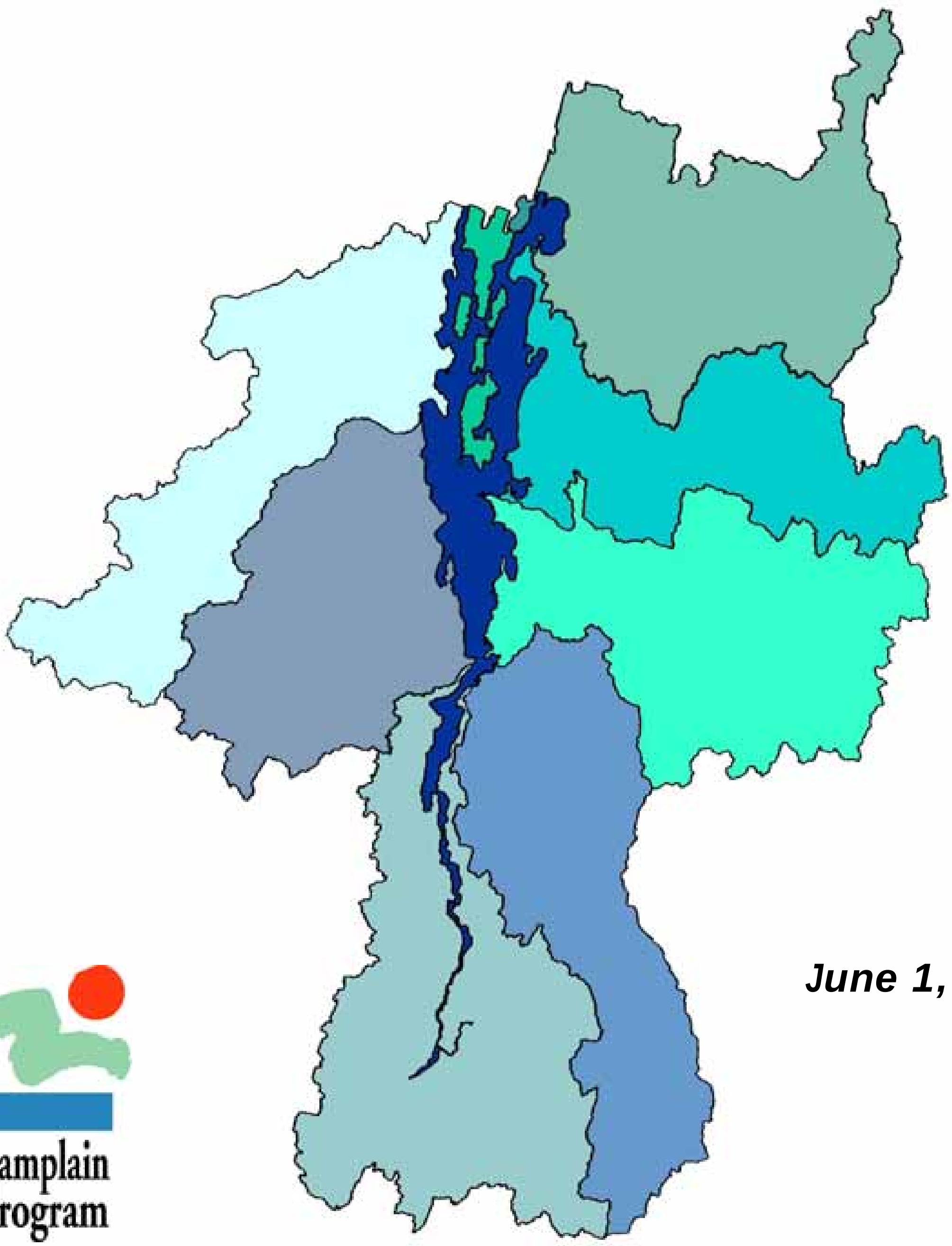
Preliminary Evaluation of Progress Toward Lake Champlain Basin Program Phosphorus Reduction Goals

A Lake Champlain Basin Program Internal Report

Prepared for the Lake Champlain Steering Committee



June 1, 2000

Lake Champlain Basin Program

ACKNOWLEDGMENTS

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Acronyms and Abbreviations

AU	animal unit
BMP	best management practice
CREP	Conservation Reserve Enhancement Program
CRP	Conservation Reserve Program
EQIP	Environmental Quality Incentives Program
GIS	Geographic Information System
HU	hydrologic unit
mgd	millions of gallons per day
mt	metric ton (1,000 kilograms)
NPS	nonpoint source
NRCS	Natural Resources Conservation Service
NRI	National Resources Inventory
NYSDEC	New York State Department of Environmental Conservation
O&M	operation and maintenance
QC MENV	Quebec Ministry of the Environment
TMDL	Total Maximum Daily Load
USDA	United States Department of Agriculture
VT ANR	Vermont Agency of Natural Resources
VT DAFM	Vermont Department of Agriculture, Food, and Markets
VT DEC	Vermont Department of Environmental Conservation
WWTP	wastewater treatment plant

EXECUTIVE SUMMARY

The Lake Champlain Basin Program's comprehensive management plan, *Opportunities for Action*, was signed by the governors of both New York and Vermont in 1996. This plan identifies reducing phosphorus to achieve in-lake water quality goals as one of its three highest priorities. The states of New York and Vermont and the Province of Quebec have committed to achieving the in-lake water quality goals by reducing phosphorus inputs to the lake over the next 20 years. Aggressive efforts to accomplish the first 25% of the necessary phosphorus reduction by the fall of 2001 are underway.

Phosphorus Reduction Team Charge and Study Approach

Since signing *Opportunities for Action* in 1996, there has been interest in accelerating the 20-year timeframe for phosphorus reduction. The Phosphorus Reduction Team was commissioned by the Lake Champlain Steering Committee to begin to evaluate progress towards the twenty-year phosphorus reduction goal and to investigate the feasibility of accelerating phosphorus reduction efforts in order to achieve that goal on a faster schedule. Membership on the Team includes technical experts on phosphorus reduction in the States of Vermont and New York and the Province of Quebec.

The Team began by assessing whether Vermont, New York and Quebec were on track to achieve the first 25% of the necessary phosphorus load reductions. It then assessed what additional reductions could be achieved by continuing to implement current point and nonpoint source reduction programs. Because the water quality goals vary by lake segment, all evaluations were made on a lake segment by lake segment basis. If the loadings targets could not be fully achieved by implementing current programs, then the Team examined additional options that might be available to reach the goals. Finally, the Team outlined future challenges that managers and policy-makers will face as they continue to move forward with an aggressive phosphorus reduction strategy under any time frame.

First 25% Phosphorus Reduction Goal Will Be Exceeded

By 2001, Vermont, New York, and Quebec will have reduced the 1995 point and nonpoint source phosphorus inputs to Lake Champlain by about 38.8 mt/yr, far exceeding the five-year interim reduction goal of 15.8 mt/yr. Most reductions in Vermont, New York, and Quebec have been accomplished by upgrading, constructing, and modifying wastewater treatment plants. By late 2001 or early 2002, a total of 22.7 metric tons of phosphorus per year will have been removed from point sources since 1995. Agricultural best management practices (BMPs) are being used to achieve the balance of the reductions. Using a crediting system developed by the states, an estimated 16.1 metric tons of phosphorus per year will be removed from agricultural nonpoint sources in the Basin by 2001. Reductions in each lake segment vary, with some segments far exceeding their targets, and some just meeting them. Missisquoi Bay is the only lake segment that may fall slightly below a 25% reduction in the first 5 years.

Considerations in Meeting the Twenty Year Goal

It does not appear that all lake segments can be brought to the loading targets needed to meet the in-lake phosphorus criteria by relying solely on existing reduction programs. By 2001 or 2002, most of the

planned reductions from wastewater treatment plant upgrades will be accomplished. That means that the remaining phosphorus reductions must come from nonpoint source reductions, focusing on agricultural lands. If agricultural BMPs were implementated on all the remaining farms in the Vermont and Quebec portions of the Basin needing treatment, an estimated maximum reduction of about 66.8 metric tons of phosphorus per year could be achieved. If this were to occur, nonpoint source loads would still be 5.7 mt/year in excess of the 20-year nonpoint source target for the Vermont and Quebec part of the Basin, not accounting for any other changes within the Basin. In some lake segments, treatment would exceed the loadings reductions necessary, but in others, the loadings reductions would be far less than needed to achieve the in-lake phosphorus goals.

Complicating the analysis, it appears that the increased phosphorus loads generated by land use changes in the Basin are offsetting some of the gains achieved by point and agricultural nonpoint source reduction efforts. Other Lake Champlain Basin Program studies have shown that developed land typically contributes more phosphorus per unit area of land than other land use types. As the population within the Basin increases, more land is becoming developed. It appears that the Otter Creek, Main Lake VT, Shelburne Bay, Burlington Bay, Malletts Bay, Northeast Arm, and St. Albans Bay lake segments are undergoing the most rapid changes in land use. Future planning for phosphorus reductions must take these changes into account.

Options for achieving the additional phosphorus reductions necessary include both additional point and nonpoint source treatment. Several emerging technologies may make it possible to reduce point source phosphorus concentrations in effluent below the levels currently achieved with advanced treatment. The feasibility of these technologies to bring about cost-effective upgrades could be explored for those lake segments not expected to meet the target loads through the current programs.

Additional nonpoint source reductions are also possible on both urban and agricultural lands. Innovative BMPs for both land uses are available and more cost-effective than in the past. On agricultural lands, conservation buffers and a mass balance approach to farm nutrient planning could achieve additional reductions. Reducing soil erosion from dirt roads would also limit phosphorus inputs to Basin tributaries. More creative site designs and emerging stormwater management technologies for new development can substantially reduce phosphorus loads from urban and suburban areas.

Conclusions

Vermont, New York, and Quebec have achieved very substantial phosphorus loadings reductions since the signing of *Opportunities for Action*. However, new approaches will need to be considered to achieve the remaining reductions necessary to achieve the in-lake phosphorus concentrations desired. To reach the final targets in the most time- and cost-efficient manner, individualized strategies must be developed, tailored to the specific needs and situations of each watershed within the basin. Strategies for offsetting the phosphorus loadings increases from land use conversions will also need to be developed. Accelerating the timeframe for meeting the reduction targets will require annual funding commitments at higher levels than in the past.

1. INTRODUCTION

The Lake Champlain Basin Program's plan, *Opportunities for Action* (Lake Champlain Management Conference, 1996), identified reducing phosphorus as one of its highest priorities and set goals for achieving in-lake water quality standards for phosphorus within a 20-year timeframe. Through this plan, the states of Vermont and New York committed to reduce the net loading of phosphorus to Lake Champlain by 57 metric tons per year (mt/yr) over the next 20 years relative to 1995 loads. Specific phosphorus loading targets were established for each of 13 lake segment watersheds. A portion of the load reduction responsibility assigned to Vermont will be shared with the province of Quebec according to an agreement being developed by the Missisquoi Bay Phosphorus Reduction Task Force. Vermont and New York are implementing specific plans to achieve the first 25% reduction by the fall of 2001 (Vermont Agency of Natural Resources, 1996; New York State Department of Environmental Conservation, 1996), and Quebec has also been addressing its responsibilities under the plan. The states have also agreed to develop specific actions to achieve the remaining 75% reduction within this first five-year period.

When signing *Opportunities for Action*, the governors of New York and Vermont responded to public concerns about the timeframe for phosphorus reduction by expressing support for accelerating the 20-year timeframe if the means were available to do so. In the fall of 1998, the Lake Champlain Committee convened a group to investigate accelerating the phosphorus reduction timeframe. The Vermont Citizen's Advisory Committee to the Lake Champlain Basin Program has also suggested that the new timeline coincide with the planned celebration of the 400 year anniversary of Samuel de Champlain's arrival to the Basin in 2009. Because of the high level of interest, the Lake Champlain Steering Committee subsequently charged the chair of the Lake Champlain Basin Program's Technical Advisory Committee with assembling a group to gather information and examine what it would take to reach the *Opportunities for Action* reduction goals by 2009.

This report is a working document for the Lake Champlain Basin Program that examines the issues surrounding phosphorus reduction efforts in the Lake Champlain basin. It summarizes anticipated reductions under current point and nonpoint source programs, explores additional reduction options, and identifies future challenges that the Lake Champlain Steering Committee will face as it considers potential next steps. It is the first step toward evaluating the progress and identifying future actions needed to ensure continued success of the phosphorus reduction plan.

2. ANTICIPATED PHOSPHORUS LOAD REDUCTIONS UNDER CURRENT PROGRAMS

2.1 Overview

There are a number of federal, state, regional, and local agencies involved in phosphorus reduction efforts. Many of the on-going pollution control programs in the Basin are well described in the

background technical information document that accompanied *Opportunities for Action* (Lake Champlain Basin Program, 1996) and will not be duplicated here. All efforts to reduce phosphorus inputs to Lake Champlain are based on the agreement signed in *Opportunities for Action* (Lake Champlain Management Conference, 1996). The following section briefly summarized those commitments in *Opportunities for Action.*

The 1996 Vermont Implementation Plan (Vermont Agency of Natural Resources, 1996) established an adjusted 20-year (Year 2016) total target load of 318.9 mt/yr, including the Quebec portion of loads from the Missisquoi Bay lake segment watershed. To meet the five-year goal of reducing the overall load by 25% of the difference between 1995 loads and target loads, Vermont must reduce phosphorus loads by 15.5 mt/yr by 2001[1]. Vermont has primarily relied on wastewater treatment plant (WWTP) upgrades to meet the first five-year targets. Vermont will have completed nearly all of the 12 facilities slated for upgrades during the first five years (see Table 2 in *Opportunities for Action*). Eighteen additional Vermont facilities were upgraded prior to 1996. The balance of the reductions required in the first five years are intended to be met through agricultural best management practice (BMP) implementation.

New York's 20-year target load is 120.1 mt/yr, and a reduction of 1.6 mt/yr is required by 2001[2]. New York expects to meet the five year phosphorus load reduction goals through a combination of point and agricultural nonpoint source projects. The greatest load reduction will be realized from cost-sharing of agricultural BMP and infrastructural improvements; the remaining reductions will result from construction and upgrade of point source controls.

Quebec has also relied upon point source phosphorus reduction to meet the five-year target with Vermont in the Missisquoi Bay lake segment. Quebec has provided funding for construction and connection to wastewater treatment plants through the Clean-Up Wastewater programs. At the end of 1999, 86% of the Quebec population in the Basin connected to municipal sewer sent waste to plants with phosphorus removal treatment.

2.2 Expected Reductions By 2001

2.2.1 Point sources

There are currently 59 Vermont facilities, 28 New York facilities, and three Quebec facilities within the Lake Champlain Basin that discharge significant quantities of phosphorus into the lake after treatment. Some other municipalities within the watershed in Quebec have direct discharges with no wastewater treatment. Table 1 summarizes the 1995 and projected 2001 point source loads in Vermont, New York, and Quebec. Units are in metric tons (1000 kg) per year. By late 2001 or 2002, when the last of scheduled wastewater treatment plant upgrades will be completed, a total of 22.7 metric tons of phosphorus per year will have been reduced from point sources in the Basin since 1995.

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[1] This number differs from the original 13.9 mt/yr required because the estimate for 1995 point source loads in Vermont has been slightly revised.

[2] This value is 25% of -6.3 mt/yr, which is the total amount of reductions required in New York. The 20-year target for Cumberland Bay is higher than 1995 loads (no reduction), but increases were not considered in the -6.3 value.

