Total Maximum Daily Loads of Phosphorus for Salisbury Pond

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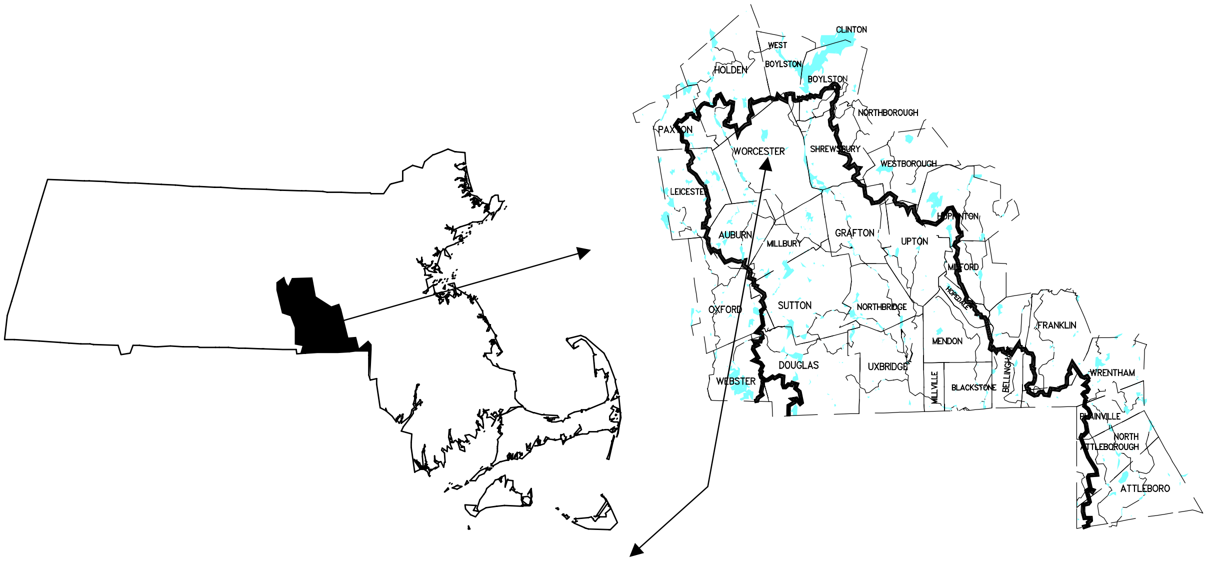
Front Cover
Photograph of Salisbury Pond in Worcester.

Total Maximum Daily Load of Phosphorus for
Salisbury Pond, Worcester, MA. (MA51142)
DEP, DWM TMDL Report MA51142-2002-010 CN 114 May 14, 2002



Location of Blackstone Basin, and Salisbury Pond in Massachusetts.

Key Feature:	Phosphorus TMDL assessment of a lake with nuisance aquatic plants and high turbidity, illicit sewage connections, bacteria, urban and highway runoff and sedimentation.
Location:	Worcester, MA - EPA Region 1
Scope/ Size:	Watershed 1820 Ha, Surface area 6.1 Ha (15.1 ac)
Land Uses:	Residential 59%, Urban 19%, Forest 17%
303d Listing:	Noxious Aquatic Plants (Code 2200); Turbidity (Code 2500)
Data Sources:	D/F Study Camp Dresser & McKee, 1987; unpublished data.
Monitoring Plan:	Massachusetts Watershed Initiative Five-year cycle; volunteer monitoring
Control Measures:	Sewage separation and system improvements, watershed, highway stormwater management, installation of structural BMPs and detention basins on inlets to pond, optional limited dredging.

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 Salisbury Pond in the Blackstone River Watershed. Salisbury Pond 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 highly developed, with a large percentage of impervious surfaces; as a result, Salisbury Pond exhibits continual water quality violations typical of urban waterways. The goal for the pond is to achieve Class B water [314 CMR 4.05(3)b]. Salisbury Pond is listed on the Massachusetts 303d list for Nuisance Aquatic Plants and Turbidity associated with high 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 pond and outlines corrective actions to achieve that goal.

The proposed Total Maximum Daily Load (TMDL) of 1082 kg/yr total phosphorus is based on a Diagnostic/Feasibility (D/F) Study conducted by Camp Dresser and McKee (CDM, 1987) and funded under the Massachusetts Clean Lakes Program. (Parts of the D/F are reproduced in Appendix 1). The Summary of the D/F study (see Appendix I) concludes that the pond is dominated by algae rather than macrophytes and that the pond volume is decreasing due to sediment inputs. The predominant source of phosphorus is from the twin culverts that constitute the major inlet of the pond. Phosphorus sources include runoff from MassHighways I-190, stormwater from surrounding urban areas, and sewage contamination.

Recent data also indicate that impairment of Salisbury Pond is also due to rapid sedimentation and excessive bacterial loads (associated with the ongoing sewage inputs). Data collected in 1999 have identified two areas of the pond that are in advanced stages of sedimentation; if material continues to fill the pond at the existing rate, these areas may be at or above the surface with the next 2 to 3 years. Rapid filling along the entire southern shore has resulted in dense stands of cattails and other macrophytes. Flagellated algae, typically associated with waters downstream of wastewater treatment plants dominated late summer algal assemblages.

The study recommended removing the sewage contamination from illicit connections, which was assumed to be a major problem and is being corrected. Sediment infilling of the pond from erosion and highway runoff is another major concern. A combination of continued separation of domestic and stormwater sewers, MassHighways BMPs, public education and erosion control is expected to bring the total phosphorus loading down to about 1082 kg/yr. The D/F study indicated that a phosphorus load of 500 kg/yr may be achieved through the installation of a stormwater diversion of the northern inlet, which would direct the Mill Brook flow to the Salisbury Pond outlet, thus bypassing the pond. However, this alternative is not recommended due to the anticipated degradation in the water quality of the Blackstone River. It is recommended to implement the TMDL in stages as the final diversion is expensive and may not be required due to the high flushing rate of the pond. The D/F study recommends watershed management to control nutrients and sediments and also recommends water level manipulation and plant harvesting (Appendix I). The proposed control effort is predicted to reduce total phosphorus concentrations from 70 ug/l to 45.5 ug/l.

Sediment control is also required in order for the pond to achieve surface water quality standards. Significant improvements in highway maintenance practices and Best Management Practices (BMPs); paving dirt roads;

implementing erosion control measures; and educating the public are expected to control sediment loading to the pond. Removal of sediment is also required to prevent infilling of the pond and sediment traps on the tributaries may be required. The sediment traps on the twin culverts and two other inlets are already being developed under a DEP Section 319 grant to the City of Worcester. An aggressive pond monitoring and maintenance program will ensure the continued viability of this urban pond.

