Phosphorus Reduction Plan
March 1990

AGENCY OF NATURAL RESOURCES
DEPARTMENT OF ENVIRONMENTAL CONSERVATION
WATERBURY, VERMONT

EXECUTIVE SUMMARY

INTRODUCTION

Section 4 of Act 88, Vermont SLA 1989, required the Agency of Natural Resources to submit to the Legislature, a plan for the reduction of phosphorus concentrations in direct discharges to waters of the state. The full text of Act 88, Section 4, is given on the following page. In considering strategies for the reduction of phosphorus in direct discharges to the Lake Champlain and Lake Memphremagog Basins and to other waters, the Department of Environmental Conservation determined that it would be necessary to propose a more comprehensive phosphorus management process including the full spectrum of Vermont's waters and addressing both point and nonpoint phosphorus sources. The Department of Environmental Conservation has prepared this phosphorus reduction plan in consultation with the Water Resources Board, and is presenting the plan with specific legislative recommendations to the Vermont General Assembly for its consideration. The plan proposed herein represents a practical and expeditious means of carrying out water quality standards now being adopted by the Water Resources Board.

This report sets forth a comprehensive program for the management of phosphorus in the state's waters in a manner leading toward attainment of water quality standards and water uses through lake and river basin planning. The program involves the establishment of numeric phosphorus criteria in Vermont's Water Quality Standards for all waters where such criteria are scientifically supported. The establishment of phosphorus standards is followed by an assessment of the phosphorus loading which must be obtained to achieve the standards. The allowable loadings are then distributed among both point source discharges and nonpoint sources through the existing Wasteload Allocation Process (Administrative Rule 87-46).

In the case of point source discharges, implementation schedules would be established through discharge permits issued under existing authority in 10 V.S.A., Chapter 47. Financial assistance to municipalities would be provided under 10 V.S.A., Chapter 55, in the form of 35% grants and low interest loans for the balance of the project costs.

This plan recognizes that nonpoint sources provide a major contribution of phosphorus to the state's waters. Control of point source discharges alone, without accompanying nonpoint source phosphorus reductions, will not attain water quality goals in most situations. Assessment, targeting, and implementation of the necessary nonpoint source phosphorus loading reductions will be pursued according to the Vermont Nonpoint Source Management Program (August 1988) and the Vermont State Clean Water Strategy (May 1989). The targets and priorities of these nonpoint source planning documents with respect to phosphorus will be modified appropriately as specific phosphorus standards are established for individual waters and loading allocations are conducted.

LANGUAGE FROM SECTION 4, ACT 88, VERMONT SLA 1989:

Sec. 4. PHOSPHORUS REDUCTION PLAN

In furtherance of the state's water quality policies the secretary shall, by January 15, 1990 and after consultation with the water resources board, submit to the president of the senate, the speaker of the house, the senate and house of representatives' committees on natural resources and energy and institutions, and to governments of adjacent states and provinces, a plan for the reduction of phosphorus concentrations in direct discharges to the waters of the state. At a minimum the plan shall include:

(1) information on the effects of phosphorus on the state's waters;

(2) a maximum phosphorus concentration allowable in direct discharges to the Lake Champlain and Lake Memphremagog Basins. This concentration will be based on that achievable with commonly accepted phosphorus removal technology which shall be described in the plan;

(3) a process for determining appropriate phosphorus concentrations in direct discharges to all waters of the state, not included in subdivision (2) of this section, when necessary for the direct discharge to meet water quality standards;

(4) a process for determining a phosphorus concentration more restrictive than that provided for in subdivision (2) of this section when such restrictive concentration is necessary to meet water quality standards in the Lake Champlain and Lake Memphremagog Basins;

(5) an estimate of the cost of achieving the concentration proposed in subdivisions (2), (3) and (4) of this section, and impact on the state capital plan;

(6) a schedule and priorities for the construction or modification of discharging facilities necessary to meet the proposed phosphorus concentrations; and

(7) other information determined by the secretary necessary to support the plan.

Approved: June 6, 1989

This Phosphorus Reduction Plan categorizes Vermont's surface waters into six water resource types, each of which require a somewhat different phosphorus management approach within the general scheme outlined above. These six water resource types are discussed in more detail below.

1. Lake Champlain and Lake Memphremagog
2. Streams above 2500 feet elevation
3. Connecticut River
4. Other streams and rivers
5. Inland lakes
6. Large impoundments

1. Lake Champlain and Lake Memphremagog

Vermont's two large interstate and international lakes together drain 53% of the state's land area. A multitude of human activities occur within their drainage basins, including major municipalities, wastewater discharges, extensive agriculture, and other industries. The Department of Environmental Conservation believes that existing phosphorus concentrations in Lake Champlain and Lake Memphremagog are generally too high to fully support all beneficial values and uses of these waters, and reductions are needed.

This plan proposes immediate action to reduce current point source phosphorus loads to these lakes by 63% from 427,000 lbs/day to 144,700 lbs/day by imposing a 0.80 mg/L effluent phosphorus limit at 32 selected sewage treatment plants. The 32 plants were selected on the basis of cost-effectiveness considerations. These plants include those already required to remove phosphorus to 1.0 mg/L under 10 V.S.A., Section 1266a and for which the more stringent effluent limit will not require added capital investment. Plants which are not currently required to remove phosphorus and which have design capacities of 200,000 gallons per day or greater and employ processes of activated sludge or rotating biological contactors would be required to install chemical coagulation equipment.

The total cost of this program is estimated to be $3.6 million, including state grant outlays of $1.3 million and an average individual user cost increase of $46 per year. The basis for the 0.80 mg/L maximum effluent phosphorus limit proposal is explained in detail in the main body of this report in response to Subdivision (2) of Act 88, Section 4. The cost estimates and priority schedules are provided in the responses to Subdivisions (5) and (6), respectively.

The 0.80 mg/L effluent phosphorus limit will be an initial step toward meeting water quality goals for Lake Champlain and Lake Memphremagog. The Department of Environmental Conservation has proposed, and the Water Resources Board is considering, specific numeric phosphorus concentration criteria in Vermont's Water Quality Standards for 13 individual segments of Lake Champlain and Lake Memphremagog. It is very likely that further reductions in both point and nonpoint source phosphorus loading beyond the reductions achieved with the 0.80 mg/L effluent limit will be necessary in order to attain the proposed in-lake criteria.

The process for attaining these criteria will involve tributary phosphorus loading measurements and lake studies followed by wasteload allocations among point and nonpoint sources basin-wide. The necessary field studies have already been initiated for Lake Champlain in a cooperative effort between the States of Vermont and New York under a major grant from the U.S. Environmental Protection Agency. The process for insuring the full attainment of phosphorus standards in Lake Champlain and Lake Memphremagog is described in move detail in the main body of this report in response to Subdivision (4) of Act 88, Section 4.

2. <u>Streams Above 2500 Feet Elevation</u>

Vermont's upland streams are high quality waters having significant ecological value and have therefore received statutory designation as Class A waters under 10 V.S.A., Section 1253a. All direct discharges of sewage and all indirect sewage discharges greater than 1,000 gallons per day are prohibited in these waters (Sections 1259c, 1259d). The Water Resources Board is proposing a phosphorus concentration limit of 0.010 mg/L in Vermont's Water Quality Standards for all streams above 2,500 feet in elevation. The Class A designation, combined with this very strict phosphorus standard, will essentially preclude any significant eutrophication impacts on upland streams. Phosphorus management considerations in upland streams are discussed in the main body of this report in response to Subdivision (3) of Act 88, Section 4.

3. <u>Connecticut River</u>

The Connecticut River is a major interstate waterway draining approximately 41% of the area of Vermont. Riverine segments alternate with a series of large impoundments, all of which can be sensitive to phosphorus and eutrophication impacts.

This plan recognizes the special phosphorus management challenge presented by the Connecticut River in that cooperative planning efforts with the State of New Hampshire throughout the river's very large drainage basin will be required to attain water quality goals. However, the planning approach for the Connecticut River should be analogous to the processes outlined for other streams and rivers and for large impoundments as summarized in the following sections and discussed in more detail in the main body of this report in response to Subdivision (3) of Act 88, Section 4.

4. Other Streams and Rivers

The relationship between phosphorus and algae growth in Vermont's streams has been very difficult to quantify. Many unique, site specific factors determine whether a particular in-stream phosphorus level will produce an algal nuisance. Therefore, it is not possible at this time to propose new numeric phosphorus water quality standards for Vermont's streams. Site specific evaluations will be required to determine compliance with the current narrative standard for nutrients in Vermont's Water Quality Standards, which states that there shall be "no increase...which has an undue adverse effect on any beneficial values or uses."

This Plan proposes a series of site specific evaluations of river segments potentially affected by direct phosphorus discharges. These site evaluations will be conducted according to a priority schedule based on the relative dilution of the effluent available from the flow of the receiving water. A determination will be made at each site as to whether the discharge is producing an "undue adverse effect."

When a specific discharge is found to be causing an undue adverse effect on eutrophication in the stream, the Department will issue an order requiring the construction of phosphorus removal facilities to an effluent concentration low enough to eliminate the impact. In many cases, however, stream eutrophication is the result of the combined effects of many upstream sources, both point and nonpoint. These cumulative impacts will be addressed through a comprehensive river basin planning process, ultimately leading to phosphorus wasteload allocations among all point and nonpoint sources.

5. Inland Lakes

Vermont's inland lakes are fragile ecosystems that are particularly sensitive to phosphorus inputs. They deserve strict protection from unwise waste disposal practices in their watersheds. The Water Resources Board is proposing a narrative phosphorus standard for inland lakes of "no significant increase over background conditions in total phosphorus."

In order to provide this high level of protection for inland lakes, this Plan proposes a statutory prohibition on new direct discharges of phosphorus to those sensitive lakes with drainage basin areas less than 40 square miles and drainage area to surface area ratios less than 500 and to tributaries of such lakes. This prohibition would impact 642 Vermont inland lakes, and would include an aggregate basin area of about 1200 square miles, or about 12% of the state's land area.

This proposed prohibition would not restrict the construction of land disposal or indirect discharging systems. Systems in compliance with the State Indirect Discharge Regulations would be considered to be in compliance with the "no significant phosphorus increase" lake standard. The basis for the proposed direct discharge prohibition for Vermont inland lakes is explained in the main body of this report in response to Subdivision (3) of Act 88, Section 4.

6. Large Impoundments

Large impoundments on rivers present a phosphorus management situation similar to Lake Champlain and Lake Memphremagog. These reservoirs must support the full range of lake values and uses, but drain large watersheds with many human activities, including wastewater discharges. For the purpose of this plan, large impoundments are defined as"artificially constructed riverine impoundments having surface areas larger than 50 acres at the mean summer pool elevation, and drainage areas greater than 40 square miles." There are 17 such impoundments within Vermont and 8 along the Connecticut River adjoining Vermont.

This plan proposes a process for managing phosphorus in large impoundments that is analogous to the approach previously discussed for Lake Champlain and Lake Memphremagog. Numeric phosphorus criteria for each impoundment will eventually be established in Vermont's Water Quality Standards, although no such standards are specifically proposed at this time because of a lack of adequate supporting information in most cases. Reservoir phosphorus loading studies will be undertaken and basin-wide phosphorus wasteload allocations among point and nonpoint sources will be conducted in a manner that attains the reservoir-specific phosphorus standards. The phosphorus management process for large impoundments is discussed in the main body of this report in response to Subdivision (3) of Act 88, Section 4.

SUMMARY

The main body of this plan is organized according to the seven subdivisions listed in Section 4 of Act 88. However, the organizational framework involving six water resource management groups as described in this executive summary has guided the Department in responding to the requirements of Act 88. The Department will continue to work in consultation with the Water Resources Board towards the implementation of appropriate phosphorus criteria in Vermont's Water Quality Standards, as discussed in this plan. Recommendations for specific legislation needed to implement the comprehensive phosphorus management process outlined in this plan are included in Appendix E of this plan.

PHOSPHORUS REDUCTION PLAN

I. INFORMATION ON THE EFFECTS OF PHOSPHORUS ON THE STATE'S WATERS

Rivers

The role of phosphorus as the nutrient most responsible for increased aquatic plant growth in rivers is well documented. This accelerated growth can manifest itself in several forms, depending upon the physical morphometry of the stream. Shallow, rocky bottomed, upland streams develop growths of periphyton, a green, fuzzy, slippery algae which attaches itself to the rocks. Streams with mud or silt bottoms will experience the growth of rooted aquatic plants and attached algae. Deeper, slow flowing, lowland streams will develop suspended phytoplankton blooms very similar to those seen in lakes.

The presence of these algal communities in streams can lead to large fluctuations in dissolved oxygen concentrations from day to night, often violating water quality standards. Other effects of the increased plant growth include reduced aesthetics, taste and odor problems in drinking water supplies, and navigational problems.

Phosphorus concentrations in streams are the result of contributions from three separate sources - point source wastewater treatment discharges, non-point source runoff, and weathering of natural geologic depositions.

Once phosphorus is introduced into a stream system, several possibilities as to its fate exist. Eutrophication of the stream in the immediate vicinity of the discharge can occur. The relationship between phosphorus and algal growth in a stream system, however, is very dependent upon other environmental variables such as light, stream velocity, and substrate. Therefore, the eutrophication effects could occur at a considerable distance downstream from the source, where the proper combination of these factors exist. The stream could serve also as a conduit, transporting excessive phosphorus loads downstream to a lake or reservoir, causing eutrophication problems there. In addition, stream systems can act as modifiers of phosphorus concentrations, attenuating concentrations in a downstream direction. One of the principle mechanisms by which this occurs is through sorption onto suspended soil particles in the water column, and subsequent settling to the stream bed.

To further confound the problem, this attenuated phosphorus can be subsequently re-released back into the water column from the depositional areas. This prevents a determination of the original sources of existing instream phosphorus concentrations at a given point in a river.

Lakes

Phosphorus is a plant nutrient that can be a pollutant in both lakes and rivers. The process of nutrient enrichment of freshwater and the subsequent proliferation of algae and other plants is termed eutrophication. Phosphorus, more than any other nutrient, is responsible for eutrophication in Vermont's lakes. Progressive eutrophication of lakes is, to some extent, a natural lake aging process, but it can be greatly accelerated by human activities. Such activities include wastewater discharges, termed "point sources," and other activities in a lake watershed such as farming and urban development that generate "nonpoint sources" of phosphorus-rich runoff.

Eutrophication of lakes can have a number of adverse effects, including those listed below.

1. Excess algae growth in the water can reduce water clarity and produce a green or scummy appearance which reduces the aesthetic and recreational enjoyment of the lake.

2. Phosphorus enrichment can stimulate algae growing attached to rocks along the shoreline, which also reduces enjoyment of the lake.

3. In severe cases, algae blooms can use up dissolved oxygen in a lake overnight, causing a sudden fish kill.

4. Algal production can contribute to oxygen depletion in the cold, deep-water zone in lakes, eliminating habitat for cold water fish species such as trout and salmon.

5. Algae can cause taste and odor problems in drinking water supplies and add to water treatment costs by increasing turbidity and organic levels, and clogging filters.

6. Algae in water supplies produce organic compounds which, when chlorinated during water treatment, can form cancer-causing and mutation-causing chemicals such as trihalomethanes.

Lakes can be classified into three categories based on the level of eutrophication. "Eutrophic" lakes have total phosphorus concentrations above 20 parts per billion (ppb) and are characterized by high algae levels and a generally green appearance of the water. At the other end of the scale, "oligotrophic" lakes have phosphorus concentrations less than 10 ppb and a clear, blue appearance. Lakes in the transition "mesotrophic" category have phosphorus levels in the 10-20 ppb range.

The eutrophication status of Vermont's lakes can be described with reference to the three categories defined above. Figure 1 shows the phosphorus levels present in Vermont's two large border lakes, Lake Champlain and Lake Memphremagog. No portion of either lake is in the low-phosphorus oligotrophic category. Most of the large open-water areas of Lake Champlain are in the mesotrophic category, with eutrophic conditions existing in certain bays and in the South Lake. The southern portion of Lake Memphremagog in Vermont is also eutrophic.

The eutrophication status of Vermont's inland lakes is shown in Figure 2, based on sampling of 196 of the state's more than 700 inland lakes. Based on the classification conventions defined above, over half of these lakes are in the oligotrophic category with phosphorus levels less than 10 ppb. Only 13% of Vermont's inland lakes are in the eutrophic category.

<u>Need for Separate Management Approach for Lakes vs. Rivers</u>

The preceding discussion of the effects of phosphorus on Vermont's waters indicates that the effects can be very different for lakes vs. rivers. The adverse consequences of eutrophication are more acutely experienced in lakes because lakes are more susceptible to algae blooms and have a greater degree of direct recreational contact by the public. The correlation between phosphorus concentration and nuisance algae growth is much stronger in lakes than in streams because fewer other factors such as light availability, flow velocity, and substrate type complicate the relationship. These differences in the way lakes and rivers respond to phosphorus enrichment and the different uses of these waters indicate that separate phosphorus management approaches are needed for lakes vs. rivers.

The diversity of lake and river types within Vermont is also important to recognize in managing these resources. Most of Vermont's inland lakes are in relatively rural, undeveloped settings without excessive phosphorus pollution. Strict protection of the existing low phosphorus levels in those lakes is warranted. On the other hand, Lake Champlain, Lake Memphremagog, and several large reservoirs drain major portions of Vermont's land area including many municipalities, and are therefore more eutrophic. Phosphorus management in these waters must minimize the impacts of the irreversible cultural development that has occurred while attaining realistically defined water quality goals that adequately protect lake uses. Similar differences exist among Vermont's river resources where nearly pristine upland streams deserve strict protection while the major rivers must assimilate the impacts of large human populations. A statewide phosphorus reduction plan should therefore consider the different management needs for these different lake and river resource types.

This plan categorizes Vermont's surface waters into six water resource types, each of which require a somewhat different management approach. They are:

1. Lake Champlain and Lake Memphremagog
2. Streams Above 2500 Feet Elevation
3. Connecticut River
4. Other Streams and Rivers
5. Inland Lakes
6. Large Impoundments

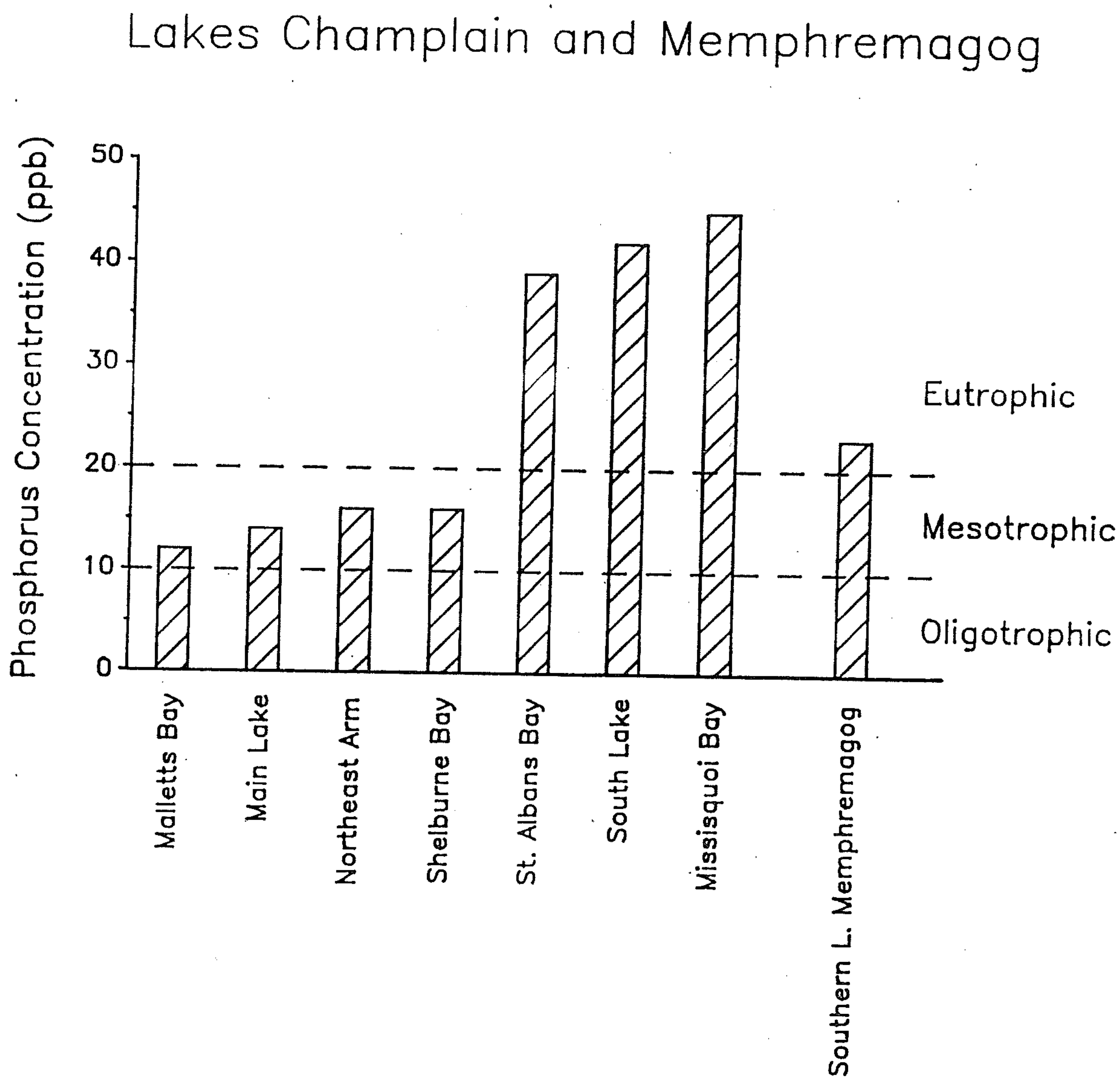

Figure 1. Average summer total phosphorus concentrations in seven segments of Lake Champlain and in the U.S. portion of Lake Memphremagog. (Vermont Department of Environmental Conservation Lay Monitoring Program data.)

