratory,

“The five specific steps of the ELOHA procedure include: 1) building a hydrologic foundation of baseline or “natural” conditions, 2) classifying river types based on natural hydrology along with potential geomorphic subclassification, 3) assessing flow alterations within each river class in relation to baseline conditions, 4) determining flow-ecology relationships for each river class, and 5) determining socially acceptable ecological limits, implementing water policies, and using adaptive management to adjust policies.”¹²¹

As one can see, the ELOHA process initially requires an effort at least as great as the pilot process in order to develop the hydrologic baselines and alteration, habitat-flow relationships, and river classifications. As of 2012, ELOHA had not been fully applied anywhere.

V.B.4. WATER MANAGEMENT PLAN DEVELOPMENT METHODS

NHDES intends to apply the pilot methods to future water management plans. These methods were used to identify the instream flow management needs, define water use patterns, compile possible response actions, and then work with dam owners and water users to confirm their management plans.

V.B.4.a. Management goals

Most management actions are applied to meet protected instream flow criteria that were determined for the most flow sensitive use; in this case, fish. These criteria result in management within a season for acute stresses and after three years for chronic stresses. Protected flows for recreation and riparian plants and wildlife frequently represent the higher flow needs of a river, which occur less frequently. These criteria are sometimes evaluated over a period of years and management is applied after a series of years when those flows do not meet the criteria.

¹¹⁹ Hal Beecher, *Standards for Instream Flows*, Rivers, Volume 1. Number 2. 1990.

¹²⁰ Poff N.L., B. Richter, A.H. Arthington, S.E.Bunn, R.J. Naiman, E. Kendy, M. Acreman, C. Apse, B.P. Bledsoe, M. Freeman, J. Henriksen, R.B. Jacobson, J. Kennen, D.M. Merritt, J. O’Keeffe, J.D. Olden, K. Rogers, R.E. Tharme & A. Warner. 2010. *The Ecological Limits of Hydrologic Alteration (ELOHA): a new framework for developing regional environmental flow standards*. *Freshwater Biology* 55:147-170.

¹²¹ McManamay, Ryan A. and Mark S. Bevelhimer, Oak Ridge National Laboratory, April 2013, *A Holistic Framework for Environmental Flows Determination in Hydropower Contexts*. pp 5-6 at <http://www.esd.ornl.gov/WindWaterPower/ORNLTM2013159.pdf>.

A key goal of the water management plans is to spread, reduce or delay the impacts of water use in order to maintain the protected instream flow criteria. Water use impacts are addressed in the water management plans by identifying water users with the most direct impact on stream flows. Water users with direct surface water withdrawals and those with groundwater withdrawals that induce recharge from the river were identified for priority actions under the management plan. Wells that do not induce recharge are currently excluded from management because of the delay between applying management and the resulting effect on the river flows.

Another goal is assisting water users to find alternate sources of water. Water users are allowed a portion of the *de minimis* amount to assist in meeting their water use needs. However, the *de minimis* amount alone will not suffice for large water users. In that case, NHDES assists in identifying alternatives for the meeting water needs when the protected criteria are not being met. Water use management actions are defined that reduce, delay and shift the effect of water use on stream flow.

V.B.4.b. Management responses

Management is initiated when the protected instream flow criteria are not met at an index location—usually a U.S. Geological Survey (USGS) stream flow gage. Stream flows and protected instream flow criteria are presented on the Instream Flow Program’s website. This website shows current conditions and allows water users to anticipate imminent water management actions. Management actions are documented in water management plans which are made up of conservation and water use plans for water user and dam management plans for dams.

Conservations plans were required for all water users. These plans have conditions that are specific to the water use type. Conservation plan actions reduce losses and waste by conducting leak detection and by quantifying the water used. Best Management Practices for each water user type are applied.

Each water user has a water use plan unique to their facility. The plan describes the management actions required and the conditions when those actions shall be applied. A water user’s pattern of use is documented to evaluate the timing and amount of their water needs, and any other conditions specific to their use. Water use alternatives are identified and assessed. Water use patterns and interviews with water users are used to identify the most viable management approach. The water use plans then identify the water user’s actions in response to extended low flow conditions. These actions reduce consumptive water use by reducing water use, changing the timing or intensity of water withdrawals, or finding alternate supplies.

If conservation and water use changes are insufficient to meet the flow criteria, a relief pulse under one or more dam management plans is applied. Water is released for a short period from dams to raise the stream flow above the protected instream flow threshold to reset the flow pattern. Dams are assessed for their volume, outlet structure, primary purpose, watershed position and refill rate to determine their usefulness in creating a relief pulse. The dams that will be included in management must have sufficient storage that a release will not harm the lake ecosystem or unduly limit the enjoyment of the public and shoreland property owners. Multiple dams may be required if there is no single facility with that capacity. Dams that are upstream of the Designated River are needed in order for a relief pulse to affect the Designated River flow. If no dams are available or suitable, then water management plans will consist only of conservation plans and water use plans.

Consumptive use of water extends and intensifies low flows. The effects of other impacts on streamflow were addressed indirectly by the water management plans. Watershed effects on stream flow such as land use changes, loss of riparian buffers, channel modification and increased impervious surfaces are currently unquantified. Unlike water use, no management actions are specified to remedy these factors affecting stream flow. Their impact is absorbed as part of the overall management. Management is applied to offset flows not meeting the protection criteria without distinguishing whether the cause is water use, dam storage, or these other factors. A watershed approach to addressing these other factors and their impacts should be discussed with town planners.

Tracking the results of management will determine if changes to the management plan are appropriate. Methods for monitoring long-term changes in fish population, riparian plants and wildlife, and recreational usage should be developed and resources found to conduct this monitoring. Methods should be developed for defining the application of adaptive management. Criteria for identifying when adaptive management should be applied must be based on assessments of changes to flows, fish, riparian species and recreation that exceed normal variability. These should be reassessed over time.

While the water management plans were sufficient to meet protected instream flows for the Lamprey and Souhegan Pilot Program, there are some rivers where few or no dams exist, thus restricting management options. The water use and conservation plans for applying management are still effective and should be used where dams are not applicable for relief flows. However, without the availability of relief pulses; other, watershed-scale management actions, such as impervious surface management, may become necessary if the effects of these plans are not sufficient or if impacts from factors other than water use, such as land use change, become dominant. Methods and resources for applying watershed-scale management and adaptive management should be developed.