Table 1. Point source phosphorus loads in the Lake Champlain basin, 1995 and 2001

Lake Segment	Estimated 1995 loads [a]	Projected 2001 loads [b]
	— (mt/yr) —	
Vermont		
South Lake B	3.1	1.3
South Lake A	0.1	0.2
Port Henry	0.0	0.0
Otter Creek	10.8	7.9
Main Lake	21.6	13.6
Shelburne Bay	0.7	1.1
Burlington Bay	2.2	2.9
Malletts Bay	4.3	3.5
Northeast Arm	0.0	0.0
St. Albans Bay	1.6	1.0
Missisquoi Bay	6.5	3.9
Isle LaMotte	0.005	0.001
Vermont total	**50.9**	**35.5**
New York		
South Lake B	2.7	2.2
South Lake A	7.0	7.1
Port Henry	2.7	0.8
Otter Creek	0.0	0.0
Main Lake	6.7	4.0
Cumberland Bay	11.8	11.6
Isle LaMotte	2.5	2.3
New York total	**33.4**	**27.9**
Quebec		
Missisquoi Bay	4.4	2.7
TOTAL	**88.7**	**66.0**

Notes:
[a] 1995 loads for Vermont and Quebec are slightly revised estimates that differ from those listed in *Opportunities For Action*. Vermont data provided by Eric Smeltzer (VT DEC), New York data provided by Joe Racette (NYSDEC), and Quebec data provided by Martin Mimeault (Quebec Ministry of the Environment).
[b] Projected 2001 loads are based on 1998 flows, with planned treatment plant upgrades taken into account. Data provided by the same sources listed in note [a].

In Vermont, facilities discharging at a rate of 0.2 million gallons per day (mgd) or higher are required to meet an effluent concentration standard of 0.8 mg/L. Lagoon facilities are currently exempt from the 0.8 mg/L standard. New York does not have a basinwide statutory phosphorus discharge limit, instead emphasizing collaborative efforts with regulated municipalities over expanded regulatory authority. In New York, those facilities that are being upgraded with Clean Water/Clean Air Bond Act funding have been designed to meet a 0.8 mg/L concentration guideline. In Quebec, facilities are required to meet a standard of 1 mg/L.

Future phosphorus loading projections shown in Table 1 for 2001 were calculated by assuming that facility flows remain at their 1998 rates, and that phosphorus removal upgrades will continue to occur according to the schedule listed below in Table 2. Effluent phosphorus sampling information was lacking for some facilities, and in these cases it was necessary to make assumptions about effluent phosphorus concentrations, or to use data obtained at the same facility during other years under similar operating conditions.

Table 2. Schedule and cost of wastewater treatment plant upgrades, 1996-2002

Vermont			*New York*		
Facility	**Fiscal year of funding [a]**	**Cost of upgrade [a]**	**Facility**	**Date of upgrade [b]**	**Est. cost of upgrade [c]**
Enosburg Falls [d]	1996	$288,826	Champlain	1996	$1,893,800
Castleton	1997	$548,347	Cadyville [e]	1997	NA
Morrisville	1998	$654,247	Lake Placid [f]	1997	$250,000
Montpelier [g]	1999	$337,434	Great Meadows Correctional	1998	NA
West Rutland	1999	$753,207	Washington Correctional	1998	NA
Brandon	2000	$500,000	Westport [h]	1998	$130,000
Fair Haven	2000	$500,050	Port Henry	2000	$3,000,000
Middlebury	2000	$2,000,000	Dannemora	2001	$1,500,000
Montpelier [g]	2000	$1,601,162	Keeseville	2001	$1,800,000
Enosburg Falls [d]	2001	$355,000	Whitehall	2001	$2,000,000
Montpelier [g]	2001	$814,810			
Poultney	2001	$1,043,000			
Milton [i]	2001	$1,408,350			
Northfield	2002	$2,840,000			
Richmond	2002	NA			
Total costs		$13,644,433	**Total costs**	(incomplete)	$10,573,800

Notes:
[a] Vermont fiscal year of funding and costs are from Eric Blatt, VT DEC. Estimates are capital costs for the phosphorus reduction portion of the upgrade. Operation and maintenance costs are not available. Funding for years 2000-2002 had not yet been awarded at the time of this publication.
[b] New York schedule is from Joe Racette, NYSDEC.
[c] Costs for New York are estimates from NYSDEC and represent total capital costs for the entire project (not just the phosphorus reduction). Operation and maintenance costs are not included as part of the estimate.
[d] The Enosburg Falls project is being completed in two phases.
[e] A new facility for Cadyville was constructed in 1997.
[f] The Lake Placid project was not a facility upgrade, but installation of an effluent reuse system for irrigation.
[g] The Montpelier project is being completed in three phases.
[h] The Westport project was a constructed wetland for sludge treatment rather than an upgrade for phosphorus removal. Westport is seeking $1,713,564 in Bond Act funding for a comprehensive upgrade.
[i] The future of the Milton expansion is uncertain because of environmental permitting issues.

2.2.2 Nonpoint sources

Nonpoint source phosphorus loads to Lake Champlain originate as surface runoff from farms, residential lands, and other developed areas. It is estimated that a hectare of developed land contributes 3.5 times more phosphorus than a hectare of agricultural land, and almost 40 times more than forested

land in the Basin (Hegman *et al.*, 1999). Agricultural land contributes approximately 56% of the nonpoint source phosphorus loads basinwide (Hegman *et al.*, 1999); for this reason efforts to reduce nonpoint source loads have thus far focused on agricultural sources.

A comprehensive measurement of nonpoint source phosphorus loads into Lake Champlain was completed in 1990-1992 as part of the Diagnostic-Feasibility Study (VT DEC and NYSDEC, 1997). Since then, assessments of nonpoint source loads, such as the 1995 estimates presented in *Opportunities for Action*, have used a crediting system to subtract the amount of phosphorus assumed to have been removed by agricultural BMPs from the loads measured in the Diagnostic-Feasibility Study. The crediting system for BMPs was developed by Dick Croft of the USDA Natural Resource Conservation Service (NRCS) based on field research in the LaPlatte watershed. Coefficients were developed and assigned to six practices. These practices, along with their costs and credits, are listed in Table 3. Milkhouse waste treatment is the storage of waste in an animal waste treatment system (filter strip or other treatment). Waste utilization is a planned system to manage liquid and solid wastes with ultimate disposal in a manner that does not degrade soil or water resources. Barnyard runoff treatment is a system to collect, control, and treat wastes from barnyards, feedlots, and other outdoor livestock concentration areas for disposal in a non-polluting manner. Erosion control is a system to reduce soil erosion and water pollution on sloping cropland to reduce overland transport of pollutants. Grazing management is the exclusion of livestock from water bodies other than from planned watering points. When a farmer applies a practice, the credit is assigned and used for tracking phosphorus reductions within the watershed where the farm is located.

Table 3. Agricultural BMP coefficients

Treatment	Cost ($/animal unit)	Phosphorus reduction (kg/au/yr)	Credited in VT	Credited in NY	Credited in QC
Milkhouse effluent treatment	81	0.091	✕	✕	✕
Waste utilization	334	0.136	✕		✕
Barnyard runoff treatment	130	0.227	✕	✕	
Erosion control	341	0.363		✕	
Grazing management	45	0.227	✕	✕	
Nutrient management	108	0.091	✕	✕	

Cost and phosphorus reduction information is from Table 32 in the Diagnostic-Feasibility Study (VT DEC and NYSDEC, 1997) based on "edge of field" phosphorus reduction estimates. Cost estimates are expressed on a present value basis, including capital costs as well as annual operation and maintenance costs, assuming a 5% discount rate over a 30-year period.

There are some differences in crediting among the states. In Vermont, milkhouse effluent treatment, waste utilization, nutrient management, barnyard runoff treatment, and grazing management are all being implemented and credited. Other practices such as streambank stabilization are being used, but crediting coefficients have not yet been developed and, therefore, are not being taken. In New York, erosion control, pasture management, nutrient management, planned grazing system, waste storage system and

structure, intensive grazing management, milkhouse waste system, and barnyard runoff treatment are being implemented and credited.

In Quebec, BMP credits have only been taken for milkhouse effluent treatment and waste utilization. Quebec provides funding and technical support to encourage sustainable agriculture practices. Projects include nutrient and manure management, agroenvironmental advisory services, erosion control, and infrastructure facilities, but phosphorus reduction coefficients have not been developed for all these practices. At this time, credits for BMPs other than milkhouse effluent treatment and waste utilization have not being taken into account.

Table 4 presents nonpoint source loads for 1995 and 2001 by lake segment. Using the coefficients for BMPs listed in Table 3, the USDA NRCS, together with Vermont Department of Agriculture, Food, and Markets (VT DAFM), have estimated phosphorus load reductions between 1996 and 2001 for the Vermont side of the Basin. Similar information from New York is not complete, but some information on BMPs implemented with Bond Act money through 1998 is shown in Table 4. Quebec Ministry of the Environment (QC MENV) has also provided an estimate for phosphorus reductions using the coefficients in Table 3. By these calculations, in 2001 a total of 16.1 metric tons of phosphorus per year will have been removed from agricultural nonpoint sources in the Basin since 1995.

As evident in note [d] in Table 4, the crediting system is not perfect, but without another round of comprehensive watershed sampling, it is our best means of estimating nonpoint source loads at this time. Several potential sources of error are explained below.

First, the original agricultural BMP estimates were based upon more than one source of information. Some data came from NRCS baseline surveys for the LaPlatte River project. These surveys took into account all livestock enterprises and were conducted by trained field personnel who were qualified to assess the functionality of any BMPs that were implemented. Some of the surveys were conducted in the middle to late 1980's, however, and the current analyses have not since taken into account any changes in livestock enterprises since then. Additional data came from surveys completed by VT DAFM, which were conducted in 1995. These surveys were compiled by town (not hydrologic unit), were only completed on dairy operations, and were conducted by personnel who were not specifically trained to properly assess the functionality of the currently installed BMPs. In these surveys, smaller areas encompassing fewer farming operations have a greater potential for error.

Another source of error comes from a discrepancy between lake segment boundaries and the way agricultural BMP data are organized. The original BMP data were organized by 11-digit hydrologic unit. Grand Isle County, however, is included in one 11-digit hydrologic unit but is split into two lake segments, Isle LaMotte and Northeast Arm. In this case, agricultural BMP estimates were interpolated based upon dividing the county and town farm and animal unit data by the percent land mass in each lake segment. There is no information available on distribution of farms in this area. Although the original agricultural BMP estimates were based upon 11-digit hydrologic unit boundaries, databases maintained by VT DAFM and VT NRCS used 14-digit hydrologic units. In the case of smaller lake segment areas, it was slightly easier to estimate potential phosphorus reductions using the 14-digit hydrologic unit data, however, estimated loads in 2001 were still calculated by comparing to the original interpolated 11-digit hydrologic unit estimates.

Table 4. Nonpoint source phosphorus loads in the Lake Champlain basin, 1995 and 2001

Lake Segment	1995 estimated NPS loads [a]	Ag. BMP reductions 1996-2001 [b]	2001 estimated NPS loads [c]
	— (mt/yr) —		
Vermont			
South Lake B	24.5	-0.4	24.1
South Lake A	1.1	-1.9	0.0 [d]
Port Henry	0.2	(with S Lake A)	0.0 [d]
Otter Creek	51.4	-3.2	48.2
Main Lake	59.1	-1.3	57.8
Shelburne Bay	11.1	-0.1	11.0
Burlington Bay	0.3	-0.0	0.3
Malletts Bay	26.9	-1.1	25.8
Northeast Arm	1.4	-0.4	1.0
St. Albans Bay	7.2	-0.3	6.9
Missisquoi Bay	142.1	-2.3	139.0 [e]
Isle LaMotte	0.3	-0.1	0.2
Vermont total	**325.6**	**-11.0**	**314.3**
New York			
South Lake B	24.3	-2.4	21.9
South Lake A	3.1	-0.6	2.5
Port Henry	1.8	-0.2	1.6
Otter Creek	0.1	-0.0	0.1
Main Lake	30.8	-0.9	29.9
Cumberland Bay	8.3	-0.1	8.2
Isle LaMotte	19.5	-0.0	19.5
New York total	**87.9**	**-4.2**	**83.7**
Quebec			
Missisquoi Bay	(with VT)	-0.9	(with VT)
TOTAL	**413.5**	**-16.1**	**398.0**

Notes:
[a] 1995 estimated nonpoint source (NPS) loads are from *Opportunities for Action*. Loads are based on 1991 inputs from the Diagnostic-Feasibility (VT DEC and NYSDEC, 1997) data then subtracting out agricultural BMP credits.
[b] Vermont agricultural reductions are from Lynn Knight (USDA NRCS) and Jeff Cook (VT DAFM). New York agricultural reductions are from *Progress '99* and include information through 1998 only. Quebec agricultural reductions are from Martin Mimeault (QC MENV).
[c] 2001 estimated NPS loads are the sum of the previous two columns (= 1991 loads minus all BMP reductions 1991-2001), with exceptions noted in [d] and [e].
[d] Estimated agricultural BMP reductions exceed the NPS loads for these two lake segments. Loads were therefore projected to be zero.
[e] 2001 load for Missisquoi Bay takes into account Vermont and Quebec BMP credits (142.1 - 2.25 - 0.89).

2.2.3 Summary of progress toward meeting the first 5-year goals

In *Opportunities for Action* the states of New York and Vermont committed to, "…reduce the difference between existing (1995) loads by contributing watershed, and target loads by contributing watershed, by at least 25% per five year period for the next 20 years" (Lake Champlain Management Conference, 1996; p. 10). For this report, five-year targets by lake segment were calculated by taking 25% of the differences between 1995 total loads (from Tables 1 and 4) and the 20-year total target loads for each lake segment, and subtracting that amount (or adding, in the case of Cumberland Bay) from the 1995 total loads. Note that the 20-year targets for Vermont are adjusted target loads from the Vermont Implementation Plan (VT ANR, 1996), not the targets listed in *Opportunities for Action*. There is no separation of point source and nonpoint source loads in the 5-year targets.

In Table 5, the 2001 projected total loads can be compared to the five-year target loads to determine if each lake segment is on track to meet the first set of goals. By agreeing to reduce phosphorus inputs by 25% of the target reductions, the states of Vermont and New York and the province of Quebec committed to a basinwide reduction of 15.8 mt/yr in the first five years[3]. By 2001, the states and Quebec will have reduced phosphorus inputs by 38.8 mt/yr basinwide, far exceeding their goal.

On a lake segment by lake segment basis, the states and Quebec will meet the five-year target concentrations in most lake segments. Missisquoi Bay is the only lake segment that will not reach the five-year target load. However, several other lake segments will just barely meet the targets, and considering the possibility for error in the loading estimates, the Shelburne Bay VT, Burlington Bay VT, South Lake A NY, and Isle LaMotte NY lake segments should be examined more closely.

2.3 Relationship to the TMDL Process

Since the signing of *Opportunities for Action*, the U.S. Environmental Protection Agency has begun implementation of new provisions in the Federal Clean Water Act that require the states to develop a Total Maximum Daily Load (TMDL) for waters where currently required point and nonpoint source pollution controls are not enough to attain compliance with water quality standards. A TMDL establishes the maximum amount of a pollutant that may be introduced to a waterbody while still ensuring attainment of water quality standards. TMDLs must include separate load allocations for point and nonpoint sources.

