Total Maximum Daily Loads of Phosphorus for Selected French Basin Lakes

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Front Cover

Photograph of Rochdale Pond in Leicester.

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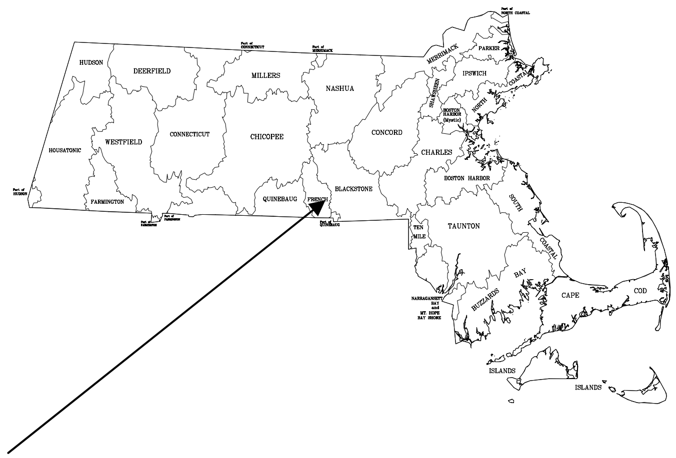

Location of French Basin in Massachusetts.

Key Feature: TMDL assessment of Total Phosphorus for 22 lakes in the French Basin Watershed. NPDES discharge permits for MA0101796 and MA0100170.

Locations: Buffumville Lake (MA42005), Charlton; Cedar Meadow Pond (MA42009), Leicester; Dresser Hill Pond (MA42014) Charlton; Dutton Pond (MA42015), Leicester; Gore Pond (MA42018), Charlton/Dudley; Granite Reservoir (MA42019) Charlton; Greenville Pond (MA42023), Leicester; Hudson Pond (MA42029), Oxford; Jones Pond (MA42030), Charlton/Spencer; Larner Pond (MA42068), Dudley; Lowes Pond (MA42034), Oxford; McKinstry Pond (MA42035), Oxford; New Pond (MA42037), Dudley; Peter Pond (MA42042), Dudley; Pierpoint Meadow Pond (MA42043), Dudley/Charlton; Pikes Pond (MA42043), Charlton; Robinson Pond (MA42047), Oxford; Rochdale Pond (MA42048), Leicester; Shepherd Pond (MA42051), Dudley; Texas Pond (MA42058), Oxford; Mosquito (Tobins) Pond (MA42060), Dudley; and Wallis Pond (MA42062), Dudley, Massachusetts.

Land Type: New England Upland

Pollutants: Twenty-two total phosphorus TMDLs (26 total TMDL stressors)

Data Sources: Synoptic and Baseline lake surveys, Land use information.

Data Mechanisms: NPSLAKE model, Reckhow model, Best Professional Judgment

Monitoring Plan: Massachusetts Watershed Initiative Five-Year Cycle.

Control Measures: NPDES permit limits, Watershed Management, Septic system maintenance, Macrophyte Management.

Executive Summary

The Massachusetts Department of Environmental Protection (DEP) is responsible for monitoring the waters of the Commonwealth, identifying those waters that are impaired, and developing a plan to bring them back into compliance with the Massachusetts Surface Water Quality Standards. The list of impaired waters, better known as the "303d list" identifies river, lake, and coastal waters and the reason for impairment.

Once a water body is identified as impaired, DEP is required by the Federal Clean Water Act to essentially develop a "pollution budget" designed to restore the health of the impaired body of water. The process of developing this budget, generally referred to as a Total Maximum Daily Load (TMDL), includes identifying the source(s) of the pollutant from direct discharges (point sources) and indirect discharges (non-point sources), determining the maximum amount of the pollutant that can be discharged to a specific water body to meet water quality standards, and developing a plan to meet that goal.

This report represents a TMDL for a group of lakes (see table below) in the French River Watershed. The lakes are listed on the state 1998 "303d" list for a variety of pollutants and stressors including low dissolved oxygen, turbidity, nutrients, and an over-abundance of nuisance aquatic plants. All of the pollutants and stressors are indicators of nutrient enriched systems, better known as the process of eutrophication. In freshwater systems the primary nutrient known to accelerate eutrophication is phosphorus. Therefore, in order to prevent further degradation in water quality and to ensure that each lake meets state water quality standards, the TMDL establishes a phosphorus limit for each lake and outlines corrective actions to achieve that goal.

In some cases, while the existing concentrations of phosphorus in the lake may be low enough already to achieve water quality standards, other actions (such as in-lake management activities) are necessary to eliminate noxious aquatic plants and to ensure that the condition does not get worse. In these cases a protective phosphorus load was established. Even when a water body is not listed for nutrients, because of the inter-relationship of the cause and effects of the pollutants and response variables, it is a prudent policy to be conservative when determining loading allocations and planning management strategies. When available, in-lake data used for this analysis were collected by DEP and combined with a landuse based phosphorus export model called NPSLAKE developed by Dr. Mark Mattson and Dr. Russell Isaac of DEP (1999).

The following table lists the lakes that were evaluated, their predicted total phosphorus concentration and load using the landuse model, the selected target phosphorus concentration and loads necessary to achieve surface water quality standards.

WBID	Lake Name	NPSLAKE Predicted TP (ppb)	NPSLAKE Predicted Load (kg/yr)	Selected Target TP (ppb)	Selected Target Load (kg/yr)
MA42005	Buffumville Lake	21.8	1253	15	862
MA42009	Cedar Meadow Pond	18.8	244	15	193
MA42014	Dresser Hill Pond	231	93.5	35	14
MA42015	Dutton Pond	64	452	35	248
MA42018	Gore Pond	21.2	160	14	106
MA42019	Granite Reservoir	18	440	15	369
MA42023	Greenville Pond	31.5	929	25	737
MA42029	Hudson Pond	26.4	42	15	24
MA42030	Jones Pond	18.6	80	15	64
MA42068	Larner Pond	33.5	260	14	108
MA42034	Lowes Pond	30.8	460	15	212
MA42035	McKinstry Pond	83.8	83	15	15
MA42037	New Pond	27.4	183	14	74
MA42042	Peter Pond	10.2	27	10	27
MA42043	Pierpoint Meadow Pond	21.5	142	14	93
MA42044	Pikes Pond	25.3	366	15	217
MA42047	Robinson Pond	13.8	64	12	56
MA42048	Rochdale Pond	29.5	1155	25	993
MA42051	Shepherd Pond	19.8	158	14	70
MA42058	Texas Pond	33.3	1401	25	1050
MA42060	Tobins Pond	40	196	14	69
MA42062	Wallis Pond	32.7	224	14	96

In four of the lakes, Dutton Pond, Greenville Pond, Rochdale Pond and Texas Pond, implementation will include new NPDES discharge limits on two wastewater treatment plants (Leicester WWTP and Oxford-Rochdale WWTP). New limits are expected to lower the allowed discharge of phosphorus from the current 1 mg/l down to 0.2 mg/l or lower.

In the case of lakes dominated by rooted aquatic plants, watershed nutrient controls alone are not expected to control plant growth; thus additional in-lake plant management programs are recommended. Because of the limited data available on discrete sources of nutrients within a given watershed, a locally organized watershed survey may be recommended to identify and target reductions in nonpoint sources of nutrients and sediments. Recommended implementation is provided in the following table:

Recommended Implementation by Lake

Recommended Implementation	Buffumvillle	Cedar	Dresser Hill	Dutton	Gore	Granite	Greenville	Hudson	Jones	Larner	Lowes	McKinstry	New	Peter	Pierpoint	Pikes	Robinson	Rochdale	Shepherd	Texas	Tobins	Wallis
Public Education	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Watershed Survey	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Lake Management Plan	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Forest BMPs	X					X			X							X	X		X			
Agriculture BMPs			X		X	X		X	X	X			X			X			X		X	X
Residential BMPs	X			X		X	X			X	X	X	X	X	X		X	X			X	X
Septic System Inspection & Maintenance		X			X	X			X						X							
Urban stormwater BMPs		X		X			X				X				X			X				
Highway BMPs	X			X			X				X	X			X	X		X		X		
In-Lake Management			X		X				X	X		X										
Other (Gravel pits, athletic fields, see text)																		X				

In most cases, authority to regulate nonpoint source pollution and thus successful implementation of this TMDL is limited to local government entities and will require cooperative support from local volunteers, lake and watershed associations, and local officials in municipal government. Those activities can take the form of expanded education, obtaining and/or providing funding, and possibly local enforcement. Funding support to aid in implementation of this TMDL is available on a competitive basis under various state programs including the Section 319 Grant Program, the State Revolving Fund Program (SRF), and the Department of Environmental Management's Lakes and Pond Small Grants Program.

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Introduction

Section 303(d) of the Federal Clean Water Act requires each state to (1) identify waters for which effluent limitations normally required are not stringent enough to attain water quality standards and (2) to establish Total Maximum Daily Loads (TMDLs) for such waters for the pollutants of concern. TMDLs may also be applied to waters threatened by excessive pollutant loadings. The TMDL establishes the allowable pollutant loading from all contributing sources at a level necessary to achieve the applicable water quality standards. The TMDLs must account for seasonal variability and include a margin of safety (MOS) to account for uncertainty of how pollutant loadings may impact the receiving water's quality. This report will be submitted to the USEPA as a TMDL under Section 303d of the Federal Clean Water Act, 40 CFR 130.7. After public comment and final approval by the EPA, the TMDL will be incorporated into the watershed action plan to be developed by the Executive Office of Environmental Affairs Basin Team (see below) and serve as a guide for future implementation activities. Where permits for wastewater and other discharges are required, TMDLs will be used by DEP to set appropriate limits.

The Massachusetts Watershed Initiative is a new structure in state government that focuses all branches of government within each watershed to manage environmental issues. The Executive Office of Environmental Affairs (EOEA) has set up Watershed Teams with a Team Leader within each watershed in Massachusetts. The Teams represent state and federal agencies and local community partners. Within each watershed will be created a Watershed Community Council that may consist of watershed associations, business councils, regional planning agencies and other groups. Stream Teams may be created to assess environmental quality, identify local problems and recommend solutions. Stream Teams may include watershed associations, municipal government and business representatives. Additional information and contact information on the Watershed Teams is available on the world wide web at http://www.state.ma.us/envir/watershd.htm.

The proposed Total Maximum Daily Loads (TMDLs) for the French Basin lakes are based on Total Phosphorus loadings estimated from the landuse based NPSLAKE model of Mattson and Isaac (1999). For lakes solely impaired by rooted aquatic macrophytes a preventative total phosphorus TMDL is established to slow the rate of eutrophication; in addition, various plant management options are discussed. For lakes impaired by algae and non-rooted macrophytes (e.g. duckweed) a total phosphorus TMDL is established to meet Massachusetts Surface Water Quality Standards, particularly the 4-foot transparency criterion for public swimming beaches. In many cases the State has limited authority to regulate nonpoint source pollution and thus successful implementation of this TMDL will require cooperative support from the public including lake and watershed associations, local officials and municipal governments in the form of education, funding and local enforcement. Additional funding support is available under various state programs including section 319 (nonpoint source) and the State Revolving Fund Program (SRF) and the Department of Environmental Management's Lakes and Pond grant program.

General Background and Rationale

Nutrient Enrichment: Nutrients are a requirement of life, but in excess can create problems. Lakes are ephemeral features of the landscape and over geological time most tend to fill with sediments and associated nutrients as they make a transition from lake to marsh to dry land. However, this natural successional ("aging") process can be and often is accelerated through the activities of humans—especially through development in the watershed. For highly productive lakes with developed watersheds, it is not easy to separate natural succession from "culturally induced " effects. Nonetheless, all feasible steps should be taken to reduce the impacts from cultural activities. The following discussion summarizes the current understanding of how nutrients influence the growth of algae and macrophytes, the time scale used in the studies, the type of models applied and the data collection methods used to create a nutrient budget. A brief description of the rationale for choosing a target load (the TMDL) as well as a brief discussion of implementation and management options is presented.

A detailed description of the current understanding of limnology (the study of lakes and freshwaters) and management of lakes and reservoirs can be found in Wetzel (1983), Cooke et al., (1993) and Holdren et al., 2001. To prevent cultural enrichment it is important to examine the nutrients required for growth of phytoplankton (algae) and macrophytes. The limiting nutrient is typically the one in shortest supply relative to the nutrient requirements of the plants. The ratio of nitrogen (N) to phosphorus (P) in both algae and macrophyte biomass is typically about 7 by weight or 16 by atomic ratio (Vallentyne, 1974). Examination of relatively high N/P ratios in water suggests P is most often limiting and careful reviews of numerous experimental studies have concluded that phosphorus is a limiting nutrient in most freshwater lakes (Likens, 1972; Schindler and Fee, 1974). Most diagnostic/feasibility studies of Massachusetts lakes also indicate phosphorus as the limiting nutrient. Even in cases where nitrogen may be limiting, previous experience has shown that it is easier, more cost-effective and more ecologically sound to control phosphorus than nitrogen. The reasons include the fact that phosphorus is related to terrestrial sources and does not have a significant atmospheric source as does nitrogen (e.g., nitrates in precipitation). Thus, non-point sources of phosphorus can be managed more effectively by best management practices (BMPs). In addition, phosphorus is relatively easy to control in point source discharges. Finally, phosphorus does not have a gaseous phase, while the atmosphere is a nearly limitless source of nitrogen gas which can be fixed by some types of phytoplankton (the blue-greens, or cyanobacteria) even in the absence of other sources of nitrogen. For all of the reasons noted above, phosphorus is chosen as the critical element to control freshwater eutrophication, particularly for algal dominated lakes or in lakes threatened with excessive nutrient loading.

There is a direct link between phosphorus loading and algal biomass (expressed as chlorophyll a) in algae dominated lakes (Vollenweider, 1976). The situation is more complex in macrophyte dominated lakes where the rooted aquatic macrophytes may obtain most of the required nutrients from the sediments. In organic, nutrient rich sediments, the plants may be limited more by light or physical constraints such as water movement than by nutrients. In such cases, it is difficult to separate the effects of sediment deposition, which reduce depth and extend the littoral zone, from the effects of increased nutrients, especially phosphorus, associated with the sediments. In Massachusetts, high densities of aquatic macrophytes are typically limited to depths less than ten feet and to lakes where organic rich sediments are found (Mattson et al., 1998). Thus, the response of rooted macrophytes to reductions in nutrients in the overlying water will be much weaker and much slower than the response of algae or non-rooted macrophytes, which rely on the water for their nutrients. In algal or non-rooted macrophyte dominated systems nutrient reduction in the water column can be expected to control growth with a lag time related to the hydraulic flushing rate of the system. In lakes dominated by rooted macrophytes, additional, direct control measures such as harvesting, herbicides or drawdowns will be required to realize reductions in plant biomass on a reasonably short time scale. In both cases, however, nutrient control is essential since any reduction in one component (either rooted macrophytes or phytoplankton) may result in a proportionate increase in the other due to the relaxation of competition for light and nutrients. In addition, it is critical to establish a Total Maximum Daily Load so that future development around the lake will not impair water quality. It is far easier to prevent nutrients from causing eutrophication than to attempt to restore a eutrophic lake. The first step in nutrient control is to calculate the current nutrient loading rate or nutrient budget for the lake.

Nutrient budgets: Nutrient budgets and loading rates in lakes are determined on a yearly basis because lakes tend to accumulate nutrients as well as algal and macrophyte biomass over long time periods compared to rivers, which constantly flush components downstream. In cases of short retention time (less than 14 days) reservoirs, nutrient budgets may be developed on a shorter time scale (e.g. monthly budgets from waste water treatment plants) but the units are expressed on a per year basis in order to be comparable to nonpoint sources estimated from landuse models. Nutrients in lakes can be released from the sediments into the bottom waters during the winter and summer and circulated to the surface during mixing events (typically fall and spring in deep lakes and also during the summer in shallow lakes). Nutrients stored in shallow lake sediments can also be directly used by rooted macrophytes during the growing season. In Massachusetts lakes, peak algal production, or blooms may begin in the spring and continue during the summer and fall while macrophyte biomass peaks in late summer. The impairment of uses is usually not severe until summer when macrophyte biomass reaches the surface of the water interfering with boating and swimming. Also, at this time of year the high daytime primary production and high nighttime respiration can cause large fluctuations in dissolved oxygen. In addition, oxygen is less soluble in warm water of summer as compared to other times of the year. The combination of these factors can drive oxygen to low levels during the summer and may cause fish kills. For these reasons the critical period for use impairment is during the summer, yet the modeling is done on a yearly basis.

There are three basic approaches to estimating current nutrient loading rates: the measured mass balance approach; the landuse export modeling approach; and modeling based on the observed in-lake concentration. The measured mass balance approach requires frequent measurements of all fluvial inputs to the lake in terms of flow rates and phosphorus concentrations. The yearly loading is the product of flow (liters per year) times concentration (mg/l), summed over all sources (i.e., all streams and other inputs) and expressed as kg/year. The landuse export approach assumes phosphorus is exported from various land areas at a rate dependent on the type of landuse. The yearly loading is the sum of the product of landuse area (Ha) times the export coefficient (in kg/Ha/yr). Using a model of in-lake phosphorus concentrations is a indirect method of estimating loading and does not provide information on the sources of input but can be used in conjunction with other methods to validate results. The mass balance method is generally considered to be more accurate, but also more time consuming and more costly due to the field sampling and analysis. For this reason, the mass balance results are used whenever possible. If a previous diagnostic/ feasibility study or mass balance budget is not available, then a landuse export model, such as Reckhow et al., (1980) or the NPSLAKE model (Mattson and Isaac, 1999) can be used to estimate nutrient loading.

Individual point sources phosphorus loadings are estimated from the most recent National Pollutant Discharge Elimination System (NPDES) data reported in the Discharge Monitoring Reports (DMRs) for the site. In many cases the permits are written with more stringent permit requirements during the non-winter months when both use and impairments are greatest. Generally, the impoundments downstream of NPDES discharges have short residence times and thus April-October data are used to compute total phosphorus loads based on actual measured flow times concentrations. If the discharge is immediately to a lake via a pipe, channel or short stream segment, then no phosphorus uptake is assumed. That is, the lake is assumed to receive 100 percent of the discharge. For lakes or reservoirs located further downstream, retention in each lake is calculated and in some cases, uptake or other retention by plants is calculated based on best available information from previous research on the pond. Thus, the TMDL reflects the amount of phosphorus which is predicted to actually reach the lake in question.

Target Load: Once the current nutrient loading rate is established, a new, lower rate of nutrient loading must be established which will meet surface water quality standards for the lake. This target load or TMDL, can be set in a variety of ways. Usually a target concentration in the lake is established and the new load must be reduced to achieve the lower concentration. This target nutrient concentration may be established by a water quality model that relates phosphorus concentrations to water quality required to maintain designated uses or specific water quality standards, such as the four-foot transparency criterion at Massachusetts swimming beaches. Alternatively, the target concentration may be set based on concentrations observed in background reference lakes for similar lake types or from concentration ranges found in lakes within the same ecological region (or sub-ecoregion). In cases of impoundments or lakes with rapid flushing times (e.g., less than 14 days), somewhat higher phosphorus targets may be used because the planktonic algae are rapidly flushed out of the system and do not have time to grow to nuisance conditions in the lake.

Various models (equations) have been used for predicting productivity or lake total phosphorus concentrations in lakes from analysis of phosphorus loads. These models typically take into consideration the waterbody’s hydraulic loading rate and some factor to account for settling and storage of phosphorus in the lake sediments. Among the more well known metrics are those of Vollenweider (1975), Dillon-Rigler (1974) and Reckhow (1979). The TMDL must account for the uncertainty in the estimates of the phosphorus loads from the sources identified above by including a “margin of safety”. The margin of safety can be specifically included, and/or included in the selection of a conservative phosphorus target, and/or included as part of conservative assumptions used to develop the TMDL.

After the target TMDL has been established, the allowed loading of nutrients is apportioned to various sources that may include point sources as well as private septic systems and various land uses within the watershed. In Massachusetts, few lakes receive direct point source discharges of nutrients. In cases where point sources exist upstream of a lake or impoundment, the point source will in most cases be targeted for a large percentage reduction in total phosphorus loading. The current loads for NPDES point sources are calculated based on current DMR data, not on the permitted discharge loading. New discharge limits at the treatment plant may be computed based on the percent reduction of current loads estimated by DMR reports. The new permitted concentrations of total phosphorus can then calculated based on total mass loading divided by permitted flow rate for the discharge.

In some cases the impairment issues include ammonia toxicity, BOD and suspended solids loadings which may require more extensive modeling (Qual2 or HPSF) which is beyond the scope of this report. The nutrient source analysis generally will be related to landuse that reflects the extent of development in the watershed. This effort can be facilitated by the use of geographic information systems (GIS) digital maps of the area that can summarize landuse categories within the watershed. The targeted reductions must be reasonable given the reductions possible with the best available technology and Best Management Practices (BMPs). The first scenario for allocating loads will be based on what is practicable and feasible for each activity and/or landuse to make the effort as equitable as possible.

Implementation: The implementation plan or watershed management plan to achieve the TMDL will vary from lake to lake depending on the type and degree of development. While the impacts from development cannot be completely eliminated, they can be minimized by prudent "good housekeeping" practices, known more formally as best management practices (BMPs). Among these BMPs are control of runoff and erosion, well-maintained subsurface wastewater disposal systems and reductions in the use of fertilizers. Activities close to the waterbody and its tributaries merit special attention for following good land management practices. In addition, there are some statewide efforts that provide part of an overall framework. These include the legislation that curbed the phosphorus content of many cleaning agents, revisions to regulations that encourage better maintenance of subsurface disposal systems (Title 5 Septic systems), and the Rivers Protection Act that provides for greater protection of land bordering waterbodies. In addition, there is the public's concern about the environment that is being harnessed to implement remediation and protection plans through efforts associated with the Massachusetts Watershed Initiative and the Basin Teams. In some cases, structural controls, such as detention ponds, may be used to reduce pollution loads to surface waters.

Although the landuse approach gives an estimate of the magnitude of typical phosphorus export from various landuses, it is important to recognize that nonpoint phosphorus pollution comes from many discrete sources within the watershed. Perhaps the most common phosphorus sources in rural areas are leaching from failed or inadequate septic systems; phosphorus associated with soil erosion and use of phosphorus lawn fertilizers. Soils tend to erode most rapidly following soil disturbances such as construction, gravel pit operations, tilling of agricultural lands, overgrazing, and trampling by animals or vehicles. A common problem with erosion in rural areas is erosion from unpaved roads. Soils may also erode rapidly where runoff water concentrates into channels and erodes the channel bottom. This may occur where impervious surfaces such as parking lots direct large volumes of water into ditches which begin to erode and may also result from excessive water drainage from roadways with poorly designed ditches and culverts. Any unvegetated drainage way is a likely source of soil erosion.

Discrete sources of nonpoint phosphorus in urban, commercial and industrial areas include a variety of sources that are lumped together as 'urban runoff' or 'stormwater' and may be considered as point sources under wasteload allocations in the tables below. As many of these urban sources are difficult to identify the most common methods to control such sources include reduction of impervious surfaces, street sweeping and other best management practices as well as treatment of stormwater runoff in detention ponds or other structural controls.

Other sources of phosphorus include phosphorus based lawn fertilizers used in residential areas, parks, cemeteries and golf courses and fertilizers used by agriculture. Manure from animals, especially dairies and other confined animal feeding areas is high in phosphorus. In some cases the manure is inappropriately spread or piled on frozen ground during winter months and the phosphorus can leach into nearby surface waters. Over a period of repeated applications of manure to local agricultural fields, the phosphorus in the manure can saturate the ability of the soil to bind phosphorus, resulting in phosphorus export to surface waters. In some cases, cows and other animals including wildlife such as flocks of ducks and geese may have access to surface waters and cause both erosion and direct deposition of feces to streams and lakes.

Perhaps the most difficult source of phosphorus to account for is the phosphorus recycled within the lake from the lake sediments. In most north temperate lakes, phosphorus that accumulated in the bottom waters of the lake during stratification is mixed into surface waters during spring and fall turnover. Phosphorus release from shallow lake sediments may be a significant input for several reasons. These reasons include higher microbial activity in shallow warmer waters that can lead to sediment anoxia and the resultant release of iron and associated phosphorus. Phosphorus release may also occur during temporary mixing events such as wind or powerboat caused turbulence or bottom feeding fish, which can resuspend phosphorus rich sediments. Phosphorus can also be released from nutrient 'pumping' by rooted aquatic macrophytes as they extract phosphorus from the sediments and excrete phosphorus to the water during seasonal growth and senescence (Cooke et al., 1993; Horne and Goldman, 1994).

Shallow lakes also have less water to dilute the phosphorus released from sediment sources and thus the impact on lake water concentrations is higher than in deeper lakes.

The most important factor controlling macrophyte growth appears to be light (Cooke et al., 1994). Due to the typically large mass of nutrients stored in lake sediments, reductions in nutrient loadings by themselves are not expected to reduce macrophyte growth in many macrophyte-dominated lakes, at least not in the short-term. In such cases additional in-lake control methods are generally recommended to directly reduce macrophyte biomass. Lake management techniques for both nutrient control and macrophyte control have been reviewed by in "Eutrophication and Aquatic Plant Management in Massachusetts. Draft Generic Environmental Impact Report" (Mattson et al., 1998). The Massachusetts Department of Environmental Protection will support in-lake remediation efforts that cost-effective, long-term and meet all environmental concerns, however, instituting such measures will depend on continued Federal support via EPA and State support via the Massachusetts Department of Environmental Management.

Financial support for implementation is potentially available on a competitive basis through both the non-point source (319) grants and the state revolving fund (SRF) loan program. The 319 grants require a 40 percent non-federal match of the total project cost although the local match can be through in-kind services such as volunteer efforts. Other sources of funding include the 604b Water Quality Management Planning Grant Program, the Community Septic Management Loan Program and the DEM Lake and Pond Grant Program. Information on these programs are available in a pamphlet "Grant and Loan Programs – Opportunities for Watershed Protection, Planning and Implementation" through the Massachusetts Department of Environmental Protection, Bureau of Resource Protection and the Massachusetts Department of Environmental Management (for the Lake and Pond Grant Program).

Since the lake restoration and improvements can take a long period of time to be realized, follow-up monitoring is essential. This can be accomplished through a variety of mechanisms including volunteer efforts. Recommended monitoring may include Secchi disk readings, lake total phosphorus, macrophyte mapping of species distribution and density, visual inspection of any structural BMPs, coordination with Conservation Commission and Board of Health activities and continued education efforts for citizens in the watershed.

Waterbody Descriptions and Problem Assessment

The pollutant stressors reported on the 1998 303d list which are related to this phosphorus TMDL are listed in Table 1 below.

Table 1. Pollutant Stressors listed on 1998 303d list.

WBID	Lake Name, Town	303d list pollutant/stressor
MA42005	Buffumville Lake, Charlton/Oxford	Noxious aquatic plants
MA42009	Cedar Meadow Pond, Leicester	Noxious aquatic plants
MA42014	Dresser Hill Pond, Charlton	Turbidity
MA42015	Dutton Pond, Leicester	Nutrients, Noxious aquatic plants
MA42018	Gore Pond, Charlton/Dudley	Noxious aquatic plants, Turbidity
MA42019	Granite Reservoir, Charlton	Noxious aquatic plants
MA42023	Greenville Pond, Leicester	Turbidity
MA42029	Hudson Pond, Oxford	Noxious aquatic plants
MA42030	Jones Pond, Charlton/Spencer	Noxious aquatic plants
MA42068	Larner Pond, Dudley	Noxious aquatic plants
MA42034	Lowes Pond, Oxford	Noxious aquatic plants
MA42035	McKinstry Pond, Oxford	Noxious aquatic plants
MA42037	New Pond, Dudley	Noxious aquatic plants
MA42042	Peter Pond, Dudley	Nutrients, Organic enrichment, Low

		dissolved Oxygen
MA42043	Pierpoint Meadow Pond, Dudley/Charlton	Noxious aquatic plants
MA42044	Pikes Pond, Charlton	Turbidity*
MA42047	Robinson Pond, Oxford	Noxious aquatic plants
MA42048	Rochdale Pond, Leicester	Nutrients, Organic enrichment, Low dissolved Oxygen
MA42051	Shepherd Pond, Dudley	Noxious aquatic plants
MA42058	Texas Pond, Oxford	Noxious aquatic plants
MA42060	Tobins Pond, Dudley	Noxious aquatic plants
MA42062	Wallis Pond, Dudley	Noxious aquatic plants

*Note: Pikes Pond is 303d listed for Flow Alteration, but this is not considered related to the phosphorus TMDL.

Landuse information for each watershed is based on MassGIS digital maps derived from aerial photography taken in 1985 or 1999. To account for changes in landuse, population growth rates are reported for towns closest to the lake. Population (census) data and estimated growth rates are from projections provided on the internet (www.umass.edu/miser/) by the Massachusetts Institute for Social and Economic Research (MISER) at the University of Massachusetts, Amherst.

Data collected from each lake varies depending on the type of survey conducted. During the 1970s-early 1990s and beginning again in 1999, baseline surveys were conducted on lakes by the Department. These early baseline surveys typically were conducted during the summer by a team of two spending one day per lake. Baseline data collected including total phosphorus concentrations, dissolved oxygen and temperature profiles, Secchi disk depth and macrophyte density and species distribution maps. Baseline surveys in 1999 and later were conducted by a team of two visiting the lake for ½ day three times during the summer. Baseline data for Gore Pond, Peter Pond, Rochdale Pond, Wallis Pond and Larner Pond, which were sampled in 1999 are available in Appendix I along with limited data from Dresser Hill Pond. In addition, less detailed synoptic surveys were conducted by the Department between 1993-1998 and were usually limited to visual surveys of macrophyte distributions and species types. Typically, synoptic surveys were conducted from observations at several points around the shore. Data from other sources is used as indicated.

The locations of the twenty-two lakes are shown in Figure 1 below. The local environs of the ponds are shown along with descriptions of the ponds, below. Macrophyte maps were generally not available for these ponds with the exception of Gore Pond, Peter Pond, Rochdale Pond, Wallis Pond and Larner Pond as shown below. The key to macrophyte species codes is available in the Appendix.

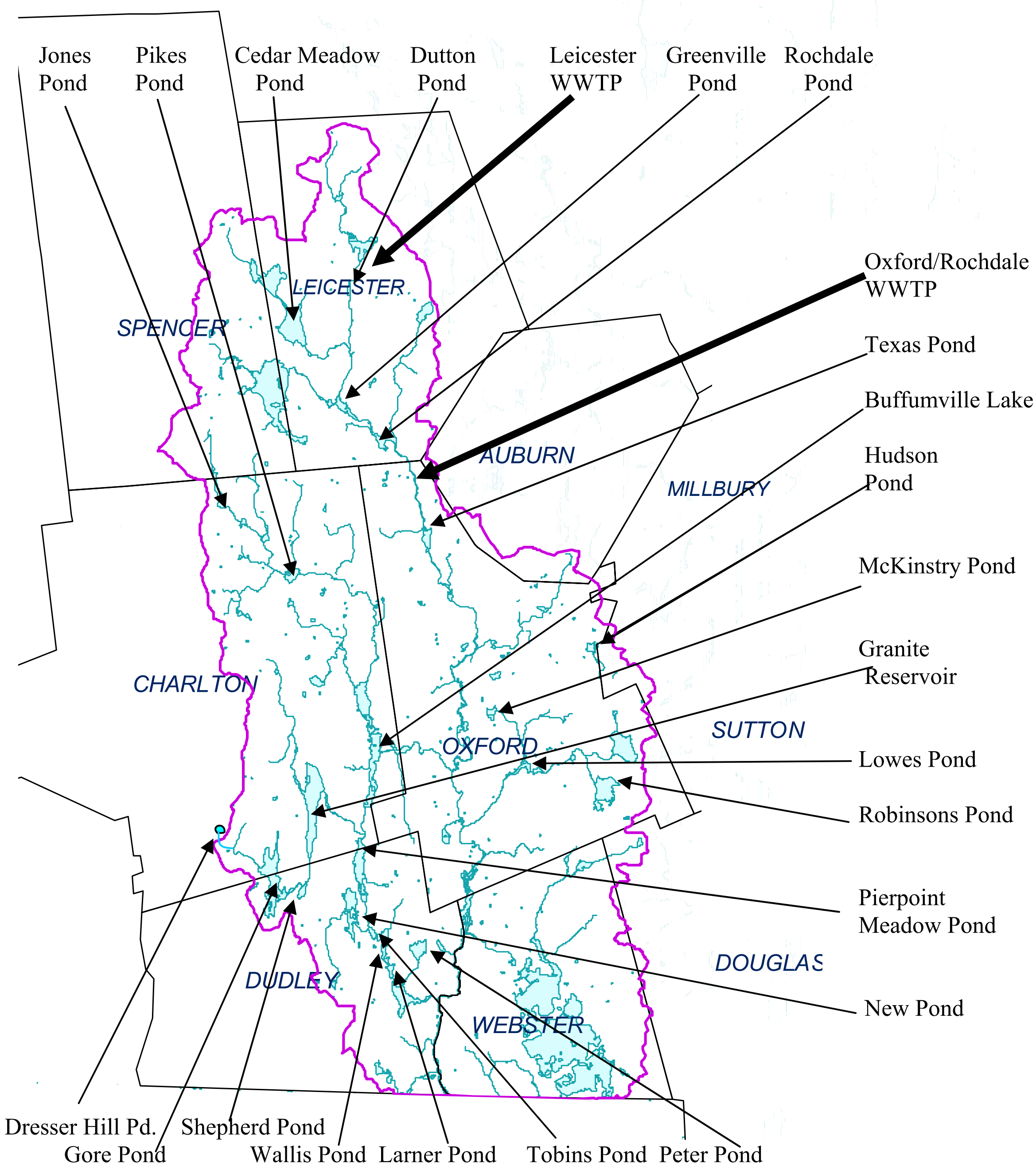

Figure 1 Locations of study ponds and associated NPDES discharges within the French Basin.

Buffumville Lake

(Buffumville Reservoir) in Charlton/Oxford is a large lake of approximately 186 acres operated by the US ACOE. The lake has two subbasins that are separated by Oxford Road. The watershed is 76 percent forested and most of remaining watershed consists of rural and agricultural land use with the following exceptions. Approximately 4 percent of the watershed is water and wetlands. Commercial-industrial landuse covers a small area that includes sections of MassHighways I-90 and Route 20. The Bennet Wildlife Management Area, the Four Chimneys Wildlife Management Area and the Conrailway are all within the watershed. Population in Charlton grew from 6,719 and 9,576 from 1980 to the 1990 census. Miser predictions on growth are 12,637 for the year 2000 and 16,655 for the year 2010 with an estimated 20 year growth rate of about 25 percent. Population in Oxford grew from 11,680 and 12,588 from 1980 to the 1990 census. Miser predictions on growth are 13,766 for the year 2000 and 14,339 for the year 2010 with an estimated 20 year growth rate of about 14 percent. Buffumville lake was assessed by DEP in the summer of 1994 and the assessment comments reported: "A 21 September 1994 synoptic survey indicates that the eastern shoreline has a vegetative border of up to 50 feet. The north shore is similar but the western shore appears to exhibit a narrower band of plants. There is about 15% coverage at this northeast end of the lake. At the public beach on the north side of Oxford Road there was 25%-50% coverage. Across Oxford Road there was 0%-25% coverage but it was difficult to tell, as about 90% of the water is free of emergent and floating leaf plants, but can't tell how far the *Myriophyllum* extends into the water. The non-native *Myriophyllum heterophyllum* threatens about 176 acres of the pond." The Army ACOE have monitored Secchi readings in July for several years. The average Secchi reading for years 1998-2000 was 2.7 meters.

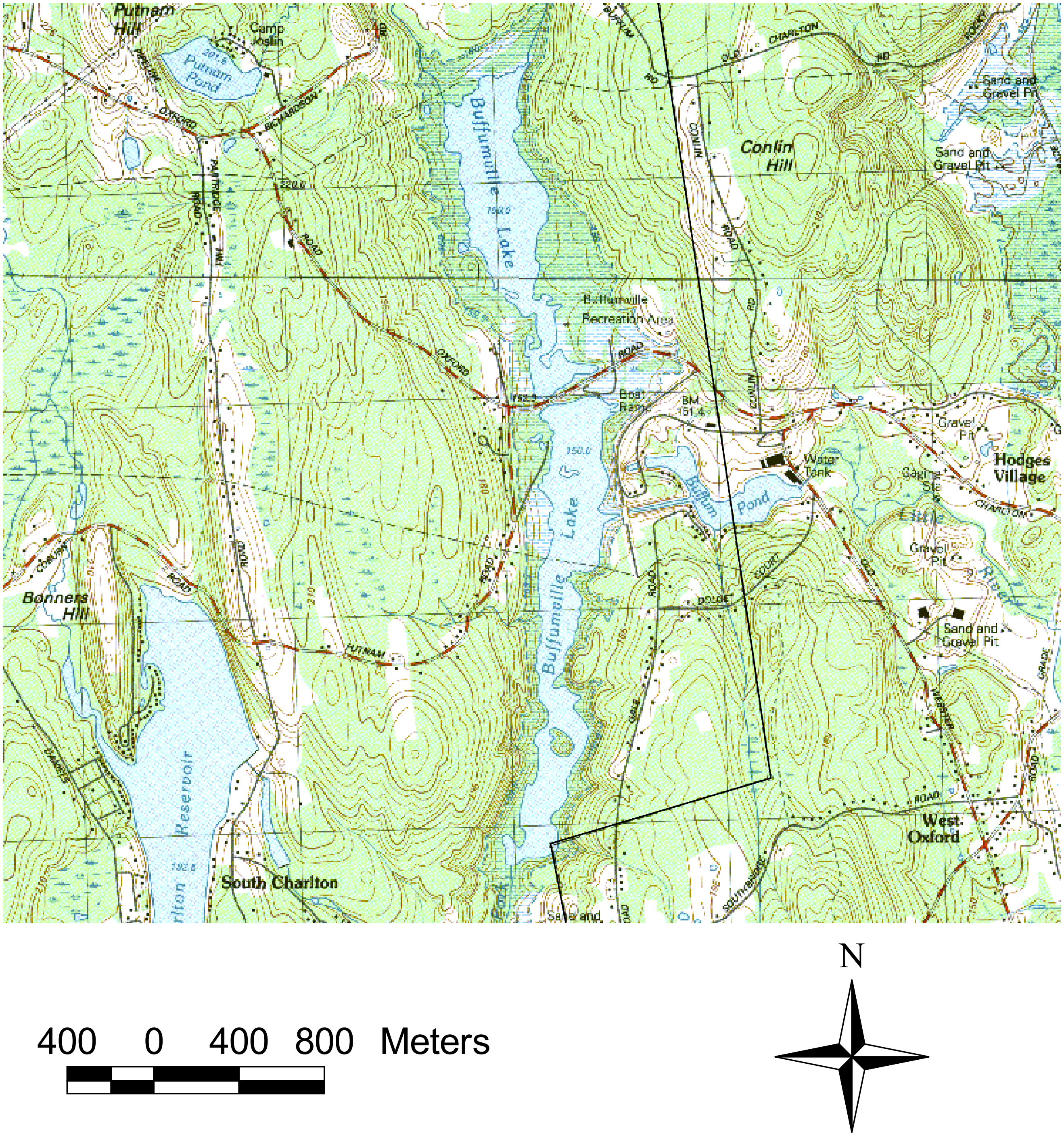

Figure 2. Buffumville Lake Environs.

