Total Maximum Daily Loads of Phosphorus for Indian Lake

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Front Cover

Photograph of Indian Lake in Worcester.

Total Maximum Daily Load of Phosphorus for Indian Lake, Worcester, MA. (MA51073)

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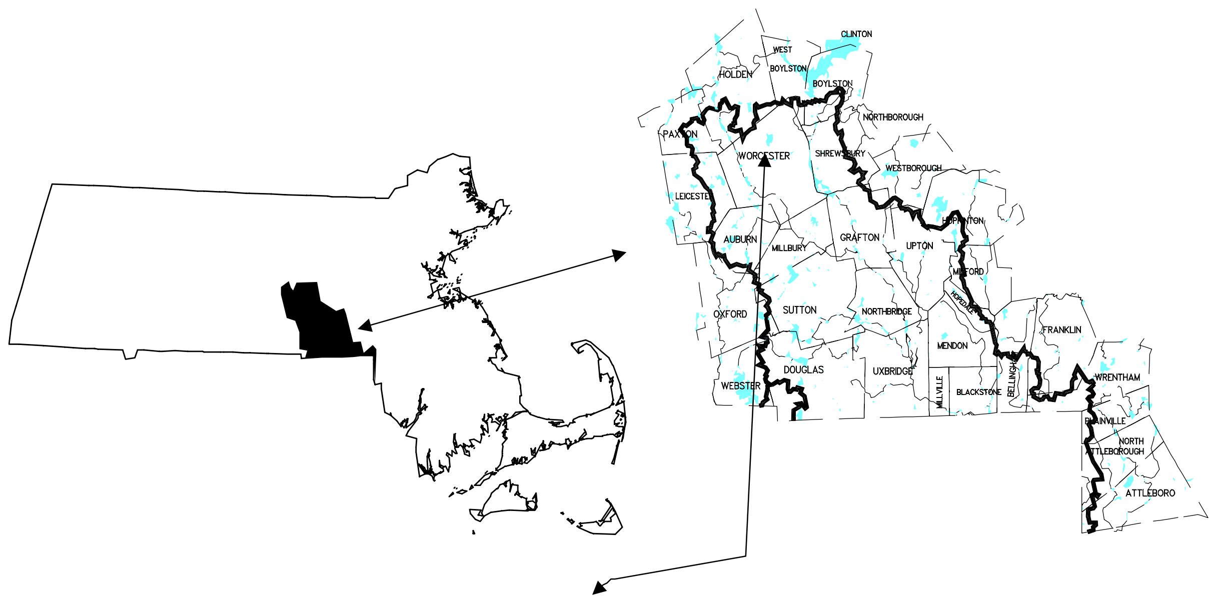

Location of Blackstone Basin, and Indian Lake in Massachusetts.

Key Feature:	Total phosphorus TMDL assessment of a lake
Location:	Worcester, MA - EPA Region 1; 42°17’50” 71°48’45”
Scope/ Size:	Watershed 795 Ha, Surface area 78. Ha (193 ac)
Land Uses:	Wooded 50%, Urban 40%, Water 10%
303d Listing:	Noxious Aquatic Plants (Code 2200) Organic enrichment and Low Dissolved Oxygen (Code 1200)
Data Sources:	D/F Study Lycott, 1989; DWPC Survey 1987.
Data Mechanisms:	Simple Model, Vollenweider Model, Best Professional Judgment
Monitoring Plan:	Massachusetts Watershed Initiative Five year cycle.
Control Measures:	Stormwater & Sewer Management, macrophyte harvesting

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 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 Indian Lake in the Blackstone River Watershed. Indian Lake is located in the headwaters of the Blackstone River Watershed, in the center of the Mill Brook sub-watershed in Worcester, MA. This area is developed, with a large percentage of impervious surfaces; as a result, Indian Lake exhibits water quality violations typical of urban waterways. The goal for the pond is to achieve Class B water [314 CMR 4.05(3)b Indian Lake is listed on the Massachusetts impaired waters 303d list for Nuisance Aquatic Plants, Organic Enrichment and Low Dissolved Oxygen. The cause of these conditions can be related to high total phosphorus loadings. These pollutants and stressors are indicators of nutrient enriched system, 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 the pond meets state water quality standards, the TMDL establishes a phosphorus limit for the lake and outlines corrective actions to achieve that goal.

This report, based on the Lycott (1989) Diagnostic/ Feasibility (D/F) study concludes that impaired water quality is due mainly to the stormwater runoff of total phosphorus from the pond's urban watershed. The D/F study recommends stormwater management and repairs and upgrades to the sanitary sewer pumps and sewer system to control nutrients. The study also recommends water level manipulation and plant harvesting (Parts of the Lycott study are reproduced in Appendix I). Although the study suggested algaecides for short-term control, these have not been applied in recent years. Furthermore, algaecides containing copper are not recommended for long term use due to the potential for accumulation in the sediments. The proposed control effort is predicted to reduce total phosphorus concentrations from 0.044 mg/l to 0.027 mg/l. Long-term monitoring of the pond is essential to ensuring that source controls continue to be implemented. This TMDL can be achieved through the cooperation and effort of state and municipal agencies, commercial entities in the watershed, and volunteers.

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 pollutant 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 used by the local Executive Office of Environmental Affairs Basin Team (see below) to guide watershed management plans in the basin. In some cases, TMDLs will be used by DEP to set appropriate limits in permits for wastewater and other discharges. Currently, no point source phosphorus discharges are permitted in the watershed with the exception of stormwater NPDES Phase I permit to the City of Worcester.

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 web at http://www.state.ma.us/envir/watershd.htm.

The proposed Total Maximum Daily Load (TMDL) is based on a Diagnostic/Feasibility (D/F) Study conducted by Lycott (1989) and funded under the Massachusetts Clean Lakes Program. (Parts of the D/F are reproduced in Appendix 1). Indian Lake is listed on the Massachusetts 303d list for Nuisance Aquatic Plants, organic enrichment and low dissolved oxygen. The Executive Summary of the D/F study (Lycott, 1989; see Appendix I) concludes that impaired water quality is due mainly to the stormwater runoff of phosphorus from the pond's urban watershed. The D/F study recommends stormwater management and repairs and upgrades to the sanitary sewer pumps and sewer system to control nutrients. The study also recommends water level manipulation and plant harvesting (Appendix I). Although the study suggested algaecides for short-term control, these have not been applied in recent years and algaecides containing copper are not recommended for long term use due to the potential for accumulation in the sediments. 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 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) and Cooke et al., (1993). 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 7:1 by weight or 16:1 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. 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 changes 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 and the landuse export approach and modeling 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.