Both Vermont and New York have listed Lake Champlain as a water needing a TMDL for phosphorus. The Lake Champlain phosphorus TMDL will be developed in a manner consistent with the in-lake total phosphorus concentration goals endorsed by New York, Vermont, and Quebec, and with the loading targets established in *Opportunities for Action* and subsequent state implementation plans. The development of the Lake Champlain phosphorus TMDL will include a public participation process in both states. It is expected that the phosphorus reduction scenarios and cost estimates presented in this report will provide important supporting information for load allocation decisions made during the development of a Lake Champlain phosphorus TMDL.

[3] This number differs from the original 14.25 mt/yr (25% of 57 mt/yr) required because the estimate for 1995 point source loads in Vermont has been slightly revised.

Table 5. Total phosphorus loads for 1995 and 2001, and 5- and 20-year target loads. Notice that the projected load for 2001 is significantly less than the 5-year target load.

Lake Segment	1995 total loads [a]	2001 projected total loads [a]	5-year total target load [b]	20-year total target load [c]
	— (mt/yr) —			
Vermont				
South Lake B	27.6	25.4	26.0	21.0
South Lake A	1.2	0.2	1.1	0.7
Port Henry	0.2	0.0	0.2	0.1
Otter Creek	62.2	56.1	57.1	41.8
Main Lake	80.7	71.4	82.0	85.8
Shelburne Bay	11.8	12.0	12.1	13.0
Burlington Bay	2.5	3.2	3.4	6.1
Malletts Bay	31.2	29.4	30.7	29.4
Northeast Arm	1.4	1.0	1.4	1.2
St. Albans Bay	8.8	8.0	9.1	9.8
Missisquoi Bay	153.0 [d]	145.5 [d]	142.2	109.7
Isle LaMotte	0.3	0.2	0.3	0.3
Vermont total	**380.9**	**352.4**	**365.4**	**318.9**
New York				
South Lake B	27.0	24.1	26.8	26.2
South Lake A	10.1	9.6	9.9	9.4
Port Henry	4.5	2.4	4.0	2.5
Otter Creek	0.1	0.1	0.1	0.0
Main Lake	37.5	33.9	36.9	35.0
Cumberland Bay	20.1	19.8	21.5	25.5
Isle LaMotte	22.0	21.8	21.9	21.5
New York total	**121.3**	**111.6**	**121.0**	**120.1**
Quebec				
Missisquoi Bay	(with VT)	(with VT)	(with VT)	(with VT)
TOTAL	**502.2**	**464.0**	**486.4**	**439.0**

Notes:
[a] Total load is the sum of point source (Table 1) and nonpoint source (Table 4) loads by lake segment, with exceptions noted in [d].
[b] 5-year target loads represent 25% of the difference between the total 1995 loads and the 20-year targets.
[c] Twenty-year targets for Vermont are adjusted target loads from Table 3 in the *Lake Champlain Phosphorus Reduction Vermont Implementation Plan* (VT ANR, 1996). Twenty-year targets for New York are total target loads presented in Table 2 of *Opportunities for Action*.
[d] Total load for Missisquoi is the sum of Vermont and Quebec point source and nonpoint source loads.

The 20-year target loads for Vermont and New York may be modified when the states conduct a Lake Champlain Phosphorus TMDL analysis. Under the agreement in *Opportunities for Action*, each state can adjust its total loading targets by contributing watershed as it sees fit, as long as the adjusted loads meet the in-lake phosphorus concentration goals.

2.4 Expected Reductions Beyond 2001 Under Current Programs

As a first step in examining additional reductions that can be used to achieve the 20-year phosphorus reduction goals, the Phosphorus Reduction Team first examined additional reductions that could be achieved using current programs. This section discusses those reductions in the years beyond 2001. Possible reductions from new programs are considered in Section 3.

2.4.1 Point sources

In Vermont, most planned wastewater treatment plant upgrades will be completed by the end of 2001. The town of Milton is hoping to upgrade and expand their aerated lagoon system to a 1.0 mgd treatment plant by 2002, but the future of the Milton expansion is uncertain because of environmental permitting issues. Facilities in Northfield and Richmond will also be upgraded after 2001. In Quebec, facilities will be constructed for Abercorn and Notre-Dame-de-Stanbridge after 2001. This will reduce phosphorus loads by 0.3 mt/yr. Plans for future upgrades in New York depend on availability and application of funding. State funding will be provided to upgrade facilities that are likely to require phosphorus discharge limits based upon prospective TMDL load allocations. Currently Granville and Westport are waiting for the funding to complete the phosphorus reduction portion of their upgrades. A new facility at Chazy is being planned and is expected to reduce inputs from failing septic systems and direct discharges; these sources have probably been counted as nonpoint source phosphorus in the past.

Point source phosphorus loads for the next ten to 20 years were projected by assuming all facilities will increase their discharges to permitted levels. The assumption is consistent with the agreement between the states and the approach taken in *Opportunities for Action*. However, this projection may overestimate future loads for some facilities most notably Plattsburgh, NY. It might also underestimate loads in towns that expand their treatment plants to accommodate growth. The total permitted loads for each lake segment are presented and discussed in section 3.1 of this report.

2.4.2 Nonpoint sources

Because the majority of current programs to reduce nonpoint source pollution address agricultural sources rather than urban sources, this subsection discusses the future of these agricultural programs exclusively. Thus far, all nonpoint source reductions have come from the agricultural sector. All agricultural reductions have been accomplished on a voluntary basis.

Future funding for these nonpoint source reductions is not clear. In New York, state Bond Act money will be exhausted before 2001, and statewide USDA EQIP funding is very competitive. In Vermont, a combination of state and federal funding has been used to provide assistance to farmers, and the level of funding through these sources has fluctuated from year to year.

In Quebec, the Agroenvironmental Investment Assistance program will provide funding until 2003 for efficient manure storage. By this time all manure storage units should be constructed. Quebec is also planning to control pollution from agricultural sources for 1999-2005 based on various actions already put in place by the Province of Quebec through the Agroenvironmental Investment Assistance and Soil and Water Conservation programs. The main objectives of these programs are the following:

- reduction of phosphorus, nitrogen, and pesticides in specific watersheds;

- promotion of proper farming practices (e.g., efficient manure storage by 2003 and soil and water conservation);
- realization of nutrient management plan as required by the Regulation respecting the reduction of pollution from agricultural sources by 2004;
- intensification of the application of the regulation to reduce pollution from agricultural sources;
- participation of many partners, local groups and farmer unions.

As a way to estimate the potential future reductions available through agricultural BMPs, the USDA NRCS, VT DAFM, and QC MENV have estimated credits in Vermont and Quebec if all remaining farms in need of BMPs (see list in Table 3) were treated. Table 6 presents this information. Credits were based on the same process described in 2.2.2. Future reductions in the Quebec portion of the Basin are based on erosion control and nutrient management BMPs to be implemented, in addition to the other BMPs identified in Table 3. Data are not yet available for New York. A timeframe for completing all BMPs has not been set.

Table 6. Projected nonpoint source phosphorus loads if agricultural BMPs are implemented on all farms needing treatment, compared to 20-year NPS target loads (VT and QC)

Lake Segment	2001 projected NPS loads [a]	Additional agricultural NPS credits [b]	Projected NPS load after treatment [c]	20-year NPS target loads [d]
Vermont		— (mt/yr) —		
South Lake B	24.1	-4.0	20.1	19.2
South Lake A	0.0 [e]	-8.2	0.0 [e]	0.6
Port Henry	0.0 [e]	(w/ S Lake A)	0.0 [e]	0.1
Otter Creek	48.2	-10.0	38.2	27.3
Main Lake	57.8	-4.0	53.8	58.1
Shelburne Bay	11.0	-0.7	10.3	11.0
Burlington Bay	0.3	0.0	0.3	0.3
Malletts Bay	25.8	-6.8	19.0	26.1
Northeast Arm	1.0	-2.1	0.0 [e]	1.2
St. Albans Bay	6.9	-1.5	5.4	7.0
Missisquoi Bay	139.0 [f]	-29.2	109.8 [f]	100.3
Isle LaMotte	0.2	-0.4	0.0 [e]	0.3
Vermont total	**314.3**	**-52.6**	**256.9**	**251.5**
Quebec				
Missisquoi Bay	(with VT)	-14.2	(with VT)	(with VT)

Notes:
[a] See Table 4.
[b] Vermont agricultural reductions are from Lynn Knight (USDA NRCS) and Jeff Cook (VT DAFM). Quebec agricultural reductions are from Martin Mimeault (QC MENV).
[c] Load is equal to 2001 loads minus the BMP credits.
[d] Twenty-year NPS target loads are from the *Vermont Phosphorus Reduction Implementation Plan* (1996).
[e] Agricultural BMP reductions exceed the loads for this lake segment. Loads were therefore projected to be zero.
[f] Load for Missisquoi takes into account Vermont and Quebec BMP credits.

It is evident that in some Vermont lake segments (South Lake A, Northeast Arm, and Isle LaMotte), implementing all BMPs will not be necessary to meet the targets. In other lake segments, even if all

current BMPs are implemented, the phosphorus reductions that would occur would not be sufficient to meet the 20-year nonpoint source target loads. The Vermont lake segments that may not meet the targets relying solely on current BMPs include South Lake B, Otter Creek, and Missisquoi Bay.

2.5 Possible Effects of Land Use Changes on Phosphorus Loads

The load estimates presented thus far have not accounted for changes in phosphorus loading resulting from changes in land use in the Basin. Because developed land contributes much more phosphorus than agricultural or forested land (Hegman *et al*., 1999), the amount of phosphorus discharged into Lake Champlain increases as more land is developed. This increase in phosphorus loading must be offset in any overall reduction strategy. In order to estimate the potential magnitude of this increase in loading, a preliminary estimate of the change in phosphorus inputs in response to land use changes has been developed.

The rate of change for agricultural, forested, and developed land from 1982 to 1992 was calculated for each 8-digit hydrologic unit in the Basin using the USDA National Resources Inventory (NRI) (Table 7). The location of each 8-digit hydrologic unit is shown in Figure 1. The NRI is based on resource data collected every five years at thousands of sample sites in every state except Alaska. The annual NRI land use change rates in each 8-digit hydrologic unit in the Basin were applied to the 1992/93 land use data (as reported in Hegman *et al.*, 1999) to estimate changes in the area of forested, agricultural, and urban lands from 1992 to 2001. Figure 2 shows the distribution of each land use type in 1982 and 1992 by state. Notice that even though the **rate** of increase in developed land is high, especially in Vermont (Table 7), the **amount** of developed land in each state is still relatively small.

To estimate phosphorus loads resulting from land use changes, the phosphorus export coefficients in Hegman *et al.* (1999) were used in each hydrologic unit. Most of the 8-digit hydrologic units encompass the watersheds of more than one lake segment (see Table 7). The data could not be separated further, making an analysis by lake segment impossible. Land use and phosphorus export analysis for the Missisquoi hydrologic unit was adjusted to account for special conditions in this part of the basin. Appendix A presents these adjustments and also includes a more detailed presentation of the overall land use data and nonpoint source loading calculations.

Land use changes are affected by the state of the economy and many other factors. This analysis assumes that the yearly land use conversion between 1992-2001 is the same as the yearly change seen from 1982-1992. Because there were significant differences in the strength of the economy in the 1980s compared to the 1990s, our estimates of change may be conservative. As additional land use change information becomes available, additional analysis is warranted..

As shown in Table 8, estimates of changes in phosphorus inputs resulting from land use changes on the New York side of the basin may not be enough to significantly affect phosphorus loads. However, if the strong economy has resulted in increased development in New York since 1992, then land use changes may significantly affect phosphorus loads in New York in the future

In Vermont, substantial increases in phosphorus loading might be occurring in the Otter Creek, Main Lake/Shelburne Bay/Burlington Bay, Malletts Bay/Northeast Arm/St. Albans Bay, and Missisquoi Bay/Isle LaMotte lake segments. In fact, the increases in some areas may be similar in magnitude to the

Table 7. Land use changes in the Lake Champlain basin, 1982-1992.

Hydrologic Unit Name	Code	Lake Segments in the Hydrologic Unit	Agriculture			Forest			Developed		
			Area (Ha)		Change	Area (Ha)		Change	Area (Ha)		Change
			1982	1992		1982	1992		1982	1992	
VERMONT											
Lake George (VT)	2010001	S Lake B, S Lake A, Port Henry	34,359	28,450	-17.2%	85,593	89,883	5.0%	6,435	7,446	15.7%
Otter	2010002	Otter Creek	89,073	78,834	-11.5%	168,151	175,921	4.6%	8,620	11,453	32.9%
Winooski	2010003	Main Lake, Shelb. Bay, Burl. Bay	50,506	41,805	-17.2%	222,946	227,276	1.9%	19,061	23,756	24.6%
Lamoille	2010005	Malletts Bay, NE Arm, St. Alb. Bay	70,174	57,750	-17.7%	162,121	169,729	4.7%	11,372	16,754	47.3%
Missisquoi	2010007	Missisquoi, NE Arm, Isle LaMotte	55,645	46,904	-15.7%	109,146	117,361	7.5%	6,354	7,244	14.0%
NEW YORK											
Lake George (NY)	2010001	S Lake B, S Lake A, Port Henry, Otter	28,652	25,253	-11.9%	156,779	163,294	4.2%	11,089	12,303	10.9%
Ausable	2010004	Main Lake	30,271	27,681	-8.6%	256,657	259,045	0.9%	10,198	10,198	0.0%
Great Chazy-Saranac	2010006	Cumberland Bay, Isle LaMotte	75,516	67,503	-10.6%	161,716	168,312	4.1%	10,036	11,534	14.9%

Source: 1992 USDA NRCS National Resources Inventory (data provided by Ray Godfrey, NRCS Winooski, VT).

Figure 1. Lake Champlain basin with 8-digit hydrologic units and town boundaries

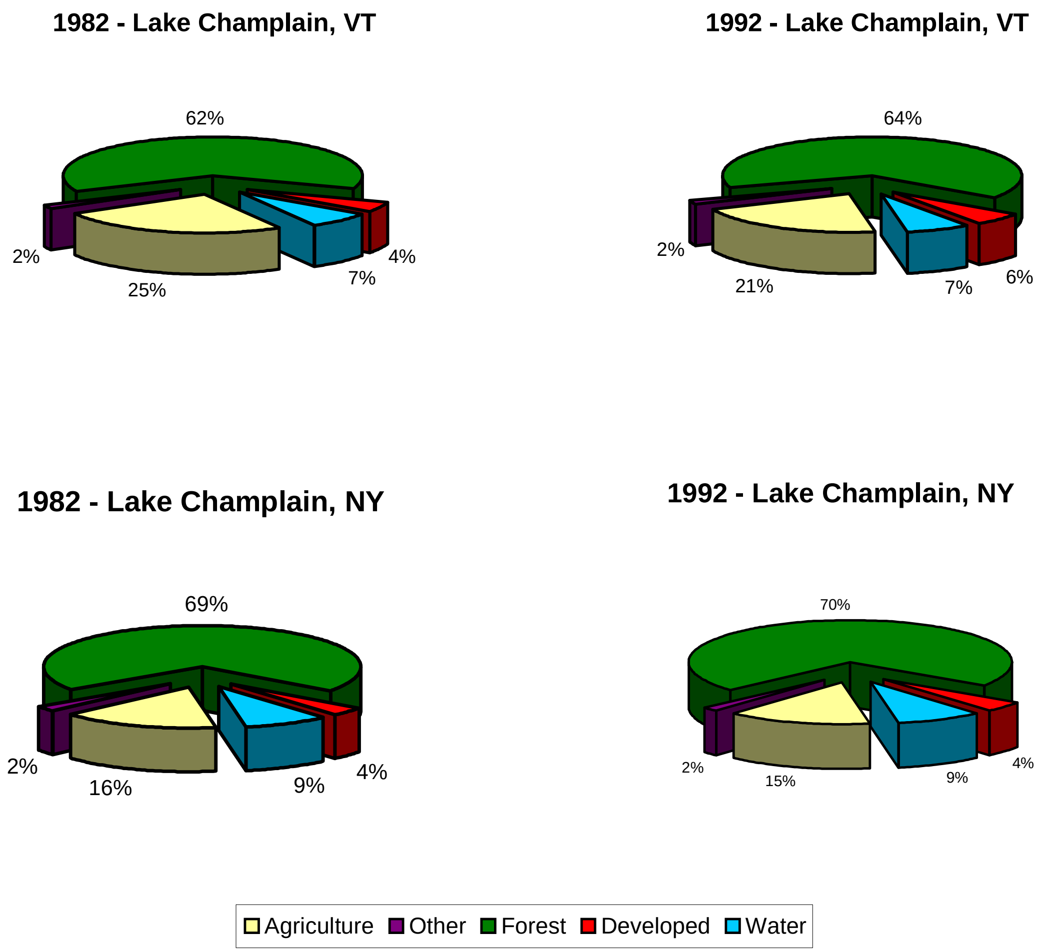

Figure 2. Distribution of major land use types in 1982 and 1992, by state.