Cedar Meadow Pond

in Leicester is a large pond of approximately 140 acres. The watershed is 58 percent forested and agricultural landuse accounts for about 14 percent. Another 14 percent of the watershed consists of water and wetlands. Most of the rest of the watershed consists of rural landuse. Approximately 5 percent of the watershed is in the urban category that includes areas of high density residential and some commercial-industrial landuse. Population in Leicester ranged between 9,446 and 10,191 from 1980 to the 1990 census. Miser predictions on growth are 11,121 for the year 2000 and 12,012 for the year 2010 with an estimated 20 year growth rate of about 18 percent. Cedar Meadow Pond was assessed by DEP in the summer of 1994 and the assessment comments reported: " A 14 July 1994 synoptic survey indicates that encroaching emergent and floating leaf plants (75-100% cover) around most of pond shore (approximately one third area) then patches of floating leaved in open water." The Army ACOE have monitored Secchi readings in July for several years. The average Secchi reading for years 1998-2000 was 2.4 meters.

Figure 3. Cedar Meadow Pond Environs.

Dresser Hill Pond

in Charlton is a small (8 acre) constructed pond located on a dairy farm just downhill of the dairy. The pond was originally listed as being in the Quinebaug River watershed until the farmer raised the pond level with a dam and the outlet was redirected to another stream that is a tributary to Gore Pond in the French Basin (see below). The farm was recently sold to a nursery and the dairy is no longer in operation. A 17 August 1994 DEP synoptic survey indicated that turbidity was the main cause of a non-supporting primary contact over the entire pond. There was a dense blue-green "algal" bloom (actually a Cyanobacterium). The Secchi reading was probably one or two inches at most. There was surface scum on windward shoreline (Schoolhouse Road). Aquatic plants, if present, were not evident. The lake has been repeatedly treated with alum and copper in 1996, 1997 and 1998. A baseline survey was not conducted in 1999, but because it was thought to be a major source of phosphorus to Gore Pond (see below) the pond was sampled at the shoreline for Secchi disk transparency and surface total phosphorus near the shoreline. The Secchi reading during August was 0.4 m and the average total phosphorus was 0.20 mg/l during August and September of 1999. An average Carlson Trophic State Index (TSI) for late summer was 77; considered to be hypereutrophic (see Appendix IV Tables for further information on Carlson TSI).

Dutton Pond

is a very small (6 acre) impoundment on the headwaters of the French River. The old stone and earth dam has been breached but a shallow pool remains. The Leicester waste water treatment plant (NPDES MA0101796) discharges to a small stream that immediately discharges to Dutton Pond. In a 1987 survey Secchi disk was recorded at 0.35m and total phosphorus readings of 4.9mg/l in the treatment effluent (later discharge permits limited this to 1 mg/l) and 0.69mg/l in the surface waters of the pond. A DEP synoptic survey in 1994 reported "Excessive brown/green turbidity, algal bloom evident, transparency estimated at less than 4 ft., filamentous algae abundant on southeastern shore, floating and emergent vegetation sparse." Although Dutton is 303d listed for Nuisance Aquatic Plants in addition to Nutrients, the former impairment apparently is referring to algae rather than macrophytes, as macrophyte densities are very low, according to 1987 macrophyte maps (not shown).

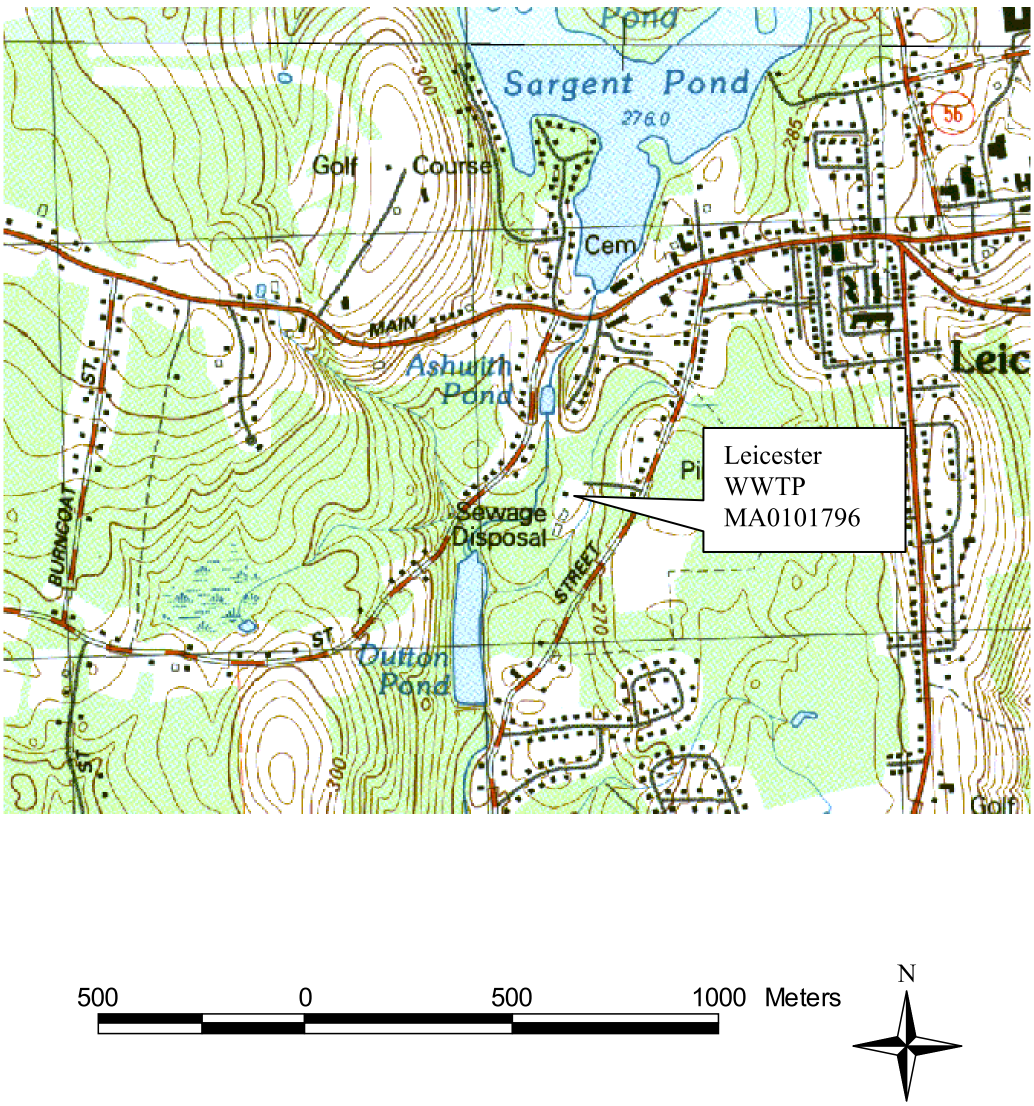

Figure 4. Environs map for Dutton Pond and Leicester WWTP.

Gore Pond

(a.k.a. Baker Pond) in Charlton/Dudley is a large pond of approximately 169 acres. The watershed is 70 percent forested and rural, agricultural landuse account for about 16 percent that includes some open land. Most of the rest of the watershed consists of water and wetlands with less than half a percent accounting for high density residential landuse. Note that due to the diversion of the Dresser Hill Pond outlet (see above), Dresser Hill now discharges to a stream that is tributary to Gore Pond. Population in Charlton has been described above. Population in Dudley ranged between 8,717 and 9,540 from 1980 to the 1990 census. Miser predictions on growth are 9,973 for the year 2000 and 10,710 for the year 2010 with an estimated 20 year growth rate of about 12 percent. Gore Pond was assessed by DEP in the summer of 1994 and the assessment comments reported: " Severe bluegreen blooms result in closing of bathing beaches (transparency below safety criteria of 4 ft. Secchi disk) and potential for diurnal pulsing of oxygen that endangers fish populations. A 17 August 1994 synoptic survey and information from local observers indicated that algal blooms had been a problem earlier in the summer (still present but transparency above 4 ft. criteria). West cove area and east cove area (near outlet) 100% covered with macrophytes. *Myriophyllum heterophyllum* noted at east cove site; representing threat to lake."

A DEP baseline survey during the summer months (October data excluded) of 1999 showed total phosphorus concentrations in the surface averaged 17.5 ppb and Secchi disk transparency averaged 2.35 m. Chlorophyll concentrations in Gore Pond ranged from less than 1 ppb to 35 ppb. The lake is deep enough to stratify for part of the summer and oxygen is absent below 3-4 meters in mid-summer (see Figure 2d and 2e below). Relatively high total phosphorus concentrations (0.10-0.14 mg/l) in the bottom of the pond indicate some potential sources of internal recycling of phosphorus (see Appendix I). Note that the lake was treated with 800 pounds of copper sulfate during the summers of 1998-99 for algae control (plus minor amounts of other herbicides). The 1999 macrophyte maps indicate *Myriophyllum heterophyllum* has apparently spread over much of the lake since the 1994 survey noted above (see map below).

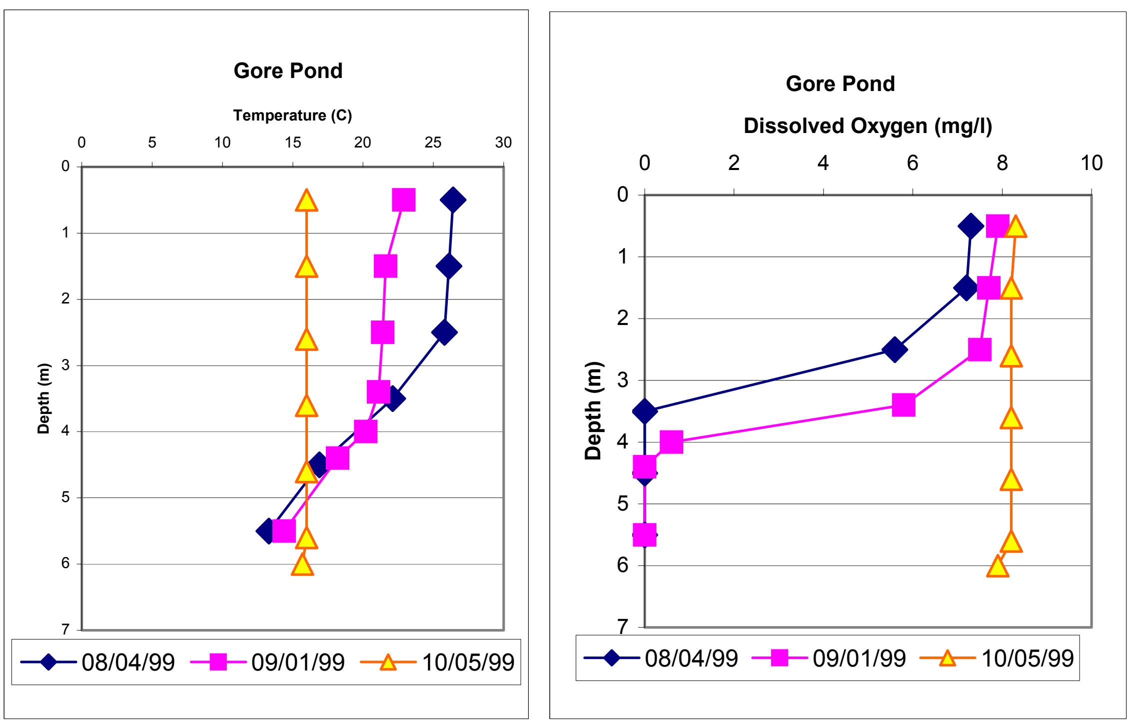

Figure 5 Gore Pond Temperature and DO Profiles.

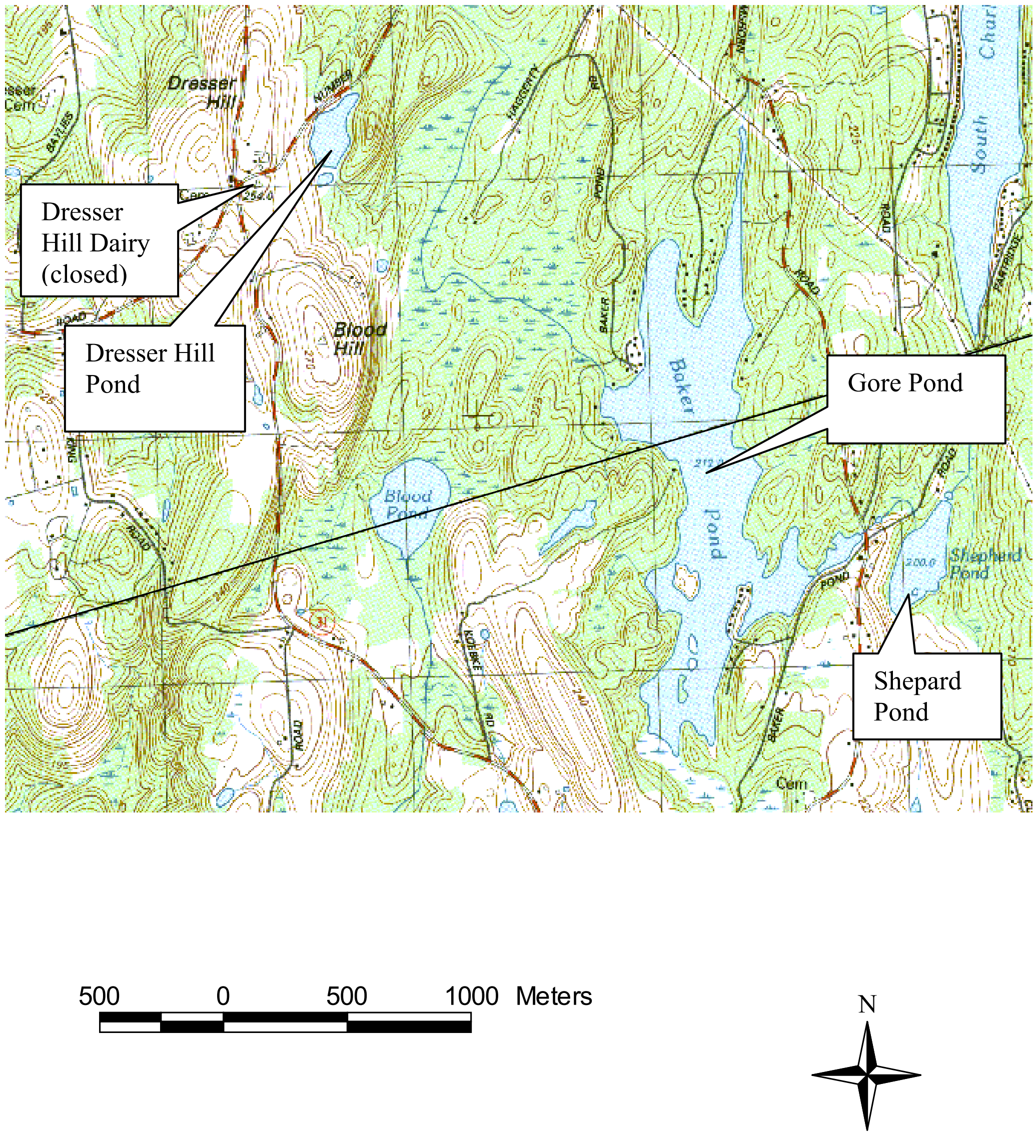

Figure 6. Environs map for Dresser Hill Pond, Gore (Baker) Pond and Shepherd Pond.

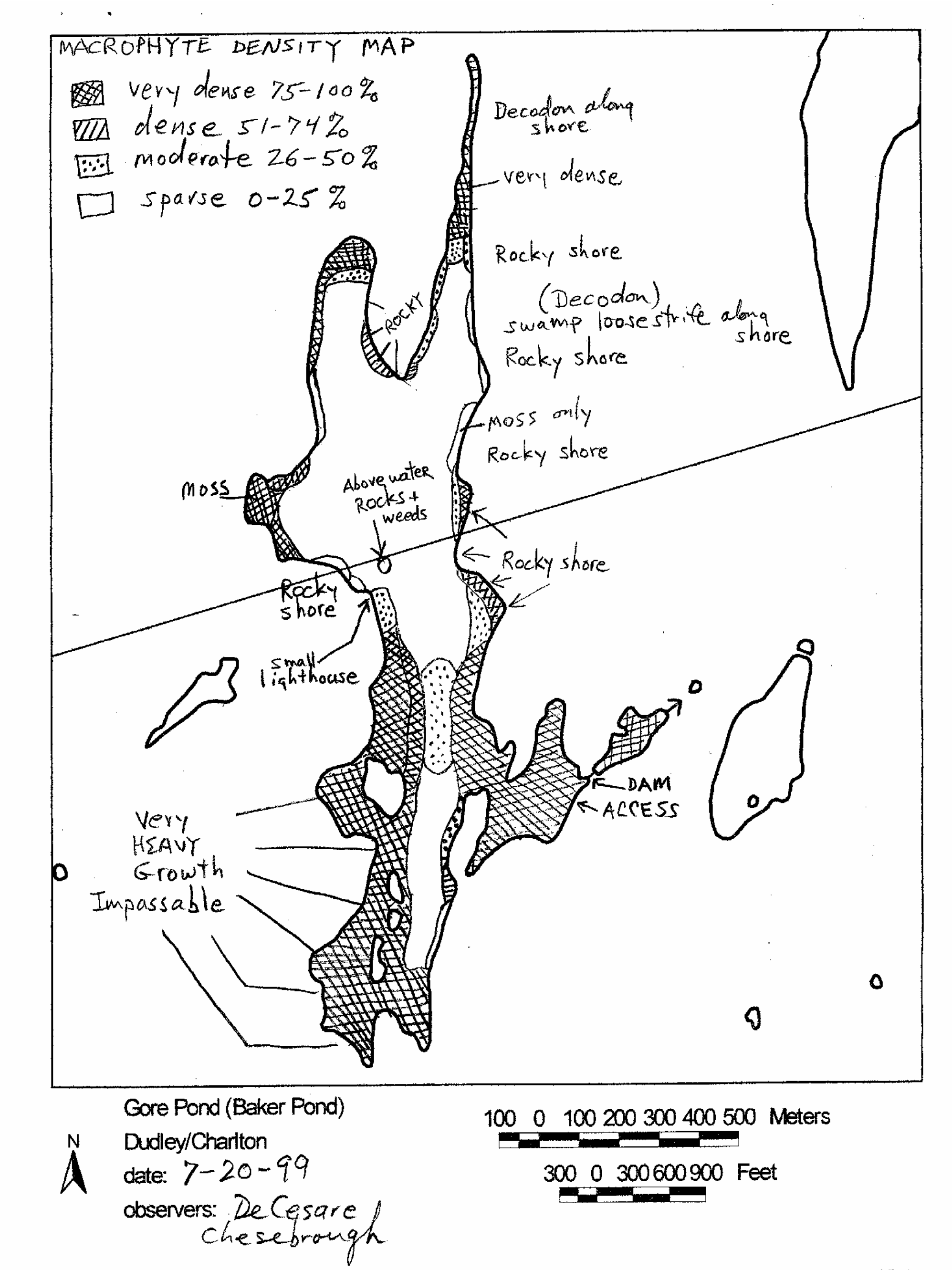

Figure 7. Gore Pond Macrophyte Density (1999).

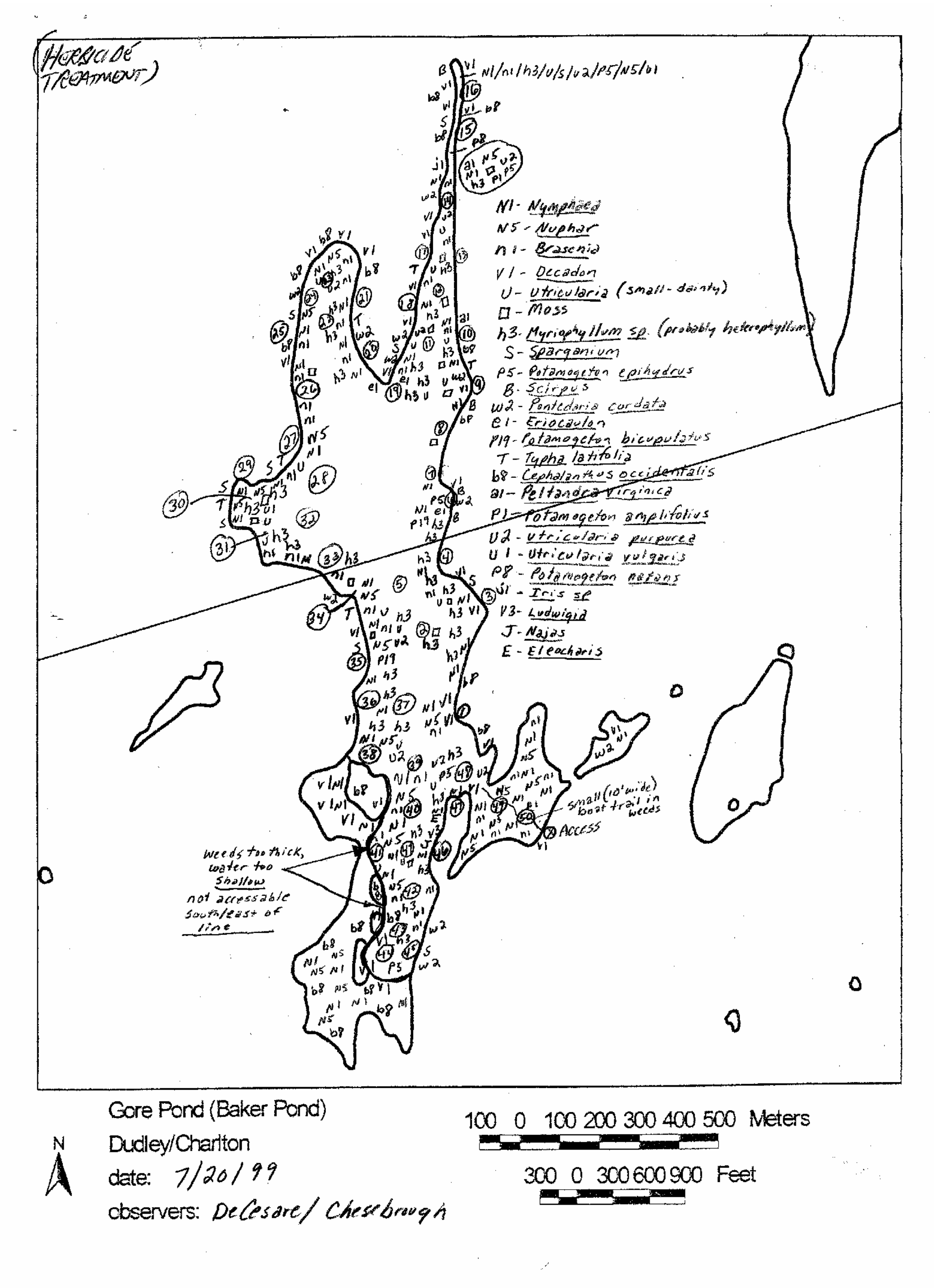

Figure 8 Gore Pond Macrophyte Species distribution (1999).

Granite Reservoir

(A.K.A. South Charlton Reservoir) in Charlton is a large pond of approximately 207 acres. The dominant landuses in the watershed are 70 percent forest, followed by 18 percent rural and agricultural land, 10 percent water and wetlands, with little urban land. Population in Charlton has been described above. Granite Reservoir was assessed by DEP in the summer of 1994 and the assessment comments reported: " A 20 September 1994 synoptic survey indicates that the observed aquatic plant density was sparse except in the south cove where approximately 50% was covered (mostly *Brasenia*). The possible non-native *Myriophyllum* (very likely *heterophyllum*) was present."

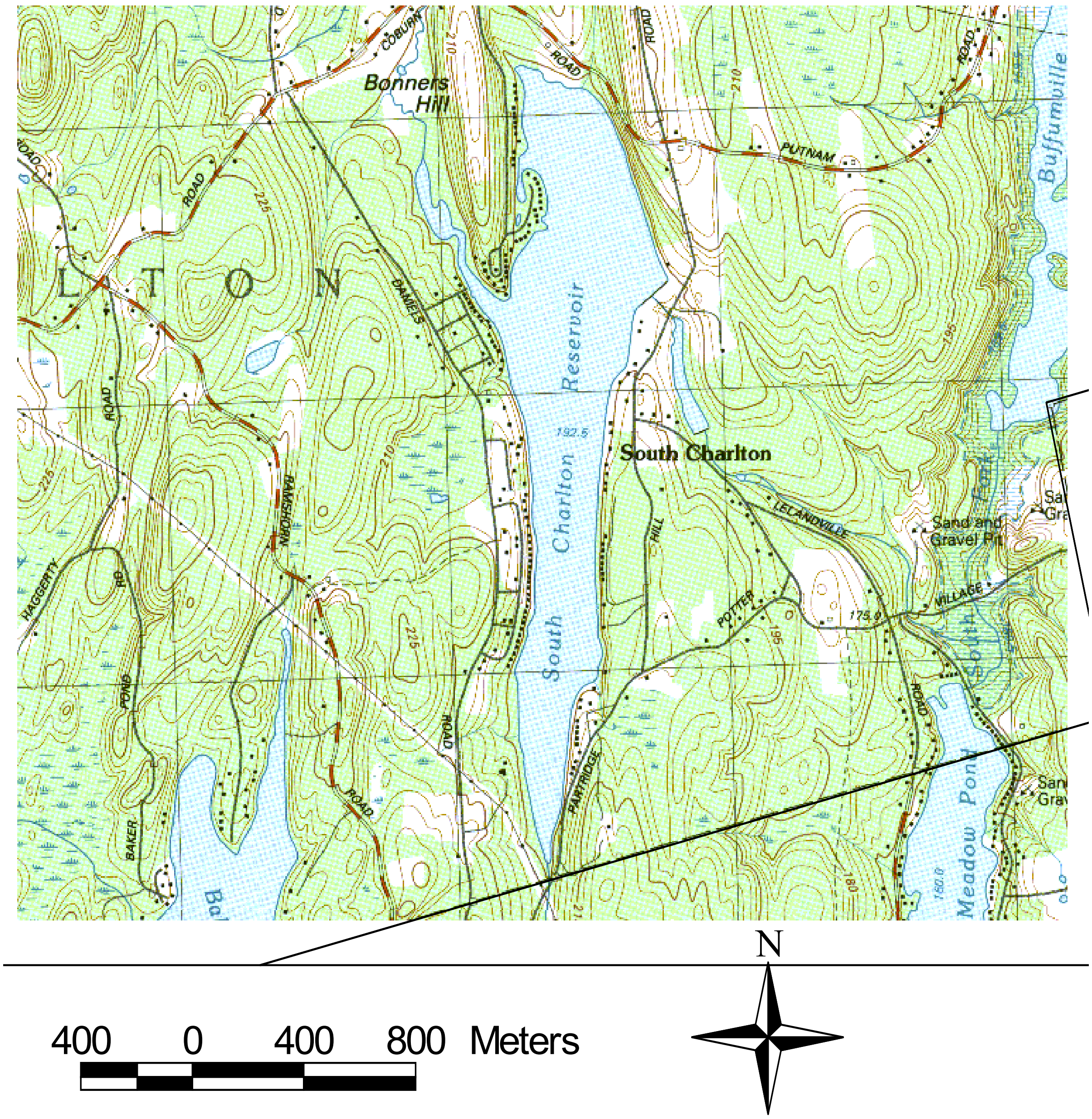

Figure 9 Granite (South Charlton) Reservoir Environs.

Greenville Pond

is a 30 acre impoundment on the French River. Is located downstream of Dutton Pond and the Leicester WWTP (see above). The pond has a well maintained concrete and earth dam with control valve. The dam holds back about 10 feet of water including 1 foot of flashboards. A 1994 survey reported " Moderate brown turbidity, bluegreen bloom evident, sparse floating and emergent vegetation throughout, bottom likely covered with submergents". The Army ACOE have monitored Secchi readings in July for several years. The average Secchi reading for years 1998-2000 was 1.9 meters.

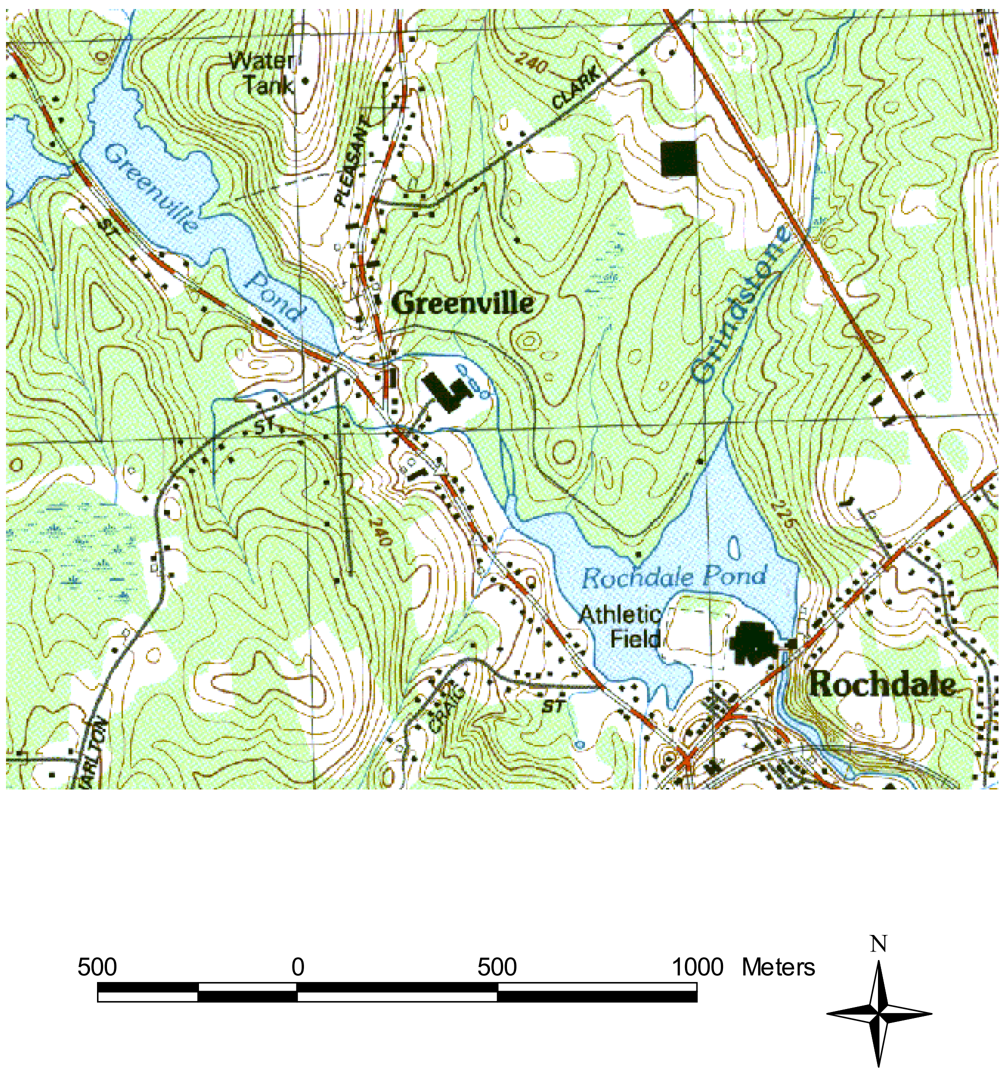

Figure 10. Greenville and Rochdale Pond environs.

Hudson Pond

in Oxford is a small pond of approximately 15 acres. The watershed is 58 percent forested and agricultural landuse accounts for 22 percent. Approximately 11 percent of the watershed is considered to be in rural category primarily consisting of low density residential land use. About 7 percent of the watershed consists of water and wetlands, commercial-industrial landuse (Oxford Airport) accounting for the rest. Population in Oxford has been described above. Hudson Pond was assessed by DEP in the summer of 1994 and the assessment comments reported: " A 21 September 1994 synoptic survey indicates that 75% of the pond was covered with floating leaf plants. It is likely that the coverage is 100% (including submerged plants and floating leaf) overall."

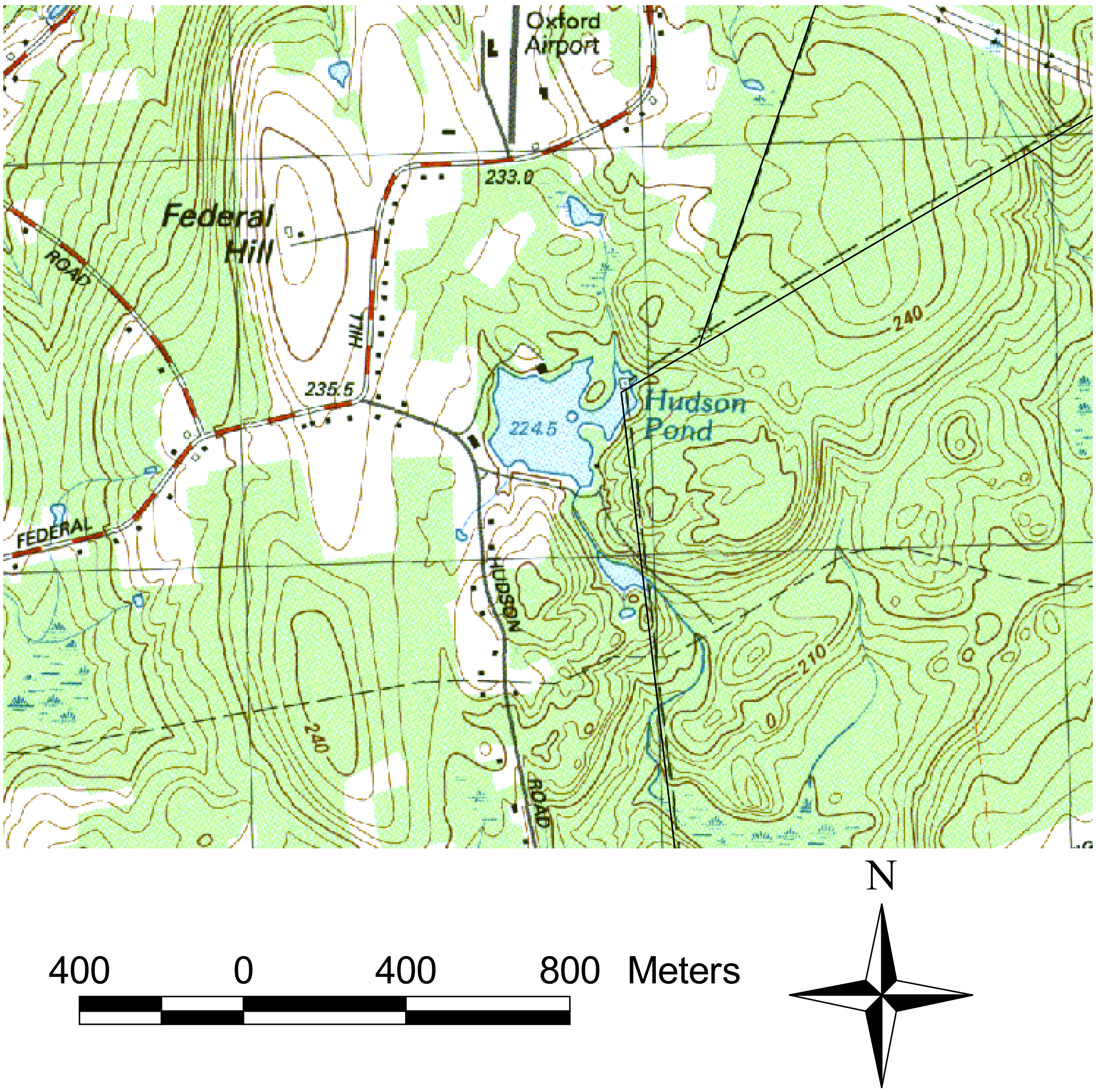

Figure 11. Hudson Pond Environs.

Jones Pond

in Charlton/Spencer is a small pond of approximately 30 acres surrounded by lands owned by the Bement Camp (Episcopal Diocese of W. Mass). The watershed is 81 percent forested and agricultural landuse accounts for 11 percent. Approximately 6 percent of the watershed is in the rural category with areas of low density residential land use and open land, both water and wetlands accounting for the rest. Four Chimney's Wildlife management area is within the watershed of the pond. Population in Charlton has been described above. Population in Spencer ranged between 10,774 and 11,645 from 1980 to the 1990 census. Miser predictions on growth are 11,944 for the year 2000 and 12,332 for the year 2010 with an estimated 20 year growth rate of about 6 percent. Jones Pond was assessed by DEP in the summer of 1994 and the assessment comments reported: "A 28 July 1994 synoptic survey indicates that at the upper end of the pond (approximately the upper half) had 75% to 100% coverage with floating plants and that the lower end had approximately 25% floating leaf plant coverage." The Bement Camp conducts a winter drawdown of approximately 4 feet to control macrophytes. The Army ACOE have monitored Secchi readings in July for several years. The average Secchi reading for years 1998-2000 was 1.4 meters.

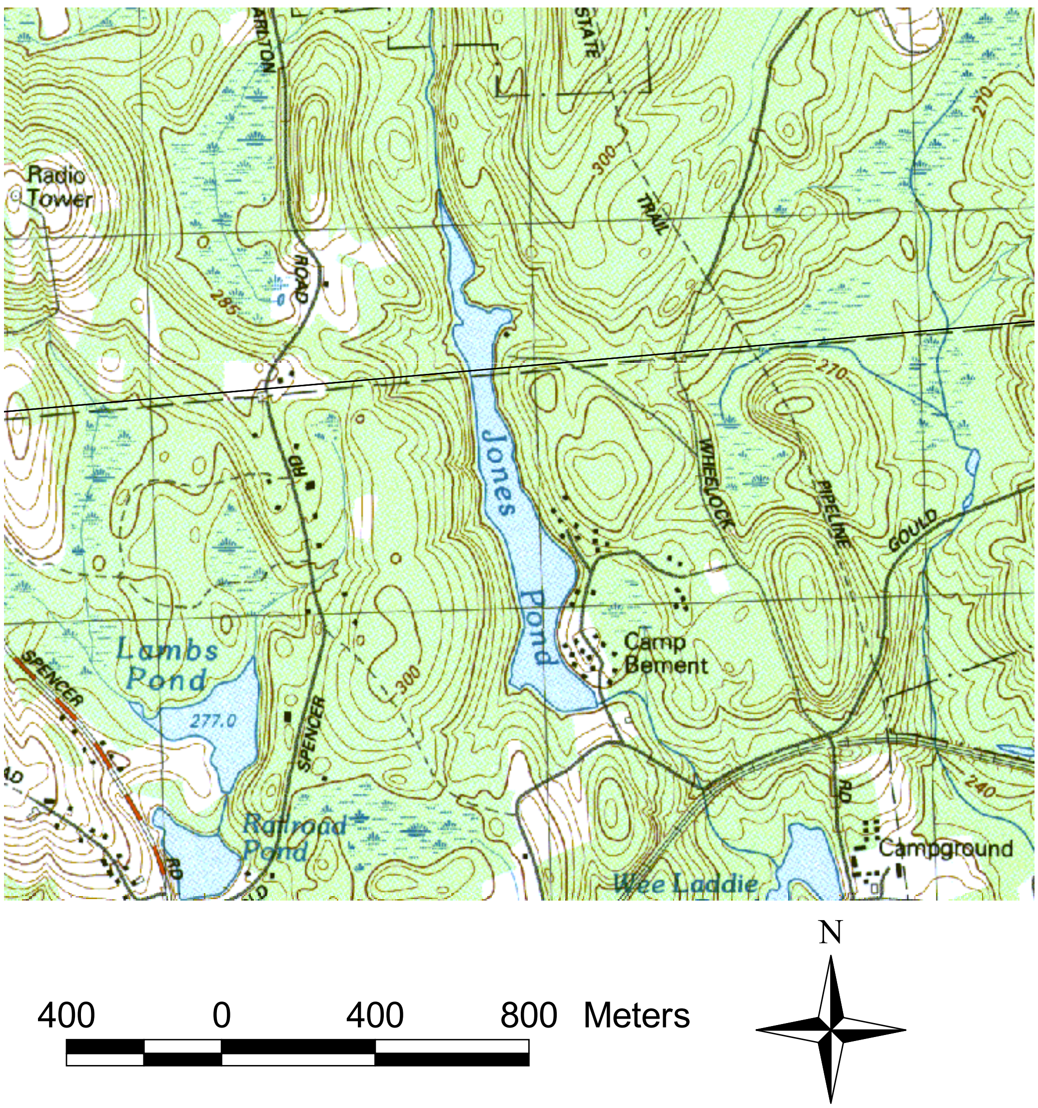

Figure 12. Jones Pond Environs.

