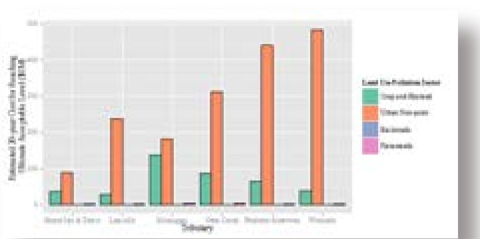
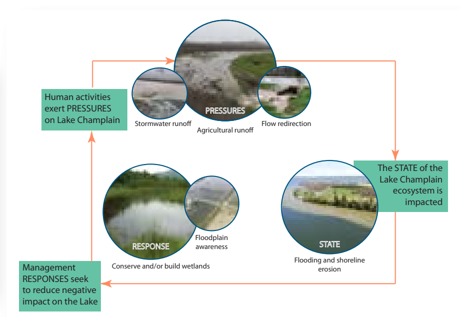
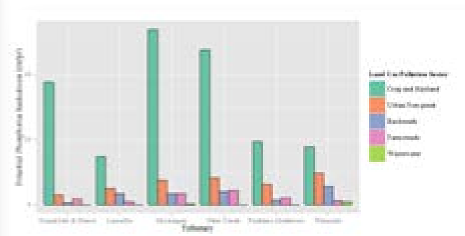
Lake Champlain Basin Program

TECHNICAL REPORT NO. 82

Development of an Indicator Database for Decision-Aiding and Adaptive Phosphorus Management in the Lake Champlain Basin







September 2015

Final Report

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For:

The Lake Champlain Basin Program and New England Interstate Water Pollution Control Commission

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Executive Project Summary

Phosphorus is widely regarded as the primary cause of consistent annual algae blooms in many parts of Lake Champlain, and as a result, reduced tributary phosphorus loads have become a primary indicator of management success. However, the existing monitoring programs in the Basin function primarily to confirm that there are fewer algae blooms and lower phosphorus loading rates, and so an ability to understand the observed lack of progress over the past 20 years is beyond the scope of the currently available data. Therefore, in addition to a lack of consistent progress toward phosphorus loading management goals, there is relatively little concrete information explaining why tributary loading rates have not decreased as expected, relative to management efforts to-date.

In 2009, as the LCBP Steering and Technical Advisory Committees began the third update of *Opportunities for Action* (OFA), the LCBP's management plan, these committees formalized a desire to develop an adaptive management framework that could be applied to the phosphorus management initiatives outlined in OFA. In particular, the Steering Committee was interested in using an adaptive management approach to make further management progress while helping to shed light on the answers to several basic questions about the relationship between the management actions taken so far in each pollution sector and the "universe of need" in those sectors, about which management actions are the most effective and the most cost-effective for achieving reductions in phosphorus loading, about what levels of phosphorus reduction could be achieved if the entire "universe of need" were to be managed, and about how filling major existing knowledge gaps could improve decision-making around which management initiatives to pursue.

To this end, the specific aims of this project were four-fold:

- to provide a method for tracking the implementation of commitments in *Opportunities for Action*, and any ecological response at a common watershed scale;
- to identify areas of strong opportunity for future management by quantifying the universe of need;
- to provide simple estimates of effectiveness and efficiency for each of the major management initiatives tracked in the Indicator table; and

- to identify important knowledge gaps in our understanding of what management actions have occurred or in the effects of that management.

We used a performance-based indicator approach modeled loosely on Watzin et al.'s 2005 report for the LCBP (*Ecosystem Indicators and an Environmental Score Card for the Lake Champlain Basin Program*), using indicators for each major management initiative defined in OFA. For each indicator, we attempted to track the current state, to set short and long term goals, to estimate reductions from achieving those goals, and to estimate cost-effectiveness of each initiative.

The data indicate that better management of agricultural crop and hayland and of runoff from impervious surface present the largest opportunities for management into the future. Wastewater treatment, farmstead management, and combined sewer overflows present comparatively small opportunities for achieving reductions on the scale required to make progress in much of Lake Champlain using existing regulatory tools. According to our estimates, 190 metric tons per year (mt/yr) of phosphorus reduction could be achieved through better management of crop and hayland, and 44 mt/yr could be reduced from managing stormwater runoff. Increased management of farmsteads, CSO abatement, backroad management, and better wastewater compliance could account for a combined 35 mt/yr.

These results suggest that those pollution sources that have defined or identifiable locations (whether they are classified as point or nonpoint sources) have been easier to manage, and that the much harder to manage sources are those that accumulate slowly and are mostly invisible, such as exposed agricultural soil and streambanks.

The data also showed clearly that the cost to achieve the reductions vary widely by management initiative. For example, although agricultural field management constitutes by far the largest opportunity for reductions, its overall cost ($392 million) is nearly an order of magnitude lower than the cost to manage runoff from impervious surfaces ($2.3 billion). The cost estimates for farmstead BMPs and CSO abatement total $184 million, though their much lower potential for reductions points to the importance of considering both total potential and cost-effectiveness.

When considering the interaction between potential for reductions and the cost to achieve those reductions, the data show that the management of runoff from impervious surfaces is by far the least cost effective of any of the practices, with an average cost of ~$2200 per kg of P compared with ~$130 per kg of P for crop and hayland practices. Farmstead BMPs and backroad maintenance are similar to in cost-effectiveness to crop and hayland practices, though as noted above, they share an overall lower potential for large scale phosphorus reductions.

The major lessons from this work were:

- Major knowledge gaps still exist in understanding the watershed-level effects of local-scale management practices, and in the effectiveness of certain novel management policies and practices (particularly those policies and practices dealing with stream corridors). These knowledge gaps can only be addressed through targeted research and subsequent long term monitoring.
- The greatest potential for future phosphorus reductions lies in the most diffuse of the nonpoint sources – agricultural crop and hayland and stormwater runoff. We estimate that these two sources account for more than 85% of the total potential reductions.
- The cost of managing each of the major pollution sources varies widely watershed to watershed and across pollution source types. The variation between watersheds can be as much as a factor of 8 or 9 while the variation across source types can be as much as a factor of 100.
- These large differences in cost to manage each pollution sector point to important tradeoffs that the LCBP and its partners will be forced to make such as those between cost-effectiveness and equal burden between pollution sectors, between implementation and research, or between relatively short- and very long-term solutions.

Acknowledgements:

The project described in this report is the result of a significant amount of work and a high degree of collaboration on the part of many of the Lake Champlain Basin Program's Partners. Many members of the LCBP's Technical Advisory Committee also served on the Adaptive Management Workgroup, which provided direction in the development of the indicators described in the Methods section and in the identification of relevant data sets. These people provided great insight for the authors and their interest and dedication made the project possible. A few individuals in particular went out of their way to be of great help, and deserve special mention.

Eric Smeltzer of the Vermont Department of Environmental Conservation acted as a liason between the authors and the State of Vermont Agency of Natural Resources, finding and delivering the datasets we sought, and answering many questions about the data and about the programs they represent.

Fred Dunlap of the New York State Department of Environmental Conservation filled the same role for the New York side of the Basin, and was similarly of great help, delivering available datasets and answering whatever questions we had.

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Introduction

Over the past several decades, algae blooms have become a consistent problem in parts of Lake Champlain, presenting impairments to recreation and occasionally causing fish kills. Recently, these blooms have become more dominated by cyanobacteria, causing additional public health concerns, including risk to drinking water intakes and further limiting public recreation. The results of early studies named excess phosphorus as the most likely driver of the increase in the occurrence of algae blooms and identified the most likely source as runoff and erosion from the Lake's watersheds (Lake Champlain Study 1979). These studies listed several watershed sources of phosphorus including wastewater treatment and non-point source loading from agricultural and urban land uses.

Initial management efforts targeted wastewater treatment to great effect, and as those projects were finished, concerted efforts to control nonpoint loading became more earnest. Due to the dispersed nature of nonpoint source phosphorus pollution, specific management actions have focused on reducing erosion from the landscape to streams, with the expectation that this will in turn reduce the occurrence of algae blooms in the Lake. As a result of this shift in management focus from algae blooms to phosphorus delivery to the lake, reduced tributary phosphorus loads have become a primary indicator of management success.

However, despite the substantial amount of time and money invested in trying to reduce phosphorus delivery to the lake, monitoring data have shown limited progress in reducing phosphorus loading or algae blooms. Because the existing monitoring programs in the Basin function primarily to confirm that the key management targets are being addressed (in this case, that there are fewer algae blooms and lower phosphorus loading rates), an ability to understand the observed lack of progress is beyond the scope of currently available data. Therefore, in addition to a lack of consistent progress toward management goals, there is relatively little concrete information explaining why tributary loading rates have not decreased as expected, relative to management efforts to-date.

In 1988, the states of Vermont, New York, and the province of Quebec signed a Memorandum of Understanding that initiated a process to establish in-lake criteria for phosphorus concentrations, and establish target watershed loadings to achieve the in-lake criteria (Stickney et al. 2001). The Lake Champlain Steering Committee was established at this point to guide that process. The Lake Champlain Special Designation Act of 1990 created a group responsible for developing a comprehensive plan to prevent and control phosphorus pollution, with the goal of restoring Lake Champlain water quality. This group, called the Lake Champlain Management Conference, produced a plan and recommended that a second body exist to coordinate the implementation of the plan, the actions of the Lake Champlain Steering Committee, and all other efforts among the three jurisdictions for research, demonstration projects, lake and tributary monitoring, and education and outreach initiatives. That group was the Lake Champlain Basin Program (LCBP), and it continues to act as the forum for coordinated management of the lake's natural and cultural resources between Vermont, New York, and Quebec.

In 2009, as the LCBP Steering and Technical Advisory Committees began the third update of *Opportunities for Action* (OFA), the LCBP's management plan, several of the issues described above led to an interest in the development of tools to help learn about the effectiveness of various management actions and to increase the use of available monitoring and research data to guide the LCBP's decision-making processes. A lack of clarity about the effectiveness of various management initiatives, disagreements about how to prioritize funding allocations, and a desire for greater self-accountability also contributed to this interest. In late 2009, the LCBP Steering Committee formalized a desire to develop an adaptive management framework that could be applied to the phosphorus management initiatives outlined in OFA. In particular, the Steering Committee was interested in using an adaptive management approach to help shed light on the answers to several questions, including:

1. What is the relationship between the management actions taken so far in each pollution sector and the "universe of need"? (i.e. how much has been done, and how much is left to do?)
2. Which management actions are the most effective and the most cost-effective for achieving reductions in phosphorus loading?
3. What levels of phosphorus reduction could be achieved if the entire "universe of need" were to be managed?
4. What major knowledge gaps exist, and how could filling those gaps improve decision-making?

Developing the answers to these questions comprise the bulk of a formal process of Adaptive Environmental Assessment and Management (AEAM) described by Carl Walters (1986). These assessments, which provide the information critical to informing adaptive management processes, serve as knowledge-gathering exercises to understand what options exist for achieving management goals and what the likely effects of those actions are. Adaptive management, which follows these assessments, describes the use of a set of tools that helps resource managers address the knowledge gaps discovered in the assessment phase, and learn more about the effectiveness of their actions on the environment. As such, the goal of an Adaptive Environmental Assessment is to enable adaptive management in the future, which in turn enables resource managers to become more effective.

In its modern form, adaptive management describes a highly structured, well-planned cycle of "learning by doing" that uses decision analysis tools to make the best possible decision about management actions given the available information and then uses an experimental approach to strategically improve the quality of information used in making future decisions. The use of the tools of adaptive management come with a few assumptions about the kind of problem addressed with this sort of approach; the management decisions are recurring at some regular and predictable interval, that there are multiple stakeholders who hold multiple objectives for the outcome of the management actions, and that there is a high degree of uncertainty about the outcomes of management actions. While there is wide opportunity for interpretation in how many steps there should be, what they are called, and how they are divided or clumped, there is wide consensus that adaptive management must consist of iterations between the decision-making component and an opportunity for learning through inference (Allen et al. 2011).

For the tools of adaptive management to prove helpful, the foundations of two key processes must be present. The first is a process for making decisions that considers multiple objectives at the same time, evaluates action alternatives relative to each other, and that produces repeatable and defensible results. The tools that enable this sort of process are referred to in general as Structured Decision-Making (SDM) methods (Gregory et al. 2012). SDM methods have been successfully used in a wide variety of situations, and increasingly are being used by the U.S. federal government in natural resources management as a way to make more informed and defensible decisions about the best use of public resources (Stankey et al. 2005, Williams and Brown 2012).

In the context of Lake Champlain, the use of SDM methods requires an understanding of what management goals are most appropriate from both a scientific and a public perspective – i.e., what do the data suggest are appropriate goals, and what goals do the public and other stakeholders want to see achieved. A large body of research has shown that explicitly including these sorts of values into decision-making improves the quality of the outcomes. However, to do that, decision-makers need to be clear about what value-based goals are important at the outset of the decision-making process. This information paves the way toward better generation of management options and better ability to make informed tradeoffs later in the decision process.

The second key process for successful application of adaptive management tools is a way to learn about management actions through inference; generally this is accomplished by using statistical methods to compare the predicted outcomes of management actions to their actual monitored outcomes (Walters 1986). Resource managers often rely on complex computer models to generate these predictions, but research and experience have shown that relatively simple estimations that use basic methods and existing data can often provide enough discrimination among alternatives to enable more informed decisions, with lower investments of time and money.

The tools of SDM and adaptive management can prove especially helpful when one or more of the following conditions is true: 1) a high degree of uncertainty about the structure and function of the ecological system exists, 2) where there are many stakeholders and multiple objectives for the relevant management agencies and 3) those agencies make recurring management decisions (either cooperatively or in parallel) about the same resource. All of these conditions are true of the Lake Champlain Basin. The use of these tools has proven especially successful in helping managers and scientists gain a better understanding of ecosystem function in other large and complex systems (Pulwarty and Melis 2001) and of how resources respond to management actions (Johnson and Williams 1999, Johnson et al. 2002).

Because adaptive management is a means for developing better understanding of complex interactions between management actions and the environment, model representations of these interactions are a major component of adaptive management efforts. Not surprisingly, many of these representations are complex computer models that require a large amount of training to build, understand, and operate. These complex models are often very useful for shedding light onto environmental phenomena and for predicting the response of the ecosystem to management interventions and natural events (NRC 2007). However, the large number of parameters and interactions in these sorts of models make them subject to large uncertainties in their predictions, which are often difficult to quantify or even identify (NRC 2007). In the context of managing water resources, these uncertainties are particularly problematic for setting targets and designing management strategies for restoration plans, such as in the EPA's Total Maximum Daily Load (TMDL) program.

In response to these large uncertainties, there has been a growing effort to develop simpler models that lend themselves well to statistical methods to quantify the precision and accuracy of the model predictions (Caulkins 2002), particularly for models used in TMDL assessment and implementation phases (Reckhow 2003, Shirmohammadi et al. 2006). In some cases, these are empirical statistical models, but there is also increasing use of various forms of system-oriented models that are able to quantify diverse kinds of relationships in situations where data are limited and in ways that are often more relevant for policy development. These sorts of models are variously called Cognitive Maps, Causal Maps, Analytic Network Process Models, or Influence Diagrams, but share the common trait that nodes representing the state of any variable are linked via arrows that represent causal connections (figure 1, from (Watzin et al. 2005)). Depending on the kind of model and its purpose, the nodes and arrows can represent real or estimated quantities or they can represent qualitative relationships. One advantage of these sorts of models is that they are easily translatable into sets of indicators of important ecological or management conditions.

A substantial amount of research has explored the use of indicators in the conservation and resource management world as a method for quantifying vague and amorphous concepts such as "ecosystem health" and the effect of management on ecosystems (EPA 2000), including work done in the Lake Champlain Basin (Watzin et al. 2005).

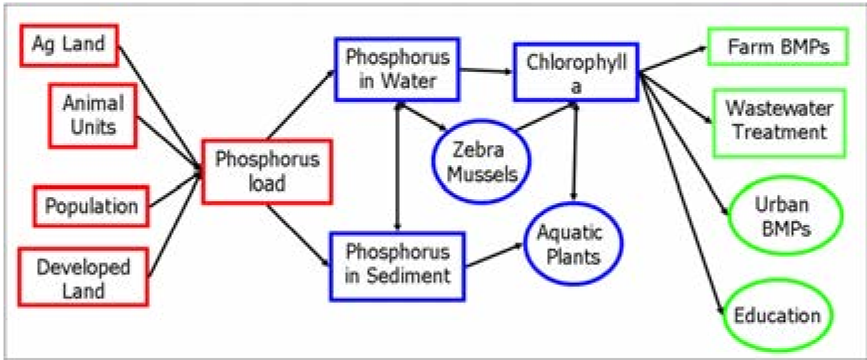

Figure 1. Model diagram showing dependencies (arrows) between different elements (circles and squares); in this case, the effect of land use on phosphorus load and subsequently on algae blooms under the Pressure-State-Response framework of Watzin et al. 2005.

Goals for this project

The overarching aim of this project was to lay the groundwork to enable the development of an adaptive management framework – that is, to enable the use of formalized SDM tools, and to generate predictions about management effectiveness and provide a method for comparing them to observations in the future. Our intention was to tabulate data that could be revised over time and that would be used as inputs to a more formal decision-making process developed separately from this effort.

There were four specific objectives we explored in the pursuit of enabling an adaptive management approach for the LCBP:

1. Provide a method for tracking the implementation of commitments in *Opportunities for Action*, and an ecological response at a common watershed scale,
2. Identify areas of strong opportunity for future management by quantifying the universe of need,
3. Provide simple estimates of effectiveness and efficiency for each of the major management initiatives tracked in the Indicator table, and
4. Identify important knowledge gaps in our understanding of what management actions have occurred or in the effects of that management.

To achieve these objectives we adopted a group of performance indicators to guide the data collection and analysis phases of this project. One of the key goals in the LCBP's developing adaptive management effort is to relate management progress to changing ecological condition. Quantitative measures of vague concepts such as "management progress" and "ecological condition" require the use of more specific, often stand-in, indicator variables for the issues of real interest. Performance indicators (referred to below as simply "indicators") fill this and several other key functions for informing the use of formal decision making tools and in enabling learning over time. Specifically, the ability of indicators to quantify specific and concrete components of broad management goals means that they can enable clear connections between the available management options (i.e. policy instruments) and their supposed ecological effect (Wolfslehner and Vacik 2011). These features of indicator systems in turn lend themselves well to the development of conceptual and quantitative models that can be used as part of adaptive management efforts.