Target Load: Once the current nutrient loading rate is established, a new, lower rate of nutrient loading must be established which will restore water quality. 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 (ecoregions). 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. This margin of safety can be specifically included, and/or included in the selection of a conservative 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 which may include point sources as well as private septic systems and various land uses within the watershed. In Massachusetts, few, if any, lakes receive direct point source discharges of nutrients. River impoundments often have upstream point sources, but these will be addressed as part of the appropriate river system. 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. 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.

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 sources in rural areas are leaching from failed or inadequate septic systems and phosphorus associated with soil erosion. 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'. 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. 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.

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 can not 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 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.

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 a Draft Generic Environmental Impact Report (Mattson et al., 1998). The Massachusetts Department of Environmental Protection will endorse in-lake remediation efforts that meet all environmental concerns, however, instituting such measures will rest with communities and the Clean Lakes Program now administered by EPA and, in Massachusetts, the 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 will be essential. This can be accomplished through a variety of mechanisms including volunteer efforts. Recommended monitoring will 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 Description and Problem Assessment

Description: Indian Lake, (MA51073) is a 193 acre, municipally-owned enhanced (enlarged) great pond located in the northern part of Worcester Massachusetts in the Blackstone Basin at approximately 42°17'50" N, 71°48'45" W. The lake was originally a 40 acre pond known as North Pond, which was dammed in the 1930s. The watershed is a mixture of residential and urban land uses. Several stormwater drains feed into the lake and the major tributary is Ararat Brook which enters at the northwest corner of the lake. The lake has a mean depth of about 3.25 m (10.7 feet). The lake was extensively used for sailing and water-skiing but existing conditions have reduced the recreational potential of the lake. There are two parks and swimming beaches on the lake and public access points for boat launching. Further information is available in Appendix II Lake Management Questionnaire.

Due to the high total phosphorus loading from the watershed the lake is experiencing nuisance algae blooms with associated high turbidity and low dissolved oxygen. The lake has a long history of management. According to Symmes (1975), the lake has been treated four times a year annually since the early 1960's with about 500 kg of copper sulfate and the lake now has relatively high copper deposits in the lake sediments (ranging from 25 to 200 mg/kg) as well as high arsenic and lead in the sediments which may place restrictions on proposed dredging. In a 1975-76 DWPC lake survey report (Chesebrough et al., 1978) it was noted that the lake had a history of algal blooms 'until copper sulfate treatment began", at which time apparently a shift occurred, and the report noted the major problem in 1975-76 being dense growths of macrophytes, especially the pondweed *Potamogeton pusillus.* According to Lycott, (1989), *Elodea* became the dominant nuisance plant in the lake in 1984-85, and a drawdown with a late spring refill in the spring of 1986 allowed *Elodea* to spread to deep water. A large herbicide treatment was conducted in the summer of 1986 at a cost of close to $100,000. (diquat and copper sulfate) which controlled the deep water *Elodea.* That apparently caused a shift back to algae. Since that time the transparency has been so limited by algae that macrophytes are no longer a major problem, most likely due to light limitation as algae became dominant again. According to DEP herbicide permit application records, between 1993 and 1996 the pond has no records of herbicide treatment, but it was treated in both 1997 and 1998 with small amounts of Sonar (Fluridone), K-TEA (copper) and Reward (diquat), apparently as spot treatments. The lake has been drawn down in winter by several feet each year, apparently for the past 10 years and according to residents this has also helped control macrophytes in shallow areas (R. Gates, pers. comm. 1998). Residents suggested *Elodea* beds have expanded during 1999, possibly due to lower water levels associated with the drought (R. Gates, pers. comm. 1999). This has led to a local desire for more chemical treatment to reduce *Elodea* again, but this is likely to further shift dominance to favor more algal blooms. The pond was listed on the 1998 Massachusetts 303d list for Nuisance Aquatic Plants and for organic enrichment and low dissolved oxygen (DEP, 1998). The overall goal is thus to restore the uses of the pond for primary and secondary contact recreation by reducing the blooms of nuisance algae and secondarily by managing macrophyte growth in residentially developed shoreline areas. This will be accomplished by a combination of reducing the total phosphorus loading to the lake and by direct control of macrophytes.

Data from a Massachusetts DWPC study in the summer of 1987 (summarized in Lycott, 1989) showed the lake was anoxic below 5 meters and water transparency varied from 1 to 1.5 meters and frequently violated the state standard for swimming of 1.2 m. The mean total phosphorus concentration measured in 1975 was 0.028 mg/l (DWPC, 1977), but increased to an average of 0.080mg/l in the 1987 survey. Mean chlorophyll a at the deep hole site in the lake during the 1987 survey was 18 mg/m^3. Based on these data the Carlson trophic state index was estimated between 55 and 64, but the Lycott report states the lake is mesotrophic near the eutrophic boundary (Lycott, 1989). A detailed sampling of aquatic plants in the Diagnostic/Feasibility Study of Lycott (1989) shows the lake to have relatively few areas of very dense or moderately dense aquatic vegetation, presumably due to the high turbidity which induces light limitation in macrophytes. A small area of emergent macrophytes such as cattails *Typha* block access to the open water from residences along the west shore in Ararat Bay in the northwest (see Fig. 5 in Appendix). Approximately 10 percent of the total lake area is covered with dense or very dense macrophytes (see Fig. 6. Appendix I). The more serious problem is the high turbidity and low transparency. Volunteer monitoring shows the Secchi disk transparency is commonly about 2 and a half feet (about 0.75m) during late summer (Brank et al., 1997). A recent site visit by DEP on October 6, 1998 showed Secchi disk transparency at 1.0 meters with an algae bloom in the water. According to R. Gates of the Indian Lake Watershed Association, there has recently been high bacteria levels at the Shore Park area, possibly due to an outdated septic system on the public restrooms there. Another source of bacteria may be the ducks and gulls along the shoreline, which have been observed being fed by the public. Two areas where sediment is washing into the lake include Barnstable Road and Hasting Avenue. The City is preparing to pave Barnstable Road and this should alleviate the problem there. Limited dredging to remove this sediment was suggested by the Indian Lake Watershed Association (R.Gates, pers. comm. 1999).