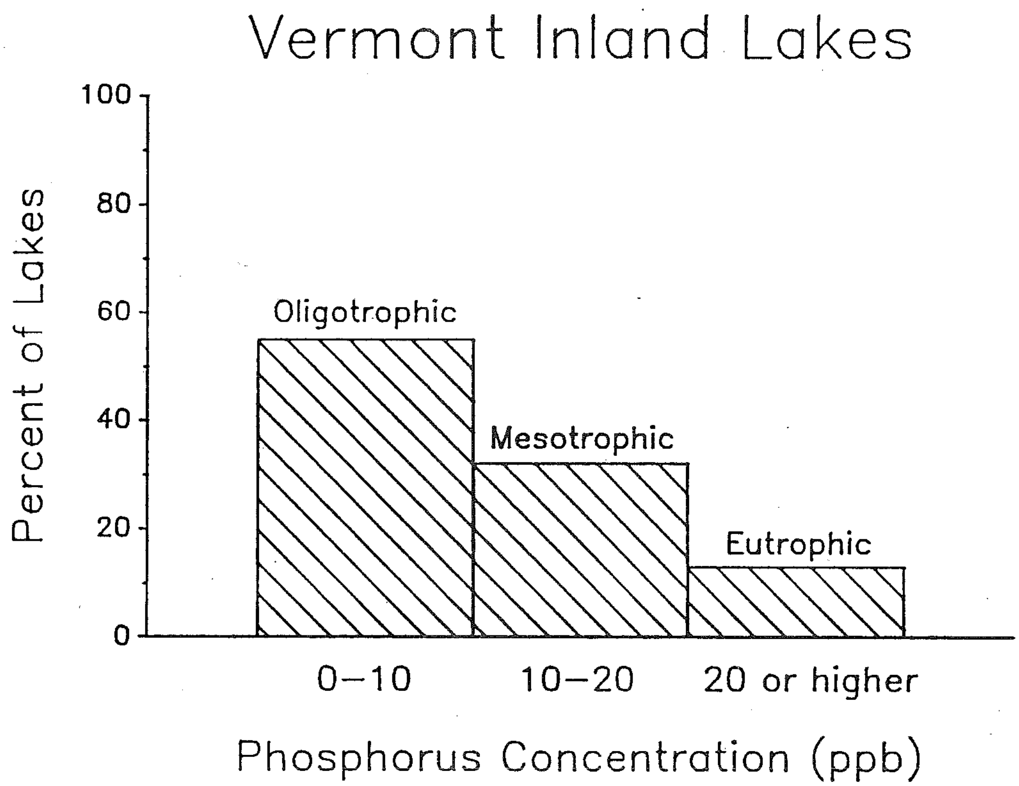

Figure 2. Distribution of spring total phosphorus concentrations in 196 Vermont inland lakes. (Vermont Department of Environmental Conservation Spring Phosphorus Program data.)

History of Phosphorus Control in Vermont

Nonpoint Source Programs

Nonpoint source programs in Vermont to control runoff of phosphorus and other pollutants have been directed at agriculture, silviculture, construction and on-site wastewater disposal since the early to mid-1970's under the auspices of Section 208 of the Federal Clean Water Act. In each case strategies were developed that utilized a combination of education, technical and financial assistance, planning, implementation, and evaluation.

Agricultural nonpoint source (NPS) control included the targeting of twenty-one sub-watersheds within the Lake Champlain and Lake Memphremagog drainages for accelerated treatment and federal cost sharing to leverage voluntary private investment in agricultural best management practices. Under the Rural Clean Water Program and the P.L. 83-566 program, long term studies have been conducted evaluating the effectiveness of these agricultural management practices on reducing nutrient and pollutant runoff and improving water quality.

A process for responding to erosion and water quality problems arising from silvicultural operations has been established using a state and industry cooperative inspection program. Efforts to control silvicultural NPS pollution have been furthered by the development of acceptable management practices for maintaining water quality on logging jobs in Vermont.

The passage of Vermont's Land Use and Development Control Law (Act 250) has created a process for the state, through district commissions, to address and control construction-related erosion. A review and permit process for stormwater runoff control compliments Act 250 activities.

Municipally-based on-site wastewater disposal programs have been developed, breaking the cycle of failed septic systems which would otherwise have necessitated the construction of additional wastewater treatment facilities.

In response to the 1987 amendments to the Federal Clean Water Act, the Vermont NPS Assessment Report and the Vermont NPS Management Program document were prepared. The Assessment was an analysis of the nature, extent, and effect of NPS pollution on the degree to which designated water uses were being supported, impaired, or threatened. The Management Program provides both an overview of NPS control methods and programs and a systematic approach to restoring and protecting water uses in specific targeted water bodies.

Future Vermont NPS management activities will build upon past lessons learned, previously identified priority actions and ongoing research findings. A directed yet flexible NPS program will rely on public participation, the exchange of information, and interagency cooperation.

Point Source Programs

In April 1977, the legislature amended 10 V.S.A., Chapter 47 to include the Phosphorus Detergent Ban (10 V.S.A., Section 1381-1384) and a requirement for the reduction in the amount of phosphorus being discharged to Lake Champlain and other designated waters (10 V.S.A., Section 1266a).

The phosphorus detergent ban required that household laundry detergents sold in the state could contain no more than trace amounts of phosphorus. This ban went into effect on April 1, 1978. Section 1266a required that, effective June 30, 1981, discharges to Lake Champlain and other designated waters could not exceed 1.0 mg/L phosphorus concentration.

A Special Report to the General Assembly in March 1981 stated that the Phosphorus Detergent Ban had "substantially reduced the quantity of phosphorus discharged from Vermont's municipal WWTFs." Sampling and analysis of selected effluents revealed that the phosphorus concentrations had been reduced by 40%. An additional benefit of the ban was the anticipated reduction (up to 50%) of the phosphorus removal operating costs which would be realized by those municipalities which were subsequently required to reduce their effluent concentration to 1.0 mg/L phosphorus.

The phosphorus removal requirement contained in 10 V.S.A., Section 1266a, required that 22 municipal facilities meet the 1.0 mg/L effluent phosphorus limit. Three small municipalities (Derby Center, Derby Line, and Glover) connected to neighboring large WWTFs. The status of the remaining 19 projects, as of November 1989, is shown in Table 1.

The status of the 5 facilities on Table 1 which have yet to install phosphorus removal is as follows:

> The 3 Burlington facilities are currently in the planning stages for construction which will expand the wastewater treatment capacities, eliminate/treat the combined sewer overflows, and provide dechlorination and phosphorus removal facilities. A consent order filed in court requires that all construction on the Burlington facilities be completed by May 1, 1994.
>
> The Swanton facility is currently under construction to provide phosphorus removal. The process was scheduled to be operational in January 1990.
>
> The Hinesburg facility is behind in meeting a schedule contained in an assurance of discontinuance. The schedule required that phosphorus removal be in operation by December 31, 1989. Construction is scheduled to begin in Spring 1991. Phosphorus removal is anticipated to be operational by December 1991.

TABLE 1

LAKE CHAMPLAIN DRAINAGE BASIN

MUNICIPALITY	OPERATIONAL	UNDER CONSTRUCTION	FINAL PLANNING	PRELIMINARY PLANNING
ALBURG	X			
BURLINGTON (M)	(1994)		X	
BURLINGTON (N)	(1994)		X	
BURLINGTON (R)	(1994)		X	
COLCHESTER	X			
ESSEX JCT.	X			
HINESBURG	(1991)			X
ST. ALBANS	X			
SHELBURNE FD#1	X			
SHELBURNE FD#2	X			
SOUTH BURLINGTON(BB)	X			
SOUTH BURLINGTON(AP)	X			
STOWE	X			
SWANTON	(11/89)	X		
VERGENNES	X			
WINOOSKI	X			

LAKE MEMPHRAMAGOG DRAINAGE BASIN

MUNICIPALITY	OPERATIONAL	UNDER CONSTRUCTION	FINAL PLANNING	PRELIMINARY PLANNING
BARTON	X			
NEWPORT	X			
ORLEANS	X			

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Both the detergent ban and the phosphorus removal requirement have proven effective in reducing the phosphorus loads going to Lakes Champlain and Memphremagog. Prior to these legislations, the estimated annual phosphorus load going to these lakes from all the wastewater treatment facilities would have been 1,442,900 lbs/year at their design flows. According to the 1981 Special Report to the General Assembly, the detergent ban reduced this loading by 40% to approximately 865,740 lbs/year. When the required phosphorus removal processes are fully implemented at the 19 facilities listed in Table 1, the anticipated maximum annual point source loading which will be discharged to these lakes will be approximately 427,000 lbs/year. The combined effect that these two legislations have had is to reduce the potential phosphorus loading from the wastewater treatment facilities to these lakes by a total of 70%.

Current Water Quality Standards Proposals

The authority to establish water quality standards in Vermont rests by statute with the Vermont Water Resources Board. The Board is currently in the process of amending Vermont's Water Quality Standards to include, for the first time, numeric phosphorus limits for the state's waters, as directed by 10 V.S.A. Section 1252(c). When adopted, these limits will be used in developing point and nonpoint source phosphorus management policies in lakes and rivers throughout the state, including those policies developed under Subsections (III) and (IV) of this plan. The plan presented herein is complimentary to the phosphorus standards now being considered by the Water Resources Board and provides for orderly planning and implementation steps to carry out those standards.

II. A MAXIMUM PHOSPHORUS CONCENTRATION ALLOWABLE IN DIRECT DISCHARGES TO THE LAKE CHAMPLAIN AND LAKE MEMPHREMAGOG BASINS. THIS CONCENTRATION WILL BE BASED ON THAT ACHIEVABLE WITH COMMONLY ACCEPTED PHOSPHORUS REMOVAL TECHNOLOGY WHICH SHALL BE DESCRIBED IN THE PLAN

1. Lake Champlain Basin

There are 48 wastewater treatment facilities discharging tributary to Lake Champlain. The breakdown of the annual phosphorus loading from these facilities is as follows:

	# of Plants	Annual P @ Design Flow	Point Source Loading
Do Not Remove P	31	355,215 lb/yr	84.6%
Practice or Req'd to Remove P	15	64,782	15.39%
Practice Land Disposal (.1 mg/L P)	2	56	.01%
TOTAL	48	420,053 lb/yr	100%

There are a number of phosphorus removal processes existing which can produce effluents with phosphorus concentrations of between 1.0 mg/L P to 0.02 mg/L P in municipal wastewater treatment facility discharges. Appendix A briefly describes 9 of these processes.

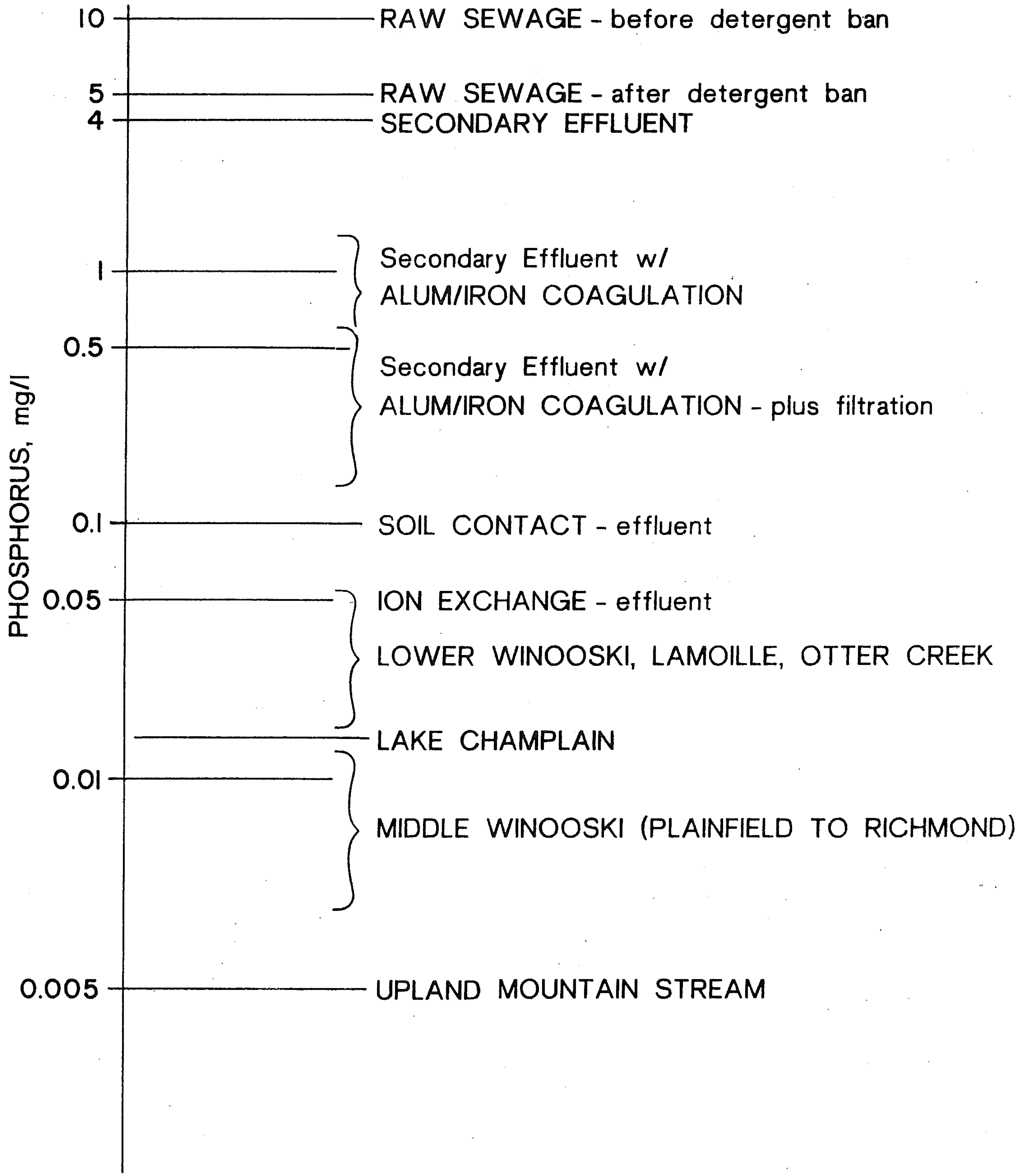
Graph 1 shows the phosphorus concentrations typical of certain Vermont surface waters and sewage treatment plant processes. The concentrations run from 10 mg/L P in domestic sewage prior to Vermont's detergent ban being implemented to 0.005 mg/L P in pristine upland mountain streams. This graph may help to put in perspective the P concentrations being discussed throughout this plan.

Table 2 compares four types of phosphorus removal which could be installed at existing wastewater treatment facilities. The comparisons shown are the expected P concentration resulting from each process, the expected % P removals and, for each process, the approximate cost to remove 1 lb of P at a 0.5 MGD facility. This table clearly shows the effect of diminishing returns - as more P is removed and a "cleaner" effluent is produced, the cost per lb of P removed increases. This increase in cost is substantial for the more advanced P removal processes.

Phosphorus removal processes also exhibit diminishing returns on investment as increasingly smaller quantities of phosphorus are removed by increasingly advanced treatment technology. Chemical precipitation with alum is the most commonly used phosphorus removal technology. It is simple to operate and is the least costly means of phosphorus removal generally employed. It is capable of reducing current raw sewage phosphorus concentrations of 5 mg/L down to 0.5 to 1.0 mg/L, an 80% to 90% removal.

A phosphorus limit of 0.80 mg/L, through the use of chemical coagulation, for many municipal WWTF effluents which contribute to Lake Champlain is considered appropriate at this time for the following reasons:

1. The Department believes that existing phosphorus concentrations in Lake Champlain are generally too high to fully support all beneficial values and uses of these waters and that reductions are needed. A recent Department review of lake monitoring data indicated that even the best areas of the Main Lake are firmly in the mesotrophic category with nuisance algal conditions and use impairment experienced by lake users on some occasions. Nuisance conditions are the norm in several eutrophic segments of the lake. A basin-wide phosphorus limitation for certain direct discharges would be a logical first step toward reducing phosphorus levels in Lake Champlain.


PHOSPHORUS, mg/l
10
RAW SEWAGE - before detergent ban
5
RAW SEWAGE - after detergent ban
4
SECONDARY EFFLUENT
1
Secondary Effluent w/
ALUM/IRON COAGULATION
0.5
Secondary Effluent w/
ALUM/IRON COAGULATION - plus filtration
0.1
SOIL CONTACT - effluent
0.05
ION EXCHANGE - effluent
LOWER WINOOSKI, LAMOILLE, OTTER CREEK
LAKE CHAMPLAIN
0.01
MIDDLE WINOOSKI (PLAINFIELD TO RICHMOND)
0.005
UPLAND MOUNTAIN STREAM

Graph 1

TABLE 2

	CHEMICAL COAGULATION	CHEMICAL COAGULATION W/FILTRATION	CHEMICAL COAGULATION W/FILTRATION & REVERSE OSMOSIS	CHEMICAL COAGULATION W/FILTRATION & ION EXCHANGE
RESULTING EFF. P	0.5-1 mg/L	0.2-0.5 mg/L	0.1-0.2 mg/L	0.05 mg/L
% REMOVAL	80 - 90%	90%	90 - 95%	99%
APPROX COST PER LB P REMOVED **	$10	$14	$28	$83

** FOR 0.5 MGD FACILITY, ASSUMING BOND AT 7% INTEREST FOR 20 YEARS:
(TOTAL ANNUAL BOND PAYMENT + TOTAL ANNUAL O&M COST)/# LBS P REMOVED PER YEAR

2. An effluent phosphorus concentration of 0.80 mg/L can be achieved either with the equipment and facilities now installed or being planned for the 15 of the sewage treatment plants tributary to Lake Champlain and Lake Memphremagog which have been ordered to remove phosphorus under 10 V.S.A., Section 1266a.