Methods:

We opted for a performance indicator-based approach that would allow specific and quantitative measures of both management progress and ecological condition, and that would enable the development of hypotheses about how certain indicators were linked. We divided the group of indicators into two categories; one that tracks the implementation of major management programs detailed in OFA (Implementation Indicators) and a second that tracks changes in various components of the ecological condition of the Lake Champlain Basin (Ecosystem State Indicators, Appendix A). For each of these indicators, our goal was to characterize the "Current State", or the best estimate of the current value using best available data, quantitative short- and long-term goals, expected phosphorus reductions that

Box 1. Translating Commitments in Opportunities for Action into measureable Implementation and Ecosystem State Indicators:

The Agencies of Agriculture for each jurisdiction have committed to ensuring that all farms falling under relevant regulation (i.e. EPA for Vermont and New York, and MDDEFP for Quebec) have the necessary structures to prevent phosphorus pollution from four locations on the farmstead – manure pits, silage bunkers, milkhouse waste, and runoff from the barnyard (OFA tasks 4.1.14, 4.1.15, 4.1.19, 4.1.20, & 4.1.21). For example:

<u>OFA task 4.1.20:</u> *Ensure that all (118) MFO farms in the Basin have the necessary structures in the production area needed to prevent direct farmstead discharges by 2013 (based on the number of farms available as of 2009).*

From these four commitments we generated an Implementation indicator that tracked the percentage of farms that have and maintain those structures:

Percent of regulated farms (LFOs/Large CAFOs & MFOs/Medium CAFOs) with regularly maintained Best Management Practice structures, by structure type & farm size.

This Implementation indicator is paired with a corresponding Ecosystem State indicator that, as a result of farmstead management, would be expected to change in value:

Estimated P loss (mt/yr) from farmsteads.

would result from achieving those goals, cost to achieve the long-term goal, and a measure of cost-effectiveness for each implementation indicator.

Development of the Indicators

The phosphorus management chapter of Opportunities for Action organizes management tasks and commitments into major land-use pollution sectors, including agricultural lands, developed lands, rural lands and backroads, and floodplains, wetlands, and riparian areas. Within each of these sectors, the major existing phosphorus control initiatives are described by the individual commitments made by each LCBP partner in OFA. We organized those commitments that detailed specific implementation actions (as opposed to, for example, maintaining partnerships) into thematic groups that informed the development of the set of specific Implementation indicators within each land use sector (table 1).

In 2010, the Adaptive Management workgroup, which comprises a subset of the LCBP Technical Advisory Committee and holds representatives from each jurisdiction, began meeting regularly to refine the language describing each indicator and to identify existing datasets that could be used to characterize the indicators. This effort was aligned very closely with a parallel effort at the Vermont Agency of Natural Resources Ecosystem Restoration Program, and so many of the many of the resulting indicators bear strong similarities to indicators developed as part of that effort. We departed from that effort slightly in that wherever possible, we attempted to replace jurisdiction-specific language or initiatives with language that was more broadly applicable.

These Implementation indicators were then related to a set of Ecosystem State indicators (table 2), which track key ecosystem elements such as land use and land cover, stream channel condition, phosphorus load from various land uses, and total tributary phosphorus load. The basis for the selection of these ecosystem elements was to try to identify variables that are more proximately influenced by management decisions than are end-of-tributary phosphorus loads, where effectiveness has been measured to date. As existing management policies are applied more widely and new management policies are developed, changes in some of these variables (such as soil P levels) may become apparent before changes are seen in end-of-tributary loads (see box 1 for an example of how we translated commitments in OFA into measurable Implementation and Ecosystem State Indicators).

Table 1. Implementation Indicators sorted by Land Use sector

Agricultural Lands
• Percent of agricultural land under enhanced land management for: a. Cover cropping b. Alternative manure spreading methods c. Conservation tillage • Percent of agricultural land acres managed under an approved Nutrient Management Plan, by farm type (LFO, MFO, SFO, or Large/Medium CAFOs) • Percent of farms operating within 5% of whole-farm P balance • Percent of regulated farms (LFOs/Large CAFOs & MFOs/Medium CAFOs) with regularly-maintained Best Management Practice structures, by structure type and farm size: a. Manure storage b. Silage leachate treatment c. Barnyard runoff treatment d. Milkhouse waste treatment • Percent of farm inspections identifying substantial violations of relevant agricultural regulation • Percent of perennial stream miles where livestock have uncontrolled access to the stream
Developed Lands
• Percent of all permitted construction stormwater sites under the Construction General Permit in substantial compliance with the permit • Percent of all permitted construction stormwater sites with Individual Permits in substantial compliance with their permit • Percent of all permitted operational stormwater sites in substantial compliance with their permit • Percent of municipalities with storm sewer systems that have completed IDDE projects • Percent of impervious area that is under stormwater management • Number of combined sewer outfalls remaining in the Lake Champlain Basin • Percent of land area in stormwater impaired watersheds in need of treatment that is receiving treatment • Number of towns with good water quality protection provisions in town plans and zoning ordinances, including incorporation of Low Impact Development standards where appropriate. • Percent of tree canopy coverage within urban landscape zones in the Lake Champlain Basin
Rural Lands/Backroads
• Percent of inspected sampling units within logging jobs in the Vermont and New York portions of the Lake Champlain Basin where harvesting operations have caused more than trace amounts of sediment to enter streams. • Percent of Vermont towns participating in the Better Backroads Program (or equivalent program) • Percent of towns that have completed road erosion needs inventories and capital budget plans • Percent of priority erosion control projects identified in road erosion needs inventories that are completed
River, Floodplain, and Wetland Conservation & Restoration
• Percent of stream miles with perennial vegetated buffers in non-forested land use areas - differentiated by adjoining land use, buffer width class, vegetation type (woody, non-woody), programmatic coverage (e.g., CREP, WRP), and consistency with any regulatory standards that apply. • Cumulative percent of river miles classified, as part of a statewide sediment regime departure analysis, to be unconfined, sediment transport reaches (i.e., incised reaches that should be depositional, and not under active management) for which floodplain access is either (a) actively or (b) passively restored • Percent of towns having adopted Town and Bridge Standards in accordance with Act 110 that contain a suite of water quality based BMPs • Percent of Basin communities with adopted municipal Fluvial Erosion Hazard ordinances • Rolling 15 year cumulative totals for acres of identified priority wetlands (a) restored and (b) conserved • Percentage of river corridor miles secured through easements for reaches of river identified as key sediment attenuation areas in completed geomorphic-based river corridor plans
Wastewater
• Percent of facilities meeting their TMDL wasteload (VT & NY) or phosphorus (PQ) allocations • Percent of wastewater treatment facilities having an approved sewage spill prevention plan for (a) the treatment plant and (b) the collection system

Table 2. Ecosystem State Indicators

Ecosystem State Indicators:
• Median animal units per acre • Ratio of imported P / exported P on agricultural lands • Average total P loss from cropland (including hay) (mt/ha/yr) • Average total P loss from farmsteads (mt/ha/yr) • Ratio of imported P / exported P on urban lands • Average total P loss from urban areas (mt/ha/yr) • Average total P loss from road network (mt/ha/yr) • Mean soil P level in cropland (includes rotated and permanent hay) • Mean soil P level in pastureland • Best recent estimates for percent of land in the following categories: a. annual crops b. hay, pasture, lawn c. impervious surface • Percent of river miles in stream geomorphic assessment category II (incised and steepening) or III (incised and widening) • P applied to developed lands (mt/ha/yr) • 5-year average wastewater phosphorus load (2007-2011) (mt/yr) • 5-year average non-point source phosphorus load (2007-2011) (mt/yr) • 5-year average tributary total phosphorus load (2007-2011) (mt/yr) • 6-year ratio of dissolved P : total P in tributary loads (2007-2012)

Calculation of Current States

One of the basic questions that we attempted to address though this effort was how much phosphorus management has occurred, in relation to the level of management that could be done (i.e. its “universe of need”). The goal was not to provide a complete census of all management actions in the sense of counting every square foot of managed impervious surface or every manure pit, but instead to get a general sense of how much effort had been expended in controlling each pollution source described in the indicator list.

In order to relate this information in one common language, we expressed the current state of each Implementation indicator relative to its universe of need, which provided some insight into where large opportunities for management still exist, and which sources have been managed at or close to the maximum level. To do this, we expressed each indicator current state as a percentage of what could be achieved. For example, the acreage of agricultural land currently cover cropped was divided by the acreage of cropland (which excludes farmstead footprints, pasture, and hayland, where cover crops could not be used). Though the approximations made in this method are relatively crude and subject to some uncertainty, it does provide a general sense of the relative possibility for expansion of each management initiative in the Lake Champlain Basin.

The datasets we used to calculate the current state values for the set of Implementation indicators were delivered directly from LCBP partner agencies over the course of 2012, and reflected the best available information at the time. In most cases, the data were summarized directly from record-keeping databases, aggregated by watershed or town. We then summarized these aggregated data by major tributary basin, which corresponds roughly to the USGS Hydrologic Unit Code 8-digit (HUC 8) watershed boundaries (figure 2). In a few cases, data were summarized at the state level and no finer-scale divisions were possible. These state-level data were generally extracted from agency annual reports. Simple summations were very often sufficient to characterize the data by watershed. Exceptions to this generalization are noted in the Indictor Table itself, and explained in Appendix B of this report, which details indicator-by-indicator calculation notes. It should be noted that many of these data sources are in constant revision. While the data used in this report reflected the best available data at the time of writing, many of the datasets have subsequently been revised, and therefore the data presented here may not reflect the most current version of any particular dataset. It is not our intention that data should be taken from this report and used elsewhere.

Data to populate the current state values of the Ecosystem State indicators came from a variety of existing datasets. The modeling effort associated with the ongoing revision of the Lake Champlain Phosphorus TMDL provided data for indicators estimating land cover and estimating phosphorus loads from different land uses. Land-use based phosphorus loads were aggregated within watersheds from all similar sources to estimate the four land use loading estimates called for in the indicator table (i.e. cropland, farmsteads, urban areas, road network). These land-use specific estimates, which were based on long-term averages, were used as the basis for estimating the phosphorus reductions discussed later in this report. Land cover estimates came from the land use layer developed as part of the same modeling effort. The land use layer developed by Tetra Tech used the National Land Cover Database (NLCD) 2006 version as a base layer, but then augmented that layer with a variety of data, including specific crop data from the 2008 Cropland Data Layer, soils data from the USDA SSURGO soils database, road and driveways locations from VTrans and the E911 GIS layers, and from NRCS for locations of farmsteads.

We estimated tributary phosphorus loads using the total phosphorus (TP) and dissolved phosphorus (DP) data from the Vermont Long Term Monitoring Program and the Weighted

Regression on Time, Discharge, and Season (WRTDS) methods developed by Robert Hirsch et al. (2010) and used recently for Lake Champlain by Laura Medalie et al. (2012). The reported total phosphorus loads are the standard estimates from that method, which are similar in nature to a USGS LOADEST estimate. Bias statistics for these estimates equaled or bettered those reported by Medalie in her recent report. Following the method used by Vermont DEC for generating tributary load estimates, the estimates of phosphorus load at the flow monitoring gauge were adjusted upward to reflect the load at the true mouth of the tributary by using the ratio of area of land upstream of the gauge relative to the area of the full watershed. To estimate the phosphorus load for the Lake Champlain Direct/Grand Isle watershed (which is not gauged or sampled), we used a similar method where the proportion of the direct drainages area relative to the total area of the gauged watersheds was applied to the total phosphorus loads from all gauged watersheds. Non-point loads are the difference between the wastewater load for each watershed and the total load for that watershed.

We calculated ratios of dissolved phosphorus (DP) to total phosphorus (TP) from estimates of daily fluxes produced by the WRTDS method for each form of phosphorus. We summed these daily fluxes by season (within years), where “fall” is the first three months of the water year (October, November, December), “winter” is January, February, and March, and so on, and calculated a ratio of the DP and TP fluxes for each season, and then averaged these values within years. We opted for this seasonal averaging method because we felt that simple ratios of daily flux estimates over-emphasized the role of DP in the winter (which is relatively higher at that time of year) and a ratio of annual flux estimates erased too much of the variability that occurs over the course of the year.

Watershed-specific estimates of stream geomorphic evolution stage were taken from results from the Vermont River Management Program’s Phase 2 Stream Geomorphic Assessment program. The proportions reported in the table are the proportion of stream reaches in evolution stage II or III to all stream reaches assessed.

The area of impervious surface in each basin was summed within HUC 8 boundaries from the recent impervious surface layer created for the LCBP by the University of Vermont Spatial Analysis Lab (O'Neil-Dunne 2013). The base data for that project was 2011 orthophotography, and auxiliary datasets to identify roads and driveways.

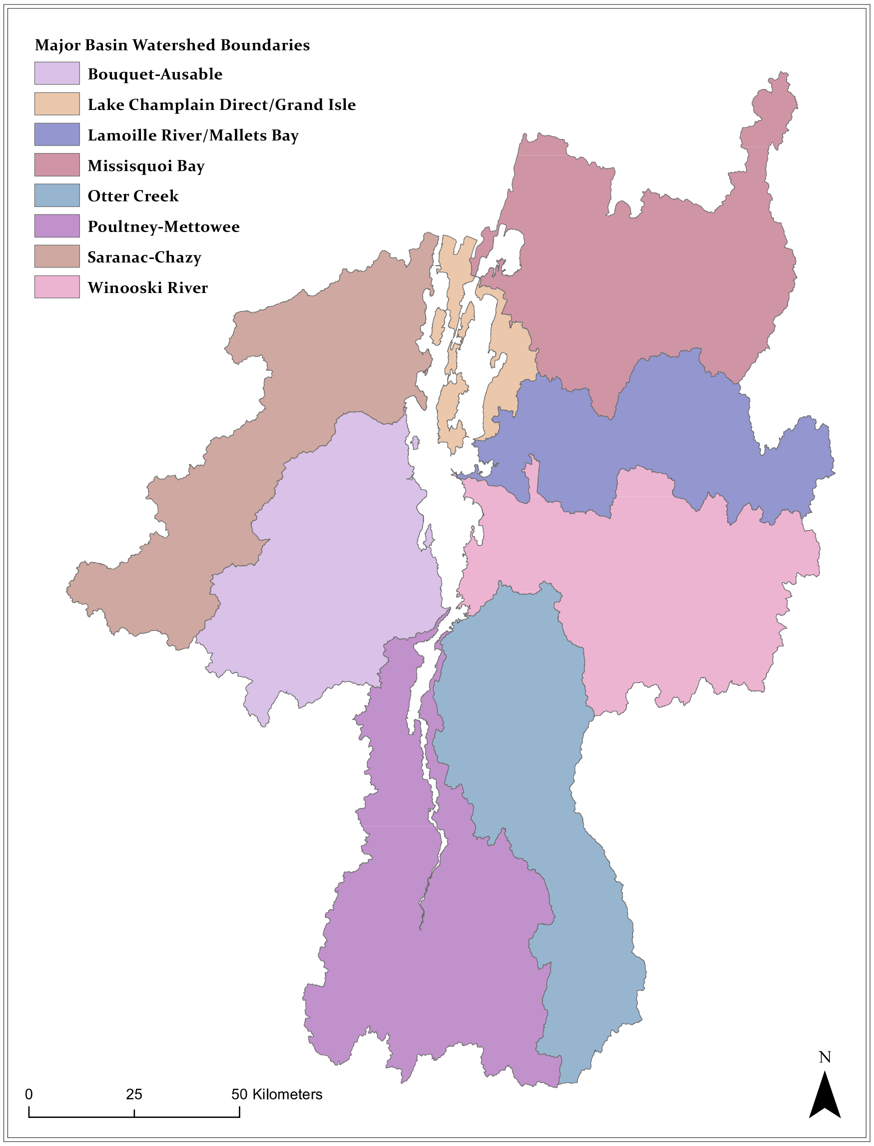

Figure 2. Major 8-digit Hydrologic Unit Code (HUC 8) tributary basins of Lake Champlain used to summarize spatially-explicit management data by basin.

Short- and Long-Term Acceptable Levels

A second aim of this project was to provide a method for relating management actions to short and long-term goals, and to tie those goals to hypothesized phosphorus reductions. In the context of this effort, the explicit short- and long-term goals (called "Acceptable Levels" in the indicator table) represented two different kinds of goals. The long-term goals represent the level of management that, according to best professional judgment, is necessary to achieve the desired ecological outcomes – in this case, reduced algae blooms. How and where these long-term goals are set is reflective of the scientific opinion of the Adaptive Management Workgroup more than of any programmatic or policy considerations. In the current iteration of the Indicator table, these goals were set essentially at the entire universe of need, but as the management community learns more about the effectiveness of management practices, these levels could and should be revised as necessary.

In contrast to the long-term goals, the short-term goals are reflections of what is politically and fiscally feasible in the short-term – they are therefore policy decisions, and not based in scientific opinion. In the current table, these levels are taken from the commitments in OFA relating to each indicator, but other targets could be used as appropriate.

Short- and Long-Term Expected Phosphorus Reductions

A key element of good decision-making is an ability to compare the outcomes of various alternatives in light of each other. In the context of water quality management, that means making clear statements about the expected benefits and costs of various management initiatives (e.g. managing stormwater versus managing farmsteads). Since phosphorus loading is the main (direct) target for these management efforts, estimated phosphorus reductions were the sole benefit considered. We acknowledge that phosphorus loading is not the only important consideration, but the effectiveness of management practices should be a key driver in future decisions about management policies. These estimates, or hypotheses, were the main method by which we attempted to link the Implementation indicators to the Ecosystem State indicators.

To estimate short-term and long-term expected reductions, we used reduction efficiency values reported in the scientific and technical literature that were reported for similar management practices, and for similar climates. We applied those efficiency values (often a percentage) to the Tetra Tech estimate of the phosphorus load associated with the appropriate

> ***Box 2. Estimating Potential Phosphorus Reductions:***
>
> In the Winooski Basin, VT AAFM reported 918 acres of cover crop for 2012, applied to the 61,274 acres of crop and hay land (estimated by Tetra Tech, 2013) in the watershed. This translates to 1.5% of the total productive land. The ultimate goal, for example, would be to cover crop all annual cropland, which represents 29.2% of the total crop and hay acres.
>
> The "current state" is 1.5%, the "ultimate acceptable level" is 29.2%.
>
> Tetra Tech estimates the average TP load from cropland (including hay) to be 28.5 mt/yr in the Winooski watershed. Michaud et al. (2002) report a 30% reduction in TP from wide-scale cover cropping.
>
> The estimated reduction from cover cropping is calculated this way:
>
> (Reduction rate * Land use load) * (Remaining opportunity)
>
> = Expected reduction
>
> (30% * 28.5 mt/yr) * (29.2% - 1.5%) = 2.4 mt/yr

land use (Tetra Tech 2013). This estimated phosphorus reduction reflects what could be achieved by implementing that practice on 100% of a particular land use. We then multiplied this reduction estimate by the proportion of that land use that could theoretically receive treatment; for our purposes, this was equivalent to the difference between the current state and the short- and long-term goals (see Box 2 for an example). Note that at the time of writing, sediment and nutrient loads provided in the model did not take into account transport loss, and therefore may have over-estimated delivered sediment and nutrient loads to the lake. Given this information, estimates of reductions provided in this report based on the TetraTech SWAT model might be high.

