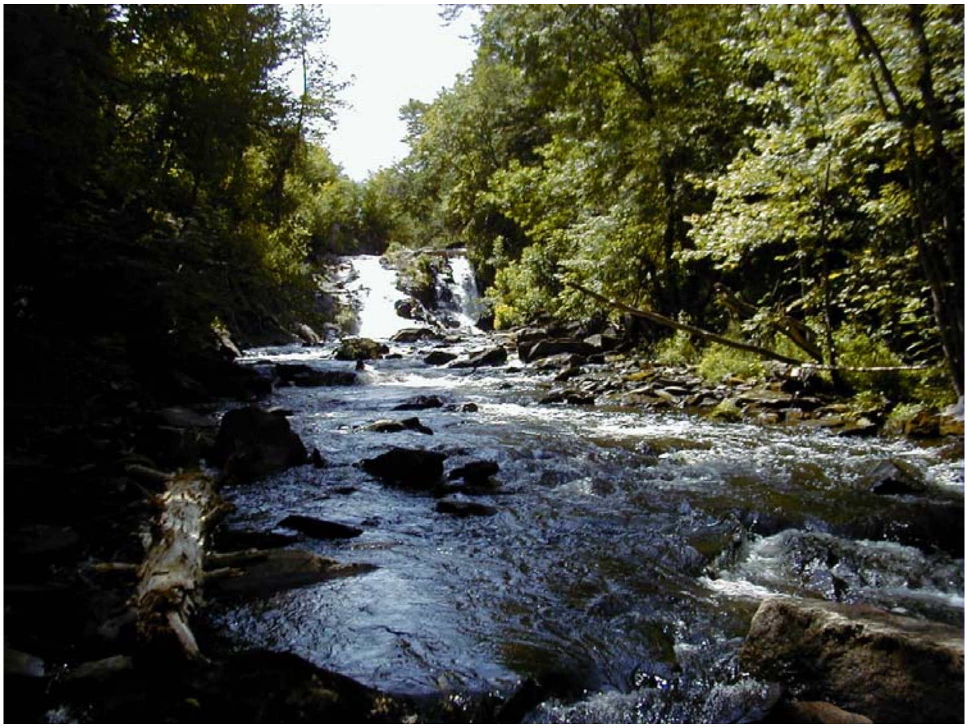
AGENCY OF NATURAL RESOURCES REPORT ON FISH STUDY METHODOLOGY



A report to the House Committee on Fish, Wildlife and Water Resources and the Senate Committee on Natural Resources and Energy of the Vermont General Assembly, prepared by the Vermont Agency of Natural Resources

March, 2009

Executive Summary

Section 38 of S.209, enacted during the 2008 session, directed the Agency of Natural Resources to report to the legislature concerning the cost of “producing a fish study methodology” that is a more economical alternative than site-specific, habitat-flow studies such as the Instream Flow Incremental Methodology (IFIM).[1] The impetus was to address the concerns of small hydro proponents over the cost of IFIM studies.

Fish need water, and the amount of flow in the stream is key to their survival. Hydropower projects also use water; as a result the two uses often compete for a limited resource. The purpose of these methodologies is to determine how much water must remain in the stream (instream flow) in order to conserve the fish and other aquatic organisms.

This report includes cost estimates for two possible methodologies. The costs presented are approximate and influenced by the study design details. Costs also do not include ANR staff time, which would be required for both technical aspects and contract administration. That work would come at the expense of other projects.

a) One seeks to develop a scientifically sound but relatively low cost site-specific instream flow needs assessment methodology. It involves a study to assess a methodology developed in France (called **Estimhab**) to see if it can be used here. The Estimhab study only addresses the summer base flow issue for small watersheds. As such, it attempts to address the core flow issue associated with recent small hydro proposals. It is possible that the assessment will show that the subject methodology is not appropriate for Vermont. While Estimhab itself is an economical method, the initial cost of the study to determine if it can be applied in Vermont could range from $80,000 to $460,000, depending on the study’s scope.

b) The second approach (called the **Hydroecological Integrity Assessment Process** or **HIP**) would produce a holistic decision support system (data and software) that Vermont could use to bring its instream flow management more in line with the emerging science. However, this approach should only be applied initially as guidance, so that everyone can better understand the method and its implications. It would not end the policy debate over instream flow management, nor initially provide new flow standards for small hydro. The total cost to develop the system is about $45,000 to $50,000 depending on what optional tasks are included.

Either of the two methods described above could lead to determinations of instream flow needs at proposed small hydro projects at a lower cost than IFIM habitat-flow studies. However, neither is likely to resolve the current debate over how much water should be reserved in the stream to assure compliance with the federal Clean Water Act and Vermont’s Water Quality Standards. A specific course of action should consider stakeholder input so as to determine whether either method is likely to achieve shared objectives.

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[1] The Instream Flow Incremental Methodology or “IFIM” was developed by the U.S. Geological Survey. This is the methodology mentioned in Section 38 of S.209. As commonly used in Vermont, it refers to an aquatic habitat modeling study methodology more correctly called PHABSIM – Physical Habitat Simulation System.