V.B.5. ONGOING MANAGEMENT METHODS

The future Instream Flow Program should include the management tasks begun during the Pilot Program. The Souhegan and Lamprey Pilot Program includes management tasks that would also be required for each of the future water management plans. There are also tasks that should be expanded under the Souhegan and Lamprey management plans that should also be incorporated into the plans for the other Designated Rivers.

V.B.5.a. Tracking protected instream flow conditions

The Souhegan and Lamprey instream flow criteria are defined in their Declaration of Establishment documents. Management actions by dam owners and water users are chiefly applied to daily flow criteria. NHDES has developed and implemented a website tool for observing the instream flow conditions. This tool provides tables and graphs demonstrating the stream flow conditions and identifying when management requirements are imminent for each river. These must be updated daily by NHDES staff. One or more of these tools will be required for each Designated River. NHDES would like to develop software to automatically update the instream flow conditions. This would require a software developer to translate the existing spreadsheets into a software program that would operate without NHDES staff.

In a separate process, NHDES is tracking stream flow conditions on an ongoing basis to ensure continued support for recreational opportunities and for the riparian vegetation and wildlife. To ensure

that water resource management continues to maintain flow variability, NHDES is applying a hydrologic assessment framework called Ecologically Sustainable Water Management¹²² to the Souhegan and Lamprey stream flow records. Using this framework, the stream flow will be compared with short, intermediate and long-term hydrologic characteristics to identify positive and negative trends.

V.B.5.b. Weather forecasting and instream flow management

Low stream flow conditions sometimes end abruptly as a result of a rainstorm. If weather conditions warrant, management actions may be cancelled or cut short by forecasting a rain event. Key decision-making factors will include the timing, expected rainfall, and probability of precipitation. In the event that a predicted storm is very likely to produce rainfall on the day that management should begin, or on the day after management should begin, NHDES may be able to allow this natural flow augmentation to replace a relief pulse.

Weather forecasting may also be used to improve the timing of applied relief pulses on Designated River flows. For instance, the August 2015 relief pulse on the Lamprey River required over two days to reach the USGS stream flow gage in the Designated River segment. The release was started on the day following the exceedence of low flow conditions, so the low-flow conditions continued in the Designated River for two additional days. In the future, NHDES will utilize the weather forecast combined with an analysis of the stream flow rate to ensure that the relief pulse will have a more timely effect on the Designated River segment.

NHDES intends to use weather forecasting as part of water management. NHDES intends to test forecasting predictions before canceling management actions. Ideally, numerical criteria will be developed that define conditions when weather forecasting would determine the cancellation of management actions.

V.B.5.c. Continued studies

Public input regarding the Lamprey River Water Management Plan raised questions that led to studies requiring several years of data to resolve. NHDES is conducting studies addressing relative outflow rates and volumes from Pawtuckaway Lake's two outlets, phosphorus export, and changes in aquatic plant volume and types. Similar site-specific studies may be needed in future instream flow efforts.

V.B.5.d. Ongoing coordination with water users and dam owners

Water management plan actions are expected to be relatively rare, and it may be years between management events. While water users and dam facilities are responsible for carrying out the water management plan provisions, staff turnover in these facilities may result in representatives responsible for management actions who are unfamiliar with the provisions of their plan. Even during the two-year implementation of the Pilot Program, NHDES has noted turnover in facility staff or changes in staff responsibilities. Existing facility representatives should be reminded of management plan provisions, and new representatives informed of their plan's components and when to apply them. NHDES recognizes a need to make regular contact with water user and dam facility contacts during non-

¹²² Richter et al., *Ecologically Sustainable Water Management: Managing River Flows For Ecological Integrity*, Ecological Applications, 13(1), 2003, pp. 206–224, by the Ecological Society of America. Available at <http://www.esajournals.org/doi/abs/10.1890/1051-0761%282003%29013%5B0206%3AESWMMR%5D2.0.CO%3B2?journalCode=ecap>

management conditions in order to maintain each facility's institutional knowledge and preparedness to manage their facilities under the water management plans.

V.B.5.e. Long-term monitoring

In order to assess positive and negative effects of instream flow management implementation, NHDES should measure the key indicators and track trends over time. A monitoring plan should be developed and a funding source for implementing the plan identified. Tracking and reporting of the status of key indicators should become a routine practice of the Instream Flow Program. The result of monitoring would also provide assessment criteria for determining whether adaptive management actions need to be applied. The elements of a monitoring plan were described earlier in this report.

V.B.5.f. Adaptive management

Adaptive management may be applied in response to significant, unforeseen and unintended negative consequences of applying instream flow water management plan actions. Adaptive management actions would attempt to correct these consequences. Key to applying adaptive management are identifying criteria representing a significant impact on the key indicators of monitoring and establishing the link to instream flow management actions. An adaptive management plan should be developed that identifies the criteria that represent a significant impact and addresses other potential sources of the negative consequences in order to rule them out.

V.C. Priorities and resource needs

The Instream Flow legislation envisioned that NHDES would set protected instream flow criteria on all Designated Rivers. The number and length of the remaining Designated Rivers represent a substantial undertaking ahead. The Rivers Act requires protected instream flow criteria for all Designated Rivers. This Section identifies possible means of selecting priorities and the resources needed to meet those priorities.

V.C.1. PRIORITIES

As of September 2015, New Hampshire has designated 18 rivers or watersheds for special protection comprising 1008 river miles (Table 2).¹²³ Some of these rivers include tributaries that are also designated, including the Lamprey, which added five tributaries and additional main stem segments in 2011. There are also two tidal segments for which the Program does not expect to define protected flows or water management. As a result, there are now 31 individual Designated River segments. The Pilot Program has so far studied 13 miles of the Lamprey¹²⁴ River segment and the Souhegan's 34 Designated River miles. There are over 950 Designated River miles that still require instream flow protection, and more rivers may be added to the Program in the future.

The Instream Flow Program first prioritized the Designated Rivers and estimated costs in 2001 in advance of the Pilot Program. Cost estimates were rudimentary, but recognized that cost drivers would include the length of the river, the number of dams and water users requiring management plans, and the need for public meetings and reports. Two years later these costs were then retained after different

¹²³ <http://des.nh.gov/organization/commissioner/pip/factsheets/rl/documents/rl-2.pdf>. A map of the Designated Rivers can be found at [\\Des\data\WD-Watershed\Rivers_Lakes\RMPP\DESIGNATED_RIVERS\Designated River Map \(Statewide\)\Designated Rivers Poster FINAL 20120308.pdf](\\Des\data\WD-Watershed\Rivers_Lakes\RMPP\DESIGNATED_RIVERS\Designated River Map (Statewide)\Designated Rivers Poster FINAL 20120308.pdf).