Larner Pond

in Dudley is a small lake of approximately 27 acres (see environs for Tobins Pond below). The watershed is 55 percent forested and agricultural landuse accounts for 22 percent. About 8 percent of the watershed consists of water and wetlands. The remainder consists of both rural and urban landuse with areas of low and high density residential land use and some open land. Population in Dudley has been described above. Larner Pond was assessed by DEP in the summer of 1994 and the assessment comments reported: " Very dense growths of aquatic macrophytes (primarily *Myriophyllum heterophyllum* and *Brasenia schreberi*) cover the littoral zone and the entire northern end of the pond. A synoptic survey conducted on 20 Sept. 1994 confirmed that conditions are virtually the same as in the past." A DEP baseline survey during the summer months of 1999 showed total phosphorus concentrations in the surface averaged 25 ppb. Secchi disk transparency was consistently above the 1.2 m standard and averaged 1.9 m. Chlorophyll concentrations in Larner Pond ranged from 2 to 20 ppb (see Appendix). On a recent site visit on April 1, 2002 the lake was drawndown approximately 8-10 feet for repairs on the dam.

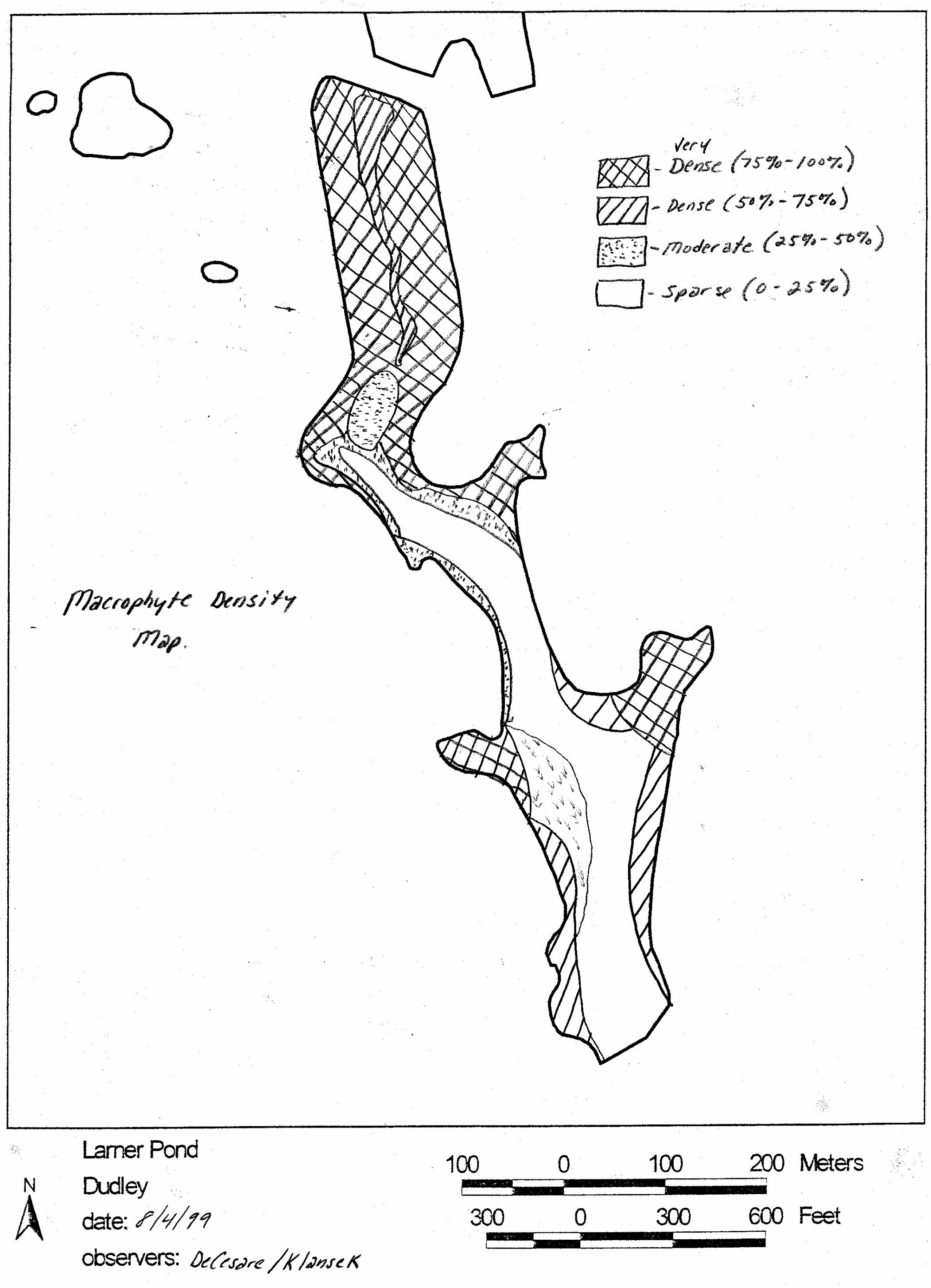

Figure 13 Larner Pond Macrophyte density distribution (1999).

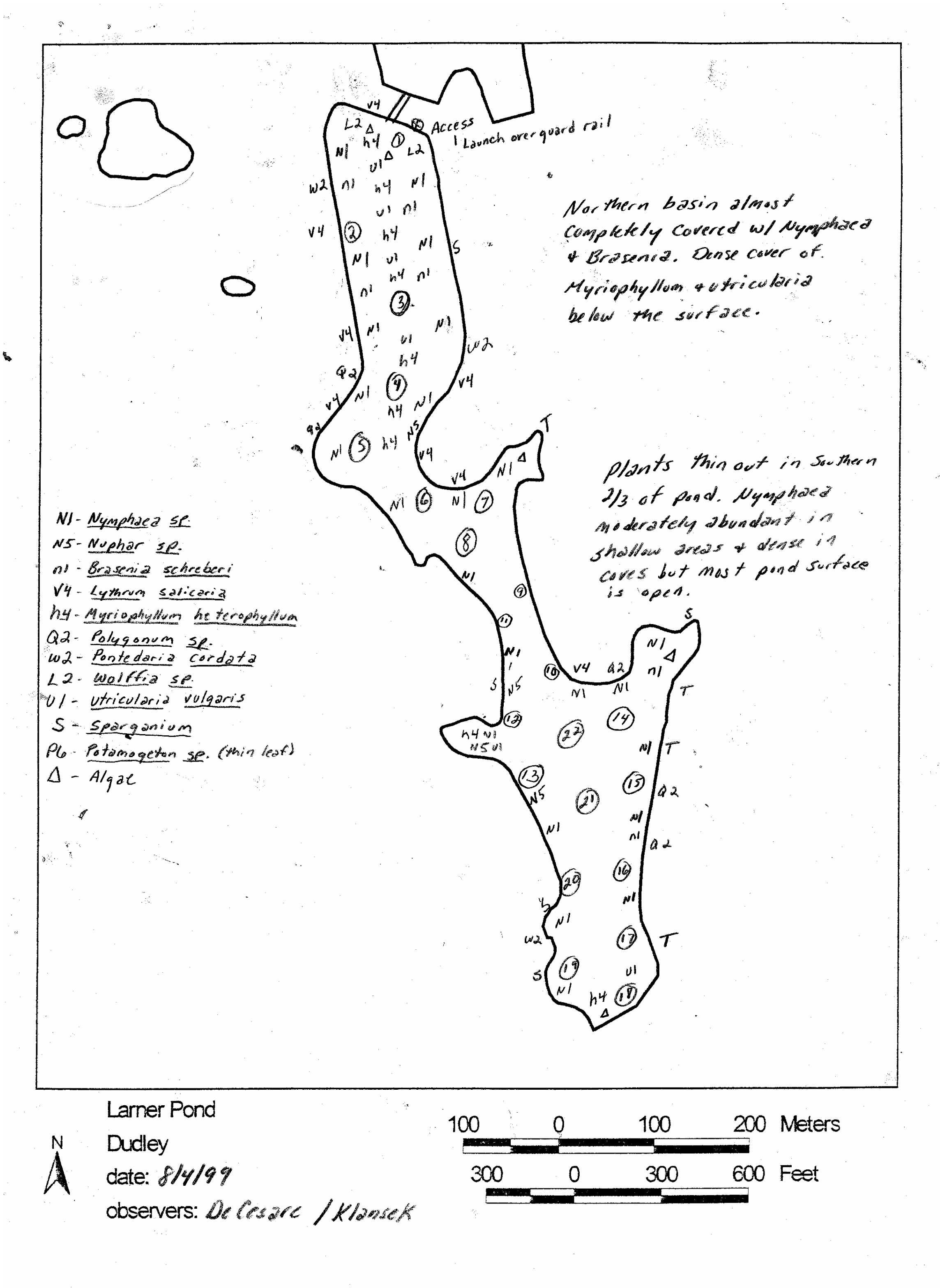

Figure 14. Larner Pond Macrophyte Species distribution (1999).

Lowes Pond

in Oxford is a small impoundment of approximately 33 acres. The dam is old and leaking but holds back about 10 vertical feet of water. The watershed is 58 percent forested and agricultural landuse accounts for 16 percent. Approximately 13 percent of the watershed is in the urban category with areas of high density residential and commercial-industrial landuse. About 7 percent is in the rural category, water and wetlands accounting for the rest. MassHighways Route 12 and I-395 are within the watershed. MassHighways I-395 bisects the pond and interchange number 4 is adjacent to the shore, thus MassHighways is a major contributor to stormwater runoff (see Figure below). Population in Oxford has been stated above. Lowes Pond was assessed by DEP in the summer of 1994 and the assessment comments reported: " A 21 September 1994 synoptic survey indicates that 75% to 100% of the pond was covered with aquatic plants. It consisted of mostly floating leaf plants."

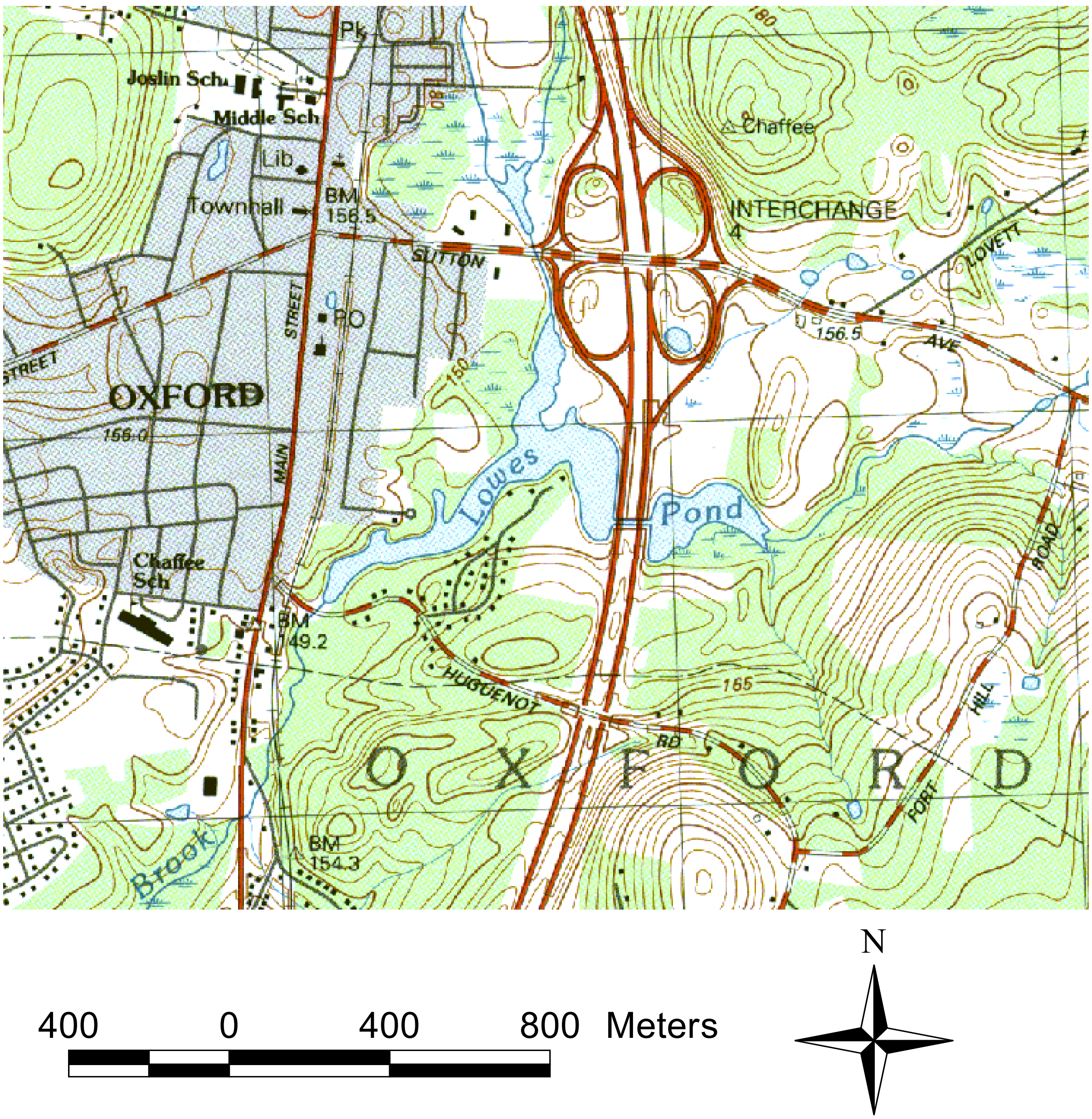

Figure 15. Lowes Pond environs.

McKinstry Pond

in Oxford is a small pond of approximately 11 acres. The dominant landuses in the watershed are 37 percent forest, followed by 33 percent high density residential landuse, 16 percent water and wetlands, and 14 percent rural landuse. Population in Oxford has been described above. MassHighways Route 12 and Route 52 are within the watershed of the reservoir. McKinstry Pond was assessed by DEP in the summer of 1994 and the assessment comments reported: "A 21 September 1994 synoptic survey indicates that there was 100% aquatic plant coverage throughout the southern two thirds (mostly floating leaf plants) and was sparse (less than 5%) throughout the northern one third of the pond." The Army ACOE have monitored Secchi readings in July for several years. The average Secchi reading for years 1998-2000 was 0.8 meters. A bloom of filamentous algae *Spirogyra* was noted during a DEP site visit in April of 2002.

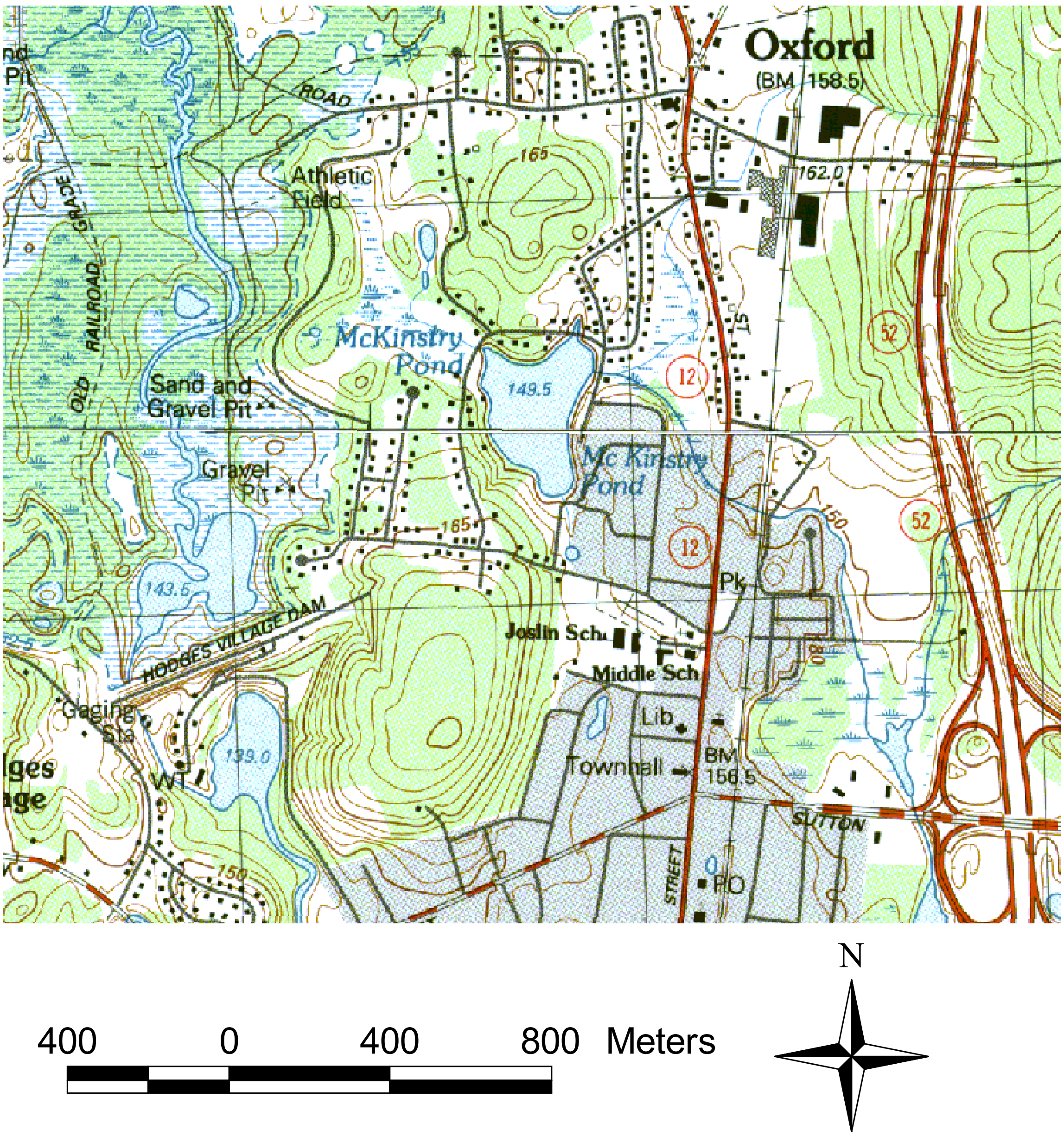

Figure 16. McKinstry Pond Environs.

New Pond

in Dudley is a small pond of approximately 33 acres. The watershed is 53 percent forested and about 25 percent accounts for agricultural land. Approximately 8 percent of the watershed consists of high density residential landuse. Water and wetlands account for 7 percent and the rest is in the rural category. Population in Dudley has been described above. New Pond was assessed by DEP in the summer of 1994 and the assessment comments reported: "A 20 September 1994 synoptic survey indicates that emergent and floating leaf plants are nearly absent but submerged plants cover approximately 90% of the northern end of the pond, there was 50% to 75% coverage of floating leaf plants and submerged plants in the extreme northwest cove, that the eastern shoreline appeared free of macrophytes, and that the western shoreline is bordered with emergent and floating leaf plants. The cove at the western end of the pond is 100% covered with macrophytes. The main body of water is free of floating leaf plants. The possible non-native *Myriophyllum* (likely *heterophyllum*) was present in the northern end of the pond."

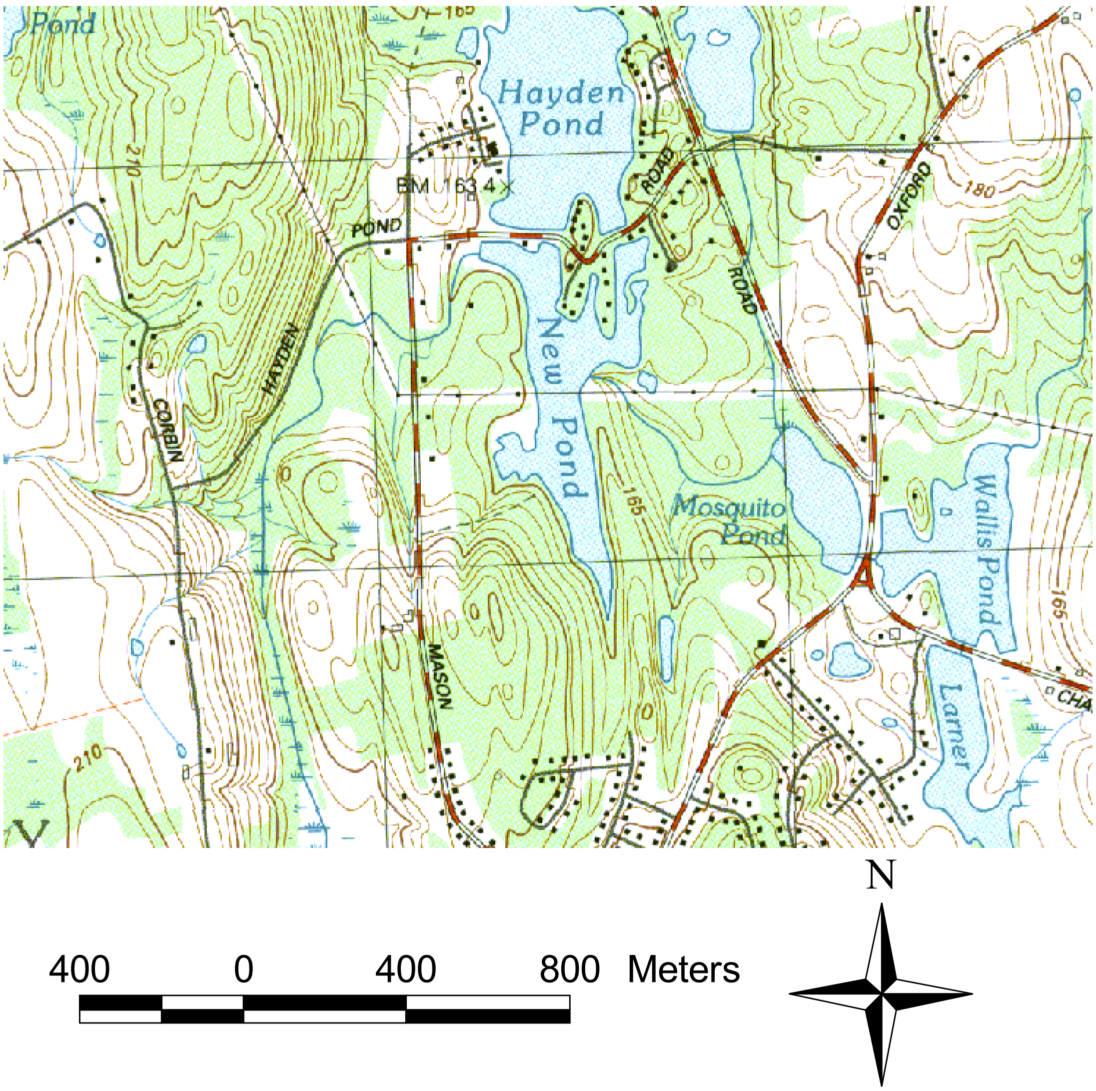

Figure 17. New Pond Environs.

Peter Pond

in Dudley is a small pond of approximately 42 acres. The watershed is 53 percent forested and 24 percent is in the rural landuse category. Approximately 20 percent of the watershed is water and wetlands, and agricultural land accounting for the rest. Population in Dudley has been described above. Peter Pond was assessed by DEP in the summer of 1994 and the assessment comments reported: "Historically high total phosphorus levels, low oxygen in the bottom waters, and high phytoplankton counts. A 20 Sept. 1994 synoptic survey noted only sparse aquatic macrophytes, not impairing any uses. No other criteria were assessed." Secchi disk transparency was recorded at 2.7m in 1987. Given that there are no obvious sources of phosphorus in the watershed and the moderately transparent waters, the historic high total phosphorus results are suspect.

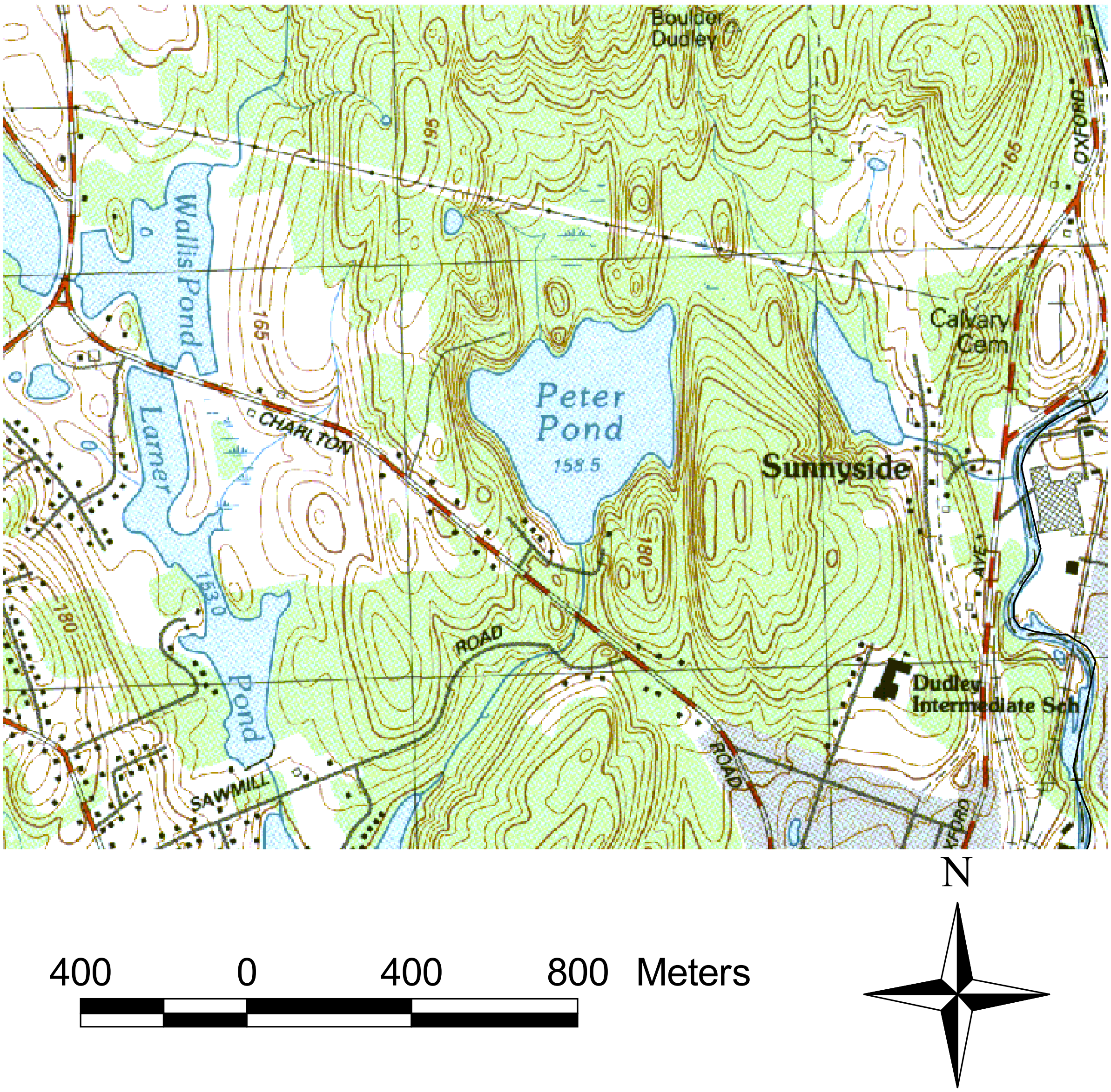

Figure 18 Peter Pond Environs.

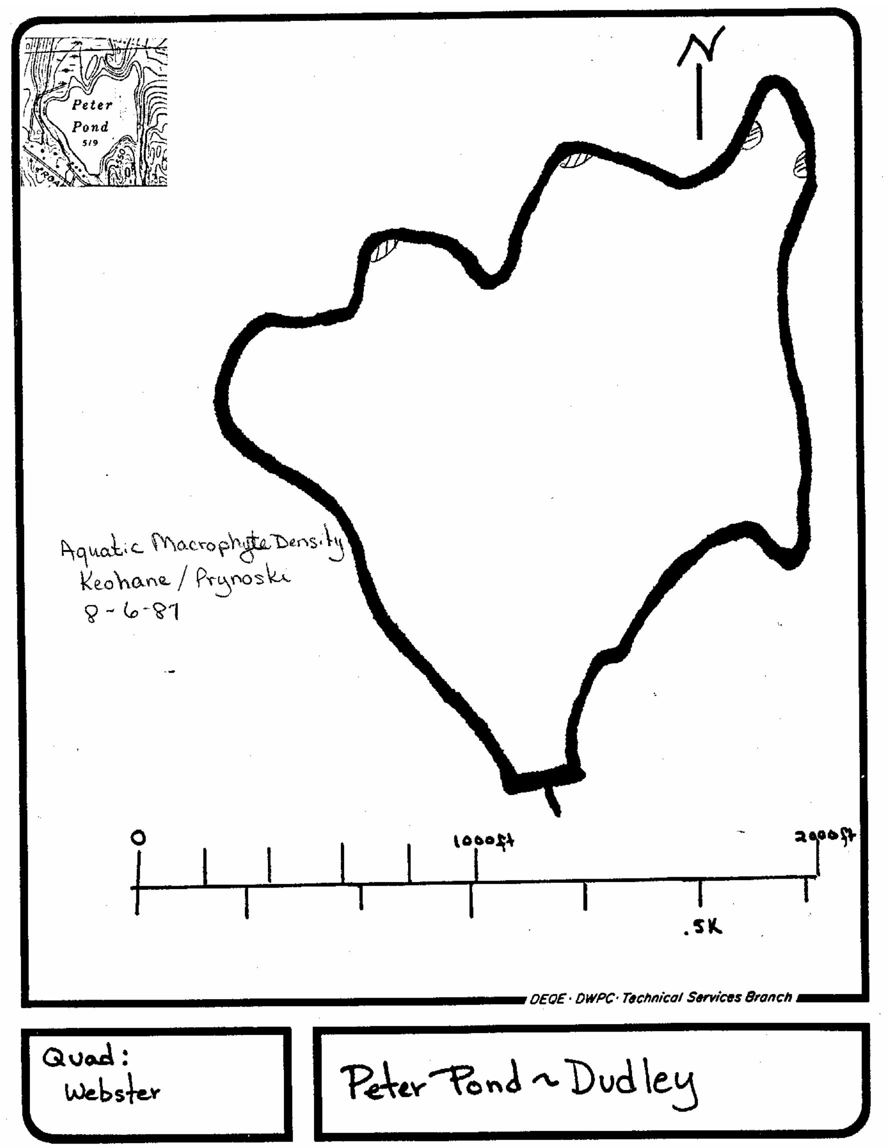

Figure 19 . Peter Pond Macrophyte density distribution (1987).

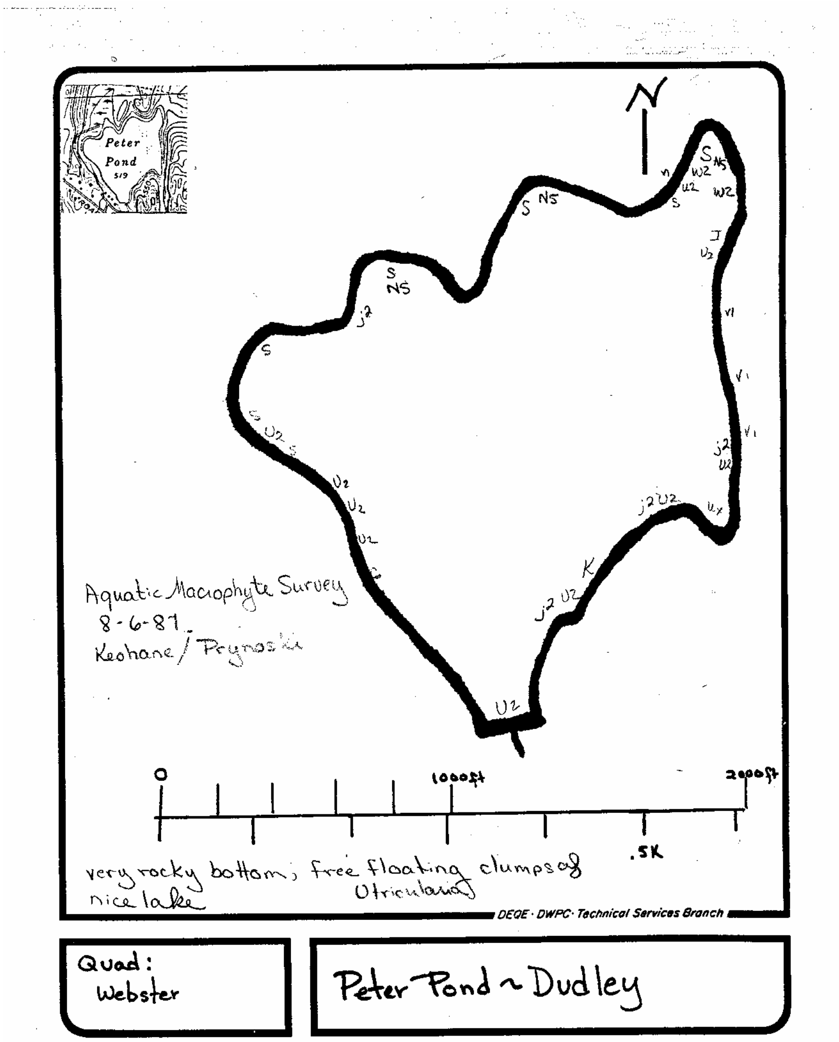

Figure 20. Peter Pond Macrophyte Species distribution (1987).

Pierpoint Meadow Pond

in Dudley/Charlton is a large pond of approximately 94 acres. The watershed is 80 percent forested and water accounts for 18 percent. Approximately 1 percent of the watershed consists of high density residential landuse and less than 1 percent is rural land. Populations in Dudley and Charlton have been described above. A sand and gravel pit lies within the watershed. Pierpoint Meadow Pond was assessed by DEP in the summer of 1994 and the assessment comments reported: " High total phosphorus levels and very dense growths of aquatic macrophytes (primarily *Myriophyllum heterophyllum*) cover the southern portion and the western littoral zone." The Army ACOE have monitored Secchi readings in July for several years. The average Secchi reading for years 1998-2000 was 2.8 meters.

A DEP baseline survey during the summer months of 1999 showed total phosphorus concentrations in the surface averaged 22 ppb and Secchi disk transparency averaged 2.1 m. Chlorophyll concentrations in Pierpoint Meadow Pond ranged from less than 1 ppb to 3 ppb. The lake is only 3.4 meters deep and usually does not stratify.

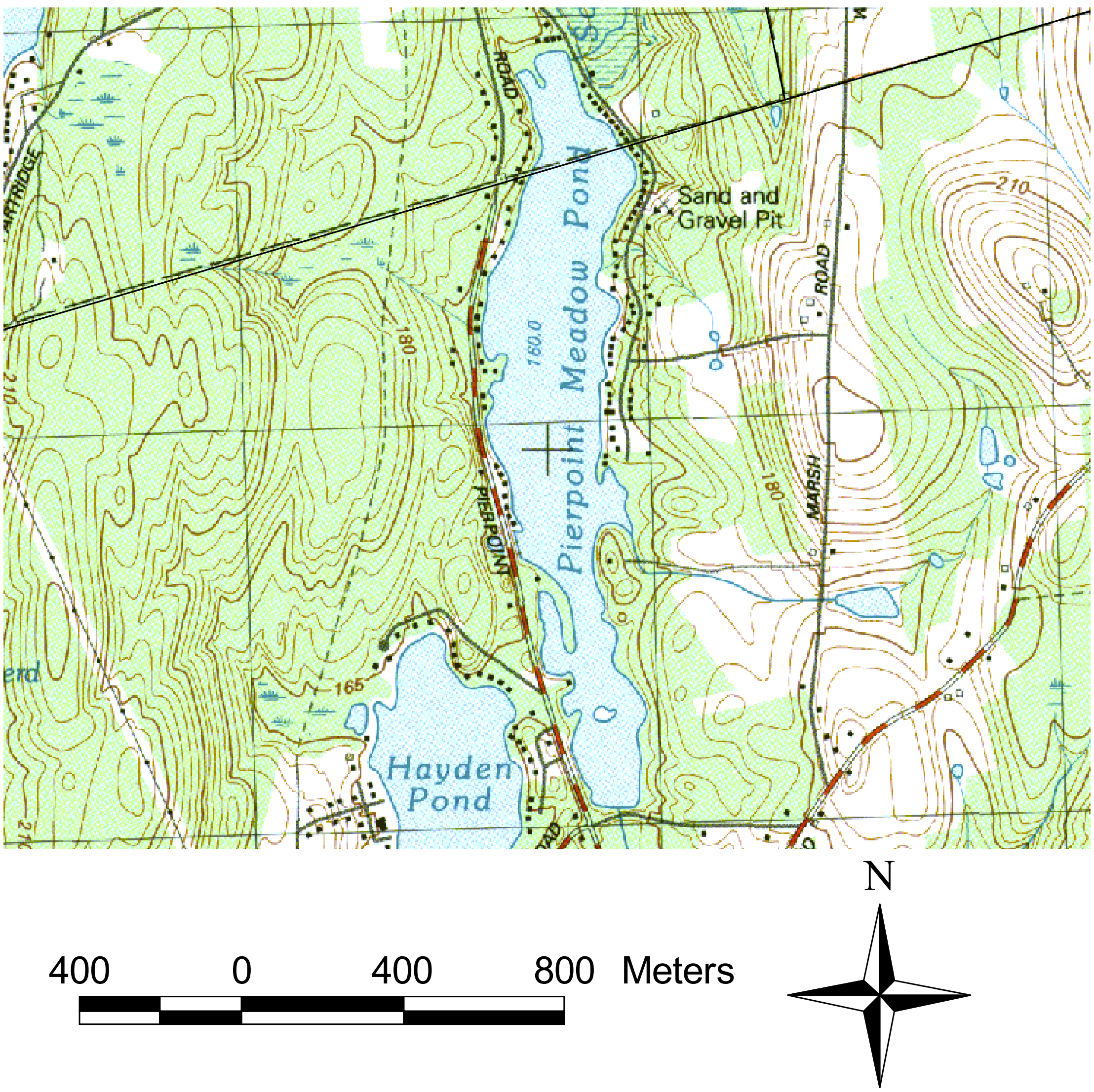

Figure 21. Pierpoint Meadow Pond Environs.