Table 8. Projected phosphorus loads for 2001, with and without consideration of land use changes, compared to targets

Lake Segment	1995 total loads	2001 total loads - No land use changes[a]	2001 total loads – With land use changes[b]	5-year total target load [c]	20-year total target load [d]
	— (mt/yr) —				
Vermont					
South Lake B, South Lake A, Port Henry	29.0	25.6	25.0	27.2	21.8
Otter Creek	62.2	56.1	60.3	57.1	41.8
Main Lake, Shelburne Bay, Burlington Bay	95.0	86.7	89.8	97.5	104.9
Malletts Bay, Northeast Arm [e], St. Albans Bay	41.4	38.3	42.0	41.1	40.4
Missisquoi Bay, Isle LaMotte	153.3	145.7	152.4	142.5	110.0
Vermont total	**380.9**	**352.4**	**369.5**	**365.4**	**318.9**
New York					
South Lake B, South Lake A, Port Henry, Otter Creek	41.7	36.2	35.5	40.8	38.1
Main Lake	37.5	33.9	33.2	36.9	35.0
Cumberland Bay, Isle LaMotte	42.1	41.5	40.9	43.3	47.0
New York total	**121.3**	**111.6**	**109.6**	**121.0**	**120.1**
Quebec					
Missisquoi Bay	(with VT)	(with VT)	(with VT)	(with VT)	(with VT)
TOTAL	**502.2**	**464.2**	**479**	**486.4**	**439.0**

Notes:
[a] 2001 load without consideration of land use changes is the 2001 load as calculated in Table 5, but lumped by 8-digit hydrologic unit.
[b] 2001 load with consideration of land use changes adjusts the 2001 load using the change factors shown in Table 7. Projected changes in phosphorus loads are by 8-digit hydrologic unit (HU), not by lake segment, because the land use change information is only available by 8-digit hydrologic unit.
[c] Five-year target loads represent 25% of the difference between the 20-year targets and the total 1995 loads.
[d] Twenty-year targets for Vermont are adjusted target loads from Table 3 in the *Lake Champlain Phosphorus Reduction Vermont Implementation Plan* (VT ANR, 1996). Twenty-year goals for New York are total target loads presented in Table 2 of *Opportunities for Action*.
[e] The Northeast Arm lake segment is located both in the Lamoille and Missisquoi 8-digit hydrologic units.

reductions from agricultural BMP implementation since 1995. Although the predicted changes cannot be attributed to specific locations with the hydrologic unit, additional phosphorus loads from growing areas such as Otter Creek, Shelburne Bay, and Burlington Bay, might mean that these lake segments will not meet their five-year targets.

In the Vermont portion of the Missisquoi Bay watershed, the amount of agricultural land overall has decreased, but the area of row crops (mainly corn) increased by 50% between 1982 and 1997 (USDA Agricultural Census, 1997; Franklin and Orleans counties) and the number of cows and cattle in Franklin County increased by 1.2% between 1987 and 1997 (USDA Agricultural Census, 1997). The agricultural land that has been lost has mainly been land used for hay and pasture. Thus the contribution of phosphorus from agricultural land has probably increased because the land is being used more intensively. For the Missisquoi Bay lake segment, the land use analysis was refined to account for these trends (for additional details, see Appendix A). The results suggest that phosphorus loads will increase by 6.7 mt/yr between 1992 and 2001, putting the lake segment further above the five-year target (Table 8).

2.6 Costs and Funding Sources for Phosphorus Reduction

2.6.1 Vermont

Between 1996 and 2001 Vermont will have spent $13.6 million, at an average cost of $883,000 per metric ton, to reduce yearly point source phosphorus inputs to the lake by 15.4 metric tons. Costs for reductions between 1991 and 1995 (77.4 metric tons of phosphorus reduced) were $7 million, with an average cost of only $91,000 per metric ton of phosphorus reduced. Vermont costs reflect construction costs of the phosphorus reduction portion of the WWTP upgrade; operation and maintenance costs are not available. Funding for these projects has mainly come from the state capital budget.

Vermont and NRCS will have spent $9.6 million to reduce yearly nonpoint source phosphorus inputs to the lake by an estimated 11.0 metric tons between 1996 and 2001, at an average cost of $871,000 per metric ton. Cost estimates are expressed on a present value basis, including capital costs as well as annual operation and maintenance costs, assuming a 5% discount rate over a 30-year period. Of this total, 58% came from federal financial assistance (EQIP and PL-566), 22% came from the state, and 20% was paid by the farmer. Point source and nonpoint source reductions have had similar costs per metric ton during the time period 1996–2001.As demonstrated in Table 6, there are still substantial nonpoint source reductions possible under the current agricultural programs. If all agricultural BMPs are implemented on farms needing them, NRCS estimates that they will cost a total of $62.7 million on the Vermont side of the Basin, or an average cost of $1.2 million per metric ton of phosphorus reduced. This average cost is higher than that for the period of 1996 to 2001 mainly because it is the more complex sites requiring more expensive BMPs that are still in need of treatment. Notice that not all farms will have to be treated to meet the target loads for each lake segment. For example, it appears that not all of the projects identified in South Lake A, Port Henry, Northeast Arm, and Isle LaMotte lake segments will need to be implemented to meet the target loads of those segments. Therefore, $62 million overestimates the total cost of nonpoint reduction necessary.

2.6.2 New York

New York has upgraded several wastewater treatment plant facilities but the cost of reducing phosphorus at these plants is not yet available. Estimated costs presented in Table 2 represent full construction costs, and in some cases do not reflect upgrades for phosphorus removal. Point source cost information for New York will be prepared during 2000. Holmes and Artuso (1996) estimated the cost of some of the upgrades in New York, but the information is incomplete and the estimates appear out of line with the actual costs in Vermont.

Relatively little federal funding has been received in recent years in the New York portion of the Basin through existing programs. Project-specific funding has been used for wastewater treatment facility improvements at Champlain and Peru, and, along with state funding, has contributed to construction of a new facility at Chazy. State funding has been the primary source of implementation money in New York, through the Clean Water/Clean Air Bond Act of 1996. This program allocated $15 million for Lake Champlain management plan implementation projects, based in part on information from Holmes and Artuso (1996). Through the end of 1999, $11 million of this allocation has been committed to a broad range of implementation projects.

2.6.3 Quebec

Between 1991 and 1998, Quebec invested $11.2 million (Can $16.4 million) to construct five new wastewater treatment facilities, two of which discharge into the Richelieu River rather than Lake Champlain. Costs of individual projects are not currently available. These costs represent the total cost of the projects rather than the phosphorus reduction portion of the total cost. Between 1999 and 2001, there will be three additional new facilities, costing $2.3 million (Can $3.3 million).

Since 1988, Quebec has invested primarily in capital construction funds for efficient manure storage through the Agroenvironmental Investment Assistance program. Between 1996 and 2001, Quebec will have spent $1.8 million (Can $2.6 million) to reduce phosphorus nonpoint sources by an estimated 0.9 mt/yr (probably an underestimate because not all practices have been credited). This fund represented 70% of the total cost with 30% coming from farmers. The BMP implementation is based on two existing assistance programs from the Province of Québec, Agroenvironmental Investment Assistance and Soil and Water Conservation.

If erosion control is fully implemented in Quebec, phosphorus nonpoint sources can be reduced by an additional 14 metric tons per year. The QC MENV estimates that this will cost a total of $13.7 million (Can $20.1 million).

3. Addressing Phosphorus Reduction Gaps

3.1 Point Sources

In the first five years since signing *Opportunities for Action*, most of the reductions achieved have come from wastewater treatment upgrades. In order to examine the potential for additional reductions from point sources, three scenarios are discussed below. The scenarios are meant to be exploratory in nature. They might be used in the future to develop cost estimates that will allow for cost-benefit analyses comparing several reduction strategies.

1. <u>Currently permitted loads</u>

This scenario assumes future loads reach the limit in the current discharge permit (permitted flow rates and discharge concentration of 0.8 mg/L) for all applicable facilities. Several facilities in Vermont and New York have specific phosphorus limits (lbs/day); for those facilities, the specific limits were used instead of flow rates and concentrations. A default concentration of 5.0 mg/L was used for most facilities that do not have phosphorus limits in their permits. Because New York has permitted flow limits but has not regulated loads, municipal treatment plants in New York that have been upgraded were assumed to meet a 0.8 mg/L phosphorus concentration and other facilities were assumed to be 5.0 mg/L.

The 20-year total target load allows for future increases in point source discharges up to currently permitted flows. This scenario allows for growth over the next 20 years, but may overestimate loads at some facilities, particularly in Plattsburgh, New York, where process changes at the Georgia-Pacific paper mill have significantly reduced influent loading to the WWTP.

2. <u>No aerated lagoon exemption</u>

This scenario is the same as scenario 1 except that the 0.8 mg/L concentration limit would be extended to eight aerated lagoon facilities with 0.2 mgd or greater permitted flow that are currently exempt from the concentration limit. The eight Vermont facilities that would be affected by this scenario are Hardwick, Hinesburg, Proctor, Richford, Swanton, Troy/Jay, Vergennes, and Waterbury.

In New York, aerated lagoons are in place at Ausable Forks, Dannemora, and St. Armand. Only Dannemora exceeds the 0.2 mgd threshold. It is scheduled for an upgrade by 2001 and so is expected to meet the 0.8 mg/L concentration limit in the near future.

3. <u>Large facility 0.2 mg/L concentration limit</u>

This scenario includes the reductions in scenario 2 as well as the addition of a 0.2 mg/L concentration limit on the 22 facilities in the Basin with a permitted flow greater than 1.0 mgd. Of the facilities affected, 15 are in Vermont and 7 are in New York. There are no facilities of this size in the Quebec portion of the Basin.

A limit of 0.2 mg/L is used in this scenario for the purposes of exploring the lowest possible reductions from large point sources. Emerging technologies (described below) have been developed recently that have succeeded in reducing effluent concentrations to below 0.2 mg/L at pilot plants. It is acknowledged that many factors would have to be considered and negotiated before adopting such a

strategy; therefore this scenario is presented here in order to demonstrate the largest reductions thought to be possible at this time. Costs would not be passed along to towns as an unfunded mandate. Other scenarios, with higher concentrations or targeting facilities only in certain lake segments, can be explored in the future.

Table 9 presents the phosphorus loads by lake segment for the three scenarios described above. It should be noted that the 20-year targets for point and nonpoint sources may be adjusted in the future.

Table 9. Point source phosphorus loads under alternative future scenarios

Lake Segment	Currently permitted load [#1]	#1 and no lagoon exemption [#2]	#2 and large WWTPs at 0.2 mg/L [#3]	20-year point source target loads [a]
	— (mt/yr) —			
Vermont				
South Lake B	1.7	1.7	1.7	1.8
South Lake A	0.2	0.2	0.2	0.1
Port Henry	0.0	0.0	0.0	0.0
Otter Creek	16.5	14.5	7.0	14.4
Main Lake	35.4	32.6	13.8	27.7
Shelburne Bay	2.1	2.0	2.0	2.0
Burlington Bay	5.5	5.5	1.5	5.9
Malletts Bay	6.1	3.9	3.1	3.3
Northeast Arm	0.0	0.0	0.0	0.0
St. Albans Bay	2.8	2.8	1.1	2.8
Missisquoi Bay	10.4	6.7	4.2	9.4
Isle LaMotte	0.2	0.2	0.2	0.0
Vermont total	**80.9**	**70.1**	**34.9**	**67.4**
New York				
South Lake B	3.1	3.1	3.1	1.9
South Lake A	17.6	17.6	5.8	7.4
Port Henry	0.6	0.6	0.6	0.7
Otter Creek	0.0	0.0	0.0	0.0
Main Lake	5.2	5.2	3.2	4.3
Cumberland Bay	19.3	19.3	7.9	17.2
Isle LaMotte	14.7	14.7	1.5	2.0
New York total	**60.6**	**60.6**	**22.1**	**33.5**
Quebec				
Missisquoi Bay	N/A	N/A	N/A	(with VT)

Notes:
[a] The 20-year targets for point sources may be adjusted in the future during the TMDL process.
N/A – not applicable

If all facilities expand to their permitted flow rates as in scenario 1, point source loads will exceed the 20-year point source target loads in nearly every lake segment. Some of these future load estimations may be inaccurate, particularly in the South Lake A NY, Cumberland Bay, and Isle LaMotte NY lake

segments. Because of the high volume, low concentration nature of the International Paper discharge, future loads to the South Lake A segment are probably being overestimated. Similarly, the city of Plattsburgh currently discharges at less than half of the permitted volume because pulping operations at the Georgia-Pacific paper mill have ceased. Therefore, an expansion to permitted discharge volume at this plant probably overestimates future loadings to the Cumberland Bay lake segment. Future loading to the Isle LaMotte segment is strongly affected by the Rouses Point discharge. Because there is no reliable effluent concentration data, a concentration of 5 mg/L was assumed. Also, the discharge from this facility is to the lake outlet (Richelieu River), north of the Rt. 2 bridge. Therefore, impacts upon the waters of Lake Champlain from this discharge are probably minor compared to other point sources in the Isle LaMotte segment.

Scenario 2 offers a reduction of 10.9 mt/yr in Vermont from permitted flow rates. If scenario 2 was implemented, almost all Vermont lake segments would meet or only slightly exceed the current 20-year point source target loads. The largest exceedance of the 20-year total target load, 4.8 mt/yr, would occur in the Main Lake segment. Costs associated with converting the eight lagoon facilities are currently being investigated.

Scenario 3 offers an additional reduction of 35.2 mt/yr for Vermont and 38.5 mt/yr for New York below the permitted rates. In Vermont, only the South Lake A and Isle LaMotte segments would slightly exceed the 20-year point source target loads if all candidate treatment plants were converted. If this scenario was implemented, the loads for Otter Creek, Main Lake VT, Cumberland Bay, and Missisquoi segments would be reduced to roughly half of the 20-year point source target loads. These additional load reductions would bring many lake segments closer to the total phosphorus load reductions necessary to achieve the 20-year targets for total phosphorus load, considering both point and nonpoint sources. If additional treatment on large plants was found to be more cost-effective than agricultural or urban nonpoint source BMPs, these additional point source reductions might be used to achieve the total target loads for those segments.