¹²⁴ The 13-mile Lamprey segment designated in 1990 only—other river segments of the Lamprey watershed were designated in 2011.

Table 2 - List of Designated Rivers and their segment lengths

Designated River Name	Designated River Length (miles)
Ammonoosuc River	56
Ashuelot River	66
Cochecho River	35
Cold River	23
Connecticut River	272
Contoocook	74
Contoocook (North Branch Contoocook) River	19
Exeter River	41
Squamscott River (Tidal)	6.6
Isinglass River	17
Lamprey River (Tidal)	1.9
Lamprey River (New Lower)	0.8
Lamprey River (Original Lower)	13
Lamprey River (Upper)	35
Lamprey River (North Branch River)	8.2
Lamprey River (Pawtuckaway River)	3.6
Lamprey River (North River)	15
Lamprey River (Little River)	7.8
Lamprey River (Piscassic River)	16
Mascoma River	25
Merrimack River (lower)	16
Merrimack River (upper)	29
Oyster River	14
Pemigewasset River	54
Piscataquog River (North Branch)	21
Piscataquog River (Middle Branch)	11
Piscataquog River (South Branch)	21
Piscataquog River (main stem)	10
Saco River	43
Souhegan River	34
Swift River	26
Total miles	1008

(Completed Designated Rivers are in bold.)

instream flow assessment methods were written into the rules for the Pilot Program. The rivers with the highest water use relative to stream flow were identified as priorities. These rivers were then assessed for the number of water user types, number of dams, presences of stream flow gages, whether there was an active advisory committee, and cost. The Souhegan and Lamprey were selected for the Pilot Program because they had enough features to test the variety of river conditions and were moderately

priced. Other Designated Rivers considered for the pilot were the Ashuelot and Exeter Rivers, and parts of the Piscataquog, Saco and Contoocook Rivers.¹²⁵

The longer the state waits to develop protected instream flows, the more complex water management plans will become. More users will have withdrawals that need to be addressed and higher levels of water use needs must be incorporated into management actions. A universal application of instream flow management on the Designated Rivers would create a level playing field for all water users. Water users in some watersheds may be subject to water management plans, when their competitors in neighboring watersheds are not.

Unfortunately, instream flow protections cannot be applied to all of the Designated Rivers immediately with current levels of staffing and funding. Therefore, NHDES recommends that priorities be identified to determine the rivers on which the Instream Flow Program should be applied sooner. The goal of prioritization today is different from the prioritization applied to the Pilot Program, with less emphasis on selecting rivers based on their potential to inform the Program and moving to other criteria.

Priority relative to water use may be given under two categories: (1) A proactive response, intended to maintain the hydrological regimes of less developed rivers to offer some level of protection of natural river flows and ecosystem characteristics; and (2) A reactive response, intended to restore certain characteristics of the pre-regulation flow regime and ecosystem in developed rivers with modified/regulated flow regimes. Both of these circumstances can be addressed using the environmental flow assessment methods currently available. Focusing on growing water demand would concentrate attention on southeastern Designated Rivers, while focusing on protecting the least impacted watersheds would prioritize the northern and western rivers.

Other methods of prioritizing are discussed below. These include the location of the Designated River within its watershed, data availability, threats to instream flow, and others. Historically, NHDES worked with the Committee to Study the Impact of Water Withdrawals on Instream Flows (SB330). This committee will expire on December 15, 2015 after submitting their final report. There may be another legislative body that could be used as the venue for discussing instream flow priorities.

To begin to identify priorities, NHDES compiled the physical and sociological characteristics of the Designated Rivers and the current availability of data pertinent to conducting instream flow criteria for all the Designated Rivers. Three examples of potential high priority rivers are examined.

V.C.1.a. Prioritization by watershed position

Designated Rivers sometimes have other Designated Rivers as tributaries. NHDES suggests that the first prioritization criterion ought to be Designated Rivers upstream of other Designated Rivers. Water users would be subject to the need to manage both rivers.

Applying water management plans first to Designated Rivers at the top of the watershed would reduce water management plan revisions. Starting at the top of a watershed and working down will result in fewer readjustments. This would have the effect of postponing the larger Designated Rivers until their tributaries are completed.

¹²⁵ The lower Merrimack was also considered because of apparent high water use, but this was due to reporting of a large, withdrawal. The report did not then indicate that the water was returned.

For administrative purposes, a water user should have only one water management plan. A water management plan that meets the protected instream flow criteria for the smaller, tributary river will be supportive of the larger, downstream system to which it belongs. Also, because a water use has a greater relative effect on the smaller river in the vicinity of the use, a management plan developed for the larger river system may need to be revised to address the water user's more direct impacts on the local river system.¹²⁶ Watershed management plans should be developed first for Designated Rivers nested within a larger Designated River system.

Table 3 lists the rivers that are uppermost within a watershed and identified as "T" for tributary. These watersheds should be addressed before the rivers identified as "R" for receiving waters. The Souhegan and Lamprey Rivers were completed during the pilot phase, however, a newly designated Lamprey segment is below the original Lamprey Designated River that has existing flow criteria and a water management plan. This segment may be considered complete since the flow criteria may be extended downstream for this short distance. New water users in this segment of the watershed would need conservation and water use plans, and dams would need dam management plans.

V.C.1.b. Prioritization by water use and watershed development

Developing management activities that will maintain protected instream flow criteria becomes more difficult as the level of water use in a river intensifies. Advanced planning to manage water needs is easier than reversing problems. Water management plans in growing watersheds will be more easily developed now than in the future. Watersheds with increasing water use should be priorities for instream flow water management plans.

Population change was chosen as a surrogate for increasing water use within the Designated River watersheds, assuming that water use will increase in a watershed in which population is growing. Census data were tallied for blocks that intersect a Designated River's watershed area, though this method slightly overestimates the population. Use of percent change removes most of the impact of this overestimate, however. The Designated Rivers, ranked by percent population change, are listed in Table 4 below.

The largest increases in population occurred in coastal watersheds, while the northern and western rivers generally increased the least. The Oyster, Isinglass and Lamprey Rivers showed the greatest percent increase in population followed closely by the Saco, Pemigewasset, Exeter/Squamscott and Cocheco. Population in the Merrimack watershed (upper and lower) increase by over 6%, but the increase in the Pemigewasset was probably responsible for a large proportion of this. This table could be used to identify priorities for developing protected instream flow criteria and water management plans.