The DEP recommends implementing a water quality improvement program in stages, with the initial focus placed on eliminating sources of phosphorus, bacteria and sediments before implementing expensive capital projects such as dredging and stormwater diversion structures. 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 and attached documents are 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. In some cases, TMDLs will be used by DEP to set appropriate limits in permits for wastewater and other discharges. No individual point source discharges are permitted in the Salisbury Pond Watershed with the exception of the Worcester Phase I Stormwater Permit and a non-contact cooling water permit to the Norton Company. All of these are not considered as itemized phosphorus sources in this report, although the Norton Company General stormwater permit has expired and the company should reapply for a stormwater permit this year. All stormwater discharges are considered to be part of the Waste Load Allocation in this TMDL.

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) for Salisbury Pond is based on a Diagnostic/Feasibility (D/F) Study conducted by Camp Dresser and McKee (CDM, 1987) and funded under the Massachusetts Clean Lakes Program. (Parts of the D/F are reproduced in Appendix 1). Salisbury Pond is listed on the Massachusetts 303d list for Nuisance Aquatic Plants and Turbidity due to high phosphorus loadings. The Summary of the D/F study (see Appendix I) concludes that the pond is dominated by algae rather than macrophytes and that the pond volume is decreasing due to sediment inputs. The predominant source of phosphorus is from the twin culverts that constitute the major inlet of the pond and that sewage contamination was observed in the twin culverts.

The study recommended removing the sewage contamination that was assumed to be the major problem. A combination of public education and erosion control is expected to bring the loading down to about 1082 kg/yr. A final stage of stormwater diversion of the twin culverts, if needed, would reduce loading to the target of 500 kg/yr.

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 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. 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: Salisbury Pond, (MA51142) is a 15 acre, municipally-owned pond located in Institute Park, adjacent to Worcester Polytechnic Institute in Worcester Massachusetts at approximately 42^{o}16'38" N, 71^{o}48'22" W. The pond was created by damming the Mill Brook in 1834 and used as a power source for a wire producing mill. The pond was reported dredged in 1956 and the National Guard did some additional sediment removal in the 1970s but the CDM (1987) study estimates the pond is filling in at a rate of 50,000 cubic feet per year between 1973 and 1987. The pond has a mean depth of only 0.96 m (3.1 feet) as of the 1987 CDM report (see map in Appendix I.) Recent depth data from a 1999 DEP survey show the pond is even more shallow now with many areas nearly filled in with sediment (see map in Appendix II).

The watershed is a mixture of residential and urban land uses. Several stormwater drains feed into the lake however the major source of water is a twin inlet culvert at the north end of the lake which is the former Mill Brook, now diverted underground. This twin culvert drains both the Mill Brook watershed to the north (generally east of and including Interstate I-190) as well as water from the outlet of Indian Lake including areas west of I-190. A separate Total Maximum Daily Load report for Indian Lake is under development in conjunction with this report and a detailed study of Indian Lake is also available (Lycott, 1989).

The park is used for concerts and picnics but numerous complaints about weed growth, odors and aesthetics indicate the pond is in poor condition and not meeting its designated uses. No boating is allowed but there are reports of people using the pond for fishing. The lake was treated with Diquat in 1986, however according to DEP records on herbicide permit applications there have been no herbicide treatments of the lake at least since 1993.

Due to the high phosphorus loading from the watershed the lake is experiencing nuisance algae blooms with associated high turbidity. Data from the CDM (1987) study showed dense macrophyte growth around the edges of the lake (see Fig. 1-8 in the Appendix). The report also states algal densities were in the range of 1000 to 1500 units/ml which indicates water quality problems with algal blooms, although no Secchi disk transparency was noted in the report. An earlier study by DWPC in 1983 reported the Secchi disk transparency of 0.7 meters and a total phosphorus concentration of 0.11 mg/l. The CDM (1987) report also states total phosphorus ranged between 0.013 - 0.17 mg/l in 1986 and that bacteria counts for fecal coliform bacteria exceed the state standard for Class B waters of a log mean of 200/100ml or 10% of samples exceeding 400/100ml. Further dry weather comparative testing of the outlet of the upstream Indian Lake to the twin culvert inlet of Salisbury Pond and observation of toilet paper and human feces near the twin culvert outlet strongly suggests there is a sewage contamination problem in the culvert between the two lakes. Raw sewage has historically impacted Salisbury Pond, and continues at this time. Sewage enters the stormwater system at many points in the Mill Brook watershed, as a result of both structural misconnections (where the sewer line from a home or business has been directed to the storm drainage system) and sewerage line failures (old pipes have rotted/broken). Recent citizen monitoring data indicates fecal coliform levels ranging from 100 to 16,600 colonies/100ml (Mass WaterWatch, 1999 unpublished data). As stated previously, there are many known and suspected sources of raw sewage to the pond. Many miles of wooden pipes are still in use in the City of Worcester, as well as many clay pipes. Observations of the condition of some of these lines compare them to “Swiss cheese” due to the degree of rot and breakage. In addition, many sewer lines from residences and businesses were misconnected to the storm system at the time of construction, and have been releasing raw sewage to Mill Brook for 70+ years. At this time, the City of Worcester has instituted an aggressive program to correct these problems, which will be discussed later in this TMDL

A recent site visit by DEP on September 9, 1998 reported a Secchi disk transparency of 0.9 and 0.5 meters at two different sites along the shore and an algae bloom in the water and duckweed on the surface. The macrophyte distribution appeared to be somewhat less extensive and restricted to very shallow water compared to the CDM (1987) map (Fig. 1-8 in the Appendix). The apparent reduction in macrophyte distribution may be a result of decreased transparency but lack of Secchi disk data from 1987 prevents any conclusions. An odor of fuel oil was evident at the lake outlet spillway and reported to DEP staff who were able to trace the spill to a storm-drain on the Norton Company property. As this site is completely fenced, the spill was assumed to be a result of discharges by Norton personnel. The Norton Company agreed to implement increased staff training and pollution awareness at the site.