In the future, this scenario could be further refined. Advanced treatment at selected facilities that are located in specific lake segments where reductions are most needed might be the only way to achieve the in-lake criteria in these problem segments. In addition, reductions achieved in some lake segments (e.g., Burlington Bay and Cumberland Bay) will help reduce in-lake concentrations in other lake segments (Main Lake).

Using the most common phosphorus reduction methods, treatment facilities typically achieve effluent concentrations of 0.5 to 2.0 mg/L. In order to achieve effluent phosphorus concentrations below 0.5 mg/L, it is essential to remove suspended solids (Stallings, 1999). By using chemical addition, tertiary clarification, and effluent filtration it is possible to achieve effluent total phosphorus concentrations of 0.10 to 0.25 mg/L (Stallings, 1999). There are also several emerging technologies that are capable of producing effluents with very low phosphorus concentrations. One new technology called the CoMag process combines the application of a low-level magnetic field with the addition of bentonite and magnetite, and resulting solid precipitates are removed with a high gradient magnetic filter (Woodard and Curren, 1998). This process has been used in a pilot program in Marlborough, Massachusetts and demonstrated an ability to achieve effluent phosphorus levels of less than 0.1 mg/L. Very preliminary cost information for installing the CoMag process at the largest facilities in the Basin have been provided

by Caambridge Water Technology (personal communication). They estimated both add-on costs, assuming that the current facility's effluent is the influent to the CoMag treatment, and an integrated capital cost, assuming that the CoMag technology is integrated within the existing WWTP such that additional chemical treatment ahead of the CoMag plant would reduce the CoMag influent phosphorus to a level that would allow bypass of a significant portion of the total flow. Costs varied from about $1.6 to $2.8 million per million gallons of flow, depending on the size of the WWTP.

Another new phosphorus removal method called the ZenoGem process uses a microfiltration membrane combined with chemical addition. Membranes are typically submerged in existing aeration tanks. Consistent phosphorus effluent levels of less than 0.1 mg/L have been achieved with this process at municipal plants in Ontario, Canada (Mourato and Thompson, 1999; Thompson *et al.*, 1999). Costs may be lower than those of conventional treatment options, but estimates for Lake Champlain facilities are not available at this time.

3.2 Nonpoint Sources

As shown in sections 2.4.2 and 2.5, implementing all remaining BMPs may not be sufficient to reach the 20-year nonpoint source targets in some lake segments. Therefore, it may be necessary to consider new practices that will help attain the water quality goals in each lake segment. The next three sections describe some ideas for additional agricultural and urban phosphorus reduction practices.

3.2.1 Agricultural nonpoint sources

3.2.1.1 Mass Balance Approach. Considerable work has occurred in the Lake Champlain basin investigating options for agricultural producers to reduce nutrient usage in their operations. Most of this work has looked at components of their operation, and not taken into account the effects of the operation as a whole. A whole-farm nutrient planning approach offers farmers a detailed look at nutrient inputs and outputs and can provide a much better picture of the gradual accumulation of nutrients on the farm. For example, an analysis of seven farms in New York and Vermont in the Lake Champlain basin showed that an average of 63% of phosphorus imported onto the farm in a single season was retained on the farm (Allshouse *et al.*, 1997). Accumulated phosphorus can be a threat to water quality if the phosphorus is eventually washed or eroded off the farmland.

As part of a mass balance approach, discussions about how much phosphorus a dairy cow needs for health and reproductivity are occurring throughout the country. The NRCS in Vermont is using a software program called Nut-Bal which is a nutrition balancer. This tool can be used to compare the amount of phosphorus in fecal samples of cattle to the stage of the animal's growth and then predict what supplemental nutrients are needed. In many cases, this tool has demonstrated to farmers that the animal's nutrient needs were being largely met by the vegetation consumed and therefore supplemental feed could be reduced or eliminated, which also reduces costs and imports of off-site nutrients. The software was developed primarily for cattle on range lands in the Midwest and West and it needs to be adapted for the lactation cycles of dairy cows and adjusted for breed and other factors. NRCS in Vermont is in the early investigative stages of refining this tool.

The next logical step in pursuing a mass-balance approach is to investigate the effects of optimizing efficiency of nutrient use on whole farms within the Lake Champlain basin. This investigation should be

done over a period of time. Implementation must consider all the environmental, social and economic factors that influence a farm producer's decision-making process. Additional research and demonstration projects are proposed for fiscal year 2000. Ben & Jerry's, St. Albans Cooperative, Poulin Grain, University of Vermont, Cornell University and other partners have initiated a "Whole Farm Nutrient Planning Pilot Project." This is a unique, industry-driven project to educate cooperative members and Poulin Grain customers about the value of developing and following whole farm nutrient management plans.

3.2.1.2 Buffers. Conservation buffers in the form of filter strips, riparian forest buffers, or grassed waterways can play a large role in capturing sediments and filtering nutrients from waterways. Even with a full conservation system in place on farms, major storm events can yield sediment-laden runoff. More collaboration and attention must be paid to buffers, especially with regard to offsetting the costs of taking buffer land out of grain production.

Traditional USDA cost-share programs offer producers money to install buffer practices but do not reimburse them for the lost productivity. The Conservation Reserve Program (CRP) offers farmers a rental payment for 10-15 years in exchange for converting productive land to a buffer, but this program does not fully or adequately reimburse farmers for land lost from production. For example, one acre of corn that yields 20 tons/acre/yr at $30/ton has a net value of $106 a year. If the rental payment is only $50 per year, the farmer would have lost $840 productive value over a 15-year CRP contract period.

The USDA has a Conservation Reserve Enhancement Program (CREP) available if states submit proposals with financial commitments to "enhance" the incentives offered to farmers. The Winooski Conservation District is currently implementing an EPA 319-funded proposal in the Mad River Watershed to demonstrate whether reimbursing farmers for the productive value of the land is sufficient to successfully market buffers to producers.

Table 10 presents preliminary cost estimates for riparian buffer installation and streambank repair within the Lake Champlain basin.

3.2.2 Urban nonpoint sources

When water runs off the impervious areas (streets, roofs, parking lots, etc.) of urban and developed land it gathers the pollutants in its path and deposits them in nearby waterbodies. On more natural land, the soil can adsorb and retain some of these pollutants. The pollutants in urban areas are from many sources and activities – automobiles, oil and salt on roads, pet wastes, construction site erosion, lawn and garden care, industrial surfaces, and atmospheric deposition are a few. These pollutants include heavy metals, pesticides, sediment, oil and grease, and bacteria, in addition to nutrients such as phosphorus. Because Vermont is the largest contributor of urban nonpoint source phosphorus in the Basin (Hegman *et al.*, 1999), this discussion concentrates on Vermont. It might be worthwhile to assess New York's urban programs and opportunities at a future time.

Phosphorus from developed areas can be controlled in a number of ways. The most widely used practices are structural BMPs that collect and store phosphorus and thereby reduce the amount in runoff. The practice or practices appropriate for a given location vary, as does their effectiveness and cost (see Table 11). Structural BMPs have a removal rate of 5% to 70% of the phosphorus in runoff. Structural

Table **10**. Cost estimates for riparian buffer installation and streambank repair

Insert USDA NRCS table.

Table 11. Urban BMP total phosphorus reduction and costs

Insert Bob Kort's table

measures can be costly and their effectiveness is reduced if design, construction, and maintenance are not appropriate.

Nonstructural runoff control practices can be incorporated with structural practices to gain increased phosphorus removal efficiencies, and also reduce the need for structural controls. Nonstructural practices include innovative site design, high-efficiency street sweeping, pollution source control, and vegetative practices. Examples of innovative site design are clustering development, narrower and shorter residential streets, open channel drainage, riparian buffers, and disconnecting rooftop runoff. Innovative site design with best management practices, compared to a conventional site with best management practices, reduces the phosphorus output by an average of 50% (Center for Watershed Protection, 1998). The cost of the runoff control practices is also typically less.

During land conversion, earthmoving activities lead to short-term soil loss and high phosphorus loading rates. Practices are available to minimize the erosion and sedimentation from construction activities. These include structural sediment controls (silt fence, basins, hay bales, etc.) and nonstructural (temporary seeding and mulching, phased construction, etc.). The nonstructural practices reduce the amount of soil erosion and are very effective. Structural sediment controls attempt to capture the sediment from an eroding site before it enters a waterway. They are less effective than erosion controls and typically more costly. Table 11 shows the costs and phosphorus reduction benefits of construction site BMPs.

Because structural and nonstructural management practices are not 100% efficient, the end result of urbanization, even with these controls as typically implemented, is a net increase in phosphorus. Consequently, the only way to achieve either no net-increase or a reduction in urban nonpoint source loads is to retrofit existing developed areas. This involves the use of management practices on previously developed areas, even if they are not undergoing redevelopment. This is a more costly venture than controls for new development because less land area is available for implementation and options are limited. Often costly underground concrete structures (e.g., the underground sand filter in Table 11) are the only option.

In an attempt to lessen the impact of urban runoff on receiving waters, the state of Vermont requires construction site erosion control permits, stormwater discharge permits, and Act 250 land use permits. Local programs also exist in some towns, but this is the exception rather than the rule. Overall, urban nonpoint phosphorus issues are not being adequately addressed. For example, lack of field inspection undercuts the effectiveness of permits to control temporary runoff. In addition, many small development projects do not come under any state or local review and, therefore, have no controls. These small, unregulated projects can have cumulative impacts on water quality.

Funding. Implementation of programs to meet phosphorus reduction goals in urban and developed areas will be costly, as shown in Table 11. Sustainable, long term funding is necessary to implement urban nonpoint source reductions. Possible sources of funding include stormwater utilities, impact fees, general revenues, state and local government permit fees, and state bond sales or taxes. Choices among methods are important because burden for payment differs.

Stormwater utilities are local government enterprises that provide stormwater services and are financially separate from other government functions. Owners of properties pay a stormwater user charge

based on stormwater runoff volume. Utilities provide a stable source of revenues for operations and maintenance, and flood control and water quality programs. Charges are assessed to be fair and reasonable, and bear a substantial relationship to the cost of service. Utilities exist at many locations around the country.

Impact fees and other developer-based actions are used to offset costs to local governments for services required and impacts from new development. These are often used for capital projects, but other funding sources are generally needed to supplement this revenue over the long term.

Permit fees are charged for the plan review, inspection, and other activities required by new development. These fees should represent the true cost of running the programs so that new development is not subsidized by the taxpayers. Permits should be issued for construction site erosion and sediment control as well as post-construction stormwater management. A system that provides financial penalties for failure to properly install or maintain construction site erosion and sediment controls would provide an incentive for their proper implementation, and also ensure that any financial burden is on those benefiting from the development.

General revenues (e.g., property and income taxes) are a possible funding source as well. They are already being used to support state and local government programs. A case would need to be made for water quality efforts to get a share of these revenues.

Bond sales are a possible source of funds for stormwater retrofits of existing areas. Bond sales have been used to finance retrofits in other states. Bond money is unlikely to fund all the retrofits that may be necessary to obtain the desired water quality improvements in more urbanized areas.

Performance bonding or other appropriate financial guarantees for all projects ensure construction of stormwater management facilities that are in compliance with state or local standards. In addition, the posting of a financial guarantee by a project applicant for the satisfactory performance and maintenance of any facility encourages proper operation and maintenance. These bonds ensure that development projects have adequate financial resources to fully implement stormwater management plan requirements and do not become a financial liability for the local government. This approach can also be used for construction site erosion and sediment controls.

3.2.3 Back roads

Soil erosion is a primary source of pollution to surface waters. Soil is eroded from exposed ground surfaces, such as roads and ditches, when rain and snow melt loosen particles and carry them downhill. Approximately 81% of Vermont's road miles are maintained by municipalities, and the majority of these roads are gravel roads. Simple maintenance techniques can save town funds and protect streams and lakes from sediment and phosphorus accumulation. The Vermont Better Back Roads Program is an ongoing effort to provide information and erosion control on gravel roads, and this program could perhaps be strengthened basinwide to further reduce phosphorus inputs from erosion off dirt roads.

In a survey of Rutland County's (Vermont) back roads, the Rutland Natural Resources Conservation District collected two samples of road runoff in the summer of 1998 and measured total phosphorus concentrations of 2.9 and 4.1 mg/L (Rutland Natural Resources Conservation District, 1999). These limited results suggest that road runoff may be a significant source of nonpoint source phosphorus to

Lake Champlain. This survey found that runoff and erosion from town roads was the principal source of silt and sediment in Rutland County waterbodies. They also found that a major problem for most town road programs is financing, especially lack of highway personnel, and that there is no state or regional agency in Vermont to oversee the management and financing of town roads. Other findings and recommendations are presented in their survey report.

3.3 Potential Reduction Scenarios for Each Lake Segment to Meet 20-year Targets

This section summarizes the analyses in this report for each lake segment in the Basin to provide a general overview of the current and expected future status of phosphorus reduction with respect to meeting the targets in *Opportunities for Action*. Strategies for meeting the targets are suggested as a starting point for dialogue on the subject.

For each lake segment, we begin with a table that presents the current loads, the projected future phosphorus loads, and the 20-year target loads. Future point source loads are estimated using the permitted point source loads as in Table 9. For Vermont and Quebec, future nonpoint source loads are estimated using measured 1991 loads and subtracting current and future agriculture BMPs. For New York, information on agricultural BMPs is currently only available through 1998, and these are subtracted from 1991 loads. Changes in nonpoint source phosphorus loads from land use changes are also presented, but the data are not available for every lake segment. The methodology used to derive future phosphorus loads from land use change is the same as in Section 2.5 and is described in detail in Appendix A. Both loads and credited reductions are in metric tons per year.

3.3.1 Vermont and Quebec

South Lake B, VT (units in mt/yr)

Point source	**Nonpoint source**				**Total**
Permitted load	1991 Measured NPS load	1991-2001 Ag. BMP credits	Potential additional Ag. BMP credits	Projected change in load by 2016 from land use conversions	20-year total target load
1.7	24.8	-0.7	-4.0	–1.5[a]	
Projected total load ~20 years, no land use change = **21.9**					**21.0**

[a] Land use change counts South Lake A, South Lake B, and Port Henry lake segments together.

Summary Assessment: The 20-year total target load may not be met, even if all remaining farms are treated using current agricultural BMPs. No additional point source reductions are possible from the scenarios described in Section 3.1.

South Lake A, VT (units in mt/yr)

Point source	**Nonpoint source**				**Total**
Permitted load	1991 Measured NPS load	1991-2001 Ag. BMP credits	Potential additional Ag. BMP credits	Projected change in load by 2016 from land use conversions	20-year total target load
0.2	2.4	-3.4 [b]	-8.2 [b]	See [a] above	**0.7**
Projected total load ~20 years, no land use change = **0**					

[b] BMP credits consider South Lake A and Port Henry lake segments together.

Summary Assessment: The 20-year total target load might be met by 2001 using agricultural nonpoint source controls. No additional point source reductions are possible in this lake segment from the scenarios described in Section 3.1.

Port Henry, VT (units in mt/yr)

Point source	**Nonpoint source**				**Total**
Permitted load	1991 Measured NPS load	1991-2001 Ag. BMP credits	Potential additional Ag. BMP credits	Projected change in load by 2016 from land use conversions	20-year total target load
0	0.4	See [b] above	See [b] above	See [a] above	**0.1**
Projected total load ~20 years, no land use change = **0**					

Summary Assessment: This lake segment covers a small area of land. The 20-year total target load could possibly be met by 2001 using agricultural nonpoint source controls.