¹²⁶ This may be the case with water users and dams on the upper part of the Lamprey watershed. The existing Lamprey water management plan concerns itself only with impacts affecting the 13-mile segment in Lee and Durham. Impacts to flow in the upper parts of the watershed may require different management actions.

Table 3 - Watershed position of Designated Rivers

Designated River Name	Designated River Length (miles)	Watershed position
Ammonoosuc River	56.0	T
Ashuelot River	65.5	T
Cold River	22.7	T
Contoocook River*	74.1	T
Contoocook River - North Branch	18.9	T
Exeter River	40.7	T
Isinglass River	16.9	T
Lamprey River (North Branch River)	8.2	T
Lamprey River (Pawtuckaway River)	3.6	T
Lamprey River (North River)	15.1	T
Lamprey River (Little River)	7.8	T
Lamprey River (Piscassic River)	15.5	T
Mascoma River	25.3	T
Oyster River	14.0	T
Pemigewasset River	53.5	T
Piscataquog River (North Branch)	21.5	T
Piscataquog River (Middle Branch)	10.9	T
Cochecho River	35.3	R
Connecticut River	272	R
Lamprey River (Upper)	34.9	R
Merrimack River (Lower)	16.2	R
Merrimack River (Upper)	29.3	R
Piscataquog River (South Branch)	20.8	R
Piscataquog River (main stem)	10.3	R
Saco River	43.3	R
Swift River	26.2	R
Lamprey River (New Lower)	0.76	Complete
Lamprey River (Lower)	12.7	Complete
Souhegan River	34.1	Complete
Squamscott River (Tidal)	6.6	--
Lamprey River (Tidal)	1.9	--

T=tributary; R=receiving; --no current methods devised;

* Contoocook and North Branch may be conducted together.

Table 4 - Change in population in Designated River watersheds

River Name	2000 NH Census Population	2010 NH Census Population	Change in Population	Percent Change
Oyster River	19,905	23,280	3,375	17.0%
Isinglass River	11,167	12,976	1,809	16.2%
Lamprey River	42,332	48,679	6,347	15.0%
Saco River	14,551	16,577	2,026	13.9%
Pemigewasset River PEM	40,820	45,595	4,775	11.7%
Exeter/Squamscott River	48,627	54,198	5,571	11.5%
Cocheco River	57,999	63,828	5,829	10.1%
Contoocook/North Branch River	66,349	72,114	5,765	8.7%
Souhegan River	46,716	50,192	3,476	7.4%
Piscataquog River	46,840	50,234	3,394	7.2%
Merrimack River (upper)	225,490	241,318	15,828	7.0%
Merrimack River (lower)	594,353	630,989	36,636	6.2%
Ammonoosuc River	15,554	16,491	937	6.0%
Connecticut River	182,410	191,146	8,736	4.8%
Cold River	5,363	5,604	241	4.5%
Ashuelot River	47,962	49,786	1,824	3.8%
Mascoma River	20,369	20,817	448	2.2%
Swift River	1,484	1,454	(30)	-2.0%

i. Watershed development

A 2014 report by the U.S. Department of Agriculture¹²⁷ ranked watersheds in the United States according to the contributions of private forest land to surface drinking water and by threats to surface water from increased housing density. Nationwide, but especially in the east, rural private forest lands are projected to experience a substantial increase in housing density from 2000 to 2030 with a potential to affect water quantity and quality. This report states that New Hampshire leads with 16 of the top eastern states' 50 at-risk-from-development watersheds.¹²⁸ A related report¹²⁹ identifies the top 15 watersheds in terms of total acreage of private forest projected to experience increased housing density. The Merrimack, Piscataqua-Salmon Falls, and Saco watersheds ranked first, third and thirteenth, respectively.¹³⁰

¹²⁷ Mockrin, M.H.; Lilja, R.L.; Weidner, E.; Stein, S.M.; Carr, M.A. 2014. *Private forests, housing growth, and America's water supply: A report from the Forests on the Edge and Forests to Faucets Projects*. Gen. Tech. Rep. RMRS-GTR-327. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 29 p.

<http://www.fs.fed.us/openspace/fote/private-forests.html>

¹²⁸ Table 2, p. 13; http://www.fs.fed.us/rm/pubs/rmrs_gtr327.pdf

¹²⁹ Stein, Susan M.; McRoberts, Ronald E.; Mahal, Lisa G.; Carr, Mary A.; Alig, Ralph J.; Comas, Sara J.; Theobald, David M.; Cundiff, Amanda. 2009. *Private forests, public benefits: increased housing density and other pressures on private forest contributions*. Gen. Tech. Rep. PNW-GTR-795. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 74 p.; <http://www.fs.fed.us/openspace/fote/benefits.html>

¹³⁰ Figure 5, p. 14 - http://www.fs.fed.us/openspace/fote/benefits_files/pnw-gtr795_pt2.pdf

ii. Water use assessments

Registered water users are required to submit reports of their monthly water use totals. These data can be compiled to identify Designated Rivers with higher levels of water use. A General Standard was defined in the Instream Flow Pilot Rules that accounted for the differences in watershed size and the variability of monthly stream flows. Using this tool, NHDES identified the months and locations where water use was high relative to the other Designated Rivers. This is another possible method for identifying the Designated Rivers with the highest level of water use.

V.C.1.c. Prioritization by data availability

The availability of stream flow data may play a significant role in prioritizing the application of instream flow protections on additional Designated Rivers. All of the Designated Rivers in New Hampshire were evaluated for the presence of sufficient stream flow data to begin developing protected instream flow criteria.

In order to develop instream flow criteria, the natural flow regime of the river must be determined or estimated. This is most readily done from analysis using reference quality,¹³¹ daily stream flow measurements that span a recent timeframe and are representative of flow conditions along the length of the river. Data records with the most desirable qualities are active (or recently active) USGS continuous record gages with stream flow data spanning a minimum of 30 years. If data of this type and quality are not available, the data may be derived by other processes.