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Introduction

The Vermont State Legislature passed S.209 during the 2008 session, and it was signed into law by the Governor. Section 38 of this law directed the Agency of Natural Resources (ANR) as follows:

> *Sec. 38. AGENCY OF NATURAL RESOURCES REPORT ON FISH STUDY METHODOLOGY*
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> *On or before January 15, 2009, the agency of natural resources shall report to the house committee on fish, wildlife and water resources and the senate committee on natural resources and energy with an estimate of the cost of producing a fish study methodology for the state of Vermont, other than the U.S. Geological Survey's instream flow incremental methodology protocols, provided that such a methodology is feasible and adequately addresses flow needs and the protection of aquatic habitat while also providing applicants for agency permits and certification with a reliable and agency accepted method for conducting fish studies.*

Why was Section 38 included in the bill? Those involved with this topic would probably all agree that the primary intent of Section 38 is to develop an economical, expeditious, and scientifically sound method for determining instream flow needs in small hydro project bypasses. This issue is explained below in more detail, followed by suggested approaches.

Organisms that live in rivers need not only clean water, but the right quantity and natural variation in river flow as well. Indeed, for the fish and other organisms that live in flowing waters such as streams, flow is a dominant influence. Consequently the amount of flow that remains in the stream is key to conserving its ecological health. A detailed discussion of this topic is beyond the scope of this report.[2]

Hydropower projects run on water, and the water that is sent to the powerhouse is not available to the section of stream between the point of removal and the point at which the powerhouse flow rejoins the stream. This section is called the "bypass" because it is bypassed by the water used for generation. To protect fish, other aquatic life and other stream values, the hydro project cannot remove a quantity of water that will cause the amount of flow in the bypass to drop below conservation flows. Water reserved for the stream bypass cannot be used for generation. This bypass flow requirement is an important issue both for hydro projects and for stream health.

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[2] To learn more about this subject, the reader is encouraged to start by reading *Why Rivers Need Water*, which was originally included as an appendix in the ANR report to the Vermont General Assembly, *The Development of Small Hydroelectric Projects in Vermont*, January 9, 2008. The full report can be found at http://www.anr.state.vt.us/dec/fed/damsafety/docs/smallhydroreport.pdf
In addition, Rod Wentworth's annotated slide presentation to the Vermont Water Resources Panel on June 19, 2008 is an easy read and covers "Flow Ecology 101," the ANR Flow Procedure, site-specific studies and hydrologic standards. It can be found at http://www.nrb.state.vt.us/wrp/docs/shipp/Wentworth%20hydro%20talk%206-19-08.pdf

If the project powerhouse is located at the base of a falls or dam, the amount of bypassed habitat is minimal and so are the instream flow needs. When the project layout involves a longer bypass, instream flow needs become a greater concern. Instream flow needs in bypasses is analyzed case by case according to the ***Agency Procedure for Determining Acceptable Minimum Stream Flows*** (a.k.a. ANR Flow Procedure). This Procedure describes how conservation flows are determined. Four alternative approaches are available to water users:

1. Use default hydrologic flow standards.
2. Determine hydrologic flow standards for the subject stream, based on a flow gage on that stream with sufficient data.
3. Conduct flow gaging on the subject stream to determine hydrologic flow standards.
4. Conduct a site-specific study to determine the relationship between aquatic habitat and flow.

There has been a growing interest in exploring the feasibility of projects in small watersheds. To lessen adverse environmental impacts, these projects would utilize existing dams and operate as run-of-river, meaning that stream water arriving at the project is not stored, but is either diverted immediately to the powerhouse or otherwise released downstream. The rivers of interest are typically ungaged, so that the site-specific hydrology is unknown. The economics of these small projects make it difficult to afford comprehensive, site-specific habitat-flow studies.

Default hydrologic standards fill a need faced by small projects – the conservation flow is determined quickly and inexpensively. However, the level of uncertainty is higher where there is no site-specific information, and a more conservative (resource protective) flow prescription is applied where there is less information. Some hydro proponents believe that the default hydrologic flow standards are too conservative.

Choosing a Method

<u>Background</u>

A number of instream flow assessment methods have been used across the U.S. and in other countries. A comprehensive review can be found in several publications.[3] However, it is exceedingly difficult to find a method that is abbreviated, inexpensive and scientifically rigorous. There is an inherent trade-off between a method's cost and its accuracy and precision. In the past, various Vermont hydro projects have used the site-specific Physical Habitat Simulation System (PHABSIM) component of the IFIM (Instream Flow Incremental Methodology) to

[3] Annear, T., I. Chisholm, H. Beecher, A. Locke, and 12 other authors. 2004. Instream Flows for Riverine Resource Stewardship, revised edition. Instream Flow Council, Cheyenne, WY.

EA Engineering Science and Technology. 1986. Instream flow methodologies. Electric Power Research Institute, Palo Alto, California, USA.

Jowett, I. G. 1997. Instream flow methods: a comparison of approaches. Regulated Rivers: Research and Management 13: 115-127.

address bypass flows. PHABSIM and similar models developed in Europe and other countries are the most widely used means for determining instream flow needs for aquatic life. However, these studies are difficult for small projects to afford. It would be highly desirable to develop an inexpensive but scientifically sound method to determine instream flow needs in small streams. The hope is of course that such a method would produce results that all could accept as scientifically valid.