Otter Creek, VT (units in mt/yr)

Point source	**Nonpoint source**				**Total**
Permitted load	1991 Measured NPS load	1991-2001 Ag. BMP credits	Potential additional Ag. BMP credits	Projected change in load by 2016 from land use conversions	20-year total target load
16.5	58.9	-10.7	-10.0	+11.3	**41.7**
Projected total load ~20 years, no land use change = **54.7**					

Summary Assessment: This lake segment is not likely to meet the 20-year total target load under current reduction programs. If all remaining farms in need of treatment are treated with current BMPs, phosphorus loads may still exceed the target load by 13.0 mt/yr. Increased phosphorus loading from land use changes may make the target even harder to achieve. The Otter Creek lake segment would benefit from a reduction of 2.1 mt/yr if point source scenario 2 was implemented and 9.5 mt/yr if point source scenario 3 was implemented. Even with further point source reduction, a combination of additional urban and agricultural nonpoint source reductions, such as those discussed in Section 3.2, will still be necessary to meet the 20-year target loads.

Main Lake, VT *(units in mt/yr)*

Point source	Nonpoint source				Total
Permitted load	1991 Measured NPS load	1991-2001 Ag. BMP credits	Potential additional Ag. BMP credits	Projected change in load by 2016 from land use conversions	20-year total target load
35.4	60.3	-2.5	-4.0	+20.8 [c]	
Projected total load ~20 years, no land use change = **89.2**					**85.8**

[c] Land use change counts Main Lake, Shelburne Bay, and Burlington Bay lake segments together.

Summary Assessment: It does not appear that this lake segment will meet the 20-year total target load under current reduction programs. If all remaining farms are treated with current BMPs, phosphorus loads may still exceed the target load by 3.4 mt/yr. Increased phosphorus loading from land use changes will make the target even harder to achieve because this part of the Basin is under relatively heavy development pressure. The Main Lake segment would benefit from a reduction of 3.0 mt/yr if point source scenario 2 was implemented and 21.6 mt/yr if point source scenario 3 was implemented. This reduction alone would be sufficient to meet the 20-year total target load. The time frame for this reduction would depend on funding for the wastewater treatment plant conversions and retrofits. If additional reductions are necessary (and they may not be until much later), it would be useful to compare the cost-effectiveness of implementing urban BMPs with the cost of treating all remaining farms in this lake segment with agricultural BMPs (see Section 3.2).

Shelburne Bay, VT (units in mt/yr)

Point source	Nonpoint source				Total
Permitted load	1991 Measured NPS load	1991-2001 Ag. BMP credits	Potential additional Ag. BMP credits	Projected change in load by 2016 from land use conversions	20-year total target load
2.1	11.1	-0.1	-0.7	See [c] above	
Projected total load ~20 years, no land use change = **12.4**					**13.0**

Summary Assessment: If no land use change occurs, this lake segment could achieve its 20-year target load under current reduction programs. However, if land use changes result in increased nonpoint source loads, this lake segment may exceed its target load. A good estimate of the land use changes specific for this lake segment is not possible at this time. The Shelburne Bay lake segment would benefit from a reduction of only 0.1 mt/yr if point source scenario 2 was implemented. Because agricultural BMPs do not currently offer many opportunities for reducing phosphorus inputs to this lake segment, additional reductions would have to come from a combination of retrofitting existing developed areas (Section 3.2.2), or implementing new agricultural BMPs on the remaining farms in this watershed (Section 3.2.1). Any water quality improvements in this lake segment would also benefit the Main Lake.

Burlington Bay, VT *(units in mt/yr)*

Point source	**Nonpoint source**				**Total**
Permitted load	1991 Measured NPS load	1991-2001 Ag. BMP credits	Potential additional Ag. BMP credits	Projected change in load by 2016 from land use conversions	20-year total target load
5.5	0.3	0	0	See [c] above	
Projected total load ~20 years, no land use change = **5.8**					**6.2**

Summary Assessment: This lake segment may meet the 20-year total target load but increased development within the city of Burlington has the potential to prevent this from happening. The city is already very developed, but increases in phosphorus inputs may come from construction runoff or increased impervious cover. The most cost-effective way of reducing phosphorus inputs in this lake segment might be to implement point source scenario 3, which could reduce phosphorus loads by 4.1 mt/yr compared to permitted loads. Such a reduction would improve water quality in both the Burlington Bay and Main Lake segments.

Malletts Bay, VT (units in mt/yr)

Point source	**Nonpoint source**				**Total**
Permitted load	1991 Measured NPS load	1991-2001 Ag. BMP credits	Potential additional Ag. BMP credits	Projected change in load by 2016 from land use conversions	20-year total target load
6.1	29.8	-4.0	-6.8	+22.7 [d]	
Projected total load ~20 years, no land use change = **25.1**					**29.4**

[d] Land use change counts Malletts Bay, Northeast Arm, and St. Albans Bay lake segments together.

Summary Assessment: This lake segment appears to be on track to meet the 20-year total target load under current reduction programs, assuming some remaining farms are treated with BMPs and no land use change occurs. However, this part of the Basin is under relatively heavy development pressure. Phosphorus load increases from land use changes may mean that these reductions are not enough to meet the 20-year total target load, although the magnitude of increases are not known specifically for this lake segment. The Malletts Bay lake segment would benefit from an additional reduction of 2.2 mt/yr (compared to permitted loads) if point source scenario 2 was implemented and 3.0 mt/yr if point source scenario 3 was implemented. To achieve additional reductions, the cost-effectiveness of implementing urban BMPs might be compared with the cost of treating the remaining farms with agricultural BMPs (see Section 3.2

Northeast Arm, VT (units in mt/yr)

Point source	**Nonpoint source**				**Total**
Permitted load	1991 Measured NPS load	1991-2001 Ag. BMP credits	Potential additional Ag. BMP credits	Projected change in load by 2016 from land use conversions	20-year total target load
0.0	3.2	-2.2	-2.1	See [d] above	
Projected total load ~20 years, no land use change = **0**					**1.2**

Summary Assessment: The 20-year total target load may be met if all remaining farms are treated under current agricultural programs. However, attention should be paid to possible increases in phosphorus loads from land use changes. No specific numbers are available for this lake segment. If additional reductions are needed, a combination of urban BMPs on new development and treating some remaining farms could reduce loads enough to meet the target load.

St. Albans Bay, VT (units in mt/yr)

Point source	**Nonpoint source**				**Total**
Permitted load	1991 Measured NPS load	1991-2001 Ag. BMP credits	Potential additional Ag. BMP credits	Projected change in load by 2016 from land use conversions	20-year total target load
2.8	7.2	-0.3	-1.5	See [d] above	
Projected total load ~20 years, no land use change = **8.2**					**9.8**

Summary Assessment: In-lake phosphorus concentrations in St. Albans Bay are very high. The target load was originally developed for this lake segment assuming that the internal load of the bay would decrease over time, but this has been slow to occur. Although it appears from this numerical analysis that the 20-year total target load may already have been met, it might be necessary to continue and accelerate nonpoint source reductions to St. Albans Bay to compensate for the internal load in the bay. The St. Albans Bay lake segment would benefit from an additional reduction of 1.7 mt/yr from permitted loads if point source scenario 3 was implemented.

Missisquoi Bay, VT and Quebec (units in mt/yr)

Point source	**Nonpoint source**				**Total**
Permitted load	1991 Measured NPS load	1991-2001 Ag. BMP credits	Potential additional Ag. BMP credits	Projected change in load by 2016 from land use conversions	20-year total target load
10.4 (VT) ? >2.4 (QC)	94.2 (VT) 57.7 (QC) [e]	-12.0 (VT) -1.3 (QC)	-15.0 (VT) -14.2 (QC)	+18.0 [f]	
Projected total load ~20 years, no land use change = **77.6 (VT)** **44.6 (QC)**					**65.8 (VT)** **43.9 (QC)**

[e] Total NPS load of 151.9 mt/yr, split 62%/38% VT/QC based on Hegman *et al*. (1999).
[f] Land use change counts the Missisquoi Bay (Vermont and Quebec portions) and Isle LaMotte lake segments together.

Summary Assessment: The allocation of the 20-year total target load between Vermont and Quebec is based on the draft Missisquoi Bay Phosphorus Reduction Task Force recommendation that the 20-year total target load should be apportioned at 60% for VT and 40% for Quebec. Credits for BMPs in Quebec between 1991 and 2001 (see Table 3) do not take into account all activities implemented during this time and may underestimate actual reductions. Two additional practices were included in estimating potential additional BMP credits beyond 2001.

Existing phosphorus reduction programs will not be sufficient to meet the 20-year target load in either the Vermont or the Quebec portions of the Missisquoi Bay lake segment, even if loading increases from land use changes do not occur. However, land use changes are likely to result in increases in phosphorus

loading to this segment. The increasing density of animals and the increasing amount of agricultural land used for row crops (mainly corn) will probably cause the phosphorus load from agricultural sources to increase, despite an overall decrease in agricultural land. A shift to a higher proportion of forest land in this lake segment watershed may slightly offset the phosphorus load increases from agricultural lands.

In the Quebec portion of the watershed, a series of phosphorus reduction efforts planned by QC MENV and the Missisquoi Bay Basin Corporation should result in significant progress toward meeting the target loads. The Vermont portion of the Missisquoi Bay lake segment would benefit from an additional reduction of 3.6 mt/yr (compared to permitted loads) if point source scenario 2 was implemented and 6.1 mt/yr if point source scenario 3 was implemented. Because urban land is minimal in this watershed, thoughtful consideration should be given to new, innovative, agricultural BMPs to achieve additional reductions (Section 3.2.1).

Isle LaMotte, VT *(units in mt/yr)*

Point source	**Nonpoint source**				**Total**
Permitted load	1991 Measured NPS load	1991-2001 Ag. BMP credits	Potential additional Ag. BMP credits	Projected change in load by 2016 from land use conversions	20-year total target load
0.2	0.6	-0.4	-0.4	See [e] above	
Projected total load ~20 years, no land use change = **0**					**0.3**

Summary Assessment: The 20-year total target load may be met by 2001 using agricultural programs, although the agricultural BMP data is difficult to separate from the Northeast Arm segment. The Champlain Islands are located in both the Isle LaMotte and Northeast Arm lake segments, but the agricultural database for BMPs does not record specific locations of farms on the islands.

3.3.2 New York

South Lake B, NY (units in mt/yr)

Point source	**Nonpoint source**				**Total**
Permitted load	1991 Measured NPS load	1991-1998 Ag. BMP credits	Potential additional Ag. BMP credits	Projected change in load by 2016 from land use conversions	20-year total target load
3.1	24.3	-2.4	unknown	+0.3 [f]	
Projected total load ~20 years, no land use change = **25.0**					**26.2**

[f] Land use change counts South Lake A, South Lake B, Port Henry, and Otter Creek lake segments together.

Summary Assessment: The 20-year total target load may not be met in this lake segment, depending on the distribution of land use changes in the area. However, potential decreases from additional agricultural BMPs have not yet been quantified. There are no additional point source reductions in this lake segment resulting from the scenarios described in Section 3.1.

South Lake A, NY (units in mt/yr)

Point source	**Nonpoint source**				**Total**
Permitted load	1991 Measured NPS load	1991-1998 Ag. BMP credits	Potential additional Ag. BMP credits	Projected change in load by 2016 from land use conversions	20-year total target load
17.6	3.5	-1.0	Unknown	See [f] above	**9.4**
Projected total load ~20 years, no land use change = **20.1**					

Summary Assessment: It does not appear that the 20-year total target load is likely to be met under current programs, although reductions from agricultural BMPs beyond 1998 have not been quantified. This segment contains one large municipal facility at Ticonderoga and the single largest volume wastewater discharge in the Basin, the International Paper Company mill. Estimation of future loading for each of these discharges requires special consideration: International Paper Company is a high volume, low concentration discharge, and Ticonderoga is designed and operated as a combined wastewater/stormwater treatment facility.

Port Henry, NY (units in mt/yr)

Point source	**Nonpoint source**				**Total**
Permitted load	1991 Measured NPS load	1991-1998 Ag. BMP credits	Potential additional Ag. BMP credits	Projected change in load by 2016 from land use conversions	20-year total target load
0.6	2.6	-1.0	unknown	See [f] above	**2.5**
Projected total load ~20 years, no land use change = **2.2**					

Summary Assessment: Although it appears that the 20-year total target load may have already been met by current agricultural practices, additional point source improvement is warranted. The Port Henry/Moriah wastewater treatment facility is being upgraded, but there are significant technical complications resulting from infiltration/inflow to the collection system and a severe lack of physical space to complete necessary expansion of the treatment facility. Additional funding is being sought to complete the upgrade of this point source. The potential phosphorus reductions achievable with such an upgrade are unknown at this time.

Otter Creek, NY (units in mt/yr)

Point source	**Nonpoint source**				**Total**
Permitted load	1991 Measured NPS load	1991-1998 Ag. BMP credits	Potential additional Ag. BMP credits	Projected change in load by 2016 from land use conversions	20-year total target load
0	0.1	0	unknown	See [f] above	**0**
Projected total load ~20 years, no land use change = **0.1**					

Summary Assessment: This lake segment covers a small, predominantly forested land area in New York. No feasible load reductions have been identified in this lake segment, therefore required load reductions must be achieved by a reallocation to adjacent lake segments.

Main Lake, NY (units in mt/yr)

Point source	Nonpoint source				Total
Permitted load	1991 Measured NPS load	1991-1998 Ag. BMP credits	Potential additional Ag. BMP credits	Projected change in load by 2016 from land use conversions	20-year total target load
5.2	31.8	-1.9	unknown	-1.2	
Projected total load ~20 years, no land use change = **35.1**					**35.1**

Summary Assessment: It appears that this lake segment may meet the 20-year total target load under current reduction programs if land use changes are minimal. Potential reductions from agricultural BMPs beyond 1998 have not been quantified. Point source scenario 3 would reduce phosphorus inputs by an additional 2.1 mt/yr compared to permitted loads.

Cumberland Bay, NY *(units in mt/yr)*

Point source	Nonpoint source				Total
Permitted load	1991 Measured NPS load	1991-1998 Ag. BMP credits	Potential additional Ag. BMP credits	Projected change in load by 2016 from land use conversions	20-year total target load
19.3	8.8	-0.6	unknown	+2.5 [g]	
Projected total load ~20 years, no land use change = **27.5**					**25.5**

[g] Land use change counts Cumberland Bay and Isle LaMotte lake segments together.

Summary Assessment: This lake segment was allocated an increase of 5.3 mt/yr of phosphorus in *Opportunities for Action*, primarily because the load allocation assumed that all point sources would grow to their permitted levels. Plattsburgh WWTP is, however, operating at less than half of its design and permitted capacity because pulping operations at the Georgia-Pacific mill have ceased. This change has resulted in a 40% reduction in the loading to this lake segment from 1991 to 1995 (17.4 mt/yr). The City of Plattsburgh has also implemented phosphorus reduction utilizing chemical addition, further reducing loading from the WWTP largest point source to this lake segment. Industrial and commercial growth in the Plattsburgh area may increase both point and nonpoint source phosphorus loads from current levels, but the allocated load is not likely to be exceeded. The phosphorus concentration in Cumberland Bay is relatively insensitive to loading changes due to the rapid exchange of water between the Cumberland Bay and the Main Lake segments during the open water season. Point source phosphorus inputs could be reduced by an additional 11.4 mt/yr (compared to permitted loads) in Cumberland Bay if point source scenario 3 was implemented. Additional reductions from agricultural BMPs beyond 1998 are not known.