Stream flow data in New Hampshire are collected at gage stations by USGS and by NHDES. These data are collected for various reasons and, as such, are of various quality and durations. USGS collects continuous record or partial record stream flow data with differing quality objectives. Continuous record data are data that have been collected and quality checked using consistent national standards. In contrast, partial record data are collected to assess only certain flow conditions and are not quality controlled outside of those conditions.¹³² NHDES also collects stream flow data for dam management but does not maintain quality controls, nor does it quality check the data. Data from active sources are available online in near real-time either permanently or temporarily for a period of days. Some gages stopped measuring flow years ago, but their long records remain available. Some gages measure stream flows that are strongly affected by dam releases and so these data do not reflect un-impacted stream flows, or reference, conditions. Reference quality stream flow data are used for instream flow analysis. Other gages measure stream flow where water use diversions occur and some measure stream flow unaffected by diversions. Measuring the effects of diversions is important during water management plan implementation. Data availability, quality, duration, representativeness will all affect the suitability of data for assessing instream flow criteria.

Continuous record stream flow data for all the active and inactive USGS stream gages on Designated Rivers were downloaded and analyzed for duration and gaps in the record. Table 5 summarizes this analysis, adding the number of registered water users in the watershed as an additional prioritization factor. This table indicates the presence of data and maximum continuous duration of that data for either management or instream flow assessment. Instream flow assessment requires a recent 30-year, continuous record. Management requires an active gage that can measure the effects of water

¹³¹ Reference quality data in this case means the stream flow data as they would occur without additions or subtractions resulting from water use diversions by withdrawals and dam management.

¹³² <http://water.usgs.gov/nsip/definition9.html>.

Table 5 – Analysis of stream gages on Designated Rivers

River Name	Water Users	Previously Gaged	Active Gage	30 Years of Record	Summary
Merrimack River	259	Y	Y	Y	Sufficient data potentially exists for protected flow development and management.
Connecticut River	122	Y	Y	Y	
Pemigewasset River	48	Y	Y	Y	
Saco River	27	Y	Y	Y	
Souhegan River	22	Y	Y	Y	
Lamprey River	17	Y	Y	Y	
Ashuelot River	16	Y	Y	Y	
Piscataquog River	11	Y	Y	Y	
Oyster River	2	Y	Y	Y	
Cold River	1	Y	Y	Y	
Exeter - Squamscott River	20	Y	Y	N	Sufficient data for management only, needs estimate of protected flows.
Cochecho River	19	Y	Y	N	
Isinglass River	4	Y	Y	N	
Contoocook River*	52	Y	N	Y	Sufficient data potentially exists for protected flow development, needs gage installed for management
Ammonoosuc River*	15	Y	N	Y	
Mascoma River**	11	Y	N	Y	
North Branch River (Contoocook)	3	Y	N	Y	
Swift River	5	Y	N	N	Insufficient data for protected flow development and management, needs estimation of protected flows and gage installation.
Piscassic River	4	N	N	N	
Piscataquog River (North Branch)	4	N	N	N	
Piscataquog River (South Branch)	2	N	N	N	
North River	1	N	N	N	
North Branch River (Lamprey)	1	N	N	N	
Little River	0	N	N	N	
Pawtuckaway River	0	N	N	N	
Piscataquog River (Middle Branch)	0	N	N	N	

Y = Yes, N = No

* Gage exists upstream of most water users

**Gage data collected by DES, not maintained

Note that water users are counted in all levels of nested watersheds (e.g. a user in the Little River is also in the Lamprey River)

withdrawals and management. The ability of the gage data to represent watershed-wide flows, the data's ability to represent reference conditions, and strategies to address situations where these qualities were not met were also explored as not all rivers have data that meet all of these qualifications.

The Ammonoosuc, Contoocook and Mascoma Rivers do not currently have active USGS gages anywhere on their length, but they do have continuous records spanning at least 30 years. The Cochecho, Exeter and Isinglass Rivers do not have a gage with a 30-year record, but do have a currently active gage. Most of the tributary rivers of the Piscataquog, Lamprey and Contoocook do not have stream flow gages, but some may use the main river's gage.

More than one gage may be needed to describe the range of streamflow conditions in a river because a river's flow varies in character as it transitions from a small brook to a large river. The Souhegan has a gage in the upper watershed and one near its mouth that demonstrate this change in character.

A gage can be used to estimate flow upstream and downstream of its location. Several hydrologists have recommended that a gage be used to represent only the watershed area within 0.5 and 1.5 times the gage's watershed area.¹³³ Using this coverage rule, some of the Designated Rivers have inadequate stream flow gaging. The Ammonoosuc River is designated for 56 miles and has a watershed area of 403 square miles. The river's one active gage measures the watershed at 86.3 square miles. Applying the coverage rule, the gage is effective within the watershed area of 44 and 131 square miles, such that only 22% of the watershed is represented by this gage. In addition, stream flow gages need to be appropriately placed if they are to measure the specific effects of water use diversions. These gages need to be located downstream of the diversion to measure the impact of a diversion. Gages may not be needed to measure the entire upstream watershed area if there are no water uses affecting stream flow.

Where stream flow gages are unavailable, the record is too short, or there are gaps, various methods can be applied to extend or interpolate from available data. These methods convert flow records from selected gages to estimate stream flows in the river of interest. Older data may be used where historical data on a river is available from gages that are no longer active or that have now been downgraded to partial record data. This older data could be used where a gage has a gap effecting the recent period of collection. Former USGS gages on the Mascoma River are now operated by NHDES to collect data with no quality assurance. Thus, where stream flow records are not ideal, a number of methods can be applied to generate daily stream flow estimates for assessing instream flow criteria. The limiting factor for using these records is the acceptability by experts and the public of the methods used in that process.

Stream flow records that have been affected by diversions need to be corrected to represent reference conditions. The stream flow record must be evaluated in context of dam management, hydropower generation, and other water diversions and corrections made if sufficient records allow. Reference flow conditions can be approximated by adding or subtracting known or estimated diversion flows.¹³⁴

The availability of gage data is a useful starting point for directing further in-depth analysis of individual river-specific conditions. This prioritization is subject to reorganization as more factors are considered including the presence of reference conditions and the location of water users relative to gage sites. Further analysis would determine where additional gages would be most useful considering these factors.