Total Cost and Cost-Effectiveness

To accomplish the third major goal of this effort, to provide simple estimates of effectiveness and efficiency for each indicator, we estimated two separate measures of cost associated with achieving the ultimate acceptable management level as specified in the Indicator Table. The first measure attempted to quantify total up-front investments to achieve the long-term acceptable levels. Many of the management practices described in the indicator table (table 1) require heavy initial investments in construction and engineering costs in addition to yearly operation and maintenance (O&M), and spreading the total cost of the these practices over the lifespan of the practice can mask the (often substantial) initial investments required. We therefore included construction costs and engineering and design costs (D&E), but excluded program administration and O&M costs. We also excluded land costs because of the extreme variability of land prices around the basin and over time, and because of the vastly different amounts of land required for each type of practice.

However, because we were interested in more direct comparisons between management policies that require heavy initial investments (such as stormwater management) and those policies that are annual costs (such as agricultural field management), we also developed a 20-year cost estimate that included all of the costs described above, in addition to annual O&M costs. We assumed 20-year lifespans for urban stormwater practices (Schueler et al. 2007), 10-year lifespans for farmstead structural Best Management Practices (BMPs) (Gitau et al. 2006) and rural road, or backroad, BMPs (Garton 2013), and single-year lifespans for agricultural field practices. To calculate the 20-year cost, we added initial construction investments to the annual

O&M costs over the lifetime of the practice. This amount was then multiplied by the number of times the practices would be replaced over 20 years, again excluding land costs.

We did not assume any diminishing (or increasing) marginal returns for the cost of different levels of management, which a more detailed economic analysis might. Economies of scale do exist for wide-scale stormwater construction efforts (Schueler et al. 2007), but a detailed assessment of the economics of watershed-scale phosphorus management was not one our intentions, and is beyond the scope of this project.

Our estimate of cost-effectiveness used the annualized 20-year cost and the long-term effectiveness to develop a ratio of the total cost to the expected phosphorus reductions when the long-term goal has been achieved for a particular BMP. This ratio was expressed in dollars per year for each kilogram of phosphorus reduced (i.e. dollars per year per kilogram per year), but can also be interpreted as dollars per kilogram of phosphorus reduced. This metric allowed direct comparisons between management policies that require heavy initial investments with those that require steady annual costs.

Results:

Goal 1: Provide a method for tracking the implementation of commitments in OFA, and any ecological response

There were large differences in the amount of available tracking data for implementation efforts both between and within jurisdictions. As a result, we were unable to characterize the current states for every indicator we developed – there were data for 75% of the Implementation indicators (24 out of 32) and 72% of the Ecosystem State indicators (13 out of 18) for the Vermont watersheds, including the Quebec portion the Missisquoi. Because of some of the differences in the existence of certain programs between Vermont and Quebec some of the data used in the calculations comes from only one jurisdiction. For the New York side of the basin, data existed for 30% of the Implementation indicators (10 out of 32) and 45% of the Ecosystem State indicators (8 out of 15).

Of those indicators for which data did exist, most did not have a clearly quantified short-term acceptable level detailed in OFA. This lack of goal-setting made the calculation of expected phosphorus reductions impossible for the short-term. However, because the Adaptive Management Workgroup did set long-term acceptable levels, we were able to calculate reductions for many of these. In the calculation of the long-term reductions, a primary limiting factor was a lack of data for management initiatives that are not common nationally. Very few of the effectiveness data we used were locally produced, and as a result, the expected reductions for practices that are not common water quality management practices nationally were difficult to quantify (e.g. maintenance of backroads – though a common management practice, it's not often thought of as a phosphorus management tool). All in all, we were able to estimate potential phosphorus reductions for 18 of the 32 indicators for the Vermont side watersheds and 6 of the 32 indicators for the New York side.

While the indicator table seems to suggest that Quebec and Vermont have more tracking data than New York, the indicators themselves do not allow for easy tracking across jurisdictions. Despite removing program-specific and jurisdiction-specific language where possible from the indicators, the apparent lack of data from New York data may be at least in part an artifact of indicators that are too Vermont-specific. However, Vermont's ongoing TMDL redevelopment has necessitated some increased accountability and a corresponding increase in data collection for the past several years in Vermont which has not been paralleled in New York – this fact may also be a factor for the differing degrees of data availability.

Goal 2: Show areas of strong opportunity for future management by comparing what's been done to the universe of need

One of the clearest results is that there has been a high level of implementation directed toward cleaning up pollution sources on regulated farmsteads (i.e. Medium and Large farmsteads), and on getting wastewater treatment and combined sewer outfalls[1] (CSOs) into compliance – evidence of this can be seen in the low level of reductions still possible to achieve from these sources (figure 3). In many of the watersheds, the ultimate acceptable levels for farmstead BMPs, CSOs and wastewater treatment have already been met. For example, across the Lake Champlain Basin, only six wastewater treatment facilities (WWTFs) have produced 3-year average loads in excess of their current TMDL allocations, equivalent to 5% of all facilities. Likewise, CSOs have been eliminated from most watersheds, and reports by the Vermont Agency of Natural Resources suggest that overflow events at the remaining outfalls are relatively rare in Vermont (Vermont Agency of Natural Resources 2013). Because rules dictating the use of farmstead BMPs for farms regulated under federal programs have existed for many years in the US, very few Medium and Large farms in the Vermont and New York portions of the basin are out of compliance with maintaining these structures at any time. In the Quebec portion of the basin, similar rules for animal farms are more stringent in terms of the size of farms that are closely regulated, and compliance rates are similarly high. Because of the lack of significant management potential, any remaining targets for these policies in these other watersheds would account for only 5% of the possible phosphorus reductions. However, enacting new, more stringent targets could change the degree of potential that exists for some of these policies. For example, lowering the allocation for WWTFs or regulating Small Farm Operations to the same level as their larger counterparts would present a some additional opportunity for reductions, but estimating the effects of these hypothetical changes was outside the scope of this effort.

On the other hand, management agencies can still work to further encourage better management of agricultural fields and in treating runoff from impervious surfaces, the two

[1] We use "outfall" in reference to the outfall pipe where combined sewer systems are discharged to a stream, and "overflow" to describe events when such a discharge occurs. In abbreviation, "CSO" refers to the outfalls, and "CSO events" refers to overflow events.

pollution source categories with the largest potential for phosphorus reductions (figure 3). In most watersheds, only a small percent of agricultural fields are managed with cover crops, alternative manure management (e.g. subsurface injection) or reduced tillage (figure 4). Reduced tillage and manure injection are considerably more common in the Missisquoi Basin because of the intensity of those practices in the Quebec portion of the basin. Throughout the Lake Champlain basin, tracking the prevalence of these and other management practices is difficult because farmers often implement them voluntarily and without any compensation. The data presented in this report only reflect the acres of each practice cost-shared by the Vermont Agency of Agriculture, and likely underestimate the actual rate of use for each management practice. However, we assume that the cost share programs capture most of the acreage, and therefore assume the actual acreage is not more than twice what we report. However, even under-reporting by as much as a factor of 5 would not change the general result that better management of agricultural fields represents the largest opportunity for phosphorus reductions across land use pollution sectors.

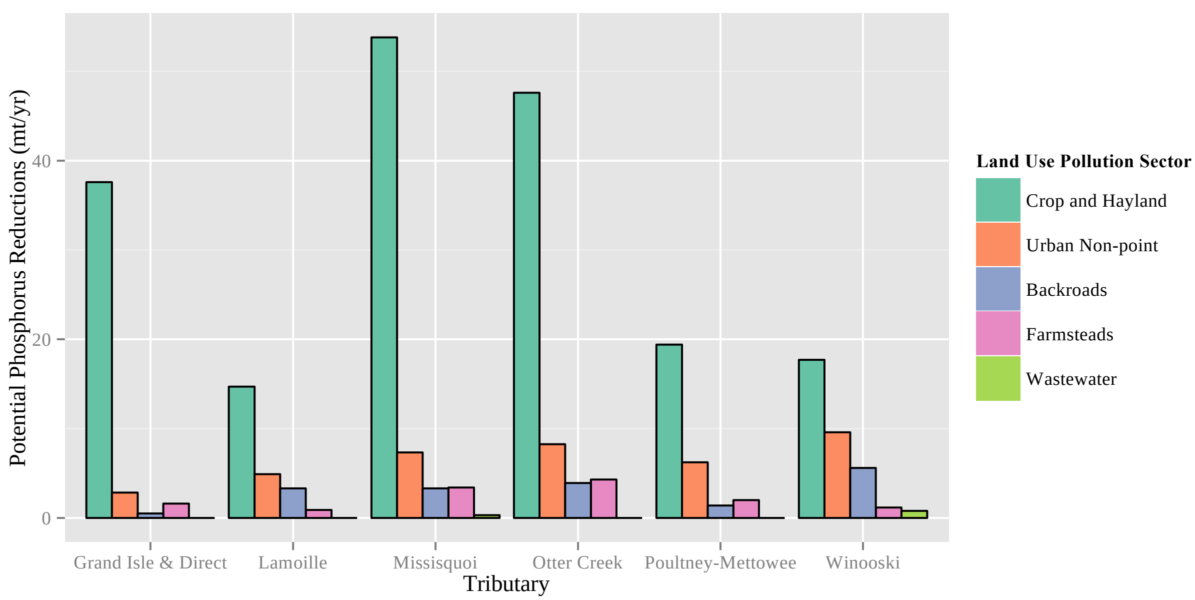

Figure 3. Potential reductions by land use pollution sector and tributary in the Vermont and Quebec portions of the Lake Champlain Basin.

The percentage of area of impervious surface under active management is also small (figure 5). Across watersheds, the average proportion of impervious surface under state permit is 5.8%. Without the Grand Isle & Direct drainage and the Winooski basins, both of which have large populated areas (St. Albans and Burlington, respectively), the average percentage of permitted impervious surface is only 2.8%. In basins with urban areas subject to the federal Municipal Separate Storm Sewer System (MS4) rules, which contain regulations for managing stormwater, these estimates could be lower than the actual impervious area under regulation. This discrepancy is a result of the fact that Vermont stormwater permits exist for parcels both inside and outside the MS4 boundaries; therefore, the area of stormwater permits issued by the State and the area of MS4 communities are two separate estimates of the impervious area under management with substantial (but less than perfect) overlap. We have chosen the first, under the assumption that the MS4 designation does not ensure effective stormwater treatment for all impervious parcels.

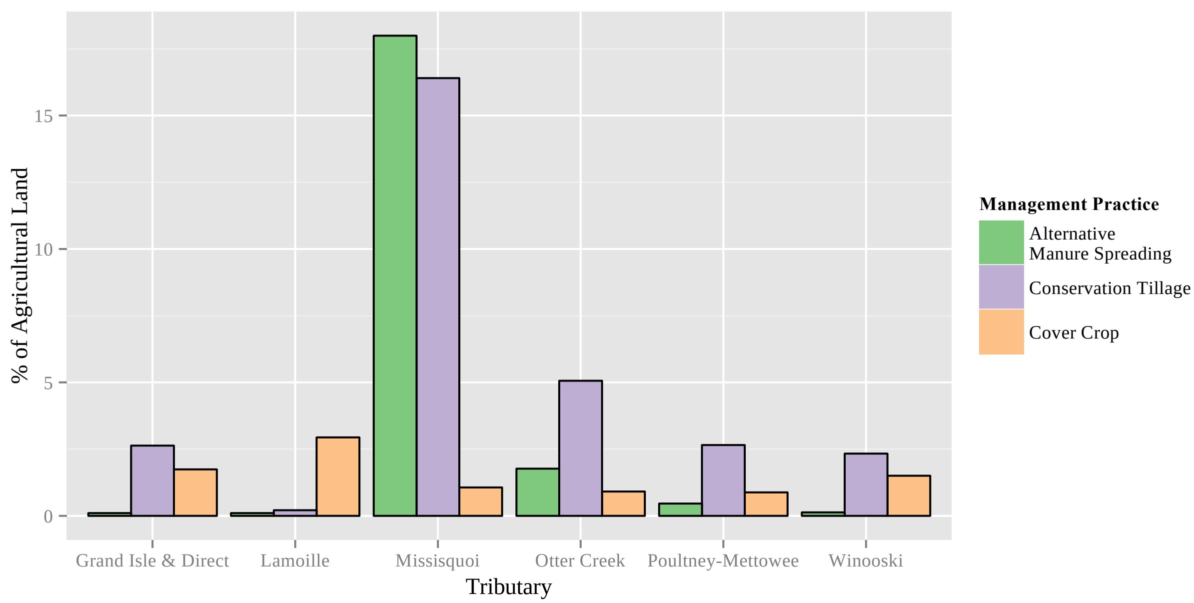

Figure 4. Percent of agricultural land under enhanced management in Vermont and Quebec portions of the Lake Champlain Basin.

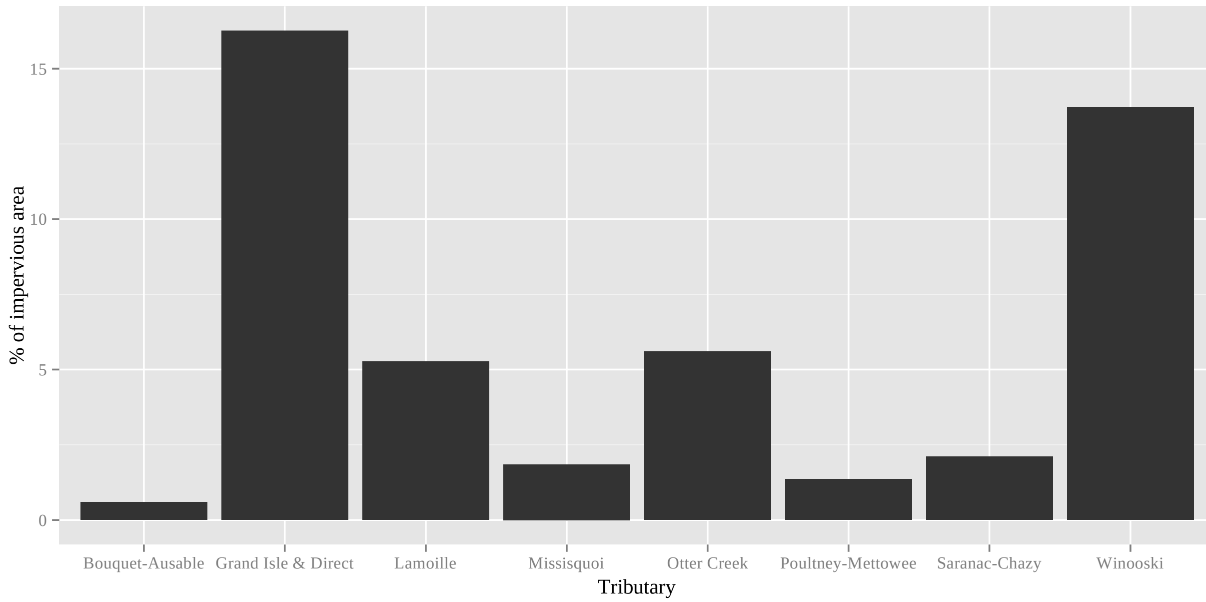

Figure 5. Percent of existing impervious area managed under stormwater permits in New York and Vermont portions of the Lake Champlain Basin

In each jurisdiction, there are different area limits for how large new impervious areas need to be in order to require permitting. This is pertinent in that it appears that much of the impervious area may lie in parcels that are too small to warrant permits. In addition, the proportion of impervious surface that is associated with roads (i.e. impervious surface that is not associated with rooftops, parking lots, etc.) varies from watershed to watershed, which is important for understanding how much of the impervious area is manageable with different practices (table 3).

Table 3. Percentage of impervious surface in each watershed associated with roads and railways in the New York and Vermont portions of the Lake Champlain Basin.

Tributary	%
Bouquet-Ausable	57.7%
Grand Isle & Lake Champlain Direct	37.9%
Lamoille	42.7%
Missisquoi	47.5%
Otter Creek	41.1%
Poultney-Mettowee	45.3%
Saranac-Chazy	49.9%
Winooski	38.9%
Mean	*45.1%*

Goal 3a: Provide simple estimates of total reduction potential for each of the major management initiatives tracked in the Indicator table:

The largest potential for land-based phosphorus reductions over the long-term appears to come from managing runoff from crop and hay land and urban non-point sources (i.e. from treating runoff from impervious areas). We estimated that wide-scale management of these two land uses to their ultimate acceptable levels could reduce tributary loads up to 235 metric tons of phosphorus per year – 191 from crop and hayland and 44 from urban areas (table 4). The large difference in reductions possible from these two sources is primarily a result of the modeling data that suggests that the phosphorus loading from agricultural lands consists of more than two-thirds of the loading from non-forested, upland areas. Because the estimates of possible reductions are based on proportions of phosphorus removed through various practices, the higher loading estimates translate to more potential to reduce those loadings. However, both of these estimates – potential reductions from agricultural fields and from urban non-point – are almost certainly optimistic to some degree.

Firstly, the reductions possible from crop and hayland assume that the three practices we included (i.e. cover crops, reduced tillage, and alternative manure handling practices) could each be implemented on every acre of agricultural field and achieve an additive level of effectiveness, which is very likely not true. However, there is no good basis for estimating what the combined efficiencies of those three practices might be on a basin-wide scale. In addition, limitations of the soil or terrain might preclude implementation of all three practices simultaneously, though again, no good basis exists for estimating where simultaneous use of the three practices could or could not be used.

Table 4. Potential long-term phosphorus reductions (mt/yr) within each land use pollution sector[1]

Tributary	Agriculture		Developed Lands		Backroads	Wastewater Treatment	Total
	Fields	Farmsteads[2]	Impervious Area	CSOs[3]			
Grand Isle/Direct	37.6	1.6	2.8	0.03	0.5	0.0	42.53
Missisquoi Bay	53.8	3.4	7.2	0.13	3.3	0.3	68.13
Lamoille	14.7	0.89	4.9	0.0	3.3	0.0	23.79
Winooski	17.7	1.2	9.5	0.08	5.6	0.8	34.88
Otter Creek	47.6	4.3	8.1	0.16	3.9	0.0	64.06
Poultney-Mettowee	19.4[4]	2.0	6.2	0.03	1.4[5]	0.0	29.03
Bouquet-Ausable	--[6]	0.86	2.3	0.0	--	0.0	3.16
Saranac-Chazy	--	1.46	3.0	0.15	--	0.0	4.61
Totals	190.8	15.71	44.0	0.58	18.0	1.1	270.19

[1] Reduction estimates are based on estimates of land use specific phosphorus loadings made by Tetra Tech (2013).