Pollutant Sources and Natural Background

The CDM (1987) D/F study concluded that phosphorus concentrations were excessive and nearly always exceeding 0.02 mg/l and ranged between 0.013 and 0.17 mg/l. The average surface total phosphorus concentration was 70 ppb (CDM, 1987). It should be noted that light may also limit macrophyte growth, particularly when turbidity is high. Direct measurement of concentrations and estimates of inflow from the culverts and storm-drains into the pond were used to estimate phosphorus loading to the pond. Separate calculations were made for stormflow and baseflow. The total annual phosphorus loading estimates of 4,646 kg/yr were much higher than those predicted by land use export coefficients (1,353 kg/yr) and the difference was attributed to sewage contamination (see below). Further study on loadings would help in the implementation of BMPs, but implementation of the BMPs recommended here should not be further delayed.

A study of the stormwater nutrient loads was included in the Diagnostic/Feasibility Study of CDM (1987). The report concludes that the excessive algae growth and aquatic macrophyte growth can be attributed to the high phosphorus loading from the twin inlet culvert to the pond and that most of this is likely due to sewer contamination of the system somewhere between Indian Lake and Salisbury Pond.

Sedimentation is another source of impairment of Salisbury Pond. The upstream watershed contains steep hills, and has a very high proportion of impervious surface, which exacerbates sedimentation and erosion conditions. Field observation and visual inspections have identified some sediment sources. These sources are: drainage from Interstate 190; unpaved private roads that drain to paved streets where runoff enters the Worcester storm drainage system (mainly via the southwestern inlet); winter sanding from private residential and commercial properties; unstabilized surfaces on brownfields industrial properties; and construction activities. 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). It is generally recommended that phosphorus inputs to lakes be less than 0.050 mg/l. There are 19.4 lane miles of Interstate 190 that drain directly to the Mill Brook and Salisbury Pond via the eastern of the twin inlet culverts. The Massachusetts Highway Department (MassHighway), which is responsible for maintenance of the interstate, applies sand liberally during snow and ice storms to provide traction. Visual inspection by the Mill Brook Task Force of surface drains exiting the highway corridor indicates periodic episodes of high flow and insufficient BMPs.
Much of this sediment appears to be coming from Interstate Route I-190, where the currently installed stormwater BMPs are apparently overwhelmed and filled with sediments in many locations (see Figures 1 and 2). The sediments have also filled in some small detention ponds along the east side of I-190.

Figure 1. Example of poorly maintained stormpipe from Interstate I-190 overpass.
Note pipe is completely clogged with sediment and debris.

Figure 2. A mound of sand covering a stormwater discharge pipe from Interstate I-190. The mound is covered with grass and weeds. Note size of shovel for scale.

Large commercial parking lots, e.g. Sam's Club and the Greendale Mall, use sand as well. The level of catch basin maintenance at these locations is either undocumented or unknown. The City of Worcester generally uses salt rather than sand on city streets, so city street sanding is thought to be only a minor contributor of sediment.

In addition to the sediment sources described above, there are several unique sites in the watershed that may also serve as significant sources of sediment. There are a number of unpaved streets with steep gradients from Rockdale St. to Mount Ave. The stream channel along the downgradient railroad has insufficient hydraulic capacity to carry runoff during large storms, and a partially collapsed culvert near Brooks Street also restricts flow. During high flows the stream exceeds bankfull capacity, and flows westward across industrial properties to Rockdale Street. At Rockdale Street, the water flows south where it returns to the stream channel. Runoff from the unpaved streets during such events flows directly to the stream overland rather than through catch basins and the MS4.

Another potentially significant source of sediment is the Wrightline Building at 160 Gold Star Boulevard, which is located within the Mill Brook flood plain. When the Wrightline Building was expanded, the City of Worcester required provision of flood storage in the form of a vault beneath the building. The vault was designed to fill when surface runoff in the area exceeds the capacity of the Worcester storm drainage system. Surface runoff from the property flows through direct inlets to the flood storage vault. When carrying capacity in the storm drainage system is available, the water is pumped from the vault into the municipal system. However, this vault has not been inspected for at least 5 years. Although the pumps have been maintained, it is unknown whether sediment has accumulated in the vault, which would reduce the available flood storage volume, as well as serve as a sediment source to the downstream watershed Additional work is needed to quantify these sediment sources in order to develop an effective sediment remediation and control plan.

Because the direct measurement of loading from runoff includes natural background it is difficult to separate this source from anthropogenic sources. In this case, not separating natural background is reasonable because the approach used to estimate loadings by subwatershed and the limited and general nature of the information available. 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.

Water Quality Standards Violations

There are two water quality violations listed on the 303d list; Nuisance Aquatic Plants and Turbidity. In consideration that the waters listed are a Class B water, the data listed above were judged sufficiently well documented to place the lake on the Massachusetts 303d list for 1998 (DEP, 1998) related to impairment of primary and secondary contact recreation and aesthetics. These 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.
>
> 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.”
>
> 5. “Solids – These waters shall be free form floating, suspended and settleable solids in concentrations and combinations that would impair any use assigned to this Class, that would cause aesthetically objectionable conditions, or that would impair the benthic biota or degrade the chemical composition of the bottom.”
>
> 6. “Color and Turbidity - These waters shall be free from color and turbidity in concentrations that are aesthetically objectionable or would impair any use assigned to this Class.”
>
> 314CMR 4.05 (5) (a): All surface waters shall be free from pollutants ......or produce undesirable or nuisance species of aquatic life”.
>
> (b):Bottom Pollutants or Alterations – All surface waters shall be free from pollutants in concentrations and combinations or from alterations that adversely affect the physical or chemical nature of the bottom, interfere with the propagation of fish or shellfish, or adversely affect populations of non-mobile or sessile benthic organisms.

The Water Quality Standards for turbidity are based on 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….

As noted above, there are also violations of water quality standards for bacteria and sediments that are not listed on the current 303d list, but which will be addressed in the BMPs proposed here. Bacteria levels are expected to meet standards as the sewer system is upgraded. Sediment inputs are expected to decline as additional BMPs are added to the highways and as BMPs or pavement are applied to the remaining local dirt roads.

TMDL Analysis

Identification of Target: There is no loading capacity *per se* for nuisance aquatic plants. The plants simply grow in response to favorable conditions and nutrient availability. 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 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) indicates the lake is in an ecoregion with concentrations of 15-19 ppb, based on spring/fall concentrations, while the 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. Based on the above ecoregion analysis and the very fast flushing rate (413 times per year) of the pond, DEP has set the target TP concentration at 45.5 ppb. Because of the flow-through nature of the pond, the fast flushing rate of the pond (0.9 times per day) would tend to flush algae and duckweed out of the pond as fast as they grow and thus water transparency meeting the 4 foot swimming criteria may be met at a higher phosphorus level than in other, slower flushing lakes in the same ecoregion. Thus, a relatively high phosphorus target is justified in this lake. The 45.5 ppb target represents a 35 percent reduction from the average surface total phosphorus concentration of 70 ppb reported in CDM (1987). Apparently CDM (1987) did not report Secchi disk transparency, however a recent unpublished DEP survey in September, 1998 reported Secchi disk transparencies of 0.9 and 0.5 meters, which is below the swimming criteria of 1.2 meters (4 foot). Although swimming is not a current use, the goal is to meet water quality standards of swimable conditions.