Isle LaMotte, NY (units in mt/yr)

Point source	Nonpoint source				Total
Permitted load	1991 Measured NPS load	1991-1998 Ag. BMP credits	Potential additional Ag. BMP credits	Projected change in load by 2016 from land use conversions	20-year total target load
14.7	20.9	-1.4	Unknown	See [g] above	
Projected total load ~20 years, no land use change = **34.2**					**21.5**

Summary Assessment: It appears that the 20-year total target load is not likely to be met under current practices. Although the in-lake phosphorus concentration in this lake segment is currently below the interim criteria of 14 μg/L, some embayments in this lake segment have been listed on the New York Priority Water List because of agricultural runoff. Several agricultural load reduction projects have been targeted to these area of the lake. The rapid growth of industrial activities along the Canadian border may require continued improvements to wastewater treatment facilities to maintain water quality in this lake segment. A new facility at Chazy is being planned and is expected to reduce inputs from failing septic systems and direct discharges, which has probably been counted as part of the nonpoint source phosphorus load in this lake segment.

4. Conclusions and Potential Next Steps

The work of the Phosphorus Reduction Team, including the analyses presented in this report, is the first step toward assessing progress toward implementing the phosphorus reduction actions outlined in *Opportunities for Action* (see Appendix B). It is intended to help the Lake Champlain Basin Program partners make decisions about the actions necessary to meet the reduction targets over the long term. This section presents a set of overall conclusions based on the data and information assembled for this report. It also presents a series of potential next steps that could be taken to continue the progress we have made thus far.

4.1 Conclusions

There is little doubt that Vermont, New York, and Quebec will meet the interim goal in *Opportunities for Action* of reducing phosphorus loads by 25% of the overall reduction targets. In fact, by 2001, Vermont, New York and Quebec will have reduced phosphorus inputs by 38.8 mt/yr basinwide, far exceeding the five-year target reduction of 15.8 mt/yr. Missisquoi Bay VT is the only individual lake segment that may not achieve a 25% reduction in the first five years.

Despite this considerable success, future planning for phosphorus reductions must account for changes in nonpoint source loads resulting from increased urbanization in the basin. Increased phosphorus loads generated by land use changes appear to be offsetting some of the gains achieved by point and agricultural nonpoint source reduction efforts. As the population within the Basin increases, particularly on the Vermont side of the lake, more land will become developed. The Otter Creek, Main Lake, Shelburne Bay, Burlington Bay, Malletts Bay, Northeast Arm, and St. Albans Bay lake segments are undergoing the most rapid changes in land use. A plan for offsetting the increased phosphorus loads from developed land is needed for the future, as well as a reliable way of tracking land use changes in a timely fashion. Because phosphorus is released both during construction and afterwards, urban BMPs used on new construction will not reduce the amount of nonpoint source phosphorus loading into Lake Champlain, however, they can dramatically reduce the increases. Techniques that minimize increases, as well as reduce overall inputs, will be necessary in order to meet the 20-year targets.

Thus far, implementation of the phosphorus reduction plan has not targeted reductions to specific watersheds. Most of the agricultural BMPs have been completed on a voluntary basis, wherever there are willing landowners. In order to achieve the final reduction targets in the most time- and cost-efficient

manner, resources may need to be targeted to priority watersheds. Phosphorus reduction programs will also need to be tailored to the specific needs and situations of each lake segment watershed.

The analysis presented in this report suggests that the 20-year phosphorus reduction targets cannot be met in several lake segments if we rely solely on the current programs. In these lake segments, additional options must be considered in order to reach the loading reductions necessary. The options available in each of these segments are summarized below.

<u>Otter Creek VT</u> – Additional point source reductions could help achieve the targets in this lake segment, but by themselves, cannot achieve the goals. Additional urban and/or agricultural nonpoint source controls must also be considered in the lake segment..

<u>Main Lake VT</u> – All necessary reductions for this lake segment could be achieved through innovative new treatments on the larger wastewater treatment plants. Additional urban and agricultural nonpoint source treatment might also be considered. An analysis of cost-effectiveness would help evaluate options.

<u>Shelburne Bay VT</u> – Load reductions sufficient to achieve the target in this lake segment might only be possible by retrofitting existing developed areas with urban BMPs. Because this lake segment is experiencing considerable new development, BMPs that minimize phosphorus loading ducring construction could be essential in reaching the long-term goal. .

<u>Burlington Bay VT</u> – Further reductions of the phosphorus loads from Burlington's main wastewater treatment plant would be sufficient to meet the lake segment target load, however, urban BMPs might also be considered to reach the targets..

<u>Malletts Bay VT</u> – Even if agricultural BMPs are implemented on all the farms still in need of treatment and point sources are further reduced, additional reductions are likely to be necessary because this lake segment is receiving increased phosphorus loads from development in the Lamoille River watershed. These reductions could be achieved by either urban or additional agricultural nonpoint source treatment.

<u>Missisquoi Bay VT and Quebec</u> – Nonpoint source loads are high in this lake segment because of high animal density. Current agricultural programs will not be sufficient to reduce phosphorus inputs to target levels. Innovative, cost-effective agricultural BMPs will need to be explored and implemented to achieve the targets in this watershed. Implementation of urban BMPs would not substantially reduce the phosphorus load because the acreage of developed land use is not high.

<u>South Lake A NY</u> – Additional agricultural BMP implementation beyond 1998 and additional adjustments of point source loads at large wastewater treatment plants may be able to reduce loads enough to meet the 20-year target in these lake segments. Urban nonpoint source treatment iss also an option worth exploring in these lake segments.

<u>Main Lake NY</u> –Urban nonpoint source treatment might be considered to ensure that the 20 year target load is met in this lake segment.

<u>Cumberland Bay NY</u> – Further reductions of the phosphorus loads from Plattsburgh's main wastewater treatment plant would be sufficient to meet the target load in this lake segment. Additional agricultural BMP implementation beyond 1998 may also be able to reduce loads.

Accelerating the timeframe for meeting the 20-year targets would largely require allocating funding to reduction programs at a much greater rate than in the past. Table 12 summarizes the dollars spent by Vermont, New York, and Quebec to reduce phosphorus since 1995. Costs of point source reduction programs cannot be directly compared between Vermont, New York, and Quebec because the costs represent different accounting methods.

Table 12. Summary of costs, 1996-2001

Reduction Program	Vermont	New York	Quebec
Point Source	Capital costs for P portion of upgrades $10,804,433 Total project costs $35,413,280	Total construction costs for various projects >$10,573,800	Total construction costs (new WWTP) in US$ $2,259,406
Agricultural Nonpoint Source	$9,572,186	Not available	$1,365,200

Costs of potential future programs per metric ton of phosphorus removed are summarized in Table 13. It is important to recognize that not all of the farms included in the cost estimate will need to be treated to achieve the phosphorus reduction goals in each lake segment. Likewise, not all point sources will need to be treated, in fact, only a few may need treatment. Tailoring programs to particular watersheds will be the best way to achieve the final targets in the most time and cost-efficient manner. Also, future costs may be borne by both public and private entities. As described in Section 3.2.2, urban BMPs and retrofits may be funded in a variety of ways.

Table 12. Projected future costs per metric ton of phosphorus removed

P reduction program	Cost range (US $ / mt-yr P)	Source of information
Nonpoint Sources		
Remaining Agricultural BMPs	$970,000 to $1.2 million	Table 6 and costs in Section 2.6.1 and 2.6.3
Stream buffers and streambank repair	Not available	-
New development urban BMPs	$521,000 to $7.8 million	Table 11, Total Cost Benefit for Life of BMP column
Urban BMP retrofits	$3.6 to $11.1 million	Table 12
Construction site BMPs	$30,000 to $62,000	Table 11, Total Cost Benefit for Life of BMP column
Point sources		
Scenario 2 (lagoons)	Not available	-
Scenario 3 (large facilities at 0.2 mg/L)	$596,000 - $2.6 million	Table 9 and Cambridge Water Technology

It is difficult to project the future costs needed to meet the targets. The most complete information is available for Vermont, which has spent approximately $22 million (from the state and the federal governments, and individual farmers) in the first five years of implementing the plan. More than half of

that money was spent to upgrade wastewater treatment plants, which will be complete by 2001 or 2002. These expenditures achieved reductions far exceeding those necessary in the first five years overall. It is likely, however, that at least the same amount of money will be needed for each subsequent 25% reduction. It will be necessary to develop new programs to achieve the total phosphorus loadings reductions needed for Lake Champlain. The exact cost of these new programs is not currently known, but the data in Table 13 provides some context. Total costs will vary by lake segment, depending on the mix of point source and nonpoint source controls that are chosen.

4.2 Potential Next Steps to Further the Phosphorus Reduction Goals

Since the agreement in *Opportunities for Action* was signed, significant phosphorus reductions have been achieved by controlling both point and nonpoint sources. Refinements to existing approaches, such as those outlined in this section, could help to realize the phosphorus reductions needed to meet the established targets in all lake segments, possibly in an accelerated time frame.

<u>Point Source</u> **--** Most of the reductions in phosphorus loads to Lake Champlain have been accomplished by upgrades to wastewater treatment plants. As shown in this report, there may still be additional reductions possible in this area. To investigate the feasibility of applying emerging phosphorus removal technologies, site-specific cost estimates using these technologies (including CoMag and ZenoGem) could be developed. Feasibility studies would be most useful if they focused on one or more "representative" municipal treatment facility in those lake segments not expected to meet their reduction targets through other methods.

<u>Agricultural Nonpoint Source</u> – Most nonpoint source efforts have focused on agricultural sources. Much has been accomplished in recent years, especially with respect to waste storage on farms. Because further reductions are needed, new programs may still need to be developed to reach the reduction goals. The most promising approaches include the following:

- "Whole farm" programs to insure that farmers use their on-farm nutrients in the most environmentally and economically efficient manner, and that phosphorus lost to waterways in runoff is minimized.
- Programs that reduce phosphorus inputs into the Basin (such as promoting low-phosphorus feeds or reducing grain imports).
- Programs that assist in exporting phosphorus outside the Basin or moving phosphorus within watersheds (for example, selling manure and compost to gardeners), rather than importing it to meet farm needs.
- Programs that promote establishing riparian buffers on agricultural land, which may include reimbursing farmers for lost productivity.
- State programs that organize and facilitate watershed "teams" comprised of local stakeholders that would focus on implementing nonpoint source phosphorus reductions. This could encourage reduction efforts in specific lake segments, and would also allow local people to develop the programs that work best for them.
- The LCBP should assist the QC MENV in its efforts to generate support from all the ministries involved, including funding and technical support for implementation of agricultural BMPs.

Urban Nonpoint Source – Our analysis suggests that some of the nonpoint source phosphorus reductions achieved to date are being offset through increased urbanization. This problem is most acute in Vermont where developed land is increasing at a relatively rapid pace. Urban nonpoint source control, therefore, seems to be a more pressing need in Vermont at this time. The following steps could contribute to offsetting the phosphorus generated by new development in Vermont. New York may choose to follow suit where applicable (please note that in New York, state stormwater controls manuals are either current or in revision).

- The state of Vermont could create a new stormwater management planning and design manual and revise its outdated erosion and sediment control manual to provide innovative, and more effective implementation guidance for land developers and local governments. Stakeholders should be involved in the development of these manuals.
- In enhancing and upgrading its stormwater management and its erosion and sediment control programs, the state of Vermont might consider the following:
  - Evaluating the phosphorus loads as part of the permitting process for development projects so that the best strategy for phosphorus control can be implemented on projects with significant potential impacts.
  - Encouraging innovative site design and other nonstructural controls.
  - Requiring retrofits for stormwater management with redevelopment of existing urban land.
  - Working to increase the funding for stormwater and erosion and sediment control programs so that planning, design, construction, compliance, and maintenance activities can be more effectively implemented. A variety of funding mechanisms could be explored, including revising the permit fees to reflect the true cost of administering the program.
- Research could be conducted to quantify the magnitude of some phosphorus sources such as the loading from back roads and their drainage systems, and contributions from urban source areas (for example, lawns, roads, commercial lots, etc.).
- Efforts for improved back road construction and maintenance could be promoted to reduce erosion and nonpoint source pollution from runoff.

4.3 Steps to Enhance the Evaluation of Progress

Assessments and predictions of phosphorus loads must be based on sound science and reliable data. The following steps could provide the information needed to more accurately evaluate progress towards phosphorus goals in the future.

- The Diagnostic-Feasibility Study (VT DEC and NYSDEC, 1997) was conducted in the early 1990's to gather baseline data on phosphorus loads, in-lake phosphorus concentrations, and other parameters needed to set the reduction targets in *Opportunities for Action*. As time passes, it is increasingly difficult to estimate nonpoint source loads accurately by crediting against these outdated measured loads. Existing data from the Long-Term Water Quality and Biological Monitoring Program for Lake Champlain on 18 basin tributaries could be used to analyze trends in nonpoint source loading in these watersheds. Regular rounds of comprehensive "snap shot" sampling, perhaps every ten years, could be used to supplement these data.

- In conjunction with the comprehensive sampling, updated land use data could be developed to document the impact of changing land use on phosphorus loads. At a minimum, the USDA National Resources Inventory data could be used to identify "hot spots," and attention could be focused on those lake segments undergoing a large amount of change. Such an analysis could be completed using satellite imagery or digitized aerial photographs. This type of information is not currently being collected by any state agency.
- To track reductions between comprehensive sampling events, the crediting system for BMPs in Vermont, New York, and Quebec could be refined. All BMP implementation in the Basin, whether by federal, state, and local programs, should be credited in a comprehensive manner. The credits for certain agricultural BMPs should also be enhanced to ensure that Vermont, New York, and Quebec are consistently applying appropriate credits for all major practices, including erosion control and riparian restoration practices. Some of this work is currently underway.
- Tracking phosphorus loads from point sources could also be improved by complete monitoring of effluent flows and concentrations from all wastewater treatment plants. Vermont, New York, and Quebec are working to improve such monitoring.

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APPENDIX A. METHODOLOGY FOR ESTIMATING LAND USE CONVERSION AND ITS IMPACT ON PHOSPHORUS LOADS TO LAKE CHAMPLAIN

Recently, concerns have been expressed about the effects of urban sprawl on water quality. Studies in the Lake Champlain region have shown that developed land typically contributes more phosphorus per unit area of land than other land use types (Budd and Meals, 1994; Hegman *et al*., 1999). In certain areas of the Lake Champlain basin, the amount of agricultural land being converted to housing and other development appears to be significant, but the most recent land use data for the basin are 7-8 years old [i.e., 1992/1993 satellite data]. To assessing the effects of land use change on phosphorus loading in the Lake Champlain basin, a method was developed to predict the potential land use distribution in the basin beyond 1992.

Hegman *et al.* (1999) estimated the relative magnitude of nonpoint source phosphorus loads from three general land use categories (forested, agricultural and developed). They developed phosphorus export coefficients based on the Basin Program's 1992/1993 land use data set and phosphorus monitoring data from the Diagnostic-Feasibility Study (VT and NY DEC, 1997). To estimate future land use areas and expected changes in phosphorus loads, conversion rates for agricultural, forested, and developed land were calculated for each 8-digit hydrologic unit in the basin, based on USDA National Resources Inventory (NRI) data for 1982-1992. Table A-9 at the end of this appendix presents the NRI land use data and identifies the land use categories that were consolidated for the analysis.

The annual NRI land use change rates were applied to the 1992/93 land use data to estimate the change in the area of forested, agricultural, and urban lands from 1992 to 2001 (Section 2.5) and from 1992 to 2016 (Section 3.3). It was assumed that the annual change rate in each hydrologic unit for any year beyond 1992 is the same as the average annual change between 1982 and 1992.