[2] "Farmsteads" refers only to regulated farmsteads - i.e. Medium and Large Farm Operations/Medium and Large CAFOs. Small Farm Operations/Small CAFOs have been excluded from this analysis because of the lack of clarity about how many exist, and because they are currently subject to less stringent regulatory standards.

[3] Insufficient data are available on CSO discharge volumes and phosphorus concentrations to accurately estimate loads or potential reductions. However, for purposes of obtaining a rough estimate of the relative magnitude of phosphorus loads from CSO discharges in comparison to other sources in the basin, CSO loading estimates were derived using some assumptions based on limited data pertaining to a few facilities, as described in Appendix B. These estimates are likely higher than actual CSO loads, as explained in more detail in Appendix B.

[4] This value reflects reductions possible from only the Vermont portion of the basin, as no data was available for the extent of these practices on the NY side of the basin.

[5] This value reflects reductions possible from only the Vermont portion of the basin, as no data was available for the phosphorus loading rate from the road network on the NY side of the basin, which is a key element of calculating possible reductions.

[6] Indicates that no data was available to estimate this value.

Secondly, managing storm water from urban impervious area (IA) often requires retrofitting practices into spaces between existing buildings, parking lots, roads, and other urban infrastructure. Very often it is impossible to retrofit enough practices to treat runoff from all IA, which we've indicated is the ultimate acceptable level for this indicator in the Indicator Table. In addition, not all IA is directly connected to waterways (via stormdrains, or otherwise), and so not every cubic foot of runoff from IA is in equal need of treatment. The IA that is connected to waterways is called effective impervious area (EIA), and though its area can be often substantially less than the total IA, its effect is disproportionately negative. The estimates of possible reductions from urban areas are based on an assumption that all impervious area is capable of receiving treatment, but for the reasons noted here, that is not an entirely realistic goal. Estimates of the extent of total IA that is feasible to treat have come from more densely populated urban areas such as Boston and have indicated that as little as 30% might be a more realistic expectation (Perkins 2013), but given the considerably lower population density of the Lake Champlain Basin's cities, a much higher proportion might be achieved here. More detailed analyses of EIA within each watershed and the potential for retrofits in more densely populated municipalities in Vermont, New York, and Quebec would provide a better estimate of what proportion of IA runoff could receive treatment and in turn what the potential for reductions might be.

In both cases described above, we had the option to develop an arbitrary reduction factor to adjust the reduction estimates according to the uncertainty noted above, or alternatively to acknowledge the uncertainty and leave the estimates in their current form. We opted for the latter path, preferring not to include calculations and adjustments to the data that could not be justified, which can imply a better understanding of what the data represent than the data actually allows (Pilkey-Jarvis and Pilkey 2008). In a similar vein, unstable river channels appear to contribute heavily to phosphorus loading in some watersheds (Tetra Tech 2013), indicating that a return to geomorphic equilibrium in could provide substantial reductions in sediment and nutrient loading. However, we did not estimate these reductions because of the substantial uncertainty about the timescale associated with achieving that equilibrium and the likely scale of the reductions once equilibrium has been achieved.

As discussed in the previous section, ensuring better compliance with current WWTF and CSO targets and addressing remaining farmstead sources with currently-existing regulations (as of the time of this writing) hold far less potential for achieving large-scale reductions, in part because a considerable amount of effort has already been exerted to alleviate these sources. The highly visible nature of these sources has made them prime targets for reducing pollution. However, it's apparent that those sources no longer represent serious potential for attaining the level of phosphorus reductions that are needed to achieve the new Lake Champlain TMDL.

In addition to clear results indicating which pollution sectors hold the most and least promise for achieving large scale phosphorus reductions, the data also make it clear that not all watersheds hold the same potential for reductions – that there is substantial geographic variation. To use agricultural fields as an example, widely implementing the three practices of interest in the Missisquoi, Grand Isle/Direct, and Otter Creek watersheds could lead to reductions of up to 125 mt/yr, which is over 70% of the total potential for all watersheds from the agricultural sector. Similarly, treating runoff from impervious areas in the Missisquoi, Winooski, and Otter Creek watersheds would address more than 50% of the potential reductions from that source category. This geographic variability represents an opportunity to apply the critical source area concept, which suggests that a small proportion of the landscape contributes disproportionately to water quality impairments. Local studies have shown that this is indeed the case, at least in the Missisquoi basin (Ghebremichael and Watzin 2010, Winchell et al. 2011). Addressing specific pollution sectors in watersheds where they are most significant provides an opportunity to make significant progress toward large reductions faster by targeting efforts into smaller geographic areas to overcome thresholds in ecosystem response (Scheffer and Carpenter 2003).

Goal 3b: Provide simple estimates of cost-effectiveness for each of the major management initiatives tracked in the Indicator table:

Total cost and cost-effectiveness also vary greatly by pollution sector and by watershed. Figure 6 shows the total cost to achieve the reductions noted in table 3. Not surprisingly, larger watersheds will incur higher costs for addressing their larger total phosphorus loads (table 5). However, variation in the relative proportions of each land use within watersheds introduces some differences in the costs between watersheds apart from their size and indicates that differences in cost-effectiveness between sectors is an important consideration.

Table 5. Estimated 20-year costs ($M) to achieve phosphorus reductions identified in table 4.

Tributary	Agriculture		Developed Lands		Backroads	Total
	Fields	Farmsteads[1]	Impervious Area	CSOs		
Grand Isle/Direct	37.12	1.68	88.38	25.05	1.26	153.49
Missisquoi Bay	137.88	4.57	182.21	7.60	35.67[2]	367.93
Lamoille	27.41	0.94	237.10	0.0	2.72	268.17
Winooski	38.30	1.93	484.40	49.63	2.99	577.25
Otter Creek	87.23	3.76	310.72	17.45	2.33	421.49
Poultney-Mettowee	64.15[3]	1.19	440.66	18.57	0.83[2]	524.65
Bouquet-Ausable	--[4]	1.52	291.05	0.0	--	292.57
Saranac-Chazy	--	1.16	343.21	49.07	--	393.44
Totals	392.17	16.75	2377.73	167.37	45.8	2999.82

[1] "Farmsteads" refers only to regulated farmsteads - i.e. Medium and Large Farm Operations/Medium and Large CAFOs. Small Farm Operations/Small CAFOs have been excluded from this analysis because of the lack of clarity about how many exist, and because they are currently subject to less stringent regulatory standards.

[2] This value reflects costs for only the Vermont portion of the basin, as no data were available for the extent of these practices on the NY side of the basin.

[3] This value reflects costs from only the Vermont portion of the basin, as no data on road BMPs were available for the NY side of the basin.

[4] Indicates that no data were available to estimate this value.

In terms of total cost, addressing stormwater in urban settings is extremely expensive (and highly variable) because of the high cost of retrofitting treatment structures into small spaces within existing infrastructure. The cost data shown here for each set of practices reflect both the initial investments – base construction costs and design and engineering costs – and estimates of annual operation and maintenance costs. In the current form of the indicator table we also calculated cost for initial investments only, since there is enormous disparity between upfront costs associated with treating urban non-point, where less than one percent of the total long-term cost is associated with annual maintenance, and the use of cropland BMPs, which present a regular annual expense. Even when extrapolating these costs out over twenty years, figure 6 and table 5 show clearly that the total cost of treating urban stormwater far exceeds the cost for managing agricultural fields, farmsteads, and backroads. In the Missisquoi watershed, the difference between the cost to manage agricultural fields and urban stormwater is small. However, in every other watershed, the difference is a factor of 2 to 10. The much larger potential for management of impervious area and of agricultural fields is the main driver of the very large cost to achieve high levels of management in these two sectors.

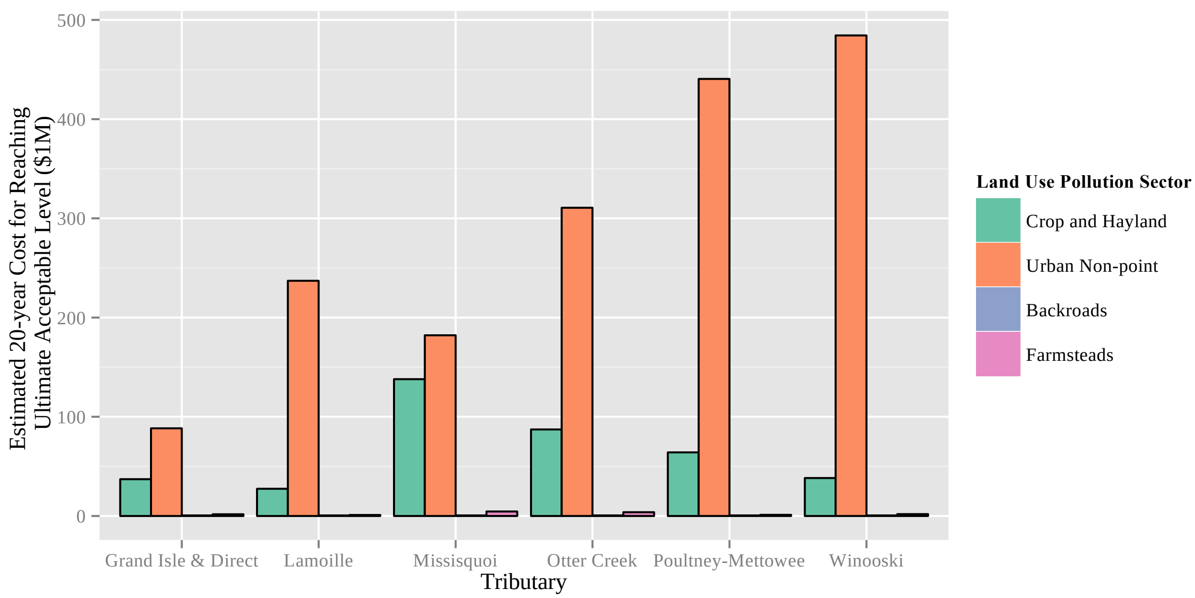

Figure 6. Total cost to achieve ultimate acceptable levels set in the Indicator table. "Crop and Hayland" category includes cover cropping, alternative manure management, and conservation tillage. Urban non-point source includes treating stormwater and eliminating CSOs.

Figure 7 shows that when effectiveness is taken into account, however, the picture can change slightly. While controlling urban pollution is still very costly[2], treating farmstead runoff, with its relatively lower effectiveness, can become more similar in terms of cost per kilogram of phosphorus, particularly in watersheds where there are higher numbers of farms still requiring structural BMPs. The effectiveness of treating stormwater ranges from roughly $1400 per kilogram of phosphorus in watersheds where the impervious area is small, to roughly $3000 per kilogram of phosphorus in watersheds with high levels of impervious surface. Implementing field practices in agricultural cropland and making wide use of backroad BMPs are orders of magnitude more efficient than their counterparts.

[2] Cost-effectiveness estimates for CSO elimination have been excluded from the urban non-point category in figure 7. At an average of $35,000 per kilogram of phosphorus, those data obscure differences between the other categories and distort the cost-effectiveness of treating stormwater, which represents the bulk of the real phosphorus reduction opportunity.

Goal 4: Identify important knowledge gaps in our understanding of what management has occurred or in the effects of that management:

One key element of an adaptive approach to any sort of resource management, including improving water quality, is to clearly articulate any gaps in knowledge or major sources of uncertainty. This process of articulating what is unknown and how those uncertainties may impact current decision-making can often point the way toward research efforts that will truly improve the long-term effectiveness of management decisions. During the course of this project, we uncovered three major categories of gaps in the collective knowledge about the management of Lake Champlain, each with different implications for the results discussed above.

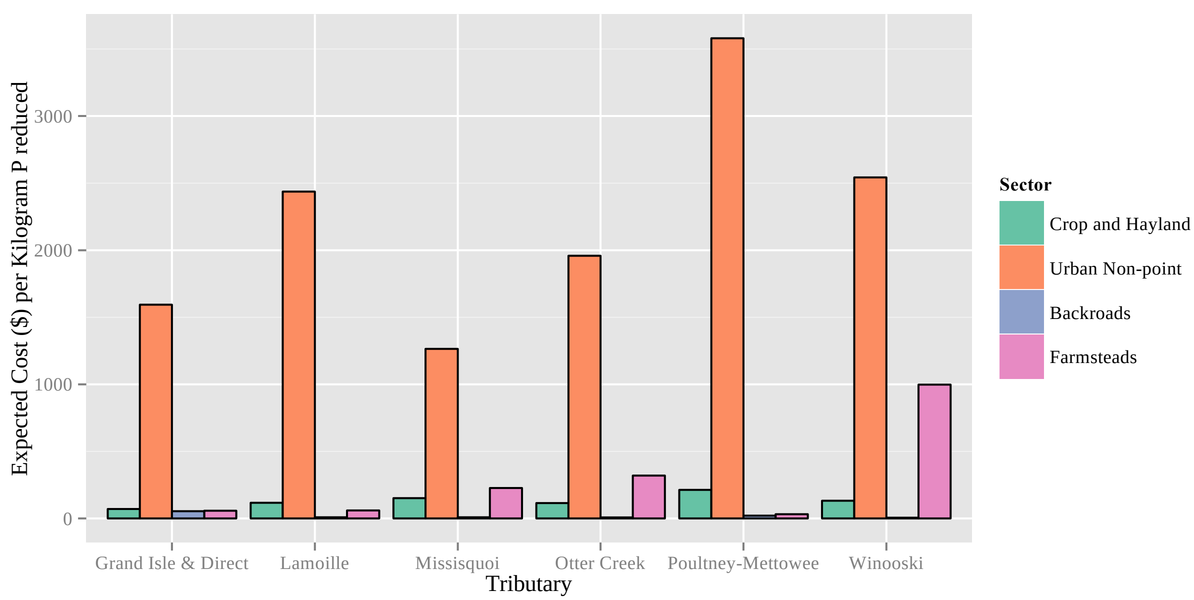

Figure 7. Average cost-effectiveness across practices within land use sectors. "Crop and Hayland" category includes cover cropping, alternative manure management, and conservation tillage. Urban non-point source includes treating stormwater but excludes eliminating CSOs.

The first major category of uncertainty is the role of variability in several of the factors key to the Indicator table estimates of reductions and cost-effectiveness. One key part of the method to calculate potential reductions used values of treatment efficiencies (called reduction rates) for each practice. The estimates we used reflected average values seen in studies in the scientific literature. However, unlike many of the other factors used in the calculations, treatment efficiencies were applied identically throughout the Lake Champlain basin when in fact there is likely to be a large amount of variation in the effectiveness of each practice at various implementation sites within and among sub-basins. Though the single estimate may be a reflection of the average performance across a wide range of conditions, the true performance within a single watershed – even a large one – may depart from that average enough to lead to different estimates of potential reductions.

This same variability also can play a significant role in the estimates of cost to implement management policies. The Center for Watershed Protection, a non-profit organization focused on watershed management issues, noted in their Urban Subwatershed Restoration Manuals that the cost to implement individual stormwater retrofits can vary over a factor of three to ten, depending on the type of practice in question (Schueler et al. 2007). This variability in cost is driven by several considerations that also vary geographically and over time, including the spatial arrangement of existing infrastructure, the complexity of the design process, the need for permitting, the cost of land, and local labor rates. All of this variability is important to consider in the cost estimates that we use for the agricultural practices, urban stormwater practices, backroad maintenance practices.

Box 3. Variability & Uncertainty

In structured decision making and adaptive management contexts, the terms *variability* and *uncertainty* refer to different concepts, and their use in this report reflects that distinction.

Variability refers to the property of predictable variation around an expected value. The practice of statistics often expresses this predictability as the standard deviation of the mean, and reliably characterizing the standard deviation requires a number of samples of the quantity in question. While more data can lead to more precise estimates of variability, the inherent variability of a population cannot be reduced.

Uncertainty, on the other hand, refers to the situation where there is no expected value for the quantity in question. Uncertainty can occur as a result of a lack of applicable data, or as a result of major disagreements between existing datasets. When uncertainty stands in the way of good decision-making, expert elicitation methods can be used to generate defensible expert opinion (Morgan and Henrion 1990). In contrast to variability, new data can and do reduce uncertainty.

Unfortunately, we were unable to characterize this variability sufficiently well to use that information in calculating potential reductions or cost-effectiveness estimates for this iteration of the Indicator table. However, in future revisions of the table, as new data are incorporated, estimates of the variability for both reduction rates and practice costs will begin to emerge and can be incorporated into new calculations. While new data can help quantify and characterize this sort of variability, it is important to remember that the variability cannot be reduced (see box 3). Characterizing and accounting for the variability in treatment efficiencies, for example, serves mainly to understand the range of potential reductions that might be expected given the information at hand, and therefore help to reduce the magnitude of any surprises when the average reductions and average costs don't apply to all watersheds equally.

The second major source of uncertainty that we uncovered is often referred to as parameter uncertainty. This describes the situation where no good average estimate exists, and we are forced to pick one that we know has limitations. This is in contrast to data variability, where we were able to find and use a good average estimate for something of interest in a calculation but unable to know how much that estimate might vary from location to location. The clearest example of this situation in the Indicator table is in estimates for the current extent of management practices. Many of these estimates have some limitations that we were unable to avoid, often due to gaps in how these practices are tracked within and across jurisdictions. Specifically, the rate of implementation of cover crops is subject to a large amount of uncertainty. The data that we present here comes from the Vermont Agency of Agriculture (VT AAFM), which provides payment to farmers who implement cover crops on their fields. However, farmers can also enroll in cost-share programs administered by the USDA Natural Resources Conservation Service (NRCS), which may provide additional cost share to those same VTAAFM-funded fields, or provide payment for different fields. Many farmers also implement cover crops without receiving compensation, either because they exceed the acreage caps set by VT AAFM and NRCS, or because they believe that cover crops are an economically or environmentally beneficial practice for their farm. Therefore, the VT AAFM data do not account for all cover cropping that occurs in Vermont and the degree of overlap with NRCS cover cropping programs and the extent of voluntary cover cropping is unknown. This category of uncertainty also applies to other management practices including structural farmsteads BMPs, and stormwater management practices.