3. Implementation of a 0.80 mg/L effluent limit at selected sewage treatment plants would achieve a total basin wide phosphorus reduction essentially equal to implementation of a basin wide effluent limit of a 1.0 mg/L at all sewage treatment plants, but at substantially less cost. This is more fully discussed below.

4. A 0.80 mg/L P limit would not create an excessive economic burden on the municipalities.

5. A reduction in the P loading coming from these point sources is easily attained, easily regulated and readily quantifiable. Non-point source reduction, in contrast, would be extremely difficult to implement under authorities currently provided in statute. In addition, it would be very difficult to quantify the benefits of non-point source reductions. The effectiveness of past efforts at non-point source reduction has not been adequately documented.

Phosphorus inputs to Lake Champlain originate from point source discharges from municipal and private sewage treatment plants and from non-point sources discussed earlier. Point source phosphorus releases, after all the treatment plants now required to remove phosphorus under 10 V.S.A., Section 1266, have phosphorus removal operational and with all plants operating at full design capacity is estimated to be 420,053 lbs P/year. This point source component of the total phosphorus load is easily and reliably estimated from effluent sampling data. The non point source phosphorus loads are more difficult to quantify and sampling and analysis of all river inputs to Lake Champlain is now underway and expected to yield usable results by 1992 (see Subsection IV). During legislative consideration of the phosphorus detergent ban, non point source contributions were estimated to be 730,000 lbs/year by the Lake Champlain Basin Study (1979). While this estimate requires revision, it (together with the point source loads) can be used to provide some comparison of the relative magnitude of phosphorus contributions.

Point Source P to Lake Champlain	420,053 lbs/year	36%
Non Point Source P to Lake Champlain	730,000 lbs/year	64%

Ten possible scenarios were looked at when determining what the P limit should be and which facilities should be subject to it:

1. Limit all facilities to $\leq$ 1.0 mg/L P.

2. Limit all facilities with design flows of ≥ .2 MGD to ≤ 1.0 mg/L.

3. Limit all activated sludge and RBC facilities to ≤ 1.0 mg/L P.

4. Limit all activated sludge and RBC facilities with design flows of ≥ .2 MGD to 1.0 mg/L P.

5. Limit all facilities to ≤ 0.5 mg/L P (a 0.5 mg/L P concentration would be attainable using chemical coagulation by increasing the chemical dosage to obtain a higher percentage of P removal. Additional costs would be incurred for the increased chemical costs and additional sludge handling expenses).

6. Limit all facilities with design flows of ≥ .2 MGD to ≤ 0.5 mg/L P.

7. Limit all activated sludge and RBC facilities to ≤ 0.5 mg/L P.

8. Limit all activated sludge and RBC facilities with design flows of ≥ .2 mg/L to ≤ 0.5 mg/L P.

9. Limit all activated sludge and RBC facilities with design flows ≥ 1.0 MGD to ≤ 0.80 mg/L P (included in this alternative are the 7 larger facilities which are currently limited to ≤ 1.0 mg/L P - the three Burlington facilities, Essex, St. Albans, So. Burlington - Airport Parkway, and Winooski).

10. Do not require P removal at any facility listed in Table 3.

These ten scenarios are shown in Table 3 together with the pounds of P which would be removed by instituting each, and the total cost of construction, the average annual user increase and the annual cost/lb P removed for each alternative. The three graphs on page 24 show the contents of Table 4 in graphic form. Table 4 contains the specific data used in the development of all the alternatives with the exception of Alternative #10. The Champlain basin facilities omitted from Table 3 include municipalities currently using P removal, municipalities which have been ordered to install P removal equipment (pursuant to 10 V.S.A., Section 1266a) and municipalities which now remove P by reason of employing land disposal of their effluent.

Point source discharges tributary to Lake Champlain would release an estimated 420,053 lbs of phosphorus per year if all were operating at full design capacity and if all those plants now required to remove P achieved the current required effluent

TABLE 3

ALTERNATIVE NUMBER	FLOW CUTOFF (MGD)	PLANT TYPES	PHOSPHORUS LIMIT	TOTAL LBS P REMOVED/YR	TOTAL CONST. COST ($) (MILLIONS)	AVG. ANNUAL USER FEE (INCREASE)	ANNUAL COST PER LB. P REMOVED (STATE TOTAL)	% OF TOTAL P REMOVED WITH EACH ALTERNATIVE
1	ALL	ALL	1	282641	11.4	167	2002	79.1 %
2	> .2	ALL	1	273089	7.6	91	334	76.5 %
3	ALL	AS+RBC	1	248061	4.5	105	377	69.5 %
4	> .2	AS+RBC	1	243015	3.4	42	130	68.1 %
5	ALL	ALL	0.5	319869	17.1 *	250.5 *	2805 *	89.6 %
6	> .2	ALL	0.5	308791	11.5 *	137 *	501 *	86.5 %
7	ALL	AS+RBC	0.5	281497	6.7 *	158 *	566 *	78.8 %
8	> .2	AS+RBC	0.5	275644	5.1 *	63 *	195 *	77.2 %
9	> .2	AS+RBC	0.8	278928	3.6 *	46 *	132 *	78.1 %
10	ALL	ALL	NO LIMIT	0	0	0	0	0.0 %

NOTES ON THE ABOVE INFORMATION

#1 THE ALTERNATIVES THAT REQUIRE TREATMENT TO LESS THAN 1 mg/L PHOSPHORUS HAVE INCREASED COSTS AS FOLLOWS: ALL COSTS INCREASED BY 10% TO ACHIEVE .80 mg/L, BY 50% TO ACHIEVE .5 mg/L.

#2 ANNUAL COST PER POUND OF P REMOVED IS THE TOTAL COST AT ALL FACILITIES PRESENTLY NOT REMOVING PHOSPHORUS, EACH REMOVING ONE POUND.

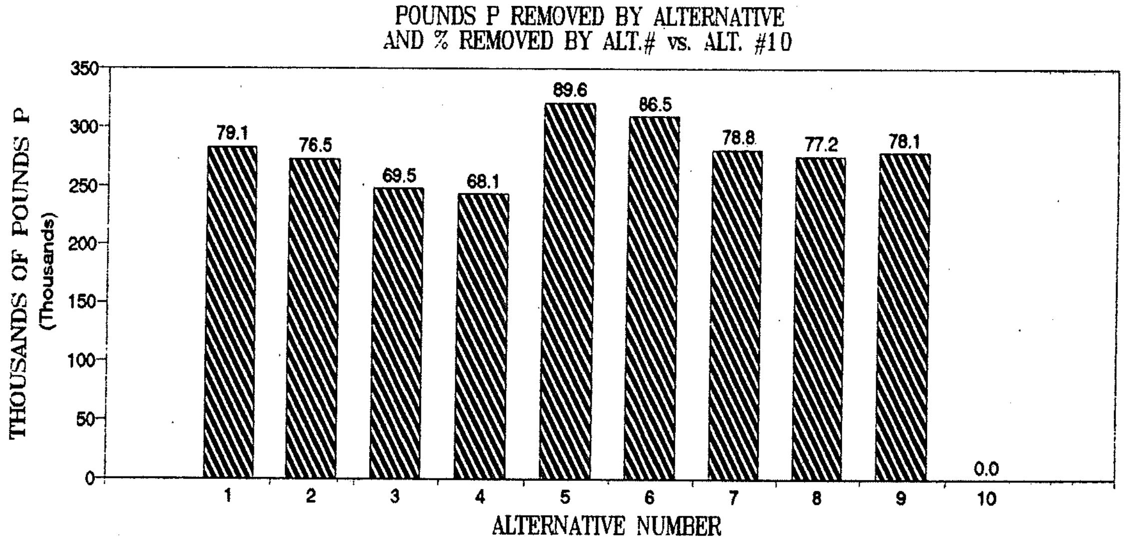
#3 THE USER FEE IS AN INCREASE OVER THE EXISTING USER FEE WITHOUT TREATMENT FOR PHOSPHORUS (OR IMPROVING P TREATMENT FROM 1 mg/L DOWN TO 0.80 mg/L AS IN ALTERNATIVE # 11).

#4 ALTERNATIVE # 9 INCLUDES FACILITIES THAT ARE PRESENTLY REQUIRED TO UTILIZE P REMOVAL. THIS ALTERNATIVE ALSO INCLUDES FACILITIES (AS & RBC) ≥ 0.2 MGD WHICH DO NOT PRESENTLY REMOVE PHOSPHORUS.

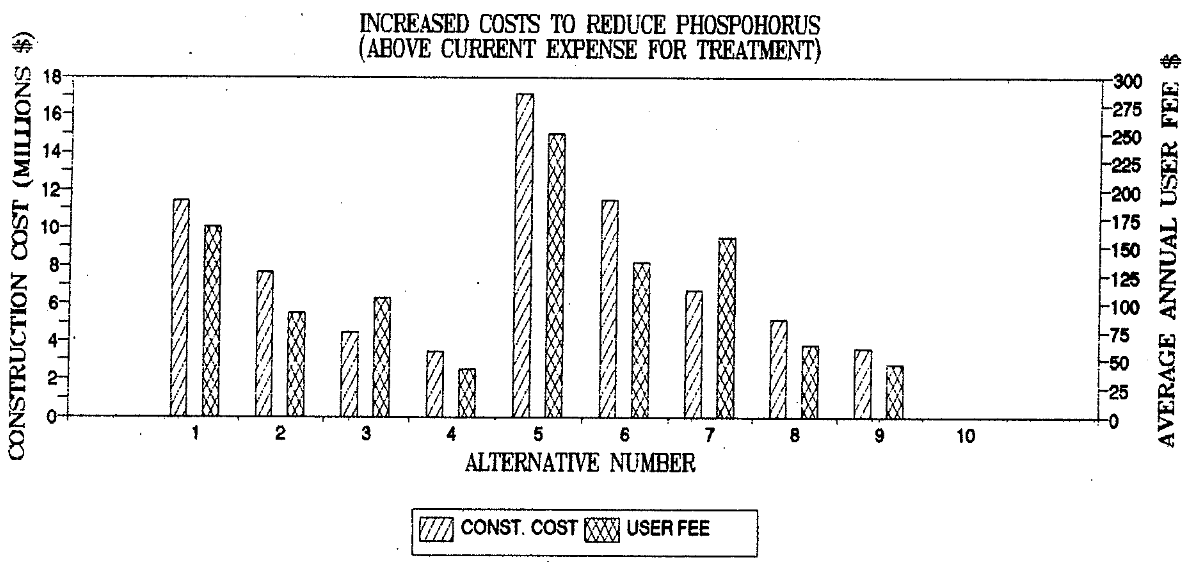
TABLE 4

FACILITY/ DRAINAGE BASIN CH = CHAMPLAIN M = MAGOG 1	LATEST ANNUAL AVG FLOW 1986 2	DESIGN ADF 3	ESTIMATED LBS P '88 USING 4.12 mg/L OF ACT. P 4	ANNUAL LBS P DISCHARGED AT DESIGN Q @ 4.12 mg/L OR ACT. P 5	CURRENT LBS PHOSPHORUS DISCHARGED IF HELD AT 1 mg/L 6	ANNUAL LBS DISCHARGED AT ADF AND 1 mg/L 7	ESTIMATED 89 CONSTRUCTION COST FOR P REMOVAL (TO 1 mg/L) 8	ESTIMATED ANNUAL USER COSTS FOR P REMOVAL 9	ESTIMATED ANNUAL COST PER POUND OF PHOSPHORUS REMOVED 10
BENSON /CH	0.005	0.018	63	226	15	54	319000	675	655
ORWELL /CH	0.02	0.033	251	414	60	100	319000	675	164
MARSHFIELD /CH	0.024	0.045	301	564	73	136	319000	675	137
FAIRFAX /CH	0.023	0.078	288	978	70	237	319000	405	187
WILLIAMSTOWN /CH	0.069	0.15	865	1881	210	456	468000	294	83
TROY /CH	0.066	0.2	4420	13394	200	608	616000	242	14
MILTON /CH	0.149	0.23	1869	2885	453	700	616000	242	46
PROCTOR /CH	0.274	0.33	3436	4139	834	1004	678000	196	26
HARDWICK /CH	0.155	0.37	1944	4640	471	1126	678000	196	50
RICHFORD /CH	0.305	0.38	3825	4766	928	1156	678000	191	25
WATERBURY /CH	0.232	0.51	2910	6396	706	1552	952000	179	41
SHELDON /CH	0.028	0.054	351	677	85	164	99000	227	35
PITTSFORD /CH	0.053	0.07	665	878	161	213	99000	192	19
PLAINFIELD /CH	0.061	0.1	765	1254	185	304	171000	230	25
N TROY /CH	0.058	0.11	727	1380	176	334	171000	230	27
WALLINGFORD /CH	0.118	0.12	1480	1505	359	365	171000	200	14
JOHNSON /CH	0.114	0.2	1430	2508	347	608	171000	67	17
FAIR HAVEN /CH	0.17	0.2	2132	2508	517	608	171000	67	11
RICHMOND /CH	0.084	0.22	1054	2759	255	669	171000	67	23
WEST RUTLAND /CH	0.187	0.33	2345	4139	569	1004	171000	48	11
POULTNEY /CH	0.253	0.35	3173	4390	770	1065	171000	48	8
CASTLETON /CH	0.22	0.36	2759	4515	669	1095	171000	48	10
MORRISVILLE /CH	0.27	0.43	3386	5393	821	1308	171000	78	6
ENOSBURG /CH	0.289	0.45	3625	5644	879	1369	231000	48	10
BRANDON /CH	0.339	0.7	4252	8779	1031	2130	231000	34	15
MIDDLEBURY /CH	0.992	2.2	66132	66970	3019	6697	319000	19	[illegible]
BARRE /CH	2.53	3.8	31730	47658	7701	11567	358000	13	4
MONTPELIER /CH	2.293	3.97	28758	49791	6980	12085	358000	13	4
RUTLAND /CH	5.24	6.6	65718	82775	15951	20091	407000	9	3
JEFFERSONVILLE /CH	0.025	0.077	314	966	76	234	319000	435	127
NORTHFIELD /CH	0.731	1.63	9168	20443	2225	4961	319000	22	7
TOTALS	15.38	24.32	250137	355215	46796	74000	10412000	6065	1807
AVERAGE	0.50	0.78	8069	11459	1510	2387	335871	196	58

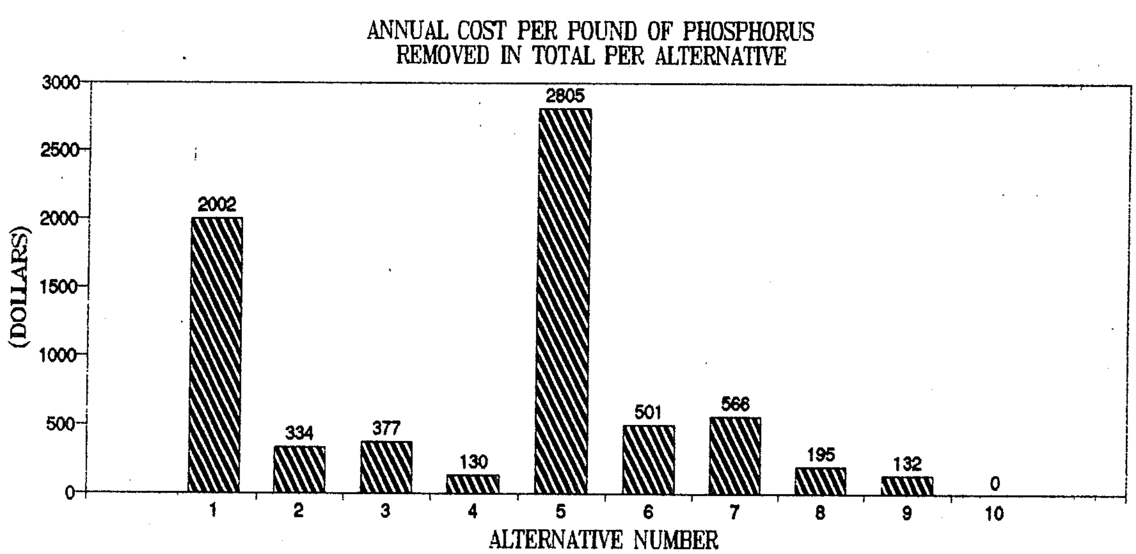
FOOTNOTES
COLUMN #8 INCLUDES CHEMICAL ADDITION, SLUDGE HANDLING & CLARIFICATION TO MEET 1 mg/L P EFFLUENT
COLUMN #9 USER COST = BOND PAYMENT + O&M COST
COLUMN #10 = (TOTAL ANNUAL BOND PAYMENT + TOTAL ANNUAL O&M COST)÷LBS OF P REMOVED AT 1988 FLOW
THE FACILITIES LISTED ARE NOT PRESENTLY TREATING FOR PHOSPHORUS REMOVAL NOR IS TREATMENT PLANNED
PHOSPHORUS CALCULATIONS FOR TROY BASED ON 22 mg/L, FOR MIDDLEBURY ON 21.9 mg/L @ PRESENT FLOW AND 10 mg/L @ DESIGN FLOW



GRAPH A



GRAPH B



GRAPH C

limit of 1.0 mg/L. The following paragraphs discuss the consequences, costs, and practicality of implementing the ten identified alternatives.

Alternative #1, a basin wide requirement that all sewage treatment plants remove phosphorus to a 1.0 mg/L effluent concentration would reduce the current 420,053 lb/year point source phosphorus load to 151,037 lbs/year.

It is the easiest reduction plan to implement and would require all the facilities (aerated lagoons, activated sludge and rotating biological contactors) to be limited to ≤ 1.0 mg/L P in their discharge. This would result in an 80% reduction in the P loading going to Lake Champlain from the point sources listed in Table 3 and a 64% overall reduction in the total point source load. Graphs B and C show that this alternative would also be one of the most expensive to implement when considering construction and operational costs. The reasons for these higher costs include:

1. The effects of diminishing returns and economy of scale (since the smaller sized treatment facilities are involved) cause high costs/lb of phosphorus removed.

2. Smaller municipalities with a limited number of users to pay for the construction and operating expense would experience sharp increases in annual user fees. Table 4 clearly shows the extremely high increase in user fees (Column 9) associated with the facilities ≤ 0.2 MGD.

3. Phosphorus removal at the 12 aerated lagoon facilities included in Alternative #1 require construction of costly clarifiers and sludge handling/storage equipment which units are a normal organic component of other forms of sewage treatment plants. These plants would experience an average annual user cost increase of $365 compared to an average annual user cost increase of $105 for other forms of treatment plants.

Alternative #2 reduces the total point source phosphorus loads to 154,111 lbs/year and prevents the facilities < 0.2 MGD from being subjected to the excessively high costs which would be caused if they were required to provide P removal. However, as all facilities ≥ 0.2 MGD would be limited to 1 mg/L P, the 6 larger aerated lagoons would still see an average increase in the user fee of $180. In contrast, the activated sludge and RBC facilities ≥ 0.2 MGD would have an average user fee increase of $42/year (Alternative #4).

Alternatives #5 - #8 are the same facility groupings as Alternatives #1 - #4, respectively. Alternatives #5 - #8, however, are targeted at effluent phosphorus concentrations of ≤ 0.5 mg/L P, which is considered attainable using the chemical coagulation process at a higher chemical dosage to increase the %

P removal. Although the number of pounds of P removed for these alternatives is measurably higher than for the respective alternatives (#1 - #4) at ≤ 1.0 mg/L P, the associated costs of these higher removals are also considerably higher. The Department believes that the added costs which would be incurred by instituting a 0.5 mg/L limit at any facility at this time are not justified. The 0.5 mg/L effluent limitation with only chemical coagulation is at the limit of that technology and specific effluent or operating characteristics of some plants may make a 0.5 mg/L limit unattainable. It is proposed that Alternative #9 be implemented until the need for further reductions can be established through the Lake Champlain Study described in Subsection (IV). That study will provide the justification for the additional costs to the users in the event a lower effluent P limit is found to be necessary at a facility.