Pollutant Sources and Natural Background

The Lycott (1989) D/F study concluded that phosphorus is most likely the limiting nutrient. It should be noted that light may also limit macrophyte growth in deep water. A combination of methods were used to estimate total phosphorus loading to the pond (see Appendix). These included measurements of stormwater loadings of total phosphorus, but these measurements were not used in the final budget as they were not considered representative of stormwater concentrations. Instead, the "Simple Method" (Schueler, 1987) was used to multiply average stormwater concentrations from the NURP project, (Schueler, 1987) by estimates of urban runoff based on percent impervious surfaces. The equation used in the Simple Method is:

$$L = [\,(P)\,(P_j)\,(Rv/12)]\,(C)\,(A)\,2.72$$

where: L = loading in pounds
P = rainfall depth in inches
P_j = correction factor for storms with no runoff
Rv= coefficient converting rainfall to runoff
C = flow-weighted mean concentration of pollutant in runoff (mg/l)
A = Area of watershed in acres
and numbers 12 and 2.72 are conversion factors (Lycott, 1989).

This loading estimate was added to estimates of atmospheric deposition, carp release and release from anoxic sediments. The data are considered valid for this analysis as there are no reports of significant change in the watershed in the past ten years.

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. The city of Worcester had an estimated 20 year growth rate of about 4 percent. Thus, some increase in loadings are likely since the data were collected, but this would not change the target concentration or the final TMDL.

Water Quality Standards Violations

In consideration that the waters listed are a designated Class B warm water fishery 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 as the cause for violation of the Water Quality Standards related to impairment of primary and secondary contact recreation and aesthetics. These Water Quality Standards are described in the Code of Massachusetts Regulations under both 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….

The Lycott (1989) study concluded nutrient inputs of phosphorus from the watershed to be the primary cause of the nuisance plant growth and the organic enrichment/ low DO conditions.

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 this case, the TMDL is expressed in terms of allowable annual loadings of total 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 total phosphorus ecoregion map of Griffith et al. (1994) indicates the lake is in an ecoregion with concentrations of 15-19 ppb, based on spring/fall concentrations, while the total phosphorus ecoregion map of Rohm et al., (1995) suggests that typical lakes in this ecoregion would have concentrations between 30 and 50 ppb, based on summer concentrations. 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.

The Vollenweider model (Vollenweider, 1975) was used to estimate in lake concentrations of total phosphorus based on the equation:

$$P = L / (10 + ZF)$$

where:

P = predicted in lake total phosphorus concentration (mg/l)
L = areal loading of total phosphorus mg P /m^2 lake surface /year
Z = mean depth = 3.3 m
F = flushing rate = 1.91/ year

The resulting estimate of 0.044 mg/l was between the two previously measured lake concentrations and was judged to be reasonable to model the lake. Using the Vollenweider model, Lycott (1989) states the total P load (including internal recycling) would have to be reduced to 60% of the current value to move from upper mesotrophic (0.044 mg/l) to mesotrophic (0.027 mg/l). This was chosen as the target concentration because mesotrophic conditions should meet water quality standards and the target concentration of 0.027 mg/l falls within the ranges suggested from the ecoregion analysis described above.

Loading Capacity

This concentration implies a target of 314 kg/yr for total phosphorus loading to the lake, or a Total Maximum Daily Load of 0.86 kg/day. According to the Carlson Trophic Index equation, the Secchi disk depth for this target condition would be about 1.8 meters.

Wasteload Allocations, Load Allocations and Margin of Safety:

DEP chose a margin of safety of 5 percent of the total TMDL. In this case, the margin of safety is 314 kg/yr*.05 or 16 kg/yr. The watershed is largely urbanized and thus the target watershed export may be considered a combination of point and nonpoint runoff that is listed under waste load allocation of 206 kg/yr. This leaves 92 kg/yr for the load allocation to nonpoint sources as indicated in the right side of Table 1. Loading allocations are based on the measured total phosphorus budget; not the landuse modeled total phosphorus budget.

Total phosphorus loading allocations for each subbasin and other sources are shown (are rounded to the nearest kg/yr) in Table 1. No reduction in atmospheric loading is targeted, because this source is impossible to control on a local basis. The remaining sources, watershed export, carp release and anoxic sediment release are each targeted for approximately 47% reductions in total phosphorus loadings. The latter loading assumes that internal recycling of total phosphorus will be proportionately reduced as the external loading is reduced, although it is expected that reductions in recycling will lag behind reductions in external loading.

The Lycott (1989) study recommended the major effort be placed on controlling total phosphorus export from the watershed. To some extent, the proliferation of aquatic macrophytes in the pond is a natural condition resulting from the availability of shallow, nutrient rich sediments being flooded when the lake was enhanced by a dam. The shallow waters along the shoreline offers 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. Reducing the supply of external total phosphorus may not meet the goals of the TMDL without additional management in the lake as discussed below.

Table 1. TMDL Load Allocations.

Source	***Current TP Loading (kg/yr)***	***Target TP Load Allocation (kg/yr)***
Load Allocation:		
Atmosphere	35	35
Carp release	72	39
Anoxic Sediment Release	34	18
Waste Load Allocation:		
Watershed export	383	206
Total Inputs	524	298

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). In this case the TMDL is:

TMDL = WLA + LA + MOS = 206 kg/yr + 92 kg/yr + 16 kg/yr = 314 kg/yr.