The third gap in our knowledge concerns the environmental effects of management actions, particularly in large watersheds. Many of the reduction estimates presented here used reduction rates that were determined in small-scale site-level studies or, in some cases, small watershed studies. However, larger-scale studies have shown that when these practices are implemented widely across a watershed that the reduction rates are often far less than they appear at small scales, i.e. watershed-level reductions are not the sum of field-level reductions. For example, Meals (1996) found that when measured at the field-scale, several practices, including the installation of vegetated filter strips and the elimination of winter manure spreading, led to very high phosphorus reduction rates, but that at the watershed scale, phosphorus load reductions were not significant over an 11-year monitoring period. Similarly, Davie and Lant (1994) predicted reduction of stream sediment loads in two large watersheds of 24% and 37% after widespread enrollment of agricultural land into the USDA Conservation Reserve Program (CRP). However, in the three years following the CRP enrollment, sediment exports were reduced just 0.0125% and 0.265% in each watershed. Both of these studies indicate that in-stream (and potentially other) processes play an important role in dampening the effects of upstream management and contribute to long lag times in realizing these effects downstream. This hypothesis is supported by numerous studies of lag times and the driving role of climate, flow, and in-stream re-suspension of sediments in generating nutrient loads (Richards et al. 2009, Meals et al. 2010, Niemitz et al. 2013). Understanding how in-stream processes mitigate the effect that management practices have on phosphorus loads would enable us to generate more realistic predictions of how long it will take to achieve large-scale phosphorus reductions and how large those reductions could be.

Conclusions & Applications:

Using the Indicator Table for decision-making

Our primary intention is for these data to inform future management decisions for Lake Champlain. Therefore, the rest of this discussion focuses on potential uses for the data moving forward, and not on a discussion of the effectiveness of past management policies.

The measures of the universe of need, expected phosphorus reductions, and expected cost to achieve those reductions for each indicator are all meant to be inputs to a rigorous and analysis-focused decision-making process focused on the best way to achieve wide-scale reductions in tributary phosphorus loads. These sorts of decision-making processes use data to enable decision-makers to weigh several alternative management strategies against each other according to their likely outcomes, and to assess the tradeoffs that would be required by selecting any combination of the alternatives (Keeney 1982, Gregory and Keeney 2002). There are two natural forums for this sort of process in the context of managing phosphorus in Lake Champlain. The first is in the redevelopment of commitments in *Opportunities for Action*, where the LCBP and its partners commit to accomplishing a suite of high-priority phosphorus management targets over the following five-to-seven years. The second is in the development and refinement of Tactical Basin Plans in Vermont, which will follow the approval of Vermont's revised Lake Champlain Phosphorus TMDL in 2014, and in similar watershed planning efforts in New York and Quebec.

One of the primary aims of revising the commitments in OFA is for LCBP's partner agencies to commit to a suite of management policies that together constitute a coordinated and coherent management strategy that reflects recent progress, current management priorities, and best professional judgment of the most effective policies and practices. A common sense evaluation of the data we present would indicate that OFA commitments focusing on implementing phosphorus conservation practices on crop and hayland by the LCBP and its partners in the Lake Champlain basin would provide the best use of time and financial resources to reduce tributary phosphorus loads, because that pollution sector presents the most cost-effective and wide-reaching phosphorus reductions. However, this common sense approach assumes that 1) resources are limited to the extent that full management of every pollution sector is not possible, 2) the only two important factors for setting strategic management priorities are total reduction potential and total cost, and that 3) implementation is the best use of available funds. While the first of these assumptions is likely to be true, the other two are not.

In addition to total reduction potential and total cost of implementation, each of the LCBP partners would likely identify several other criteria that are more or less important or desirable for guiding management priorities (Gregory 2013). Some of these criteria might include the timeliness of management effects (e.g. policies with long-term effects vs. short-term effects), the ability to leverage existing legislation to encourage further reductions, equity in cost and benefit[3] between geographic sections of the lake (e.g. jurisdictions, north vs. south lake), equity in cost and benefit between different pollution sectors (urban vs. agricultural), or equitable distribution of responsibility between public and private entities. A thoughtful process of eliciting and weighing these and other criteria and understanding how new OFA commitments perform in relation to these criteria is clearly an important step toward making commitments to more efficient and effective phosphorus management policies. Multiple criteria decision analysis (MCDA) methods are designed to do exactly this and are a core element in SDM practice. The data we report here are intended to be an input to this process, as some of the conclusions lend themselves directly to inclusion in an SDM process rooted in MCDA.

The third assumption listed above is consistent with the higher value that organizations and the public generally place on implementation of management actions relative to other activities associated with environmental management, such as monitoring or research (Allan and Curtis 2005). However, monitoring and research have clear value for understanding variability in BMP efficiency and for reducing uncertainty, and many studies have documented that investments in such activities pay for themselves over time in the context of resource management (Borisova et al. 2005, Kangas et al. 2010, Williams et al. 2011). There are two important ways that research and monitoring can improve the decision-making process and outcomes. Firstly, variability in any estimate, such as the phosphorus reduction rate of a particular management practice in a watershed or the cost to implement that same practice in a new watershed, often interacts with the variability of other estimates in somewhat unpredictable ways. These interactions can produce surprising and unforeseeable results, particularly if the

[3] The term "cost" is meant in this context to include the social cost of being recognized as responsible for the lake's impaired status in addition to realized financial burden. "Benefit" is meant to recognize that funding streams are often concomitant with the responsibility for environmental clean-up activities.

range of variability for each estimate is not well understood. For example, while we report the average reduction rate for cover cropping across the Champlain basin, the actual reduction rate in any tributary may be higher or lower than the average. Similarly, the actual cost to implement cover crops in that same tributary may also depart from the average, and the interaction of these sources of variability may mean that the cost-effectiveness of cover cropping on a local scale may be much higher or much lower than expected based on the average estimates. Understanding the extent of variability for each estimate and how they might interact can help decision-makers generate a more realistic range of outcomes, reducing the likelihood of a result that deviates widely from expectations.

While we did not perform any Value of Information analyses, our data do point to several examples of variability that are good candidates for more explicit characterization, including reduction rates for the most common management practices, and the costs to implement those practices. These figures are clearly key to the estimates of potential reductions for each watershed and the estimates of cost effectiveness, both of which are critical pieces of information for good decision making. The data also indicate that some values, while subject to high variability, are probably not worth further characterization because the result of better understanding would not inform future decisions differently. For example, phosphorus loading from combined sewer overflow events is subject to very high variability because of the sporadic timing, unpredictable water quality of the effluent, and the wide range of volumes and intensities that can occur in these events. However, the total loading from CSOs accounts for 1.3% of the urban phosphorus load basin wide, and further understanding of CSO events is unlikely to move their management from its current low-priority status (in terms of phosphorus) to a high priority status in the context of nutrient management (though this may be a different priority in the context of toxin pollution reduction).

The second benefit of research and monitoring is that these activities, when designed to target specific uncertainties, can shed light on the complex relationships between policies and their environmental effects. Uncovering these relationships can reduce the length of time that an ineffective policy is relied upon before being changed, or, more ideally, can reduce the likelihood of implementing ineffective policies in the first place (Morgan and Henrion 1990, Lempert et al. 2003, NRC 2007). In addition, gaining this understanding can generate more broadly applicable knowledge about how ecosystems respond to management and about what forms and targets of management are most effective. Developing this deeper ecological understanding is the one of the key intentions of the adaptive management approach (Walters 1986, Gunderson 2001), and can be extremely useful for addressing other similar management problems.

A second application of these data is to assist the State of Vermont in the process of developing Tactical Basin Plans to achieve the loading targets set in Vermont's Total Maximum Daily Load (TMDL) for phosphorus, which is currently under revision by the EPA. As part of the TMDL revision effort, the EPA developed a scenario tool to assist the State of Vermont in implementing a plan to achieve the TMDL reduction recommendations. These data could be of great use for developing scenarios in each major basin to achieve the loading targets set in the TMDL. Because the Indicator Table makes slightly different assumptions and uses slightly different data sources than the EPA scenario tool, the different estimates of potential reductions they produce can provide additional information that each tool could not provide independently. These small differences between the tools' estimates can lend some insight into the range of uncertainty in the calculations and the effects of the assumptions of each method. These insights in turn help to provide greater confidence when the results are similar, and can point to key assumptions in need of further investigation when the results are not (Arabi et al. 2012). In both situations, the average model predictions are generally more accurate than either individual model, which helps to produce more realistic expectations on the part of the decision-makers and the public (Osmond et al. 2012). The practice of using multiple models in this way for complex problems has gained wide use in recent years because of the increased understanding that decision makers get from seeing multiple solutions to a problem (Lempert et al. 2003, NRC 2007). In the context of adaptive management, the use of multiple models has become commonplace not only because of the ease with which the data can be integrated in statistically defensible ways, but also because the difference in performance between models can indicate the level of overall uncertainty in the system (Martin et al. 2011), and because over time model performance can be compared to monitoring results to provide increased confidence in the predictions from a subset of the models (Johnson and Williams 1999).

Maintaining and updating the Indicator Table

Adaptive management requires a continual process of management decisions, monitoring their outcomes, and then using new monitoring information to inform the next round of decisions. In order to be effective over the long term, all parts of the Indicator Table, including the data elements and the indicators themselves, should be revisited at regular intervals as better information becomes available. In particular, Current State information (for both the Implementation and Ecosystem State indicators) should continue to be updated with new monitoring data, and practice reduction rates and unit cost estimates should be updated as studies within the Lake Champlain basin develop more locally-relevant data.

One of the purposes of adaptive management frameworks is to provide an explicit and regular opportunity for new monitoring data to be used to revisit and update management objectives as more is learned about the feasibility of attaining specific objectives. Over time, as the quality of the data increases, new analyses of those data should in turn inform the revision of management objectives held by the LCBP and its partners. New indicators will be added to the Indicator Table as new management initiatives are developed, and existing indicators will be eliminated as the initiatives they represent are de-emphasized. Because the Indicator Table is intended as a decision-aid for the LCBP's management strategy, the Indicator Table should be revised in preparation for OFA updates.

Appendix A – Phosphorus Indicator Table

Missisquoi Basin	Current State	Acceptable Level (short term)	Acceptable Level (ultimate)	Expected short-term P reduction (mt/yr)	Expected ultimate P reduction (mt/yr)	Initial Investments to reach ultimate acceptable level ($)	Real 20-year cost to reach ultimate level ($)	Expected Cost ($) per expected kg P	Data Sources
Agricultural Lands									
Percent of agricultural land under enhanced land management for:									
a. Cover cropping	1.06%	11.10%	54.44%	2.7	14.4	$1,673,455	$33,469,106.87	$116	1,2,17
b. Alternative manure spreading methods	17.99%	37.21%	100.00%	3.6	15.5	$3,595,166	$71,903,322.13	$231	1,2,18
c. Conservation tillage	16.40%	21.30%	54.44%	2.0	15.4	$1,625,611	$32,512,220.77	$105	1,2,17
Percent of agricultural land acres managed under an approved Nutrient Management Plan, by farm type (LFO, MFO, SFO)	83.99%	83.99%	100%	0.0	8.5				3,7
Percent of regulated farms (LFOs/Large CAFOs & MFOs/Medium CAFOs) with regularly-maintained Best Management Practice structures, by farm type									
a. Manure storage (practices/farms)	L - 18/7 M - 25/30	L - 18/7 M - 30/30	100%	0.05	0.05	$700,000	$1,850,000	$685	5,6,7
b. Silage leachate treatment (practices/farms)	L - 5/7 M - 17/30	L - 7/7 M - 30/30	100%	1.02	1.02	$675,000	$1,390,500	$33	5,6,8
c. Barnyard runoff treatment (practices/farms)	L - 4/7 M - 29/30	L - 7/7 M - 30/30	100%	0.02	0.02	$60,000	$201,000	$175	5,6,7
d. Milkhouse waste treatment (practices/farms)	L - 2/7 M - 2/30	L - 7/7 M - 30/30	100%	2.31	2.31	$548,625	$1,124,250	$12	5,6,8
Percent of farm inspections identifying substantial violations of relevant agricultural regulation	9.00%		0%		0.0				5
Developed Lands									
Percent of all permitted construction stormwater sites under the Construction General Permit in substantial compliance with the permit	46%	NA		NA	0.0			NA	5
Percent of all permitted construction stormwater sites with Individual Permits in substantial compliance with their permit	90%	NA		NA	0.0			NA	5
Percent of all permitted operational stormwater sites in substantial compliance with their permit	85%	NA		NA	0.0			NA	5
Percent of impervious area that is under stormwater management	1.85%	NA	100%	NA	7.2	$181,222,179	$182,206,379	$1,264	9,11,19,20,21
Number of combined sewer overflows remaining in the Lake Champlain Basin	22		0		0.1	$167,187,649	$167,187,649	$64,303	10,12,13,22,30
Number of towns with good water quality protection provisions in town plans and zoning ordinances, including incorporation of Low Impact Development standards where appropriate.	67%								5,10
Percent of tree canopy coverage within urban landscape zones in the Lake Champlain Basin	7.84%								23
Rural Lands/Backroads									
Percent of inspected sampling units within logging jobs in the Vermont and New York portions of the Lake Champlain Basin where harvesting operations have caused more than trace amounts of sediment to enter streams.	17%								24
Percent of towns participating in the Better Backroads Program (or equivalent program)	19%		100%	0.0	0.0			NA	5
Percent of towns that have completed road erosion needs inventories and capital budget plans	16%		100%	0.0	0.0			NA	5
Percent of priority erosion control projects identified in road erosion needs inventories that are completed	57%		100%		3.3	$199,331	$578,060	$9	5,15,16
River, Floodplain, and Wetland Conservation & Restoration									
Percent of towns having adopted Town and Bridge Standards in accordance with Act 110 that contain a suite of water quality based BMPs	94%								10,25
Percent of Basin communities with adopted municipal Fluvial Erosion Hazard ordinances	2%								5
Wastewater									
Percent of facilities meeting their TMDL wasteload (VT & NY) or phosphorus (PQ) allocations (R)	86%	100%	100%	0.27	0.27				26
Percent of wastewater treatment facilities having an approved sewage spill prevention plan for (a) the treatment plant and (b) the collection system (P)	(a) 100% (b) 0%	a. 100% b. 75%	a. 100% b. 100%						27
Ecosystem Process & Ecosystem State Indicators:									
Median animal units per acre	0.7								3
avg. mt/yr P loss from cropland (including hay)	90.2		TBD						2
avg. mt/yr P loss from farmsteads	0.9		TBD						2
avg. mt/yr P loss from urban areas	15.3		TBD						2
avg. mt/yr P loss from road network	11.9		TBD						2
Best recent estimates for % of land in the following categories:									
a. annual crops	11.50%								2
b. hay, pasture, lawn	14.64%								2
c. impervious surface	1.63%								2
Percent of river reaches in stream geomorphic assessment category II (incised and steepening) or III (incised and widening) (R)	55%	50%	30%						
5 year avg. wastewater phosphorus load (2007-2011) (mt/y)	2.15		TBD						28,29
5 year avg. non-point phosphorus load (2007-2011) (mt/y)	261		TBD						28,29
5 year avg. total tributary P loads (2007-2011) (mt/y)	263		TBD						28,29
5-year Ratio of dissolved P : total P in tributary loads (2007-2012 conc.)	0.386								28,29

Grand Isle & Lake Champlain Direct	Current State	Acceptable Level (short term)	Acceptable Level (ultimate)	Expected short-term P reduction (mt/yr)	Expected ultimate P reduction (mt/yr)	Initial Investments to reach ultimate acceptable level ($)	Real 20-year cost to reach ultimate level ($)	Expected Cost ($) per expected kg P	Data Sources
Agricultural Lands									
Percent of agricultural land under enhanced land management for:									
a. Cover cropping	1.74%	11.10%	54.97%	1.0	5.5	$415,087	$8,301,730	$75	1,2,17
b. Alternative manure spreading methods	0.00%	16.40%	100.0%	1.7	10.3	$1,027,627	$20,552,540	$99	1,2,18
c. Conservation tillage	2.63%	0.47%	54.97%	0.0	11.6	$413,273	$8,265,456	$36	1,2,17
Percent of agricultural land acres managed under an approved Nutrient Management Plan, by farm type (LFO, MFO, SFO)	64.70%	75.00%	100%	3.0	10.2				3,7
Percent of regulated farms (LFOs/Large CAFOs & MFOs/Medium CAFOs) with regularly-maintained Best Management Practice structures, by farm type									
a. Manure storage (practices/farms)	L - NA M - 28/17	L - NA M - 28/17	100%	0.0	0.0	$0	$0	NA	5,6,7
b. Silage leachate treatment (practices/farms)	L - NA M - 5/17	L - NA M - 17/17	100%	0.7	0.7	$540,000	$1,120,500	$84	5,6,8
c. Barnyard runoff treatment (practices/farms)	L - NA M - 20/17	L - NA M - 20/17	100%	0.0	0.0	$0	$0	NA	5,6,7
d. Milkhouse waste treatment (practices/farms)	L - NA M - 1/17	L - NA M - 17/17	100%	0.9	0.9	$266,000	$559,000	$31	5,6,8
Percent of farm inspections identifying substantial violations of relevant agricultural regulation	5.00%		0%		0.0				5
Developed Lands									
Percent of all permitted construction stormwater sites under the Construction General Permit in substantial compliance with the permit	46%	NA		NA	0.0			NA	5
Percent of all permitted construction stormwater sites with Individual Permits in substantial compliance with their permit	90%	NA		NA	0.0			NA	5
Percent of all permitted operational stormwater sites in substantial compliance with their permit	85%	NA		NA	0.0			NA	5
Percent of impervious area that is under stormwater management	16.26%	NA	100%	NA	2.8	$88,345,542	$88,378,792	$1,593	9,11,19,20,21
Number of combined sewer overflows remaining in the Lake Champlain Basin	1		0		0.0	$25,054,719	$25,054,719	$41,758	12,13,22,30
Number of towns with good water quality protection provisions in town plans and zoning ordinances, including incorporation of Low Impact Development standards where appropriate.	23%								5
Percent of tree canopy coverage within urban landscape zones in the Lake Champlain Basin	10.10%								23
Rural Lands/Backroads									
Percent of inspected sampling units within logging jobs in the Vermont and New York portions of the Lake Champlain Basin where harvesting operations have caused more than trace amounts of sediment to enter streams.	17%								24
Percent of towns participating in the Better Backroads Program (or equivalent program)	60%		100%	0.0	0.0			NA	5
Percent of towns that have completed road erosion needs inventories and capital budget plans	16%		100%	0.0	0.0			NA	5
Percent of priority erosion control projects identified in road erosion needs inventories that are completed	57%		100%		0.5	$199,331	$578,060	$54	5,15,16
River, Floodplain, and Wetland Conservation & Restoration									
Percent of towns having adopted Town and Bridge Standards in accordance with Act 110 that contain a suite of water quality based BMPs	75%								25
Percent of Basin communities with adopted municipal Fluvial Erosion Hazard ordinances	0%								5
Wastewater									
Percent of facilities meeting their TMDL wasteload (VT & NY) or phosphorus (PQ) allocations (3-yr avg)	100%	100%	100%	0.0	0.0				26
Percent of wastewater treatment facilities having an approved sewage spill prevention plan for (a) the treatment plant and (b) the collection system (P)	(a) 100% (b) 0%	a. 100% b. 75%	a. 100% b. 100%						27
Ecosystem Process & Ecosystem State Indicators:									
Median animal units per acre	0.58								3
avg. mt/yr P loss from cropland (including hay)	49.2		TBD						2
avg. mt/yr P loss from farmsteads	0.1		TBD						2
avg. mt/yr P loss from urban areas	6.9		TBD						2
avg. mt/yr P loss from road network	1.9		TBD						2
Best recent estimates for % of land in the following categories:									
a. annual crops	21.64%								2
b. hay, pasture, lawn	26.25%								2
c. impervious surface	3.61%								2
Percent of river reaches in stream geomorphic assessment category II (incised and steepening) or III (incised and widening) (R)	71%	50%	30%						
5 year avg. wastewater phosphorus load (2007-2011) (mt/y)	21.84		TBD						28,29
5 year avg. non-point phosphorus load (2007-2011) (mt/y)	196		TBD						28,29
5 year avg. total tributary P loads (2007-2011) (mt/y)	218		TBD						28,29
6-year Ratio of dissolved P : total P in tributary loads (2007-2012 conc.)									