Pikes Pond

in Charlton is a small pond of approximately 28 acres. The dominant landuses in the watershed are 77 percent forest, followed by 12 percent agricultural and 6 percent rural land. About 3 percent of the watershed is water and wetlands, urban landuse accounting for the rest. The Massachusetts Turnpike (I-90) crosses the watershed of the pond. Historically, the pond was downstream of a small NPDES discharge from the MassPike rest area. This NPDES discharge was closed and diverted to Charlton WWTP in 1996. The pond receives highway runoff from the MassPike via several streams (see below). Population in Charlton has been described above. DEP assessment comments reported: "A 28 July 1994 synoptic survey indicates that the aquatic plant coverage was sparse except for the flooded terrestrials. Flow alteration and turbidity seem to be the causes of the use impairments. The pond was very turbid and had a Secchi disk reading of less than 4 feet. The water level appeared very low (down approximately 4 feet) and the area was reduced by one third to one half." Recent observations on March 20, 2002 noted the pond had what appeared to be a new concrete and earth dam and water level was restored to normal levels. The Army ACOE reported July average Secchi reading for years 1998-2000 was 0.9 meters.

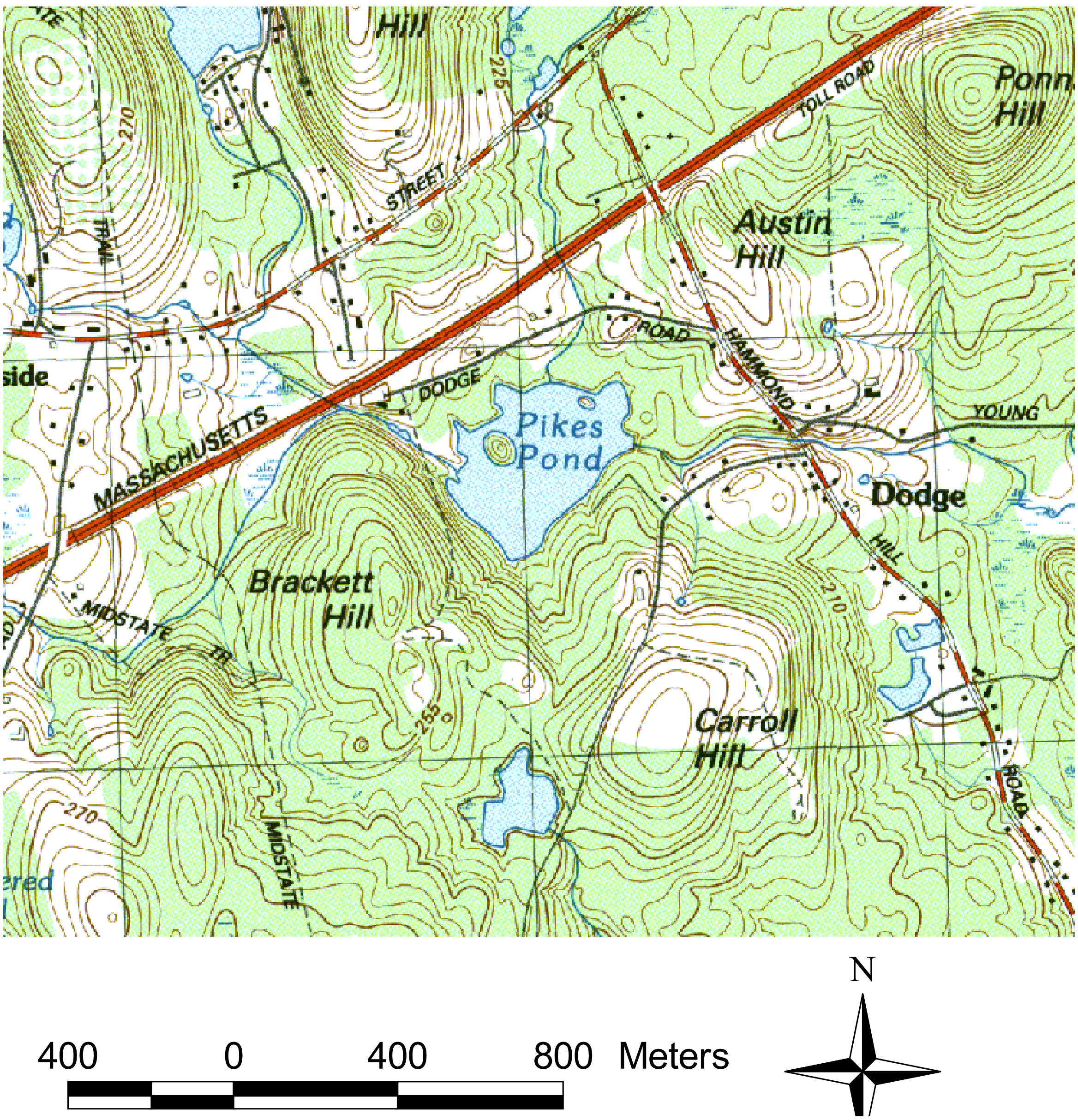

Figure 22. Pikes Pond Environs

Robinson Pond

in Oxford is a large pond of approximately 99 acres. The watershed is 78 percent forested. Water and wetlands accounts for 15 percent. Approximately 5 percent of the watershed is employed in agricultural landuse, rural land accounting for the rest. Populations in Oxford has been described above. Robinson Pond was assessed by DEP in the summer of 1994 and the assessment comments reported: " Historically moderate total phosphorus levels and very dense growths of aquatic macrophytes (primarily *Myriophyllum* sp.) cover the entire pond. A synoptic survey conducted on 21 Sept. 1994 noted 100% floating vegetation (*Nypmphaea* sp. primarily) at the north end of the pond and 75-100% in the west cove and south end of the pond."

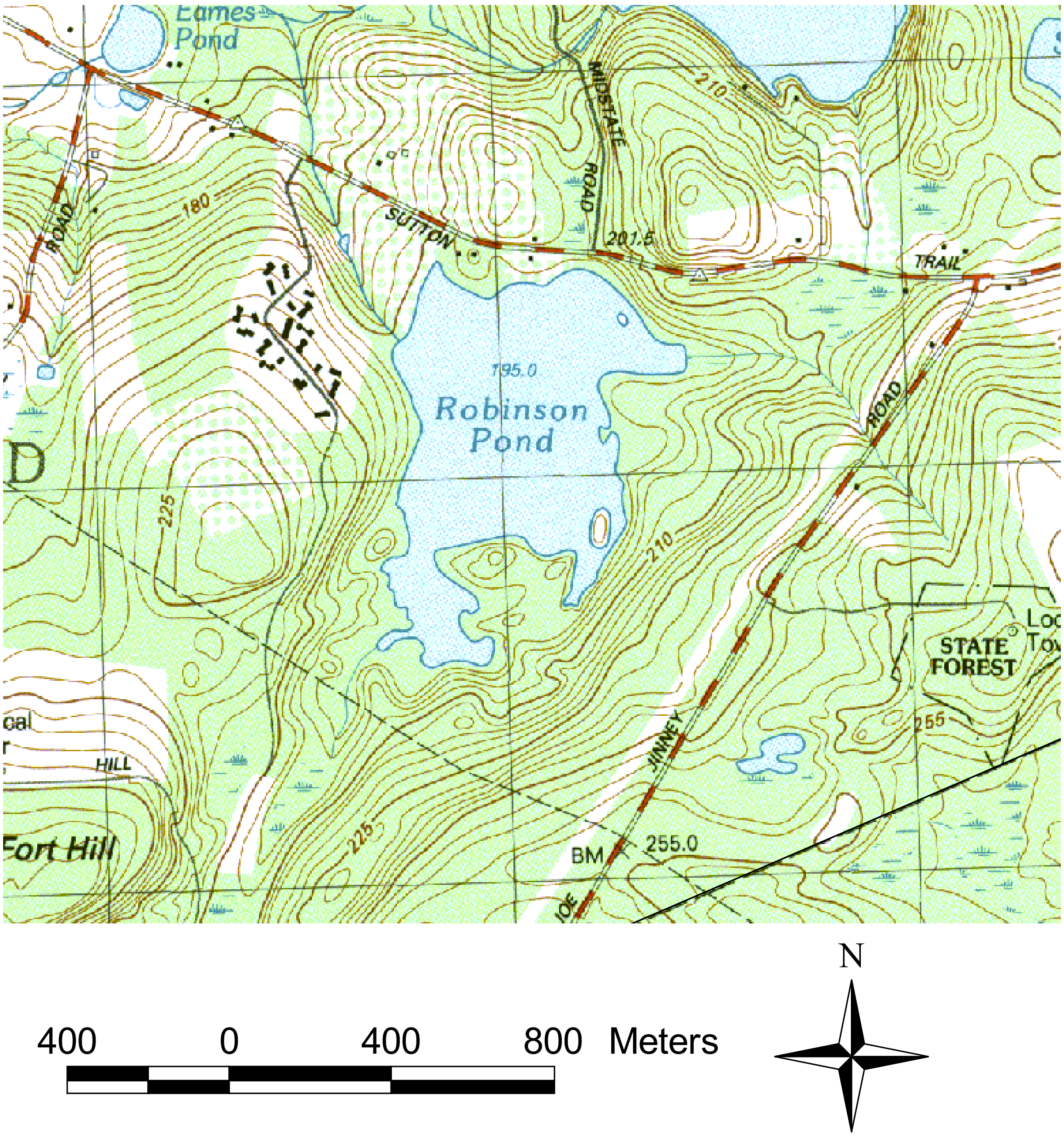

Figure 23. Robinson Pond Environs.

Rochdale Pond

in Leicester is a small reservoir of approximately 43 acres. The pond is located downstream of Greenville Pond and the Leicester WWTP (see above). The dominant landuses in the watershed are 69 percent forest, followed by 11 percent rural and about 9 percent urban land. Much of the rest of the watershed is occupied by agricultural landuse and only about 3 percent is water and wetlands. MassHighways Route 56 and a small section of Route 9 cross the watershed. The Pine Grove cemetery, the Tucker cemetery, a sand and gravel pit and several golf courses are within the watershed and an athletic field occupies much of the southern shore. Population in Leicester has been described above. DEP assessment comments reported: " Historically moderately high total phosphorus levels, severe oxygen depletion in the hypolimnion, and reports of bathing beach closures due to algal blooms. A 27 July 1994 DEP synoptic survey noted 50-75% aquatic macrophytes along the shoreline but most of surface free of impairing plants. *Myriophyllum* sp. (possibly *heterophyllum*) noted." The Army ACOE reported the average July Secchi reading for years 1998-2000 was 2.0 meters. A DEP baseline survey during the summer months of 1999 showed total phosphorus concentrations in the surface averaged 33 ppb and Secchi disk transparency averaged 2.2 m. Chlorophyll concentrations in Rochdale Pond ranged from 1 ppb to 17 ppb. The pond is only 3.4 meters deep and shows only weak stratification. The water is moderately colored (average apparent color of 51 PCU) which may reduce transparency to some extent. The lake exhibits a mix of open water habitat (in deeper areas) and dense to very dense vegetated areas in shallow waters. The dam at the outlet is part of a mill-factory complex that is still in operation.

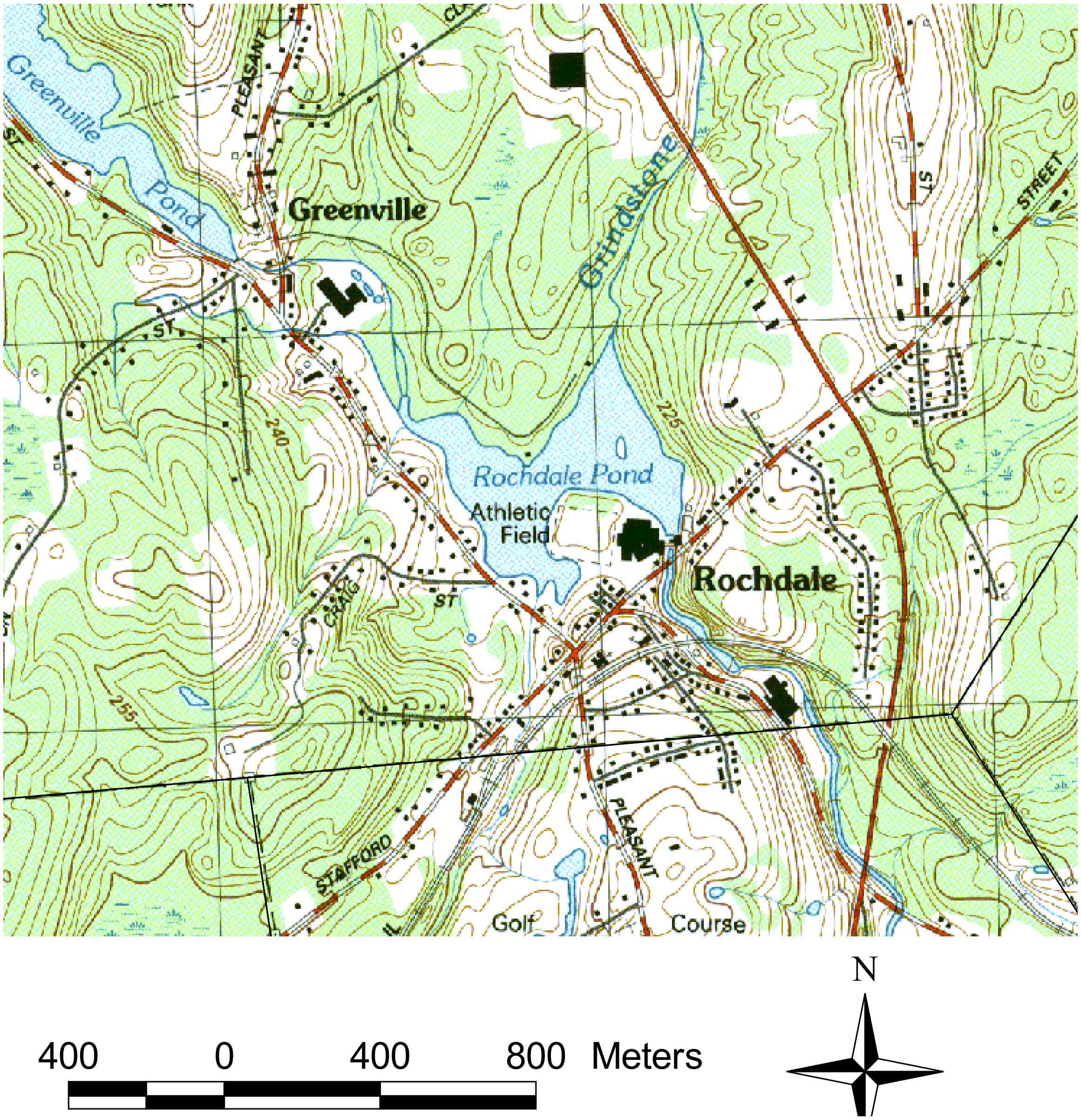

Figure 24. Rochdale Pond Environs

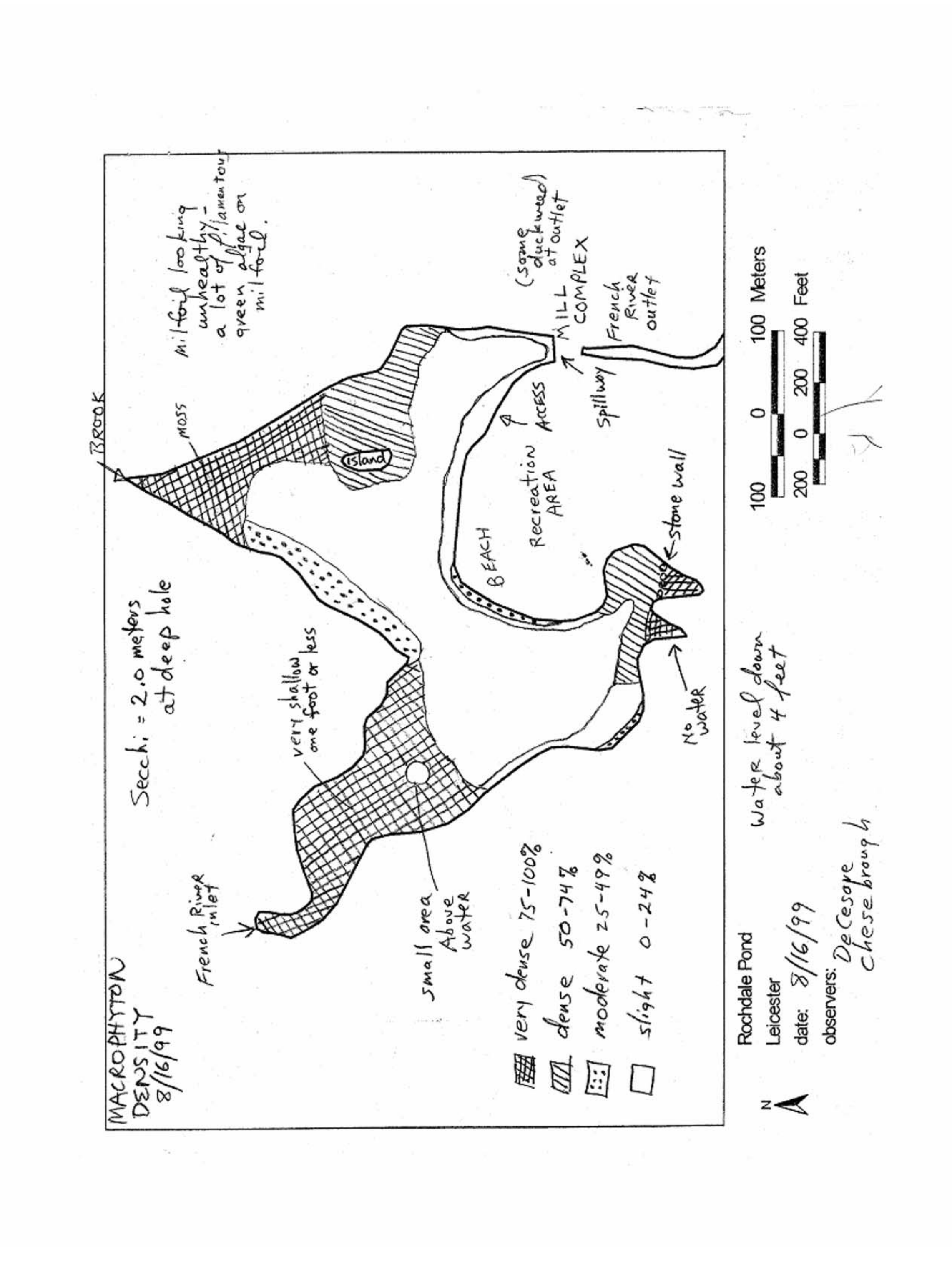

Figure 25. Rochdale Pond Macrophyte density distribution (1999).

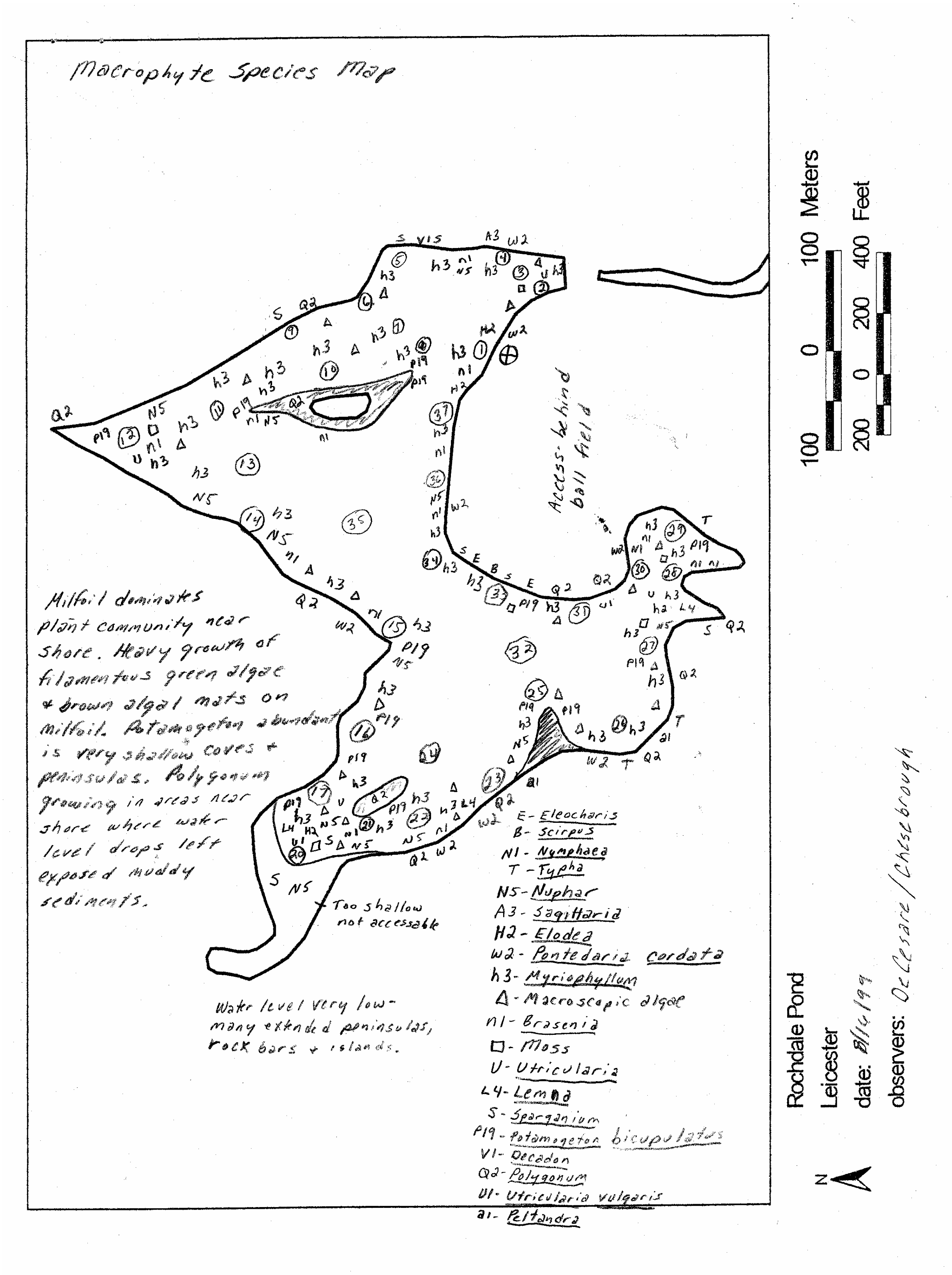

Figure 26. Rochdale Pond Macrophyte Species distribution (1999).

Shepherd Pond

in Dudley is a small pond of approximately 16 acres. The watershed is 68 percent forested. Water and wetlands account for about 14 percent. Approximately 12 percent of the watershed is employed in agricultural landuse and about 6 percent consists of rural landuse with areas of low density residential landuse. Population in Dudley has been described above. Shepherd Pond was assessed by DEP in the summer of 1994 and the assessment comments reported: " A 17 August 1994 synoptic survey indicates that there was 100% coverage of aquatic plants (mostly emergent plants). " Recent observations indicate the southern half of the pond appears to be covered by *Phragmites.*

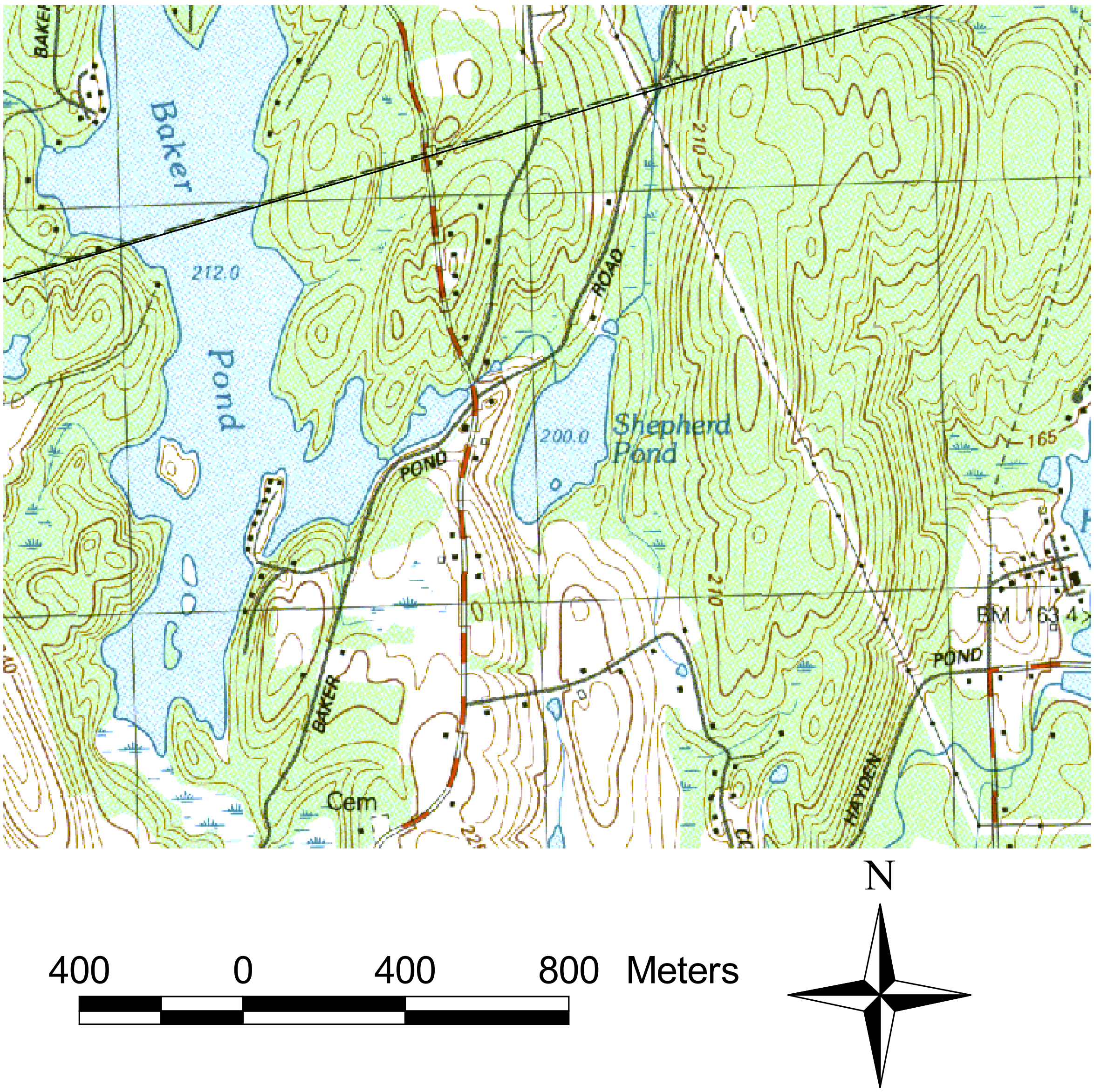

Figure 27. Shepherd Pond Environs.

Texas Pond

in Oxford is a small reservoir of approximately 28 acres. The dam has been breached, but a shallow reservoir remains. The pond is located downstream of the Oxford Rochdale WWTP (NPDES MA0100170) and is also below the Leicester WWTP noted above (see Dutton Pond). The dominant landuses in the watershed are 70 percent forest, followed by 10 percent agricultural and 9 percent rural landuse. Approximately 6 percent of the watershed consists of water and wetlands. High density residential land use accounts for about 3 percent and the remaining land is in commercial-industrial landuse that includes MassHighways Route 56, Route 20 and small sections of Route 9 and I-90. The Pine Grove cemetery, a sand and gravel pit and several golf courses are within the watershed. Population in Oxford has been described above. Texas Pond was assessed by DEP in the summer of 1994 and the assessment comments reported: " Very dense aquatic macrophyte growths cover the nearshore littoral zone around the entire pond. Historically very high total phosphorus levels and suspended solids reducing transparency to below the safety criteria (1.2 meters or 4 ft. Secchi disk)." The Army (ACOE) have monitored Secchi readings in July for several years. The average Secchi reading for years 1998-2000 was 1.4 meters.

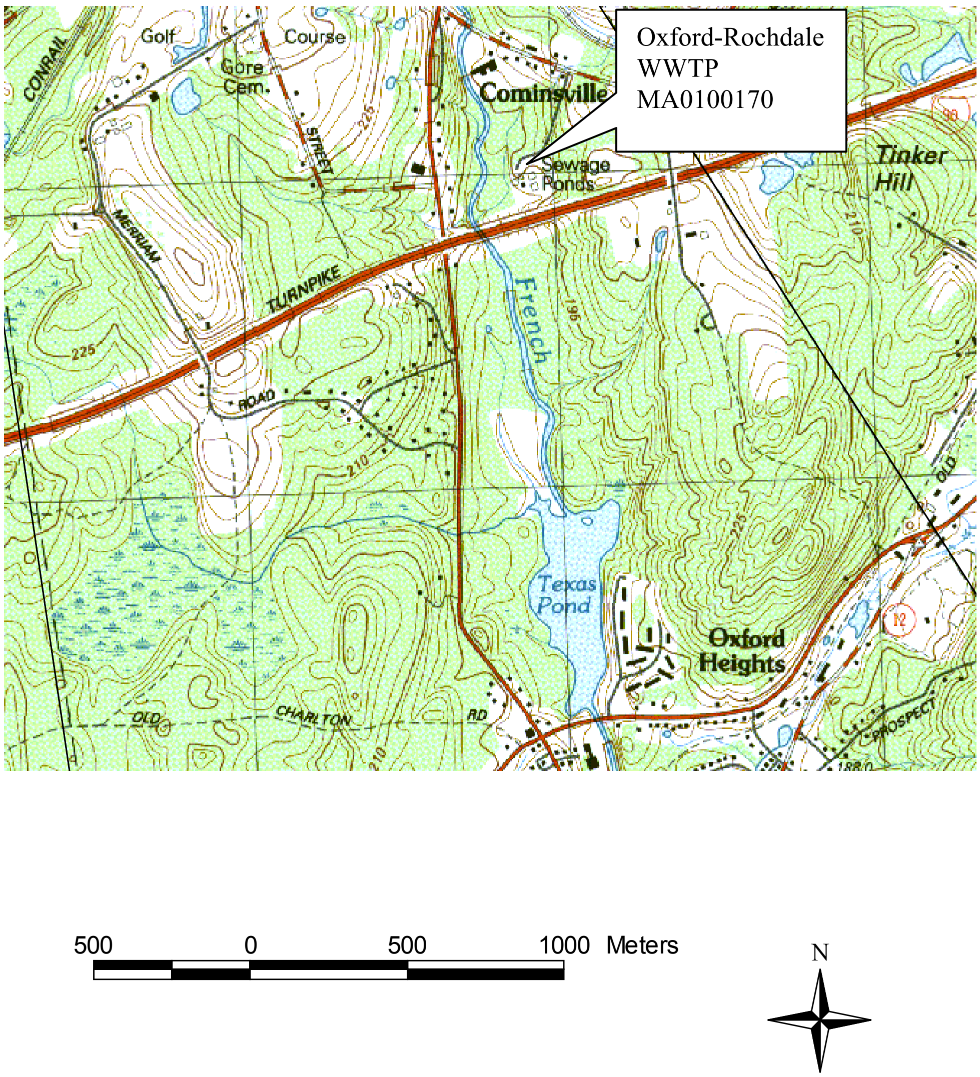

Figure 28 Texas Pond Environs with Oxford-Rochdale WWTP.

Tobins Pond

(a.k.a. Mosquito Pond) in Dudley is a small lake of approximately 11 acres. The dominant landuses in the watershed are 53 percent forest, followed by 24 percent agricultural and 8 percent urban land. About 7 percent of the watershed is water and wetlands. The remainder consists of rural land that includes some open land and low density residential landuse. Population in Dudley has been described above. Tobins Pond was assessed by DEP in the summer of 1994 and the assessment comments reported: " A 20 September 1994 synoptic survey indicates that 100% of the pond was covered with aquatic plants. There was a loss of open-water habitat."

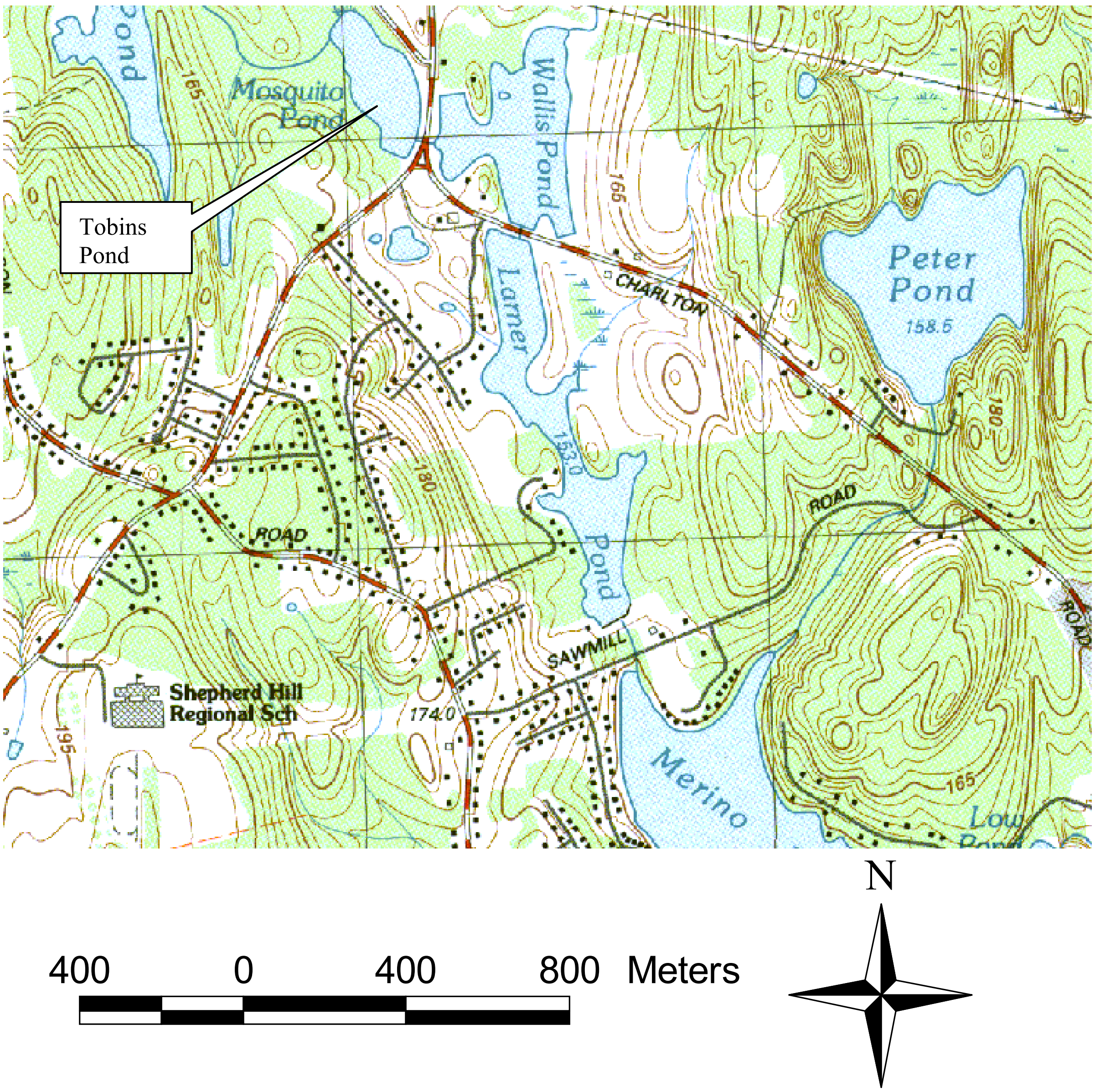

Figure 29. Tobins (Mosquito),Wallis, Larner Pond Environs.

Wallis Pond

in Dudley is a small lake of approximately 24 acres (see environs map above). The watershed is 58 percent forested and agricultural landuse accounts for 22 percent. Approximately 7 percent of the watershed is water and wetlands. The remainder consists of both rural and urban land with some open land and areas of low and high density residential land use. Population in Dudley has been described above. Wallis Pond was assessed by DEP in the summer of 1994 and the assessment comments reported: "A 30 September 1994 synoptic survey indicates that 100% of the pond was covered solid with aquatic plants. There was a loss of open-water habitat." A DEP baseline survey during the summer months of 1999 showed total phosphorus concentrations in the surface averaged 24 ppb and Secchi disk transparency was consistently below the 1.2 m standard and averaged 0.8 m. Chlorophyll concentrations in Wallis Pond ranged from less than 1 ppb to 3 ppb.

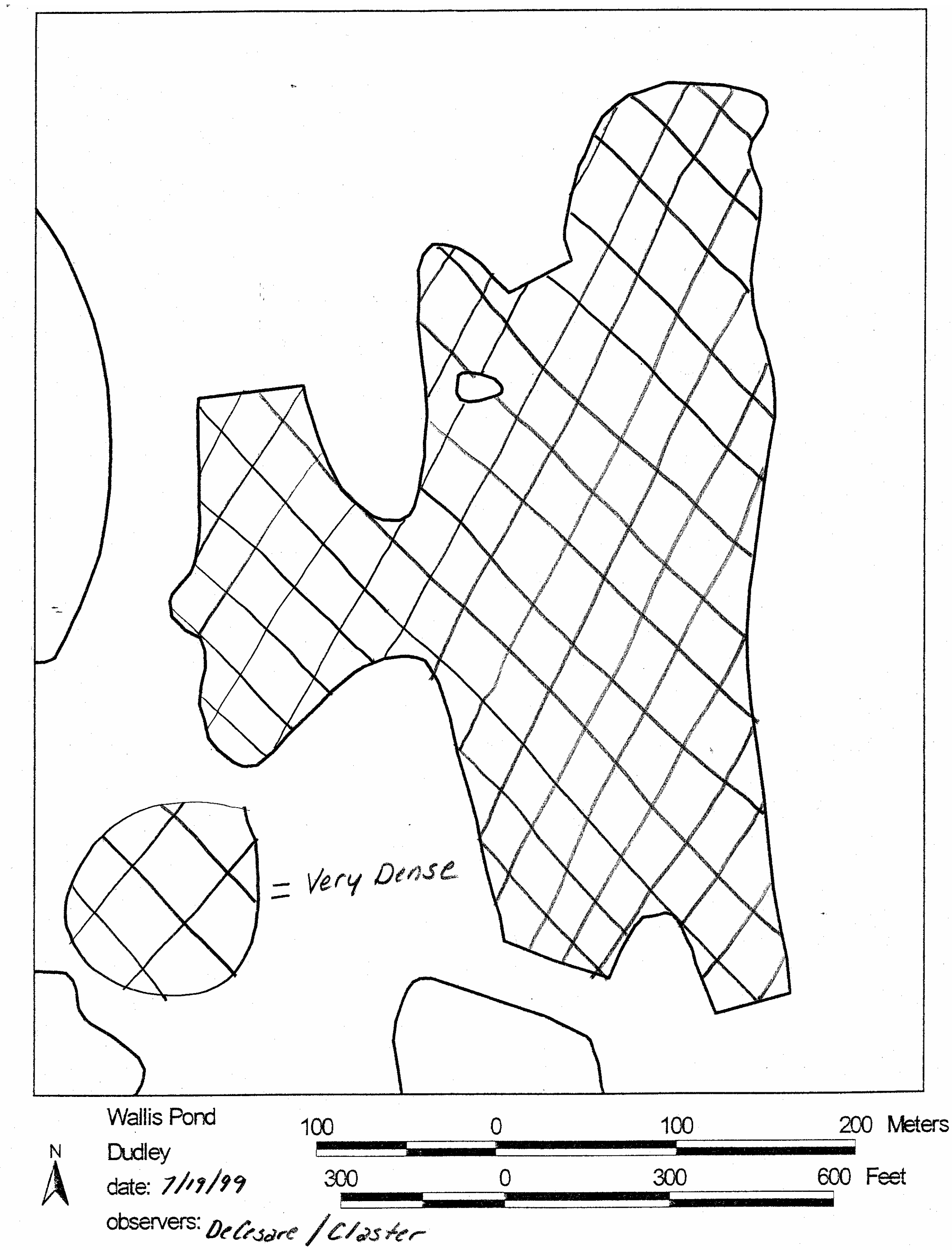

Figure 30. Wallis Pond Macrophyte density distribution (1999).