Before narrowing to address this specific charge of Section 38, it is useful to step back and look at instream flow management in a broader context. What are instream flow practitioners using today and what are the emerging trends? Several different scientific approaches to determining instream flow needs are currently in use.

Standard-setting approaches are still widely used. They are short-cut methods that use a pre-determined set of formulas or numeric rules to define a threshold flow regime below which water should not be withdrawn. They are typically designed to protect aquatic resources at some acceptable level, but are approximate in nature and less scientifically accepted since they are based on limited or no site-specific information. Standard-setting approaches do however fill a need for determining instream flow needs quickly and inexpensively. These methods provide results that are generally regarded as "coarse filter" and do not have the same level of scientific rigor or detailed output as more intensive methods. Since they are less accurate or precise, typically a margin of safety is built in. The ANR Flow Procedure includes hydrologic flow standards.

Detailed site-specific studies are also common. Given enough resources, the level of study and detail of models can be increased so as to accurately replicate reality and predict biological responses. This approach is research and field intensive, so it can be very costly. Since resources are never unlimited, these studies often face financial constraints.

There is considerable interest in an instream flow needs determination that lies somewhere between "big studies" and standard-setting. It is understood that comprehensive site-specific studies cannot be done everywhere and another approach is needed. Some attempts have been made to look for generalizations that can be made from the numerous past studies, so as to develop a methodology with reduced data needs. The IHA method (Indicators of Hydrologic Alteration) uses flow gage data to analyze ecologically relevant metrics and assess the level of impact of a project relative to the natural flow regime.

<u>An Emerging Framework</u>

Many have recognized the need to establish an instream flow protection framework that does not require site-specific studies of every section of every river and stream. A direction appears to be emerging that uses available site-specific data to calibrate a methodology that can then be applied across a greater geographic area, without the need for data from all locations. Emerging approaches generally share these elements:

1. Development of models that utilize steam flow gage data to synthesize the hydrology in ungaged watersheds.

2. Classification of streams into types based on their physical form, hydrology and biology, recognizing the diversity of systems and the need to group them and not treat all the same.

3. Site-specific work to establish levels of biological health in aquatic life and how this can be correlated to flow regime and physical variables.

4. Combining the above to apply across a greater geographic area since measurements cannot be done everywhere. In essence, this is the use of site-specific data to calibrate and validate for broader application and prediction.

5. Establish categories for acceptable levels of river health. This brings in the social, political, and legal considerations.

The scientific basis for this type of approach was published by an international group of river scientists.[4] The Nature Conservancy subsequently proposed an implementation framework called the ***Ecological Limits of Hydrologic Alteration (ELOHA)***.[5] Some scientists consider this type of approach to be the emerging state-of-the-art in environmental flow management. ***ELOHA*** does not require detailed site-specific hydrologic or biological information for each river, but it does require a good deal of data to "build" the system for a region/state. Data on stream hydrology, geomorphology and biology must be analyzed and built into a software system.

This is a direction to which Vermont could move towards for its instream flow management, although something simpler could suffice for small hydro bypasses. The topic is introduced here to provide context for thinking about a future direction and because one of the methods suggested follows this framework.

The Natural Flow Paradigm

Vermont has very dynamic stream systems. The conditions change considerably from year to year, season to season and within each season (winter severity, thaws, floods, summer droughts, and so on). Our fishes have evolved to survive under such conditions; indeed, they depend on them. Fish habitat is not a steady state condition nor is a steady state desirable. Fish survival and growth is not the same every year; one set of conditions may favor certain species or life stages whereas others will do better the next year.

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[4] Arthington, A.E., S.E. Bunn, L. Poff and R.J. Naiman. 2006. Ecological Applications 16(4): 1311-1318.

[5] Submitted to *Freshwater Biology* for publication. See http://www.nature.org/initiatives/freshwater/resources/art23977.html

The core concept has become known as the *Natural Flow Paradigm*: "the ecological integrity of river ecosystems depends on their natural dynamic character." [6] *Environmental flows* describe the quantity, timing, and quality of water flows required to sustain our flowing water ecosystems and the human livelihoods and well-being that depend on these ecosystems. Instream flow science and management are moving in the direction of addressing environmental flows, although this is still a work in progress.[7]

Today the term *minimum flow* is falling out of use due to recognition that a flat-line flow regime will result in habitat degradation. There is a general agreement among scientists that fish and other aquatic life require a flow regime that mirrors natural flow patterns, including seasonal and year-to-year variability. For example, high flows can be important to channel maintenance and flushing sediment downstream. Salmon are behaviorally influenced to move upstream for spawning by flow increases in the fall. Intermediate flows often provide optimal conditions for fish survival and growth.

Emerging state-of-the-art methods for determining environmental flow standards start from a baseline of the existing natural hydrology. The amount of flow alteration from this baseline that can be permitted while maintaining acceptable levels of river health is then determined. However, implementing environmental flows as flow standards is a complicated subject. It is discussed further later in this report.