Lamoille River Basin	Current State	Acceptable Level (short term)	Acceptable Level (ultimate)	Expected short-term P reduction (mt/yr)	Expected ultimate P reduction (mt/yr)	Initial Investments to reach ultimate acceptable level ($)	Real 20-year cost to reach ultimate level ($)	Expected Cost ($) per expected kg P	Data Sources
Agricultural Lands									
Percent of agricultural land under enhanced land management for:									
a. Cover cropping	2.94%	11%	32.0%	0.6	2.0	$156,208	$3,124,159	$79	1,2,17
b. Alternative manure spreading methods	0.00%	16.40%	100.0%	0.8	4.8	$1,053,420	$21,068,401	$221	1,2,18
c. Conservation tillage	0.21%	0.47%	32.0%	0.0	3.2	$160,997	$3,219,949	$50	1,2,17
Percent of agricultural land acres managed under an approved Nutrient Management Plan, by farm type (LFO, MFO, SFO)	64.70%	75.00%	100%	1.4	4.7				3,7
Percent of regulated farms (LFOs/Large CAFOs & MFOs/Medium CAFOs) with regularly-maintained Best Management Practice structures, by farm type									
a. Manure storage (practices/farms)	L - NA M - 19/10	L - NA M - 19/10	100%	0.00	0.00	$0	$0	NA	5,6,7
b. Silage leachate treatment (practices/farms)	L - NA M - 4/10	L - NA M - 10/10	100%	0.33	0.33	$270,000	$580,500	$87	5,6,8
c. Barnyard runoff treatment (practices/farms)	L - NA M - 11/10	L - NA M - 11/10	100%	0.00	0.00	$0	$0	NA	5,6,7
d. Milkhouse waste treatment (practices/farms)	L - NA M - 0/10	L - NA M - 10/10	100%	0.56	0.56	$166,250	$359,500	$32	5,6,8
Percent of farm inspections identifying substantial violations of relevant agricultural regulation	5.00%		0%	0.0	0.0				5
Developed Lands									
Percent of all permitted construction stormwater sites under the Construction General Permit in substantial compliance with the permit	46%	NA		NA	0.0			NA	5
Percent of all permitted construction stormwater sites with Individual Permits in substantial compliance with their permit	90%	NA		NA	0.0			NA	5
Percent of all permitted operational stormwater sites in substantial compliance with their permit	85%	NA		NA	0.0			NA	5
Percent of impervious area that is under stormwater management	5.27%	NA	100%	NA	4.9	$237,065,169	$237,098,419	$2,437	9,11,19,20,21
Number of combined sewer overflows remaining in the Lake Champlain Basin	0	0	0	0	0.0	$0		$0	12,13,22,30
Number of towns with good water quality protection provisions in town plans and zoning ordinances, including incorporation of Low Impact Development standards where appropriate.	23%								5
Percent of tree canopy coverage within urban landscape zones in the Lake Champlain Basin	12.76%								23
Rural Lands/Backroads									
Percent of inspected sampling units within logging jobs in the Vermont and New York portions of the Lake Champlain Basin where harvesting operations have caused more than trace amounts of sediment to enter streams.	17%								24
Percent of towns participating in the Better Backroads Program (or equivalent program)	85%		100%	0	0.0			NA	5
Percent of towns that have completed road erosion needs inventories and capital budget plans	16%		100%	0	0.0			NA	5
Percent of priority erosion control projects identified in road erosion needs inventories that are completed	57%		100%		3.3	$199,331	$578,060	$9	5,15,16
River, Floodplain, and Wetland Conservation & Restoration									
Percent of towns having adopted Town and Bridge Standards in accordance with Act 110 that contain a suite of water quality based BMPs	60%								25
Percent of Basin communities with adopted municipal Fluvial Erosion Hazard ordinances	5%								5
Wastewater									
Percent of facilities meeting their TMDL wasteload (VT & NY) or phosphorus (PQ) allocations (R)	88%	100%	100%	0.0	0.0				26
Percent of wastewater treatment facilities having an approved sewage spill prevention plan for (a) the treatment plant and (b) the collection system (P)	(a) 100% (b) 10%	a. 100% b. 75%	a. 100% b. 100%						27
Ecosystem Process & Ecosystem State Indicators:									
Median animal units per acre	0.49								3
avg. mt/yr P loss from cropland (including hay)	22.7		TBD						2
avg. mt/yr P loss from farmsteads	0.5		TBD						2
avg. mt/yr P loss from urban areas	10.7		TBD						2
avg. mt/yr P loss from road network	11.8		TBD						2
Best recent estimates for % of land in the following categories:									
a. annual crops	2.77%								2
b. hay, pasture, lawn	10.45%								2
c. impervious surface	1.99%								2
Percent of river reaches in stream geomorphic assessment category II (incised and steepening) or III (incised and widening) (R)	75%	50%	30%						
5 year avg. wastewater phosphorus load (2007-2011) (mt/y)	1.31		TBD						28,29
5 year avg. non-point phosphorus load (2007-2011) (mt/y)	68		TBD						28,29
5 year avg. total tributary P loads (2007-2011) (mt/y)	69		TBD						28,29
6-year Ratio of dissolved P : total P in tributary loads (2007-2012 conc.)	0.347								28,29

Winooski Basin	Current State	Acceptable Level (short term)	Acceptable Level (ultimate)	Expected short-term P reduction (mt/yr)	Expected ultimate P reduction (mt/yr)	Initial Investments to reach ultimate acceptable level ($)	Real 20-year cost to reach ultimate level ($)	Expected Cost ($) per expected kg P	Data Sources
Agricultural Lands									
Percent of cropland (incl. hay) under enhanced land management for:									
a. Cover cropping	1.50%	11.10%	29.20%	0.8	2.4	$196,065	$3,921,297.16	$83	1,2,17
b. Alternative manure spreading methods	0.13%	16.40%	100.00%	1.0	6.0	$1,524,978	$30,499,569.33	$255	1,2,18
c. Conservation tillage	2.33%	0.47%	29.20%	0.0	3.4	$194,067	$3,881,335.06	$56	1,2,17
Percent of agricultural land acres managed under an approved Nutrient Management Plan, by farm type (LFO, MFO, SFO)	64.70%	75.00%	100%	1.7	5.9				3,7
Percent of regulated farms (LFOs/Large CAFOs & MFOs/Medium CAFOs) with regularly-maintained Best Management Practice structures, by farm type									
a. Manure storage (practices/farms)	L - 0/1 M - 23/11	L - 1/1 M - 23/11	100%	0.01	0.01	$140,000	$730,000	$3,476	5,6,7
b. Silage leachate treatment (practices/farms)	L - 0/1 M - 4/11	L - 1/1 M - 11/11	100%	0.54	0.54	$360,000	$760,500	$70	5,6,8
c. Barnyard runoff treatment (practices/farms)	L - 0/1 M - 28/11	L - 1/1 M - 28/11	100%	0.01	0.01	$15,000	$111,000	$419	5,6,7
d. Milkhouse waste treatment (practices/farms)	L - 0/1 M - 3/11	L - 1/1 M - 11/11	100%	0.60	0.60	$149,625	$326,250	$27	5,6,8
Percent of farm inspections identifying substantial violations of relevant agricultural regulation	5.00%		0%	0.0	0.0				5
Developed Lands									
Percent of all permitted construction stormwater sites under the Construction General Permit in substantial compliance with the permit	46%	NA		NA	0.0			NA	5
Percent of all permitted construction stormwater sites with Individual Permits in substantial compliance with their permit	90%	NA		NA	0.0			NA	5
Percent of all permitted operational stormwater sites in substantial compliance with their permit	85%	NA		NA	0.0			NA	5
Percent of impervious area that is under stormwater management	13.72%	NA	100%	NA	9.5	$484,363,023	$484,396,273	$2,543	9,11,19,20,21
Number of combined sewer overflows remaining in the Lake Champlain Basin	10		0		0.1	$49,627,223	$49,627,223	$31,017	12,13,22,30
Percentage of towns with good water quality protection provisions in town plans and zoning ordinances, including incorporation of Low Impact Development standards where appropriate.	23%								5
Percent of tree canopy coverage within urban landscape zones in the Lake Champlain Basin	15.50%								23
Rural Lands/Backroads									
Percent of inspected sampling units within logging jobs in the Vermont and New York portions of the Lake Champlain Basin where harvesting operations have caused more than trace amounts of sediment to enter streams.	17%								24
Percent of towns participating in the Better Backroads Program (or equivalent program)	72%		100%	0.0	0.0			NA	5
Percent of towns that have completed road erosion needs inventories and capital budget plans	16%		100%	0.0	0.0			NA	5
Percent of priority erosion control projects identified in road erosion needs inventories that are completed	57%		100%		5.6	$199,331	$578,060	$5	5,15,16
River, Floodplain, and Wetland Conservation & Restoration									
Percent of towns having adopted Town and Bridge Standards in accordance with Act 110 that contain a suite of water quality based BMPs	66%								25
Percent of Basin communities with adopted municipal Fluvial Erosion Hazard ordinances	19%				0.0			NA	5
Wastewater									
Percent of facilities meeting their TMDL wasteload (VT & NY) or phosphorus (PQ) allocations	95%	100%	100%	0.77	0.77				26
Percent of wastewater treatment facilities having an approved sewage spill prevention plan for (a) the treatment plant and (b) the collection system	(a) 100% (b) 35%	a. 100% b. 75%	a. 100% b. 100%						27
Ecosystem Process & Ecosystem State Indicators:									
Median animal units per acre	0.45								3
avg. mt/yr P loss from cropland (including hay)	28.5		TBD						2
avg. mt/yr P loss from farmsteads	0.3		TBD						2
avg. mt/yr P loss from urban areas	23		TBD						2
avg. mt/yr P loss from road network	20.2		TBD						2
Best recent estimates for % of land in the following categories:									
a. annual crops	2.43%								2
b. hay, pasture, lawn	11.10%								2
c. impervious surface	2.98%								2
Percent of river reaches in stream geomorphic assessment category II (incised and steepening) or III (incised and widening)	70%	50%	30%						
5 year avg. wastewater phosphorus load (2007-2011) (mt/y)	8.26		TBD						28,29
5 year avg. non-point phosphorus load (2007-2011) (mt/y)	244		TBD						28,29
5 year avg. total tributary P loads (2007-2011) (mt/y)	252		TBD						28,29
6-year Ratio of dissolved P : total P in tributary loads (2007-2012 conc.)	0.304								28,29

Otter Creek Basin	Current State	Acceptable Level (short term)	Acceptable Level (ultimate)	Expected short-term P reduction (mt/yr)	Expected ultimate P reduction (mt/yr)	Initial Investments to reach ultimate acceptable level ($)	Real 20-year cost to reach ultimate level ($)	Expected Cost ($) per Expected kg P	Data Sources
Agricultural Lands									
Percent of agricultural land under enhanced land management for:									
a. Cover cropping	0.91%	11.10%	33.30%	2.3	7.2	$528,855	$10,577,100	$73	1,2,17
b. Alternative manure spreading methods	1.77%	16.40%	100.00%	2.3	15.4	$3,327,736	$66,554,716	$217	1,2,18
c. Conservation tillage	5.06%	0.47%	33.30%	0.0	9.5	$504,769	$10,095,378	$53	1,2,17
Percent of agricultural land acres managed under an approved Nutrient Management Plan, by farm type (LFO, MFO, SFO)	64.70%	75.00%	100%	4.5	15.5				3,7
Percent of regulated farms (LFOs/Large CAFOs & MFOs/Medium CAFOs) with regularly-maintained Best Management Practice structures, by farm type									
a. Manure storage (practices/farms)	L - 6/4 M - 49/35	L - 6/4 M - 49/35	100%	0.0	0.0	$0	$0	$0	5,6,7
b. Silage leachate treatment (practices/farms)	L - 1/4 M - 13/35	L - 3/4 M - 35/35	100%	1.7	1.7	$1,125,000	$2,290,500	$68	5,6,8
c. Barnyard runoff treatment (practices/farms)	L - 2/4 M - 37/35	L - 4/4 M - 37/35	100%	0.0	0.0	$30,000	$141,000	$865	5,6,7
d. Milkhouse waste treatment (practices/farms)	L - 0/4 M - 0/35	L - 4/4 M - 35/35	100%	2.6	2.6	$648,375	$1,323,750	$26	5,6,8
Percent of farm inspections identifying substantial violations of relevant agricultural regulation	5.00%		0%		0.0				5
Developed Lands									
Percent of all permitted construction stormwater sites under the Construction General Permit in substantial compliance with the permit	46%	NA		NA	0.0			NA	5
Percent of all permitted construction stormwater sites with Individual Permits in substantial compliance with their permit	90%	NA		NA	0.0			NA	5
Percent of all permitted operational stormwater sites in substantial compliance with their permit	85%	NA		NA	0.0			NA	5
Percent of impervious area that is under stormwater management	5.60%	NA	100%	NA	7.9	$310,684,961	$310,718,211	$1,959	9,11,19,20,21
Number of combined sewer overflows remaining in the Lake Champlain Basin	7		0		0.2	$17,453,006	$17,453,006	$5,454	12,13,22,30
Number of towns with good water quality protection provisions in town plans and zoning ordinances, including incorporation of Low Impact Development standards where appropriate.	23%								5
Percent of tree canopy coverage within urban landscape zones in the Lake Champlain Basin	11.50%								23
Rural Lands/Backroads									
Percent of inspected sampling units within logging jobs in the Vermont and New York portions of the Lake Champlain Basin where harvesting operations have caused more than trace amounts of sediment to enter streams.	17%								24
Percent of towns participating in the Better Backroads Program (or equivalent program)	71%		100%	0.0	0.0			NA	5
Percent of towns that have completed road erosion needs inventories and capital budget plans	16%		100%	0.0	0.0			NA	5
Percent of priority erosion control projects identified in road erosion needs inventories that are completed	57%		100%		3.9	$199,331	$578,060	$7	5,15,16
River, Floodplain, and Wetland Conservation & Restoration									
Percent of towns having adopted Town and Bridge Standards in accordance with Act 110 that contain a suite of water quality based BMPs	62%								25
Percent of Basin communities with adopted municipal Fluvial Erosion Hazard ordinances	9%								5
Wastewater									
Percent of facilities meeting their TMDL wasteload (VT & NY) or phosphorus (PQ) allocations (R)	100%	100%	100%	0.0	0.0				26
Percent of wastewater treatment facilities having an approved sewage spill prevention plan for (a) the treatment plant and (b) the collection system (P)	(a) 43% (b) 0%	a. 100% b. 75%	a. 100% b. 100%						27
Ecosystem Process & Ecosystem State Indicators:									
Median animal units per acre	0.489								3
avg. mt/yr P loss from cropland (including hay)	74.5		TBD						2
avg. mt/yr P loss from farmsteads	1.3		TBD						2
avg. mt/yr P loss from urban areas	17.5		TBD						2
avg. mt/yr P loss from road network	14.1		TBD						2
Best recent estimates for % of land in the following categories:									
a. annual crops	6.42%								2
b. hay, pasture, lawn	19.18%								2
c. impervious surface	1.85%								2
Percent of river reaches in stream geomorphic assessment category II (incised and steepening) or III (incised and widening) (R)	43%	50%	30%						
5 year avg. wastewater phosphorus load (2007-2011) (mt/y)	3.89		TBD						28,29
5 year avg. non-point phosphorus load (2007-2011) (mt/y)	172		TBD						28,29
5 year avg. total tributary P loads (2007-2011) (mt/y)	176		TBD						28,29
5-year Ratio of dissolved P : total P in tributary loads (2007-2012 conc.)	0.385								28,29