Alternative #9 appears to be the most effectively, least costly approach to achieving significant point source phosphorus reductions. Current point source loadings would be reduced from 420,053 lbs/year to 151,037 lbs/year by requiring a 0.80 mg/L effluent phosphorus concentration at 29 facilities. These facilities include 14 activated sludge and rotating biological contactors with design capacities greater than or equal to 200,000 gallons per day which do not currently removal phosphorus and the 15 facilities which currently remove phosphorus down to 1.0 mg/L. Of this last group, Hinesburg and Swanton as lagoon facilities may have difficulty meeting the lowered 0.80 mg/L limit without the addition of expensive sand filters. In consideration of the small additional amount of phosphorus which would be removed (700 lbs/year or .5% of the total) at an estimated capital cost of $1 million to install the sand filters, if it is found that the 0.80 mg/L concentration cannot be met with the existing P removal equipment, the Department will defer the lower limit at this time at Hinesburg and Swanton. Total capital cost then of this program is estimated at $3.615 million with an average annual user cost increase of $46. Appendix D lists those municipalities which would be impacted by this alternative. Alternative #9 achieves essentially the same phosphorus reductions as Alternative #1 (1.0 mg/L effluent limit at all plants) but at only 41% of the overall cost and with annual average user cost increases of only 32% of those in Alternative #1.

The resulting annual P loading going to Lake Champlain as a result of implementing Alternative #9 is shown below:

	# of Plants	Annual P @ Design Flow	% of Total Point Source Loading
Do Not Remove P	17	46,943 lb/yr	31%
Practice or Req'd to Remove P	29	104,038	69%
Practice Land Disposal (.1 mg/L P)	2	56	<0.5%
TOTAL	48	151,037 lb/yr	100%

Implementing the recommended P reductions will result in a 64% decrease in the current 420,053 lbs total point source P loading entering Lake Champlain.

All of the facilities discharging tributary to Lake Champlain are also subject to the proposed Water Quality Standard for P - that of causing no undue, adverse effect on beneficial values and uses downstream from the discharge. The process for determining the allowable phosphorus concentrations in regard to this standard is described on page 33 of this plan. Sewage treatment plants found to create "undue adverse effects on the beneficial values and uses" downstream of the discharge would be subjected to more stringent effluent phosphorus concentration limits determined based on site specific stream conditions.

2. Lake Memphremagog

There are 6 wastewater treatment facilities which discharge tributary to Lake Memphremagog. The breakdown of the annual phosphorus loading from these facilities is as follows:

	# of Plants	Annual P @ Design Flow	% of Total Point Source Loading
Do Not Remove P	1	1,881 lb/yr	27.1%
Practice or Req'd to Remove P	3	5,038	72.6%
Practice Land Disposal (.1 mg/L P)	2	15	0.3%
TOTAL	6	6,934 lb/yr	100%

The one facility which does not currently remove P is the Brighton WWTF which is an aerated lagoon facility. To install P removal to meet a 1.0 mg/L P limit would cause an estimated increase in the annual user fee of $294 in Brighton. As discussed previously in regards to those lagoon systems discharging tributary to Lake Champlain, the Department believes that this high increase in user fees for such little P removal (in this specific case to remove 1,425 lbs a year) is not justified at this time.

The Department recommends that the municipalities of Newport City, Barton, and Orleans be required to operate existing phosphorus removal equipment and facilities to achieve a 0.80 mg/L effluent phosphorus concentration. This action will require no additional capital expenditure, only slight increases in annual operating costs and annual user costs (estimated at $5 per user/year) operating costs and annual users costs, and will result in reducing the current 6,934 lb/year discharge to 5,926 lb/year, as shown below.

	# of Plants	Annual P @ Design Flow	% of Total Point Source Loading
Do Not Remove P	1	1,881 lb/yr	32%
Practice or Req'd to Remove P	3	4,030	68%
Practice Land Disposal (.1 mg/L P)	2	15	1%
TOTAL	6	5,926 lb/yr	100%

Implementing the recommended P reductions will result in an 14% decrease in the current 6,934 lbs total point source P loading entering Lake Memphremagog.

The facilities discharging tributary to Lake Memphremagog are also subject to the Water Quality Standard for P of causing no undue adverse effect. These facilities would, therefore, be subject to the process described on page 33 of this plan.

III.A PROCESS FOR DETERMINING APPROPRIATE PHOSPHORUS CONCENTRATIONS IN DIRECT DISCHARGES TO ALL WATERS OF THE STATE, NOT INCLUDED IN SUBDIVISION (2) OF THIS SECTION, WHEN NECESSARY FOR THE DIRECT DISCHARGE TO MEET WATER QUALITY STANDARDS

1. General

The present overall water quality standard which governs a discharge containing phosphorus is "No increase which would accelerate eutrophication or result in concentrations that may stimulate the growth of aquatic plants, fungi or bacteria, in a manner which has an undue adverse effect on any beneficial values or uses." Recently, concern over excess eutrophication of the state's waters has given rise to a call for the development of state-wide instream numerical phosphorus standards. However, this is an extremely difficult and complex undertaking.

Since the relationship between a given phosphorus concentration and a corresponding eutrophication effect is dependent upon several other site specific variables, there is no single numeric standard which will prevent excess growth at all sites, while still allowing for reasonable uses of the receiving water. Current technology does not provide the ability to develop empirical or stochastic models to predict the threshold concentration which would "trigger" excess growth at particular river sites. Therefore, the following resource specific approach is proposed as a process for the determination of appropriate phosphorus concentrations.

2. Upland Streams

Vermont's upland streams (herein defined as those above 2500' MSL), are typified by rocky substrates, rapid velocities, and sparse algal communities. These relatively sterile mountain streams should be protected from activities which could alter their pristine character.

Although it is difficult to predict the exact threshold concentration of phosphorus which would cause eutrophication to occur, it is generally felt that a total phosphorus concentration of less than 0.010 mg/L would ensure the existence of oligotrophic conditions. Therefore, in an effort to maintain the desirable qualities of Vermont's mountain streams, a maximum instream concentration of 0.010 mg/L at median monthly flow should be adopted in the Vermont Water Quality Standards.

Vermont's upland streams are currently designated as Class A by statute (10 V.S.A., Section 1253a) and are therefore, subject to a prohibition on all direct sewage discharges and all indirect sewage discharges greater than 1000 gpd (10 V.S.A., Sections 1259c and 1259d). This existing discharge prohibition, combined with the proposed 0.010 mg/L phosphorus limit in the Water Quality Standards, will provide these streams with the desired strict protection from eutrophication.

3. Connecticut River

The Connecticut River forms the eastern border of Vermont, and drains approximately 40% of the state's land area. Eleven major Vermont rivers are tributary to the Connecticut River system, and several large reservoir systems are effectively inter-connected along its length. Table 5 on Page 33 contains the treatment facilities which discharge to the Connecticut River system and their present phosphorus loadings.

Streams and rivers within the Connecticut River basin may exhibit localized adverse water quality effects immediately downstream of point source discharges. In addition, these discharges may cause eutrophication effects in downstream impoundments. These effects can be due to phosphorus coming from a combination of point and nonpoint sources. This situation is particularly important in the Connecticut River, an interstate water shared with New Hampshire. Drainage basin planning will first be undertaken along the main stem of the Connecticut to identify excessive eutrophication in impoundments, and to identify the limiting phosphorus values needed to eliminate that eutrophication. Vermont would then undertake cooperative efforts with New Hampshire to divide those phosphorus loads between states and to subsequently assign Vermont's phosphorus loads to point sources and nonpoint sources within Vermont through the existing wasteload allocation process. Drainage basin planning for each of Vermont's major tributary rivers would then proceed to identify phosphorus loads from each point source discharge necessary to control both localized downstream adverse effects and downstream impoundment eutrophication.

Simultaneously with the above basin planning effort, the Department would undertake specific evaluations of existing point source discharges to identify particularly troublesome but localized adverse water quality effects caused by phosphorus discharges. That process is summarized in the following section.

4. Other Streams and Rivers

Almost all of Vermont's wastewater treatment facilities discharge to streams or rivers below 2500' MSL. In some cases localized effects are apparent immediately downstream of the point of discharge. In other cases effects are felt in further downstream reaches or in receiving lakes, and may be caused by a combination of several point source discharges. Differentiation of the relative impact of these point source inputs versus nonpoint contributions is difficult if not impossible.

The reliability, effectiveness and regulatory control of nonpoint source control measures have not developed sufficiently so that Vermont could rely on such measures to achieve water quality objectives. In two experimental watersheds within the state where nonpoint control measures have been implemented, little change in net phosphorus exports have been noted. The technology needed to control phosphorus in point source dis-

TABLE 5

FACILITY/ DRAINAGE BASIN CH = CHAMPLAIN CO= CONNECTICUT M = MAGOG H = HUDSON 1	LATEST ANNUAL AVG FLOW 1988 2	DESIGN ADF 3	ESTIMATED LBS P '88 USING 4.12 mg/L OR ACT. P 4	LBS P DISCHARGED AT DESIGN Q @ 4.12 mg/L OR ACT. P 5	CURRENT LBS PHOSPHORUS DISCHARGED IF HELD AT 1 mg/L 6	LBS P DISCHARGED AT ADF AND 1 mg/L 7	ESTIMATED 89 CONSTRUCTION COST FOR P REMOVAL (TO 1 mg/L) 8	ESTIMATED ANNUAL USER COSTS FOR P REMOVAL 9	ESTIMATED ANNUAL COST PER POUND OF PHOSPHORUS REMOVED 10
WOODSTOCK T /CO	0.01	0.01	125	125	30	30	99000	227	97
WHITINGHAM /CO	0.015	0.012	188	151	45	36	99000	275	99
WINDSOR W.H. /CO	0.013	0.015	163	188	39	45	99000	227	75
BENSON /CH	0.005	0.018	63	226	15	54	319000	675	655
ORWELL /CH	0.02	0.033	251	414	60	100	319000	675	164
WEST PAWLET /H	0.013	0.04	163	502	39	121	99000	227	74
BRIDGEWATER /CO	0.011	0.043	138	539	33	130	99000	227	136
MARSHFIELD /CH	0.024	0.045	301	564	73	136	319000	675	137
WOODSTOCK S /CO	0.025	0.05	314	627	76	152	99000	227	39
JACKSONVILLE /CO	0.038	0.05	477	627	115	152	99000	227	39
SHELDON /CH	0.028	0.054	351	677	85	164	99000	227	35
CHELSEA /CO	0.032	0.055	401	690	97	167	99000	227	30
DANVILLE /CO	0.03	0.06	376	753	91	182	319000	435	136
PITTSFORD /CH	0.053	0.07	665	878	161	213	99000	192	19
S ROYALTON /CO	0.026	0.07	326	878	79	213	319000	435	157
READSBORO /CO	0.044	0.075	552	941	133	228	319000	435	93
LUNENBURG FD#2/CO	0.049	0.076	615	953	149	231	319000	435	84
JEFFERSONVILLE/CH	0.025	0.077	314	966	76	234	319000	435	127
FAIRFAX /CH	0.023	0.078	288	978	70	237	319000	405	187
PUTNEY /CO	0.04	0.08	502	1003	121	243	171000	230	39
WILMINGTON /CO	0.096	0.09	1204	1129	292	273	319000	375	48
PLAINFIELD /CH	0.061	0.1	765	1254	185	204	171000	230	25
CAVENDISH /CO	0.059	0.1	740	1254	179	304	319000	420	71
SAXTONS RIVER /CO	0.037	0.105	464	1317	112	319	171000	230	42
N TROY /CH	0.058	0.11	727	1380	176	334	171000	230	27
WALLINGFORD /CH	0.118	0.12	1480	1505	359	365	171000	200	14
BETHEL /CO	0.05	0.135	627	1693	152	410	171000	230	31
BRADFORD /CO	0.09	0.137	1129	1718	273	417	171000	150	19
WILLIAMSTOWN /CH	0.069	0.15	865	1881	210	456	468000	294	83
BRIGHTON /M	0.09	0.15	1129	1881	273	456	468000	294	64
CHESTER /CO	0.088	0.175	1104	2195	267	532	171000	125	21
CANAAN /CO	0.134	0.185	1681	2320	407	563	468000	294	45
JOHNSON /CH	0.114	0.2	1430	2508	347	608	171000	67	17
FAIR HAVEN /CH	0.17	0.2	2132	2508	517	608	171000	67	11
TROY /CH	0.066	0.2	828	2508	200	608	616000	242	14
RICHMOND /CH	0.084	0.22	1054	2759	255	669	171000	67	23
MILTON /CH	0.149	0.23	1869	2885	453	700	616000	242	46
SHERBURNE FD#1/CO	0.086	0.3	1079	3763	261	913	171000	52	22
WEST RUTLAND /CH	0.187	0.33	2345	4139	569	1004	171000	48	11
PROCTOR /CH	0.274	0.33	3436	4139	834	1004	678000	196	28
POULTNEY /CH	0.253	0.35	3173	4390	770	1065	171000	48	8
CASTLETON /CH	0.22	0.36	2759	4515	669	1095	171000	48	10
HARDWICK /CH	0.155	0.37	1944	4640	471	1126	678000	196	50
RICHFORD /CH	0.305	0.38	3825	4766	928	1156	678000	191	25
RANDOLPH /CO	0.235	0.4	2947	5017	715	1217	171000	38	10
MORRISVILLE /CH	0.27	0.43	3386	5393	821	1308	171000	78	6
WOODSTOCK M /CO	0.259	0.45	3248	5644	788	1369	231000	48	11
ENOSBURG /CH	0.289	0.45	3625	5644	879	1369	231000	48	10
WATERBURY /CH	0.232	0.51	2910	6396	706	1552	352000	179	41
MANCHESTER /H	0.31	0.6	3888	7525	943	1826	952000	149	33
LUDLOW /CO	0.382	0.7	4791	8779	1162	2130	231000	34	10
BRANDON /CH	0.339	0.7	4252	8779	1031	2130	231000	34	15
LYNDONVILLE /CO	0.394	0.75	4941	9406	1199	2283	231000	34	9
WINDSOR M /CO	0.587	1.13	7362	14172	1786	3439	319000	22	9
HARTFORD WRJ /CO	0.437	1.215	5481	15238	1330	3698	231000	23	8
BELLOWS FALLS /CO	0.426	1.4	5343	17558	1296	4261	319000	22	13
NORTHFIELD /CH	0.731	1.63	9168	20443	2225	4961	319000	22	7
ST JOHNSBURY /CO	0.969	1.9	12153	23829	2949	5783	319000	19	7
SPRINGFIELD /CO	1.238	2.2	15527	27592	3768	6697	358000	18	5
MIDDLEBURY /CH	0.992	2.2	12441	27592	3019	6697	319000	19	6
BRATTLEBORO /CO	1.703	3	21359	37625	5184	9132	358000	14	4
BARRE /CH	2.53	3.8	31730	47658	7701	11567	358000	13	4
MONTPELIER /CH	2.293	3.97	28758	49791	6980	12085	358000	13	4
BENNINGTON /H	4.02	5.1	50418	63963	12237	15524	407000	11	3
RUTLAND /CH	5.24	6.6	65718	82775	15951	20091	407000	9	3
TOTALS	27.39	45.15	343492	566270	83341	137410	19009000	11999	3199
AVERAGE	0.43	0.72	5452	8988	1323	2181	301730	190	51

FOOTNOTES
COLUMN #10 INCLUDES CHEMICAL ADDITION, SLUDGE HANDLING & CLARIFICATION TO MEET 1 mg/L P EFFLUENT
COLUMN #11 PROJECT BOND PAYMENT BASED ON 20 YEAR BOND AT 7% INTEREST RATE DIVIDED BY # USERS
COLUMN #12 USER COST = BOND PAYMENT + O&M COST
COLUMN #14 = (TOTAL ANNUAL BOND PAYMENT + TOTAL ANNUAL O&M COST)÷LBS OF P REMOVED AT 1988 FLOW
PHOSPHORUS [illegible]

charges is well established, and results can reliably be achieved and monitored.

Also, while the state controls phosphorus levels in point source discharges through phosphorus limits in NPDES and indirect discharge permits, there is no such regulatory mechanism currently in place to specifically control <u>phosphorus</u> <u>loadings</u> coming from non-point sources.

Control over potential water quality degradation during logging operations was provided by the 1986 amendments to the Water Quality Statutes (10 V.S.A., Section 1259(a) and (f) and Section 1274). These amendments provided for the creation of "acceptable management practices" which have the force of law. Ten V.S.A., Section 1259(f) required the Commissioner of Agriculture to define "accepted agricultural practices." The purpose of these accepted practices is to reduce the risk of water quality degradation due to agricultural practices. Individuals who carry out accepted agricultural practices are in compliance with Vermont Water Quality Standards.

The easiest way to insure that these direct discharges do not have an adverse effect on the receiving streams would be to issue a blanket order requiring all these facilities to install a phosphorus removal down to 0.80 mg/L. It is believed that such an order would unnecessarily impose additional costs to the users since sufficient data does not exist to support such a blanket order at this time. Any requirement for phosphorus reduction should be based on the results of an on-site evaluation of the receiving streams to determine if any adverse effects are noticeable. This process would consist of three principle steps.

a) Wastewater treatment facilities were ranked according to the anticipated phosphorus concentration downstream from their discharge (Appendix B). The anticipated downstream concentration was calculated by determining a dilution ratio using the facility's design flow and the receiving stream's low median monthly flow. The expected effluent P concentration is multiplied by this dilution ratio and the product is added to the background P concentration of the receiving stream.

b) The resulting ranking will now be used as a means to prioritize the scheduling of site specific evaluations by the Department. These studies will be designed to determine whether the phosphorus loadings from the facilities in question are indeed creating an undue adverse effect on the receiving water.

   Consideration will be given to such factors as the presence of existing upstream eutrophication effects, impact on downstream receiving lakes, and the ratio of existing loads to design loadings.

   If there is more than one wastewater facility upstream from a particular stream or river reach which is found to contribute to an undue adverse effect condition during the site specific evaluation, then a phosphorus wasteload allocation process will have to be undertaken. This allocation will insure that all the facilities responsible for contributing to problem will assume responsibility for improving the quality of the receiving stream.

c) In the event the Department determines the need for phosphorus reduction at a facility, the Department will issue an order which will require the planning, construction and operation of phosphorus removal facilities to produce an effluent phosphorus concentration needed to eliminate the adverse effect. Such orders will generally require implementation within 3 years.

Where localized effects or downstream conditions dictate the need for effluent phosphorus load reductions below levels achievable with conventional technology, an evaluation of the costs and reliabilities of additional effluent concentration reductions versus other basin-wide control techniques will be made on a case by case basis.

5. <u>Inland Lakes</u>

Vermont's inland lakes are particularly fragile ecosystems. In contrast with rivers, water passes through lakes relatively slowly, and sometimes years are required for a complete flushing. Phosphorus can therefore accumulate in a lake's sediments to be recycled within the system for many years even after a pollution source is eliminated. Changes in lake phosphorus concentrations of only a few parts per billion (ppb) can be enough to cause nuisance algae blooms in sensitive lakes. In recognition of the extreme sensitivity of Vermont's inland lakes to phosphorus inputs, the Water Resources Board is proposing a strict narrative phosphorus water quality standard for these waters which states that there shall be "no significant increase above the existing lake phosphorus concentration."

For these reasons, lakes are the wrong place to put direct discharges of phosphorus and other pollutants. Most of the other New England states have statutes or standards that prohibit new direct discharges to lakes or their tributaries. Vermont should also prohibit new direct phosphorus discharges to its lakes, with exceptions as follows.

Lakes Champlain and Memphremagog and several large reservoirs in Vermont have very large drainage basins containing a multitude of human activities including major municipalities, industries, and extensive agriculture. A basin-wide direct discharge prohibition would therefore be impractical in watersheds larger than 40 square miles in area. Other Vermont lakes are run-of-the-river in nature and therefore less sensitive to the eutrophication effects of phosphorus discharges. Rapidly flushed lakes having drainage basin area to surface area ratios greater than 500 could be excluded from a discharge prohibition.