Modeling Assumptions, Key Input, Calibration and Validation:

There was no modeling performed on the nuisance aquatic plants and control of nuisance aquatic plants is based on established literature and best professional judgment. Control of nuisance algae was based on control of in lake total phosphorus concentrations. The Vollenweider (1975) model is based on the assumptions of a mass balance model for a continuously stirred tank reactor and does a fairly good job of modeling in lake total phosphorus concentrations for Massachusetts lakes (Mattson et al., 1998). The key input is the loading rate. In this case the loading rate was estimated from the Simple Model of landuse and literature coefficients for concentrations of total phosphorus in runoff (based in part on the measured values for Lake Quinsigamond Massachusetts 4 km to the east) along with estimates of atmospheric, carp and sediment sources. As noted above, the predicted Total Phosphorus of 0.044 mg/L falls midway between the actual measured TP values of 0.028 and 0.080 mg/l as noted above and this agreement with predicting suggests the modeling assumptions are not grossly in error. While there is a wide range of error possible in the final model prediction, our best professional judgment, based on other urban lakes in the region, suggest the proportional allocations of nutrient sources are probably roughly correct, and that the 40 percent reduction in overall loading with an emphasis on targeting watershed exports is a reasonable approach.

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 total 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 Indian Lake total 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 annual total phosphorus load to Indian Lake will result in the application of total 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).

Implementation

Considering the lack of information on discrete sources of total phosphorus to the lake the implementation plan will of necessity include an organizational phase, an information gathering phase, and the actual remedial action phase. Phosphorus sources can not 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 facilitating the implementation of the TMDL are shown in Table 2. The next step will be to release this TMDL for public comment to watershed and lake associations, town Conservation Commissions and the interested public. Depending on public response, a public meeting will be held to obtain comments on the report, define goals and to organize groups for implementation. The local citizens within the watershed will be encouraged to participate in the information gathering phase. This phase may include a citizen questionnaire 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 in the watershed. The most important part of the information-gathering phase is to conduct a 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 and 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 3. A description of funding sources for these efforts is provided in the Program Background section, above.

The major BMP implementation effort would take place during the year 2000 as part of a rotating 5-year cycle, but would continue in the "off years" as well. Nutrient and stormwater 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). BMPs for general nonpoint source pollution control and examples of town bylaws for zoning and construction are presented in the Nonpoint Source Management Manual by Boutiette and Duerring (1994), that was distributed to all municipalities in Massachusetts. BMPs for erosion and sediment control are presented in DEP (1997). The Commonwealth has provided a strong framework to encourage watershed management through the recent 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 the lake be monitored on a regular basis and if the lake does not meet the water quality standards additional implementation measures may be implemented. For example, if total phosphorus concentrations remain high after watershed controls are in place, then in-lake control of sediment phosphorus recycling may be considered.

Reducing the supply of nutrients will not in itself result in achievement of the goals of the TMDL and continued macrophyte management is an essential part of the implementation plan. The Lycott (1989) study listed detailed waterhshed remediation alternatives in Table 19 of the Appendix (some of which have been implemented since the report) including in-lake management techniques (some of which have been implemented). A number of recommendations and the benefits associated with each are listed in Table 20 of the Appendix. To date, upgrades of the sewage pumping stations at Holden Street has resulted in increased sewage pumping capacity and no further reports of sewage overflows to the lake. The lake has been drawn down in the winter on a regular basis to control macrophyte growth. Other recommendations have not been implemented to date (R.Gates, pers. comm., 1998). The most important of these is control of erosion and sediment associated with stormwater runoff and conducting studies to identify any bacteria problems near the beaches. A public education program was also recommended.

Although selective dredging would be beneficial, problems with disposal of sediments may limits this option. According to the Lycott (1989) study, which reviewed earlier (1987) sediment data from the Massachusetts Division of Water Pollution Control the sediments are classified as Type III. However, the sediments may qualify as suitable for reuse as cover material at landfills.

Carp control was also discussed as a means to control turbidity caused by the feeding and excrement associated with carp. As the lake is very large the current recommendation is to encourage fishing. As the lake clears it is expected that young carp will be more susceptible to predation by visual feeding sportfish such as bass and pike, if appropriately stocked. If the lake is drawn down then it may be possible to use nets to collect and remove many of the nuisance carp while they are concentrated in the remaining pool of water. Sport and commercial fishing of carp should be encouraged to further reduce carp populations. According to a DEP memorandum (Maietta, 1989), carp from the lake were collected and tested for mercury and other metals as well as for PCBs. All fish tested were found to be acceptable for public consumption.

Alum treatments were also evaluated in the Lycott (1989) report, but as stated in the report, alum is not recommended until total phosphorus sources from the watershed have been reduced.

BMPs for general nonpoint source pollution control are described in a manual by Boutiette and Duerring (1994). Stormwater Management BMPs are detailed in the DEP CZM (1997) handbook. The Commonwealth has provided a strong framework to encourage watershed protection by legislation requiring low phosphorus detergents. All of these actions will be emphasized during the outreach efforts of the Watershed Team.

Many of the proposed stormwater management proposals have already been formally incorporated into the City of Worcester's Municipal Separate Storm Sewer System (MS4) NPDES discharge permit MAS010002. That permit requires controls necessary to reduce the discharge of pollutants from the MS4 to the Maximum Extent Practicable. This includes, among other requirements: No discharge of pollutants in quantities that would cause a violation of State water quality standards.

The permit also states the permittee shall operate and maintain structural controls (catch basins cleaned at least every other year and more frequently if more than 50% full). The permittee shall also act to minimize discharges of pollutants from areas of new development, roadways, flood control projects and discharges resulting from pesticide, herbicide and fertilizer applications to public right of ways and municipal facilities. The permittee shall continue programs to: detect and remove illicit discharges, spill prevention and response, and to monitor and control industrial runoff, construction site runoff and to implement a public education program on pollution prevention.