Poultney-Mettawee Basin	Current State	Acceptable Level (short term)	Acceptable Level (ultimate)	Expected short-term P reduction (mt/yr)	Expected ultimate P reduction	Initial Investments to reach ultimate acceptable level ($)	Real 20-year cost to reach ultimate level ($)	Expected Cost ($) per expected kg P	Data Sources
Agricultural Lands									
Percent of agricultural land under enhanced land management for:									
a. Cover cropping	0.88%	11.10%	33.00%	0.9	2.9	$463,982	$9,279,634	$161	1,2,17
b. Alternative manure spreading methods	0.47%	16.40%	100.00%	1.0	6.2	$2,283,407	$45,668,148	$365	1,2,18
c. Conservation tillage	2.65%	0.47%	33.00%	0.0	4.1	$460,265	$9,205,309	$113	1,2,17
Percent of agricultural land acres managed under an approved Nutrient Management Plan, by farm type (LFO, MFO, SFO)	64.70%	75.00%	100%	1.8	6.2				3,7
Percent of regulated farms (LFOs/Large CAFOs & MFOs/Medium CAFOs) with regularly-maintained Best Management Practice structures, by farm type									
a. Manure storage (practices/farms)	47/20	47/20	100%	0.0	0.0	$0	$0	NA	5,6,7
b. Silage leachate treatment (practices/farms)	12/20	20/20	100%	0.8	0.8	$360,000	$760,500	$46	5,6,7
c. Barnyard runoff treatment (practices/farms)	54/20	54/20	100%	0.0	0.0	$0	$0	NA	5,6,8
d. Milkhouse waste treatment (practices/farms)	8/20	20/20	100%	1.2	1.2	$199,500	$426,000	$17	5,6,7
Percent of farm inspections identifying substantial violations of relevant agricultural regulation	5.00%		0%		0.0				5,8
Developed Lands									
Percent of all permitted construction stormwater sites under the Construction General Permit in substantial compliance with the permit	46%	NA		NA	0.0			NA	5
Percent of all permitted construction stormwater sites with Individual Permits in substantial compliance with their permit	90%	NA		NA	0.0			NA	5
Percent of all permitted operational stormwater sites in substantial compliance with their permit	85%	NA		NA	0.0			NA	5
Percent of impervious area that is under stormwater management	1.36%	NA	100%	NA	6.2	$440,631,743	$440,664,993	$3,580	9,11,19,20,21,33
Number of combined sewer overflows remaining in the Lake Champlain Basin	2		0		0.0	$18,574,384	$18,574,384	$30,957	12,13,22,30,34
Number of towns with good water quality protection provisions in town plans and zoning ordinances, including incorporation of Low Impact Development standards where appropriate.	23%								5
Percent of tree canopy coverage within urban landscape zones in the Lake Champlain Basin	11.80%								23
Rural Lands/Backroads									
Percent of inspected sampling units within logging jobs in the Vermont and New York portions of the Lake Champlain Basin where harvesting operations have caused more than trace amounts of sediment to enter streams.	17%								24
Percent of towns participating in the Better Backroads Program (or equivalent program)	94%		100%	0.0	0.0			NA	5
Percent of towns that have completed road erosion needs inventories and capital budget plans	16%		100%	0.0	0.0			NA	5
Percent of priority erosion control projects identified in road erosion needs inventories that are completed	57%		100%		1.4	$199,331	$578,060	$20	5,15,16
River, Floodplain, and Wetland Conservation & Restoration									
Percent of towns having adopted Town and Bridge Standards in accordance with Act 110 that contain a suite of water quality based BMPs	94%								25
Percent of Basin communities with adopted municipal Fluvial Erosion Hazard ordinances	3%								5
Wastewater									
Percent of facilities meeting their TMDL wasteload (VT & NY) or phosphorus (PQ) allocations (R)	100%	100%	100%	0.0	0.0				26
Percent of wastewater treatment facilities having an approved sewage spill prevention plan for (a) the treatment plant and (b) the collection system (P)	(a) 90% (b) 20%	a. 100% b. 75%	a. 100% b. 100%						27
Ecosystem Process & Ecosystem State Indicators:									
Median animal units per acre									3
avg. mt/yr P loss from cropland (including hay)	29.9		TBD						2
avg. mt/yr P loss from farmsteads	0.3		TBD						2
avg. mt/yr P loss from urban areas	13		TBD						2
avg. mt/yr P loss from road network	5.1		TBD						2
Best recent estimates for % of land in the following categories:									
a. annual crops	3.66%								2
b. hay, pasture, lawn	13.81%								2
c. impervious surface	2.18%								2
Percent of river reaches in stream geomorphic assessment category II (incised and steepening) or III (incised and widening) (R)	41%	50%	30%						
5 year avg. wastewater phosphorus load (2007-2011) (mt/y)	1.48		TBD						28,29
5 year avg. non-point phosphorus load (2007-2011) (mt/y)	185		TBD						28,29
5 year avg. total tributary P loads (2007-2011) (mt/y)	187		TBD						28,29
5-year Ratio of dissolved P : total P in tributary loads (2007-2012 conc.)	0.378								28,29

Bouquet-Ausable Basin	Current State	Acceptable Level (short term)	Acceptable Level (ultimate)	Expected short-term P reduction (mt/yr)	Expected ultimate P reduction	Initial Investments to reach ultimate acceptable level ($)	Real 20-year cost to reach ultimate level ($)	Expected Cost ($) per expected kg P	Data Sources
Agricultural Lands									
Percent of agricultural land under enhanced land management for:									
a. Cover cropping									
b. Alternative manure spreading methods									
c. Conservation tillage									
Percent of agricultural land acres managed under an approved Nutrient Management Plan, by farm type (LFO, MFO, SFO)									
Percent of regulated farms (LFOs/Large CAFOs & MFOs/Medium CAFOs) with regularly-maintained Best Management Practice structures, by farm type									
a. Manure storage (practices/farms)	6/7	7/7	100%	0.01	0.01	$140,000	$730,000	$3,154	6,7,32
b. Silage leachate treatment (practices/farms)	1/7	7/7	100%	0.62	0.62	$270,000	$580,500	$47	6,8, 32
c. Barnyard runoff treatment (practices/farms)	6/7	1/7	100%	0.02	0.02	$15,000	$111,000	$244	6,7,32
d. Milkhouse waste treatment (practices/farms)	5/7	7/7	100%	0.21	0.21	$33,250	$93,500	$23	6,8,32
Percent of farm inspections identifying substantial violations of relevant agricultural regulation									
Developed Lands									
Percent of all permitted construction stormwater sites under the Construction General Permit in substantial compliance with the permit									
Percent of all permitted construction stormwater sites with Individual Permits in substantial compliance with their permit									
Percent of all permitted operational stormwater sites in substantial compliance with their permit									
Percent of impervious area that is under stormwater management	0.59%		100%		2.3	$291,018,052	$291,051,302	$6,224	9,11,20,21,33
Number of combined sewer overflows remaining in the Lake Champlain Basin	0		0		0.0	$0	$0		12,13,30,34
Number of towns with good water quality protection provisions in town plans and zoning ordinances, including incorporation of Low Impact Development standards where appropriate.									
Percent of tree canopy coverage within urban landscape zones in the Lake Champlain Basin									
Rural Lands/Backroads									
Percent of inspected sampling units within logging jobs in the Vermont and New York portions of the Lake Champlain Basin where harvesting operations have caused more than trace amounts of sediment to enter streams.									
Percent of towns participating in the Better Backroads Program (or equivalent program)	92%		100%		0.0				15
Percent of towns that have completed road erosion needs inventories and capital budget plans	92%		100%		0.0				15
Percent of priority erosion control projects identified in road erosion needs inventories that are completed									
River, Floodplain, and Wetland Conservation & Restoration									
Percent of towns having adopted Town and Bridge Standards in accordance with Act 110 that contain a suite of water quality based BMPs									
Percent of Basin communities with adopted municipal Fluvial Erosion Hazard ordinances									
Wastewater									
Percent of facilities meeting their TMDL wasteload (VT & NY) or phosphorus (PQ) allocations (R)	88%	100%	100%	0.01	0.01				26
Percent of wastewater treatment facilities having an approved sewage spill prevention plan for (a) the treatment plant and (b) the collection system (P)	NA	a. 100% b. 75%	a. 100% b. 100%						27
Ecosystem Process & Ecosystem State Indicators:									
Median animal units per acre									
avg. mt/yr P loss from cropland (including hay)	4.0								2
avg. mt/yr P loss from farmsteads	0.2								2
avg. mt/yr P loss from urban areas	4.9								2
avg. mt/yr P loss from road network									
Best recent estimates for % of land in the following categories:									
a. annual crops	1.94%								2
b. hay, pasture, lawn	7.42%								2
c. impervious surface	1.73%								2
Percent of river reaches in stream geomorphic assessment category II (incised and steepening) or III (incised and widening) (R)									
5 year avg. wastewater phosphorus load (2007-2011) (mt/y)	2.52								28,29
5 year avg. non-point phosphorus load (2007-2011) (mt/y)	93								28,29
5 year avg. total tributary P loads (2007-2011) (mt/y)	95								28,29
5-year Ratio of dissolved P : total P in tributary loads (2007-2012 conc.)	0.381								28,29

Saranac-Chazy Basin	Current State	Acceptable Level (short term)	Acceptable Level (ultimate)	Expected short-term P reduction (mt/yr)	Expected ultimate P reduction	Cost of reaching ultimate acceptable level ($)	Real cost to reach ultimate level (20-year) ($)	Expected Cost ($) per expected kg P	Data Sources
Agricultural Lands									
Percent of agricultural land under enhanced land management for:									
a. Cover cropping									
b. Alternative manure spreading methods									
c. Conservation tillage									
Percent of agricultural land acres managed under an approved Nutrient Management Plan, by farm type (LFO, MFO, SFO)									
Percent of regulated farms (LFOs/Large CAFOs & MFOs/Medium CAFOs) with regularly-maintained Best Management Practice structures, by farm type									
a. Manure storage (practices/farms)	16/13	16/13	100%	0.00	0.00	$0	$0	$0	6,7,32
b. Silage leachate treatment (practices/farms)	7/13	13/13	100%	0.62	0.62	$270,000	$580,500	$47	6,8, 32
c. Barnyard runoff treatment (practices/farms)	5/13	13/13	100%	0.10	0.12	$120,000	$321,000	$137	6,7,32
d. Milkhouse waste treatment (practices/farms)	6/13	13/13	100%	0.72	0.72	$116,375	$259,750	$18	6,8,32
Percent of farm inspections identifying substantial violations of relevant agricultural regulation			0%						
Developed Lands									
Percent of all permitted construction stormwater sites under the Construction General Permit in substantial compliance with the permit									
Percent of all permitted construction stormwater sites with Individual Permits in substantial compliance with their permit									
Percent of all permitted operational stormwater sites in substantial compliance with their permit									
Percent of impervious area that is under stormwater management	2.10%		100%		3.0	$343,180,686	$343,213,936	$5,706	9,11,20,21,33
Number of combined sewer overflows remaining in the Lake Champlain Basin	11	5	0	0.07	0.2	$49,069,946	$49,069,946	$16,357	12,13,30,34
Number of towns with good water quality protection provisions in town plans and zoning ordinances, including incorporation of Low Impact Development standards where appropriate.									
Percent of tree canopy coverage within urban landscape zones in the Lake Champlain Basin									
Rural Lands/Backroads									
Percent of inspected sampling units within logging jobs in the Vermont and New York portions of the Lake Champlain Basin where harvesting operations have caused more than trace amounts of sediment to enter streams.									
Percent of towns participating in the Better Backroads Program (or equivalent program)	53%		100%		0.0				15
Percent of towns that have completed road erosion needs inventories and capital budget plans	53%		100%		0.0				15
Percent of priority erosion control projects identified in road erosion needs inventories that are completed									
River, Floodplain, and Wetland Conservation & Restoration									
Percent of towns having adopted Town and Bridge Standards in accordance with Act 110 that contain a suite of water quality based BMPs									
Percent of Basin communities with adopted municipal Fluvial Erosion Hazard ordinances									
Wastewater									
Percent of facilities meeting their TMDL wasteload (VT & NY) or phosphorus (PQ) allocations (R)	100%	100%	100%	0.0	0.0				26
Percent of wastewater treatment facilities having an approved sewage spill prevention plan for (a) the treatment plant and (b) the collection system (P)	NA	a. 100% b. 75%	a. 100% b. 100%						27
Ecosystem Process & Ecosystem State Indicators:									
Median animal units per acre									
avg. mt/yr P loss from cropland (including hay)	9.9								2
avg. mt/yr P loss from farmsteads	0.4								2
avg. mt/yr P loss from urban areas	6.4								2
avg. mt/yr P loss from road network									
Best recent estimates for % of land in the following categories:									
a. annual crops	1.96%								2
b. hay, pasture, lawn	8.84%								2
c. impervious surface	2.22%								2
Percent of river reaches in stream geomorphic assessment category II (incised and steepening) or III (incised and widening) (R)		50%	30%						
5 year avg. wastewater phosphorus load (2007-2011) (mt/y)	4.26								28,29
5 year avg. non-point phosphorus load (2007-2011) (mt/y)	65								28,29
5 year avg. total tributary P loads (2007-2011) (mt/y)	69								28,29
5-year Ratio of dissolved P : total P in tributary loads (2007-2012 conc.)	0.535								28,29

Data Sources

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Appendix B – Indicator by Indicator Calculation Notes and Caveats

General Notes:

For the purposes of summing implementation data and the phosphorus loading data, the 18 gauged tributaries are divided into the 8 major basins as follows:

- "Missisquoi" includes the Missisquoi and Pike Rivers.
- "Winooski" includes the Winooski and La Platte Rivers
- "Lamoille" includes the Lamoille River and Mallet's Bay watersheds
- "Otter Creek" includes Otter, Little Otter, and Lewis Creeks
- "Poultney-Mettawee" includes the Poultney and Mettawee Rivers, and Putnam Creek.
- "Bouquet-Ausable" includes Bouquet, Little Ausable, Ausable, and Salmon River drainages.
- "Saranac-Chazy" includes the Saranac, Little Chazy, and Great Chazy Rivers.
- "Grand Isle/Direct" includes St. Albans Bay watershed, the Northeast Arm watershed, and the Isle La Motte watersheds.

Agricultural Lands:

<u>% Ag land under enhanced management</u>

Current State: Acreage of agricultural land was calculated from the Tetra Tech Land Use raster layer developed as part of the ongoing TMDL update, using tabulate areas by HUC 8 tool (Tetra Tech 2013). Cover cropping acreages calculated from VT AAFM FAP program records, delivered 01/2012 by Nate Sands. "Cover cropping" includes the following practices: cover cropping, nurse cover crops, and cover crop seed incorporation practices. Conservation tillage includes conservation tillage, aeration tillage and cross-slope tillage. There is only one practice for manure methods. These data are an underestimate because there are other programs (e.g. through UVM Extension) that help farmers do cover cropping and conservation tillage, although there is overlap between those programs that is difficult to quantify. The difference might be as large as a factor of 2, but is likely much less.

For Missisquoi Bay, the proportions for each practice are area-weighted. The data (from Stats Canada 2011 Agricultural Census) on cover cropping seems to indicate that little cover cropping occurs in the Quebec portion of the watershed. For conservation tillage, the proportion was calculated as the ratio of hectares with no-till and reduced tillage to the total land prepared for seeding. The average of these proportions was then multiplied by the area of cropland on either side of the border.

It would be a better estimate to use the acreage of land that is capable of supporting each of the practices (rather than total cropland), which could be done using the GIS soils layer and automated field selection routine (performed in ArcGIS ModelBuilder) developed by Philip Halteman in the fall of 2011. The process requires a current Common Land Unit (CLU) layer, which is held by VT AAFM or NRCS. The basic selection process selects fields capable of supporting these three practices based on soil characteristics and topography, and exports these as a new GIS layer.

Acceptable Levels: The Ultimate Acceptable level is the proportion of the area of agricultural fields (annual cropland, rotated cropland, permanent hay) that could theoretically support the practice in question. For cover crops and conservation tillage, this is equal to the area of land in annual crops (annual cropland plus one-half of the rotated corn-hay land use – this reflects an even rotation of corn and hay, which could be adjusted), and for manure injection it is both annual cropland and hayland (i.e. 100% of agricultural fields. The short-term acceptable levels are calculated by taking the areas noted in OFA and calculating the percent of the total area that these targets represent.

Expected Reductions: Expected reductions are calculated following the general method described in the text (box 2).

Cost data: Costs to achieve the expected reductions are calculated by multiplying the difference in acreage between the current state and the ultimate goal by the average payment per acre by VT AAFM across all FAP financial programs ($21), which was calculated by dividing the total amount paid to landowners for 2011 (reported in the 2011 ERP Annual Report) by the total acreage enrolled for that year. As discussed in the text, this (intentionally) does not include program administration costs (see Methods: Total Cost and Cost-Effectiveness).

% of agricultural land managed under an NMP

Current State: This number was taken from a recent survey by UVM Extension which surveyed dairy farms in Vermont (Darby et al. 2013). The survey requested information including total acreage managed by the farm (including rented or leased land), and whether the farmer had an actively maintained NMP (updated in the last 3 years). Those farms with actively maintained NMPs represented just under 65% of the land base. For the Quebec portion of the Missisquoi all farms are managed under NMPs, and so the higher percentage reflects an area-weighted ratio.

It is worth noting here that other data collected as part of the same survey indicated that in any particular year, producers apply the NMP recommendations to only 75% of their acreage. Survey responses identified poor weather as the primary cause for the less than 100% compliance. If that's true, then reaching 100% compliance in every year is impossible since the cause is a random occurrence.

Acceptable Levels: The long term-level was set by the AMWG in early meetings. There are no short-term levels specified in OFA for Vermont, and for New York, no data are currently available for acreage currently managed under NMPs, although a target is stated in OFA. The short-term goal is therefore arbitrary.

Expected Reductions: The reduction rate from Gitau et al. (2005) is applied to only 75% of the load from fields, to reflect the lower rate of use as noted above. Otherwise, the method is the same.

Cost estimates: There are no clear cost data for this indicator.

% farms with structural BMPs:

Current State: Values for Vermont are from the VT AAFM BMP database, delivered 4/2012. Practices were identified using selections from the "TPC title" field. For New York, numbers of practices on farms noted as "CAFO" were taken from the 2010 Ag BMP reporting project done by CWICNY and NYS Department of Agriculture & Markets (Snell and Brower 2011). Numbers of practices were aggregated to HUC 8 due to inconsistent use of the newer HUC 12 and older HUC 14 codes (on the Vermont side). Though the records in the Vermont AAFM database contained farm size information, the data we had for the total numbers of farms in each watershed only detailed the number of Medium and Large Farms (or Medium and Large CAFOs). Therefore, we only report numbers of practices for these regulated farms.

For the Vermont database, "Manure storage" in the indicator table includes practice records with the following TPC titles: Waste Storage Structure, Waste Storage Pond, Waste Transfer, Concrete Stacking Pad. "Silage Treatment" includes practice records with TPC title Waste Treatment – Silage. "Barnyard Runoff" includes practice records with TPC Titles: Barnyard Runoff Treatment, Roof Runoff, Diversion, Heavy Use area protection, Structure for Water Control. Milkhouse waste treatment includes practices with the following TPC titles: Milkhouse Wastewater Treatment, Milkhouse Wastewater Transfer, Milkhouse Wastewater infiltration area, Waste Treatment – Milkhouse, Wastewater infiltration area).

For the Vermont side, it should be noted here that there was no effective method to understand what numbers of practices are adequate for a particular farm from the database. In some cases, a single farm has cost-shared multiple manure pits, for example, and in some cases, a farm may have the necessary structures but not cost-shared them (a clear example is the single LFO in the Winooski watershed – that farm may have not cost-shared any of the practices, but it likely has structures necessary to manage waste.) It is therefore difficult to know whether the estimates are over- or underestimates. The best interpretation of these data is to compare the relative numbers of practices to farms to see where the emphasis has been (e.g. manure storage and barnyard runoff).