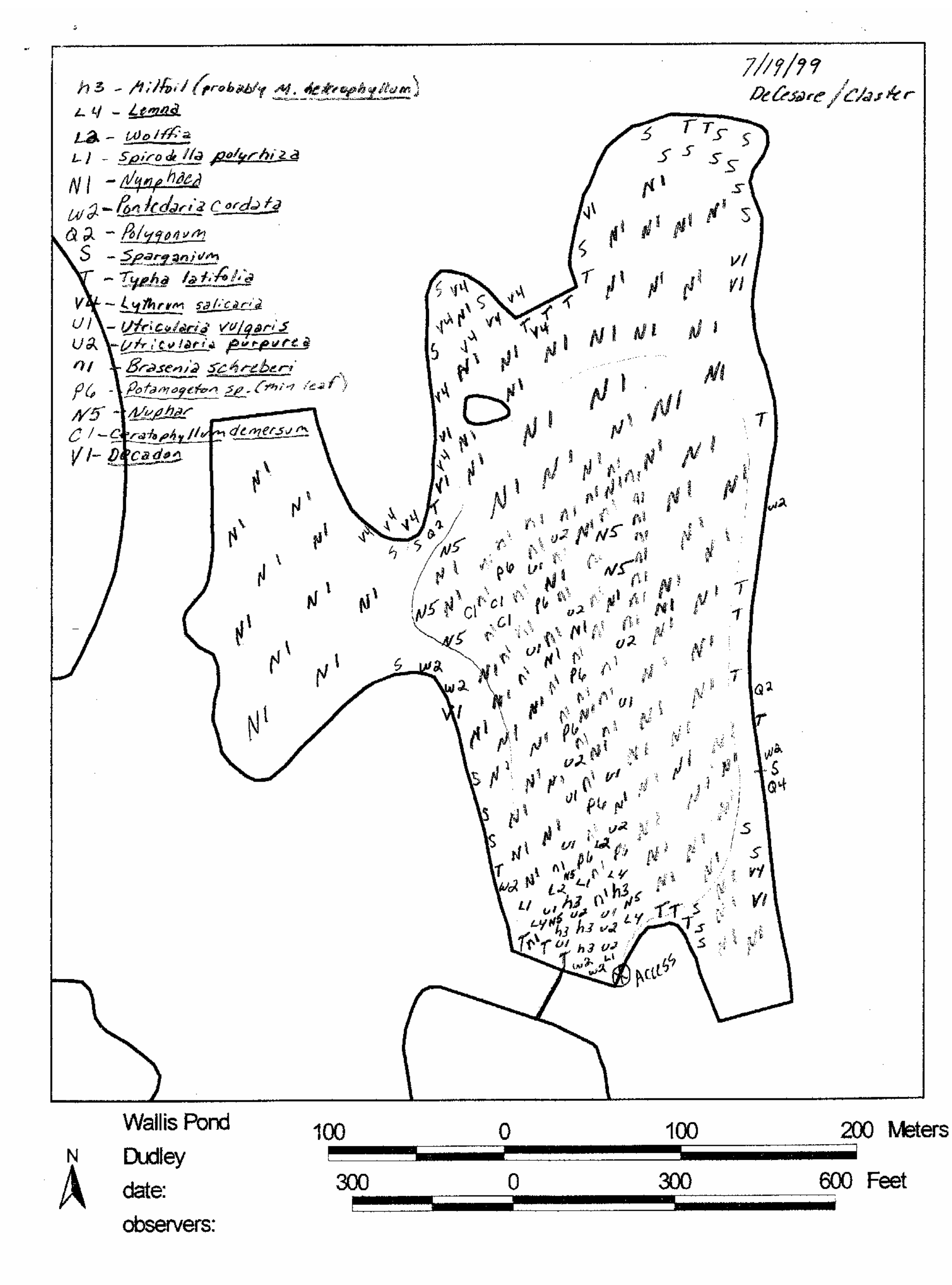

Figure 31. Wallis Pond Macrophyte Species distribution (1999).

Pollutant Sources and Background:

Unfortunately, no detailed study of the nutrient sources within the lake watersheds has been conducted to date. Thus, nutrient sources were estimated based on land use modeling within the DEP's NPSLAKE model as discussed below (Mattson and Isaac, 1999). The NPSLAKE model of Mattson and Isaac (1999) was designed to estimate watershed loading rates of phosphorus to lakes. The phosphorus loading estimates from the model are used with estimates of water runoff and these are used as inputs into a water quality model of Reckhow (1979). A brief description of the NPSLAKE model and data inputs is given here. MassGIS digital maps of land use (1985 or 1999 when available) within the watershed were used to calculate areas of landuse within three major types: Forest, rural and urban landuse. This model takes the area in hectares of land use within each of three categories and applies an export coefficient to each to predict the annual external loading of phosphorus to the lake from the watershed. Because some of the landuse data is based on old (1985) aerial photographs, the current landuses within the watershed may be different today. This can be important in the development of the TMDL because different landuses can result in different phosphorus loadings to the waterbody in question. For many rural areas, landuse changes often result in conversion of open or agricultural lands to low density housing, in which case, the export coefficients of the NPSLAKE model are the same and no change in loading is predicted to occur. However, in cases where development changes forests to residential areas or rural landuses to urban landuses, phosphorus loadings are predicted to increase. In some cases, loadings are predicted to decrease if additional agricultural land is abandoned and forest regrowth occurs. To account for this uncertainty in landuse changes, a conservative target is chosen (see below). In addition, the MassGIS landuse maps are scheduled to be updated with current aerial photos and the TMDL can be modified as additional information is obtained.

Other phosphorus sources, such as septic system inputs of phosphorus, are estimated from an export coefficient multiplied by the number of homes within 100 meters of the lake. Point sources are estimated manually based on discharge information and site specific information for uptake and storage. Other sources such as atmospheric deposition to lakes was determined to be small and not significant in the NPSLAKE model, perhaps because lakes tend to be sinks rather than sources of phosphorus (Mattson and Isaac, 1999). For similar reasons, wetlands were also not considered to be significant sources of phosphorus following (see discussion and references in Mattson and Isaac, 1999). Other, non-landuse sources of phosphorus such as inputs from waterfowl were generally not included (except as noted below), but can be added as additional information becomes available. If large numbers of waterfowl are using the lake the total phosphorus budget may be an underestimate, and control measures should be considered.

An internal source (recycling) of phosphorus is not included because it is not considered as a net external load to the lake, but rather a seasonal recycling of phosphorus already present in the lake. In cases where this internal source is large it may result in surface concentrations higher than predicted from landuse loading models and may contribute to water quality violations during the critical summer period. As additional monitoring data become available, these lakes will be assessed for internal contributions and possibly control of these sources by alum or other means. The major sources according to the land use analysis are shown for each lake in Appendix V.

The NPSLAKE model assumes land uses are accurately represented by the MassGIS digital maps and that land use has not changed appreciably since the maps were compiled in 1985. The predicted loading is based on the equation:

$$\text{P Loading (kg/yr)} = 0.5^{*}\ \text{septics} + 0.13^{*}\ \text{forest ha} + 0.3^{*}\ \text{rural ha} + 14^{*}\ (\text{urban ha})^{0.5}$$

The coefficients of the model are based on a combination of values estimated with the aid of multiple regression on a Massachusetts data set and of typical values reported in previous diagnostic/feasibility studies in Massachusetts. All coefficients fall within the range of values reported in other studies such as Reckhow et al., (1980). Further details on the methods, assumptions, calibration and validation of the NPSLAKE model can be found in Mattson and Isaac (1999). The overall standard error of the model is approximately 172 kg/yr. If no data is available for internal loading a rough estimate of the magnitude of this sources can be estimated from the Reckhow model (see below) by substitution of the in-lake concentration for TP. The difference in predicted loadings from this approach and the landuse approach is the best estimate of internal loading.

The NPSLAKE model also generates predictions of estimated yearly average water runoff to the lake based on total watershed area and runoff maps of Massachusetts (see Mattson and Isaac, 1999). Other estimates of nitrogen and total suspended solids (TSS) loading rates are estimates based on Reckhow et al.(1980) and EPA (1983) respectively, and are provided here for informational and comparison purposes only.

Because of the general nature of the landuse loading approach, natural background is included in land use based export coefficients. Natural background can be estimated based on the forest export coefficient of 0.13 kg/ha/yr multiplied by the hectares of the watershed assuming the watershed to be entirely forested. Without site specific information regarding soil phosphorus and natural erosion rates the accuracy of this estimate would be uncertain and would add little value to the analysis.

The results of the NPSLAKE model analysis for each pond are presented in tables in Appendix V. Also included are the model estimates of in-lake phosphorus concentrations and expected Secchi disk transparencies.

In the case of several ponds there is large amounts of stormwater runoff discharged from roadways administered by towns, Massachusetts Highway Department (MassHighways) or the Massachusetts Turnpike Authority (MassPike). The Massachusetts Highway Department, which is responsible for maintenance of state highways applies sand liberally during snow and ice storms to provide traction. Visual inspection of the roadway and discharge structures around selected lakes indicates periodic episodes of high flow and inadequate BMPs. Lake with stormwater contributions from MassHighways include: Buffumville Lake, Texas Pond and Rochdale Pond which have stormwater contributions from Routes 9, 20 and 56, and most notably, Lowes Pond, which is bisected by I-395. Similar problems exist along the MassPike (I-90), which is in close proximity to Pikes Pond. Many of the other ponds such as McKinstry Pond in Oxford have local roadways discharging stormwater into them.

In the case of Dresser Hill Pond, the default landuse classification resulted in extreme underestimates of current in-lake total phosphorus concentrations. One acre of what was considered farmland was actually a dairy farm that was apparently contributing phosphorus to the pond. Using the Reckhow et al. (1980) median estimate for phosphorus export for animal feedlot and manure storage of 224 kg/ha/yr, an additional input of 91 kg/yr of total phosphorus was added to the current loading (see other inputs in Appendix V). In turn, Gore Pond, which is downstream of Dresser Hill pond, was modified to include an additional 35 kg/yr input from the above mentioned dairy farm. This input was calculated by assuming the 91 kg/yr input to Dresser Hill Pond from the dairy farm was attenuated by plant and soil uptake in the wetland stream leading to Gore Pond. The attenuation factor of 62% was calculated from the one minus the ratio of the concentration in the stream inlet at Gore Pond to the concentration upstream at Dresser Hill Pond both taken on October 5, 1999 (see appendix). Thus, approximately 38% of the total phosphorus from the Dresser Hill Pond reaches Gore Pond and thus the 91 kg/yr was attenuated to a 35kg/yr input to Gore Pond (see Table 2d).

There were three active point sources within the watersheds of the lakes. These include the Leicester WWTP MA0101796 (operated by Leicester water supply), the Oxford/Rochdale Sewer MA0100170 and the Bay Path Vocational High School MA0026395. The Bay Path High School (in the Granite Reservoir watershed) recently ceased operation as it was tied into the Charlton WWTP (in the Quinebaug River Basin) on February 28, 2002. Point source total phosphorus discharges from the remaining two point sources were calculated from the most recent NPDES Discharge Monitoring Reports (DMRs). Calculations for loadings from the point sources are presented in Appendix III.

Water Quality Standards Violations:

In consideration that all lakes are listed are designated Class B waters under the Massachusetts Surface Water Quality Standards, the data listed above were judged sufficiently well documented to place the lake on the Massachusetts 303d list for 1998 (DEP, 1998) with Noxious Aquatic Plants listed for most lakes. Several lakes are also listed variously for the following impairments: nutrients, organic enrichment & low dissolved oxygen and turbidity (see Table 1 for complete list).

The Surface Water Quality Standards are described in the Code of Massachusetts Regulations under sections:

314CMR 4.04 subsection 5:
(5) Control of Eutrophication. From and after the date 314 CMR 4.00 become effective there shall be no new or increased point source discharge of nutrients, primarily phosphorus and nitrogen, directly to lakes and ponds. There shall be no new or increased point source discharge to tributaries of lakes or ponds that would encourage cultural eutrophication or the growth of weeds or algae in these lakes or ponds. Any existing point source discharge containing nutrients in concentrations which encourage eutrophication or growth of weeds or algae shall be provided with the highest and best practical treatment to remove such nutrients. Activities which result in the nonpoint source discharge of nutrients to lakes and ponds shall be provided with all reasonable best management practices for nonpoint source control.

and

> 314CMR 4.05 (3) b: "These waters are designated as a habitat for aquatic life, and wildlife, and for primary and secondary contact recreation...These waters shall have consistently good aesthetic value.
>
> 1. Dissolved Oxygen:
>   a. Shall not be less than 6.0 mg/l in cold water fisheries nor less than 5.0 mg/l in warm water fisheries unless background conditions are lower;
>   b. natural seasonal and daily variations above this level shall be maintained…

and

> 314CMR 4.05 (5) a: All surface waters shall be free from pollutants ......or produce undesirable or nuisance species of aquatic life".

Section 314 CMR 4.40(3) subsection 6 also states:

> 6. Color and Turbidity - These waters shall be free from color and turbidity in concentrations or combinations that are aesthetically objectionable or would impair any use assigned to this class.

In addition, the Minimum Standards for Bathing Beaches established by the Massachusetts Department of Public Health which state that swimming and bathing are not permitted at public beaches when:

> 105CMR 445.10 (2b) A black disk, six inches in diameter, on a white field placed at a depth of at least 4 feet of water is not readily visible from the surface of the water; or when, under normal usage, such disk is not readily visible from the surface of the water when placed on the bottom where the water depth is less than four feet….

TMDL Analysis

Identification of Target: There is no loading capacity *per se* for nuisance aquatic plants. As the term implies, TMDLs are often expressed as maximum daily loads. However, as specified in 40 CFR 130.2(I), TMDLs may be expressed in other terms when appropriate. For these cases, the TMDLs are expressed in terms of allowable annual loadings of phosphorus because the growth of phytoplankton and macrophytes responds to changes in annual rather than daily loadings of nutrients. The target in-lake total phosphorus concentration chosen is based on consideration of the typical concentrations expected in lakes in the region. The phosphorus ecoregion map of Griffith et al. (1994) is based on spring/fall concentrations, while the phosphorus ecoregion map of Rohm et al., (1995) is based on summer concentrations. Table 3 shows the ecoregion expected TP concentrations for both spring and summer, and the target TP that was chosen for each lake. The TP predicted by the NPSLAKE model and the surface TP concentrations are also shown for comparison. Note that according to the Carlson Trophic State analysis (Carlson,1977) a lake should have total phosphorus concentrations of about 40 ppb to meet the 4-foot transparency requirement for swimming beaches in Massachusetts. The target should be set lower than this to allow for a margin of safety. The lower phosphorus concentrations will lessen the chance of nuisance algal blooms, which may occur as macrophyte biomass is reduced by direct controls.

In the case of Dresser Hill Pond, the target was set higher than the ecoregion range due to the fact that this was an impoundment on a dairy farm. The target of 35 ppb will still allow the pond to meet the 4-foot visibility water quality criteria. Total phosphorus targets for Dutton Pond was also set at 35 ppb, because this is an extremely small "run-of-the-river" impoundment on the French River and no phytoplankton growth is expected. Greenville Pond, Rochdale Pond and Texas Pond were set at 25 ppb, somewhat higher than the ecoregion ranges because these ponds are also relatively small, run of the river systems with fast flushing rates. In all cases the targets are less than the 40 ppb generally expected to attain a 4-foot visibility standard.

Shallow nutrient rich sediments offer an ideal habitat for natural growth of aquatic macrophytes, which provide habitat for fish and wildlife and as such complete elimination of macrophytes is neither possible nor desired. In many cases, the proliferation of aquatic macrophytes in the pond is a natural condition resulting from nutrient rich riparian soils being flooded when streams and lakes were dammed for hydropower. Thus reducing the supply of external phosphorus may not meet the goals of the TMDL without additional management in the lake as discussed below.

Table 3 . TMDL Total Phosphorus Targets.

Griffith ecoregions are based on Griffith et al. (1994). Rohm ecoregions are based on Rohm et al., (1995). Latest surface total phosphorus concentrations are based on survey data (see text). Note: Early (pre-1990) survey TP concentrations have a detection limit of approximately 50 ppb, and values reported less than this are suspect.

WBID	Lake Name	TP (ppb) range in Griffith ecoregion	TP (ppb) range in Rohm ecoregion	NPSLAKE Predicted TP (ppb)	Surface TP data (ppb)	Selected Target TP (ppb)
MA42005	Buffumville Lake	15-19	10-14	21.8	NA	15
MA42009	Cedar Meadow Pond	15-19	10-14	18.8	NA	15
MA42014	Dresser Hill Pond	10-14	10-14	231.	200	35
MA42015	Dutton Pond	15-19	10-14	64.	NA	35
MA42018	Gore Pond	10-14	10-14	21.2	17.5	14
MA42019	Granite Reservoir	15-19	10-14	18	NA	15
MA42023	Greenville Pond	15-19	10-14	31.5	NA	25
MA42029	Hudson Pond	15-19	10-14	26.4	NA	15
MA42030	Jones Pond	15-19	10-14	18.6	NA	15
MA51150	Larner Pond	10-14	10-14	33.5	26	14
MA42034	Lowes Pond	15-19	10-14	30.8	NA	15
MA42035	McKinstry Pond	15-19	10-14	83.8	NA	15
MA42037	New Pond	10-14	10-14	27.4	20	14
MA42042	Peter Pond	10-14	10-14	10.2	200*	10
MA42043	Pierpoint Meadow Pond	10-14	10-14	21.5	NA	14
MA42044	Pikes Pond	15-19	10-14	25.3	NA	15
MA42047	Robinson Pond	10-14	10-14	13.8	NA	12
MA42048	Rochdale Pond	15-19	10-14	29.5	31.5	25

MA42051	Shepherd Pond	10-14	10-14	19.8	NA	14
MA42058	Texas Pond	15-19	10-14	33.3	NA	25
MA42060	Tobins Pond	10-14	10-14	40	NA	14
MA42062	Wallis Pond	10-14	10-14	32.7	24.5	14

*This historic TP result is suspect and should be rechecked.

Loading Capacity

Modeling Assumptions, Key Input, Calibration and Validation:
There are no numeric models available to predict the growth of rooted aquatic macrophytes as a function of nutrient loading estimates, therefore the control of nuisance aquatic plants is based on best professional judgment. However, as previously stated, the goal of the TMDL is to prevent future eutrophication from occurring, thus the nutrient loading still needs to be controlled. To control eutrophication, the Carlson Trophic State Index (TSI) (Carlson,1977) predicts a lake should have total phosphorus concentrations of about 40 ppb to meet the 4-foot transparency requirement for swimming beaches in Massachusetts and targets are set lower than this. Due to the lack of data on mean depth and other parameters, a simple water quality model was used to link watershed phosphorus loading to in-lake total phosphorus concentration targets. Based on the NPSLAKE model phosphorus loading output and predicted water runoff volumes, an estimated in-lake total phosphorus (TP) concentration was derived based on the Reckhow (1979) model:

$$TP=L/(11.6+1.2*q)*1000$$

where TP= the predicted average total phosphorus concentration (mg/l) in the lake.
L= Phosphorus loading in $g/m^2/yr$ (the total loading in grams divided by lake area in meters).
q= The areal water loading in m/yr from total water runoff in m^3/yr divided by lake area in m^2.

Similarly, by setting the TP to the target total phosphorus concentration, a target load was estimated by solving the equation above. As noted in Mattson and Isaac (1999) the Reckhow (1979) model was developed on similar, north temperate lakes and most Massachusetts lakes will fall within the range of phosphorus loading and hydrology of the calibration data set. Additional assumptions, and details of calibration and validation are given in Reckhow (1979).

Wasteload Allocations, Load Allocations and Margin of Safety:

For most lakes, point source wasteload allocation is zero since no point sources have been identified. For lakes with permitted point sources the loading is based on flow and concentrations reported in the DMR reports. The margin of safety is set by establishing a target that is below that expected to meet the 4-foot swimming standard (about 40 ppb). Thus, the TMDL is the same as the target load allocation to nonpoint sources as indicated in the right side of Table 4. Loading allocations are based on the NPSLAKE landuse modeled phosphorus budget. Note that some lakes have surface TP concentrations that are much larger than those predicted by the NPSLAKE. It is difficult to determine the cause of the discrepancy because only one data point was available for each lake and that one sample may not be representative of the lake. If further sampling confirms a discrepancy in these lakes, internal sources of phosphorus, such as the sediments, may also be a contributing source of phosphorus to the surface waters and should be considered for further evaluation and control.

Phosphorus loading allocations for each landuse category are shown (rounded to the nearest kg/yr) in the Tables 4a-4v. No reduction in forest loading is targeted, because other than logging operations, which are relatively rare and already have BMPs in place, this source is unlikely to be reduced by additional BMPs. The remaining load reductions are allocated as a proportional phosphorus loading reduction (except as noted below).

The TMDL is the sum of the wasteload allocations (WLA) from point sources (e.g., sewage treatment plants) plus load allocations (LA) from nonpoint sources (e.g., landuse sources) plus a margin of safety (MOS). Thus, the TMDL can be written as:

TMDL = WLA + LA + MOS

Four lakes have NPDES point source contributions. The Waste Load Allocations include the two NPDES point sources that are the Waste Water Treatment Plants (WWTP) for Leicester and for Oxford-Rochdale. Because of the relatively high total phosphorus loading from the Leicester WWTP into Dutton Pond, the treatment plant would be required to reduce loads by 75% with the resulting target WLA of 45 kg/yr during the summer months as shown in Table 4d(i), 4g(i), 4q(i) and 4s(i) below. A proposed option is to divert the discharge approximately 500 meters around Dutton Pond into the river just below the dam. This would eliminate the point source from consideration in the Dutton Pond TMDL. Such a diversion would result in slightly higher phosphorus loading to Greenville, Rochdale and Texas Ponds due to the elimination of phosphorus retention by Dutton Pond. However, such a diversion would allow the WWTP to meet the TMDL for Dutton Pond (bypassing it) and meet the TMDLs of the remaining downstream ponds (Greenville, Rochdale and Texas Ponds) with a smaller reduction in loading of 44% during summer months as shown in Tables 4d(ii), 4g(ii), 4q(ii) and 4s(ii) below. Note that the "current" loads shown in the aforementioned tables are calculated as if the Dutton diversion was in place, but under current phosphorus loading rate for the Leicester treatment plant. The plant could meet with the resulting target WLA of 100 kg/yr at the plant discharge assuming 0.35 MGD (million gallon per day) flows and 0.2 mg/l concentrations for total phosphorus. The Oxford-Rochdale WWTP NPDES can meet the requirements of the Texas Pond TMDL (138kg/yr at the plant during summer months) by reducing concentrations to 0.2 mg/l at currently permitted flow rates of 0.5 MGD. If the permit is written with monthly maximum phosphorus concentrations of 0.2 mg/l, actual loadings will be less assuming wastewater flows are less than permitted flows.

Table 4a. Buffumville Lake MA42005 TMDL Load Allocation.

Source	*Current TP Loading (kg/yr)*	*Target TP Load Allocation (kg/yr)*
Load Allocation		
Forest	577	577
Agriculture	141	59
Open Land	63	27
Residential (Low den.)	258	109
Septic System	0	0
Other	0	0
Waste Load Allocation		
Comm. Indust.	116	49
Residential (High den.)	98	41
Total Inputs	1253	862

Table 4b. Cedar Meadow Pond MA42009 TMDL Load Allocation.

Source	*Current TP Loading (kg/yr)*	*Target TP Load Allocation (kg/yr)*
Load Allocation:		
Forest	65	65
Agriculture	37	26
Open Land	7	5
Residential (Low den.)	15	11
Septic System	25	18
Other	0	0
Wasteload Allocation:		
Residential (High den.)	74	53
Comm. Indust.	21	15
Total Inputs	244	193

Table 4c. Dresser Hill Pond MA42014 TMDL Load Allocation.

Source	*Current TP Loading (kg/yr)*	*Target TP Load Allocation (kg/yr)*
Load Allocation:		
Forest	0.3	0.3
Agriculture	2.2	1.7
Open Land	0.0	0.0
Residential (Low den.)	0.0	0.0
Septic System	0.0	0.0
Dairy manure	91	12.0*
Wasteload Allocation:		
Residential (High den.)	0.0	0.0
Comm. Indust.	0.0	0.0
Total Inputs	93.5	14.0

*Dairy source to be reduced by 86 percent.

Table 4d(i). Dutton Pond MA42015 TMDL Load Allocation.

Source	*Current TP Loading (kg/yr)*	*Target TP Load Allocation (kg/yr)*
Load Allocation:		
Forest	72.	72.
Agriculture	23.	15.
Open Land	22.	14.
Residential (Low den.)	26.	17.
Septic System	0.	0.
Wasteload Allocation:		
Residential (High den.)	116.	75.
Comm. Indust.	14.	9.
NPDES MA0101796	179.	45.*
Total Inputs	452.	248.

*Assuming Leicester NPDES source MA0101796 to be reduced by 75 percent (April-October). To maintain permit flow at 0.35 MGD would require a phosphorus concentration limit of about 0.09 mg/l (see text).

Table 4d(ii). Dutton Pond MA42015 TMDL Load Allocation.

Source	*Current TP Loading (kg/yr)*	*Target TP Load Allocation (kg/yr)*
Load Allocation:		
Forest	72	72.0
Agriculture	23	20.1
Open Land	22	19.3
Residential (Low den.)	26	22.8
Septic System	0	0.0
Wasteload Allocation:		
Residential (High den.)	116	101.6
Comm. Indust.	14	12.3
NPDES MA0101796	179	0.0*
Total Inputs	452	248.0

*Assuming Leicester NPDES source MA0101796 is diverted (bypassed) around Dutton Pond.

Table 4e. Gore Pond MA42018 TMDL Load Allocation.

Source	*Current TP Loading (kg/yr)*	*Target TP Load Allocation (kg/yr)*
Load Allocation:		
Forest	47	47
Agriculture	20	14
Open Land	3	2
Residential (Low den.)	18	13
Septic System	22	15
Dairy manure	35	5*
Wasteload Allocation:		
Residential (High den.)	15	10
Comm. Indust.	0	0
Total Inputs	160	106

*Dairy source to be reduced by 86 percent.

Table 4f. Granite Reservoir MA42019 TMDL Load Allocation.

Source	*Current TP Loading (kg/yr)*	*Target TP Load Allocation (kg/yr)*
Load Allocation:		
Forest	184	184
Agriculture	56	40
Open Land	10	7
Residential (Low den.)	47	34
Septic System	71	51
Other	0	0
Wasteload Allocation:		
Residential (High den.)	57	41
Comm. Indust.	15	11
Total Inputs	440	369

Table 4g(i). Greenville Pond MA42023 TMDL Load Allocation.

Source	*Current TP Loading (kg/yr)*	*Target TP Load Allocation (kg/yr)*
Load Allocation:		
Forest	306	306.
Agriculture	94	77.
Open Land	46	38.
Residential (Low den.)	125	103.
Septic System	7	6.
Wasteload Allocation:		
Residential (High den.)	190	156.
Comm. Indust.	20	16.
NPDES MA0101796	141	35.*
Total Inputs	929	737.

*Assuming no Dutton diversion and Leicester NPDES source MA0101796 to be reduced by 75 percent (April-October).

Table 4g(ii). Greenville Pond MA42023 TMDL Load Allocation.

This table based on assumption that NPDES source MA0101796 is diverted to bypass Dutton Pond resulting in slightly more loading to Greenville Pond.

Source	*Current TP Loading (kg/yr)*	*Target TP Load Allocation (kg/yr)*
Load Allocation:		
Forest	306	306
Agriculture	94	68
Open Land	46	33
Residential (Low den.)	125	90
Septic System	7	5
Wasteload Allocation:		
Residential (High den.)	190	137
Comm. Indust.	20	14
NPDES MA0101796	150	84
Total Inputs	938	737

*Assuming Dutton diversion and Leicester NPDES source MA0101796 to be reduced by 44 percent (April-October). Load at plant of 100 kg/yr that can be achieved by permit flow at .35 MGD and concentration of 0.2mg/l =97 kg/yr.

Table 4h. Hudson Pond MA42029 TMDL Load Allocation.

Source	*Current TP Loading (kg/yr)*	*Target TP Load Allocation (kg/yr)*
Load Allocation:		
Forest	9	9
Agriculture	8	4
Open Land	0	0
Residential (Low den.)	4	2
Septic System	0	0
Other	0	0
Wasteload Allocation:		
Residential (High den.)	0	0
Comm. Indust.	21	10
Total Inputs	42	24

Table 4i. Jones Pond MA42030 TMDL Load Allocation.

Source	*Current TP Loading (kg/yr)*	*Target TP Load Allocation (kg/yr)*
Load Allocation:		
Forest	41	41
Agriculture	13	8
Open Land	2	1
Residential (Low den.)	4	2
Septic System	11	6
Other	0	0
Wasteload Allocation:		
Residential (High den.)	9	5
Comm. Indust.	0	0
Total Inputs	80	64

Table 4j. Larner Pond MA42068 TMDL Load Allocation.

Source	*Current TP Loading (kg/yr)*	*Target TP Load Allocation (kg/yr)*
Load Allocation:		
Forest	63	63
Agriculture	59	13
Open Land	9	2
Residential (Low den.)	10	2
Septic System	0	0
Other	0	0
Wasteload Allocation:		
Residential (High den.)	119	27
Comm. Indust.	0	0
Total Inputs	260	108

Table 4k. Lowes Pond MA42034 TMDL Load Allocation.

Source	*Current TP Loading (kg/yr)*	*Target TP Load Allocation (kg/yr)*
Load Allocation:		
Forest	130	130
Agriculture	82	20
Open Land	8	2
Residential (Low den.)	27	7
Septic System	5	1
Other	0	0
Wasteload Allocation:		
Residential (High den.)	114	28
Comm. Indust.	94	23
Total Inputs	460	212

Table 4l. McKinstry Pond MA42035 TMDL Load Allocation.

Source	***Current TP Loading (kg/yr)***	***Target TP Load Allocation (kg/yr)***
Load Allocation:		
Forest	3	3
Agriculture	0	0
Open Land	1	0
Residential (Low den.)	2	0
Septic System	12	2
Other	0	0
Wasteload Allocation:		
Residential (High den.)	65	10
Comm. Indust.	0	0
Total Inputs	83	15

Table 4m. New Pond MA42037 TMDL Load Allocation.

Source	***Current TP Loading (kg/yr)***	***Target TP Load Allocation (kg/yr)***
Load Allocation:		
Forest	35	35
Agriculture	38	10
Open Land	5	1
Residential (Low den.)	5	1
Septic System	10	3
Other	0	0
Wasteload Allocation:		
Residential (High den.)	90	24
Comm. Indust.	0	0
Total Inputs	183	74

Table 4n. Peter Pond MA42042 TMDL Load Allocation.

Source	***Current TP Loading (kg/yr)***	***Target TP Load Allocation (kg/yr)***
Load Allocation:		
Forest	10	10
Agriculture	0	0
Open Land	0	0
Residential (Low den.)	0.2	0.2
Septic System	2.5	2.5
Other	0	0
Wasteload Allocation:		
Residential (High den.)	14.3	14.3
Comm. Indust.	0	0
Total Inputs	27	27

Table 4o. Pierpoint Meadow Pond MA42043 TMDL Load Allocation.

Source	***Current TP Loading (kg/yr)***	***Target TP Load Allocation (kg/yr)***
Load Allocation:		
Forest	23	23
Agriculture	15	9
Open Land	0	0
Residential (Low den.)	6	4
Septic System	46	27
Other	0	0
Wasteload Allocation:		
Residential (High den.)	52	31
Comm. Indust.	0	0
Total Inputs	142	93

Table 4p. Pikes Pond MA42044 TMDL Load Allocation.

Source	***Current TP Loading (kg/yr)***	***Target TP Load Allocation (kg/yr)***
Load Allocation:		
Forest	180	180
Agriculture	63	13
Open Land	8	2
Residential (Low den.)	26	5
Septic System	0	0
Other	0	0
Wasteload Allocation:		
Residential (High den.)	26	5
Comm. Indust.	63	13
Total Inputs	366	217

Table 4q. Robinson Pond MA42047 TMDL Load Allocation.

Source	***Current TP Loading (kg/yr)***	***Target TP Load Allocation (kg/yr)***
Load Allocation:		
Forest	29	29
Agriculture	2	1
Open Land	3	2
Residential (Low den.)	6	5
Septic System	3	2
Other	0	0
Wasteload Allocation:		
Residential (High den.)	22	17
Comm. Indust.	0	0
Total Inputs	64	56

Table 4r(i). Rochdale Pond MA42048 TMDL Load Allocation.

Source	*Current TP Loading (kg/yr)*	*Target TP Load Allocation (kg/yr)*
Load Allocation:		
Forest	409	409
Agriculture	115	103
Open Land	71	63
Residential (Low den.)	153	136
Septic System	0	0
Wasteload Allocation:		
Residential (High den.)	235	209
Comm. Indust.	46	41
NPDES MA0101796	126	32*
Total Inputs	1155	993

*Assuming NPDES source MA0101796 to be reduced by 75 percent (April-October).

Table 4r(ii). Rochdale Pond MA42048 TMDL Load Allocation.

This table based on assumption that NPDES source MA0101796 is reduced to 0.2 mg/l TP, but discharge diverted to bypass Dutton Pond resulting in slightly more loading to Greenville Pond and Rochdale Pond.

Source	*Current TP Loading (kg/yr)*	*Target TP Load Allocation (kg/yr)*
Load Allocation:		
Forest	409	409
Agriculture	115	94
Open Land	71	58
Residential (Low den.)	153	126
Septic System	0	0
Wasteload Allocation:		
Residential (High den.)	235	193
Comm. Indust.	46	38
NPDES MA0101796	135	75
Total Inputs	1164	993

*Assuming Dutton diversion of NPDES source MA0101796 to be reduced by 44 percent (April-October).

Table 4s. Shepherd Pond MA42051 TMDL Load Allocation.

Source	*Current TP Loading (kg/yr)*	*Target TP Load Allocation (kg/yr)*
Load Allocation:		
Forest	51.1	51
Agriculture	20.3	8
Open Land	1.4	1
Residential (Low den.)	8.8	4
Septic System	0.5	0
Other	0	0
Wasteload Allocation:		
Residential (High den.)	14.7	6
Comm. Indust.	1.6	1
Total Inputs	98.4	70

Table 4t(i). Texas Pond MA42058 TMDL Load Allocation.

Source	*Current TP Loading (kg/yr)*	*Target TP Load Allocation (kg/yr)**
Load Allocation:		
Forest	449	449
Agriculture	123	81
Open Land	80	52
Residential (Low den.)	176	115
Septic System	0	0
Wasteload Allocation:		
Residential (High den.)	236	155
Comm. Indust.	65	43
NPDES MA0101796	99	25
NPDES MA0100170	173	130
Total Inputs	1401	1050

*Assumes Leicester NPDES source MA0101796 to be reduced by 75 percent (April-October) and Oxford-Rochdale NPDES MA0100170 to be reduced by 25 percent (April-October).

Table 4t(ii). Texas Pond MA42058 TMDL Load Allocation.

Source	*Current TP Loading (kg/yr)**	*Target TP Load Allocation (kg/yr)***
Load Allocation:		
Forest	449	449
Agriculture	123	75
Open Land	80	48
Residential (Low den.)	176	107
Septic System	0	0
Wasteload Allocation:		
Residential (High den.)	236	143
Comm. Indust.	65	39
NPDES MA0101796	107	59
NPDES MA0100170	173	130
Total Inputs	1409	1050

*Assumes Leicester NPDES sources MA0101796 to be diverted around Dutton.
**Assuming Dutton diversion of Leicester MA0101796 and discharge reduced by 44% and Oxford-Rochdale NPDES MA0100170 to be reduced by 25 percent (April-October).

Table 4u. Tobins Pond MA42060 TMDL Load Allocation.

Source	*Current TP Loading (kg/yr)*	*Target TP Load Allocation (kg/yr)*
Load Allocation:		
Forest	42	42
Agriculture	43	8
Open Land	6	1
Residential (Low den.)	7	1
Septic System	1	0
Other	0	0
Wasteload Allocation:		
Residential (High den.)	97	17

Comm. Indust.	0	0
Total Inputs	196	69

Table 4v. Wallis Pond MA42062 TMDL Load Allocation.

Source	***Current TP Loading (kg/yr)***	***Target TP Load Allocation (kg/yr)***
Load Allocation:		
Forest	59	59
Agriculture	52	12
Open Land	7	2
Residential (Low den.)	9	2
Septic System	0	0
Other	0	0
Wasteload Allocation:		
Residential (High den.)	97	22
Comm. Indust.	0	0
Total Inputs	224	96

Seasonality: As the term implies, TMDLs are often expressed as maximum daily loads. However, as specified in 40 CFR 130.2(I), TMDLs may be expressed in other terms when appropriate. For this case, the TMDL is expressed in terms of allowable annual loadings of phosphorus. Although critical conditions occur during the summer season when weed growth is more likely to interfere with uses, water quality in many lakes is generally not sensitive to daily or short term loading, but is more a function of loadings that occur over longer periods of time (e.g. annually). Therefore, seasonal variation is taken into account with the estimation of annual loads. In addition, evaluating the effectiveness of nonpoint source controls can be more easily accomplished on an annual basis rather than a daily basis.

For most lakes, it is appropriate and justifiable to express a nutrient TMDL in terms of allowable annual loadings. The annual load should inherently account for seasonal variations by being protective of the most sensitive time of year. The most sensitive time of year in most lakes occurs during summer, when the frequency and occurrence of nuisance algal blooms and macrophyte growth are usually greatest. Therefore, because the phosphorus TMDL was established to be protective of the most environmentally sensitive period (i.e., the summer season), it will also be protective of water quality during all other seasons. Additionally, the targeted reduction in the annual phosphorus load to lakes will result in the application of phosphorus controls that also address seasonal variation. For example, certain control practices such as stabilizing eroding drainage ways or maintaining septic systems will be in place throughout the year while others will be in effect during the times the sources are active (e.g., application of lawn fertilizer). In cases of rapidly flushing (less than 14 days) lakes or impoundments downstream of point sources it may be appropriate to set seasonal limits on phosphorus inputs based on the growing season (April-October). In such cases permit limits in the winter months could be relaxed (e.g. 1 mg/l total phosphorus), provided that permit limits on total suspended solids remain in effect.

Implementation

The major implementation will focus on the two waste water treatment plants and on storm water runoff from roads and urban areas. In conjunction with this TMDL the U.S. Environmental Protection Agency is developing new permit limits for both the Leicester and the Oxford-Rochdale treatment plants. Because of the reservoirs located downstream of both plants, the discharges will be required to at least meet the new "Highest and Best" treatment standard which limits phosphorus concentrations in the discharge water to 0.2 mg/l, at least during the growing season.