Table 2. Proposed Tasks and Responsibilities

Tasks	Responsible Group
TMDL development	DEP
Public comments on TMDL, Public meeting	DEP and Watershed Team
Response to public comments	DEP
Organization, contacts with Volunteer Groups	Watershed Team
Develop guidance for NPS watershed field survey.	DEP
Organize and implement NPS watershed field survey	Watershed Team and Indian Lake Watershed Association
Compile and prioritize results of NPS watershed surveys	Watershed Team and Indian Lake Watershed Association
Organize implementation; work with stakeholders and local officials to identify remedial measures and potential funding sources.	Watershed Team, Indian Lake Watershed Association and Conservation Commission
Encourage carp fishing in lake.	Mass. Fish & Wildlife.
Write grant and loan funding proposals	Indian Lake Watershed Association, Mill Brook Watershed Associations, Towns, Planning Agencies, NRCS
Organize and implement education, outreach programs	Indian Lake Watershed Association, Mill Brook Watershed Associations,
Implement remedial measures for discrete NPS pollution	See Table 3 below.
Include proposed remedial actions in the Watershed Management 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 Indian Lake Watershed Association (annually)

Table 3. Guide to Urban Nonpoint Source Control of Phosphorus and Erosion

Type of NPS Pollution	Whom to Contact	Types of Remedial Actions
Industrial		
Phosphorus Cleaning Agents	Industry Manager	Reuse and reduce or eliminate phosphorus containing cleaning agents.
Floor drains connected to storm sewers	Industry Manager and Regional DEP	Redirect floor drains to sewer system.
Stormdrains	Industry Manager and Regional DEP	Label stormdrains and forbid dumping or washing of chemicals into stormdrains. Add detention/ filtration basins to all stormdrains.
Stormwater runoff	Industry Manager, EPA	Use nonstructural BMPs for reducing stormwater pollution including fertilizer use, street and parking lot sweeping and Pollution Prevention Plans, Multi-sector NPDES permits.
Construction		
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.
Stormwater Runoff		
Turf Management	Golf Courses, Parks & Recreation Departments	Use non-phosphorus containing fertilizers. Apply fertilizers only after soil tests.
Urban Runoff from public roads	MassHighway, Town or city Dept. Public Works,	Reduce impervious surfaces, institute increased street sweeping and catch basin cleaning; install detention basins etc.
Unpaved Road runoff	Town or city Dept. Public Works	Pave heavily used roads, divert runoff to vegetated areas, install riprap or vegetate eroded ditches.
Residential areas		
Septic Systems	Homeowner, Lake associations, Town Board of Health, Town officials	Establish a septic system inspection program to identify and replace systems in non-compliance with Title 5. Establish a regular septic system inspection program. Discourage garbage disposals in septic systems.
Lawn and Garden fertilizers	Homeowner, Lake associations	Establish an outreach and education program to encourage homeowners to eliminate the use of phosphorus fertilizers on lawns, encourage perennial plantings over lawns.
Runoff from Housing lots	Homeowner, Lake associations	Divert runoff to vegetated areas, plant buffer strips between house and lake
Other stream or lakeside erosion	Landowner, Conservation Commission	Determine cause of problem; install riprap, plant vegetation.

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 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 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

A synoptic survey of the lake from vantage points on the shoreline was conducted by DEP in August of 1998 and as noted above most of the lake surface (approximately 70-80 percent) was apparently clear of nuisance aquatic vegetation. Monitoring by DEP staff 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 effectiveness in reducing plant cover and reducing total phosphorus concentrations can be re-evaluated and the TMDL modified, if necessary. Additional monitoring by volunteer groups are encouraged.

Public Participation

A preliminary public meeting was held on Nov. 10, 1999 with state and local government representatives and local environmental groups including the Indian Lake Watershed Association. at the DEP office in Worcester to discuss an earlier draft of this and other local TMDL reports. A public meeting to discuss each the draft TMDLs for both Indian Lake and Salisbury Pond was announced in the Environmental Monitor and in various letters sent to public officials, regional planning agencies and local environmental organizations. The public meeting was held October 18, 2001 at the Bancroft School in Worcester near Indian Lake. An attendance list for the meeting is presented in Appendix III.

Public Comment and Reply

No written comments were received within the 30 day comment period following the meeting. The following comments were taken at the public meeting. Note that some comments were generic and are included in both Indian Lake and Salisbury Pond TMDLs.

Comment: What is the enforcement status of the Indian Hill Development Project? Erosion and sedimentation has had a significant effect to Indian Lake since 1980's (~ 10' of sediment over the course of the last 10 years?).
Response: DEP's Central Regional Office, Bureau of Resource Protection executed an Administrative Consent Order with Penalty (ACOP) with Indian Hill Partnership in Worcester for $10,000.00. The fine was issued for erosion and siltation to off-site wetland resource areas. The ACOP required immediate improvements to erosion and drainage controls and restoration or compensation for an off-site pond that was silted.

Comment: It was suggested there should be a statewide discussion (including DEP, Army Corp f Engineers (ACOE) and other state / federal agencies) to formulate a "workable" dredging policy. Specific guidance and or fact sheets on what dredging materials and thresholds are considered "hazardous waste"? And what materials thresholds could potentially be used for daily cover at landfills etc? This guidance and or fact sheets would be extremely helpful to community officials, lake and watershed associations and advocacy groups who are evaluating dredging as an In-Lake Management option.
Response: The new Generic Environmental Impact Report (GEIR) on lake management should be available within a year and should have this information.

Comment: Lynne Welsh EOEA Blackstone River Team Leader requested a copy of the Walden Pond Porous Pavement Demonstration Project funded under the Nonpoint Source Section 319 grants program.
Response: Mike DiBara has located a copy of the February, 1986 Research Project titled: Installation and Evaluation of Permeable Pavement at Walden Pond State Reservation, by Irvine Wei, Department of Civil Engineering at Northeastern University. Several copies of this report are being made and one will be forwarded to Lynne.

Comment: What can be done about inputs of sediments and nutrients from MassHighways?
Response: This was more of a problem in Salisbury Pond than in Indian Lake. It was noted at the meeting that MassHighways will be required to comply with a new Phase II Stormwater discharge permit. In addition, the Regional DEP office in Worcester has submitted a written request to the Regional office of MassHighways to give the roads in the Millbrook drainage area (including parts of Indian Lake Watershed) priority for increased Best Management Practices such as sweeping and catchbasin cleaning. See the Salisbury Pond TMDL report for further information.

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Appendix I Reprint of Lycott, (1989).

The following pages are selectively reproduced from Lycott (1989). Diagnostic/Feasibility Study for the Management of Indian Lake, Worcester, Massachusetts.