<u>What about Small Hydro Bypasses in Vermont</u>

Why might we treat small hydro bypasses differently in terms of environmental flow requirements? Fortunately, in Vermont small hydro projects on small streams do not control streamflows all the time. Additional water passes the dam and enters the bypass whenever the streamflow exceeds the project's capacity. As such, ecologically important flow variability does occur. The time of concern is when streamflows are near or less than project capacity, in which case the project can significantly or completely control bypass flows. The ANR Flow Procedure seeks to address this issue by setting conservation flow limits. A project is not permitted to reduce streamflow below those limits. This can still result in a "flat-line" flow regime at times, although adequate conservation flow limits should still conserve aquatic life in compliance with Vermont's Water Quality Standards.

<u>Be Careful What You Ask For</u>

Back in the early days of computers, a scientist asked the world's most powerful computer, "What is the meaning of life?" The computer sprang to life, with disks spinning and lights flashing until it came up with the unequivocal answer: "42."[8] We face a related difficulty with

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[6] Poff, N.L., J.D. Allan, M.B. Bain, J.R. Karr, K.L. Prestegaard, B.D. Richter, R.E. Sparks, and J.C. Stromberg. 1997. The natural flow regime – a paradigm for conservation and restoration of river ecosystems. BioScience 47: 769–784.

[7] ELOHA case study information can be found at http://conserveonline.org/workspaces/eloha

[8] Anecdote modified from *The Hitchhiker's Guide to the Galaxy*, Douglas Adams, 1979.

instream flow methods – everyone wants an unequivocal answer but most methods don't provide it. Life or flow isn't that simple.

Standard-setting methods do generally provide clear-cut numbers – numbers that some water users don't like. Virtually all other approaches do not yield a single numeric answer. They show the amount of habitat as a function of flow, typically graphically as a curve. On one hand these results can be viewed as exactly the correct information needed for decision making and thoughtful negotiation. However, they can also lead to intractable disputes over what flow requirements should follow from them. Indeed, this was in part behind the development of the water withdrawals for snowmaking rules, which moved away from site-specific incremental studies (sometimes called IFIM) in favor of singular use of hydrologic standards.

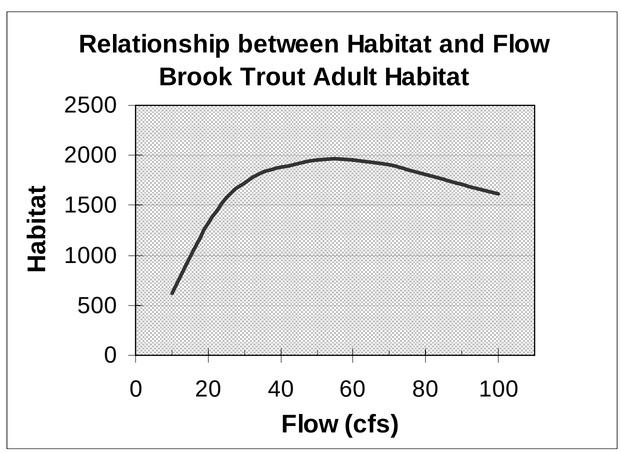
Choosing a methodology that will fit the situation at hand has every bit as much to do with the stakeholders and legal/institutional/political considerations as it does with science.

Recommendations

Section 38 of S.209 asked about possible alternative instream flow needs assessment methodologies and their costs. Two options are presented here; each has both strengths and weaknesses. Prior to implementation, study proposals would need to be fine-tuned based on scientific peer review, stakeholder input and other considerations such as budget. The costs presented do not include ANR staff time, which would be required for both technical aspects and contract administration. This work would come at the expense of other projects.

Estimhab

Estimhab (short for "Estimate habitat") is a site-specific incremental method developed in France.[9] It produces output like that of the PHABSIM component of IFIM – curves showing the relationship between habitat quantity/quality and flow for selected aquatic species and life stages. However, it is relatively low in cost since it requires much less input data. Both Estimhab and PHABSIM follow the same basic construct: physical measurements are used to determine hydraulic habitat conditions (such as water depth and



[9] Lamouroux N. (2002) Estimhab: estimating instream habitat quality changes associated with river management. Shareware & User's guide. http://www.lyon.cemagref.fr/bea/dynam/dynamENG/estimhabENG.shtml . Cemagref, Lyon.

Lamouroux, N. and H. Capra. 2002. Simple predictions of instream habitat model outputs for target fish populations. Freshwater Biology, 47(8): 1543-1556.

velocity) at different flows. This information is combined with biological information about the habitat needs of various species and life stages to show how the quality and quantity of habitat changes with flow.

Estimhab requires the following input data:

1) Mean annual flow, from gage data or estimated hydrology.
2) Stream width measurements at about 10-15 transects at two flows, approximately spanning the flow range of interest.
3) About 40-100 depth measurements and substrate size, taken along the transects under both flow conditions.

If the flow at the time of measurement cannot be determined from nearby gage data then it must be measured. Such is usually the case.