It is proposed that a statutory prohibition be established against all new direct discharges containing other than a trace concentration of phosphorus to lakes and their tributaries, for Vermont lakes having drainage areas less than 40 square miles and drainage area to surface area ratios less than 500. There are approximately 642 such lakes in the state. Their watersheds include about 1200 square miles, or about 12% of the land area of Vermont. Some of these waters are currently designated as Class A and are therefore already under a statutory discharge prohibition (10 V.S.A. Sections 1253a, 1259d).

The lakes that would be included in the proposed direct discharge prohibition are listed in Appendix C. These lakes are generally located in rural settings with limited development in their watersheds. There are currently only two existing permitted direct discharges in these watersheds (on Lake St. Catherine and Lake Paran), so present lake use and development patterns could continue without serious constraint under the proposed direct discharge prohibition. The proposal is aimed at protecting Vermont's sensitive lakes from unwise waste disposal practices that might be attempted in the future as development pressures increase in Vermont's lake watersheds.

This proposed prohibition would not restrict the construction of land disposal or indirect discharging systems. Systems in compliance with the State Indirect Discharge Regulations would be considered to be in compliance with the "no significant phosphorus increase" lake standard.

The proposed direct discharge prohibition could be implemented by an amendment to Vermont's Water Pollution Control Statute (10 V.S.A., Chapter 47). A new subsection (f) under 10 V.S.A., Section 1259 should be added between the existing Subsections 1259(e) and (f) as follows:

> **(f) No person shall cause a new or increased direct discharge of wastes containing phosphorus above a trace amount, as determined by the Secretary of the Agency, into any lake having a drainage basin area less than 40 square miles and a drainage area to surface area ratio less than 500, or to any tributary of such a lake.**

6. Large Impoundments

Large impoundments on rivers present a phosphorus management situation similar to Lake Champlain and Lake Memphremagog. These reservoirs must support the full range of lake values and uses, but drain large watersheds with many human activities, including wastewater discharges. For the purpose of this plan, large impoundments are defined as "artificially constructed riverine impoundments having surface areas larger than 50 acres at the mean summer pool elevation, and drainage areas greater than 40 square miles." There are 17 such impoundments within Vermont and eight along the Connecticut River adjoining Vermont, as listed in Table 6.

Phosphorus in these impoundments will be managed according to a process that is analogous to the approach outlined in detail for Lake Champlain and Lake Memphremagog in Subdivision (4) of this plan. Numeric phosphorus criteria for each impoundment will eventually be established in Vermont's Water Quality Standards, although no such standards are specifically proposed at this time because of a lack of adequate supporting information in most cases. Reservoir phosphorus loading studies will be undertaken and basin-wide phosphorus wasteload allocations among point and nonpoint sources will be conducted in a manner that attains the reservoir specific phosphorus standards.

TABLE 6. Large Impoundments with Drainage Areas Greater than 40 Square Miles and Surface Areas Greater than 50 Acres

Impoundment	Drainage Area (square miles)	Surface Area (acres)
Within Vermont:		
Arrowhead Mtn.	692	732
Ball Mountain	172	85
Clyde	140	177
Hardwick	118	145
Harriman	184	2157
Lamoille	222	130
Mill (Windsor)	44	70
North Hartland	220	215
North Montpelier	51	72
North Springfield	158	290
Pensioner	105	170
Salem	131	788
Sherman	224	160
Stone Bridge	50	441
Townshend	278	100
Waterbury	109	823
Wrightsville	69	89
Connecticut River:		
Vernon	6266	2550
Bellows Falls	5414	2804
Wilder	3375	3100
Ryegate	2215	297
McIndoes	2200	543
Comerford	1635	732
Moore	1600	3475
Gilman	1514	394

IV. A PROCESS FOR DETERMINING A PHOSPHORUS CONCENTRATION MORE RESTRICTIVE THAN THAT PROVIDED FOR IN SUBDIVISION (2) OF THIS SECTION WHEN SUCH RESTRICTIVE CONCENTRATION IS NECESSARY TO MEET WATER QUALITY STANDARDS IN THE LAKE CHAMPLAIN AND LAKE MEMPHREMAGOG BASINS.

Subsection (II) of this plan recommended a basin-wide 0.80 mg/L phosphorus effluent limit for RBC/activated sludge facilities with design flows ≥ 0.2 mg/L in the Lake Champlain and Lake Memphremagog drainage basins. This recommendation was based on the premise that the existing phosphorus concentrations in these two lakes are too high, and that reducing effluent phosphorus concentrations in direct discharges to a level consistent with commonly accepted technology would be a logical and proper first step to improve lake water quality. This recommendation therefore did not require the creation of special lake water quality standards or detailed water quality modeling analyses for its justification.

Effluent limits significantly more restrictive than 0.80 mg/L would result in increasing costs per pound of phosphorus removed (see Subsection II). Nonpoint sources are also important contributors of phosphorus to Lake Champlain and Lake Memphremagog, and the relative cost-effectiveness of point vs. nonpoint source phosphorus controls should be considered in developing basin-wide phosphorus management strategies. Numeric phosphorus standards for these lakes are necessary to provide specific targets defining the extent to which further phosphorus controls should be implemented.

For these reasons, more restrictive phosphorus limits for direct discharges should be considered within the context of a comprehensive phosphorus management approach for the Lake Champlain and Lake Memphremagog basins involving the following three steps.

1. Establish numeric phosphorus criteria in Vermont's Water Quality Standards applicable to Lake Champlain and Lake Memphremagog.

2. Conduct lake studies and water quality modeling analyses to determine the amount of phosphorus loading reductions needed to attain the water quality standards.

3. Develop and implement a comprehensive basin-wide phosphorus management plan for each of these two lakes that identifies the most cost-effective combination of point and nonpoint source phosphorus controls to attain the target loading reductions.

Each of these three steps is discussed in more detail below.

Numeric Phosphorus Criteria

The establishment of specific and realistic water quality standards for phosphorus is an essential prerequisite for the development of a comprehensive phosphorus management plan because the standards are what define the goals of the plan. However, the narrative "no undue adverse effect" standard for nutrients currently specified in Vermont's Water Quality Standards is inadequate for this purpose. This narrative standard is applied on a case-specific basis and therefore does not support comprehensive basin-wide cost-effectiveness considerations, nor does it address the cumulative nature of phosphorus impacts in Vermont's large lake basins where no single phosphorus source is significant on a lake-wide basis, yet many sources add together to produce a problem. Numeric phosphorus criteria are preferable because they establish a finite upper limit for the cumulative impact of many individually small phosphorus sources, and because numeric criteria allow for their attainment through comprehensive, rather than case-specific management.

Numeric phosphorus criteria established for Lake Champlain and Lake Memphremagog should represent realistically attainable management goals while preserving the beneficial values and uses of these waters. Because of the large spatial variations in water quality within these lakes (see Figure 1), separate phosphorus criteria should be established for individual lake segments.

As discussed in Subsection (VI), funding and construction of the facilities necessary to meet the requirements of this plan will require several years at least. Therefore, the effective date of any numerical phosphorus criteria established in Vermont's Water Quality Standards should be delayed in order to allow adequate time for facilities to achieve compliance with the new phosphorus limits proposed. This is necessary so that this Department can continue to issue discharge permits for facilities in the Lake Champlain and Lake Memphremagog drainage basins in the interim period without resorting to numerous Assurance of Discontinuance Orders under 10 V.S.A. Section 8007.

The Vermont Water Resources Board is in the process of revising Vermont's Water Quality Standards with respect to phosphorus and other constituents. The Department of Environmental Conservation has submitted a proposal to the Board (dated January 3, 1990) that includes the considerations discussed above and recommends numeric, segment-specific phosphorus criteria for Lake Champlain and Lake Memphremagog. These proposed criteria represent realistically attainable and desirable water quality goals that will require reductions in phosphorus loadings to these lakes for their attainment. The Department's proposed phosphorus criteria for Lake Champlain and Lake Memphremagog should be incorporated into Vermont's Water Quality Standards in order to provide effective guidance for the comprehensive, basin-wide phosphorus management approach described in this subsection.

Lake Studies

In order to make the link between lake water quality standards and the specific phosphorus reductions needed to attain the standards, certain lake scientific studies are necessary. These studies involve the measurement of phosphorus loadings from all tributaries, direct discharges, and other sources, combined with extensive lake sampling. This data is used to develop lake models describing the effects of phosphorus loadings on water quality in various segments of a lake.

The Vermont Department of Environmental Conservation has recently initiated a major phosphorus study on Lake Champlain in cooperation with the State of New York. The cost of the study is in excess of $900,000 with funding provided by the U.S. Environmental Protection Agency and the U.S. Geological Survey, and matching services provided by the States of Vermont and New York.

The Lake Champlain Phosphorus Study will involve year-round sampling of 34 tributary streams, 15 direct wastewater discharges, and 55 lake stations in Vermont, New York, and Quebec over a two year period in 1990 and 1991. The data will be used to develop a whole-lake water quality model for Lake Champlain. The model will identify the specific phosphorus load reductions at the tributary mouths and direct discharges necessary to attain the applicable phosphorus criteria for each segment of the lake.

A phosphorus study is also needed for Lake Memphremagog, although extensive loading and lake modeling analyses were conducted on Lake Memphremagog in the 1970's. These studies should be reviewed and updated with data obtained under present-day conditions.

Comprehensive Phosphorus Management

Comprehensive phosphorus management will be undertaken through a drainage basin planning process which will identify allowable phosphorus loads from point source discharges necessary to prevent localized adverse water quality effects and to achieve targeted phosphorus loads into Lake Champlain and Lake Memphremagog. Those tributaries targeted for phosphorus load reductions by the lake modeling studies will require a second study phase to identify specific upstream sources where phosphorus controls are needed to meet the target loads for the tributary. This process will involve a consideration of the relative cost-effectiveness of further effluent limitations below 0.80 mg/L vs. alternative phosphorus reduction efforts aimed at farm runoff, urban stormwater, indirect discharges, and other sources. Within each of the targeted sub-watersheds, the most cost-effective combination of point and nonpoint source phosphorus controls will be identified.

The technical reliability of point vs. nonpoint source phosphorus controls must be weighed in selecting the optimal phosphorus reduction strategy for a sub-watershed. For example, the cost of removing phosphorus in direct wastewater discharges from 0.80 mg/L to 0.50 mg/L or lower might be high compared with the cost of implementing agricultural best management practices on farms in a particular sub-watershed. However, advanced wastewater treatment for phosphorus removal is a tried and true technology, whereas the effectiveness of agricultural best management practices in improving water quality in Vermont is not well documented. Long term studies conducted by the University of Vermont in the St. Albans Bay and LaPlatte River Watersheds where conventional best management practices have been extensively implemented have yet to show significant in-stream phosphorus reductions. Therefore, greater weight should be given to point source controls in designing a phosphorus reduction strategy for a sub-watershed until the effectiveness on nonpoint source controls are better demonstrated in Vermont or similar settings.

A basin-wide phosphorus management program on Lake Champlain could be effective only if all tributaries throughout the basin were brought into compliance with their target phosphorus loads. Accomplishing this will require a commitment from Vermont, New York, and Quebec to implement the necessary control measures. A general mechanism for achieving such inter-jurisdictional cooperation was established by the Memorandum of Understanding on Environmental Cooperation on the Management of Lake Champlain, signed by the Governors of Vermont and New York and the Quebec Premier on August 23, 1988.

A similar phosphorus management process would be appropriate for Lake Memphremagog. Lake standards would need to be established to guide the phosphorus control efforts and the necessary lake studies should be conducted. A considerable phosphorus abatement effort has already occurred in the Lake Memphremagog Basin. All the major direct discharges, including Newport City, are removing phosphorus to 1.0 mg/L in their effluent. Nonpoint sources control projects are in progress for the Black, Barton, and Clyde River Watersheds.

A regulatory mechanism in Vermont for assigning phosphorus reductions to direct discharges in order to meet the tributary loading targets is provided by the State's Wasteload Allocation Process (Administrative Rule 87-46). This process is administered by the Agency of Natural Resources and provides a means for equitably allocating the assimilative capacity of a water segment among both point and nonpoint phosphorus sources in order to attain water quality standards. The process includes public hearings, and the allocations are appealable to the Water Resources Board.

Applying the wasteload allocation process to Lake Champlain or Lake Memphremagog tributaries would involve the assignment by permit of total average daily allowable phosphorus loads to each discharge within a sub-watershed in a manner which, when combined with additional nonpoint source reductions, would meet the target load for the tributary and thereby attain the water quality standards for Lake Champlain. In making the allocations to the direct discharges, capacity would be reserved for anticipated future population growth.

It should be recognized that phosphorus removal at direct discharges, even to levels below 0.80 mg/L in the effluent, is not likely by itself to attain water quality standards in every segment of Lake Champlain or Lake Memphremagog. Nonpoint sources are major phosphorus contributors to these lakes, and control of both point and nonpoint sources will probably be necessary to meet the standards. This situation could present an administrative difficulty for Vermont's discharge permitting program when numeric phosphorus criteria are adopted for these lakes. A situation could arise in which a discharge was in compliance with its assigned phosphorus wasteload allocation, yet the lake phosphorus criteria were still violated because of uncontrolled nonpoint source loads. To facilitate the comprehensive cost-effective phosphorus management approach proposed here for the Lake Champlain and Lake Memphremagog Basins, there should be a provision established in Vermont's Water Quality Standards allowing for compliance with numeric phosphorus limits through compliance with basin plans and phosphorus wasteload allocations.

Implementation of the comprehensive phosphorus management process proposed here for the Lake Champlain and Lake Memphremagog Basins will not be possible for several years. The Lake Champlain Phosphorus Study will be completed in 1992, but the follow-up study phase in which specific upstream phosphorus control measures are identified will not produce a basin-wide phosphorus management plan for Lake Champlain until 1994, at the earliest. Given the potentially high cost of basin-wide phosphorus controls, the time and money spent on such studies and planning efforts should be seen as a wise investment to assure that water quality standards are attained in the most cost-effective manner possible. However, there is no reason to delay implementing the basin-wide 0.80 mg/L effluent phosphorus limit recommended in Subsection (II) according to the schedule of priorities established in Subsection (VI). Regardless of the specific results obtained from the lake modeling studies, the recommended 0.80 mg/L effluent limit would be a logical and necessary initial step to attain water quality standards in Lake Champlain and Lake Memphremagog.

Finally, it should be noted that the phosphorus management process recommended in this subsection for Lake Champlain and Lake Memphremagog is directly analogous to the successful precedent established for the Great Lakes Basin over the past two decades. The International Great Lakes Water Quality Agreement of 1978 established in-lake phosphorus concentration objectives (numeric standards) for each segment of the Great Lakes, and defined the target loading reductions necessary to meet these objectives. The Agreement called for a basin-wide maximum discharge phosphorus concentration of 1.0 mg/L for all municipal treatment plants with flows greater than one million gallons per day, along with basin-wide phosphorus detergent bans. The remaining phosphorus reductions necessary to meet the in-lake objectives were to be attained either through nonpoint source controls or by further effluent phosphorus reductions to 0.5 mg/L in some areas.

Significant progress has been made in attaining the target phosphorus loads for the Great Lakes,and substantial water quality improvements have been recorded in formerly eutrophic segments such as Lake Erie, Lake Ontario, and Saginaw Bay. The general phosphorus management approach applied to the Great Lakes Basin therefore provides a good model for Vermont, New York, and Quebec to follow for Lake Champlain and Lake Memphremagog.

V. AN ESTIMATE OF THE COST OF ACHIEVING THE CONCENTRATION PROPOSED IN SUBSECTIONS (II), (III), AND (IV) OF THIS SECTION, AND IMPACT ON THE STATE CAPITAL PLAN.

For those 14 activated sludge and RBC facilities which would be required under this plan to construct phosphorus removal facilities to meet 0.80 mg/L P as proposed in Subsection (II), the estimated construction costs in 1989 dollars would total 3.6 million dollars. This cost is assuming the installation of alum/ferrous chloride chemical addition, chemical storage and additional sludge storage facilities and also includes the approximated engineering costs.

During 1989, the Department of Environmental Conservation estimated the cost of all environmental infrastructure works for which the state provides financial assistance. The aggregate cost of installing phosphorus removal capability at all sewage treatment plants not currently required to remove phosphorus was estimated to be 21.4 million. With state grant assistance of a 35% grant authorized under 10 V.S.A., Section 1625, a total state outlay of 7.5 million dollars would have been required. Adoption of the plan recommended herein to require phosphorus removal at only activated sludge/RBC plants tributary to Lake Champlain with design flows of $\geq$ 0.2 MGD would reduce the total need from $21.4 million to $3.75 million with concomitant state grant outlays reduced from $7.5 million to $1.3 million.

Generally, it is anticipated that additional construction will not be required at the facilities currently removing P which will now have to meet a lower limit of 0.80 mg/L. All but one of these facilities either have or are undergoing upgrades and expansions. It is believed that adequate sludge handling facilities are in place at these locations to handle the small increase in sludge production which will result in meeting the lower limit. The increase in sludge production is expected to be small because of the nature of the coagulation process - the current chemical feed rate at these facilities has been found to usually be adequate to drop the effluent P concentration to less than 0.80 mg/L already.

The exception to the above is the Winooski facility. This facility is over 15 years old and is nearing its design capacity at this time. An engineering study of this facility to determine if additional sludge handling capabilities will be needed. The estimated cost of such a study would be $15,000. This cost has been included in the 3.75 million dollar figure discussed above.

It is also recommended that the State provide increased financial assistance to these municipalities in the form of low interest loans available under the Vermont Pollution Control Revolving Fund authorized under 24 V.S.A., Chapter 120 to cover the 65% local share of project capital costs. The adoption of this proposal would require an outlay of an additional 2.3 million dollars. Loan payments would be returned to the revolving fund for subsequent lending to other municipalities. Terms of all loans would be as specified in 24 V.S.A., Chapter 120 at interest rates set by the Treasurer at between 0% and 80% of the rate on state debt, terms not to exceed 20 years, and equal annual payments over the term of the loan. Added financial assistance of this kind is justified and the State is requiring the larger facilities to remove more phosphorus in order to achieve about the same P loading reductions as requiring removal at <u>all</u> these facilities. As the driving force behind this recommendation is to enable the smaller facilities to avoid incurring the much higher cost/lb of P removed, it is believed that additional monetary support to the affected municipalities is in order.

At this point in time, it is impossible to predict the specific required effluent P concentrations which will result from the studies outlined in Subsections (III) and (IV). It is impossible therefore to estimate the capital costs associated with the future requirements. When study results are finalized and the need for further P reductions are documented, the costs and state capital plan impacts will be determined at that time.

VI. A SCHEDULE AND PRIORITIES FOR THE CONSTRUCTION OR MODIFICATION OF DISCHARGING FACILITIES NECESSARY OF DISCHARGING FACILITIES NECESSARY TO MEET THE PROPOSED PHOSPHORUS CONCENTRATIONS

It is recommended that implementation of the 0.80 mg/L monthly average P limits be accomplished through the issuance of 1272 Orders to the affected municipalities (see Appendix E). Before such an order can be issued, a statute will have to be passed requiring the lower limit. The proposed statute is included in Appendix E. This method of implementation is considered equitable in that all affected municipalities will have to meet the P limit in the same time frame.

Those facilities which do not currently have P removal will be issued an Order requiring the installation and operation of P removal within 3 years.

Those facilities which currently meet a 1.0 mg/L monthly average P limit will be issued an Order requiring that they immediately meet the reduced 0.80 mg/L P limit.

This method of implementation will place minimal increased workload on the Permits, Compliance & Protection Division as the Orders will be identical except for some minor specific changes (names and permit number of the permittee, etc.).