COMMONWEALTH OF MASSACHUSETTS
CLEAN LAKES & GREAT PONDS PROGRAM

DIAGNOSTIC/FEASIBILITY STUDY FOR THE MANAGEMENT OF INDIAN LAKE WORCESTER, MASSACHUSETTS

PREPARED FOR THE
CITY OF WORCESTER AND THE
MASSACHUSETTS DIVISION OF WATER POLLUTION CONTROL

BY:

LYCOTT ENVIRONMENTAL RESEARCH, INC.
600 CHARLTON STREET
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FINAL REPORT

FEBRUARY, 1989

LYCOTT

Summary of Findings and Recommendations

The findings and recommendations contained in this report are the result of a Phase I study conducted by Lycott Environmental Research, Inc. for the City of Worcester, Department of Public Works and the Massachusetts Division of Water Pollution Control. The project was funded by the City of Worcester and by the Commonwealth of Massachusetts, under the authority of M.G.L. Chapter 628, The Clean Lakes and Great Ponds Program.

Indian Lake is an urban lake which suffers from impaired water quality, principally due to high phosphorus loading from the watershed. As a result, the lake is experiencing nuisance algae "blooms" and has high turbidity which makes it aesthetically unappealing. Stormwater runoff to the lake has been identified as a major factor in the high phosphorus loading.

The following watershed controls have been recommended to address stormwater phosphorus loading and water circulation enhancement: rehabilitation and repairs to the Holden Street sanitary sewer and the Holden Street sewage pumping station; an enlarged culvert under Sears Island causeway; a sediment retention basin for Huntington Avenue stormdrain; stormwater filtration in the Ararat Brook and Forest Street watersheds; paving Barnstable Road and a public education program to promote awareness and control of diffuse sources of phosphorus loading.

Additionally, the following in-lake management techniques have been recommended to control internal sources of sediment and nutrients and to control nuisance weed growth: mechanical weed raking of aquatic weeds in residentially developed shoreline areas; and periodic water level drawdown during the winter to control weed growth, to improve the recreational fishery, and to modify the physical characteristics of the near-shore sediments. Continued use of algicides is the only viable short-term method to control nuisance algal blooms. In the long-run, the control of phosphorus export from the watershed will result in a clearer lake.

These alternatives, when implemented, will provide a comprehensive management plan for Indian Lake and the surrounding watershed area. This program is intended to manage the lake and to improve its recreational potential for both current and future generations of Worcester residents.

Table 13
Watershed Phosphorus Export

	ACREAGES		PERCENT IMPERVIOUS	PHOSPHORUS LOADING (lbs./ year)		
	URBAN	**WOODED**	**URBAN***	**URBAN**	**WOODED**	**TOTAL**
1 Ararat Bk.	570	580	30	387	109	496
2 Parkton Ave. Shoreham St.	125	45	33	92	9	101
3 Route 122A/ Holden St.	128	122	33	95	23	118
4 Ltl. Indian Lake	109	11	33	81	2	83
5,6 & Ovrlnd. Flow	60	20	33	44	4	48
			Total			846

* Wooded land assumed 2 % impervious.

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SEDIMENT RELEASE

In computing the overall phosphorus loading to Indian Lake, internal sources due to anoxic sediment release were estimated. Phosphorus release for the two-month stratification period of 1987 was estimated from the measured increase in phosphorus concentration in the stratified bottom water. From May to July, the stratified volume-- taken to be an area of 24 acres with a mean depth of 5 feet-- increased in total phosphorus concentration from 50 mg/m^3 to 260 mg/m^3. This represented an increase of 34 kg within the stratified bottom layer. Because of the uncertainty in estimating the appropriate volume of elevated phosphorus and the possibility of some disturbance of the sediment during sampling with concurrent release of phosphorus-rich pore water, the actual magnitude of the phosphorus increase due to bottom release could well be from 10 kg to 60 kg. During the 1987 study year, the re-stratification of the bottom waters during September did not result in a significant increase in bottom water phosphorus. Thus, our estimate of sediment phosphorus release during 1987 would be 10 kg to 60 kg. This number would clearly vary depending upon the length of the stratified period which, in a weakly stratified system such as Indian Lake, is strongly dependent upon the presence or absence of intense mixing forces due to winds or stormflows of Ararat Brook.

Total Phosphorus Loading

Accounting for watershed export, internal release, and atmospheric deposition, the total annual load of phosphorus to Indian lake is estimated at 524 kg/yr (Table 13).