Loading Capacity

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 phosphorus because the growth of phytoplankton and macrophytes responds to changes in annual rather than daily loadings of nutrients. Because of the rapid flushing rate (0.9 per day), a simple mass balance approach was used to predict phosphorus concentrations based on mass of phosphorus input divided by volume of water loading per year. The CDM (1987) report established several target conditions based on phases of implementation. The final CDM (1987) target was based on the assumption that the sewage contamination could be eliminated and the loading reduced to that expected from the land use analysis (1,353 kg/yr). The remaining non-point source pollution could be reduced 10-20 percent by a combination of public education and erosion control.

The prudent approach, however, is to implement the target in phases, beginning first with elimination of sewage contamination and implementing a 20% reduction in watershed loading, or 1082 kg/yr as described in the CDM (1987) report, combined with an aggressive stormwater control program for both the City of Worcester and MassHighway. With current water loading rates of $2.38 \times 10^7 m^3$ per year, this would result in a predicted in lake phosphorus concentration of:

Average P in pond = P loading/ water loading = $1082 kg / 2.38 \times 10^7 m^3 = 0.0455$ mg/l

Although is still rather high, the fast flushing rate of the pond (0.9 times per day) would tend to flush algae and duckweed out of the pond as fast as they grow. However, during the summer low flow period the flushing rate would be greatly reduced and the possibility exists for continued algal growth.

Wasteload Allocations, Load Allocations and Margin of Safety:

Although there is some uncertainty with the predictions, the first two stages of implementation (sewage elimination and NPS reduction) may be able to achieve the water quality standards, controlling both eutrophication and meeting water transparency criteria. If so, this pond could meet water quality standards without the need for the final stage: the proposed diversion with a cost estimated at $328,000 in 1987.

The CDM (1987) study recommended the major effort be placed on controlling phosphorus export particularly that associated with stormwater from the major twin culvert inlet. 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 pond offers an ideal habitat for natural growth of aquatic macrophytes and complete elimination of macrophytes is neither possible nor desired. Thus reducing the supply of external phosphorus may not meet the goals of the TMDL without additional management in the lake as discussed below.

DEP chose an additional margin of safety of 5 percent of the total TMDL. In this case, the margin of safety is 1082 kg/yr*.05 or 54 kg/yr. The watershed is largely urbanized and thus the culverts drains and runoff listed in Table 1 may be considered a combination of point and nonpoint runoff that is listed under waste load allocation. The waste load allocation is 1028 kg/yr, with a load allocation of zero for the target allocations as indicated in the right side of Table 1. By far the largest reduction is targeted for the twin culverts, most of which is expected to be accomplished by removal of the sewage contamination and by implementation of stormwater BMPs at the inlets and at MassHighways sites, which is expected to reduce overall loading of the twin culverts to 888 kg/yr. Similarly, a 20 percent reduction in loading is targeted for drain #4. No reduction is targeted for other runoff.

Table 1. TMDL Load Allocations.

Source	*Current TP Loading (kg/yr)*	*Target TP Load Allocation (kg/yr)*
Load Allocation:	0	0
Waste Load Allocation:		
Twin Culvert Inlet *	4480	888
Drain #4 Stormflow	149	123
Other drains & runoff	17	17
Total Inputs	4646	1028

*Note that the Twin Culvert Inlet includes illicit stormwater connections, as well as runoff from MassHighways I-190 and city streets. These sources were not separately estimated in the report.

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 = 1028 kg/yr + 0 kg/yr + 54 kg/yr = 1082 kg/yr.

Modeling Assumptions, Key Input, Calibration and Validation:

No models currently exist to predict a reduction of nuisance aquatic macrophytes as a result of phosphorus controls, therefore, no macrophyte models were used. Control of nuisance aquatic macrophytes is based on established literature and best professional judgment. In-lake nutrient concentrations were modeled by simple, conservative flow through equations, based on the rapid flushing rate. Control of nuisance algae was based on control of in lake phosphorus concentrations, which were assumed to be predictable from total phosphorus loading divided by total water loading. The essential input is the loading rate. In this case, the loading rate was estimated from measured total phosphorus concentrations and estimated flows based on nearby gaged watersheds. Flows in the watershed may be even higher due to the large percentage of impervious surfaces in the watershed. As noted above, the total phosphorus in the pond was so variable that it cannot be used for reliable modeling verification. While there is a wide range of error possible in the final model prediction, our best professional judgment is that the proposed reduction of nearly 78 percent of inputs would result in noticeable improvements in water quality.

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 Salisbury Pond is likely to respond to daily loadings due to the very fast flushing rate not enough data is available to construct daily loading estimates. Furthermore, the sediment infilling of the pond occurs over a longer time scale and therefore an annual basis for loading is preferred. Because critical conditions occur during the summer season when weed growth is more likely to interfere with uses and this TMDL is intended to meet water quality standards during the summer this TMDL will also meet water quality standards during other times of the year. 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 Salisbury Pond 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 phosphorus load to Salisbury Pond will result in the application of phosphorus controls that also address seasonal variation. For example, certain control practices such as diverting runoff and stabilizing eroding drainage ways 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

The CDM (1987) study recommended replacing the sewage pumping station near Indian Lake. This has already been done and no further sewage overflows from this site have been reported since that time. In addition, according to Joseph Buckley (pers. comm. 1999) the Sewer Operation Division located and corrected some illicit connections in the pipes leading to Salisbury Pond, but many more are known or suspected to exist. Although the twin invert modifications to the sewer system in the Salisbury Pond area is not completed, the work is ongoing. In 1998, the City was issued a NPDES permit MAS010002 for stormwater discharges. Mr. Buckley notes the stormwater controls and BMPs required by the City of Worcester as part of the NPDES Stormwater permit application are being implemented.