V.C.1.d. Prioritization options

Priority may be given to Designated Rivers where strong interest is demonstrated for developing protected flow criteria and water management plans. NHDES will evaluate various aspects of instream flow protection on the Designated Rivers. One of the criteria for higher priority will be rivers where there is strong interest in applying instream flow protection. Examples of possible high priority rivers

As part of this evaluation, the Program took a preliminary look at the Designated Rivers through the lens of the criteria described above in order to develop some examples of how they might be applied to determine the priority rivers for the application of the Instream Flow Program. Three example rivers are described below. Two of the rivers are larger in watershed area than the two Pilot rivers and are

¹³³ Ries, K.G., III, and Friesz, P.J., 2000, *Methods for estimating low-flow statistics for Massachusetts streams*: U.S. Geological Survey Water Resources Investigations Report 00-4135, 81 p. <http://pubs.usgs.gov/wri/wri004135/>

¹³⁴ See discussion on estimating daily stream flow records in the section V.B.2.b Stream flow data" above

located in the slower growing western or northern parts of the state. One river is smaller and located in the faster-growing southeast. These are not necessarily recommended as the next rivers to receive instream flow assessments, rather they are described here for illustrative purposes.

i. Ashuelot

The Ashuelot River, at 422 square miles, has a larger watershed than either the Souhegan or Lamprey. It is located in the Connecticut drainage basin so it will be home to a different fish community. There are four stream flow gages, however, two have multi-year gaps in the recent record. The designated segment ranges from third to sixth in stream order. This river was a priority river in 2001 because its level of water use which can be seasonally high in parts of the watershed, so it represents a reactive development of protected instream flow criteria. This river currently has no tributaries that are also Designated Rivers. The Ashuelot may be considered of higher priority because of its high water use, the availability of a high quality, long-term, stream flow record with other active stream flow gages in the watershed, and its location in a western region of the state.

ii. Pemigewasset

With its 1023 square mile watershed, the Pemigewasset River is many times larger than the pilot rivers. It is located in the upper Merrimack River drainage basin. The designated segment starts as a small, high altitude stream and continues to a large river, ranging from first to sixth order. There are three stream gages with long records on this river, however, two have multi-year gaps in the recent record. This river has little water use relative to its flow, so it represents a proactive development of protected instream flow criteria. This river currently has no tributaries that are also Designated Rivers. The Pemigewasset may be considered of higher priority because of its relatively low water use, the availability of a high quality, long-term, stream flow record with other active stream flow gages in the watershed, and its location in a central to more northern region of the state.

iii. Oyster

The Oyster River has a small watershed of 31 square miles. It is a low-elevation stream located in the fast-growing, coastal region. There is one stream flow gage with a long, uninterrupted period of measurement. The designated segment ranges from first to fourth order. Water use on this river was high, but declined significantly after 2008 when it was no longer used as the primary supply for the UNH/Durham water system. This river may represent a reactive development of protected instream flow criteria. This river has no tributaries that are also Designated Rivers. It may be considered of higher priority because of its location in a high growth area, a potentially high water use, and the availability of a high quality, long-term, stream flow record.

NHDES recommends that the legislature discuss the approaches for prioritization of rivers for instream flow protection. Once an appropriate approach has been determined, each of the Designated Rivers should be reviewed to define their priority for protected instream flow management. Given the expense both in time and funding for instream flow analysis and management, it is important that the prioritization process clearly articulate the highest needs for the Program.

V.C.2. RESOURCES AND FUNDING NEEDS

The Instream Flow Program does not currently have a dedicated funding source to conduct this plan. Without additional funding, little can be done to complete the legislative requirement to determine and enforce protected flows, or to fully maintain the existing Program. NHDES is presently utilizing federal funds meant for the Water Quality Program. These funds are subject to the priorities of the federal government.

Costs for developing instream flow protection on the remaining Designated Rivers depend on a number of factors, not the least of which is the condition of the river's flow alteration and whether flow alteration is a result of land use changes, dam management, or water withdrawals. Water management plans become more complex as more management is necessary. The physical and ecological variability of each river also determines the number of assessments needed. Other cost factors include the length of the Designated River, the number and impact of water withdrawals, availability of suitable stream flow gage data, and the number, size and location of dams. Costs relating to response to public input and public comment should be shifted from consulting firms to NHDES to provide the support for public interaction.

There is also a cost associated with ongoing management. The water management plans will continue to evolve as water use changes or new water users enter the Program. The Program requires ongoing funding after the study and water management plan development for administering flow tracking, monitoring environmental responses, maintaining water management plans, coordinating with water users and dam owners, and applying adaptive management methods. Additional funds are still needed to complete the dam capabilities to manage flows on the Souhegan River and perhaps other facilities in other watersheds as the result of future instream flow evaluations.

In the sections below, NHDES provides estimates of costs for supporting the current and future Instream Flow Program.

V.C.2.a. Pilot instream flow studies costs

In September 2003, the New Hampshire General Court provided \$355,000 towards the Instream Flow Pilot Program.¹³⁵ In 2004, NHDES applied that money to the Souhegan pilot. In 2005, \$245,000 from a \$545,000 National Oceanic and Atmospheric Administration grant was applied to consulting costs of the Lamprey pilot to conduct the instream flow studies and to develop the water management plan. The Lamprey consulting costs were later increased to \$307,500 for an additional low flow survey and for testing of alternative pilot methods.¹³⁶ The remaining funding was applied to NHDES's Instream Flow Program costs including staffing, supplies, equipment and travel. Funding for these costs has been paid from general funds from 2008 through 2009 and from federal funds since then.

Instream flow assessments require study of the flow-dependent species on the individual Designated River to describe the relationships between various fish species habitat use and stream flow. With only one Instream Flow Specialist available at NHDES, each Pilot Program was contracted out to three consulting firms.

After the pilots were completed, NHDES asked a member of the participating consulting firms whether the budgets would be sufficient for the same two pilot project today. The consultant thought that this would be the right amount for the methods and procedures that were defined. That amount of funds would not be sufficient if additional method development or if the methods themselves were subject to a lengthy public process.

¹³⁵ Laws of 2003- HB2 - Transfer of Funds. The sum of \$355,000 shall be transferred from department of environmental services PAU 03-04-02-01-01, class 92, source water protection program, to department of environmental services PAU 03-04-02-06-10, class 92, Protected Instream Flow Pilot Program.

¹³⁶ The Lamprey was originally contracted at \$245,000. Three additional tasks were added totaling \$62,500.