Due to the small watershed size and limited dilution at Dutton Pond, the Leicester WWTP could not meet the target TMDL unless further reductions, down to 0.09mg/l were imposed. As an alternative, it is proposed here to divert the Leicester discharge to a point below Dutton Pond. The diverted discharge of the Leicester WWTP, and the discharge of the Oxford-Rochdale WWTP would both be required to meet the 0.2mg/l phosphorus limit in order to meet the TMDL for the downstream ponds.

The dairy at Dresser Hill has already been sold to a nursery and thus, a major source of phosphorus has already been removed. An 86 percent reduction in loading from this source along with reductions in other agricultural sources, is expected to meet the TMDL for Dresser Hill Pond and improve conditions in other downstream ponds (e.g. Gore Pond). However, due to storage of adsorbed phosphorus in the soils in the vicinity the dairy, it is expected that some leaching of phosphorus will occur over the next few years. The pond has been treated with alum in past years but continued treatment over time will be required for the pond to meet the TMDL target of 35 ppb.

Implementation at McKinstry Pond will require further study to determine the major sources of phosphorus to the pond. A watershed survey is recommended for this pond.

For most lakes in this report there is a lack of information on discrete sources of phosphorus to the lake and thus the implementation plan will of necessity include an organizational phase, an information gathering phase, and the actual remedial action phase. Phosphorus sources cannot be reduced or eliminated until the sources of phosphorus are identified. Because many of the nutrient sources are not under regulatory control of the state, engagement and cooperation with local citizens groups, landowners, local officials and government organizations will be needed to implement this TMDL. The Massachusetts Department of Environmental Protection will use the Watershed Basin Team as the primary means for obtaining public comment and support for this TMDL. The proposed tasks and responsibilities for implementing the TMDL are shown in Table 5. The local citizens within the watershed will be encouraged to participate in the information gathering phase. This phase may include a citizen questionnaire (available on DEP website, inside cover) mailed to homeowners within the watershed to obtain information on use of the lake, identify problem areas in the lake and to survey phosphorus use and Best Management Practices (BMPs) in the watershed. The most important part of the information-gathering phase is to conduct a NPS lake watershed field survey to locate and describe sources of erosion and phosphorus within the watershed, following methods described in the DEP guidebook "Surveying a Lake Watershed and Preparing an Action Plan" (DEP, 2001). For this survey volunteers are organized and assigned to subwatersheds to specifically identify, describe and locate potential sources of erosion and other phosphorus sources by driving the roads and walking the streams. Once the survey is completed, the Basin Team will be asked to review and compile the data and make recommendations for implementation. Responsibility for remediation of each identified source will vary depending on land ownership, local jurisdiction and expertise as indicated in Table 6. For example, the lake association may organize a septic tank pumping program on a two to three year schedule for all lakeside homeowners. Usually a discount for the pumping fee can be arranged if a large number of homeowners apply together. Farmers can apply for money to implement BMPs as part of the NRCS programs in soil conservation. Town public works departments will generally be responsible for reducing sediment inputs from town roadways and urban runoff. The Conservation Commissions will generally be responsible for ensuring that BMPs are being followed to minimize erosion from construction within the town. A description of potential funding sources for these efforts is provided in the Program Background section, above.

The major implementation effort would take place during the year 2006 as part of a rotating 5-year cycle, but would continue in the "off years" as well. The major components for each lake will focus on the major sources of nutrients as summarized in Table 7. This will usually include urban BMPs in urban areas and septic system inspections and other rural BMPs in rural areas. Additional nutrient and erosion control will focus on enforcement of the Wetlands Protection Act by the local Conservation Commission and various best management practices supported by the National Resource Conservation Service (NRCS formerly SCS). Best Management Practices for logging are presented in Kittredge and Parker (1995) and BMPs for general nonpoint source pollution control are described in a manual by Boutiette and Duerring (1994), BMPs for erosion and sediment control are presented in DEP (1997). The Commonwealth has provided a strong framework to encourage watershed management through modifications to on-site septic system regulations under Title 5 and by legislation requiring low phosphorus detergents. All of these actions will be emphasized during the outreach efforts of the Watershed Team.

The Department is recommending that each lake be monitored on a regular basis and if the lake does not meet water quality standards, additional implementation measures may be necessary. For example, if phosphorus concentrations remain high after watershed controls are in place, then in-lake control of sediment phosphorus recycling may be considered.

As new housing development expands within the watershed, additional measures are needed to minimize the associated additional inputs of phosphorus. A proactive approach to protecting the lake may include limiting development, particularly on steep slopes near the lake, changes in zoning laws and lot sizes, requirements that new developments and new roadways include BMPs for runoff management and more stringent regulation of septic systems. Examples of town bylaws for zoning and construction, as well as descriptions of BMPs are presented in the Nonpoint Source Management Manual by Boutiette and Duerring (1994), that was distributed to all municipalities in Massachusetts. Other voluntary measures may include encouraging the establishment of a vegetative buffer around the lake and along its tributaries, encouraging the use of non-phosphorus lawn fertilizers and controlling runoff from agriculture and timber harvesting operations. Such actions can be initiated in stages and at low cost. They provide enhancements that residents should find attractive and, therefore, should facilitate voluntary implementation. The National Resource Conservation Service is an ideal agency for such an effort and the residents will be encouraged to pursue NRCS' aid.

Reducing the supply of nutrients will not in itself result in achievement of all the goals of the TMDL and continued macrophyte management must be considered in the implementation plan for each lake.

Table 5. Recommended Tasks and Responsibilities

Tasks	Responsible Group
TMDL development	DEP
Organization, contacts with Volunteer Groups	Watershed Team
Develop new NPDES permits for Leicester WWTP and Oxford-Rochdale WWTP	USEPA and DEP
Conduct loading study and develop methodology to calculate loadings from highways	MassHighway
Initiate twice yearly sweeping and catch basin inspection and cleaning program along I-395 (MassHighways) I-90 (MassPike) and other roadways (see text). Install additional BMPs as needed to address pollutant loadings identified above.	MassHighway, MassPike and local towns
Prepare stormwater management plan for Phase II.	MassHighways, MassPike and Towns of Charlton, Leicester and Oxford
Organize and implement NPS watershed field survey	Watershed Team and Local Volunteer Associations
Compile and prioritize results of NPS watershed surveys	Watershed Team and Local Volunteer Associations
Organize implementation; work with stakeholders and local officials to identify remedial measures and potential funding sources. Develop lake management plans	Watershed Team and Local Volunteer Associations and local Conservation Commission
Write grant and loan funding proposals	Towns, Planning Agencies, NRCS
Organize and implement education, outreach programs	Watershed Team and Local Volunteer Associations and local Conservation Commission
Implement remedial measures for discrete NPS pollution	See Table 4 below.
Include proposed remedial actions in the Watershed 5-year Action Plan	Watershed Team
Provide periodic status reports on implementation of remedial actions to DEP	Watershed Team
Monitoring of lake conditions	DEP (year 2 of cycle) and Local Volunteer Associations

Table 6. Guide to Nonpoint Source Control of Phosphorus and Erosion

Type of Pollution	Whom to Contact	Types of Remedial Actions
Agricultural		
Erosion from Tilled Fields	Landowner and NRCS	Conservation tillage (no-till planting); contour farming; cover crops; filter strips; etc.
Fertilizer leaching	Landowner and NRCS and UMass Extension	Conduct soil P tests; apply no more fertilizer than required. Install BMPs to prevent runoff to surface waters.
Manure leaching	Landowner and NRCS and UMass Extension	Conduct soil P tests. Apply no more manure than required by soil P test. Install manure BMPs.
Erosion and Animal related impacts	Landowner and NRCS	Fence animals away from streams; provide alternate source of water.
Construction, Resource Extraction		
Erosion, pollution from development and new construction.	Conservation Commission, Town officials, planning boards	Enact bylaws requiring BMPs and slope restrictions for new construction, zoning regulations, strict septic regulations. Enforce Wetlands Protection Act
Erosion at construction sites	Contractors, Conservation Commission	Various techniques including seeding, diversion dikes, sediment fences, detention ponds etc.
Timber Harvesting	Landowner, logger, Regional DEM forester	Check that an approved forest cutting plan is in place and BMPs for erosion are being followed
Gravel Pits	Pit owner, Regional DEP, Conservation Commission	Check permits for compliance, recycle wash water, install sedimentation ponds and berms. Install rinsing ponds.
Residential, urban areas		
Septic Systems	Homeowner, Town Board of Health, Town officials	Establish a septic system inspection program to identify and replace systems in non-compliance with Title 5. Discourage garbage disposals in septic systems.
Lawn and Garden fertilizers	Homeowner, Lake associations	Establish an outreach and education, eliminate P fertilizers on lawns, encourage perennial plantings.
Runoff from Housing lots	Homeowner, Lake associations	Divert runoff to vegetated areas, plant buffer strips between house and lake
Urban Runoff	Town or city Dept. Public Works	Implement Phase II Stormwater Runoff Program. Reduce impervious surfaces, institute street sweeping program, batch basin cleaning, install detention basins.
Highway Runoff	MassHighway, Mass Turnpike	Regulate road sanding, salting, regular sweeping, and installation of BMPs.
Unpaved Road runoff	Town or city Dept. Public Works	Pave heavily eroding roads, divert runoff to vegetated areas, install riprap or vegetate eroded ditches.
Other stream or lakeside erosion	Landowner, Conservation	Determine cause of problem; install riprap, plant vegetation.

	Commission

Table 7. Recommended Implementation by Lake

Recommended Implementation	Buffumvillle	Cedar Meadow	Dresser Hill	Dutton	Gore	Granite	Greenville	Hudson	Jones	Larner	Lowes	McKinstry	New	Peter	Pierpoint	Pikes	Robinson	Rochdale	Shepherd	Texas	Tobins	Wallis
Public Education	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
NPS Survey	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Lake Management Plan	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Forest BMPs	X					X			X							X	X		X			
Agriculture BMPs			X		X	X		X	X	X			X			X			X		X	X
Residential BMPs	X			X		X	X			X	X	X	X	X	X		X	X			X	X
Septic System Maintenance		X			X	X			X						X							
Urban stormwater BMPs		X		X			X				X				X			X				
Highway BMPs	X			X			X				X	X			X	X		X		X		
In-Lake Management			X		X				X	X		X										
Other (Gravel pits, athletic fields, see text)																		X				

Reasonable Assurances

Reasonable assurances that the TMDL will be implemented include both enforcement of current regulations, availability of financial incentives, and the various local, state and federal program for pollution control. Enforcement of regulations includes enforcement of the permit conditions for point sources (as well as Stormwater Phase II permits) under the National Pollutant Discharge Elimination System (NPDES). Enforcement of regulations controlling nonpoint discharges include local enforcement of the states Wetlands Protection Act and Rivers Protection Act; the Title 5 regulations for septic systems and various local regulations including zoning regulations. Financial incentives include Federal monies available under the 319 NPS program and the 604 and 104b programs, which are provided as part of the Performance Partnership Agreement between DEP and the USEPA. Additional financial incentives include state income tax credits for Title 5 upgrades, low interest loans for Title 5 septic system upgrades, Clean Water Act State Revolving Fund (SFR) loans, and cost sharing for agricultural BMPs under the Federal NRCS program. Lake management grants are also provided by the State Department of Environmental Management Lakes and Ponds Program.

Water Quality Standards Attainment Statement

The proposed TMDL, if fully implemented, will result in the attainment of all applicable water quality standards, including designated uses and numeric criteria for each pollutant named in the Water Quality Standards Violations noted above.

Monitoring

Monitoring by DEP will be continued on a regular basis according to the five-year watershed cycle. Baseline surveys on the lake should include Secchi disk transparency, nutrient analyses, temperature and oxygen profiles and aquatic vegetation maps of distribution and density. At that time the strategy for reducing plant cover and reducing total phosphorus concentrations can be re-evaluated and the TMDL modified, if necessary. Additional monitoring by volunteer groups is encouraged.

Public Participation

A public meeting was announced by letter to town officials, wastewater treatment plant operators, lake associations and other interested parties. The public meeting was held April 30, 2002 at 6:30-9:00 pm at the ACOE Hodges Village Dam conference center in Oxford MA with 15 people in attendance (see Appendix V).

Public Comment and Reply

Public comments were received at the public meeting and three sets of comments were received in writing within a 15-day comment period following the public meeting. Comments (combined and edited for clarity in some cases) and the DEP responses are summarized below.

1) **Comment:** It appears that the limits that have been set for the LWSD WWTP point source in the report are purely arbitrary. It also appears that the new limits have no relationship to the current phosphorus removal practices at the existing WWTP. The report indicates on page 60, that The LWSD can either treat to 0.09 mg/l TP or pump around Dutton Pond and treat to 0.2 mg/l TP. Currently the LWSD WWTP removes over 90% of the influent wastewater phosphorus. Most of the WWTP influent phosphorus originates from the addition of water system corrosion control chemicals to limit the quantity of lead and copper that leaches into the communities drinking water. A further reduction in the WWTP discharge levels of TP does not seem to be justified. It would be far more effective to reduce the phosphorus generated from other basin sources before further work is performed at the WWTP.

   Reply: Under the Federal Clean Water Act, we are required to develop Total Maximum Daily Loads for waters that do not meet the State's Water Quality Standards. The lakes downstream of the treatment plant do not meet the standards. The TMDL was developed based on the best available data and the most appropriate scientific model. The discharge limits to meet the TMDL are also in agreement with the Surface Water Quality Standards 314CMR 4.04(5) which state the "highest and best practicable treatment" for nutrient control is required for point sources and that nonpoint sources of nutrients "shall be provided with all reasonable best management practices...". A concentration of 0.2 mg/l phosphorus has been considered as a reasonable and best practicable treatment level for point sources. Construction of a bypass around Dutton Pond is also presented as a reasonable option to consider. While phosphorus is often added as a corrosion control agent in drinking water supplies, alternatives to phosphorus should be considered. We will be considering all reasonable best management practices for nonpoint sources as part of our implementation plan.

2) **Comment:** The report indicates on page 68 that point source loads will be limited to 0.2 mg/l. It appears that the limit of 0.2 mg/l is again an arbitrary limit. The LWSD requests that the MADEP provide the

District with data to substantiate the effluent phosphorus limit of 0.2 mg/l. The District also requests that the NPDES limits for TP for the facility be specified as pounds of TP per day in the discharge permit.

Reply: Data for the TMDL are presented in the Appendices (also see Reply to Comment #1 above). We will pass on your request for pounds per day to the permit staff at EPA and DEP.

3) **Comment:** The report indicates that the study is focusing on the point sources and storm water run off from roads and urban areas. It appears that the study is concentrating on these phosphorous generators because they are easy to identify and can be controlled either through the NPDES permit process or storm drain control measures. Control of these sources to these levels needs to be justified.

Reply: When forests are excluded as a "pollution" source (see reply to Comment #6 below), stormwater runoff and point sources are often the major contributors to nutrients to lakes and thus they are targeted for reductions. In most cases the percentage reductions are equal for the various landuses. In cases where specific agricultural sources are identified (e.g. dairies) we do target them for BMPs.

4) **Comment:** Page 59 indicates that the TMDL includes a factor for a "margin of safety." However, the value of this factor is not identified in the report. The factor that was used for a "margin of safety" needs to be identified.

Reply: As noted on page 13, the margin of safety can be either specifically included and/or included in the selection of a conservative target. As stated on page 58, DEP chose a conservative target for each lake that was below the 40 ppb total phosphorus concentration estimated to meet the 4-foot visibility standard for swimming beaches.

5) **Comment:** Page 75 discusses the base line surveys that were performed to develop the TMDLs. It appears that no sampling was actually performed for Dutton Pond or Greenville Pond or Texas Pond. It appears that the reduction in phosphorus for this area of the French basin are "computer" generated. If the wastewater treatment plants were required to reduce their effluent TP, it would seem that it should be based on actual river/pond sampling data.

Reply: The NPSLAKE model predicts loads and conditions in the lake, but these conditions and concentrations are supported by available data, collected from several lakes over a period of several years. As noted in the report, Dutton Pond was assessed in 1994 by DEP when it was noted that there was excessive brown/green turbidity, algal blooms and poor transparency (estimated at less than the 4 foot standard). This indicates severe eutrophication problems with the lake. The 1994 survey of Greenville Pond also noted moderate turbidity and a bluegreen bloom present both of which are indicators of eutrophication. As noted above, the Baseline survey for Rochdale Pond conducted in 1999 also noted low transparency and relatively high total phosphorus levels ranging between 28 and 37 ppb with an average of 33 ppb, in good agreement with the NPSLAKE model predictions of 29.5 ppb. Thus, the available evidence, data and model all agree on the conditions of high total phosphorus and resulting eutrophic conditions which result in the lakes downstream of the wastewater treatment plants not meeting the state water quality standards.

6) **Comment:** On page 60, the report indicates that the existing LWSD WWTP contributes 40% of the TP load to Dutton Pond. The data generated for the modified WWTP indicates that the LWSD WWTP will be required to reduce their contribution to 19%. The TP loads are unevenly distributed and it appears that the WWTP has been singled out as the source to be reduced the most of all the TP generators. This selection must be justified.

Reply: As noted in the report, some sources are more difficult to reduce. For example, forests may contribute a large absolute amount of total phosphorus per year, but they are the lowest land use exporters of phosphorus on a per acre basis because most forest intercept rainfall, prevent erosion and take up phosphorus as the forest grows. It is difficult to target forests for reductions unless there are significant logging operations causing erosion. Also, most of the form of the phosphorus contributed from forests is in a particulate form that is relatively unavailable for growth by algae and aquatic plants. The form of phosphorus discharged from wastewater treatment plants tends to be largely dissolved phosphorus which is highly available and is discharged directly, or nearly directly to the surface water with little chance for uptake and immobilization by soil and terrestrial or wetland plants. Thus discharges from wastewater treatment plants causes proportionately greater eutrophication impacts to the lake. For these reasons wastewater treatment plants are often the focus of proportionately larger reductions in phosphorus loading.

7) **Comment:** The report does not indicate how the non-point source contributions to the basin are going to be managed. Management of the non-point sources is the key to success of the TMDL program. The WWTPs could be forced to spend millions of dollars to reduce their TP load and without the reduction of the non-point sources, the program will not be successful. This must be justified.

Reply: The Implementation section of the report details the steps to be taken to reduce nonpoint sources of phosphorus. Table 5 includes a proposed task for organizing and implementing a nonpoint source lake watershed field survey. The Department has developed a Lake Watershed Survey Manual to be used for surveys to identify significant sources of phosphorus in the watershed and to target those for remediation. The Department has funded a lake watershed survey position within the Riverways section of the Department of Fish and Wildlife. The Department is also encouraging nonpoint source reductions by offering grant monies via several programs as noted in the report.

8) **Comment:** Page 44 of the report indicates that drainage from several golf courses is directed to the subject ponds. It would seem that management of the fertilizers and phosphorus laden chemicals used at these facilities would be far a more cost effective means of lowering the TP levels in the French River in comparison to constructing new facilities at the LWSD WWTP.

Reply: We agree that reduction in fertilizer use is the most cost effective means to reduce phosphorus from this source. We will forward a copy of this report to the golf courses along with our brochures on fertilizer and turf grass management and refer the issue to the DEP Nonpoint Source Coordinator for further action as needed.

9) **Comment:** The report indicates that the District maybe required to reduce their phosphorous load to the French River by 98%, while the District only contributes 8% of the load to Texas Pond. This unequal reduction of phosphorous needs to be justified by the DEP.

Reply: The primary impact of the Leicester WWTP is not on Texas Pond, which is furthest downstream, rather, the primary impact is on the ponds closest to the discharge, Dutton Pond and Greenville Pond. A relatively large reduction in loading from the WWTP is required in those ponds because of the relatively small watershed related lack of dilution by streamwater.

10) **Comment:** Dutton Pond is a 6-acre water body with an average depth of less than 10 feet. The dam on the pond is breached and the pond is not used for recreational purposes. Page 72 of the report indicates that the DEP will implement a program that includes public education, NPS surveys, a Lake Management Plan, residential BMP's, urban stormwater BMP's and highway BMP's relative to the pond. An expenditure of this magnitude for this type of water body needs to be justified.

Reply: The recommended implementation does not have to be limited to a single lake such as Dutton Pond but can be applied to many lakes as a "package". It would be more cost effective for towns to combine implementation for groups of nearby lakes and a single watershed survey, a general lake management plan and other BMPs could be implemented in the combined watershed. Many of these BMPs will be required as part of the new Phase II stormwater discharge permits in any case.

11) **Comment:** It was stated at the hearing that it is not known if a reduction of the input of phosphorous to the basin to the levels cited in the report will actually correct the eutrophication problems in the selected ponds in French River Basin. Better justification for the reduction in input levels of phosphorous levels needs to be provided.

Reply: We used the best available data and applicable models to estimate the current loads and reductions required to reach the target conditions. As noted in the report and related references, the overwhelming evidence from the scientific literature suggests reducing phosphorus to the low concentration levels will result in meeting standards for nuisance plant growth of algae and meeting the 4 foot visibility standard.

12) **Comment:** It appears that the limits that have been set for the ORSD WWTP point source in the report are purely arbitrary. It also appears that the new limits have no relationship to the current phosphorus removal practices at the existing WWTP. The report indicates on page 66, that a 25% reduction in the current effluent phosphorous level will be required to meet the TMDL goals for Texas Pond. Currently, the ORSD WWTP removes approximately 90% of the influent wastewater phosphorus. A further reduction does not seem to be justified since no one has done anything to reduce the other phosphorous loads to the basin. It may be far more effective to reduce the phosphorous generated from other basin sources.

Reply: See reply to Comment #1 above.

13) **Comment:** The report indicates on page 68 that point source loads will be limited to 0.2 mg/l. This does not translate into the 25% reduction that is only required on page 66 for Texas Pond for the ORSD facility. It appears that the limit of 0.2 mg/l is again an arbitrary limit. The Oxford-Rochdale Sewer District requests that the MADEP provide the District with data to substantiate the effluent phosphorous limit of 0.2 mg/l.

Reply: The 25% percent reduction is all that is required based on actual DMR flow data. The actual flow is currently only a fraction of the permitted flow (0.15 mgd vs 0.5 mgd). If the treatment plants wish to maintain the current higher permitted flow then further reductions in concentrations are required to comply with the TMDL. See also the reply to Comment #1 above.

14) **Comment:** The report does not indicate how the non-point source contributes to the basin are going to be managed. Since the phosphorous contribution from the ORSD WWTP to the basin is approximately 12% of the TP load, the District maybe forced to make improvements to the WWTP that could ultimately have no effect on the state of eutrophication in Texas Pond or the downstream water bodies. Making improvements to the ORSD WWTP needs to be justified.

Reply: See reply to Comment #7 above.

15) **Comment:** The report indicates that the District maybe required to reduce their phosphorous load to the French River by 75%, while the District only contributes 12% of the load to the stream. This unequal reduction of phosphorous needs to be justified by the DEP.

Reply: The percentage reduction in loading required to meet the TMDL is not related to percent each source contributes to the total load. A small source and a large source can each be allocated similar percentage reductions in loadings.

16) **Comment:** ORSD requests that NPDES phosphorous levels for WWTPs be specified in pounds of total P per day and that the permit flow remain at 0.5 MGD.

Reply: We will pass on your request for pounds per day to the permit staff at EPA and DEP.

17) **Comment:** As I have commented on the prior TMDL reports (for three Worcester-area lakes), this report sets forth an assumption that highways are significant contributors of phosphorus to receiving waters. To our knowledge, the majority of contaminants contained in highway runoff (especially in particulate form) are associated with the sand used during winter maintenance operations, which is assumed to contain only minor amounts of nutrients. These sands have relatively large particle sizes, with correspondingly low surface area that would serve as phosphate adsorption sites. However, conditions may vary from highway to highway. This is one of the reasons that MassHighway is working toward developing a research study

that would collect stormwater data and develop a contaminant loading model for highway runoff (as you mentioned in Table 5, p.73 of French Basin Lakes TMDL Report).

Reply: While sand may be considered low in nutrients, high concentrations of nutrients are known to be associated with highway runoff in both dissolved form and associated with fine sediments that run off the roadway. A review of many highway runoff studies conducted by the Federal Highway Administration (FHWA) reported the Event Mean Concentration for suspended solids was 143 mg/l and that the EMC for PO_4-P was 0.435 mg/l (Driscoll et al., 1990). These levels that are not considered "minor amounts" as EPA generally recommends that phosphorus inputs to lakes be less than 0.050 mg/l. A USGS review of dozens of other reports also indicated substantial biological impacts from highway runoff (Buckler and Granato, 1999). There are many lane miles of both Interstate (I395) and state highways (e.g. Route 56) that drain directly to many of the ponds in the French Basin. In addition, nutrients are not the sole focus of pollutant runoff from MassHighways. Highway sand and other solids discharged from roadways are a pollution source that also contributes to infilling of wetlands and lakes

We are pleased that you have developed scope of work for further research on highway runoff. Unfortunately, the study as written does not currently address the parameters of concern associated with this and other TMDLs (total phosphorus, suspended solids, bedload sediments and bacteria). As previously discussed, DEP would be happy to work with you on a revised scope to address these issues from a statewide prospective. However, DEP cannot delay the development of the TMDLs any further. The Federal Clean Water Act, Federal regulations and EPA policy require us to complete the TMDLs based on best available evidence and that is basis for this TMDL. In order to implement the TMDL in the absence of loading information for specific highways and city streets, DEP has established a set of performance standards for maintenance of all roadways within the affected watershed.

18) **Comment:** MassHighway has very limited maintenance budgets and staff. The cost-effectiveness, and necessity of cleaning catch basins twice per year should be closely evaluated rather than arbitrarily set. Evaluation criteria include sediment accumulation rates, and phosphorus concentrations in catch basin sediments. For example, catch basins at the sag of a hill will accumulate sediments at a greater rate than those at the crest of a hill. MassHighway's approach to monitoring catch basins will be included in its NPDES Stormwater Management Plan (to be submitted to EPA on 3/10/03).

Reply: The twice-yearly schedule was based on best available literature, however DEP is willing to work with MassHighway to establish site-specific schedules.

19) **Comment:** MassHighway believes that the most cost-effective approach to improving stormwater quality is to focus on source control measures, rather than end-of-pipe BMPs. Two important examples include reducing winter road sand application rates, and stabilizing shoulder areas that erode onto road surfaces. Again, these measures will be described in the NPDES Stormwater Management Plan.

Reply: Your comment is noted.

20) **Comment: p.58, para.5** – This paragraph focuses on MassHighway roadways, and uses rather qualitative and subjective terms. These terms (and our corresponding questions/comments) are as follows:
"large amounts of stormwater runoff discharged" to several ponds. (What percentage of the total inflow do these discharges represent? The Report's language implies that MassHighway is primarily responsible for the lakes' impairment.)
MassHighway "applies sand liberally." (The implication is that the amounts are excessive. As of last winter season, MassHighway has been reducing its sand application rates.)
"Visual inspection … indicates periodic episodes of high flow and inadequate BMPs." (Were eroding banks observed? If so, should the conveyance channels be armored? Why were the BMPs inadequate? Were sand deposits observed?). Perhaps MassHighway's future stormwater loading model (mentioned above) will better quantify some of these terms.

Reply: Volumes of stormwater were not individually quantified in this study. Evidence of sand and other solids washing from the roadway into culverts leading to surface waters was observed in the French Basin. The BMPs (street sweeping in this case) appeared to be inadequate. However, DEP was working with MassHighways and

USGS on a project to quantify inflows from MassHighways to 303d listed surface waters. It is our understanding that MassHighways has declined to fund the proposed USGS study. We would like to know if funds will be made available for the USGS proposed work within the next year.

21) **Comment: p.73, Task 5**. As described above, MassHighway has very limited maintenance budgets. MassHighway is developing a realistic Operation and Maintenance approach to its road system – which will be incorporated into our NPDES Stormwater Management Plan. MassHighway currently believes that, unless extraordinary conditions exist, that catch basins cannot be practicably cleaned more often than once every one or two years. (At present, MassHighway's road network contains approximately 83,000 catch basins.)

Reply: The availability of funding may help set priorities but does not relieve a community or an agency from achieving water quality goals. We are not targeting all 83,000 of MassHighways catch basins for twice yearly cleaning. We will however target catch basins and highway BMPs in watersheds of critical 303d listed waters.

22) **Comment: p.74, Table 6**. This table pertains to remedial actions for controlling phosphorus and erosion. Therefore any reference to "salting" should be omitted from the Remedial Actions for Highway Runoff. Also, "Better management of" should replace the term "Regulate," so as to avoid any confusion by the reader that actual laws will be promulgated which mandate specific maintenance requirements.

Reply: It is DEP's understanding that phosphorus is in some cases being added to roadsalt as a corrosion preventative agent. We would like to obtain further information from MassHighways about the phosphorus content of the salt and sand used before we modify the report.

23) **Comment:** In addition, under "Unpaved Road Runoff," we suggest that municipal DPWs pave heavily eroding roads – a condition that should be of paramount concern, and not only when a high number of vehicles are using the dirt road (which in and of itself may not create water quality problems).

Reply: The change in the text was made.

References

Carlson, R.E. 1977. A Trophic State Index for Lakes. Limnol. Oceanogr. 22(2):361-369.

Cooke, G.D., E.B. Welsh, S.A. Peterson, P.R. Newroth. 1993. Restoration and Management of Lakes and Reservoirs. 2nd Ed. Lewis Publishers. Boca Raton.

BEC. 1989. Diagnostic/Feasibility Study for the Management of Forge Pond, Granby, Massachusetts. Baystate Environmental Consultants, Inc. East Longmeadow, MA.

Boutiette, L.N.Jr., and C.L. Duerring. 1994. Massachusetts Nonpoint Source Management Manual. "The MegaManual" A Guidance Document for Municipal Officials. Mass. Dept. Environmental Protection., Boston, MA.

DEP. 1996. (Revision of 1995). Massachusetts Surface Water Quality Standards. . Mass. Dept. Environmental Protection, Division of Water Pollution Control, Technical Services Branch. Westborough, MA 114p. (Revision of 314 CMR 4.00 effective June 23, 1996).

DEP, 1997. Massachusetts Erosion and Sediment Control Guidelines for Urban and Suburban Areas. A Guide for Planners, Designers and Municipal Officials. Massachusetts Dept. Environmental Protection., EOEA, State Commission for Conservation of Soil, Water and Related Resources, Natural Resources Conservation Service USDA.

DEP, 1999. Massachusetts Section 303(d) List of Waters- 1998. Department of Environmental Protection, Division of Watershed Management, Worcester, MA.

DEP, DWM. 1998. Commonwealth of Massachusetts, Summary of Water Quality, 1998. Department of Environmental Protection, Division of Watershed Management, Worcester, MA.

DEP DWM, 1999a. Baseline Lake Survey Quality Assurance Project Plan. Massachusetts Department of Environmental Protection, Division of Watershed Management, Worcester, MA.

DEP, 2001. Massachusetts Volunteers Guide for Surveying a Lake Watershed and Preparing an Action Plan. Department of Environmental Protection, Boston MA.

Dillon, P.J. and F.H. Rigler. 1974. A test of a simple nutrient budget model predicting the phosphorus concentration in lake water. J. Fish. Res. Bd. Can. 31:1771-1778.

Griffith, G.E., J.M. Omernik, S.M. Pierson, and C.W. Kiilsgaard. 1994. Massachusetts Ecological Regions Project. USEPA Corvallis. Massachusetts DEP, DWM Publication No. 17587-74-70-6/94-D.E.P.

Holdren, C.W., W. Jones and J. Taggart. 2001. Managing Lakes and Reservoirs. N. Am. Lake Manage. Soc. And Terrene Inst. In coop. With Off. Water Assess. Watershed Prot. Div. U.S. Environ. Prot. Agency, Madison, WI.

Horne, A.J. and C.R. Goldman. 1994. Limnology. 2nd Ed. McGraw-Hill Inc. New York.

Kittredge, D.B., Jr. and Parker, M. 1995. Massachusetts Forestry Best Management Practices Manual. Mass. Dept. Environmental Protection. Office of Watershed Management and U.S.E.P.A. 56pp.

Likens, G.E. 1972. Nutrients and Eutrophication.: The Limiting-Nutrient Controversy. Limnology and Oceanography, Special Symposia Volume I. 328pp.

Mattson, M.D., P.J. Godfrey, R.A. Barletta and A. Aiello. 1998. Draft Generic Environmental Impact Report. Eutrophication and Aquatic Plant Management in Massachusetts. Massachusetts Department of Environmental Protection and Massachusetts Department of Environmental Management. 435 pp.

Mattson, M.D. and R.A. Isaac. 1999. Calibration of Phosphorus Export coefficients for Total Maximum Daily Loads of Massachusetts Lakes. Lake and Reservoir Man. 15(3):209-219.

Reckhow, K.H. 1979. Uncertainty Analysis Applied to Vollenweider's Phosphorus Loading Criteria. J. Water Poll. Control Fed. 51(8):2123-2128.

Reckhow, K.H., M.N. Beaulac, J.T. Simpson. 1980. Modeling Phosphorus Loading and Lake Response Under Uncertainty: A Manual and Compilation of Export Coefficients. U.S.E.P.A. Washington DC. EPA 440/5-80-011.

Rohm, C.M., J.M. Omernik, and C.W. Kiilsgaard. 1995. Regional Patterns of Total Phosphorus in Lakes of the Northeastern United States. Lake and Reservoir Man. 11(1): 1-14.

Schindler, D.W. and E.J. Fee. 1974. Experimental Lakes Area: Whole-Lake Experiments in Eutrophication. J. Fish. Res. Bd. Can. 31:937-953.

Snow, P.D., and F.A. DiGiano. 1976. Mathematical Modeling of Phosphorus Exchange Between Sediments and Overlying Water in Shallow Eutrophic Lakes. Sept. 1976 Report No. Env. E. 54-76-3, Envir. Eng. Dept. Civil Eng. Umass, Amherst, MA.

Vallentyne, J.R. 1974. The Algal Bowl – Lakes and Man. Ottawa, Misc. Spec. Publ. 22. Dept. of the Environ.. 185pp.

Vollenweider, R.A. 1975. Input-Output Models with Special Reference to the Phosphorus Loading Concept in Limnology. Sch. Zeit. Hydrologic 37:53-84.

Vollenweider, R.A. 1976. Advances in Defining Critical Loading Leveles for Phosphorus in Lake Eutrophication. Mem. Ist. Ital. Idrobiol., 33:53-83.

Wetzel, R.G. 1983. Limnology. 2nd Ed. Saunders College Publishing. New York.

Appendix I Baseline Lakes Data.

Selected Data from Appendix B of French & Quinebaug River Watersheds 2001 Water Quality Assessment Reports. L.E. Kennedy, S.Kiras, and R. McVoy. 2002. Dept. Environ. Protection, Division of Watershed Management, Worcester, MA.

BASELINE LAKE SURVEYS

Six of the 303d listed lakes in the French River Basin (31 confirmed and 1 needing confirmation in this basin) were selected for baseline surveys. Lakes were preferentially targeted for sampling based on the severity of the nutrient-related problem and the size of the lake (MA DEP 1999a). Those lakes that were listed solely for non-nutrient related issues (e.g., lakes listed for fish consumption advisories) and those with previous diagnostic/feasibility studies were not selected. Baseline surveys were conducted to provide information on the current chemical, physical and biological conditions of the lake system (i.e., in-lake and in the surrounding watershed).

Each baseline lake survey included a macrophyte survey conducted once during the late summer at the peak of macrophyte growth (generally in July/August/September). The survey data are used in several ways: 1) to determine if the macrophyte growth causes nuisance conditions such that the lake would be listed or delisted on the state's 303d list for violations of water quality standards; 2) to determine if the lake meets designed uses in the 305b assessments; 3) to monitor changes in density of plant growth following implementation of a TMDL; 4) to document invasive species distributions in the state; and 5) to suggest macrophyte management options for the lake. The data are used to validate Total Maximum Daily Load (TMDL) phosphorus loading models and to document the present trophic conditions as well as assessing the status of lake's designated uses. The total phosphorus data are used to evaluate accuracy of land use loading estimates (Mattson and Isaac 1999) of total phosphorus to lakes by comparing predictions of lake concentrations based on modeling to actual measured lake concentrations. These may be used as a basis for estimation of internal loading or other unmeasured phosphorus sources. Concurrently a lake database will be developed for both 303d development and for 305b evaluation based on lakes that are on the current 303d list. The data contained in this database along with the other data collected are used in TMDL development or to monitor lakes for changes in water quality and nuisance plant growth after TMDL implementation.

In the French River Basin, baseline lake surveys were conducted between July and October 1999 to coincide with maximum growth of aquatic vegetation, highest recreational use, and highest lake productivity. Lakes (Figure B2) were sampled three times each (monthly intervals).

- The deep hole in the northern quadrant of Gore Pond, Charlton and a second site in the approximate center of the southern quadrant of Gore Pond, Dudley were sampled 4-August, 1 September and 5 October 1999. Sampling of an unnamed northwestern tributary to Gore Pond, Dudley on 4-August 1999 was unsuccessful due to lack of water. This station was sampled for total phosphorous only on 5 October 1999.
- The deep hole of Larner Pond, Dudley was sampled 28 July, 26 August and 22 September 1999. A second site on Larner Pond (in the center of the lobe east of Wayne Avenue and Michael Lane, Dudley) was sampled for total phosphorous only 28 July 1999.
- The deep hole of Pierpoint Meadow Pond, Dudley was sampled 4-August, 1 September and 5 October 1999.
- The deep hole of Rochdale Pond, Leicester was sampled 5-August, 2 September and 28 September 1999.
- The deep hole of Wallis Pond, Dudley was sampled 28 July, 26 August, and 22 September 1999.