The City has committed to and begun implementation of an aggressive program designed to identify and correct sources of sewage to the storm drain system. This program has had major successes in the Mill Brook watershed in the past year alone. Under the stormwater permit, the city must look at each of its major watersheds on a five-year cycle; Mill Brook is scheduled for (calendar year) 2000. On 2 January 2000, staff members of the DPW had already identified one significant source: an office building of 50 staff members. This building, which has housed numerous commercial enterprises, was misconnected to the stormwater system in 1928, and has been discharging raw sewage to the Mill Brook less than one mile upstream of Salisbury Pond since that time. The Worcester Health Department has instructed the owners to correct this situation immediately.

However, other significant sources of sewage are not addressed in such a timely manner. Projects necessitating replacement of sections of sewer pipes require large capital outlays, and are not within the scope of the annual budget of the Worcester DPW. Such projects may not receive the requisite funding for several years, during which time raw sewage will continue to impact Salisbury Pond.

Details of the stormwater controls can be found in the permit applications (DPW, 1992 and DPW, 1993). This permit requires the following:

Street Sweeping Program- Residential streets twice a year; downtown streets weekly or more often.

Catch Basins Cleaning—about 7,000 basins (more than 50 percent of total) will be cleaned and inspected annually. On average, each basin will be cleaned every other year.

Illicit connections—A program to detect and remove illicit connections to the sewer will be carried out.

Dual manhole modification program—Nearly 30 percent of manholes within Worcester are dual manholes; a common structure that provides access to separate sanitary and storm sewer lines. To alleviate cross contamination during high stormwater flows aluminum plates were and are currently being bolted over the sanitary invert. The sewer system discharges are treated and discharged to the Blackstone River and does not impact Salisbury Pond.

The City of Worcester Department of Public Works, (DPW), was the first city in New England to receive a NPDES permit for its Municipal Separate Storm Sewer System or MS4. The Permit is issued by the United States Environmental Protection Agency, and covers any City owned drainage outfalls that discharge to lakes, streams, rivers, and ponds within the City of Worcester, including Salisbury Pond. Under the auspices of the Stormwater Management Program, the City performs many Best Management Practices, or BMPs. Some of these BMPs include education, public outreach, street sweeping, catch basin cleaning, source control and structural modifications. These BMPs when combined with the sampling and monitoring program within Stormwater Management Program continue to locate and eliminate pollution sources throughout the life of the permit term. As part of the NPDES stormwater permit the City of Worcester is required to implement both wet and dry weather monitoring to estimate annual, mean and seasonal discharge loadings from all major outfalls and to identify illicit connections and improper discharges. An annual report summarizing the stormwater discharge program must be submitted to both DEP and EPA beginning April 1, 2000. According to a letter (Feb. 1999) provided by J. Buckley of the City of Worcester Department of Public Works, the City has been implementing BMPs since 1994.

The DPW cleans all City owned catch basins on a two-year cycle. The DPW estimates they are currently responsible for some (14,000- 15,000) catch basins. The catch basin location data is currently available through the Cities Geographic Information Systems (GIS) database. As the Stormwater Management Program is a component of the NPDES permitting structure, which is a five year cycle, DPW is hoping to track problem basins over the next five years, and recording that information in a digital format. The City estimates that it produces an annual 5,000 cubic yards of catch basin cleanings. The DPW Street Sweeping Program covers 950 curb-miles of streets; some 560 miles of streets are residential streets. The streets are swept in the fall for leaf collection producing about 50,000 cubic yards of material. All streets are also swept in the spring to collect de-icing material, and there is a year round main line and arterial sweeping. Street sweeping produces approximately 7,000 cubic yards of material annually. The Mill Brook watershed is covered in the second year of the EPA approved Sampling and Monitoring Program section of DPW’s Stormwater Management Program. Dry weather screening of outfalls which effect Salisbury Pond began in January of 2,000. An update of progress on the BMPs related to the NPDES stormwater permit can be found in the Labovites (1998) report to the EPA.

MassHighway which maintains the Interstate Highways including I-190 as well as state roads such as Route 122 and Route 12 will also be required to apply for the EPA Phase II General Stormwater NPDES Permit by March 10 of 2003. MassHighways does have a draft Stormwater Handbook (MassHighways 2000) which details BMP installation and maintenance on new construction. Apparently these types of BMPs and general maintenance of the stormwater system are not being followed diligently in the case of I-190.

To reduce loadings of sediments and associated nutrients to the target level this TMDL will require the following additional minimal, performance standards for roadways within the watershed area of the TMDL (see map in Appendix I). :

1)Visually inspect the roads monthly and sweep as needed. Any solids or "visible roadway accumulation" (debris, sand, dust, etc.) on paved roads must be removed. At a minimum, roads must be swept a least twice a year as soon after snowmelt as possible or by April 1st of each year and again in the fall. It is recommended that future purchases of sweepers should be of the high efficiency design.
2)Inspect catch basins at least twice a year and any other settling or detention basins once a year to measure depth of solids. If solids are one half or more of design volume for solids, then completely remove all solids.
3)Inspect and maintain all structural components of stormwater system on a yearly basis.

The Salisbury Pond Watershed is also included in the DEP DWM and USEPA (1997) TMDL interim report on the Blackstone watershed. The DEP has one staff person assigned to education and outreach for industrial and construction site stormwater controls within the City of Worcester.

In addition, the Mill Brook Task Force was established as a grass roots organization in 1998. The Task Force consists of dedicated state and municipal agencies, environmental groups, local businessmen, students, and citizens focused on improving water quality within the Mill Brook watershed. A major accomplishment of the group has been the establishment of a citizen monitoring program, coupled with a municipal and state response mechanism. This program has met with continued successes in identifying pollutants and other conditions at the inlets to the pond. When problems have been noted, the appropriate municipal and/or state agents were notified, and the problem addressed. Numerous releases of sewage and oil, as well as trash, have been identified and ceased or remediated as a direct result of the citizen monitoring program. The City of Worcester has cooperated with the Mill Brook Task force to apply for, and be awarded a large Section 319 grant from DEP. This grant will fund the construction of a large settling basin at the Twin Culverts and will also fund the installation of two smaller sediment traps on additional inlets. Inlet number 4 apparently has a forbay in the pond that has filled in and needs to be cleaned out. A public education and water quality monitoring components are also included in the project.

Considering the lack of information on discrete sources of 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 implementing the TMDL are shown in Table 2. The local citizens within the watershed will be encouraged to participate in the education and outreach program. This program 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. An important part of the process is to conduct a NPS watershed field survey to locate and describe sources of erosion and phosphorus within the watershed following methods described in “Massachusetts Volunteers Guide for 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 3. Town public works departments will generally be responsible for reduction of erosion from town roadways and urban runoff. The conservation commission will generally be responsible for ensuring the BMPs are being followed to minimize erosion from construction within the city. A description of funding sources for these efforts is provided in the Program Background section, above.