V.C.2.b. Instream flow study costs on other Designated Rivers

NHDES has estimated the costs for conducting the instream flow studies and developing water management plans for each Designated River segment in Table 6 below. These preliminary estimates of costs are based on the Lamprey and Souhegan pilots, discussions with one of the original consultants, and the assumptions below:

- Costs are in today's dollars.
- A defined and limited public process for the field work and analytical methods for the protected instream flow study leaving the majority of the public participation for the writing of water management plans.
- Consultants will be hired to conduct the protected instream flow study, and NHDES staff will complete the water management plan.
- Costs include development of a Target Fish Community. Costs would be reduced if a state-wide Target Fish Community for the Designated Rivers were developed separately.
- Costs do not include any retrofit costs (such as are required for the three flood control dams in the Souhegan water management plan), or any other capital or equipment or additional sampling or study costs.
- Cost estimates do not include management and implementation costs beyond the adoption of the water management plan.

The cost estimates were determined by applying costs per mile for the Souhegan and Lamprey instream flow studies. Also considered was a historical rule of thumb rate that protected instream flow assessments cost \$3000 per mile. The rates applied to the various Designated Rivers assumed that there will be a savings for longer Designated Rivers as a result of spreading fixed administrative costs and thus a lower cost per mile. These rates do not consider the variability of habitat conditions. Costs will be lower for a river with more uniform habitat and higher where there is more variable habitat.

This plan was developed recognizing the present lack of resources and funding allocated to the Program. Under current conditions, developing protected instream flow criteria and water management plans on all the Designated Rivers will take decades. The more rapid development of instream flow protection desirable to provide river protections and more equitable treatment of water users in those parts of the state included in river designations would require a significant investment by the state.

In this report, NHDES recommends that an average of \$195,000 per year be applied to developing protected instream flow studies—one study per year. Initially the funding would be applied to the 11 tributary Designated Rivers—those that are at the headwaters as opposed to those rivers downstream of other Designated Rivers. The funding should be increased if a higher rate of completion is desired. Experience with conducting the instream flow studies may provide insights into economies of scale and ways of moving the study process faster.

Table 6 - Cost estimates for instream flow study and protected flow criteria development on New Hampshire's Designated Rivers

Designated River Name	Designated River Length (miles)	Estimated PISF study cost
Ammonoosuc	56	\$226,909
Ashuelot	65.5	\$265,402
Cochecho	35.3	\$143,034
Cold	22.7	\$135,131
Connecticut	272	\$816,000
Contoocook and North Branch	93	\$376,831
Exeter (without tidal Squamscott)	40.7	\$164,914
Isinglass	16.9	\$132,730
Lamprey (upper)	34.9	\$141,413
North Branch Lamprey	8.2	\$ 64,402
Pawtuckaway	3.6	\$ 28,274
North	15.1	\$118,593
Little	7.8	\$ 61,260
Piscassic	15.5	\$121,735
Lamprey (original lower) (Complete)	12.7	\$ 99,744
Lamprey (new lower) (Complete*)	0.76	\$ 5,969
Lamprey (tidal)	1.9	\$ -
Mascoma	25.3	\$102,514
Merrimack (lower)	16.2	\$127,232
Merrimack (upper)	29.3	\$174,420
Oyster	14	\$109,954
Pemigewasset	53.5	\$216,779
Piscataquog/North/Middle/South Branches	63.5	\$257,298
Saco	43.3	\$175,449
Souhegan (Complete)	34.1	\$138,171
Squamscott (tidal portion of Exeter)	6.6	\$ -
Swift	26.2	\$155,966

* Assumes that the protected flows for the original Lamprey Designated River (1990) can be applied to the newly-designated lower segment.

V.C.2.c. Development of a statewide Target Fish Community for Designated Rivers

Protected instream flow assessments are based on fish communities that are expected to exist in the river. These expected populations are derived from assessments of similar rivers that have fish data and very low anthropogenic influences. These rivers are considered reference rivers and are the best currently available, but are not pristine. These rivers form the basis for instream flow protection on the Designated River by describing a fish population. This population is both the goal for management and identifies the species to be modeled during the instream flow assessment.

Completion of the Target Fish Community identifies the water quality goals for the Designated River. This information would also be useful for other programs. A single, statewide Target Fish Community assessment for all of the current Designated Rivers would be most cost effective in searching databases for fish collection data and determining river characteristics and have the uniformity of results derived from applying a consistent method.

NHDES reviewed the results of a similar program in Massachusetts completed in 2009.¹³⁷ The cost of this program was estimated at \$200,000 for 11 mainstem rivers. New Hampshire has 18 Designated Rivers, some of which are smaller than the Massachusetts rivers and so determined \$250,000 as an estimate of the cost.

V.C.2.d. Remaining pilot implementation costs

In the Souhegan watershed, there are three state-owned flood control dams that are well located to manage stream flows. However, these dams do not have outlet structures that can be operated for causing release flows that are part of the management plan. In 2009, NHDES Dam Bureau estimated that \$136,000 would be needed to retrofit one flood control dam to make it operable for managing stream flow. An average inflation rate of 1.60% was applied over 7 years resulting in an estimated 2015 cost of \$151,200. The resulting estimate to retrofit three dam outlets is \$454,000. This estimate is being reevaluated. A capital budget request would be required to fund these retrofits.

NHDES programs, such as Dam Bureau, Water Conservation Program, the Instream Flow Program and the Watershed Management Bureau all have activities to perform to support the Souhegan and Lamprey water management plans. For example, the NHDES Dam Bureau allocates staff to manage relief pulses and to manage lake storage to support the releases. At a minimum, there are costs for staff time, but there are also costs for sampling, travel, and equipment and supplies. For the time being, these costs are being absorbed by those programs. This would not be possible if all the Designated Rivers were to be managed.

V.C.2.e. Costs to install and maintain stream flow gage stations

Stream flow gages provide data for both instream flow assessments and for assessing conditions for management. Yet some Designated Rivers have no continuous USGS stream flow gage stations. NHDES Watershed Management Bureau staff are conducting an assessment of the historical and current stream flow gage network to determine the need for additional stations. USGS provides stream flow gage stations of proven quality where real-time data are available online and the gage accuracy is continually tested and updated. Installation of stream flow gages by USGS is estimated to cost about

¹³⁷ Kashiwagi, Michael, and Richards, Todd, 2009, *Development of target fish-community models for Massachusetts mainstem rivers*: Boston, Commonwealth of Massachusetts Department of Fish and Game, Division of Fisheries and Wildlife Technical Report, 85 p. Available at <http://www.mass.gov/eea/docs/dfg/dfw/fisheries/target-fish-models.pdf>.

\$14,800 and annual maintenance is \$13,790, although this may be less if federal matching funds are available.