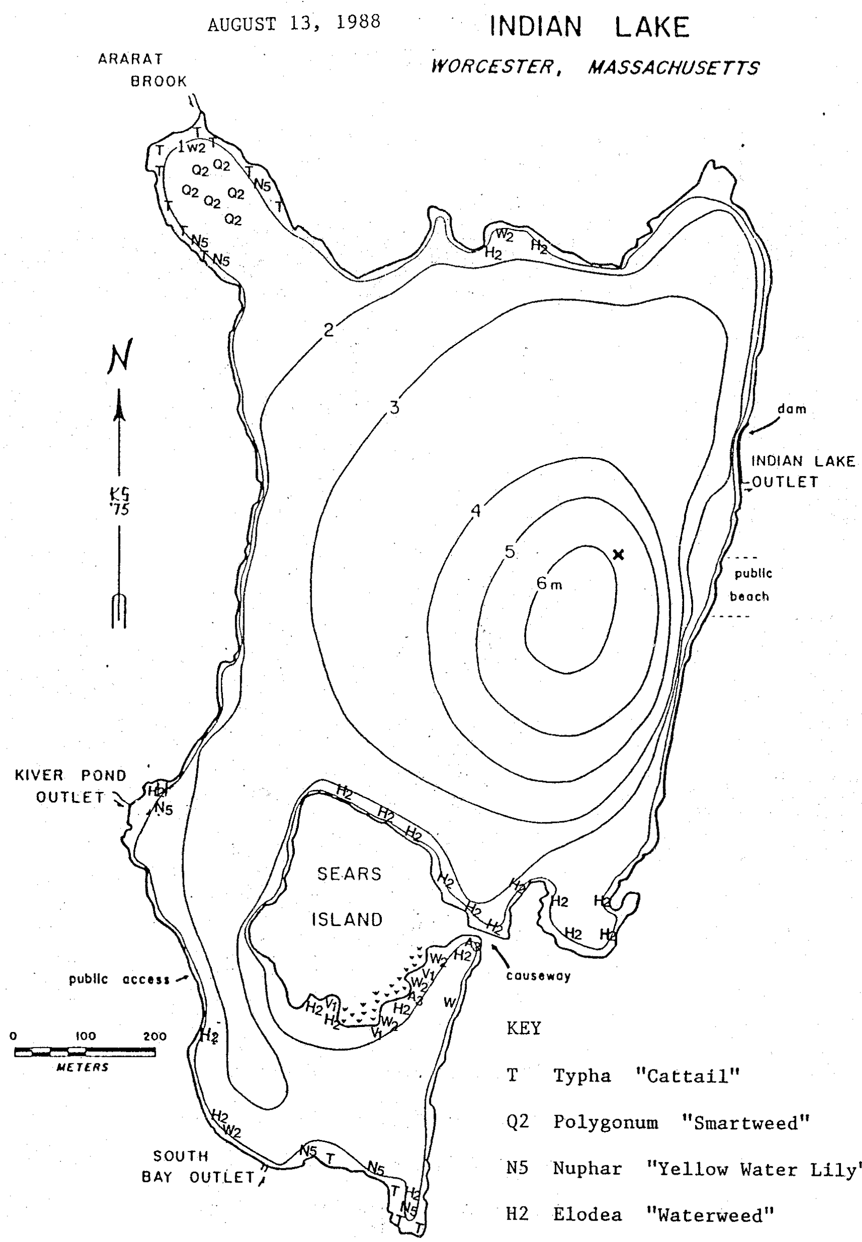
TABLE 14

Overall Phosphorus Loading to Indian Lake

Source	Loading (kg Tot P/yr)	Percentage
Watershed Export	383	73.1
Atmospheric Deposition	35	6.7
Carp Release	72	13.7
Release from Anoxic Sediments	34	6.5
Total Load	**524**	

The major loading of phosphorus to Indian Lake is clearly from its highly urbanized watershed.

AQUATIC WEEDS: SPECIES DISTRIBUTION



contour intervals in meters

KEY

T Typha "Cattail"

Q2 Polygonum "Smartweed"

N5 Nuphar "Yellow Water Lily"

H2 Elodea "Waterweed"

W2 Pontederia "Pickerelweed"

V1 Decodon 'Swamp Loosestrife"

A3 Sagittaria "Arrowhead"

FIGURE 5

LYCOTT

35

AQUATIC MACROPHYTE DENSITY AUGUST 13, 1988

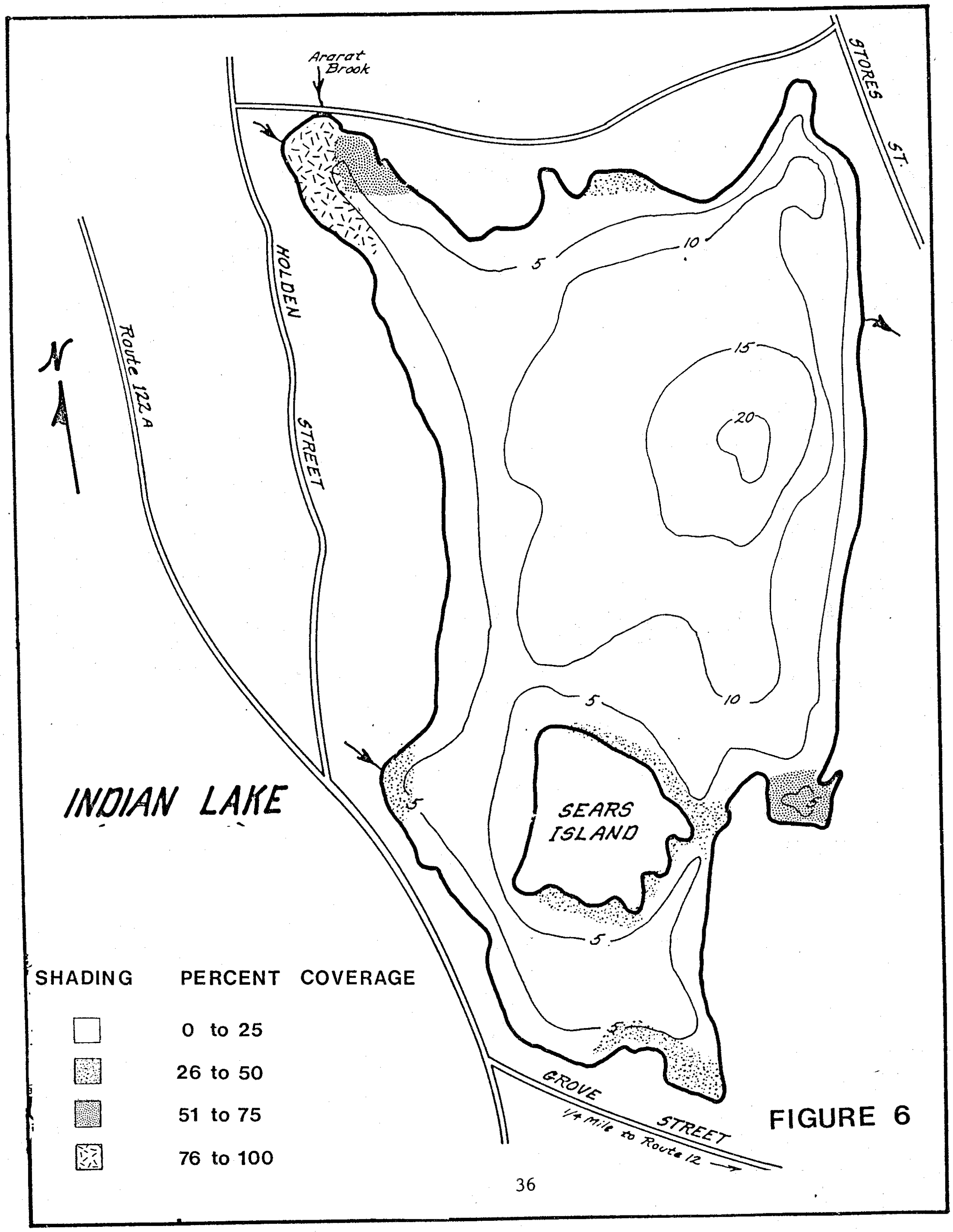


FIGURE 6

36

Appendix II. Indian Lake Management Questionnaire.