The method is based on the assumption that this reduced set of measurements can adequately determine the habitat-flow relationship. Studies comparing Estimhab with more intensive modeling methods such as PHABSIM show that Estimhab produces similar but more variable results.[10] Estimhab appears to trade off accuracy and precision of the results against time and cost efficiency. ANR believes that Estimhab might be a viable method for use with small hydro bypass base flow needs determinations. However, the method should be assessed here in Vermont to determine its suitability. It is not appropriate to adopt this method without first validating its results.

This method has two attributes that small hydro proponents have expressed an interest in: it is a site-specific determination and it is more economical that an IFIM study. There are however a number of disadvantages. First, it is rather costly to do the prerequisite validation of the method to determine if it can be applied in Vermont. It is also possible that this research will suggest that it should not be used here.

Estimhab appears to have been based primarily on larger streams. Most of the recent small hydropower proposals are sited on steep brooks whose channel characteristics and hydraulics are different from valley streams and do not readily lend themselves to studies based on hydraulic modeling. It may be necessary to do measurements in riffle reaches that are not entirely typical of the subject bypass. This should be viewed as making the best of a difficult study situation, and is part of the reason why the method must be validated prior to adoption.

Obtaining the flow measurements at two flow means that scheduling depends on the weather – one has to wait for the target stream flow to occur. Flow measurements require specialized

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[10] Lamouroux and Capra, 2002.

Lamouroux, N. and I.G. Jowett. 2005. Generalized instream habitat models. Can. J. Fish. Aquat. Sci 62: 7-14.

Halleraker, J.H., K. Alfredsen, M. Stickler and C. Kitzler. 2005. Comparison of habitat modeling approaches to find seasonal environmental flow requirements in a Norwegian national salmon water course. Proceedings COST 626 final meeting, Silkeborg, Denmark.

equipment, although consultants working in this arena do have this equipment. Also, this method would address only the summer base flow need. If higher flows are needed seasonally for migration, or spawning and incubation, those needs would have to be addressed in another manner. Estimhab could possibly be used to address spawning and egg incubation flow needs, but that would require expanding the validation study and most likely the application method as well. Lastly but importantly, since Estimhab does not produce a single numeric "answer," negotiation is necessary and disputes are possible.

Appendix 1 includes a study plan for investigating the feasibility of Estimhab for determining summer instream flow needs in small Vermont streams. Briefly, the plan calls for the collection of field data that would enable flow needs to be determined using both PHABSIM (of IFIM) and Estimhab at a number of different streams. The results would then be compared. The following cost estimates are based on consultant input from a review of the study plan. There are two cost drivers: the amount of field work and the reporting. The cost of conducting this study at 10 different streams and taking measurements at five flows, could be as much as $460,000 (high-side estimate). For six streams at five flows, the cost is about $295,000. These estimates assume that nine species/life stages would be included and that data would be collected for both PHABSIM and Estimhab. In some cases, PHABSIM studies are done by measuring just two flows and then using hydraulic modeling. This can be problematic in steep streams. However, if this approach were used, it would cost about $300,000 to assess 10 streams and $200,000 to assess six. Another possibility is to only assess sites where PHABSIM studies have already been done and data are available. Estimhab field work would still be done, but resulting costs would be about $5,000 per location. If analysis and reporting are included, the total cost would be about $8,500 per location. However, small hydro proponents want to focus on smaller watersheds, and only a few PHABSIM studies have been done in Vermont on small watersheds. It may be possible to find small streams in other nearby states where PHABSIM studies have been done. However, such studies in watersheds much less than 50 square miles in size are likely to be rare.

Another alternative is to do the Estimhab investigation through the USGS Fish and Wildlife Cooperative Research Unit at UVM as a graduate project. This would involve a graduate student working on the project with related support, over about a two-year time frame. A ballpark cost is $80,000. Costs would increase if there is a lot of travel.

Researching the efficacy of Estimhab is probably not worth the cost. ANR encourages small hydro project configurations with the powerhouse next to the dam. This design minimizes environmental impacts and usually does not necessitate an instream flow study. The study methodology is relevant for projects with notable bypasses. If the method is ultimately found to be usable in Vermont, it would be cheaper than the scaled down IFIM habitat-flow studies that ANR has accepted at various small hydro projects in the past.[11] A small-scale IFIM study would cost about $25,000 - $35,000 (including field work, analysis and reporting) for a small stream. Estimhab would cost about one third of that. The following table compares Estimhab with the small-scale IFIM study.

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[11] For example: Arnold Falls, Gage, Passumpsic and Pierce Mills projects on the Passumpsic River; Barton project on the Clyde River; Canaan project on the Connecticut River; West Danville project on Joes Brook.

A Comparison of Study Attributes		
	Estimhab	**Small-scale IFIM Habitat-Flow Study**
# Transects	10-15	2-5
# Flows	2	3-5
Data Collected	depth, substrate size	depth, substrate size, velocity
Approx. Cost	$10,000	$30,000

While a small-scale IFIM study involves fewer transects, extra time is required to measure water velocities. Each flow for which data must be obtained adds to a study's cost. IFIM studies sometimes utilize hydraulic modeling in combination with data collection at only two flows. The small-scale IFIM studies referenced above do not use hydraulic modeling because it can be inaccurate in steep, bouldery channels. However, it might be possible to utilize hydraulic modeling with data collection at only two flows, provided that water elevations are obtained at several other flows. The study accuracy would decrease but it would probably still exceed that of Estimhab. This would reduce the small-scale IFIM costs to about $20,000.