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. 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 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 phosphorus concentrations remain high after watershed controls are in place, then in-lake control of sediment phosphorus recycling may be considered.

The current TMDL proposes only a 20 percent reduction in phosphorus loading from landuse and this is assumed to be feasible. As new housing development expands within the watershed, additional measures are needed to control the associated additional inputs of phosphorus. 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. 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 the goals of the TMDL and continued macrophyte management is an essential part of the implementation plan. The approach is to continue with close monitoring and to conduct spot harvesting as required and seek opportunities to get selected areas dredged at reduced cost.

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 and Mill Brook Task Force
Develop guidance for NPS watershed field survey.	DEP
Initiate intensive roadway sweeping, catch basin cleaning and BMP inspection program (see text)	MassHighway and City of Worcester
Develop methodology to calculate loadings from highways	MassHighway
Conduct pilot project to assess loadings and test BMPs on highways	MassHighway
Organize and implement NPS watershed field survey	Watershed Team and Mill Brook Task Force
Compile and prioritize results of NPS watershed surveys	Watershed Team and Mill Brook Task Force
Organize implementation; work with stakeholders and local officials to identify remedial measures and potential funding sources.	Watershed Team, Mill Brook Task Force and local Conservation Commission.
Write grant and loan funding proposals	Mill Brook Task Force, Mill Brook Watershed Associations, Towns, Central MA Regional Planning Comm., NRCS Holden Field Office
Organize and implement education, outreach programs	Mill Brook Task Force, City of Worcester, MassHighway, Massachusetts Audubon Society
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 Mill Brook Task Force (annually), City of Worcester DPW.

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 more frequent street sweeping and catch basin cleaning, install detention basins, dredge and maintain stormwater 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. Specific programs have already been described above. Enforcement of regulations includes enforcement of the permit conditions for point sources and in some cases stormwater 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. 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 90 percent) was apparently clear of nuisance aquatic vegetation although the Secchi disk transparency averaged only 0.7 meters. 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 reducing total phosphorus concentrations can be re-evaluated and the TMDL modified, if necessary. Additional monitoring by volunteer groups will be 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 Millbrook Task Force at the DEP office in Worcester to discuss an earlier draft of the TMDL 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 the TMDL. A public meeting to discuss 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 available in Appendix III.

Public Comment and Reply

The following comments were taken at the public meeting or are written comments that were received within the 30 day comment period following the 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 (about 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: 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 submitted a written request to the Regional office of MassHighways (which received a positive response) 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 catch basin cleaning. This TMDL will include specific BMPs that MassHighways should be conducting and may be included in future Phase II Stormwater Permits.

Comment: These reports set forth an assumption that highways are significant contributors of nutrients to receiving waters. To our (MassHighways) knowledge, the majority of the 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. However, conditions may be different along Interstates 290 and 190. It is for these reasons that we need a valid method of calculating nutrient (and other contaminant) loadings from highways.

As I have mentioned in the past, MassHighway is working toward developing a research study that would collect data and develop a contaminant loading model for highway runoff. Sometime in the next couple of weeks I would like to provide you with a general scope of work for this study -- for your review and comment.

Response: 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 19.4 lane miles of Interstate 190 that drain directly to the Mill Brook and Salisbury Pond via the eastern of the twin inlet culverts. 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, as is the case in the Salisbury Pond.

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. We have discussed specific recommendations with the MassHighways District office and have received assurance that efforts will be made to reduce non-point source pollutants from State controlled roadways within the sub-watershed.

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Appendix I Reprint of Camp Desser McKee (1987).

The following pages are selectively reproduced from CDM (1987). Final Report. Diagnostic/Feasibility Study of Salisbury Pond. Worcester, Massachusetts.

FINAL REPORT

DIAGNOSTIC/FEASIBILITY STUDY

SALISBURY POND

City of Worcester, Massachusetts

Department of Parks and Recreation

October, 1987

SUMMARY

DIAGNOSTIC STUDY

- The residence time of Salisbury Pond is on the order of one day, and the flushing rate is very high. At many times of the year, the residence time of water in the pond may not be long enough to permit chemical or biological processes that would remove nutrients and heavy metals.

- The plant community of Salisbury Pond is dominated by algae rather than aquatic weeds.

- Sediment depths are greatest in the western basin of Salisbury Pond, reaching a maximum of 2.5 meters or 7.5 feet. The volume of the pond has decreased by 460,000 cubic feet (13,000 cubic meters) since 1973.

- At Salisbury Pond, the predominant phosphorus source is storm runoff through the twin culverts that constitute the major inlet stream.

- The phosphorus budget indicates an annual loading of approximately ~~2560~~ 4480 kilograms of phosphorus through this drain, more than 90% of the total loading of phosphorus to the pond.

- Observations made at the "twin culvert" inlet indicate severely polluted conditions.

- Bacterial levels and phosphorus concentrations were relatively high even for an urban pond. Bacteria are at levels that indicate sewage pollution of some form, even during dry weather.

- The two main areas where sewage pollution is suspected are the inlet culvert between Indian Lake and Salisbury Pond, the Indian Lake pump stations during storms, and a partially clogged sewer at the intersection of Massachusetts Avenue and Salisbury Street.

- It is likely that these point sources are contributing a large portion of the phosphorus loading, and the nutrient status of the pond will be substantially improved when they are corrected.

- These point sources of pollution are probably also contributing to the high turbidity of the pond and its rapid filling-in, as well as aesthetic problems such as scum and odors. Marked improvement expected in the aesthetics and water quality of the pond can be expected upon removal of these sources.

FEASIBILITY STUDY

- Problems that will remain after the correction of the bacterial sources will include shallow depth, high nutrients, and gradual filling-in of the pond. A total of 16 alternative technologies were evaluated to address these problems. This was followed by a detailed evaluation of alternative projects.