VII. OTHER INFORMATION DETERMINED BY THE SECRETARY NECESSARY TO SUPPORT THE PLAN

As noted previously, the phosphorus removal process will produce an additional amount of sludge at the facilities which must be disposed of. Table 7 gives a breakdown of the additional pounds of sludge anticipated to be produced at the facilities which will be required to install P removal. Table 6 also lists the approximate number of acres which will be needed by each municipality for ultimate disposal of the sludge by land application.

At this point in time, four of these municipalities either are close to or are already using the disposal capacity of their certified acreage - Barre City, Montpelier, Northfield, and Rutland. These municipalities would need to pursue locating and certifying the additional acreage listed within a short time frame.

The other municipalities either have adequate acreage available to them or are planning composting facilities in the future.

TABLE 7

Anticipated increase in sludge production using chemical precipitation and acreage needed for disposal.

Chemical added prior to primary clarifier - estimate 10% increase in dry solids produced from primaries:

Facility	Additional # Sludge/yr (*1)	Total # Acres Necessary for Ultimate Sludge Disposal (*2)
Sherburne FD#1	13,700	2.5
Northfield	74,430	12.5
Middlebury	100,450	17.0
Barre	173,510	29.0
Montpelier	181,280	30.0
Rutland	301,360	50.0

Chemical added at secondary process - estimate 20% increase in dry solids produced from secondaries:

Facility	Additional # Sludge/yr (*3)	Total # Acres Necessary for Ultimate Sludge Disposal (*2)
Fair Haven	15,220	2.5
Johnson	15,220	2.5
Richmond	16,740	3.0
West Rutland	25,110	4.0
Poultney	26,640	4.5
Castleton	27,400	4.5
Morrisville	32,720	5.5
Enosburg	34,250	6.0
Brandon	53,270	9.0

Footnotes:

*1 Assuming 250 mg/L TSS Inf., 60% solids removal in primary clarifier, 10% increase in sludge mass produced.

*2 Assuming sludge contains moderate nitrogen level requiring application rate of 3 tons sludge/acre.

*3 Assuming 250 mg/L BOD Inf., 1/2 lb sludge produced per lb of BOD removed, and 20% increase in sludge mass produced.

APPENDIX A

P Removal Technologies

Chemical Precipitation

1. Addition of Ferric Chloride or Alum

The chemical used can be added either prior to the primary clarifier, at the inlet of the secondary treatment or prior to the secondary clarifier.

Addition to the inlet of the primary clarifier will result in significantly higher TSS and BOD removals in the clarifier and approximately 30% increase in the volume of primary sludge produced. This volume would equate to a 10% increase in the mass of dry solids produced. The lower BOD loading going to the secondary treatment could cause more effective biological treatment of the wastewater resulting in lower electrical costs for aeration and lower BOD concentration in the final effluent. This feeding location requires a higher chemical feed rate than feeding into the inlet of the secondary treatment. In addition, wastewater which has relatively low alkalinity (buffering capacity) and which is required by the permit to undergo nitrification will require lime or sodium hydroxide addition prior to secondary treatment. This additional chemical addition is necessary to counteract the drop in pH which will occur as a result of the addition of either alum or ferric chloride.

Addition of the precipitating chemical to the inlet of the secondary treatment requires a lower chemical feed rate. This lower rate is due to the recycling of a portion of the secondary sludge back into the secondary process. This recycled sludge contains some of the precipitating chemical which will help to augment the chemical feed taking place at the secondary inlet. Adding the precipitating chemical at this location will result in a 50% increase in the sludge volume produced (or 20% increase in the dry solids production) by the wastewater treatment process.

Pros/Cons of Alum and Ferrous Chloride

The use of these chemicals at the primary treatment unit will increase the BOD/TSS removal of this unit in addition to providing P removal. This will result in a lower organic load going to the secondary treatment unit which could conceivably reduce operations costs via reduced aeration requirement, decreased chlorine demand and improved sludge filterability.

As a result of the higher BOD/TSS removals, the sludge volume produced will also increase and will have to be treated and disposed of. Other additional operational costs could come from chemical addition to raise depressed pH and the cost of polymer that may be used to enhance flocculation.

2. Lime Addition

Lime, if used, is generally added before the primary clarifier via a flash mixer. The P combines with the available calcium component of the lime and precipitates out in the clarifier as hydroxyapatite. Two lime processes are available - low lime and high lime.

The low lime process requires adding enough lime to increase the pH of the wastewater to close to 10. This higher pH level leaving the primary clarifier will be reduced in the secondary system by reacting with the carbon dioxide which is constantly produced by the biomass' metabolism. Low lime can provide 80%P removal consistently. The effluent P concentration can be further reduced via tertiary filtration and the addition of metal coagulants and polymers to near 1.0 mg/L P.

Lime processes will cause an increase in the mass of sludge produced at a conventional activated sludge plant of 100%. Substantial additional acreage would have to be found for ultimate disposal of this additional sludge.

The high lime process requires adding enough lime prior to primary clarification to increase the wastewater's pH to 11. Together with flocculent aids and final filtration,this process can produce an effluent P of below 1.0 mg/L consistently. A drawback of the high lime system is the probable need to provide pH adjustment to the wastewater prior to the secondary process. Although the secondary's biomass has been shown to be relatively unaffected by low lime's pH of 10, it is highly unlikely that it would survive the higher pH of 11.

<u>Physical Processes</u>

3. Ion Exchange

In this process, the secondarily treated wastewater is passed thru columns containing a synthetic resin. An ion in the resin will be selectively removed and replaced by a P ion. The generally low P concentrations found in most WWTF effluents would not be removed selectively by most available resins. Ion exchange would be applicable for effluents containing higher than normal P concentrations, however.

The resins must be regenerated periodically using a strong base solution. Consideration must be given to the proper disposal of the regeneration materials (the wash, the strong regenerant, and the rinse waters).

4. Ultrafiltration

This system would remove P contained as discrete suspended or colloidal material. It could be used to remove micro-colloids of calcium phosphate or the iron and aluminum salts of phosphates following chemical addition P removal processes.

In this process, the wastewater (which must have <50 mg/L TSS) is collected in a large receiving reservoir and then pumped through porous membranes.

5. Reverse Osmosis

The water flow in this system does not pass through discrete pores or holes in the membranes, rather it occurs on a molecular level. Flow goes from one side of the membrane to other due to the difference in concentrations on either side of the membrane.

Prior to a reverse osmosis unit, the wastewater must be pretreated to remove colloids and gross suspended material (ie., coagulation, flocculation, sedimentation and filtration).

The reverse osmosis process can removed up to 95 to 99% of the P sent to it.

6. Land Treatment

In this process the secondary effluent is applied to land to obtain further treatment of the wastewater. It is collected via an underdrain system or culvert system and discharged to the receiving stream. Phosphorus removal is obtained when the phosphorus reacts with the iron, calcium, and aluminum contents of the soil to form insoluble phosphates. The soil used in such a treatment system does have a limited use as every ten years a one foot depth of the soil will be saturated with phosphorus (ie., unable to provide additional P removal).

There are three types of land treatment systems, however only the slow rate system at this time is proven for long term phosphorus removal.

Slow rate provides up to 98% removal (down to .05 mg/L P in the effluent). This system requires the most land to provide the necessary removals and is therefore the most expensive of the three systems.

Capital and operating costs are generally comparable or less than conventional secondary or advanced wastewater treatment. The feasibility of using this type of phosphorus removal in conjunction with already existing facilities is doubtful considering the general lack of availability of land adjoining existing facilities.

<u>Biological processes</u> - Although discussed here, the following processes are not so readily "retrofitted" into existing activated sludge facilities to provide P removal. These processes would more logically be considered when required to construct a new wastewater treatment plant where P removal was to be included.

Biological Processes

7. Phosphorus Strip

This is an activated sludge process in which all or part of return sludge is subjected to anaerobic conditions in a stripper tank for 8-12 hours. During this time, some of the cells will lyse and the phosphorus contained in the cells will be released to the water. The overflow from the stripper tank is now phosphorus enriched and is piped to the primary clarifier where lime is added for P precipitation. The sludge in the stripper tank is returned to the aeration tank. This process can produce effluent P concentrations of .3 mg/L to 1.0 mg/L.

8. A/O Process

The A/O process is an activated sludge process which removes pH by purely biological means. Basically it is composed of the influent going thru 3 anaerobic stages, followed by 3 aerobic or toxic stages and then to the clarifier. The return sludge from the clarifier is mixed back into the influent of the anaerobic stages. Once in the anaerobic stages the same lysing of cells occurs as in the Phos-strip process. The P thus released is taken up by the biomass in the aerobic stages.

The P is ultimately taken out of the system in the waste sludge (which may contain 4 to 6% P by dry weight). Temperature extremes of $5^{o}C$ and $30^{o}C$ are considered acceptable. This process can produce effluent P concentrations of .4 to 1.2 mg/L.

9. Barden-pho

Phosphorus and nitrogen are removed biologically by this activated sludge process.

The flow is first subjected to a fermentation (or anaerobic) stage. This is then followed by a series of anoxic/aerobic stages where the P is taken up by the biomass and nitrogen removal is accomplished by the denitrification process. P is again removed from the system via the waste sludge. Low BOD, TSS and ammonium nitrogen effluent concentrations are possible with this process in addition to P concentrations of <1.0 mg/L. The long solids retention time in the system provides an aerobically stabilized sludge which needs no other stabilization prior to disposal.

APPENDIX B
PHOSPHORUS DILUTION RATIOS

WWTF	AVERAGE DESIGN Q (mgd)	LOW MONTH. MEDIAN Q (mgd)	ASSUMED WWTF P (mg/l)	ASSUMED BCKGRD (mg/l)	PROJECTED MIXED (mg/l)
GROUP #1					
WILLIAMSTOWN	0.150	0.2	4.20	0.010	1.682
PAWLETT	0.265	0.8	4.20	0.040	1.030
ST ALBANS	4.000	0.6	0.85	0.040	0.750
SHERBURNE FD#1	0.300	1.7	4.20	0.025	0.643
BENSON	0.018	0.1	4.20	0.040	0.510
DANVILLE	0.060	0.5	4.20	0.010	0.465
BENNINGTON	5.000	45.5	4.20	0.025	0.438
HINESBURG	0.250	1.1	1.00	0.040	0.213
SPRINGFIELD MAIN	2.200	51.3	4.20	0.040	0.211
RANDOLPH	0.320	6.7	4.20	0.010	0.201
TROY	0.200	28.4	22.00	0.040	0.194
ORWELL	0.033	0.8	4.20	0.025	0.189
JACKSONVILLE	0.050	1.2	4.20	0.010	0.180
BARRE CITY	3.800	17.4	0.85	0.025	0.173
LUDLOW	0.600	17.8	4.20	0.025	0.161
WOODSTOCK SO	0.050	1.7	4.20	0.025	0.144
NORTHFIELD	1.630	10.1	0.85	0.025	0.139
CHESTER	0.175	6.7	4.20	0.025	0.131
PUTNEY	0.080	3.1	4.20	0.025	0.131
ST JOHNSBURY	1.900	73.1	4.20	0.025	0.131
WHITINGHAM	0.012	0.5	4.20	0.025	0.120
BRANDON	0.700	7.4	0.85	0.040	0.110
SAXTONS RIVER	0.105	5.7	4.20	0.025	0.100
NEWPORT CTR	0.042	2.3	4.20	0.025	0.099
GROUP #2					
MANCHESTER	0.600	38.9	4.20	0.025	0.088
RUTLAND CITY	6.600	107.9	0.85	0.040	0.087
CHELSEA	0.055	3.3	4.20	0.010	0.078
WILMINGTON	0.070	5.5	4.20	0.025	0.077
SHELBURNE FD#2	0.450	11.7	1.00	0.040	0.075
POULTNEY	0.350	5.8	0.85	0.025	0.072
LYNDONVILLE	0.750	71.3	4.20	0.025	0.068
CASTLETON	0.360	11.7	0.85	0.040	0.064
MONTPELIER	3.970	95.7	0.85	0.025	0.058
PITTSFORD	0.070	17.6	4.20	0.040	0.056
NORTH TROY	0.110	33.8	4.20	0.040	0.053
FAIR HAVEN	0.200	13.8	0.85	0.040	0.052
PROCTOR	0.325	127.6	4.20	0.040	0.051
PLAINFIELD	0.100	17.2	4.20	0.025	0.049
MIDDLEBURY	2.200	220.8	0.85	0.040	0.048
HARDWICK	0.371	67.1	4.20	0.025	0.048

WWTF	AVERAGE DESIGN Q (mgd)	LOW MONTH. MEDIAN Q (mgd)	ASSUMED WWTF P (mg/l)	ASSUMED BCKGRD (mg/l)	PROJECTED MIXED (mg/l)
WOODSTOCK MAIN	0.250	46.1	4.20	0.025	0.048
JOHNSON	0.200	24.2	0.85	0.040	0.047
SWANTON	0.900	149.5	1.00	0.040	0.046
BURL., NORTH	2.000	311.3	0.85	0.040	0.045
MILTON	0.225	248.0	4.20	0.040	0.044
SHELDON	0.054	63.0	4.20	0.040	0.044
ESSEX VILLAGE	1.250	296.2	0.85	0.040	0.043
CAVENDISH	0.100	22.7	4.20	0.025	0.043
SO BURLINGTON AP	1.200	305.2	0.85	0.040	0.043
WINOOSKI	1.200	306.4	0.85	0.040	0.043
BURL., RIVER	1.000	306.4	0.85	0.040	0.043
VERGENNES	0.660	283.0	1.00	0.040	0.042
SHELBURNE FD#1	0.250	155.7	1.00	0.040	0.042
BRIGHTON	0.150	20.0	4.20	0.010	0.041
FAIRFAX	0.078	314.8	4.20	0.040	0.041
WOODSTOCK TAFT	0.010	41.6	4.20	0.040	0.041
COLCHESTER FD#1	0.310	305.5	1.00	0.040	0.041
WEST RUTLAND	0.320	16.6	0.85	0.025	0.041
HARTFORD QUECHEE	0.300	88.0	4.20	0.025	0.039
RICHFORD	0.380	112.2	4.20	0.025	0.039
WALLINGFORD	0.120	36.8	4.20	0.025	0.039
NEWPORT CITY	0.975	68.5	0.85	0.025	0.037
READSBORO	0.075	29.5	4.20	0.025	0.036
BARTON	0.265	10.1	1.00	0.010	0.035
WATERBURY	0.510	247.3	4.20	0.025	0.034
BRIDGEWATER	0.043	22.5	4.20	0.025	0.033
BRADFORD	0.137	26.1	4.20	0.010	0.032
BRATTLEBORO	2.500	1950.5	4.20	0.025	0.030
MARSHFIELD	0.045	9.5	4.20	0.010	0.030
MORRISVILLE	0.425	81.6	0.85	0.025	0.029
WINDSOR MAIN	1.300	1440.9	4.20	0.025	0.029
BELLOWS FALLS	1.500	1703.5	4.20	0.025	0.029
HARTFORD-WT-RIV	0.970	1287.3	4.20	0.025	0.028
HARTFORD-WILDER	0.400	720.9	4.20	0.025	0.027
SO BURLINGTON BB	0.700	305.5	1.00	0.025	0.027
ENOSBURG FALLS	0.330	141.3	0.85	0.025	0.027
RICHMOND	0.222	271.5	0.85	0.025	0.026
WINDSOR WEST	0.015	1440.9	4.20	0.025	0.025
ORLEANS	0.190	12.9	1.00	0.010	0.024
STOWE	0.167	29.8	1.00	0.010	0.016
CANAAN	0.185	155.7	4.20	0.010	0.015
SO ROYALTON	0.070	198.9	4.20	0.010	0.011
LUNENBURG FD#1	0.076	476.3	4.20	0.010	0.011

APPENDIX C

Vermont inland lakes subject to the proposed discharge prohibition, having drainage basin areas less than 40 square miles and basin area to lake surface area **radius** less than 500.

Lake	Town	Lake Area (acres)	Basin Area (square miles)	Basin Area / Lake Area Ratio (acres/acres)
ABBEY	RIPTON	3	.7	144.3
ABENAKI	THETFORD	44	1.0	14.7
ADAM	JAMAICA	7	.3	26.6
ADAMS (ENOS)	ENOSBURG	11	2.3	134.3
ADAMS (WOOD)	WOODFORD	21	1.3	38.9
ALBERT LORD;	CAVENDISH	7	.1	8.9
AMHERST	PLYMOUTH	76	19.1	160.6
ANDOVER;	ANDOVER	11	.6	35.4
ANSEL	BETHEL	2	.9	272.0
ATHENS	ATHENS	21	.6	17.0
ATHENS - 357;	ATHENS	6	.7	79.5
AUSTIN	HUBBARDTON	28	4.9	112.0
BACK	BRIGHTON	10	3.8	243.2
BAILEY	MARSHFIELD	17	6.0	226.3
BAILEYS MILLS;	CHESTER	10	.2	10.3
BAKER (BART)	BARTON	51	2.2	28.2
BAKER (BROOK)	BROOKFIELD	35	1.7	30.5
BAKERSFIELD - N;	BAKERSFIELD	10	.3	19.7
BALD HILL	WESTMORE	104	4.0	24.9
BALDWIN	STARKSBORO	9	.3	22.3
BANCROFT	PLAINFIELD	14	.3	11.9
BARBER	POWNAL	19	.3	8.9
BARBOS	SANDGATE	7	.1	6.9
BEAN (LYN)	LYNDON	24	.3	9.3
BEAN (SUT)	SUTTON	30	1.9	40.3
BEAR	CAMBRIDGE	1	.0	2.0
BEAVER (HART)	HARTLAND	2	.2	78.5
BEAVER (HOL)	HOLLAND	40	1.1	18.0
BEAVER (HYDE);	HYDE PARK	16	1.1	42.7
BEAVER (MEN)	MENDON	6	.5	58.2
BEAVER (PROCT)	PROCTOR	9	.4	31.9
BEAVER (ROXBURY)	ROXBURY	10	.1	4.0
BEAVER MEADOW B - L;	ENOSBURG	18	3.4	119.3
BEAVER MEADOW B - U;	ENOSBURG	14	.3	15.9
BEAVER MEADOW;	BALTIMORE	5	.3	35.6
BEAVER MEADOWS	CHITTENDEN	3	.6	126.7
BEAVER;	WEATHERSFIELD	49	.8	9.8
BECK	NEWARK	6	.5	49.0
BEEBE (HUB)	HUBBARDTON	100	2.9	18.4
BEEBE (SUND)	SUNDERLAND	8	.2	18.5
BEECHER	BRIGHTON	15	.9	39.8
BELDING	JOHNSON	4	.1	21.5
BELVIDERE - NE;	BELVIDERE	9	.7	47.3
BERKSHIRE;	BERKSHIRE	8	2.1	164.0
BERLIN	BERLIN	256	10.5	26.3
BIG	WOODFORD	31	1.1	23.1
BIG MUD	MT. TABOR	15	.6	23.7
BIG MUDDY	EDEN	17	.2	7.2
BILLINGS MARSH	WEST HAVEN	56	.4	5.1
BLACK (HUB)	HUBBARDTON	20	.2	6.3
BLACK (PLY)	PLYMOUTH	20	.5	14.6