Hydroecological Integrity Assessment Process

The *Hydroecological Integrity Assessment Process (HIP)* and related software was developed by the U.S. Geological Survey Fort Collins Science Center (Colorado).[12] This approach includes several of the elements described above as an "emerging framework." As such, this method could be used to address Vermont's instream flow management holistically. It has been used to build an application for the State of New Jersey, and some parts of the methodology were developed for Texas and Missouri. The primary developers of HIP have since retired from USGS and are now consulting and offering their services to construct region-specific applications elsewhere. Since the HIP tool has already been developed, the remaining work to customize it to a specific state is much less.

HIP involves four major steps:

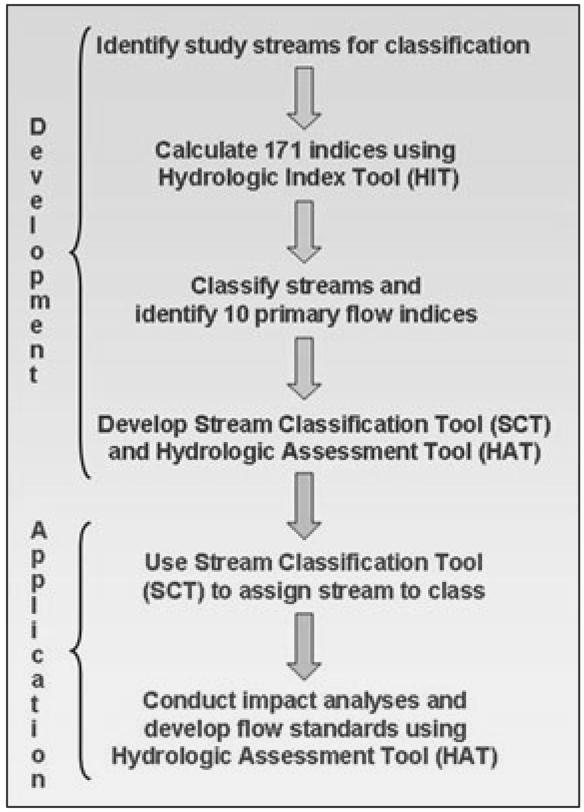
1. Classify streams with adequate gage data into classes based on their hydrology.
2. Identify a set of hydrologic indices to characterize the flow regime for each stream class.
3. Develop a tool that classifies remaining streams into the classes from step #1.
4. Develop an area-specific Hydrologic Assessment Tool (HAT) which establishes baseline hydrology (time period specific) and environmental flow standards

In other words, HIP establishes standards to maintain ecologically relevant hydrologic variability, and it does this based on a sophisticated analysis of hydrologic data. Biological data can be used if available to better define the biological responses to flow and refine the environmental flow standards.

[12] For further information: http://www.fort.usgs.gov/Resources/Research_Briefs/HIP.asp

That sounds good, but what does it mean? What would HIP give us for a small, ungaged stream? First, it is important to note that the application of HIP requires either flow gage data or the development of synthesized hydrology for the subject stream. The method does not synthesize such data; other tools are used for this purpose such as the *StreamStats* applications being developed by USGS.[13]

HIP starts with data from gaged streams. From that data, several categories are defined. Each stream in Vermont would fall into one. For example, two of the four categories from New Jersey are "flashy with low base flow" and "stable with high base flow." For each category, 10 non-redundant, biologically relevant hydrologic indices are identified. For example, the indices for low flow conditions could include the median flow for each month, the base flow and corresponding measures of variation. Standards can then be developed in terms of the allowable deviation from the pre-project indices.



Steps taken to develop and apply the regional Hydroecological Integrity Assessment Process (HIP)[12]

This explanation no doubt falls short of providing a complete understanding of a rather complex method. Certainly Vermont's use of something like HIP would need to begin only as guidance, so that everyone can better understand the method and its implications. As such, it would not immediately provide a new set of regulatory standards. This fact and the complexity of this method may make it unattractive to small hydro developers. However, it does include attributes that small hydro proponents have expressed interest in:

- use of site-specific hydrology,
- predictable results,
- no field studies needed, and
- economical to apply once developed.

After development, HIP could be made available as an online application that could be used by potential developers to determine the instream flow requirements at any given site. While this sounds attractive, there will be many details to work out before HIP could be used in this way. Ultimately, the level of support from water users will depend on how much water they get versus the stream. This is true regardless of the method used.

[13] http://water.usgs.gov/osw/streamstats/

HIP is also forward looking and can be refined based on additional data. The greater value of its application is to determine instream flow needs statewide, not just relative to small hydro bypasses.

A project proposal and budget are attached as Appendix 2. The total cost is about $45,000 to $50,000 depending on what optional tasks are included. This cost does not reflect the time commitment of ANR staff that would be needed to participate in this project.