- The selected project has components of Limited Diversion of Stormflows, In-pond Aeration, and a Public Education/Erosion Control Program. The components are as follows:

  1. Implementation of a Public Education/Erosion Control Program to reduce sediment and nutrient loading to the pond. The program is divided into two parts, with the first to include the development of comprehensive mailing lists; meetings with municipal and other agencies; development, printing, and distribution of informational materials; and special assistance to certain groups such as the Conservation Commission to implement the program. The second part

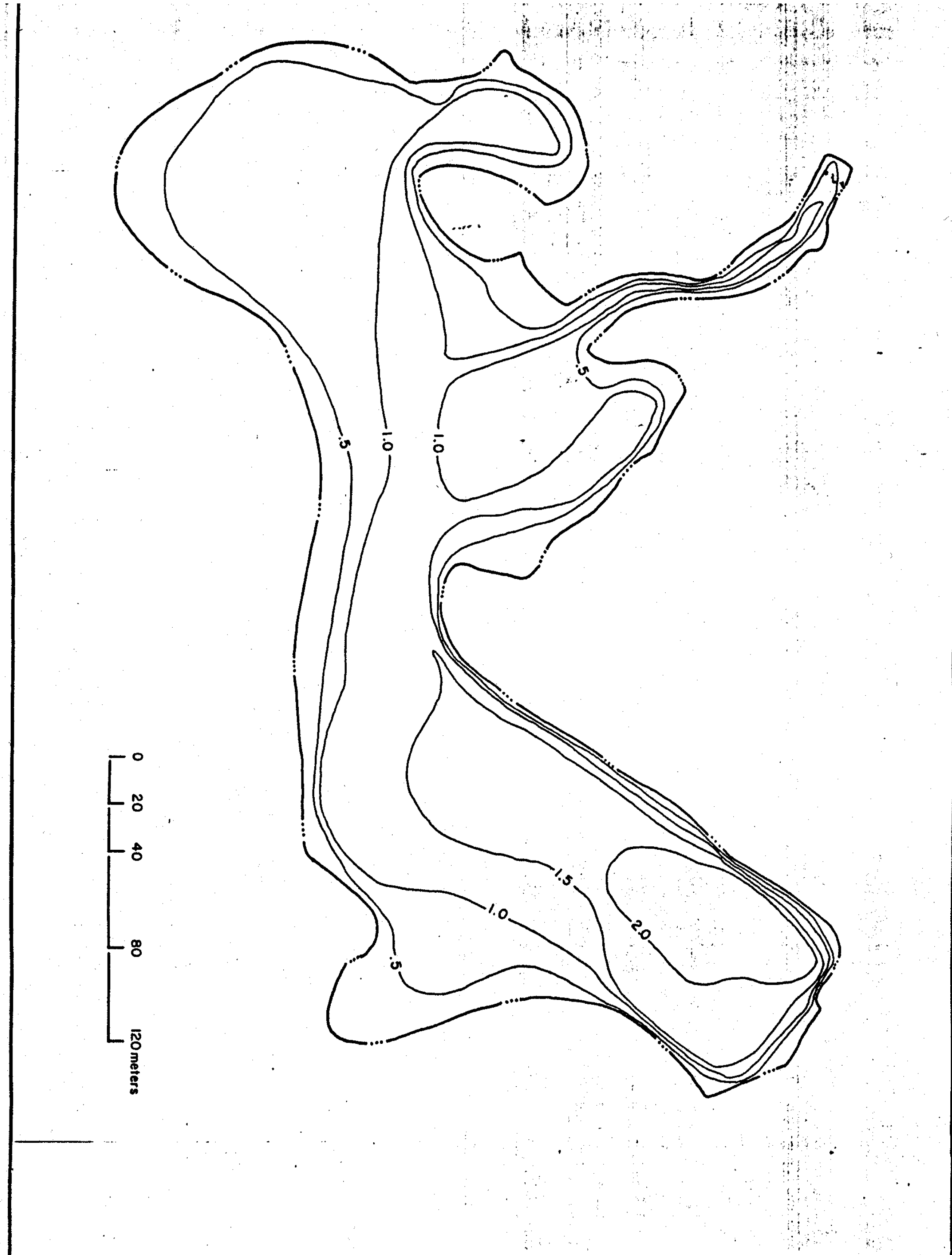
of the program is geared towards enforcement and will include meetings with municipal agencies, the development of a systematic approach to deal with pollution sources, and the implementation of the program.

2. Construction of a limited diversion of "first flush" stormwater from the main inlet via a pipe to the outlet spillway. This stormwater currently contributes about 90% of the total phosphorus load to the pond.

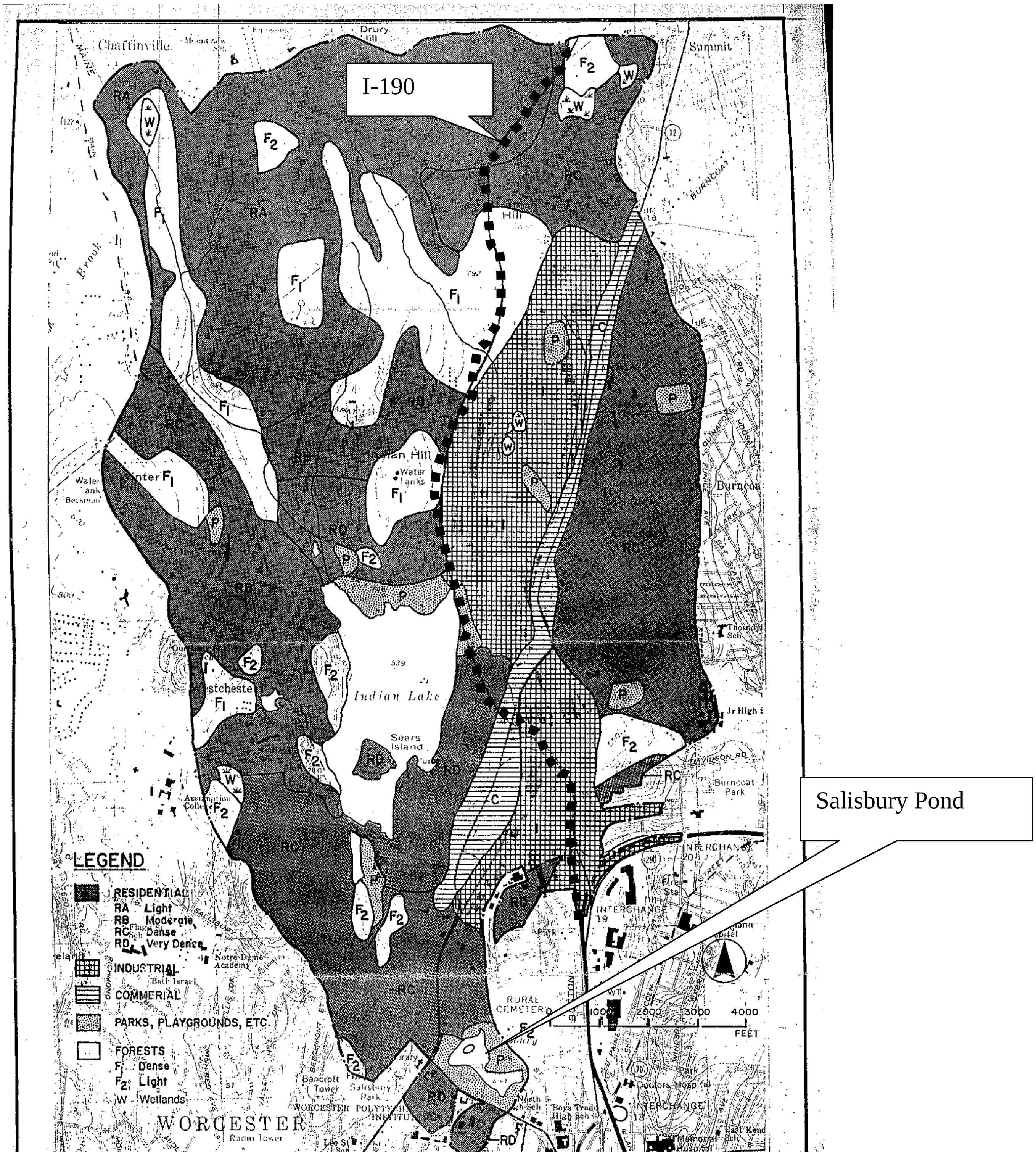
3. Construction of an aerator "fountain" in the pond to eliminate odor problems caused by sediment gases released during low flow conditions.