Lake	Town	Lake Area (acres)	Basin Area (square miles)	Basin Area / Lake Area Ratio (acres/acres)
BLAKE (SHEF)	SHEFFIELD	7	.3	22.9
BLAKE (SUT)	SUTTON	8	.2	12.8
BLISS	CALAIS	46	.9	12.8
BLODGETT;	BRADFORD	15	4.6	197.6
BLOODSUCKER	SPRINGFIELD	4	.1	19.3
BLUE	CALAIS	6	.1	11.7
BLUEBERRY	WARREN	48	1.2	15.4
BM1145;	PLYMOUTH	8	.1	10.9
BM746;	BROOKFIELD	9	6.8	485.6
BOG (FAIRLEE)	FAIRLEE	1	.0	16.0
BOLSTER	BARRE	5	.4	48.4
BOMOSEEN	CASTLETON	2360	36.9	10.0
BOURN	SUNDERLAND	48	.6	8.5
BRANCH	SUNDERLAND	34	.5	9.7
BREESE	HUBBARDTON	12	.6	29.5
BRILYEA EAST	ADDISON	126	23.0	116.8
BRILYEA WEST	ADDISON	186	14.7	50.6
BRISTOL - NW;	BRISTOL	9	.2	11.6
BROCKLEBANK;	TUNBRIDGE	7	.3	28.1
BROWN	WESTMORE	15	.4	16.9
BROWNINGTON	BROWNINGTON	136	5.3	24.7
BROWNS	BAKERSFIELD	10	7.3	466.1
BRUCE	SHEFFIELD	27	.6	13.7
BRUNSWICK SPRINGS	BRUNSWICK	16	.2	8.8
BUCK	WOODBURY	39	.4	5.8
BUGBEE;	WOODFORD	8	2.2	178.5
BULLHEAD (BENSON)	BENSON	7	.1	7.6
BULLHEAD (MANCH)	MANCHESTER	5	.0	5.8
BULLIS;	FRANKLIN	11	5.7	334.4
BURBEE	WINDHAM	50	3.9	49.6
BURLESON	BERKSHIRE	2	.0	11.5
BURNELL	BRANDON	7	.2	20.6
BURNHAM MTN;	TOPSHAM	8	.7	57.9
BURR (PITT)	PITTSFORD	20	.2	7.1
BURR (SUD)	SUDBURY	74	2.7	23.5
BUTLER	PITTSFORD	3	.2	33.0
C.C.C.	SHARON	9	.3	19.3
CAMBRIDGEPORT;	ROCKINGHAM	6	3.3	347.7
CAP HILL;	JERICHO	9	.3	22.2
CARLTON	WOODSTOCK	4	.1	18.8
CARMI	FRANKLIN	1375	12.1	5.6
CASPIAN	GREENSBORO	739	7.0	6.1
CEDAR	MONKTON	114	1.2	6.6
CENTER	NEWARK	80	5.9	47.4
CHAMPAGNE	RANDOLPH	3	.4	81.0
CHANDLER	WHEELOCK	65	1.6	16.2
CHANDLER;	WATERFORD	6	2.1	218.8
CHAPELS	EAST MONTPELIER	2	.5	147.5
CHESTER	CHESTER	5	.6	79.8
CHILDS	THETFORD	10	.1	3.3
CHIPMAN	TINMOUTH	81	.8	6.6
CHITTENDEN	CHITTENDEN	674	15.9	15.1

Lake	Town	Lake Area (acres)	Basin Area (square miles)	Basin Area / Lake Area Ratio (acres/acres)
CHOATE	ORWELL	11	.1	6.9
CLARA	WHITINGHAM	18	.6	22.9
CLEAR	HYDE PARK	8	.1	5.0
CLOSSON	ROCKINGHAM	1	.0	16.0
COBB	DERBY	27	.2	5.1
COBURN	RYEGATE	5	.1	12.8
COGGMAN	WEST HAVEN	20	.6	18.4
COITS	CABOT	40	.5	8.1
COLBY	PLYMOUTH	20	.5	15.7
COLCHESTER	COLCHESTER	167	2.0	7.5
COLE	JAMAICA	41	.4	6.9
COLES	WALDEN	125	1.2	6.0
COLLINS	HYDE PARK	16	.7	27.7
COLTON	SHERBURNE	27	.8	18.6
COOK	LUDLOW	3	.1	18.7
COOKS (SHREWS)	SHREWSBURY	12	.3	15.3
COOKS (WEATHERS)	WEATHERSFIELD	10	.3	21.8
COREZ	LOWELL	9	.9	61.7
COW HILL;	PEACHAM	8	.3	23.1
COW MOUNTAIN	GRANBY	10	.2	12.8
COX	WOODSTOCK	2	.5	164.5
CRANBERRY BOG	WEYBRIDGE	2	.2	64.0
CRANBERRY MEADOW	WOODBURY	28	3.0	68.0
CRESCENT	SHARON	20	1.5	47.8
CROW HILL;	ST. JOHNSBURY	5	.5	65.6
CRYSTAL (BARTON)	BARTON	778	22.6	18.6
CRYSTAL (HART)	HARTLAND	2	.1	40.5
CURTIS	CALAIS	76	1.4	12.1
CUSHING HILL;	UNDERHILL	9	.6	41.2
CUTLER	HIGHGATE	25	.4	11.0
CUTTER	WILLIAMSTOWN	16	1.3	53.6
DANBY	DANBY	56	.6	6.9
DANIELS	GLOVER	61	1.7	17.7
DANVILLE	DANVILLE	2	1.3	419.5
DANYOW	FERRISBURG	192	.6	2.0
DEER PARK	HALIFAX	22	.9	27.6
DEER PARK - WEST;	HALIFAX	6	.4	41.2
DENNIS	BRUNSWICK	185	8.3	28.8
DERBY	DERBY	206	1.8	5.6
DEWEYS MILL	HARTFORD	56	1.5	17.3
DOBSON	WOODBURY	9	.2	13.6
DOLLIF;	BRIGHTON	5	1.0	128.0
DOLLOFF - S	SUTTON	3	1.2	256.0
DOUGHTY	ORWELL	17	.7	24.9
DOW	MIDDLEBURY	11	2.6	152.0
DRY RIDGE;	JOHNSON	6	1.3	141.7
DUCK (BURKE)	BURKE	4	.1	8.0
DUCK (CRAFT)	CRAFTSBURY	9	.1	9.2
DUCK (HOL)	HOLLAND	6	.2	19.2
DUCK (SHEF)	SHEFFIELD	7	.3	24.7
DUCK (SHEL)	SHELBURNE	4	.2	24.0
DUCK (SUT)	SUTTON	8	.2	17.6

Lake	Town	Lake Area (acres)	Basin Area (square miles)	Basin Area / Lake Area Ratio (acres/acres)
DUCK (WATER)	WATERFORD	16	.3	13.4
DUNMORE	SALISBURY	985	20.4	13.3
DUTTON	MAIDSTONE	12	.2	9.6
EAGLE	ALBURG	2	.0	7.0
EAST CREEK	ORWELL	31	14.1	291.1
EAST LONG	WOODBURY	177	3.5	12.6
EASTMAN	NEWBURY	4	.1	10.8
ECHO (CHARLES)	CHARLESTON	544	23.7	27.9
ECHO (HUB)	HUBBARDTON	53	.9	10.3
ECHO (PLY)	PLYMOUTH	96	26.3	175.2
EDDY	RUTLAND	10	2.6	165.0
EDEN	EDEN	186	3.7	12.6
ELBOW;	MENDON	8	.3	20.3
ELFIN	WALLINGFORD	16	.4	14.3
ELLIGO	GREENSBORO	190	5.1	17.0
ELMORE	ELMORE	224	8.7	24.9
ELY;	THETFORD	5	.3	33.6
EMERALD	DORSET	28	5.7	129.6
EQUINOX	MANCHESTER	15	.8	35.8
EWELL	PEACHAM	50	3.1	39.6
FAIR HAVEN - W;	FAIR HAVEN	18	.3	9.7
FAIRFIELD	FAIRFIELD	464	5.9	8.1
FAIRFIELD - NE;	FAIRFIELD	12	.5	26.7
FAIRFIELD - SE;	FAIRFIELD	18	.4	12.6
FAIRFIELD - SW1;	FAIRFIELD	7	.1	11.7
FAIRFIELD - SW2;	FAIRFIELD	7	.5	42.0
FAIRFIELD SWAMP	SWANTON	160	11.6	46.4
FAIRLEE	THETFORD	463	20.3	28.0
FAN;	WELLS	12	.4	23.3
FAY;	STRAFFORD	10	.3	22.3
FELCHNER;	NORTHFIELD	12	.2	11.6
FERN	LEICESTER	61	.8	8.3
FIFIELD	WALLINGFORD	6	1.1	119.5
FLAGG	WHEELOCK	108	3.6	21.1
FOREST (AVERILL)	AVERILL	62	2.2	22.2
FOREST (CALAIS)	CALAIS	125	4.4	22.6
FORESTER	JAMAICA	9	.1	8.6
FORTIER	ORWELL	4	.0	7.5
FOSTERS	PEACHAM	62	1.0	10.4
GALE MEADOWS	LONDONDERRY	195	10.3	33.7
GALUSHA;	TOPSHAM	5	.2	30.4
GARFIELD;	HYDE PARK	9	.1	5.2
GATES	WHITINGHAM	30	2.3	49.5
GEORGIA PLAINS;	GEORGIA	19	5.8	196.1
GILLETT	RICHMOND	30	2.2	46.3
GILMORE	BRISTOL	6	.5	53.8
GLEN	CASTLETON	191	3.2	10.7
GOODALL	WOODBURY	7	.2	20.1
GOODSELL;	SHELDON	10	.1	8.6
GOOSE	BOLTON	2	.1	24.5
GOSLANT	PEACHAM	5	.1	15.4
GOULDS;	SPRINGFIELD	6	2.6	275.2

Lake	Town	Lake Area (acres)	Basin Area (square miles)	Basin Area / Lake Area Ratio (acres/acres)
GRAHAMVILLE;	LUDLOW	8	.1	5.4
GRASS	PLYMOUTH	3	.3	56.3
GRAYS	LYNDON	1	.1	72.0
GREAT AVERILL	NORTON	812	11.9	9.4
GREAT HOSMER	CRAFTSBURY	155	1.3	5.5
GREEN RIVER	HYDE PARK	554	14.2	16.4
GREENWOOD	WOODBURY	83	1.8	13.7
GRIFFITH	PERU	18	.3	9.1
GRIGGS	ALBANY	6	.3	26.7
GROTON	GROTON	414	18.8	29.0
GROUT	STRATTON	86	.6	4.3
GUILFORD - E;	GUILFORD	5	.1	8.2
GUILLMETTES	RICHFORD	12	.8	42.5
GUT	EDEN	13	.2	11.8
HALF MOON	HUBBARDTON	23	.5	14.0
HALFMOON	FLETCHER	21	.3	9.2
HALFMOON COVE	COLCHESTER	14	.2	9.5
HALFWAY	NORTON	22	.2	6.9
HALLOCK;	STARKSBORO	15	.3	13.8
HALLS	NEWBURY	84	.9	6.7
HANCOCK (BRIGHT)	BRIGHTON	7	.2	22.0
HANCOCK (STAM)	STAMFORD	51	.4	5.1
HANCOCK MT;	ROCHESTER	14	.5	22.8
HAPGOOD	PERU	7	2.5	224.0
HARDWOOD	ELMORE	44	.4	6.5
HARRIMAN (NEWBURY)	NEWBURY	20	2.2	71.9
HARTWELL	ALBANY	16	1.0	38.9
HARVEYS	BARNET	352	8.4	15.2
HAWKINS	CALAIS	9	.3	21.1
HAYSTACK	WILMINGTON	27	.2	4.4
HEART	ALBANY	6	.1	15.0
HEDGEHOG;	WESTMORE	12	.3	16.0
HICKORY;	WESTMINSTER	16	.1	5.3
HIDDEN	MARLBORO	17	1.1	42.5
HIGH (HUB)	HUBBARDTON	3	.0	6.7
HIGH (SUD)	SUDBURY	20	.3	8.7
HINKUM	SUDBURY	56	.6	6.3
HOLDENS	BROOKFIELD	10	.5	32.4
HOLLAND	HOLLAND	334	6.9	13.3
HORN OF THE MOON	EAST MONTPELIER	10	.2	13.9
HORSE	GREENSBORO	32	.8	16.6
HORTONIA	HUBBARDTON	449	7.0	9.9
HOUGH	SUDBURY	16	.5	21.5
HOVEY;	HARDWICK	6	.3	33.0
HOWE	READSBORO	50	2.9	36.5
INDIAN BROOK (COL);	COLCHESTER	16	9.5	379.9
INDIAN BROOK (ESSEX)	ESSEX	47	1.2	16.2
INMAN	FAIR HAVEN	76	.4	3.2
IROQUOIS	HINESBURG	229	3.8	10.6
ISLAND	BRIGHTON	608	9.8	10.4
JACKSONVILLE	WHITINGHAM	20	5.2	167.5
JEROME;	ADDISON	18	.5	17.8

Lake	Town	Lake Area (acres)	Basin Area (square miles)	Basin Area / Lake Area Ratio (acres/acres)
JEWELL BK #1;	LUDLOW	14	1.8	81.6
JEWELL BK #2;	LUDLOW	17	2.1	77.8
JEWELL BK #3;	LUDLOW	18	1.3	44.6
JOBS	WESTMORE	39	.4	6.9
JOES (DANVILLE)	DANVILLE	396	28.8	46.6
JOES (MORRIS)	MORRISTOWN	9	1.2	87.4
JOHNSON (KIRBY)	KIRBY	7	1.1	98.7
JOHNSON (ORWELL)	ORWELL	15	.2	9.3
JOHNSON (SHREWS)	SHREWSBURY	12	.3	17.5
JONES	CHELSEA	2	.1	27.0
JOSLIN TURN;	CONCORD	10	.3	16.5
KEELER	WOLCOTT	5	.9	108.8
KEISER	DANVILLE	33	2.5	48.8
KENNY	NEWFANE	26	.4	9.2
KENT	SHERBURNE	71	3.7	33.5
KENT HOLLOW;	SANDGATE	10	.9	57.9
KETTLE	GROTON	104	1.3	8.0
KEYSER;	CHELSEA	7	.8	76.0
KIDDER	IRASBURG	16	.3	13.5
KING - N	WOODBURY	3	.1	10.7
KING - S	WOODBURY	4	.1	14.5
KINGS	ROCHESTER	4	.0	4.3
KINGS HILL	BAKERSFIELD	6	.2	18.7
KIRBY	KIRBY	10	.5	32.6
KNAPP BROOK #1	CAVENDISH	25	3.2	83.0
KNAPP BROOK #2	CAVENDISH	35	2.9	53.4
KNOB HILL	MARSHFIELD	16	.2	8.6
LAIRD	MARSHFIELD	12	4.1	219.8
LAKE-OF-THE-CLOUDS	CAMBRIDGE	1	.0	2.0
LAKOTA	BARNARD	20	.6	19.3
LAMSON	BROOKFIELD	24	.4	9.6
LANDFILL;	EDEN	7	.1	4.9
LANPHER MEADOW	EDEN	6	.7	70.5
LAUREL	WHITINGHAM	16	.1	4.8
LEECH	WOODBURY	4	.2	33.5
LEFFERTS	CHITTENDEN	55	6.0	69.3
LEIGHTON HILL;	NEWBURY	6	.3	35.5
LEVI	GROTON	22	.3	8.1
LEWIN	NORWICH	4	.0	6.0
LEWIS	LEWIS	64	2.0	19.6
LIGHT TROUT CLUB	MORETOWN	7	3.4	310.4
LILY (ATHENS)	ATHENS	12	.2	13.3
LILY (CAS)	CASTLETON	9	.1	7.8
LILY (LON)	LONDONDERRY	21	.5	14.1
LILY (LYN)	LYNDON	8	.0	3.3
LILY (NORWICH)	NORWICH	6	.1	9.5
LILY (POUL)	POULTNEY	21	2.0	61.3
LILY (THET);	THETFORD	19	.4	14.9
LILY (VERNON)	VERNON	41	.7	11.3
LILY PAD	COLCHESTER	2	.1	38.0
LIMEHURST	WILLIAMSTOWN	13	.9	45.9
LINE (BARNARD)	BARNARD	10	.2	11.0

Lake	Town	Lake Area (acres)	Basin Area (square miles)	Basin Area / Lake Area Ratio (acres/acres)
LINE (HOL)	HOLLAND	5	.2	23.0
LITTLE (CALAIS)	CALAIS	7	.4	32.9
LITTLE (ELM)	ELMORE	14	.2	7.3
LITTLE (FRANK)	FRANKLIN	95	.9	6.2
LITTLE (WELLS)	WELLS	172	14.0	52.3
LITTLE (WIN)	WINHALL	18	.2	7.3
LITTLE (WOOD)	WOODFORD	16	.5	20.4
LITTLE AVERILL	AVERILL	483	4.5	5.9
LITTLE ELIGO	HARDWICK	15	1.0	43.5
LITTLE ELMORE	ELMORE	24	.5	13.2
LITTLE HOSMER	CRAFTSBURY	183	2.8	9.8
LITTLE MUD (GRANBY)	GRANBY	2	.0	1.5
LITTLE MUD (MT. TAB)	MT. TABOR	7	.7	62.1
LITTLE MUD (WIN)	WINHALL	4	.1	20.8
LITTLE MUD (WOOD)	WOODBURY	10	.3	16.0
LITTLE ROCK	WALLINGFORD	18	.3	10.9
LITTLE WHEELER	BRUNSWICK	9	6.6	469.3
LOCKWOOD	LOWELL	1	.1	38.0
LONG (EDEN)	EDEN	93	1.1	7.8
LONG (GREENS)	GREENSBORO	97	3.0	19.7
LONG (MILTON)	MILTON	47	.7	9.2
LONG (NEWBURY)	NEWBURY	15	.4	16.1
LONG (SHEF)	SHEFFIELD	38	.3	5.4
LONG (WEST)	WESTMORE	103	1.1	7.1
LONG HOLE	PERU	18	3.2	114.1
LONG MEADOW;	CALAIS	7	.3	25.1
LOST (BELV)	BELVIDERE	3	.1	16.3
LOST (GEORGIA)	GEORGIA	10	.2	11.4
LOST (GLASTEN)	GLASTENBURY	1	.1	68.0
LOST (SUND)	SUNDERLAND	2	.5	149.5
LOVES MARSH	CASTLETON	62	1.8	18.7
LOWELL	LONDONDERRY	102	2.1	12.9
LOWER	HINESBURG	61	5.4	56.7
LOWER HURRICANE	HARTFORD	7	.2	15.0
LOWER SYMES	RYEGATE	57	4.1	46.2
LOWER WINOOSKI;	COLCHESTER	4	.3	48.8
LYE BROOK - N;	SUNDERLAND	10	.2	9.6
LYE BROOK - S;	SUNDERLAND	18	.4	14.1
LYFORD	WALDEN	33	.5	9.1
LYMAN HILL;	MARLBORO	9	.6	45.7
MACKVILLE	HARDWICK	11	3.3	190.8
MADELEINE	SANDGATE	20	.2	5.0
MAIDSTONE	MAIDSTONE	796	4.8	3.9
MANCHESTERS;	THETFORD	6	.3	37.2
MANSFIELD	STOWE	35	2.4	44.5
MARL	SUTTON	10	.4	25.6
MARLBORO - 431;	MARLBORO	10	2.6	169.3
MARSHFIELD	MARSHFIELD	65	5.8	57.0
MARTIN;	WILLIAMSTOWN	28	1.4	31.6
MARTINS	PEACHAM	77	1.3	10.4
MAY	BARTON	116	1.7	9.4
MCALLISTER	LOWELL	25	.8	21.3