<u>Estimating Hydrology at Ungaged Streams</u>

The seasonal availability of water in our rivers and streams forms the basis of many decisions concerning instream flow recommendations. Indeed, this hydrology is the basis for the Aquatic Base Flow policy included in the ANR Flow Procedure as well as other methods.[14] Knowledge of water availability is also critically important for hydro developers as it drives project viability and design specifications. Recently there has been more and more use of sophisticated computer driven methods for estimating the hydrology in ungaged streams. It is likely this trend will continue and Vermont will adopt such a method at some point.

As an example, the Massachusetts-Rhode Island Water Science Center of the U.S. Geological Survey has been funded to complete a project entitled *An interactive, GIS-based application to estimate continuous, unimpacted daily streamflow at ungaged locations in the Connecticut River Basin*. The project objective is to develop an easy-to-use, screening-level tool to estimate continuous unimpacted streamflow at ungaged locations within the Connecticut River Basin. The project leverages existing USGS work in the Connecticut River watershed concerning the estimation of daily streamflow at ungaged sites, the development of decision-support tools for water management, and national programs and datasets (such as StreamStats, National Hydrography Dataset). It will also integrate current work being completed in cooperation with the Massachusetts Department of Environmental Protection and the Connecticut Department of Environmental Protection. The total project cost is about $100,000 and is jointly funded by USGS, The Nature Conservancy, and the New England Association of Fish and Wildlife Agencies. It should be completed in spring 2010. This project will cover that portion of Vermont in the Connecticut River watershed, but less than 50 percent of the entire state. As a screening level tool still under development, its utility for determining aquatic base flow standards and related hydrologic indices is uncertain.

The current dissatisfaction of small hydro proponents with the Agency Flow Procedure focuses on the default flow standards that are applied where gage data is lacking, and much less on the flow determinations based on site-specific gage data. While the implementation of a method in Vermont for estimating hydrology in ungaged watersheds could help resolve these differences, it could also be subject to similar criticism. The problem that could come up is that the techniques for estimating hydrology may not be sufficiently accurate or precise, and therefore may require some level of conservatism to be built into their application. Those who believe that the current default flow standards are too conservative may well feel similarly about a new technique since both practice caution in the context of uncertainty.

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[14] For example: the Indicators of Hydrologic Alteration, Hydroecological Integrity Assessment Process, and various hydrologic standards used in other states and provinces.

Conclusions

Certainly it would be a step forward to implement methods for determining instream flow needs that are scientifically more robust or less expensive. However, there are inherent trade-offs between scientific rigor, accuracy and study costs; the challenge is to find a suitable balance. It is important to recognize that the method used is less important to water users than the ultimate flow requirement, so that an improved method should not be expected to eliminate the argument over how much water is enough for instream resource stewardship. No one should assume that development of a new method will automatically result in lower instream flow requirements. It may not. In the end, projects must ultimately meet the management objectives and criteria in Vermont's Water Quality Standards and the requirements of the federal Clean Water Act. A specific course of action should consider stakeholder input so as to determine whether either method is likely to achieve shared objectives.

Appendix 1

Study Proposal for Investigating the Feasibility of an Inexpensive Site-Specific Method for Determining Summer Instream Flow Needs in Small Vermont Streams

Problem statement:

There is a growing interest in exploring the feasibility of small hydro project development in small watersheds. These projects would operate as run-of-river and would be located at existing dams or utilize a damless diversion. The rivers of interest are typically ungaged, so that the site-specific hydrology is unknown. Project size makes it difficult to afford comprehensive site-specific habitat-flow studies. Flows can typically not be regulated for study purposes. While ANR has flow standards that can be used in lieu of site-specific studies, some hydro proponents believe that they are too conservative. It would be highly desirable to develop an inexpensive but scientifically sound site-specific method to determine instream flow needs in small streams.

Goal:

To test and if possible develop a relatively simple, inexpensive and scientifically sound site-specific method for determining summer instream flow needs in small streams, for application to hydropower bypasses. The method will use physical stream measurements to predict instream flow needs for aquatic habitat. This study focuses on the summer base flow and would not address seasonal flow needs associated with spawning, incubation or migration.

Hypothesis: Simple stream physical measurements can provide a reasonable prediction of the habitat-flow relationship in small streams.

Alternate Hypothesis: Simple stream physical measurements do not adequately predict the habitat-flow relationship in small streams.

Approach:

1. Select a set of study streams and reaches. Define stream types/sizes to include in the study (e.g. Rosgen type, drainage area size range).
2. Collect transect data in riffle reaches, including depth, velocity, substrate, channel slope, with vertical control between transects. Do this over a range of flows, such as 4-5 flows from near 7Q10 up to about 1 csm.
3. Use standard PHABSIM methods to analyze the habitat-flow relationship for a number of selected target species and life stages (using existing habitat suitability criteria).
4. Sub-sample the data to test the **Estimhab** method of Lamouroux.[1]

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[1] Lamouroux N. 2002. Estimhab: estimating instream habitat quality changes associated with river management. Shareware & User's guide. http://www.lyon.cemagref.fr/bea/dynam/dynamENG/estimhabENG.shtml . Cemagref, Lyon.