NHDES's budget for stream flow gage support is \$187,000 from general funds. New Hampshire loses gages when inflation increases the costs for the USGS stream flow gages. As costs increase from year to year, gages are closed to make up the difference. A five percent annual increase to cover inflation in costs may forestall further gage losses. These losses could be prevented by an allowance to account for rising costs starting at \$9,350.

V.C.2.f. Staffing costs

Expanding the Instream Flow Program to the other Designated Rivers will increase Watershed Management Bureau staffing requirements for both developing new protected instream flow criteria and water management plans and for sustaining water management operations. The Program currently collects, manages and assesses fisheries and biological monitoring data, stream flow and groundwater data, and numerical models that integrate the hydrological and biological data. Expert staff with these capabilities are needed. The Program also requires significant and continued interaction with municipalities, individuals, and interest groups to develop, assess and operate management plans. Trained staff will be needed to operate, update, and maintain the existing water management plans, as well as develop plans and implement monitoring on other rivers. Additional water management plans will be needed as new water users begin operations in the Souhegan and Lamprey watersheds.

The Instream Flow Program is presently staffed by the Instream Flow Specialist (Hydrogeologist III). Annual salary and benefits (effective 1/9/2015) for this existing position at LG 27-Step 8 @ \$70,064 + 51.5% = \$106,147 annually. This position is currently federally funded. The suggested staffing for the Program is to add either a hydrogeologist (Hydrogeologist III) and an aquatic biologist (Environmentalist IV or Biologist III), or both. Annual salary and benefits (effective 1/9/2015) for these positions for LG 27-step 1 @ \$51,772.50 + 51.5% for benefits = \$78,435

VI. Conclusions

In summary, NHDES conducted a Pilot on the Lamprey and Souhegan Designated Rivers to determine whether adequate information and analyses could be developed to support the development of protected instream flows and water management plans for those rivers and to also demonstrate that such a program could be administered effectively and fairly.¹³⁸ The Pilot demonstrated that numerical criteria that protect instream public uses can be defined that support the goals and purposes of the Program's legislation. The Pilot also showed that the components of the management plans can successfully implement the flow criteria. The Pilot's results also confirmed that instream flow management actions can be accommodated by water users, dam owners and abutters, and that the instream flow protections can be put into practice by balancing societal interests with those of the ecosystem. Accordingly, the Pilot Program demonstrates both the feasibility and benefits of developing instream flows for other New Hampshire rivers. Under current law, RSA 483:9-c instream flow protections would be applied on the remaining Designated River segments.

The Instream Flow Pilot Program is an investment in the health and wellbeing of the people of New Hampshire. It is a proactive planning tool that not only addresses current river use but establishes a process for managing the demand for future water uses. Fully implemented, the Program will result in Designated Rivers that have healthy, balanced ecosystems and robust water supplies for drinking water, business and other off-stream uses, which are capable of fully providing for water needs during low-flow conditions.

The Program encourages more sustainable use of water resources. There are significant long-term benefits to investing in sustainable water resources and ecological health. The people of the state benefit from having flows that protect valued stream qualities such as recreational boating, native plants, fish and wildlife, and from having a water management program that supports existing water uses and provides for new water use as well.

The instream flow pilot studies resulted in protected instream flow criteria that can discriminate between low-flow conditions that support fish, wildlife and recreation and those that do not. The result is that some low flows are allowed to occur, and management is applied sparingly. The flow criteria interpret the water quality standards. The water quality standards require flows that protect biological integrity and support fish, wildlife and recreation. The protected instream flow criteria provide the numerical threshold values to achieve these standards.

The methods developed during the Pilot Program should be applied to the development of protected instream flows and water management plans on other Designated Rivers, subject to some suggested process changes that would result in reduced costs and shortened project durations. Costs and project length could be reduced by contracting out only the instream flow studies while NHDES staff concurrently develops the water management plans.

Changes should be made to the advisory committee structure established for the Pilot Program. Technical issues should be reviewed by experts in the instream flow protection field. More time should be allocated

¹³⁸ Laws of 2002, Chapter 278:1. Available at <http://des.nh.gov/organization/divisions/water/wmb/rivers/instream/documents/ch278.pdf>

to public outreach earlier in the process, providing greater opportunity for stakeholders to incorporate local knowledge into the water management plans from the beginning. Interested parties should be asked to focus on the effects of proposed management actions on the public and the environment.

The amount of monitoring of biological conditions is not currently sufficient to fully discern long-term trends. In order to fully determine the effectiveness of the Instream Flow Program and also inform any necessary adaptive management, a long-term monitoring program would need to be defined and applied. The effects of the Instream Flow Program on the two pilot rivers should be assessed over many years in order to determine whether the implementation of management is effective in maintaining and protecting instream public uses, and whether adjustments should be made as a result of changing conditions. Importantly, protected instream flow criteria are based on the concepts of natural flow pattern and variability that are the foundation of instream flow practices. Even without biological monitoring, the maintenance of stream flows based on these concepts will best support the instream public uses the Program was intended to protect.

Pilot water management plans were developed that can effectively implement the protected flow criteria. The water management plans under the Instream Flow Program provide an effective mechanism for ensuring that use of water by all users is balanced with protection of the ecosystem. After two years of assessment, these criteria appear to be appropriate means for protecting stream flow. Application of instream flow to the other Designated Rivers should follow the Pilot Program's procedures. These procedures were tested and provide a clear and effective process that meets the water quality goals.

The Pilot Program clearly demonstrated the need for river-specific instream flow studies, as were conducted on the Lamprey and Souhegan rivers, rather than generalizing protected flows based on watershed size, geographic region, or some other factor. Methods that link biology and hydrology are best suited to identifying critical thresholds for protection. Application of these site-specific assessment methods allows for more flexibility in defining the standard variability in stream flows, thereby leaving more water for withdrawal than the typical standard-setting methods, while still protecting water quality and instream public uses.

Meeting the goals of the Instream Flow Program may be improved by making some changes to the existing law. The science of instream flow has evolved considerably, and the Rivers Act should be updated to reflect today's deeper understanding of instream flow protection. Amendments to clarify the Instream Flow Program's links to and coordination with other NHDES programs are also suggested.

A proposed plan for applying instream flow protections to the other Designated Rivers has been provided in this report. Resources in the form of staff and funding would be needed to carry out this plan. Instream flow assessments require stream flow and biological data. The legislature may wish to determine Designated River priorities for instream flow protection. Changes in legislation are proposed in order to update the instream flow protection practices and streamline the process in a manner consistent with this report's recommendations.