Lake	Town	Lake Area (acres)	Basin Area (square miles)	Basin Area / Lake Area Ratio (acres/acres)
MCCONNELL	BRIGHTON	89	5.7	40.7
MCGOWAN - E;	HIGHGATE	18	1.1	39.6
MCGOWAN - W;	HIGHGATE	10	.4	25.2
MCINTOSH	ROYALTON	23	.9	26.3
MECAWEE	READING	11	1.3	77.5
METCALF	FLETCHER	71	1.3	11.3
MIDDLE WOODBURY;	WOODBURY	9	1.6	110.2
MILE	FERDINAND	26	.2	6.0
MILES	CONCORD	206	6.5	20.2
MILL (BENSON)	BENSON	39	22.0	360.6
MILL (WOOD)	WOODFORD	7	1.5	141.1
MILLER	STRAFFORD	63	1.0	10.5
MILLER;	ARLINGTON	11	5.7	330.5
MILTON	MILTON	24	.4	11.1
MINARDS	ROCKINGHAM	46	.3	4.4
MINSEY;	ALBANY	8	.2	14.4
MIRROR	CALAIS	86	5.2	38.9
MITCHELL	SHARON	28	7.3	166.1
MOLLYS	CABOT	38	2.1	34.7
MOLLYS FALLS	CABOT	411	22.8	35.5
MOORE - L	PLYMOUTH	5	.4	47.6
MOORE - U	PLYMOUTH	3	.3	67.7
MOOSE;	MORGAN	10	1.5	94.1
MOREY	FAIRLEE	538	8.0	9.5
MOSCOW	HUBBARDTON	3	.2	37.0
MOSES	WESTON	12	.1	5.3
MUD (BENSON)	BENSON	8	.2	16.1
MUD (BRAIN)	BRAINTREE	10	1.1	68.1
MUD (BRIGHTON - E)	BRIGHTON	4	.0	4.8
MUD (BRIGHTON - W)	BRIGHTON	6	.0	3.2
MUD (BRUNS)	BRUNSWICK	5	.5	64.0
MUD (CHARLES)	CHARLESTON	4	.6	89.0
MUD (CRAFT)	CRAFTSBURY	35	.7	12.1
MUD (EAST HAVEN)	EAST HAVEN	5	.1	9.0
MUD (EDEN - N)	LOWELL	2	.0	13.0
MUD (EDEN - S)	EDEN	1	.1	38.0
MUD (GRANBY)	GRANBY	55	3.3	38.7
MUD (GREENS - NE)	GREENSBORO	9	2.1	150.8
MUD (GREENS - SW)	GREENSBORO	5	.1	14.0
MUD (HOL)	HOLLAND	14	.6	25.6
MUD (HYDE PARK)	HYDE PARK	14	.3	12.6
MUD (IRA)	IRASBURG	5	.4	48.6
MUD (LEICESTER)	LEICESTER	23	.5	12.6
MUD (MORGAN - N)	MORGAN	35	1.9	34.4
MUD (MORGAN - W)	MORGAN	11	1.7	101.3
MUD (ORWELL)	ORWELL	10	.2	10.6
MUD (PEACHAM)	PEACHAM	34	.5	9.4
MUD (PERU)	PERU	10	.6	37.1
MUD (SHEF)	SHEFFIELD	5	.1	11.6
MUD (STAM)	WOODFORD	6	.0	3.8
MUD (THET)	THETFORD	20	.7	21.9
MUD (WESTMORE)	WESTMORE	9	.8	59.0

Lake	Town	Lake Area (acres)	Basin Area (square miles)	Basin Area / Lake Area Ratio (acres/acres)
MUD (WOOD - E)	WOODBURY	10	.3	16.8
MUD (WOOD - N)	WOODBURY	16	.1	4.4
MUD (WOOD - SE)	WOODBURY	18	.3	11.3
MUD CREEK	ALBURG	318	10.0	20.1
MUDD	HUBBARDTON	20	1.0	30.4
MUDDY (NEWBURY)	NEWBURY	3	.2	50.7
MUDDY (RUTLAND)	RUTLAND	10	.7	44.8
N.E. DEVELOPERS	WELLS	27	.7	15.4
NEAL	LUNENBURG	182	8.9	31.4
NELSON (E. MONT)	EAST MONTPELIER	10	.2	15.6
NEWARK	NEWARK	163	.9	3.4
NICHOLS	WOODBURY	167	4.6	17.5
NINEVAH	MT. HOLLY	237	1.2	3.2
NORFORD	THETFORD	21	.9	28.8
NORTH (BRISTOL)	BRISTOL	6	.1	5.5
NORTH (BROOK)	BROOKFIELD	24	1.3	34.5
NORTH (CHIT)	CHITTENDEN	3	.1	11.7
NORTH (WHITING)	WHITINGHAM	20	.4	11.5
NORTH UNDERHILL;	UNDERHILL	12	1.8	93.6
NORTON	NORTON	583	17.4	19.1
NOTCH	FERDINAND	22	.8	22.7
NOYES	GROTON	39	3.8	61.7
NULHEGAN	BRIGHTON	37	8.5	146.5
NUMBER ELEVEN;	WESTFORD	12	.5	25.0
OAK HILL;	WILLISTON	8	2.4	191.8
OLD MARSH	FAIR HAVEN	123	2.8	14.7
OLYMPUS POOL	PROCTOR	3	.2	32.0
OSMORE	PEACHAM	48	1.2	16.2
OXBOW;	SWANTON	27	.3	7.0
PAGE	ALBANY	16	.2	6.6
PARAN	BENNINGTON	40	14.6	232.8
PARKER	GLOVER	239	8.5	22.7
PAUL STREAM	BRUNSWICK	20	.2	7.6
PEACHAM	PEACHAM	331	5.9	11.3
PECKS	BARRE	16	.7	27.7
PERCH (BENSON)	BENSON	24	.2	4.6
PERCH (WOLCOTT)	WOLCOTT	7	1.4	128.9
PHILLIPS	WESTFIELD	4	.1	19.3
PICKEREL	MANCHESTER	9	.0	3.4
PICKETT	WOODBURY	5	.7	83.2
PICKLES	BROOKFIELD	17	.4	15.8
PICO	SHERBURNE	12	.9	48.4
PIGEON	GROTON	72	1.3	11.1
PINE	CASTLETON	40	1.2	19.4
PINNACLE;	WELLS	6	.3	27.2
PINNEO	HARTFORD	50	.2	3.0
PLEASANT VALLEY	BRATTLEBORO	25	1.0	26.0
PLEIAD	HANCOCK	6	.1	9.0
POTTERS	ALBANY	5	.2	25.8
PRENTISS	DORSET	5	.3	41.4
PRESTON	BOLTON	9	.3	22.9
PROPER	HIGHGATE	9	.2	17.4

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QUARRY	WEATHERSFIELD	1	.0	15.0
QUARRY;	CASTLETON	17	.1	5.1
RANDOLPH - N;	RANDOLPH	10	.2	11.7
RAPONDA	WILMINGTON	116	1.0	5.3
READING	READING	22	1.0	30.1
RED MILL	WOODFORD	7	2.0	179.7
RESCUE	LUDLOW	180	35.7	127.0
REYNOLDS	PROCTOR	3	.1	28.7
RICE;	SUTTON	3	.2	51.3
RICHARDS;	MARSHFIELD	14	1.1	50.3
RICHMOND	RICHMOND	24	.8	22.5
RICHVILLE	SHOREHAM	124	28.0	144.5
RICKER	GROTON	92	21.3	148.1
RIDDEL	ORANGE	15	2.0	86.3
RIPTON - NW;	RIPTON	8	.6	44.0
RITTERBUSH	EDEN	14	.6	26.6
RITTERBUSH MEADOW;	EDEN	10	1.4	92.1
ROACH	HUBBARDTON	20	.2	7.3
ROBINSON;	NORTHFIELD	7	4.0	364.7
ROCKY	RUTLAND	8	.1	9.3
ROOD	WILLIAMSTOWN	23	.5	14.9
ROOT	BENSON	18	.9	32.1
ROUND (EDEN)	EDEN	10	.2	9.8
ROUND (HOL)	HOLLAND	14	.2	7.3
ROUND (MILTON)	MILTON	22	.2	5.3
ROUND (NEWBURY)	NEWBURY	30	.4	8.7
ROUND (SHEF)	SHEFFIELD	13	.2	11.8
ROWE;	WEST WINDSOR	7	.4	37.6
ROXBURY FLAT;	ROXBURY	13	2.8	138.9
ROYALTON HILL;	ROYALTON	11	.3	18.1
RUNNEMEDE	WINDSOR	53	.2	2.5
RUSH	EDEN	14	.2	9.4
RUSS	ELMORE	7	.1	8.4
RUTLAND CITY	RUTLAND	13	.1	3.8
RYDER	WHITINGHAM	14	.2	8.2
RYEGATE CENTER;	RYEGATE	7	.3	26.7
SABIN	CALAIS	142	14.1	63.5
SADAWGA	WHITINGHAM	194	1.8	6.0
SALMON;	PUTNEY	6	.7	77.3
SARAH MOORES	BARNET	13	.5	22.2
SARGENT	COVENTRY	6	2.0	217.7
SAWDUST	NEWARK	15	4.3	183.4
SAXE;	HIGHGATE	5	.5	70.0
SCHOFIELD	HYDE PARK	29	1.5	32.3
SEARSBURG	SEARSBURG	25	.2	3.9
SEYMOUR	MORGAN	1777	20.2	7.3
SHADOW (CONC)	CONCORD	114	2.6	14.5
SHADOW (GLOV)	GLOVER	199	5.6	18.0
SHADOW (WOOD)	WOODBURY	2	.2	57.5
SHAFTSBURY	SHAFTSBURY	27	3.6	85.6
SHARON - E;	SHARON	8	.5	38.0
SHAWVILLE;	HIGHGATE	11	.5	26.2

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SHELBURNE	SHELBURNE	450	7.7	10.9
SHELDON;	FAIR HAVEN	2	.2	62.0
SHIPPEE	WHITINGHAM	24	.6	15.3
SILVER (BAR)	BARNARD	84	1.7	13.0
SILVER (GEORGIA)	GEORGIA	27	.2	4.7
SILVER (LEICESTER)	LEICESTER	103	.6	4.0
SIMPSONVILLE;	TOWNSHEND	12	.7	36.1
SKYLIGHT	RIPTON	2	.0	10.5
SLAYTON (WOOD)	WOODBURY	8	.3	20.8
SMITH (COV)	COVENTRY	8	.2	17.6
SMITH (PITT)	PITTSFORD	6	.1	9.5
SMITH (WOOD)	WOODBURY	4	.1	22.5
SODOM	EAST MONTPELIER	21	2.9	88.1
SOMERSET	SOMERSET	1597	30.0	12.0
SOUTH (BROOK)	BROOKFIELD	16	.6	22.8
SOUTH (CHIT)	CHITTENDEN	10	.4	25.4
SOUTH (EDEN)	EDEN	109	2.2	12.7
SOUTH (MARL)	MARLBORO	68	.5	5.1
SOUTH AMERICA	FERDINAND	29	.8	17.6
SOUTH READING;	READING	12	1.0	53.7
SOUTH RICHFORD;	RICHFORD	12	.5	24.6
SOUTH STREAM	POWNAL	24	5.4	144.0
SOUTH VILLAGE	DORSET	5	.1	17.0
SOUTH WOODBURY;	WOODBURY	6	3.1	331.7
SPECTACLE	BRIGHTON	102	1.6	10.0
SPOONERVILLE;	CHESTER	8	.2	19.3
SPRING (BRANDON)	BRANDON	5	.1	17.2
SPRING (SHREWS)	SHREWSBURY	64	.4	4.3
SPRINGFIELD	WEATHERSFIELD	10	2.7	169.6
SPRUCE (ORWELL)	ORWELL	25	.4	11.3
ST. ALBANS - N	FAIRFAX	35	1.6	29.6
ST. ALBANS - S	FAIRFAX	27	2.1	49.9
ST. CATHERINE	WELLS	852	11.6	8.7
STAMFORD	STAMFORD	12	.4	21.7
STANDING	SHARON	15	.1	5.1
STANNARD	STANNARD	25	.2	5.0
STAPLES	WILLIAMSTOWN	15	.5	21.7
STAR	MT. HOLLY	56	1.1	12.7
STERLING	CAMBRIDGE	8	.0	2.1
STEVENS	MAIDSTONE	26	.3	6.8
STILES	WATERFORD	146	6.1	26.6
STOUGHTON	WEATHERSFIELD	65	30.1	296.3
STRAFFORD;	STRAFFORD	18	.3	11.6
STRATTON	STRATTON	46	.4	5.8
STUART	LYNDON	4	.2	28.8
SUGAR HILL	GOSHEN	60	2.6	27.8
SUGAR HOLLOW	PITTSFORD	21	.4	13.2
SUKES	BRIGHTON	9	.1	6.4
SUNRISE	BENSON	52	2.8	34.1
SUNSET (BENSON)	BENSON	195	1.9	6.1
SUNSET (BROOK)	BROOKFIELD	25	4.2	106.6
SUNSET (MARL)	MARLBORO	95	.8	5.7

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SWAMP	LEICESTER	5	.0	5.8
SWEENEY	GLOVER	9	.1	7.8
SWEET	GUILFORD	20	1.1	34.1
TABOR	CALAIS	5	.0	1.2
TELEPHONE;	CHESTER	15	.5	23.3
TENNY	NEWBURY	10	.2	14.4
THE FISH	NEWBURY	6	.6	63.3
THE POGUE	WOODSTOCK	11	.1	7.3
THOMPSONS	POWNAL	28	.9	19.6
THURMAN W. DIX	ORANGE	119	9.4	50.3
TICKLENAKED	RYEGATE	48	2.3	30.1
TILDYS	GLOVER	33	1.7	32.7
TINY	LUDLOW	29	1.0	21.2
TOAD (CHARLES)	CHARLESTON	22	3.4	98.5
TOAD (MORGAN)	MORGAN	12	.9	48.0
TROUT BROOK;	BERKSHIRE	5	1.8	226.8
TUNBRIDGE TROUT	TUNBRIDGE	5	.4	45.8
TURTLE	HOLLAND	27	1.9	45.5
TUTTLE (BRUN)	BRUNSWICK	14	.3	12.6
TUTTLE (HARD)	HARDWICK	21	.5	16.3
TWIN	BROOKFIELD	16	.7	27.4
TWIN - E	ATHENS	3	.0	5.0
TWIN - W	ATHENS	1	.0	1.0
UNDERPASS	MORGAN	3	.5	104.7
UNKNOWN (AV GORE)	AVERYS GORE	19	.4	13.8
UNKNOWN (FERD)	FERDINAND	12	.3	15.5
UPPER DANVILLE;	DANVILLE	19	.4	13.3
UPPER HURRICANE	HARTFORD	4	.1	19.0
UPPER SYMES	RYEGATE	20	3.2	101.8
UPPER WINOOSKI;	COLCHESTER	10	.3	17.6
VAIL	SUTTON	16	.2	8.9
VALLEY	WOODBURY	83	.7	5.7
VERGENNES WATERSHED	BRISTOL	15	.2	6.7
VERSHIRE - E;	VERSHIRE	10	1.0	60.8
VIEW	WOODSTOCK	4	.3	54.0
VONDELL	WOODSTOCK	10	.6	40.5
WAITS;	TOPSHAM	6	1.0	110.0
WALDEN - S;	WALDEN	8	.1	11.3
WALKER (COV)	COVENTRY	18	.3	11.3
WALKER (HUB)	HUBBARDTON	13	.5	24.0
WALKER (NEWARK)	NEWARK	3	.1	15.0
WALLACE	CANAAN	532	30.3	36.4
WALLINGFORD	WALLINGFORD	86	2.3	17.1
WALTON	WOODBURY	13	.2	9.8
WANTASTIQUET	WESTON	44	1.9	27.3
WAPANACKI	WOLCOTT	21	.4	13.6
WARDEN	BARNET	46	1.7	23.6
WATERFORD - E;	WATERFORD	5	.3	39.0
WATSON	CALAIS	11	.2	9.3
WEATHERHEAD HOLLOW	GUILFORD	33	1.0	18.8
WEAVER;	GRAFTON	12	.5	27.8
WEST FAIRLEE;	WEST FAIRLEE	15	9.3	397.1

Lake	Town	Lake Area (acres)	Basin Area (square miles)	Basin Area / Lake Area Ratio (acres/acres)
WEST HILL	CABOT	46	2.3	32.1
WEST MOUNTAIN	MAIDSTONE	62	3.6	37.3
WESTFORD	WESTFORD	9	.5	37.6
WESTMINSTER - E;	WESTMINSTER	16	.1	3.8
WESTMINSTER - W;	WESTMINSTER	8	1.8	140.1
WHEELER (BART)	BARTON	15	1.2	49.5
WHEELER (BRUN)	BRUNSWICK	70	6.5	59.4
WHEELER (WOOD)	WOODBURY	4	.1	16.0
WHEELOCK	CALAIS	4	.2	32.0
WHITEHOUSE	VERSHIRE	5	.0	5.8
WILLIAMSTOWN - NE;	WILLIAMSTOWN	7	.2	15.1
WILLOUGHBY	WESTMORE	1653	19.2	7.4
WINONA	BRISTOL	234	4.0	11.0
WOLCOTT	WOLCOTT	68	1.4	13.5
WOODWARD	PLYMOUTH	105	2.9	17.9
WORCESTER - L	WORCESTER	35	1.5	26.9
WORCESTER - U	WORCESTER	11	.9	52.8
WRIGHT	HARTFORD	4	.1	13.3
ZACK WOODS	HYDE PARK	23	.1	1.6

APPENDIX D

The following facilities are already required to provide phosphorus removal and will be required to meet a reduced limit of 0.80 mg/L in a 1272 Order:

Barton
Burlington, Main
Burlington, North End
Burlington, Riverside
Colchester
Essex Junction
Hinesburg
Newport City
Orleans
St. Albans
Shelburne FD#1
Shelburne FD#2
So. Burlington, Airport Parkway
So. Burlington, Bartletts Bay
Stowe
Swanton
Vergennes
Winooski

The following facilities are not currently required to remove P. They will be put on a compliance schedule upon permit renewal to meet 0.80 mg/L limit 3 years from the 1272 Order issuance date:

Barre City
Brandon
Castleton
Enosburg
Fair Haven
Johnson
Middlebury
Montpelier
Morrisville
Northfield
Poultney
Richmond
Rutland City
West Rutland

The municipal direct discharging facilities which are not contained in either list will not be required to remove P at this time.

APPENDIX E

Draft Phosphorus Implementation Statutes

Section 1

The Secretary of the Agency of Natural Resources is directed to carry out the Phosphorus Reduction Plan dated ______________ and submitted in accord with Act 88 of the Acts of 1989.

Section 2

Adds a new 10 V.S.A., §1625(e) to read:

(e) Any municipality required to install phosphorus removal equipment and facilities pursuant to an order of the secretary, and where such equipment and facilities are required to produce an effluent total phosphorus concentration not exceeding 0.80 mg/L on a monthly average basis shall be eligible to receive a state grant of 25 percent and a state loan in an amount of 65 percent of the project cost which loan shall be awarded pursuant to 24 V.S.A., Chapter 120.

Section 3

Amend 10 V.S.A., §1266(a) to read:

[As soon as possible, but not later than July 1, 1985 no person discharging into Lake Champlain, or to other waters of the state which are designated by the secretary through adoption of a river basin water quality management plan under 33 U.S.C., Sections 1288 or 1313(e), shall discharge any waste into these waters when the wastes contain a phosphorus concentration in excess of 1 milligram per liter.]

(a) Persons directly discharging waste tributary to Lake Champlain or Lake Memphremagog as of the effective date of this act, in permitted volumes equal to or exceeding 200,000 gallons per day shall reduce the effluent phosphorus concentration of such discharges to a monthly average value of 0.80 milligrams per liter or less.

(b) All new direct discharges within the drainage basins of Lake Champlain or Lake Memphremagog which are awarded permits pursuant to 10 V.S.A., Chapter 47 after the effective date of this act shall remove effluent phosphorus to a monthly average concentration not exceeding 0.80 milligrams per liter.

(c) Notwithstanding subsections a) and b) of this section, the secretary may order any person who directly discharges waste to surface waters of the state to remove phosphorus to an effluent concentration which in the secretary's determination is necessary to meet water quality standards.

(d) Municipalities operating aerated lagoon type secondary sewage treatment plants shall not be subject to requirements of subsection a) of this section.

Section 4

Discharge prohibition to small lakes.

Adds a new subsection (f) under 10 V.S.A., Chapter 47, Section 1259 between the existing subsections (e) and (f):

(f) No person shall cause a new or increased direct discharge of wastes containing phosphorus above a trace amount, as determined by the secretary of the agency, into any lake having a drainage basin area less than 40 square miles and a drainage area to surface area ratio less than 500, or to any tributary of such a lake.