Lamouroux, N. and Capra, H. 2002. Simple predictions of instream habitat model outputs for target fish populations. Freshwater Biology, 47(8): 1543-1556.

5. From the results of Steps 3 and 4, recommend a specific field methodology. Recommend if application of **Estimhab** in Vermont can meet the goal.
6. Recommend how the results of the methodology should be applied as flow standards that will meet the requirements of the VWQS.

Alternatives:

Study cost is affected by the number of streams included in the study. Two possible alternatives are suggested below.

Option 1: Select only small brooks with a watershed area < 15 square miles or so. Select 10 different brooks geographically distributed across the state.
Pro: Less costly.
Con: Applicable only to small brooks.

Option 2: Select several types (3?) of streams with watershed areas < 100 square miles or so. Select 6 streams in each category, geographically distributed across the state. Analyze results separately for each category and for all pooled.
Pro: Applicable to a reasonably broad range of streams.
Con: More costly.

Since **Estimhab** requires the mean annual discharge (MAD) as input data, there are advantages to selecting gaged streams. If gage data are not available, the MAD must be estimated.

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Appendix 2

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Subject: Cooperative Agreement Tasks and Budget Proposal Prepared by Environmental Flow Specialists, Inc. for Vermont Fish and Wildlife

Date: January 23, 2009

<u>BASIC SERVICE TASKS</u>

1. Conduct pre-project planning and identify client needs – (no travel required).
    a. Provide a detailed explanation of EFS's basic and optional service tasks.
    b. Provide an overview of EFS's StreamFlow software features.
    c. Evaluate and consider client's current policy, approach, and methods for evaluating proposed water development projects and establishing environmental flow requirements/standards. Identify client's perceived needs to further advance policy, approach, and methods to develop environmental flow recommendations/standards.
2. Conduct a hydroecological classification of all gaged streams within the State of Vermont using a unique set of hydrologic indices.
    a. Compile available flow data from the USGS National Water Information System (NWIS) for all gaged streams within the State with a period of record => 15 years
    b. For each gage, identify the baseline (unaltered) flow period of record and, if present, altered period of record using historical information and EFS's special indices that are sensitive to a variety of flow alterations.
    c. Conduct a cluster analysis for selected gages to identify distinct hydrologic stream classes within the State, a principle component analysis to identify unique indices for each stream class for 9 flow components that best characterizes each class's hydrological variability, and a discriminate function analysis that identifies indices and coefficients that are used to build a stream classification tool to classify unclassified streams (e.g. synthesized stream flow data).
    d. Provide the stream flow data used in the above analyses, organized by stream gage identification number.
3. Customize EFS's StreamFlow software that is used to: 1) develop stream or stream class specific environmental flow recommendations or standards, 2) evaluate proposed and past water development projects (including land use change) and conduct impact analyses, and 3) guide research for conducing stream class specific flow/biologic or geomorphic response relationships to refine and further develop environmental flow recommendations and standards.
    a. Incorporate State specific stream classes and the 9 flow component indices for each stream class into EFS's StreamFlow software.
    b. Develop and incorporate the State specific stream classification tool into the StreamFlow software.
    c. Modify the software to best meet State specific needs.

4. Software technical assistance (no travel required).
    a. StreamFlow software user's manual (PDF format).
    b. Software support 90 days (email, phone).

Products

1. Computer disk containing an organized folder of gage specific flow data files. A spreadsheet containing the unaltered and altered period of record for each gage.
2. EFS's StreamFlow software customized for the streams within the State of Vermont.
3. A Vermont StreamFlow software training manual (PDF).
4. 90 days of software technical assistance for the Vermont StreamFlow software.

Optional Tasks

A. Directly accessible StreamFlow database (unaltered and altered period of records organized by stream class) incorporated into StreamFlow software.
B. Basic Service Task 1 - Conduct pre-project planning and identification of envisioned implementation needs - described above but conducted at client's on-site location (travel by EFS staff required).
C. Software training conducted at client's on-site location for several individuals (training manuals will be provided for each participant).

Client's Cooperative Agreement Tasks

- Assist EFS staff in collecting historical information concerning known hydrologic alterations, specifically, the nature and date of the alteration, for each selected USGS gage (Basic Service Task 2.a.). Identify specific client needs in regards to current environmental flow policy, standards, approaches that can be incorporated into the StreamFlow software.
- Provide, if available, one or two previous project evaluation reports, developed by the client, where environmental flow recommendations/standards were established.
- Provide a project for the application of EFS's StreamFlow software and work with EFS staff to develop procedures and modifications to meet the client's needs.
- Conduct a comprehensive review of the State specific StreamFlow software and provide written comments addressing the utility of the software.

Budget

BASIC SERVICE TASK	COST	COOP AGREEMENT CREDIT	ACTUAL COST
1-4	$55,500.	$13,875.	$41,625.
OPTIONAL TASKS	**COST**	**COOP AGREEMENT CREDIT**	**ACTUAL COST**
A	$5,000.	$1,250.	$3,750.
B	$4,800.	$1,200.	$3,600.
C	$6,600.	$1,650.	$4,950.