Acceptable Levels: In OFA 2010, New York and Vermont made commitments to ensure that all regulated farms (Medium and Large CAFOs) have these structures in place. The short-term acceptable level is therefore the same as the Ultimate acceptable level.

Expected Reductions: Manure storage and Barnyard runoff practice efficiencies were reported in Gitau et al. (2005) as percentages. The NY Ag BMP report provided rates for silage leachate and milkhouse waste treatment on an animal unit basis (Snell and Brower 2011). From the UVM Extension survey, we calculated a median AU/acre based on animal data provided by survey respondents, and also calculated a median AU for each farm size (Darby et al. 2013). To calculate reductions, the animal unit-based reductions were multiplied by the animal unit estimates per farm, and then multiplied by the remaining number of farms requiring that practice.

Cost Data: Cost data come from the Vermont State Act 78 Report of 2009, which estimated the need for these sorts of practices across the state. In addition to estimating numbers of farms in need of these practices, that report estimated a per-farm cost, or a per-AU cost (depending on the practice). Where per-farm costs were given, that cost was multiplied by the number of farms in need of that practice according to this analysis, and where per-AU costs were given, the median AU value for the relevant farm size was used.

<u>% of inspections identifying violations:</u>

Current State: Data from 2011 VT ERP Annual Report. Missisquoi data are from Québec MDDEFP. This is a simple average of the Vermont rate (5%) and the rate for Missisquoi inspections (13%), since there is not enough information to calculate a more appropriate ratio based on inspection numbers in the Missisquoi watershed.

Acceptable Levels: There are no short-term goals stated in OFA. The AMWG set the Ultimate Level.

Expected Reductions: For this project, we have given all inspection programs no reduction value. The logic is that the effectiveness we report and use in calculations assumes full compliance. Providing an additional reduction value for the inspections would double-count reductions. The role of inspection programs is to ensure that the level of reduction reaches its potential. One application of these data may be to subtract a proportion of the expected reductions according to a function of the non-compliance rate.

Developed Lands:

<u>% of permitted construction stormwater sites in compliance</u>:

Current State: Values taken from the Vermont ERP 2011 Annual report. There are no similar data available for Quebec or New York.

Acceptable Levels: No targets are set for this indicator in OFA, so there is no short-term acceptable level. The AMWG set the Ultimate Level.

Expected Reductions: See discussion above, in the Agricultural Lands section, about reduction effectiveness of inspection programs.

% of permitted operational stormwater sites in compliance:

Current State: Values taken from the Vermont ERP 2011 Annual report. There are no similar data available for Quebec or New York.

Acceptable Levels: No targets are set for this indicator in OFA, so there is no short-term acceptable level. The AMWG set the Ultimate Level.

Expected Reductions: See discussion above, in the Agricultural Lands section, about reduction effectiveness of inspection programs.

% impervious under stormwater management:

Current State: Acreages of impervious surface with stormwater permit provided by VT DEC from their stormwater database, and by NYS DEC. Acreages for Vermont were summarized by VT DEC Tactical Basin boundaries. Regarding the data from VT DEC: "Approximately 5.4% of the records are missing impervious acreage in the database. Impervious surfaces are generally not tracked for MSGP or Construction permits, so they were not included in this analysis." Therefore, this is an underestimate, but probably not significantly. Because of data entry issues with permit locations in their database, New York acreages were aggregated by town, and then summarized by HUC 8 basin. The total permitted impervious acreage for each basin (VT and NY) was divided by the area of impervious surface in each HUC 8 basin derived from the UVM SAL impervious area mapping effort (2011 imagery, NDVI + OBIA approach) (O'Neil-Dunne 2013).

A second possible method for estimating this is to use the total number of acres of impervious surface within regulatory boundaries (MS4 and stormwater impaired watersheds, where applicable). The values obtained from this method are roughly similar to the values from the above method that we used. There is a large degree of overlap (but less than 100%) between the two methods, so they can't be combined or substituted directly.

Acceptable Levels: There are no targets set for this value in OFA. The Ultimate level was set by the AMWG, but should probably be revised downward to reflect what is necessary to manage (i.e. estimates of the difference between total impervious areas [TIA] vs.

effective impervious area [EIA]) and what is possible to manage in terms of considerations about the feasibility of on-site treatment.

Expected Reductions: Reduction values are from appendices D and E of the Center for Watershed Protection's Urban Subwatershed Restoration Manual 3 (available for free from www.cwp.org), which provides data on the effectiveness and costs of retrofitting stormwater management practices. The data in this report are compiled from several wide-reaching literature reviews, so these data incorporate a large number of studies.

Effectiveness values used in the Indicator Table are median effectiveness values for phosphorus across all types of practices included, as it is likely that in a large-scale effort to retrofit practices into the Lake Champlain Basin, a wide mixture of practices would be used.

Cost Estimates: Cost estimates used here are median costs to treat an acre of impervious surface, across all practice types. As mentioned above, the first estimate includes only base construction costs and design and engineering, not annual O&M, or land acquisition. The D&E costs are 32% of base construction costs, and include project management, design, permitting, landscaping, and erosion and sediment control during the construction phase. The second cost estimate uses annual maintenance costs from an estimate for retrofitting the Puget Sound urban areas, which is averaged across practice types.

Number of CSOs by town:

Current State: Numbers of current and recently abated Combined Sewer Outfalls[4] (CSOs) were given by VT DEC and NYS DEC.

Acceptable Levels: No targets are set for this indicator in OFA for the Vermont portion of the basin, though New York has committed to eliminating 50% of their outfalls by 2020.

Expected Reductions: To calculate reductions possible from eliminating CSO events, we required estimates of how much loading occurs from CSOs, and assumed that by eliminating outfalls, loading from CSO events would be essentially eliminated (though

[4] We use "outfall" in reference to the outfall pipe where combined sewer systems are discharged to a stream, and "overflow" to describe events when such a discharge occurs. In abbreviation, "CSO" refers to the outfalls, and "CSO events" refers to overflow events.

see Heath et al. 2004). Estimates of loading were developed by obtaining an estimate of the (1) number of overflow events per year per facility (from VT ANR Wastewater Division, reporting number of overflow events 2007-2011), (2) an estimate of the volume of overflow per event (from several monthly VT ANR Wastewater Overflow reports in 2011, which estimated volumes for some of the events: the range of volumes was 8,000 gal to 830,000 gal. The median of reported volumes was used, which was 190,000 gal per event), and (3) an estimate of the concentration of CSO effluent. Because the majority of the VT ANR overflow reports described having discharged "untreated sewage", an estimate of the influent TP concentration from the Middlebury WWTF was used. Those data are from Paul Klebs, of Aqua-Aerobic Systems Inc., which collected data on influent concentrations as part of a study of the efficiency of the Middlebury wastewater treatment system (Klebs 2008). Data were collected in 8 of the 12 months in 2002, and influent concentration averaged 17.8 mg/L TP. In wet-weather events (i.e. when CSO events most frequently occur), this concentration overestimates the true concentration (due to a dilution effect), which means that the estimates of reductions are probably optimistic. The amount of dilution from stormwater is highly variable from one facility to another based on the specific characteristics of the CSO system upstream of the CSO discharge structure, but it is typically very substantial. In addition, the influent phosphorus concentration levels used from the Middlebury plant are much higher than typical New England influent phosphorus levels, which are usually in the 4 to 5 mg/L range, suggesting the Middlebury influent data are unusually high and probably not representative of most Vermont plants. These considerations suggest that the estimates of loads and potential reductions from CSOs presented in this report are likely higher than actual loads. The estimates of CSO loads are intended only for purposes of understanding the approximate relative magnitude of CSO loads in comparison to other phosphorus sources in the basin. Accurate estimates of CSO phosphorus loads are not feasible given the lack of facility-specific data in Vermont. *Cost Data:* Cost estimates of CSO elimination came primarily from the EPA report to Congress on CSOs and associated documents which provided cost estimates per acre treated by a CSO system, and estimates of cost per foot of CSO pipe eliminated (EPA 1999). Estimates for the area of impervious surface in "downtown" areas of each town with CSOs were developed by calculating the area within a polygon surrounding the densely populated areas of each town where CSOs still exist. Because it's unlikely that the entirety of these areas is served by a combined system, these acreages were then multiplied by a reduction rate that was an estimate of the area actually served by combined sewers. The Burlington stormwater department reported these data in a 2008 report, which estimated that 60% of Burlington area was served by CSO. This rate was applied to all 10 towns with CSOs, and the EPA estimate of cost per acre was used. These rates should be adjusted in the future if better estimates of any of the input data are developed.

<u>Urban Tree Canopy %:</u>

Current State: Vermont Forest, Parks, & Recreation conducted an urban tree canopy assessment within "urban" land use zones, which uses E911 housing density to estimate parcel sizes. "Urban" zones are those where housing parcels are less than 5 acres in size. Urban tree canopy (UTC) percent was assessed in those zones. For this analysis, the UTC layer was overlaid with HUC 12 watershed boundaries, and UTC polygons were split and reassigned to the HUC 12 in which they reside. The HUC 12 received a tree canopy percentage that represents the area-weighted mean percentage for each of the UTC polygons in that watershed. The number reported here is best interpreted as the average tree canopy across all urban land use zones in the watershed.

Acceptable Levels: The Ultimate Level for this indicator has been set by Vermont's 2010 Forest Resources Plan (http://www.vtfpr.org/htm/documents/VT%20Forest%20Resources%20Plan.pdf).

Expected Reductions: There are currently no data available to estimate phosphorus reductions based on increasing UTC cover.

Cost Data: Similarly, there are no existing data for estimating cost of increasing UTC.

Rural Lands/Backroads:

<u>% logging jobs causing sediment to enter streams</u>:

Current State: USFS and the Northeastern Area Association of State Foresters (www.wetpartnership.org) conducted inspections on 94 sampling units in Vermont in 2004. These data are based on what the document identifies as "opportunities to observe" erosion, of which there are 5 per site (470 observations). Proportions of those "opportunities" therefore correspond roughly to site-level proportions.

Acceptable Levels: No short-term acceptable level has been set for this indicator.

Expected Reductions: The connection between upper watershed sediment loading and end-of-tributary phosphorus loading has not been articulated or quantified in a way that is applicable to this project. There are a wide variety of data on upper watershed sediment loading and downstream effects of various kinds, but phosphorus loadings have not been as clearly documented in this context.

Cost Data: Because there are a variety of management initiatives that pertain to this indicator, there is no clear way of calculating cost data for this indicator.

<u>% of towns participating in Better Backroads Program (or equivalent)</u>:

Current State: Data for Vermont are from taken from the ERP 2011 Annual Report, and specific to the Lake Champlain Basin as a whole. Data for New York are from the Lake Champlain - Lake George Regional Planning Board 2012 report (LCLGRPB 2012).

Acceptable Levels: There are no short-term targets set for this indicator. The AMWG set the long-term target.

Expected Reductions: See above, in the Agricultural Lands section, for reduction effectiveness of inspections and basic program involvement.

Cost Data: There were no clear cost data for "participation" in the BBR program that did not include administration costs.

<u>% of towns having completed erosion needs inventories and capital budget plans</u>:

Current State: Data for Vermont are taken from the VT ERP 2011 Annual Report, and specific to the Lake Champlain Basin as a whole. Data for New York are from the Lake Champlain - Lake George Regional Planning Board 2012 report to the LCBP. This report detailed capital needs by town, which addresses the intent for this indicator.

Acceptable Levels: There are no short-term targets set for this indicator. The AMWG set the long term target.

Expected Reductions: See above, in the Agricultural Lands section, for reduction effectiveness of inspections and basic program involvement.

Cost Data: There were no clear cost data for "participation" in the BBR program that did not include administration costs.

<u>% of priority erosion control projects identified in road erosion needs inventories that are completed</u>:

Current State: Data for Vermont are from taken from the ERP 2011 Annual Report, and are specific to the Lake Champlain Basin as a whole. It is unclear whether any of the projects identified in the LCLGRPB report have been completed.

Acceptable Levels: There are no short-term targets set for this indicator. The AMWG set the long-term target.

Expected Reductions: There are no good data for estimating the effect on phosphorus loss of managing roadside erosion through the sort of erosion control practices this indicator describes. Beverley Wemple (UVM) is currently in the second phase of a project to evaluate common BMPs for unpaved road maintenance (Wemple 2013). Until these data are published, the reduction rate data used here should be used as a stand-in only. The reduction estimate used here refers to total sediment, NOT total phosphorus, and at 65%, is likely an overestimate for total phosphorus, which means that the expected reductions should probably be lower, and the cost per kg of phosphorus should be higher.

Cost Data: Cost data are from the LCLGRPB report. The estimated cost to remedy each of the erosion problems they documented. We calculated the average cost of this group of projects (n=319, with a total estimated cost of slightly more than $1.7M), which ranged widely from hundreds to tens of thousands of dollars. We then estimated how many of these erosion control projects had not been completed for the Vermont side (from the ERP 2011 Annual Report) and then applied the average cost per project to the number of projects remaining. One caveat of note is that many of the erosion projects for which costs were estimated in the LCLGRPB project involved light grading and hydro-seeding, which is very inexpensive, but probably confers significantly less P reduction potential when compared to stone-lined ditches, for example. Therefore, this estimate of project cost may be an underestimate for the phosphorus reduction rate, despite being reasonably accurate across all project types.

River, Floodplain, and Wetland Conservation and Restoration:

<u>% of towns adopted standards in accordance with Act 110:</u>

Current State: List of towns having adopted Act 110 codes & standards, delivered from VT DEC, last updated 7/2/2012.

Acceptable Levels: No targets exist for this indicator in OFA. The AMWG set the Ultimate goal.

Expected Reductions: There are no existing data that describes a relationship between standards for riparian area development and construction and phosphorus reductions downstream.

Cost Data: There are no cost data for this indicator that do not include program administration.

<u>% of towns with adopted municipal Fluvial Erosion Hazard ordinances</u>:

Current State: List of towns with FEH ordinances taken from the VT ERP 2011 Annual Report.

Acceptable Levels: The targets for this indicator in OFA are not directly translatable into the structure for this table. The AMWG set the Ultimate goal.

Expected Reductions: There is no existing data that describes a relationship between town-level ordinances and phosphorus reductions downstream.

Cost Data: There are no cost data for this indicator that do not include program administration.

Wastewater:

<u>% of facilities meeting their relevant regulatory allocations:</u>

Current State: Wastewater Treatment Facility (WWTF) load limits and actual loads were delivered by Eric Smeltzer (VTDEC) in October of 2012. The tables document TMDL allocation for each facility and its actual load, enabling easy calculation of how many facilities exceeded their limit over a three-year average. Entries were then grouped by watershed to calculate a percentage of facilities within the basin that meet their target.

Acceptable Levels: Acceptable levels were set by the AMWG during the initial stages of the indicator development.

Expected Reductions: In this case, expected reductions equaled the difference between the 3-year average load and the regulatory limit set for the facility. These differences were summed within watersheds.

Cost Data: No cost data for bringing treatment facilities up to 100% compliance was found.

<u>% of facilities having approved Spill Prevention Plans:</u>

Current State: Status reports for the approval of WWTF spill prevention plans were provided by Eric Smeltzer late September 2012. The figures provided here are simple tallies within watersheds.

Acceptable Levels: Acceptable levels were set by the AMWG during the initial stages of the indicator development.

Expected Reductions: Expected reductions are impossible to calculate for this indicator, because loading estimates from WWTF spills is not available.

Cost Data: No cost data for bringing treatment facilities up to 100% compliance was available.

Ecosystem Response Indicators:

<u>Median Animal Units per acre:</u> This number was from a recent survey by UVM Extension that surveyed dairy farms in Vermont. Among the information collected in the survey was total acreage managed by the farm (including rented or leased land), and numbers of animals. From these data we calculated a median animal unit value per acre. Survey respondents also reported their county, and the value here by watershed is the area-weighted average of the county-level values for the counties within that watershed.

<u>P loss from cropland, farmsteads, urban areas, and the road network:</u>

Tetra Tech reported proportions of the total load from each land use category in the calibration report for their SWAT model. The proportions were applied to the total load they reported, to keep consistent with their modeling results. For the Grand Isle direct drainage area, land use areas within the watershed were multiplied by the mean loading rates (across all drainages) identified in the SWAT calibration report (Tetra Tech 2013).

% land in annual crops, hay/pasture/lawn, and impervious surface:

Annual crops: Land use data from Tetra Tech SWAT modeling effort was used to estimate the area in each HUC 8 level watershed. "Annual cropland" is the sum of corn, soy, etc. plus the generic cropland category, plus ½ of the crop-hay rotation land use, which assumes that the rotations are of equal time (e.g. 4 years corn, 4 years hay). This could be adjusted to reflect a more dominant rotation (which, for example, may be 6 corn/4 hay, raising the proportion in corn over the long term).

Hay pasture lawn: the grass/hay/pasture category was constructed from the Tetra Tech land use layer (Tetra Tech 2013), summing the area of herbaceous (71), pasture (81), and hay (87), and adding half of the corn-hay rotation class (to complement the annual crops area), and adding 80% of the Developed – open category. This last addition reflects the "lawn" portion, which is generally counted in either the herbaceous category where it's in a rural context, or in the open development when in an urban context. No more than 20% of the Developed Open category is in impervious surface, and by extension, no less than 80% is "open", or lawn.

Impervious surface: estimates from UVM SAL's impervious surface analysis were summed for each HUC 8, and divided by the total area of the watershed (shape_area field minus "water") (O'Neil-Dunne 2013).

% River miles in Channel Evolution Stage II or III: These data are taken from the VT River Management Program's Phase 2 Stream Geomorphic Assessment data sheets. We downloaded all datasheets for watersheds in the Lake Champlain Basin, and tallied those reaches in each channel evolution stage. Similar data were not available for New York or Québec.

5 yr. avg Wastewater load: Running average over the last 5 years (2007-2011). Tables delivered by Eric Smelzter 10/1/12, updated through 2011.

5-year avg. NP load (2007-2011): This is estimated by subtracting the yearly wasteload from the yearly estimate of the total load (flux) obtained from the WRTDS procedure. The values are then averaged. For basins that include more than one drainage, these averaged values are summed to get the "whole basin" average non-point load.

5-year avg. total load: This is estimated using the WRTDS method, using the program defaults, which seem to perform well, for most tributaries. Flux bias statistics were similar to Medalie (2013).

DP:TP flux: This is calculated by summing the estimated fluxes for each 3-month season (broken by water year, such that fall is Oct. 1 – Dec.31, winter is Jan. 1-March 31, spring is April 1 – June 30, and summer is July 1 – September 30), and then calculating the ratio of the season-specific fluxes per year.

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