The phosphorus export coefficients from Hegman *et al.* (1999) (Table A-1) were then applied to the current and future land areas to estimate phosphorus loads by hydrologic unit. Most of the 8-digit hydrologic units encompass the watersheds of more than one lake segment, therefore it was not possible to assign loads to each specific lake segment. Estimated loads for 1992, 2001, and 2016 are shown in Tables A-2 through A-4 below. The Missisquoi Bay lake segment was analyzed using a different method, described below. Note: The increase in total land area of the basin over time is an artifact of using approximate land use change rates to predict into the future. The increase is less than 1% over 10 years.

Table A-1. Area phosphorus export coefficients for major land uses in the Lake Champlain Basin (kg/ha/yr).

Forest	Agriculture	Urban
0.04	0.42	1.50

Source: Hegman et al, 1999.

Table A-2: 1992/1993 Land use and phosphorus loads for major watersheds in the Lake Champlain basin.

			1992/1993 Hegman *et al*. (1999) land use					1992/1993 nonpoint source phosphorus loads			
Hydrologic Unit Name	**HU**	**Lake Segment**	**Agricultural**	**Forested**	**Developed**	**Water**	*Total*	**Agricultural**	**Forested**	**Developed**	*Total*
			Area (hectares)					Loads (mt/yr)			
VERMONT											
Lake George (VT)	02010001	S Lake B, S Lake A, Port Henry	29,438	77,125	5,743	8,837	121,143	12.4	3.1	8.6	24.1
Otter	02010002	Otter Creek	70,192	182,907	15,701	15,484	284,284	29.5	7.3	23.6	60.3
Winooski	02010003	Main Lake, Shelb. Bay, Burl. Bay	43,594	210,450	31,520	15,042	300,605	18.3	8.4	47.3	74.0
Lamoille	02010005	Malletts Bay, NE Arm, St. Alb Bay	49,753	164,545	18,118	17,940	250,355	20.9	6.6	27.2	54.7
Missisquoi	02010007	Missisquoi, NE Arm, Is LaMotte	79,971	199,815	14,655	15,945	310,386	(see separate analysis)			
NEW YORK											
Lake George (NY)	02010001	S Lake B, S Lake A, Port Henry	39,960	151,890	11,387	4,365	207,602	16.8	6.1	17.1	39.9
Ausable	02010004	Main Lake	15,779	225,785	8,952	6,391	256,906	6.6	9.0	13.4	29.1
Great Chazy-Saranac	02010006	Cumberland Bay, Isle LaMotte	37,482	212,544	10,563	15,174	275,763	15.7	8.5	15.8	40.1
		Total	**366,168**	**1,425,060**	**116,638**	**99,179**	**2,007,045**	**120.2**	**49.0**	**153.0**	**322.2**

Table A-3: Projected 2001 Land use and phosphorus loads for major watersheds in the Lake Champlain basin.

			Projected 2001 land use					2001 NPS phosphorus loads			
Hydrologic Unit Name	**HU**	**Lake Segment**	**Agricultural**	**Forested**	**Developed**	**Water**	*Total*	**Agricultural**	**Forested**	**Developed**	*Total*
			Area (hectares)					Loads (mt/yr)			
VERMONT											
Lake George (VT)	02010001	S Lake B, S Lake A, Port Henry	24,882	80,604	6,555	8,837	120,878	10.5	3.2	9.8	23.5
Otter	02010002	Otter Creek	62,931	190,514	20,345	15,484	289,273	26.4	7.6	30.5	64.6
Winooski	02010003	Main Lake, Shelb. Bay, Burl. Bay	36,835	214,128	35,374	15,042	301,380	15.5	8.6	53.1	77.1
Lamoille	02010005	Malletts Bay, NE Arm, St. Alb Bay	41,825	171,494	22,644	17,940	253,904	17.6	6.9	34.0	58.4
Missisquoi	02010007	Missisquoi, NE Arm, Is LaMotte	68,665	213,351	15,915	15,945	313,876	(see separate analysis)			
NEW YORK											
Lake George (NY)	02010001	S Lake B, S Lake A, Port Henry	35,693	157,571	11,948	4,365	209,577	15.0	6.3	17.9	39.2
Ausable	02010004	Main Lake	14,564	227,675	8,792	6,391	257,422	6.1	9.1	13.2	28.4
Great Chazy-Saranac	02010006	Cumberland Bay, Isle LaMotte	33,902	220,347	10,985	15,174	280,408	14.2	8.8	16.5	39.5
		Total	**319,295**	**1,475,685**	**132,559**	**99,179**	**2,026,717**	**105.3**	**50.5**	**175.0**	**330.7**

Table A-4: Projected 2016 Land use and phosphorus loads for major watersheds in the Lake Champlain basin.

			Projected 2016 land use					2016 NPS phosphorus loads			
Hydrologic Unit Name	**HU**	**Lake Segment**	**Agricultural**	**Forested**	**Developed**	**Water**	*Total*	**Agricultural**	**Forested**	**Developed**	*Total*
			Area (hectares)					Loads (mt/yr)			
VERMONT											
Lake George (VT)	02010001	S Lake B, S Lake A, Port Henry	17,288	86,402	7,910	8,837	120,437	7.3	3.5	11.9	22.6
Otter	02010002	Otter Creek	50,828	203,192	28,084	15,484	297,589	21.3	8.1	42.1	71.6
Winooski	02010003	Main Lake, Shelb. Bay, Burl. Bay	25,570	220,260	50,151	15,042	311,022	10.7	8.8	75.2	94.8
Lamoille	02010005	Malletts Bay, NE Arm, St. Alb Bay	28,612	183,077	38,699	17,940	268,329	12.0	7.3	58.0	77.4
Missisquoi	02010007	Missisquoi, NE Arm, Is LaMotte	49,820	235,911	19,583	15,945	321,260	(see separate analysis)			
NEW YORK											
Lake George (NY)	02010001	S Lake B, S Lake A, Port Henry	28,582	167,040	14,380	4,365	214,365	12.0	6.7	21.6	40.3
Ausable	02010004	Main Lake	12,539	230,826	8,952	6,391	258,707	5.3	9.2	13.4	27.9
Great Chazy-Saranac	02010006	Cumberland Bay, Isle LaMotte	27,936	233,352	14,345	15,174	290,807	11.7	9.3	21.5	42.6
		Total	**241,175**	**1,560,059**	**182,104**	**99,179**	**2,082,516**	**80.4**	**53.0**	**243.8**	**377.1**

Land use analysis for Missisquoi Bay lake segment

For the Missisquoi Bay lake segment, the analysis above showed a decline in phosphorus loadingbecause forested land increased at a relatively high rate between 1982 and 1992, and forested land has a much lower phosphorus export coefficient than agricultural land (Table A-1). However, despite the decrease in agricultural land overall in the Missisqoi Bay watershed, more land is being used for row crops and there has been no decline in the number of cows in the region despite the decline in agricultural land. In addition, Hegman *et al*. (1999) found that the three sub-watersheds that comprise the Missisquoi Bay watershed did not fit the export coefficient model developed for the rest of the basin To accurately predict phosphorus loads, the density of animals in the watershed was factored into the model, along with land use.

To predict phosphorus loads from nonpoint sources in the Missisquoi Bay lake segment watershed that reflected these anomalies, the density of animal units was factored into the load estimates from agricultural land, and new export coefficients were developed for two specific types of agricultural land: row crops and hay/pasture. First, the area of land covered by these land types was determined. Although the two land types were classified in the Hegman *et al*. (1999) report, the area of land used as row crops was very high compared to that of the NRI and the USDA Agricultural Census (data obtained from USDA NRCS, VT State Office). Because the satellite imagery used to develop the 1992/1993 land use data is difficult to interpret with respect to specific land use types, the 1992 USDA Agricultural Census for Franklin and Orleans Counties was used to determine the percent of agricultural land in row crops (15%) (see www.nass.usda.gov). The NRI value for the Missisquoi HU is in close agreement (15.9%), but the margin of error is higher. The amount of land in row crops tends to vary widely from year to year.

Next, new agricultural coefficients were determined based on the Diagnostic-Feasibility Study loading data for the Missisquoi, Pike, and Rock watersheds. Literature coefficients for corn row crops and hay/pasture were reviewed (Budd and Meals, 1994) and it was assumed that row crops have a coefficient three times that of hay and pasture. Using the export coefficients from Hegman *et al*. (1999) for urban land, forested land, and animal units, and land use area data from Hegman *et al*. (except using the percentage of row crops from the USDA Agricultural Census), an export model was developed for each watershed. The equation was set equal to the measured load resulting from the Diagnostic-Feasibility Study (VT DEC and NYSDEC, 1997) and solved for the export coefficient for hay/pasture. The resulting coefficients are shown in Table A-5.

Table A-5. Areal phosphorus export coefficients used for Missisquoi Bay sub-watersheds (kg.ha/yr, except Animal Units, kg.yr).

Sub-watershed	Forest	Ag – row crop	Ag – pasture	Urban	Animal Units
Missisquoi	0.04	1.01	0.34	1.5	1.75
Pike	0.04	0.64	0.21	1.5	1.75
Rock	0.04	5.2	1.74	1.5	1.75

These phosphorus export coefficients were then applied to the current and future land areas and animal unit data to estimate phosphorus loads by watershed. According to the 1997 Agricultural Census for Franklin and Orleans counties, the area of row crops increased by approximately 50% and the area of hay/pasture land decreased by 24%, with an overall decrease of 17% agricultural land between 1982 and

1997. The land use change rates from the USDA Agricultural Census were used instead of those from the NRI in this case because the margin of error of the NRI data in the Missisquoi area was higher than that of the Census. The land use change rates were assumed to be the same for the three watersheds that comprise the Missisquoi lake segment. Land use trends in the Quebec portion of the watershed are not currently available. In addition, a yearly increase in the number of cattle and calves in the lake segment was assumed based on a 5% increase in the Pike River watershed between 1992 and 1997 (personal communication, Martin Mimeault; data cited from Ministére de l'Agriculture, des Pêcheries et de l'Alimentation du Québec), and a 1.2% increase in Franklin County between 1987 and 1997 (USDA Agricultural Census). The Franklin County rate was applied to the Missisquoi and Rock River watersheds. Estimated loads for 1992, 2001, and 2016 are shown in Tables A-6 through A-8 below.

Table A-6: 1992/1993 Land use and phosphorus loads for Missiquoi Bay sub-watersheds.

	1992/1993 Hegman *et al*. (1999) land use					1992/1993 NPS phosphorus loads					
Watershed	**Ag-row crop**	**Ag-pasture**	**Forested**	**Developed**	*Excess AU*	**Ag-row crop**	**Ag-pasture**	**Forested**	**Developed**	**Animal Unit**	*Total*
	Area (hectares)					Loads (mt/yr)					
VERMONT											
Missisquoi	5,633	31,923	157,160	10,158	21,224	5.7	10.8	6.3	15.2	37.1	75.1
Pike	4,540	25,729	28,724	3,058	17,307	2.9	5.5	1.1	4.6	30.3	44.4
Rock	909	5,152	5,863	796	7,864	4.7	9.0	0.2	1.2	13.8	28.9
Total	**11,083**	**62,803**	**191,747**	**14,012**	**46,395**	**13.3**	**25.2**	**7.7**	**21.0**	**81.2**	**148.4**

Table A-7: Projected 2001 land use and phosphorus loads for Missiquoi Bay sub-watersheds.

	Projected 2001 land use					2001 NPS phosphorus loads					
Watershed	**Ag-row crop**	**Ag-pasture**	**Forested**	**Developed**	*Excess AU*	**Ag-row crop**	**Ag-pasture**	**Forested**	**Developed**	**Animal Unit**	*Total*
	Area (hectares)					Loads (mt/yr)					
VERMONT											
Missisquoi	7,323	27,230	167,806	11,439	21,453	7.4	9.2	6.7	17.2	37.5	78.0
Pike	5,902	21,947	30,670	3,444	18,865	3.8	4.7	1.2	5.2	33.0	47.9
Rock	1,182	4,395	6,260	896	7,949	6.1	7.6	0.3	1.3	13.9	29.3
Total	**14,408**	**53,571**	**204,736**	**15,779**	**48,267**	**17.3**	**21.5**	**8.2**	**23.7**	**84.5**	**155.1**

Table A-8: Projected 2001 land use and phosphorus loads for Missiquoi Bay sub-watersheds.

	Projected 2016 land use					2016 NPS phosphorus loads					
Watershed	**Ag-row crop**	**Ag-pasture**	**Forested**	**Developed**	*Excess AU*	**Ag-row crop**	**Ag-pasture**	**Forested**	**Developed**	**Animal Unit**	*Total*
	Area (hectares)					Loads (mt/yr)					
VERMONT											
Missisquoi	10,140	19,409	185,550	13,574	21,835	10.2	6.5	7.4	20.4	38.2	82.8
Pike	8,173	15,643	33,913	4,086	21,461	5.2	3.3	1.4	6.1	37.6	53.6
Rock	1,636	3,132	6,922	1,064	8,090	8.5	5.5	0.3	1.6	14.2	30.0
Total	**19,949**	**38,184**	**226,385**	**18,724**	**51,386**	**24.0**	**15.3**	**9.1**	**28.1**	**89.9**	**166.4**

Note that total nonpoint source phosphorus loads for each watershed in 1992/93 are equal to the measured values from the Diagnostic-Feasibility Study (VT DEC and NYSDEC, 1997).

Insert Tables A-9 andA-10 here.

APPENDIX B. PHOSPHORUS REDUCTION RECOMMENDATIONS IN *OPPORTUNITIES FOR ACTION*

Included below in Table 15, as a reference, are the phosphorus reduction recommendations listed in *Opportunities for Action.* These recommended actions are the framework for the phosphorus reduction efforts now and in the future.

Table B-1. Priority actions for phosphorus reduction, as listed in *Opportunities for Action*

Highest Priority Actions	1. Identify specific actions by October 1, 1996, for attaining the first 25% of the targeted phosphorus load reductions 2. Focus phosphorus reduction efforts on targeted watersheds (targeted watersheds are South Lake A VT, South Lake A NY, South Lake B VT, South Lake B VT, Port Henry NY, Otter Creek VT, Missisquoi Bay VT, Main Lake VT, Main Lake NY, Malletts Bay VT, Northeast Arm VT, and Isle LaMotte NY) 3. Develop and begin implementing phosphorus reduction strategies for targeted watersheds 4. Provide funding for point source phosphorus reductions
High Priority Actions	5. Expand and accelerate implementation of existing federal agricultural nonpoint source pollution programs 6. Expand implementation of state agricultural nonpoint source programs
Priority Actions	7. Promote the implementation of nutrient management plans 8. Expand NRCS/FSA, USFWS, and other agency cost-sharing for streambank restoration and the installation of buffer strips 9. Implement retrofitted stormwater management systems and other measures for reducing phosphorus from urban and developed land within targeted sub-basins identified in Action 2 above 10. Research and demonstrate the effectiveness of nutrient management practices
Other Actions for Consid-eration	11. Continue to support the Agricultural Advisory Council (AAC) 12. Develop and implement an awards program for basin farmers 13. Upgrade state stormwater control programs 14. Encourage local and state implementation of BMPs for road construction, repair, and maintenance 15. Encourage local governments to implement BMPs for new development 16. Encourage cooperative development of local shoreland 17. Encourage continued implementation of state management practices for forestry activities 18. Demonstrate the use of constructed wetlands for treating wastewater and improving water quality 19. Investigate cumulative water quality impact methodologies and demonstrate their utility in sub-basins