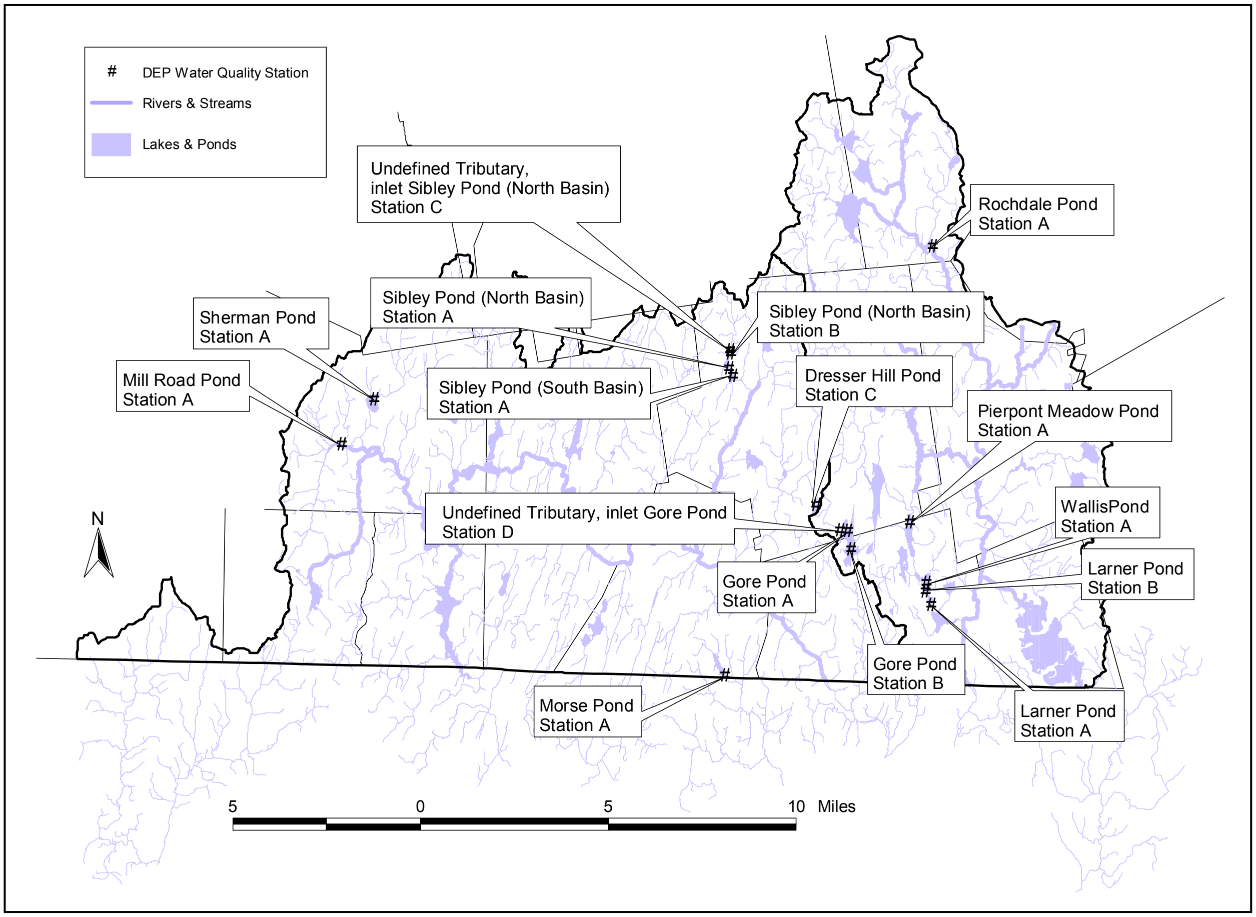

Figure B2. Locations of 1999 TMDL sampling stations in the French & Quinebaug River Basins.

In situ measurements using the Hydrolab® (measures dissolved oxygen, water temperature, pH, conductivity, and depth and calculates total dissolved solids and % oxygen saturation) were recorded. At deep hole stations measurements were recorded at various depths creating profiles. In-lake (as well as unnamed tributary) samples were also collected for alkalinity, total phosphorus, apparent color, and chlorophyll *a* (an integrated sample). Procedures used for water sampling and sample handling are described in the *Grab Collection Techniques for DWM Water Quality Sampling Standard Operating Procedure* and the *Hydrolab® Series 3 Multiprobe Standard Operating Procedure* (MA DEP 1999b and MA DEP 1999c). The Wall Experiment Station (WES), the Department's analytical laboratory, supplied all sample bottles and field preservatives, which were prepared according to the WES *Laboratory Quality Assurance Plan and Standard Operating Procedures* (MA DEP 1995). Samples were preserved in the field as necessary, transported on ice to WES, and analyzed according to the WES Standard Operating Procedure (SOP). The quality control protocol that was followed for field and equipment blank samples is described in Appendix I of this report. Both quality control samples (field blanks, trip blanks, and split samples) and raw water quality samples were transported on ice to WES on each sampling date; they were subsequently analyzed according to the WES SOP. Information about data quality objectives (accuracy, precision, detection limits, holding times, representativeness and comparability) is also presented in Appendix I. Apparent color and chlorophyll *a* were measured according to standard procedures at the DEP DWM office in Worcester (MA DEP 1999d and MA DEP 1999e). An aquatic macrophyte survey was conducted at each lake. The aquatic plant cover (native and non-native) and species distribution was mapped and recorded. Details on procedures used can be found in the *Baseline Lake Survey Quality Assurance Project Plan* (DEP DWM 1999a).

The *in-situ* Hydrolab® lake data are provided in Table B13. Alkalinity, total phosphorus, apparent color, chlorophyll *a*, and Secchi depth data are provided in Table B14. These data are managed and maintained in DWM's *Water Quality Data Access Database*.

Table B13. 1999 MA DEP DWM French & Quinebaug River Basins *in-situ* Hydrolab® lake data.

Date	OWMID	OWMID QA/QC	Time (24hr)	Depth (m)	Temp (°C)	pH (SU)	Cond @ 25 °C (µS/cm)	TDS (mg/l)	DO (mg/l)	SAT (%)
French River Basin										
Gore Pond (Baker Pond) (Palis: 42018)										
Station: A	**Description: deep hole in northern quadrant, Charlton**									
08/04/99	LB-0099		09:42	0.5	26.4	6.8	59.5	38.0	7.3	89
			09:49	1.5	26.1	6.8	59.3	38.0	7.2	87
			09:55	2.5	25.8	6.5	59.4	38.0	5.6 **u**	68 **u**
			10:00	3.5	22.1 **u**	6.0	59.1	37.9	<0.2	<2
			10:06	4.5	16.9 **u**	6.1	66.0	42.2	<0.2	<2
			10:13	5.5	13.3	6.6	104	66.8	<0.2	<2
09/01/99	LB-0505		14:13	0.5	22.9	6.6	58.8	37.6	7.9	89
			14:20	1.5	21.6	6.6	58.6	37.5	7.7	85
			14:27	2.5	21.4	6.5	58.4	37.4	7.5	82
			14:32	3.4	21.1	6.2	58.6	37.5	5.8 **u**	63 **u**
			14:41	4.0	20.2	5.9	58.5	37.4	0.6	6
			14:47	4.4	18.2	6.2	73.8	47.3	<0.2	<2
			14:53	5.5	14.4	6.5	121	77.5	<0.2	<2
10/05/99	LB-0402		11:23	0.5	16.0	6.5	59.4	38.0	8.3	82
			11:28	1.5	16.0	6.6	59.5	38.1	8.2	81
			11:33	2.6	16.0	6.6	59.7	38.2	8.2	81
			11:37	3.6	16.0	6.6	59.5	38.1	8.2	81
			11:42	4.6	16.0	6.6	59.7	38.2	8.2	81
			11:47	5.6	16.0	6.6	60.2	38.5	8.2	81
			11:52	6.0	15.7	6.5	59.1	37.8	7.9	78
Station: B	**Description: approximate center of southern quadrant, Dudley**									
09/01/99	LB-0506		15:41	2.6	20.2	6.0	56.9	36.4	6.0	64
10/05/99	LB-0499		12:47	0.5	14.7	6.2	53.5	34.2	7.5	72
			12:53	1.4	14.7	6.2	53.7	34.4	7.5	72
			13:00	2.6	14.6	6.2	53.7	34.4	7.5	72
Larner Pond (Palis: 42068)										
Station: A	**Description: deep hole, southern end near dam, Dudley**									
07/28/99	LB-0074	LB-0075	09:50	0.5	26.9	6.8	107	68.2	6.7	83
			09:56	1.5	26.8	6.8	107	68.2	6.7	83
			10:05	2.5	25.8	6.4	108	68.9	1.0 **u**	12 **u**
			10:14	2.9	24.8	6.4	115	73.3	<0.2	<2
	LB-0075	LB-0074	10:34	0.5	27.0	6.9	107	68.2	6.7	83
			10:40	1.5	26.9	6.9	107	68.3	6.8	84
			10:46	2.5	25.8 **u**	6.4	108	68.8	0.8	10
			10:51	2.9	24.7	6.4	114	72.7	<0.2	<2
08/26/99	LB-0219		11:00	0.5	23.0	7.0	108	69.3	8.3	95
			11:05	1.5	22.9	6.9	108	69.4	7.8	89
			11:10	2.5	21.7	6.6	107	68.7	4.7	53
			11:16	2.8	21.5	6.5	108	68.8	3.7	41
09/22/99	LB-0373		08:17	0.4	18.6	6.9	111	71.3	8.1	85
			08:22	1.5	18.6	6.8	112	71.4	7.9	84
			08:25	2.5	18.4	6.8	112	71.5	7.4 **u**	78 **u**
			08:29	3.0	18.1	6.6	111	71.1	6.1 **u**	64 **u**

" i " = **i**naccurate readings from Hydrolab® multiprobe likely; may be due to significant pre-survey calibration problems, post-survey calibration readings outside typical acceptance range for the low ionic check and for the deionized blank water check, or lack of calibration of the depth sensor prior to use.

“ **m** ” = **m**ethod not followed; one or more protocols contained in the DWM Hydrolab® SOP not followed, ie. operator error (eg. less than 3 readings per station (rivers) or per depth (lakes), or instrument failure not allowing method to be implemented.

“ **u** ” = **u**nstable readings, due to lack of sufficient equilibration time prior to final readings, non-representative location, highly-variable water quality conditions, etc. (See Section 4.1 for acceptance criteria.)

Table B13. Continued. 1999 MA DEP DWM French & Quinebaug River Basins *in-situ* Hydrolab® lake data.

Date	OWMID	OWMID QA/QC	Time (24hr)	Depth (m)	Temp (°C)	pH (SU)	Cond @ 25 °C (µS/cm)	TDS (mg/l)	DO (mg/l)	SAT (%)
French River Basin										
Pierpoint Meadow Pond (Palis: 42043)										
Station: A	**Description: deep hole south of Charlton/Dudley border, Dudley**									
08/04/99	LB-0098	LB-0100	13:41	0.5	27.7	7.1	66.3	42.4	7.5	93
			13:47	1.5	27.7	7.1	66.3	42.4	7.4	93
			13:50	2.5 **m**	27.2 **mu**	7.0 **m**	66.0 **m**	42.2 **m**	7.0 **m**	86 **m**
			13:54	2.8 **m**	26.9 **m**	7.0 **m**	66.2 **m**	42.4 **m**	7.0 **m**	85 **m**
	LB-0100	LB-0098	14:05	0.5	27.7	7.1	66.3	42.4	7.5	94
			14:11	1.5	27.7	7.1	66.3	42.4	7.5	94
			14:16	2.5	27.4	7.1	65.9	42.2	7.2 **u**	89 **u**
			14:26	2.8	27.0	7.0	65.8	42.1	6.9	85
09/01/99	LB-0503		10:40	0.5	22.5	7.0	65.4	41.9	8.2	92
			10:48	1.5	22.1	7.0	65.4	41.9	8.2	91
			10:55	2.5	22.1	6.9	65.5	41.9	7.9	88
10/05/99	LB-0393		09:43	0.4	16.3	6.9	60.9	38.9	8.8	88
			09:48	1.5	16.3	6.9	61.0	39.1	8.8	87
			09:53	2.5	16.3	6.9	61.3	39.2	8.8	88
			09:58	3.0	16.3	7.0	60.9	38.9	8.8	88
Rochdale Pond (Palis: 42048)										
Station: A	**Description: deep hole in southeastern quadrant near outlet, Leicester**									
08/05/99	LB-0109		13:14	0.5	26.6	7.0	137	87.6	7.1	88
			13:21	1.5	25.5	6.9	137	87.5	6.5	79
			13:28	2.5	24.0	6.6	137	87.9	5.7 **u**	67 **u**
			13:34	3.1	20.2 **u**	6.5	150	95.6	0.8	9
09/02/99	LB-0253		10:20	0.5	21.4	7.0	136	87.1	8.4	92
			10:28	1.5	21.2	6.9	136	87.3	8.0	88
			10:43	2.5	20.4	6.4	137	87.6	2.5	27
09/28/99	LB-0412		09:49	0.5	17.4	6.6	143	91.3	8.0	81
			09:56	1.5	16.7	6.4	143	91.4	6.5	65
			10:03	2.4	16.2	6.3	140	89.6	6.3	62
			10:10	3.4	15.8	6.2	150	96.0	3.3	32
			10:16	3.8	15.6	6.1	153	98.0	2.2	22
Wallis Pond (Palis: 42062)										
Station: A	**Description: deep hole, southern central lobe near dam, Dudley**									
07/28/99	LB-0068		08:17	0.4	23.2	6.0	114	73.1	0.2	3
08/26/99	LB-0213		10:04	0.3	20.2	6.2	169	108	0.8 **u**	9 **u**
09/22/99	LB-0368		10:14	0.1 **i**	17.6	6.1	109	69.7	3.0	31

Table B14. 1999 MA DEP DWM French & Quinebaug River Basins inlake Secchi depth, alkalinity, color, total phosphorus and chlorophyll *a* data.

Date	Time (24hr)	Secchi Depth (m)	Station Depth (m)	OWMID	OWMID QA/QC	Sample Depth (m)	Alkalinity (mg/l)	Apparent Color (PCU)	Total Phosphorus mg/l	Chlorophyll *a* (mg/m^3)
French River Basin										
Dresser Hill Pond (Palis: 42014)										
Station: C			**Description: northern shore of pond (near outlet), south off No 6 Schoolhouse Road, Charlton**							
08/04/99	**	0.4	**							
				LB-0092		**	--	--	0.25	--
09/01/99	**	**	**							
				LB-0247		0.1	59	60	0.16	--
10/05/99	**	>0.5	**							
				LB-0401		0.5	--	--	0.12	--
Gore Pond (Baker Pond) (Palis: 42018)										
Station: A			**Description: deep hole in northern quadrant, Charlton**							
08/04/99	9:30	2.1	6.1							
				LB-0090		0 - 5.5	--	--	--	35
				LB-0088		0.5	7.0	29	0.018	--
				LB-0089		5.5	18	170	0.10	--
09/01/99	14:12	2.6	6.1							
				LB-0245		** - **	--	--	--	1
				LB-0243		0.5	6.5	40	0.017	--
				LB-0244		5.5	27	160	0.14	--
10/05/99	12:20	3.2	6.1							
				LB-0396		0 - 6.0	--	--	--	<1
				LB-0394		0.5	7.0	48	0.019	--
				LB-0395		5.6	6.5	50	0.014	--
Station: B			**Description: approximate center of southern quadrant, Dudley**							
08/04/99	**	**	**							
				LB-0091		**	--	--	0.015	--
09/01/99	**	**	3.1							
				LB-0246		0.5	6.0	40	0.018	--
10/05/99	**	2.9	**							
				LB-0399		0 - 2.5	--	--	--	**m
				LB-0397		0.5	7.0	50	0.018	--
				LB-0398		2.5	5.5	55	0.016	--
Unnamed Tributary										
Station: D			**Description: northwest inlet of Gore Pond from downstream side of unnamed road which is southwest off of Baker Pond Road, Charlton**							
08/04/99	**	--	**							
				------------------------ *Not enough water to take sample*----------------------						-- --
		--				--				
10/05/99	**	--	**							
				LB-0400		0.5	--	--	0.046	--

" ** " = Censored or missing data

" -- " = No data

" b " = **b**lank Contamination in lab reagent blanks and/or field blank samples (indicating possible bias high and false positives).

" **d** " = precision of field **d**uplicates (as RPD) did not meet project data quality objectives identified for program or in QAPP; batch samples may also be affected

" **h** " = **h**olding time violation (usually indicating possible bias low)

" **m** " = **m**ethod SOP not followed, only partially implemented or not implemented at all, due to complications with sample matrix (e.g. sediment in sample, floc formation), lab error (e.g., cross-contamination between samples), additional steps taken by the lab to deal with matrix complications, and lost/unanalyzed samples.

" **p** " = samples not **p**reserved per SOP or analytical method requirements.

Table B14. Continued. 1999 MA DEP DWM French & Quinebaug River Basins inlake Secchi depth, alkalinity, color, total phosphorus and chlorophyll *a* data.

Date	Time (24hr)	Secchi Depth (m)	Station Depth (m)	OWMID	OWMID QA/QC	Sample Depth (m)	Alkalinity (mg/l)	Apparent Color (PCU)	Total Phosphorus mg/l	Chlorophyll *a* (mg/m^3)
French River Basin										
Larner Pond (Palis: 42068)										
Station: A			**Description: deep hole, southern end near dam, Dudley**							
07/28/99	11:00	1.7	3.4							
	11:05	1.6		LB-0071		0 - 2.9	--	--	--	2**b**
				LB-0069		0.5	19	17**d**	0.028	--
				LB-0070		2.9	20	70**d**	0.033	--
08/26/99	**	1.8	3.4							
				LB-0223		0 - 2.5	--	--	--	8
				LB-0221		**	19	35	0.024	--
				LB-0220		0.5	20	<15	0.023	--
09/22/99	8:30	2.3	3.5							
				LB-0372		0 - 3.0	--	--	--	20
				LB-0370		0.5	18	38	0.024	--
				LB-0371		3.0	18	32	0.022	--
Station: B			**Description: center of the lobe east of Wayne Avenue and Michael Lane, Dudley**							
07/28/99	**	**	**							
				LB-0072		0.5	--	--	0.048	--
Pierpoint Meadow Pond (Palis: 42043)										
Station: A			**Description: deep hole south of Charlton/Dudley border, Dudley**							
08/04/99	13:38	1.8	3.4							
	13:45	1.9		LB-0097		** - **	--	--	--	3
				LB-0095	LB-0094	0.5	10	17	****d**	--
				LB-0094	LB-0095	0.5	12	17	****d**	--
				LB-0101		2.9	12	17	0.018**d**	--
09/01/99	10:45	1.9	2.8							
				LB-0242		** - **	--	--	--	****m**
				LB-0239	LB-0238	0.5	12	29	0.019	--
				LB-0238	LB-0239	0.5	11	29	0.022	--
				LB-0240		2.5	12	23	0.019	--
10/05/99	**	2.6	3.4							
				LB-0392		0 - 3.0	--	--	--	<1
				LB-0389	LB-0388	0.5	11	22	0.016**d**	--
				LB-0388	LB-0389	0.5	11	23	0.027**d**	--
				LB-0391		3.0	11	24	0.019**d**	--
Rochdale Pond (Palis: 42048)										
Station: A			**Description: deep hole in southeastern quadrant near outlet, Leicester**							
08/05/99	13:00	2.2	3.6							
				LB-0110		0 - 3.5	--	--	--	17
				LB-0106		0.5	14	60	0.035	--
				LB-0114		3.1	21	85	0.10	--
09/02/99	10:00	2.3	3.5							
				LB-0258		** - **	--	--	--	1
				LB-0255	LB-0254	0.5	13	--	0.028	--
				LB-0254	LB-0255	0.5	14	46	0.028	--
				LB-0257		3.0	14	46	0.037	--
09/28/99	10:00	2.0	4.3							
	10:10	2.2		LB-0411		0 - 3.8	--	--	--	1
				LB-0409		0.5	11	70	0.037	--
				LB-0410		3.8	10	70	0.034	--

Table B14. Continued. 1999 MA DEP DWM French & Quinebaug River Basins inlake Secchi depth, alkalinity, color, total phosphorus and chlorophyll *a* data.

Date	Time (24hr)	Secchi Depth (m)	Station Depth (m)	OWMID	OWMID QA/QC	Sample Depth (m)	Alkalinity (mg/l)	Apparent Color (PCU)	Total Phosphorus mg/l	Chlorophyll *a* (mg/m^3)
French River Basin										
Wallis Pond (Palis: 42062)										
Station: A			**Description: deep hole, southern central lobe near dam, Dudley**							
07/28/99	9:05	>0.8	0.8							
				LB-0066		0 - 0.4	--	--	--	3**b**
				LB-0063	LB-0064	0.4	20	46**d**	0.021	--
				LB-0064	LB-0063	0.4	21	60**d**	0.022	--
				LB-0067		0.4	19	46**d**	0.026	--
08/26/99	10:30	>0.5	0.5							
				LB-0217		0.5	--	--	--	<1
				LB-0215	LB-0214	0.5	31	31	0.028	--
				LB-0214	LB-0215	0.5	30	43	0.028	--
09/22/99	10:15	>1.0	1.0							
				LB-0367		** - **	--	--	--	<1
				LB-0364	LB-0363	0.5	14	60	0.025	--
				LB-0363	LB-0364	0.5	12	49	0.025	--

“ ** ” = Censored or missing data **“ -- ”** = No data

“ **b** ” = **b**lank Contamination in lab reagent blanks and/or field blank samples (indicating possible bias high and false positives).

“ **d** ” = precision of field **d**uplicates (as RPD) did not meet project data quality objectives identified for program or in QAPP; batch samples may also be affected

“ **h** ” = **h**olding time violation (usually indicating possible bias low)

“ **m** ” = **m**ethod SOP not followed, only partially implemented or not implemented at all, due to complications with sample matrix (e.g. sediment in sample, floc formation), lab error (e.g., cross-contamination between samples), additional steps taken by the lab to deal with matrix complications, and lost/unanalyzed samples.

Appendix II. Macrophyte Species Codes.

Plant species (common name)	Code
Macroscopic algae (mats, clumps, etc.)	Δ
Chara sp. "Muskgrass"	Δ1
Nitella sp. "Stonewort"	Δ2
Bryozoan	Δ3
Moss	
Riccia fluitans "Slender Riccia"	M1
Ricciocarpus natans "Purple-fringed Riccia"	M2
Other aquatic ferns	N
Osmunda regalis "Royal Fern"	N1
Marsilea quadrofolia "Pepperwort"	N2
Azolla caroliniana "Water-velvet"	N3
Salvinia rotundifolia "Floating Moss"	N4
Isoetes sp. "Quillwort"	I
I. tuckermani "Quillwort"	I1
Typha latifolia "Common Cattail"	T
Typha angustifolia "Narrow-leaved Cattail"	T1
Typha glauca "Hybrid Cattail"	T2
Sparganium sp. "Bur Reed"	S
S. fluctuans "Water Bur Reed"	S1
S. eurycarpum "Giant Bur Reed"	S2
S. americanum "Bur Reed"	S3
Potamogeton sp. "Pondweed"	P
P. amplifolias "Largeleaf Pondweed"	P1
P. crispus "Curlyleaf Pondweed"	P2
P. richardsonii "Richardson Pondweed"	P3
P. robbinsii "Flatleaf Pondweed"	P4
P. epihydrus "Ribbonleaf Pondweed"	P5
P. sp. "Thin-leaved Pondweed"	P6
P. gramineus "Grassleaf Pondweed"	P7
P. natans "Floatingleaf Pondweed"	P8
P. vaseyi "Vasey's Pondweed"	P9
P. capillaceus "Pondweed"	P10
P. folisus "Leafy Pondweed"	P11
P. tenuifolius "Pondweed"	P12
P. perfoliatus "Redhead Grass"	P13
P. pusillus "Slender Pondweed" or "Baby Pondweed"	P14
P. spirillus "Snailseed Pondweed"	P15
P. pectinatus "Sago Pondweed"	P16
P. illinoensis "Illinois Pondweed"	P17

Plant species (common name)	Code
Najas sp. "Bushy Pondweed" or Naiad"	J
Ruppia maritima "Widgeon Grass"	J1
Najas flexilis "Slender Naiad"	J2
Najas minor "European Naiad"	J3
Najas guadalupensis "Naiad"	J4
Najas gracillima	J5
Alisma sp. "Water-Plantain"	A1
Echinodorus sp. "Burhead"	A2
Sagittaria sp. "Arrowhead" or "Duck Potato"	A3
Sagittaria sp. (submerged form only)	A4
S. latifolia "Common Arrowhead"	A5
S. rigida "Stiff Arrowhead"	A6
S. teres "Dwarf Wapato	A7
S. graminea "Grassy Arrowhead"	A8
Vallisneria americana "Wild Celery" or "Tape Grass"	H1
Elodea sp. "Waterweed"	H2
E. nattallii "Waterweed"	H3
E. canadensis "Canadian Waterweed"	H4
Egeria densa "Brazilian elodea"	H5
Gramineae (Grass Family)	G
Cyperus sp. "Flat Sedge"	Y1
Dulichium arundinaceum "Three-way Sedge"	Y2
Fimbristylis sp. "Fimbristylis"	Y3
Rynchospora sp. "Beak Rush"	Y4
Cladium sp. "Twig Rush" or "Sawgrass"	Y5
Carex sp.	X
Scirpus sp. "Bulrush"	B
S. validus "Softstem Bulrush"	B1
S. cyperinus "Woolgrass Bulrush"	B2
S. americanus "American Bulrush"	B3
S. atrovirens "Dark-green Bulrush"	B4
S. subterminalis	B5
Eleocharis sp. "Spike Rush"	E
E. acicularis "Needle Spike Rush"	E1
E. smallii "Spike Rush"	E2
E. palustris "Common Spike Rush"	E3
Peltandra virginica "Arrow Arum"	a1

P. pulcher	"Heartleaf Pondweed"	P18
P. bicupulatus	"Snailseed Pondweed"	P19
P. zosteriformis	"Flatstem Pondweed"	P20
P. nodosus		P21
P. oakesianus		P22
Spirodela polyrhiza	"Big Duckweed"	L1
Wolffia sp.	"Watermeal"	L2
Wolffiella floridana	"Florida Wolffiella"	L3
Lemna sp.	"Duckweed"	L4
L. minor	"Common Duckweed"	L5
L. trisulca	"Star Duckweed"	L6
Xyris sp.	"Yellow-eyed Grass"	e
Eriocaulon sp.	"Pipewort"	e1
E. septangulare	"Pipewort"	e2
Heteranthera dubia	"Mud Plantain"	W1
Pontederia cordata	"Pickerelweed"	W2
P. cordata forma taenia	"Pickerelweed"	W3
Iris sp.	"Iris"	j1
Juncus sp.	"Rush"	j2
Saururus cernuus	"Lizard's tail"	j3
Rumex sp.	"Dock"	Q1
Polygonum sp.	"Smartweed"	Q2
Salix sp.	"Willow"	b1
Myrica gale	"Sweet Gale"	b2
Alnus sp.	"Alder"	b3
Nyssa sp.	"Sour Gum" or "Tupelo"	b4
Cornus sp.	"Dogwood"	b5
Chamaedaphne calyculata	"Leatherleaf"	b6
Fraxinus sp.	"Ash"	b7
Cephalanthus occidentalis	"Buttonbush"	b8
Ilex verticillata	"Virginia Winterberry" or "Black Alder"	b9
Clethra alnifolia	"Sweet Pepperbush"	b10
Ceratophyllum sp.	"Coontail"	C
Ceratophyllum demersum	"Coontail"	C1
C. echinatum		C2
Nymphaea sp.	"Water Lily"	N1
N. odorata	"Fragrant Water Lily"	N2
N. tuberosa	"White Water Lily"	N3
Nuphar sp.	"Yellow Water Lily", or "Spatterdock"	N5
N. variegatum	"Painted Cow Lily"	N6
Brasenia schreberi	"Water Shield"	n1
Nelumbo lutea	"American Lotus"	n2
Cabomba caroliniana	"Fanwort"	n3

Calla palustris	"Water Arum"	a2
Orontium aquaticum	"Golden Club"	a3
Acorus calamus	"Sweet Flag"	a4
Subularia aquatica	"Awlwort"	M1
Neobeckia aquatica	"Lake Cress"	M2
Cardamine sp.	"Bitter Cress"	M3
Rorippa sp.	"Water Cress"	M4
Podostenum sp.	"River Weed"	r
Callitriche sp.	"Water Starwort"	k1
Elatine sp.	"Waterwort"	k2
Viola sp.	"Violet"	k3
Hypericum sp.	"St. John's-wort"	k4
H. boreale f. callitrichoides	"St. John's-wort"	k5
Decodon verticillatus	"Swamp Loosestrife"	V1
Trapa natans	"Water Chestnut"	V2
Ludwigia sp.	"False Loosestrife"	V3
Lythrum salicaria	"Purple or Spiked Loosestrife"	V4
Rhexia virginica	"Virginia Meadow-beauty"	V5
Hippuris vulgaris	"Mare's-tail"	h1
Prosperinaca sp.	"Mermaid Weed"	h2
Myriophyllum sp.	"Water Milfoil	h3
M. heterophyllum	"Broadleaf Water Milfoil"	h4
M. humile	"Water Milfoil"	h5
M. tenellum	"Leafless Milfoil"	h6
M. spicatum		h7
Sium suave	"Water Parsnip"	f1
Hydrocotyle sp.	"Water Pennywort"	f2
Cicuta sp.	"Water Hemlock"	f3
Hottonia inflata	"Featherfoil"	m1
Samolus sp.	"Water Pimpernel"	m2
Lysimachia sp.	"Loosestrife"	m3
L. ciliata	"Loosestrife"	m4
Nymphoides cordatum	"Floating Heart"	g1
Asclepias sp.	"Milkweed"	g2
Myosotis sp.	"Forget-me-not"	g3
Stachys sp.	"Hedge Nettle"	t1
Scutellaria sp.	"Skullcap"	t2
Physostegia sp.	"False Dragonhead"	t3
Lycopus sp.	"Water Horehound"	t4
Mentha sp.	"Mint"	t5
Solanum dulcamara	"Nightshade"	t6

Caltha palustris ”Marsh Marigold” R1
Myosurus minimus “Mousetail” R2
Ranunculus sp. “Buttercup” or “Crowfoot” R3

Bacopa sp. “Water Hyssop” F1
Limosella sp. “Mudwort” F2
Veronica sp. “Speedwell” F3
Chelone sp. “Turtlehead” F4
Mimulus sp. “Monkey Flower” F5
Lindernia sp. “False Pimpernel” F6
Gratiola sp. “Hedge Hyssop” F7
G. virginiana “Hedge Hyssop” F8

Lobelia sp. O
L. cardinalis “Cardinal Flower” O1
L. dortmanna “Water Lobelia” O2

Utricularia sp. “Bladderwort” U
U. vulgaris “Common Bladderwort” U1
U. purpurea “Purple Bladderwort” U2
U. radiata “Floating Bladderwort” U3
U. intermedia “Flat-leaved Bladderwort” U4
Megalodonta beckii “Water Marigold” Z1
Eupatorium sp. “Joe-pye Weed” Z2
Bidens sp. “Bur Marigold”, “Beggar-ticks”, Z3
Helenium sp. “Sneezeweed” Z4
Solidago sp. “Goldenrod” Z5
Aster sp. “Aster” Z6
Coreopis rosea “Pink Tickseed” Z7

Equisetum sp. “Horsetail” i
E. fluviatile “Swamp or Water Horsetail” i1

Drosera rotundifolia “Roundleaf Sundew” D

Vaccinium sp. “Cranberry” d

Phragmites sp. “Reed Grass” q

Appendix III Calculations for Point Source Loads to Lakes.

The Leicester WWTP (MA0101796) discharges to a small unnamed stream which runs approximately 250m to Dutton Pond. The treatment plant currently has a 1 mg/l total phosphorus limit in the summer with a permitted flow of 0.35 MGD. The DMR report for 2001 showed the average flow during April-October was 0.16MGD and the average concentration was 0.82 mg/l. The calculated weighted average summer loading rate, expressed as a yearly rate, was 179 kg/yr. Because of the short distance to the pond and no intervening wetlands, all of this phosphorus load was assumed to reach Dutton Pond.

To calculate how much of this load reach downstream lakes (Greenville Pond, Rochdale Pond and Texas Pond) retention in ponds and riparian uptake were estimated based on methods described in the Appendix of the Connecticut Lakes TMDL, (DEP, 2001). Briefly, retention in ponds is calculated by the retention coefficient Rp, based on the Kirchner and Dillon equation cited in BEC (1989):

$$Rp = 13.2/(13.2+q)$$

Where Rp = fraction of P retained in lake
q = water loading rate to lake (m/yr).

Thus, the amount of the point source phosphorus leaving the lake is estimated to be:

Load entering lake kg/yr * (1-Rp) = load leaving lake kg/yr.

For Dutton Pond, where q= 194.1 m/yr (from Table 2c), Rp is 0.063 or 6.3% retained. With an input of 179 kg/yr the amount exiting the lake is calculated to be 168 kg/yr. Similar calculations were applied to other downstream lakes based on calculated inlet concentrations of the load attributed to the point sources.

Riparian uptake of the point source loads within the stream channel between ponds is calculated based on the uptake coefficient of 5.5% per km of stream based on calculations in Appendix of the Connecticut Lakes TMDL, (DEP, 2001). To predict what fraction of the point source phosphorus reached a given downstream lake we used the equation:

$$f = (1-X)^K$$

Where f = fraction of point source reaching site.
X= fractional uptake rate per km = 0.055
K = distance in km to site from upstream point source.

For example, given that Greenville Pond is approximately 3 km downstream f is calculated to be 0.84, or 84 percent times 168 kg/yr= 141 kg/yr reaches Greenville Pond. Similar stepwise calculations were used to estimate the point source loads to other lakes and reservoirs further downstream as summarized below:

The amount retained in Greenville: 10 kg/yr amount exported 131 kg/yr.

The amount retained in 0.72km to Rochdale =5 amount exported 126 kg/yr

Retained in Rochdale:8; amount exported = 118kg/yr

Retained in 2 km reach to Oxford-Rochdale WWTP: 13 kg/yr; amount exported= 105 kg/yr.

The Oxford Rochdale WWTP (MA0100170) discharges to the French River upstream of Texas Pond. The treatment plant currently has a 1 mg/l total phosphorus limit in the summer with a permitted flow of 0.5 MGD. The DMR report for 2000 showed the average flow during April-October was 0.15 MGD and the average concentration was 0.88 mg/l. The calculated weighted average summer loading rate, expressed as a yearly rate, was 183 kg/yr.

Sum of both point sources at discharge of Oxford-Rochdale WWTP =105 + 183= 288 kg/yr

Retained in 1km reach to Texas pond: 6 kg/yr and 10 kg/yr
Thus, the amount delivered to Texas pond for each treatment plant is:105 *.945=99 kg/yr and 183 *.945=173 kg/yr
For a total of 272kg/yr.

Appendix IV Summer Carlson Trophic State Index (TSI) Calculations.

Table IVa. Average Summer (July-August) Trophic Status of French Basin Lakes Surveyed in 1999.

Pond Name	Secchi m	Chl a ppb	TP ppb	PCU color	Secchi TSI	Chl a TSI	TP TSI	Average TSI	Trophic State
Dresser	0.4	Na	205	60	73	Na	81	77	Hyper-eutrophic
Gore	2.4	18	18	35	48	59	45	51	Eutrophic
Pierpoint	1.9	3	19	23	51	41	47	46	Mesotrophic
Rochdale	2.3	9	32	53	48	52	54	51	Eutrophic
Wallis	0.7	2	25	39	66	37	50	51	Eutrophic
Larner	1.8	5	26	16	52	46	51	50	Mesotrophic

Table IVb. Carlson's Trophic State Index and Attributes of Lakes.
(Modified from http://dipin.kent.edu/tsi.htm and Carlson and Simpson (1996).

A list of possible changes that might be expected in a north temperate lake as the amount of algae changes along the trophic state gradient.

TSI	Chl (ug/L)	SD (m)	TP (ug/L)	Attributes	Water Supply	Fisheries & Recreation
<30	<0.95	>8	<6	**Oligotrophy:** Clear water, oxygen throughout the year in the hypolimnion	Water may be suitable for an unfiltered water supply.	Salmonid fisheries dominate
30-40	0.95-2.6	8-4	6-12	Hypolimnia of shallower lakes may become anoxic		Salmonid fisheries in deep lakes only
40-50	2.6-7.3	4-2	12-24	**Mesotrophy:** Water moderately clear; increasing probability of hypolimnetic anoxia during summer	Iron, manganese, taste, and odor problems worsen. Raw water turbidity requires filtration.	Hypolimnetic anoxia results in loss of salmonids. Walleye may predominate
50-60	7.3-20	2-1	24-48	**Eutrophy:** Anoxic hypolimnia, macrophyte problems possible		Warm-water fisheries only. Bass may dominate.
60-70	20-56	0.5-1	48-96	Blue-green algae dominate, algal scums and macrophyte problems	Episodes of severe taste and odor possible.	Nuisance macrophytes, algal scums, and low transparency discourage swimming and boating.
70-80	56-155	0.25-0.5	96-192	**Hypereutrophy:** (light limited). Dense algae & macrophytes		
>80	>155	<0.25	192-384	Algal scums, few macrophytes		Rough fish dominate; summer fish kills possible

Reference:

Carlson, R.E. and J. Simpson. 1996. A Coordinator's Guide to Volunteer Lake Monitoring Methods. North American Lake Management Society. 96 pp.

Appendix V NPSLAKE model results.

Table 2a. Buffumville Lake MA42005

Total Estimated Nonpoint Source Pollution loads based on GIS Landuse

Watershed Area=	6630.3 Ha (25.6 mi2)
Average Annual Water Load =	40418479.3 m3/yr (45.8 cfs)
Average Runoff=	61.0 cm/yr (24.0 in/yr)
Lake area=	77.7 Ha. (191.9ac)
Areal water loading to lake: q=	52.0 m/yr.
Homes with septic systems within 100m of lake.=	0.0
Other P inputs =	0.0 kg/yr

Estimate of annual Nonpoint Source Pollution Loads by land use

Land use	Area Ha (%)	P Load kg/yr (%)	N Load kg/yr	TSS Load kg/yr
Forest category				
Forest:	4441.7 (67.0)	577.4 (46.1)	11104.1	106599.8
Rural category				
Agriculture:	468.5 (7.1)	140.6 (11.2)	4397.5	152353.1
Open land:	211.5 (3.2)	63.4 (5.1)	1099.5	19129.5
Residential Low:	860.6 (13.0)	258.2 (20.6)	4733.5	333925.8
Urban category				
Residential High:	106.3 (1.6)	97.7 (7.8)	772.7	56270.7
Comm - Ind:	125.7 (1.9)	115.6 (9.2)	1253.4	70430.6
Other Landuses				
Water:	297.3 (4.5)	0.0 (0.0)	0.0	0.0
Wetlands:	118.7 (1.8)	0.0 (0.0)	0.0	6292.6
Subtotal	6630.3	1252.9	23712.8	749682.8
Other P inputs:	NA	0.0 (0.0)		
0.0 Septics:	NA	0.0 (0.0)		
Total	6630.3 (100.0)	1252.9(100)	23712.8	749682.8

Summary of Lake Total Phosphorus Modeling Results

Areal P loading L= 1.6 g/m2/yr.
Reckhow (1979) model predicts lake TP = L/(11.6+1.2q)*1000 = 21.8 ppb.
Predicted transparency = 2.2 meters.

Table 2b. Cedar Meadow Pond MA42009

Total Estimated Nonpoint Source Pollution loads based on GIS Landuse

Watershed Area=	1038.0 Ha (4.0 mi2)
Average Annual Water Load =	6327716.8 m3/yr (7.2 cfs)
Average Runoff=	61.0 cm/yr (24.0 in/yr)
Lake area=	59.8 Ha. (147.6ac)
Areal water loading to lake: q=	10.6 m/yr.
Homes with septic systems within 100m of lake.=	50.0
Other P inputs =	0.0 kg/yr

Estimate of annual Nonpoint Source Pollution Loads by land use

Land use	Area Ha (%)	P Load kg/yr (%)	N Load kg/yr	TSS Load kg/yr
Forest category				
Forest:	622.7 (60.0)	80.9 (29.7)	1556.7	14943.8
Rural category				
Agriculture:	124.3 (12.0)	37.3 (13.7)	1352.6	47994.7
Open land:	27.0 (2.6)	8.1 (3.0)	140.2	765.6
Residential Low:	80.8 (7.8)	24.2 (8.9)	444.2	31333.8
Urban category				
Residential High:	37.5 (3.6)	75.4 (27.6)	271.8	19815.4
Comm - Ind:	10.9 (1.1)	22.0 (8.1)	109.1	7300.3
Other Landuses				
Water:	114.3 (11.0)	0.0 (0.0)	0.0	0.0
Wetlands:	20.6 (2.0)	0.0 (0.0)	0.0	1090.2
Subtotal	1038.0	248.0	3886.3	123398.2
Other P inputs:	NA	0.0 (0.0)		
50.0 Septics:	NA	25.0 (9.2)		
Total	1038.0 (100.0)	273.0(100)	3886.3	123398.2

Summary of Lake Total Phosphorus Modeling Results

Areal P loading L= 0.5 g/m2/yr.
Reckhow (1979) model predicts lake TP = L/(11.6+1.2q)*1000 = 18.8 ppb.
Predicted transparency = 2.6 meters.