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Preliminary Lake Management Survey For Municipalities, ConComms and Lake Associations

This information will be used to help develop Total Maximum Daily Load Reports as part of the Federal Clean Water Act requirements under section 303(d) and to help develop funding priorities. If you are unsure of the accuracy of your answer to any question then add a question mark? and provide a name and phone number that we can call for further information on the subject. Add a separate page with additional comments if you wish.

Return to: Dr. Mark D. Mattson, Dept. Environmental Protection, DWM, 627 Main St. 2nd Fl
Worcester, MA 01608 (508) 767-2868 email mark.mattson@state.ma.us

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Type of Waterbody: Lake Town: WORCESTER Lake Name: INDIAN LAKE
ID number: Pollutant Stressor:
Comments:

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1)Your Name and position title: ROBERT E. GATES PRESIDENT Phone:(508) 8526325 email: GATESARMY.AOL.COM

2)Name of Municipality or Lake or Watershed Association and address:

INDIAN LAKE WATERSHE ASSOCIATION INC.

3)Describe any unique or valuable features of the lake (ownership, historic, watersupply, only beach in town, in a park, tourist attraction, rare species etc.) OWNED BY CITY OF WORC. 2 BEACHS 2 PARKS BOAT RAMP. SAIL CLUB, WATERSK CLUB, HEADWATER OF BLACKSTON.

4)Roughly estimate daily public use (# of people on lake during the day) during summer months for each of the following activities:
a) Boating 20-50 b) Fishing 0-15 c)Swimming 75-125 d)Sightseeing, picnic 200 e)other

5)Does the lake have a dam at the outlet? Yes X No ____ If yes, how high? (ie how many vertical feet of water does the dam hold back? 20 ft.) Is the lake level adjustable from the dam? (i.e., splash boards, gate, or valve?) and are they in good working order to conduct a drawdown? YES Are annual drawdowns conducted? YES If yes, how many feet? 6 1/2 ft VERT.
Who owns the dam ?

6)How many public bathing beaches are present? (where): 3 SHORE PARK, INDIAN LAKE BEACH, HOLDEN PARK

7)How many other beaches (e.g. resorts) are used by public (where): SEVERAL HOME OWNERS

8)Are there current problems with swimming in the lake? a) bacteria, b)transparency <4ft c) weeds, d)no serious problems
e)other Have the beaches been closed last year due to any of above causes? YES

9)How many public boatlaunches are available? (where): 1. ON HOLDEN ST

10)How many other boat launches (e.g. resorts) are used by the public? MANY HOMES HAVE THERE OWN

11)Are there current problems with boating or fishing on lake? a)weeds along shore b) weeds cover on 90 % of lake surface c)fish kills d) exotic weeds (list) e)boating noise f) boating turbidity, g) algae blooms h) low oxygen i)no serious problems, Other problems? Explain.

ELODIA

12) Are aquatic weeds a problem in the lake? YES Have the species been identified? ELODIA

13)What is considered to be the major sources of pollution? a)Farms b) urban runoff, c)septic systems d)gravel pits e)unknown e)other

14)What type of sewage treatment is used for homes on the lakeshore (within 100 yards) ?: a)private septic (b)sewer) c)unknown
Contact person and phone 4526325

15)For each category listed below, what has been done in the past ten years to remedy lake problems? (Roughly estimate money spent and provide contact person):
a) Volunteer or local water quality monitoring; Yes X, No ? Years 5 Contact BOB GATES 4526325

b)Please provide title, year and author of any recent studies or lake management plans: SEE CITY OF WORC DPW

c) Describe any in-lake treatments (i.e. harvesting, herbicide, water level drawdown, etc.) and include what kind are bing applied, what years were the treatments conducted, details of treatments and approximate cost (continue on back or separate sheet)

DRAW DOWN 1 NOV – 15 FEB TO 6½ VERTICAL
1985 CHEMICAL TREATMENT DIQUAT FOR WEED ELODIA

d)How effective and long lasting was the treatment? 10 YEAR'S 100% 11 YEARS AND BEYOND LESS THAN 10%

e) Work either on shore or in the watershed to reduce pollution entering lake .e.g. new sewer hookups for homes, major sewer repairs, public education, erosion control, BMPs etc.:

f) Please identify any other grants or grant applications or future management plans, including sewer upgrades, street maintenence:

NONE IN PROCESS AT THIS TIME

Appendix III. Public Meeting Attendance List.

Meeting presented by Mark Mattson and Mike DiBara of DEP.

COMMONWEALTH OF MASSACHUSETTS
EXECUTIVE OFFICE OF ENVIRONMENTAL AFFAIRS
DEPARTMENT OF ENVIRONMENTAL PROTECTION
Division of Watershed Management, 627 Main Street, Worcester, MA 01608

ARGEO PAUL CELLUCCI
Governor

JANE SWIFT
Lieutenant Governor

BOB DURAND
Secretary

LAUREN A. LISS
Commissioner

MEETING ATTENDEES LIST

Meeting: Indian Lake + Salisbury Pond TMDL
Date: Oct. 18 2001 Place: Broncroft Worcester MA

	Name	Affiliation	phone	email
1	ROBERT E GATES	INDIAN LAKE WATERSHED	508 852 6325	ROBERT.GATES@NATICK.ARMY.MIL
2	Lynne Welsh	EOEA Blackstone Rv	508 792-7423 X503	
3	ED BRANK	INDIAN LAKE Watershed	508-852-5987	
4	TERRY BEAUDOIN	MA DEP	(508) 7672742	Therese.Beaudoin@state.ma.us
5	Richard Chase	MADEP/DWM		Richard.Chase@massmail.state.ma.us
6	MATT LABOVITES	WDPW	508.799.1480	
7	Kerrie Carnes	Sen. Harriette Chandler	617.722.1544	Kcarnes@senate.state.ma.us
8	ALAN F SMITH	NORTH WORCESTER RESOURCE PRESERVATION SOCIETY	508 8535245	
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