Table 2c. Dresser Hill Pond MA42014

Total Estimated Nonpoint Source Pollution loads based on GIS Landuse

Watershed Area=	12.5 Ha (0.0 mi2)
Average Annual Water Load =	76484.6 m3/yr (0.1 cfs)
Average Runoff=	61.0 cm/yr (24.0 in/yr)
Lake area=	2.7 Ha. (6.7ac)
Areal water loading to lake: q=	2.8 m/yr.
Homes with septic systems within 100m of lake.=	0.0
Other P inputs =	91.0 kg/yr

Estimate of annual Nonpoint Source Pollution Loads by land use

Land use	Area Ha (%)	P Load kg/yr (%)	N Load kg/yr	TSS Load kg/yr
Forest category				
Forest:	2.5 (19.6)	0.3 (0.3)	6.1	59.0
Rural category				
Agriculture:	7.4 (58.9)	2.2 (2.4)	90.6	3324.7
Open land:	0.0 (0.0)	0.0 (0.0)	0.0	0.0
Residential Low:	0.0 (0.0)	0.0 (0.0)	0.0	0.0
Urban category				
Residential High:	0.0 (0.0)	0.0 (0.0)	0.0	0.0
Comm - Ind:	0.0 (0.0)	0.0 (0.0)	0.0	0.0
Other Landuses				
Water:	2.7 (21.5)	0.0 (0.0)	0.0	0.0
Wetlands:	0.0 (0.0)	0.0 (0.0)	0.0	0.0
Subtotal	12.5	2.5	96.8	3383.7
Other P inputs*:	NA	91.0 (97.3)		
0.0 Septics:	NA	0.0 (0.0)		
Total	12.5 (100.0)	93.5(100)	96.8	3383.7

Summary of Lake Total Phosphorus Modeling Results

Areal P loading L= 3.5 g/m2/yr.
Reckhow (1979) model predicts lake TP = L/(11.6+1.2q)*1000 = 231.0 ppb.
Predicted transparency = 0.2 meters.

*Other P inputs due to estimated 91 kg/yr from 1 acre feedlot on Dresser Hill (see text).

Table 2d. Dutton Pond MA42015

Total Estimated Nonpoint Source Pollution loads based on GIS Landuse

Watershed Area=	921.1 Ha (3.6 mi2)
Average Annual Water Load =	5614752.5 m3/yr (6.4 cfs)
Average Runoff=	61.0 cm/yr (24.0 in/yr)
Lake area=	2.9 Ha. (7.1ac)
Areal water loading to lake: q=	194.1 m/yr.
Homes with septic systems within 100m of lake.=	0.0
Other P inputs =	179.0 kg/yr

Estimate of annual Nonpoint Source Pollution Loads by land use

Land use	Area Ha (%)	P Load kg/yr (%)	N Load kg/yr	TSS Load kg/yr
Forest category				
Forest:	555.1 (60.3)	72.2 (15.9)	1387.7	13322.4
Rural category				
Agriculture:	77.0 (8.4)	23.1 (5.1)	603.8	18591.0
Open land:	74.5 (8.1)	22.3 (4.9)	387.3	14544.9
Residential Low:	84.6 (9.2)	25.4 (5.6)	465.1	32809.4
Urban category				
Residential High:	77.5 (8.4)	116.3 (25.7)	473.8	38127.8
Comm - Ind:	9.6 (1.0)	14.4 (3.2)	95.5	5702.9
Other Landuses				
Water:	32.3 (3.5)	0.0 (0.0)	0.0	0.0
Wetlands:	10.5 (1.1)	0.0 (0.0)	0.0	557.7
Subtotal	921.1	273.6	3413.2	123656.1
NPDES P inputs:	NA	179.0 (39.5)		
0.0 Septics:	NA	0.0 (0.0)		
Total	921.1 (100.0)	452.6(100)	3413.2	123656.1

Summary of Lake Total Phosphorus Modeling Results

Areal P loading L= 15.6 g/m2/yr.
Reckhow (1979) model predicts lake TP = L/(11.6+1.2q)*1000 = 64.0 ppb.
Predicted transparency = 0.8 meters.

Table 2e. Gore Pond MA42018

Total Estimated Nonpoint Source Pollution loads based on GIS Landuse

Watershed Area=	580.1 Ha (2.2 mi2)
Average Annual Water Load =	3536344.8 m3/yr (4.0 cfs)
Average Runoff=	61.0 cm/yr (24.0 in/yr)
Lake area=	28.7 Ha. (70.8ac)
Areal water loading to lake: q=	12.3 m/yr.
Homes with septic systems within 100m of lake.=	44.0
Other P inputs =	35.0 kg/yr

Estimate of annual Nonpoint Source Pollution Loads by land use

Land use	Area Ha (%)	P Load kg/yr (%)	N Load kg/yr	TSS Load kg/yr
Forest category				
Forest:	364.3 (62.8)	47.4 (29.5)	910.6	8742.0
Rural category				
Agriculture:	66.4 (11.4)	19.9 (12.4)	710.5	24981.1
Open land:	9.2 (1.6)	2.8 (1.7)	47.7	1173.8
Residential Low:	58.7 (10.1)	17.6 (11.0)	322.8	22771.2
Urban category				
Residential High:	1.2 (0.2)	15.6 (9.8)	6.9	582.3
Comm - Ind:	0.0 (0.0)	0.0 (0.0)	0.0	0.0
Other Landuses				
Water:	48.5 (8.4)	0.0 (0.0)	0.0	0.0
Wetlands:	31.9 (5.5)	0.0 (0.0)	0.0	1688.9
Subtotal	580.1	103.3	1998.4	59939.4
Other P inputs*:	NA	35.0 (21.8)		
44.0 Septics:	NA	22.0 (13.7)		
Total	580.1 (100.0)	160.3(100)	1998.4	59939.4

Summary of Lake Total Phosphorus Modeling Results

Areal P loading L= 0.6 g/m2/yr.
Reckhow (1979) model predicts lake TP = L/(11.6+1.2q)*1000 = 21.2 ppb.
Predicted transparency = 2.3 meters.

*Other P inputs due to estimated 35kg/yr net inputs from 1 acre feedlot on Dresser Hill (see text).

Table 2f. Granite Reservoir MA42019

Total Estimated Nonpoint Source Pollution loads based on GIS Landuse

Watershed Area=	2026.7 Ha (7.8 mi2)
Average Annual Water Load =	12354526.2 m3/yr (14.0 cfs)
Average Runoff=	61.0 cm/yr (24.0 in/yr)
Lake area=	83.7 Ha. (206.8ac)
Areal water loading to lake: q=	14.8 m/yr.
Homes with septic systems within 100m of lake.=	142.0
Other P inputs =	0.0 kg/yr

Estimate of annual Nonpoint Source Pollution Loads by land use

Land use	Area Ha (%)	P Load kg/yr (%)	N Load kg/yr	TSS Load kg/yr
Forest category				
Forest:	1418.1 (70.0)	184.4 (41.8)	3545.4	34035.6
Rural category				
Agriculture:	187.1 (9.2)	56.1 (12.7)	1653.4	56756.0
Open land:	34.8 (1.7)	10.4 (2.4)	180.8	3609.8
Residential Low:	155.2 (7.7)	46.6 (10.6)	853.8	60235.1
Urban category				
Residential High:	21.2 (1.0)	57.3 (13.0)	198.5	12804.6
Comm - Ind:	5.6 (0.3)	15.1 (3.4)	55.7	1580.2
Other Landuses				
Water:	151.5 (7.5)	0.0 (0.0)	0.0	0.0
Wetlands:	53.1 (2.6)	0.0 (0.0)	0.0	2816.4
Subtotal	2026.7	369.9	6679.5	174388.8
Other P inputs:	NA	0.0 (0.0)		
142.0 Septics:	NA	71.0 (16.1)		
Total	2026.7 (100.0)	440.9(100)	6679.5	174388.8

Summary of Lake Total Phosphorus Modeling Results

Areal P loading L= 0.5 g/m2/yr.
Reckhow (1979) model predicts lake TP = L/(11.6+1.2q)*1000 = 18.0 ppb.
Predicted transparency = 2.7 meters.

Table 2g. Greenville Pond MA42023

Total Estimated Nonpoint Source Pollution loads based on GIS Landuse

Watershed Area=	3822.0 Ha (14.8 mi2)
Average Annual Water Load =	23299196.1 m3/yr (26.4 cfs)
Average Runoff=	61.0 cm/yr (24.0 in/yr)
Lake area=	13.2 Ha. (32.6ac)
Areal water loading to lake: q=	176.5 m/yr.
Homes with septic systems within 100m of lake.=	14.0
Other P inputs =	141.0 kg/yr

Estimate of annual Nonpoint Source Pollution Loads by land use

Land use	Area Ha (%)	P Load kg/yr (%)	N Load kg/yr	TSS Load kg/yr
Forest category				
Forest:	2351.1 (61.5)	305.6 (32.9)	5877.8	56426.9
Rural category				
Agriculture:	315.0 (8.2)	94.5 (10.2)	3121.5	107375.2
Open land:	152.5 (4.0)	45.8 (4.9)	793.2	21178.2
Residential Low:	416.9 (10.9)	125.1 (13.5)	2293.2	161774.3
Urban category				
Residential High:	203.5 (5.3)	189.8 (20.4)	1473.8	107846.2
Comm - Ind:	21.9 (0.6)	20.4 (2.2)	218.4	13883.7
Other Landuses				
Water:	310.9 (8.1)	0.0 (0.0)	0.0	0.0
Wetlands:	50.1 (1.3)	0.0 (0.0)	0.0	2653.4
Subtotal	3822.0	781.2	13819.9	471696.6
Other P inputs:	NA	141.0 (15.2)		
14.0 Septics:	NA	7.0 (0.8)		
Total	3822.0 (100.0)	929.2(100)	13819.9	471696.6

Summary of Lake Total Phosphorus Modeling Results

Areal P loading L= 7.0 g/m2/yr.
Reckhow (1979) model predicts lake TP = L/(11.6+1.2q)*1000 = 31.5 ppb.
Predicted transparency = 1.5 meters.

Table 2h. Hudson Pond MA42029

Total Estimated Nonpoint Source Pollution loads based on GIS Landuse

Watershed Area=	119.4 Ha (0.5 mi2)
Average Annual Water Load =	727628.7 m3/yr (0.8 cfs)
Average Runoff=	61.0 cm/yr (24.0 in/yr)
Lake area=	6.2 Ha. (15.4ac)
Areal water loading to lake: q=	11.7 m/yr.
Homes with septic systems within 100m of lake.=	0.0
Other P inputs =	0.0 kg/yr

Estimate of annual Nonpoint Source Pollution Loads by land use

Land use	Area Ha (%)	P Load kg/yr (%)	N Load kg/yr	TSS Load kg/yr
Forest category				
Forest:	69.2 (58.0)	9.0 (21.3)	173.0	1660.7
Rural category				
Agriculture:	26.5 (22.2)	8.0 (18.9)	317.8	11580.9
Open land:	0.0 (0.0)	0.0 (0.0)	0.0	0.0
Residential Low:	13.5 (11.3)	4.1 (9.6)	74.3	5242.8
Urban category				
Residential High:	0.0 (0.0)	0.0 (0.0)	0.0	0.0
Comm - Ind:	2.3 (1.9)	21.1 (50.2)	22.7	2210.5
Other Landuses				
Water:	5.8 (4.9)	0.0 (0.0)	0.0	0.0
Wetlands:	2.0 (1.7)	0.0 (0.0)	0.0	107.6
Subtotal	119.4	42.1	587.9	20802.4
Other P inputs:	NA	0.0 (0.0)		
0.0 Septics:	NA	0.0 (0.0)		
Total	119.4 (100.0)	42.1(100)	587.9	20802.4

Summary of Lake Total Phosphorus Modeling Results

Areal P loading L= 0.7 g/m2/yr.
Reckhow (1979) model predicts lake TP = L/(11.6+1.2q)*1000 = 26.4 ppb.
Predicted transparency = 1.8 meters.

Table 2i. Jones Pond MA42030

Total Estimated Nonpoint Source Pollution loads based on GIS Landuse

Watershed Area=	387.9 Ha (1.5 mi2)
Average Annual Water Load =	2364503.4 m3/yr (2.7 cfs)
Average Runoff=	61.0 cm/yr (24.0 in/yr)
Lake area=	12.2 Ha. (30.2ac)
Areal water loading to lake: q=	19.4 m/yr.
Homes with septic systems within 100m of lake.=	22.0
Other P inputs =	0.0 kg/yr

Estimate of annual Nonpoint Source Pollution Loads by land use

Land use	Area Ha (%)	P Load kg/yr (%)	N Load kg/yr	TSS Load kg/yr
Forest category				
Forest:	312.3 (80.5)	40.6 (51.3)	780.8	7495.6
Rural category				
Agriculture:	42.9 (11.1)	12.9 (16.3)	426.9	15080.6
Open land:	7.5 (1.9)	2.3 (2.8)	39.0	299.4
Residential Low:	12.7 (3.3)	3.8 (4.8)	70.1	4943.3
Urban category				
Residential High:	0.4 (0.1)	8.6 (10.9)	2.1	175.7
Comm - Ind:	0.0 (0.0)	0.0 (0.0)	0.0	0.0
Other Landuses				
Water:	10.2 (2.6)	0.0 (0.0)	0.0	0.0
Wetlands:	1.8 (0.5)	0.0 (0.0)	0.0	94.3
Subtotal	387.9	68.2	1350.8	28513.9
Other P inputs:	NA	0.0 (0.0)		
22.0 Septics:	NA	11.0 (13.9)		
Total	387.9 (100.0)	79.2(100)	1350.8	28513.9

Summary of Lake Total Phosphorus Modeling Results

Areal P loading L= 0.6 g/m2/yr.
Reckhow (1979) model predicts lake TP = L/(11.6+1.2q)*1000 = 18.6 ppb.
Predicted transparency = 2.6 meters.

Table 2j. Larner Pond MA42068

Total Estimated Nonpoint Source Pollution loads based on GIS Landuse

Watershed Area=	882.6 Ha (3.4 mi2)
Average Annual Water Load =	5380121.8 m3/yr (6.1 cfs)
Average Runoff=	61.0 cm/yr (24.0 in/yr)
Lake area=	11.1 Ha. (27.4ac)
Areal water loading to lake: q=	48.5 m/yr.
Homes with septic systems within 100m of lake.=	0.0
Other P inputs =	0.0 kg/yr

Estimate of annual Nonpoint Source Pollution Loads by land use

Land use	Area Ha (%)	P Load kg/yr (%)	N Load kg/yr	TSS Load kg/yr
Forest category				
Forest:	482.5 (54.7)	62.7 (24.2)	1206.2	11579.1
Rural category				
Agriculture:	197.2 (22.3)	59.2 (22.8)	2267.7	82062.7
Open land:	28.7 (3.2)	8.6 (3.3)	149.1	3660.5
Residential Low:	32.1 (3.6)	9.6 (3.7)	176.3	12436.8
Urban category				
Residential High:	72.7 (8.2)	119.4 (46.0)	432.2	35051.8
Comm - Ind:	0.0 (0.0)	0.0 (0.0)	0.0	0.0
Other Landuses				
Water:	55.7 (6.3)	0.0 (0.0)	0.0	0.0
Wetlands:	13.7 (1.6)	0.0 (0.0)	0.0	727.0
Subtotal	882.6	259.5	4262.4	145928.7
Other P inputs:	NA	0.0 (0.0)		
0.0 Septics:	NA	0.0 (0.0)		
Total	882.6 (100.0)	259.5(100)	4262.4	145928.7

Summary of Lake Total Phosphorus Modeling Results

Areal P loading L= 2.3 g/m2/yr.
Reckhow (1979) model predicts lake TP = L/(11.6+1.2q)*1000 = 33.5 ppb.
Predicted transparency = 1.4 meters.

Table 2k. Lowes Pond MA42034

Total Estimated Nonpoint Source Pollution loads based on GIS Landuse

Watershed Area=	2006.8 Ha (7.7 mi2)
Average Annual Water Load =	12233573.0 m3/yr (13.9 cfs)
Average Runoff=	61.0 cm/yr (24.0 in/yr)
Lake area=	13.5 Ha. (33.3ac)
Areal water loading to lake: q=	90.6 m/yr.
Homes with septic systems within 100m of lake.=	9.0
Other P inputs =	0.0 kg/yr

Estimate of annual Nonpoint Source Pollution Loads by land use

Land use	Area Ha (%)	P Load kg/yr (%)	N Load kg/yr	TSS Load kg/yr
Forest category				
Forest:	1205.4 (60.1)	156.7 (31.3)	3013.5	28930.0
Rural category				
Agriculture:	146.6 (7.3)	44.0 (8.8)	1674.5	60254.5
Open land:	120.1 (6.0)	36.0 (7.2)	624.4	4531.4
Residential Low:	150.6 (7.5)	45.2 (9.0)	828.1	58420.7
Urban category				
Residential High:	138.7 (6.9)	127.2 (25.4)	893.9	71394.3
Comm - Ind:	94.2 (4.7)	86.4 (17.3)	938.9	80922.8
Other Landuses				
Water:	88.0 (4.4)	0.0 (0.0)	0.0	0.0
Wetlands:	63.2 (3.2)	0.0 (0.0)	0.0	3350.5
Subtotal	2006.8	495.5	7981.7	307916.8
Other P inputs:	NA	0.0 (0.0)		
9.0 Septics:	NA	4.5 (0.9)		
Total	2006.8 (100.0)	500.0(100)	7981.7	307916.8

Summary of Lake Total Phosphorus Modeling Results

Areal P loading L= 3.7 g/m2/yr.
Reckhow (1979) model predicts lake TP = L/(11.6+1.2q)*1000 = 30.8 ppb.
Predicted transparency = 1.6 meters.

Table 2l. McKinstry Pond MA42035

Total Estimated Nonpoint Source Pollution loads based on GIS Landuse

Watershed Area=	65.3 Ha (0.3 mi2)
Average Annual Water Load =	397975.3 m3/yr (0.5 cfs)
Average Runoff=	61.0 cm/yr (24.0 in/yr)
Lake area=	4.4 Ha. (11.0ac)
Areal water loading to lake: q=	9.0 m/yr.
Homes with septic systems within 100m of lake.=	24.0
Other P inputs =	0.0 kg/yr

Estimate of annual Nonpoint Source Pollution Loads by land use

Land use	Area Ha (%)	P Load kg/yr (%)	N Load kg/yr	TSS Load kg/yr
Forest category				
Forest:	24.1 (36.9)	3.1 (3.8)	60.2	578.1
Rural category				
Agriculture:	0.0 (0.0)	0.0 (0.0)	0.0	0.0
Open land:	1.8 (2.7)	0.5 (0.6)	9.1	503.9
Residential Low:	7.1 (10.9)	2.1 (2.6)	39.3	2773.3
Urban category				
Residential High:	21.8 (33.4)	65.3 (78.6)	119.8	10150.7
Comm - Ind:	0.0 (0.0)	0.0 (0.0)	0.0	0.0
Other Landuses				
Water:	1.8 (2.8)	0.0 (0.0)	0.0	0.0
Wetlands:	8.7 (13.3)	0.0 (0.0)	0.0	459.9
Subtotal	65.3	71.1	228.4	14465.8
Other P inputs:	NA	0.0 (0.0)		
24.0 Septics:	NA	12.0 (14.4)		
Total	65.3 (100.0)	83.1(100)	228.4	14465.8

Summary of Lake Total Phosphorus Modeling Results

Areal P loading L= 1.9 g/m2/yr.
Reckhow (1979) model predicts lake TP = L/(11.6+1.2q)*1000 = 83.8 ppb.
Predicted transparency = 0.6 meters.

Table 2m. New Pond MA42037

Total Estimated Nonpoint Source Pollution loads based on GIS Landuse

Watershed Area=	483.4 Ha (1.9 mi2)
Average Annual Water Load =	2946627.8 m3/yr (3.3 cfs)
Average Runoff=	61.0 cm/yr (24.0 in/yr)
Lake area=	30.1 Ha. (74.4ac)
Areal water loading to lake: q=	9.8 m/yr.
Homes with septic systems within 100m of lake.=	20.0
Other P inputs =	0.0 kg/yr

Estimate of annual Nonpoint Source Pollution Loads by land use

Land use	Area Ha (%)	P Load kg/yr (%)	N Load kg/yr	TSS Load kg/yr
Forest category				
Forest:	224.2 (46.4)	29.1 (15.1)	560.6	5381.5
Rural category				
Agriculture:	100.6 (20.8)	30.2 (15.7)	1185.5	42984.6
Open land:	28.9 (6.0)	8.7 (4.5)	150.3	5167.2
Residential Low:	40.1 (8.3)	12.0 (6.2)	220.5	15552.3
Urban category				
Residential High:	53.6 (11.1)	102.5 (53.2)	318.7	25835.9
Comm - Ind:	0.0 (0.0)	0.0 (0.0)	0.0	0.0
Other Landuses				
Water:	30.1 (6.2)	0.0 (0.0)	0.0	0.0
Wetlands:	5.8 (1.2)	0.0 (0.0)	0.0	308.3
Subtotal	483.4	182.5	2435.7	95229.7
Other P inputs:	NA	0.0 (0.0)		
20.0 Septics:	NA	10.0 (5.2)		
Total	483.4 (100.0)	192.5(100)	2435.7	95229.7

Summary of Lake Total Phosphorus Modeling Results

Areal P loading L= 0.6 g/m2/yr.
Reckhow (1979) model predicts lake TP = L/(11.6+1.2q)*1000 = 27.4 ppb.
Predicted transparency = 1.8 meters.

Table 2n. Peter Pond MA42042

Total Estimated Nonpoint Source Pollution loads based on GIS Landuse

Watershed Area=	95.7 Ha (0.4 mi2)
Average Annual Water Load =	583619.0 m3/yr (0.7 cfs)
Average Runoff=	61.0 cm/yr (24.0 in/yr)
Lake area=	16.9 Ha. (41.8ac)
Areal water loading to lake: q=	3.5 m/yr.
Homes with septic systems within 100m of lake.=	5.0
Other P inputs =	0.0 kg/yr

Estimate of annual Nonpoint Source Pollution Loads by land use

Land use	Area Ha (%)	P Load kg/yr (%)	N Load kg/yr	TSS Load kg/yr
Forest category				
Forest:	77.1 (80.5)	10.0 (37.1)	192.7	1849.8
Rural category				
Agriculture:	0.0 (0.0)	0.0 (0.0)	0.0	0.0
Open land:	0.0 (0.0)	0.0 (0.0)	0.0	0.0
Residential Low:	0.7 (0.7)	0.2 (0.8)	3.9	275.8
Urban category				
Residential High:	1.0 (1.1)	14.3 (52.9)	5.7	485.6
Comm - Ind:	0.0 (0.0)	0.0 (0.0)	0.0	0.0
Other Landuses				
Water:	16.9 (17.7)	0.0 (0.0)	0.0	0.0
Wetlands:	0.0 (0.0)	0.0 (0.0)	0.0	0.0
Subtotal	95.7	24.5	202.3	2611.1
Other P inputs:	NA	0.0 (0.0)		
5.0 Septics:	NA	2.5 (9.3)		
Total	95.7 (100.0)	27.0(100)	202.3	2611.1

Summary of Lake Total Phosphorus Modeling Results

Areal P loading L= 0.2 g/m2/yr.
Reckhow (1979) model predicts lake TP = L/(11.6+1.2q)*1000 = 10.2 ppb.
Predicted transparency = 4.7 meters.

Table 2o. Pierpoint Meadow Pond MA42043

Total Estimated Nonpoint Source Pollution loads based on GIS Landuse

Watershed Area=	299.1 Ha (1.2 mi2)
Average Annual Water Load =	1823388.4 m3/yr (2.1 cfs)
Average Runoff=	61.0 cm/yr (24.0 in/yr)
Lake area=	38.2 Ha. (94.3ac)
Areal water loading to lake: q=	4.8 m/yr.
Homes with septic systems within 100m of lake.=	92.0
Other P inputs =	0.0 kg/yr

Estimate of annual Nonpoint Source Pollution Loads by land use

Land use	Area Ha (%)	P Load kg/yr (%)	N Load kg/yr	TSS Load kg/yr
Forest category				
Forest:	176.1 (58.9)	22.9 (16.1)	440.2	4226.4
Rural category				
Agriculture:	50.3 (16.8)	15.1 (10.6)	578.9	20839.1
Open land:	1.4 (0.5)	0.4 (0.3)	7.0	248.9
Residential Low:	18.5 (6.2)	5.5 (3.9)	101.6	7167.2
Urban category				
Residential High:	14.0 (4.7)	52.3 (36.8)	147.9	9058.1
Comm - Ind:	0.0 (0.0)	0.0 (0.0)	0.0	0.0
Other Landuses				
Water:	37.5 (12.5)	0.0 (0.0)	0.0	0.0
Wetlands:	1.4 (0.5)	0.0 (0.0)	0.0	76.1
Subtotal	299.1	96.3	1275.7	41615.7
Other P inputs:	NA	0.0 (0.0)		
92.0 Septics:	NA	46.0 (32.3)		
Total	299.1 (100.0)	142.3(100)	1275.7	41615.7

Summary of Lake Total Phosphorus Modeling Results

Areal P loading L= 0.4 g/m2/yr.
Reckhow (1979) model predicts lake TP = L/(11.6+1.2q)*1000 = 21.5 ppb.
Predicted transparency = 2.2 meters.

Table 2p. Pikes Pond MA42044

Total Estimated Nonpoint Source Pollution loads based on GIS Landuse

Watershed Area=	1795.1 Ha (6.9 mi2)
Average Annual Water Load =	10943163.6 m3/yr (12.4 cfs)
Average Runoff=	61.0 cm/yr (24.0 in/yr)
Lake area=	11.4 Ha. (28.2ac)
Areal water loading to lake: q=	95.9 m/yr.
Homes with septic systems within 100m of lake.=	0.0
Other P inputs =	0.0 kg/yr

Estimate of annual Nonpoint Source Pollution Loads by land use

Land use	Area Ha (%)	P Load kg/yr (%)	N Load kg/yr	TSS Load kg/yr
Forest category				
Forest:	1385.8 (77.2)	180.2 (49.2)	3464.4	33258.7
Rural category				
Agriculture:	211.4 (11.8)	63.4 (17.3)	1976.6	68235.1
Open land:	25.9 (1.4)	7.8 (2.1)	134.6	3469.2
Residential Low:	87.0 (4.8)	26.1 (7.1)	478.7	33771.1
Urban category				
Residential High:	11.7 (0.7)	26.0 (7.1)	64.4	5457.7
Comm - Ind:	28.2 (1.6)	62.5 (17.1)	280.9	26673.1
Other Landuses				
Water:	36.5 (2.0)	0.0 (0.0)	0.0	0.0
Wetlands:	8.7 (0.5)	0.0 (0.0)	0.0	459.0
Subtotal	1795.1	365.9	6547.6	173289.9
Other P inputs:	NA	0.0 (0.0)		
0.0 Septics:	NA	0.0 (0.0)		
Total	1795.1 (100.0)	365.9(100)	6547.6	173289.9

Summary of Lake Total Phosphorus Modeling Results

Areal P loading L= 3.2 g/m2/yr.
Reckhow (1979) model predicts lake TP = L/(11.6+1.2q)*1000 = 25.3 ppb.
Predicted transparency = 1.9 meters.

Table 2q. Robinson Pond MA42047

Total Estimated Nonpoint Source Pollution loads based on GIS Landuse

Watershed Area=	304.2 Ha (1.2 mi2)
Average Annual Water Load =	1854565.2 m3/yr (2.1 cfs)
Average Runoff=	61.0 cm/yr (24.0 in/yr)
Lake area=	20.7 Ha. (51.2ac)
Areal water loading to lake: q=	9.0 m/yr.
Homes with septic systems within 100m of lake.=	6.0
Other P inputs =	0.0 kg/yr

Estimate of annual Nonpoint Source Pollution Loads by land use

Land use	Area Ha (%)	P Load kg/yr (%)	N Load kg/yr	TSS Load kg/yr
Forest category				
Forest:	222.0 (73.0)	28.9 (45.0)	555.0	5328.3
Rural category				
Agriculture:	4.9 (1.6)	1.5 (2.3)	60.8	2243.6
Open land:	10.5 (3.5)	3.2 (4.9)	54.8	157.9
Residential Low:	19.9 (6.6)	6.0 (9.3)	109.7	7738.2
Urban category				
Residential High:	2.4 (0.8)	21.6 (33.7)	26.8	1956.9
Comm - Ind:	0.0 (0.0)	0.0 (0.0)	0.0	0.0
Other Landuses				
Water:	20.7 (6.8)	0.0 (0.0)	0.0	0.0
Wetlands:	23.8 (7.8)	0.0 (0.0)	0.0	1260.1
Subtotal	304.2	61.1	807.2	18685.0
Other P inputs:	NA	0.0 (0.0)		
6.0 Septics:	NA	3.0 (4.7)		
Total	304.2 (100.0)	64.1(100)	807.2	18685.0

Summary of Lake Total Phosphorus Modeling Results

Areal P loading L= 0.3 g/m2/yr.
Reckhow (1979) model predicts lake TP = L/(11.6+1.2q)*1000 = 13.8 ppb.
Predicted transparency = 3.5 meters.

Table 2r. Rochdale Pond MA42048

Total Estimated Nonpoint Source Pollution loads based on GIS Landuse

Watershed Area=	5089.3 Ha (19.6 mi2)
Average Annual Water Load =	31024361.3 m3/yr (35.1 cfs)
Average Runoff=	61.0 cm/yr (24.0 in/yr)
Lake area=	16.8 Ha. (41.5ac)
Areal water loading to lake: q=	184.7 m/yr.
Homes with septic systems within 100m of lake.=	0.0
Other P inputs =	126.0 kg/yr

Estimate of annual Nonpoint Source Pollution Loads by land use

Land use	Area Ha (%)	P Load kg/yr (%)	N Load kg/yr	TSS Load kg/yr
Forest category				
Forest:	3148.3 (61.9)	409.3 (35.4)	7870.7	75559.2
Rural category				
Agriculture:	382.3 (7.5)	114.7 (9.9)	3849.0	133035.1
Open land:	235.7 (4.6)	70.7 (6.1)	1225.8	39110.6
Residential Low:	509.1 (10.0)	152.7 (13.2)	2799.9	197521.8
Urban category				
Residential High:	338.8 (6.7)	235.5 (20.4)	2278.2	173551.8
Comm - Ind:	67.0 (1.3)	46.6 (4.0)	667.8	47419.3
Other Landuses				
Water:	343.0 (6.7)	0.0 (0.0)	0.0	0.0
Wetlands:	65.0 (1.3)	0.0 (0.0)	0.0	3446.5
Subtotal	5089.3	1029.4	18733.6	670203.0
Other P inputs:	NA	126.0 (10.9)		
0.0 Septics:	NA	0.0 (0.0)		
Total	5089.3 (100.0)	1155.4(100)	18733.6	670203.0

Summary of Lake Total Phosphorus Modeling Results

Areal P loading L= 6.9 g/m2/yr.
Reckhow (1979) model predicts lake TP = L/(11.6+1.2q)*1000 = 29.5 ppb.
Predicted transparency = 1.6 meters.

If all land were primeval forest P export would be 608.6 kg/yr
And the forested condition lake TP would be 15.5 ppb.
Thus anthropogenic inputs increase lake TP by 89.9 percent.
The Trophic State Index has increased from 43.7 to 53.0
The Lake is predicted to be eutrophic and in a natural condition.

Table 2s. Shepherd Pond MA42051

Total Estimated Nonpoint Source Pollution loads based on GIS Landuse

Watershed Area=	579.3 Ha (2.2 mi2)
Average Annual Water Load =	3531467.4 m3/yr (4.0 cfs)
Average Runoff=	61.0 cm/yr (24.0 in/yr)
Lake area=	6.4 Ha. (15.8ac)
Areal water loading to lake: q=	55.1 m/yr.
Homes with septic systems within 100m of lake.=	1.0
Other P inputs =	0.0 kg/yr

Estimate of annual Nonpoint Source Pollution Loads by land use

Land use	Area Ha (%)	P Load kg/yr (%)	N Load kg/yr	TSS Load kg/yr
Forest category				
Forest:	393.0 (67.8)	51.1 (51.9)	982.6	9432.7
Rural category				
Agriculture:	67.7 (11.7)	20.3 (20.6)	684.0	23563.7
Open land:	4.7 (0.8)	1.4 (1.4)	24.4	1400.7
Residential Low:	29.3 (5.1)	8.8 (8.9)	161.4	11384.1
Urban category				
Residential High:	1.2 (0.2)	14.7 (15.0)	6.8	575.1
Comm - Ind:	0.1 (0.0)	1.6 (1.7)	1.4	93.6
Other Landuses				
Water:	68.1 (11.8)	0.0 (0.0)	0.0	0.0
Wetlands:	15.1 (2.6)	0.0 (0.0)	0.0	798.8
Subtotal	579.3	98.0	1860.6	47248.8
Other P inputs:	NA	0.0 (0.0)		
1.0 Septics:	NA	0.5 (0.5)		
Total	579.3 (100.0)	98.5(100)	1860.6	47248.8

Summary of Lake Total Phosphorus Modeling Results

Areal P loading L= 1.5 g/m2/yr.
Reckhow (1979) model predicts lake TP = L/(11.6+1.2q)*1000 = 19.8 ppb.
Predicted transparency = 2.4 meters.

Table 2t. Texas Pond MA42058

Total Estimated Nonpoint Source Pollution loads based on GIS Landuse

Watershed Area=	5577.0 Ha (21.5 mi2)
Average Annual Water Load =	33997762.7 m3/yr (38.5 cfs)
Average Runoff=	61.0 cm/yr (24.0 in/yr)
Lake area=	10.5 Ha. (25.9ac)
Areal water loading to lake: q=	323.8 m/yr.
Homes with septic systems within 100m of lake.=	0.0
Other P inputs =	272.0 kg/yr

Estimate of annual Nonpoint Source Pollution Loads by land use

Land use	Area Ha (%)	P Load kg/yr (%)	N Load kg/yr	TSS Load kg/yr
Forest category				
Forest:	3452.8 (61.9)	448.9 (32.1)	8632.0	82867.2
Rural category				
Agriculture:	410.4 (7.4)	123.1 (8.8)	4162.0	144194.1
Open land:	266.2 (4.8)	79.9 (5.7)	1384.2	44303.0
Residential Low:	584.9 (10.5)	175.5 (12.5)	3217.1	226955.2
Urban category				
Residential High:	363.6 (6.5)	236.5 (16.9)	2539.9	192211.9
Comm - Ind:	99.5 (1.8)	64.7 (4.6)	991.7	74607.3
Other Landuses				
Water:	340.4 (6.1)	0.0 (0.0)	0.0	0.0
Wetlands:	59.3 (1.1)	0.0 (0.0)	0.0	3144.5
Subtotal	5577.0	1128.6	20969.0	768842.0
Other P inputs:	NA	272.0 (19.4)		
0.0 Septics:	NA	0.0 (0.0)		
Total	5577.0 (100.0)	1400.6(100)	20969.0	768842.0

Summary of Lake Total Phosphorus Modeling Results

Areal P loading L= 13.3 g/m2/yr.
Reckhow (1979) model predicts lake TP = L/(11.6+1.2q)*1000 = 33.3 ppb.
Predicted transparency = 1.4 meters.

Table 2u. Tobins Pond MA42060

Total Estimated Nonpoint Source Pollution loads based on GIS Landuse

Watershed Area=	602.1 Ha (2.3 mi2)
Average Annual Water Load =	3670474.8 m3/yr (4.2 cfs)
Average Runoff=	61.0 cm/yr (24.0 in/yr)
Lake area=	4.3 Ha. (10.5ac)
Areal water loading to lake: q=	86.2 m/yr.
Homes with septic systems within 100m of lake.=	2.0
Other P inputs =	0.0 kg/yr

Estimate of annual Nonpoint Source Pollution Loads by land use

Land use	Area Ha (%)	P Load kg/yr (%)	N Load kg/yr	TSS Load kg/yr
Forest category				
Forest:	321.7 (53.4)	41.8 (21.3)	804.4	7721.8
Rural category				
Agriculture:	143.7 (23.9)	43.1 (22.0)	1627.6	58748.3
Open land:	19.9 (3.3)	6.0 (3.0)	103.4	3528.8
Residential Low:	23.2 (3.9)	7.0 (3.6)	127.8	9017.0
Urban category				
Residential High:	48.1 (8.0)	97.1 (49.6)	296.9	23583.5
Comm - Ind:	0.0 (0.0)	0.0 (0.0)	0.0	0.0
Other Landuses				
Water:	35.8 (5.9)	0.0 (0.0)	0.0	0.0
Wetlands:	9.7 (1.6)	0.0 (0.0)	0.0	512.2
Subtotal	602.1	195.0	2990.9	103522.3
Other P inputs:	NA	0.0 (0.0)		
2.0 Septics:	NA	1.0 (0.5)		
Total	602.1 (100.0)	196.0(100)	2990.9	103522.3

Summary of Lake Total Phosphorus Modeling Results

Areal P loading L= 4.6 g/m2/yr.
Reckhow (1979) model predicts lake TP = L/(11.6+1.2q)*1000 = 40.0 ppb.
Predicted transparency = 1.2 meters.

Table 2v. Wallis Pond MA42062

Total Estimated Nonpoint Source Pollution loads based on GIS Landuse

Watershed Area=	785.3 Ha (3.0 mi2)
Average Annual Water Load =	4787241.3 m3/yr (5.4 cfs)
Average Runoff=	61.0 cm/yr (24.0 in/yr)
Lake area=	9.6 Ha. (23.8ac)
Areal water loading to lake: q=	49.7 m/yr.
Homes with septic systems within 100m of lake.=	0.0
Other P inputs =	0.0 kg/yr

Estimate of annual Nonpoint Source Pollution Loads by land use

Land use	Area Ha (%)	P Load kg/yr (%)	N Load kg/yr	TSS Load kg/yr
Forest category				
Forest:	452.3 (57.6)	58.8 (26.2)	1130.7	10854.4
Rural category				
Agriculture:	173.4 (22.1)	52.0 (23.2)	1988.0	71932.0
Open land:	24.1 (3.1)	7.2 (3.2)	125.1	3591.3
Residential Low:	30.3 (3.9)	9.1 (4.1)	166.7	11761.6
Urban category				
Residential High:	48.1 (6.1)	97.1 (43.3)	296.9	23583.5
Comm - Ind:	0.0 (0.0)	0.0 (0.0)	0.0	0.0
Other Landuses				
Water:	45.7 (5.8)	0.0 (0.0)	0.0	0.0
Wetlands:	11.5 (1.5)	0.0 (0.0)	0.0	607.6
Subtotal	785.3	224.2	3738.2	122741.1
Other P inputs:	NA	0.0 (0.0)		
0.0 Septics:	NA	0.0 (0.0)		
Total	785.3 (100.0)	224.2(100)	3738.2	122741.1

Summary of Lake Total Phosphorus Modeling Results

Areal P loading L= 2.3 g/m2/yr.
Reckhow (1979) model predicts lake TP = L/(11.6+1.2q)*1000 = 32.7 ppb.
Predicted transparency = 1.5 meters.