- The project is expected to dramatically improve conditions in the pond with minimal environmental impact downstream because the overall conditions downstream will also be substantially improved on a long-term basis.

- In comparison with the "no action" alternative (in which the pond will fill in rapidly over the next 10 years), the project will significantly improve the pond as an aesthetic and recreational resource and preserve the pond indefinitely. The aerator fountain has a project life of about 20 years, the limited diversion has a project life of about 50 years, and the public education/erosion control portion of the project will provide permanent improvements.



SALISBURY POND DIAGNOSTIC AND FEASIBILITY STUDY	FIGURE 1-5: WATER DEPTH	SCALE: 1" = 40m DEPTH IN METERS
	CAMP DRESSER & McKEE INC. in association with IEP, INC.	



SALISBURY POND

DIAGNOSTIC AND FEASIBILITY STUDY

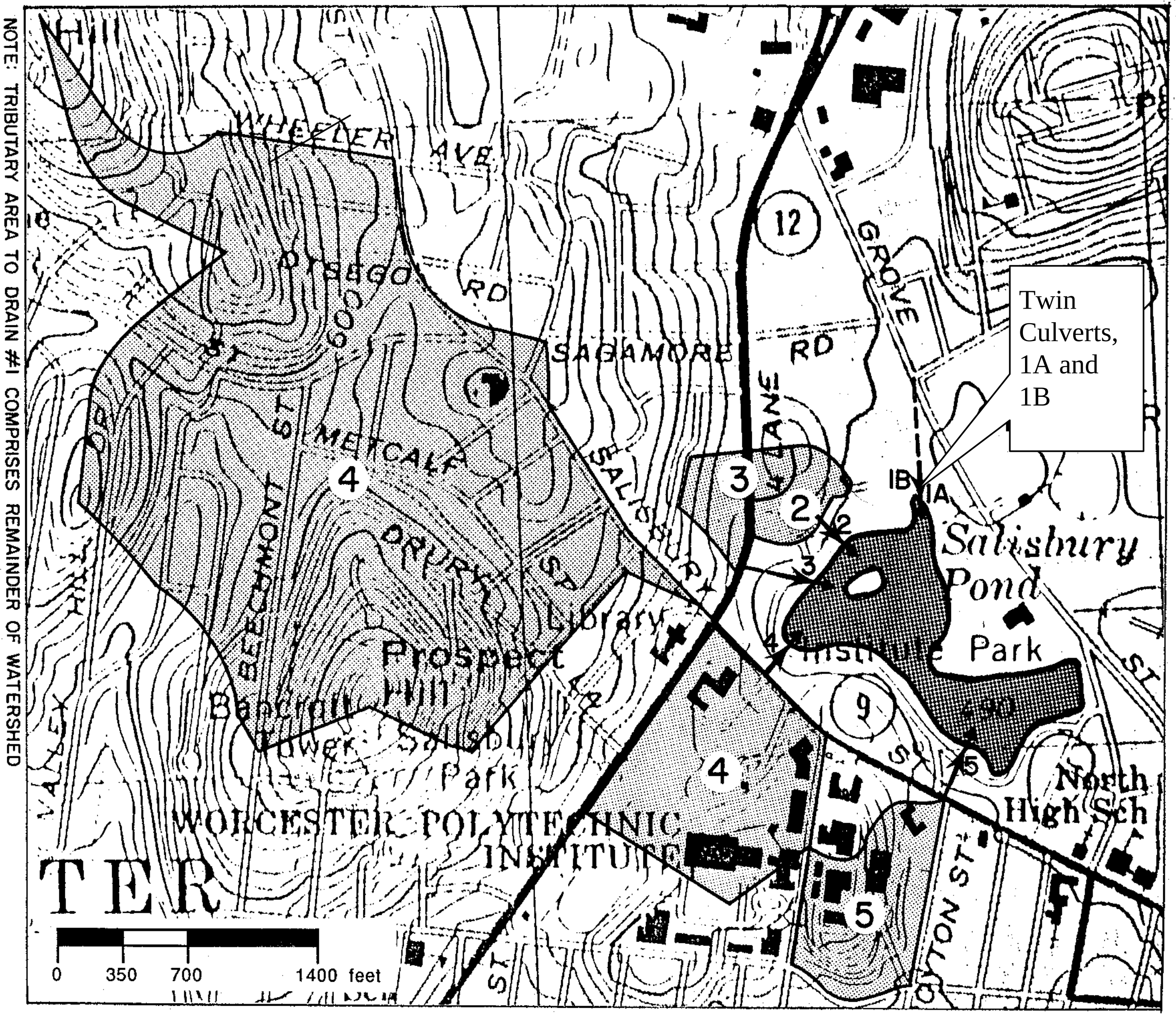
FIGURE 1-4:

LAND USE

CAMP DRESSER & McKEE INC. in association with IEP, INC.

I-190: ■ ■ ■ ■

NOTE: TRIBUTARY AREA TO DRAIN #1 COMPRISES REMAINDER OF WATERSHED



SALISBURY POND
DIAGNOSTIC AND FEASIBILITY STUDY

FIGURE 1–9:
STORM DRAIN TRIBUTARY AREAS

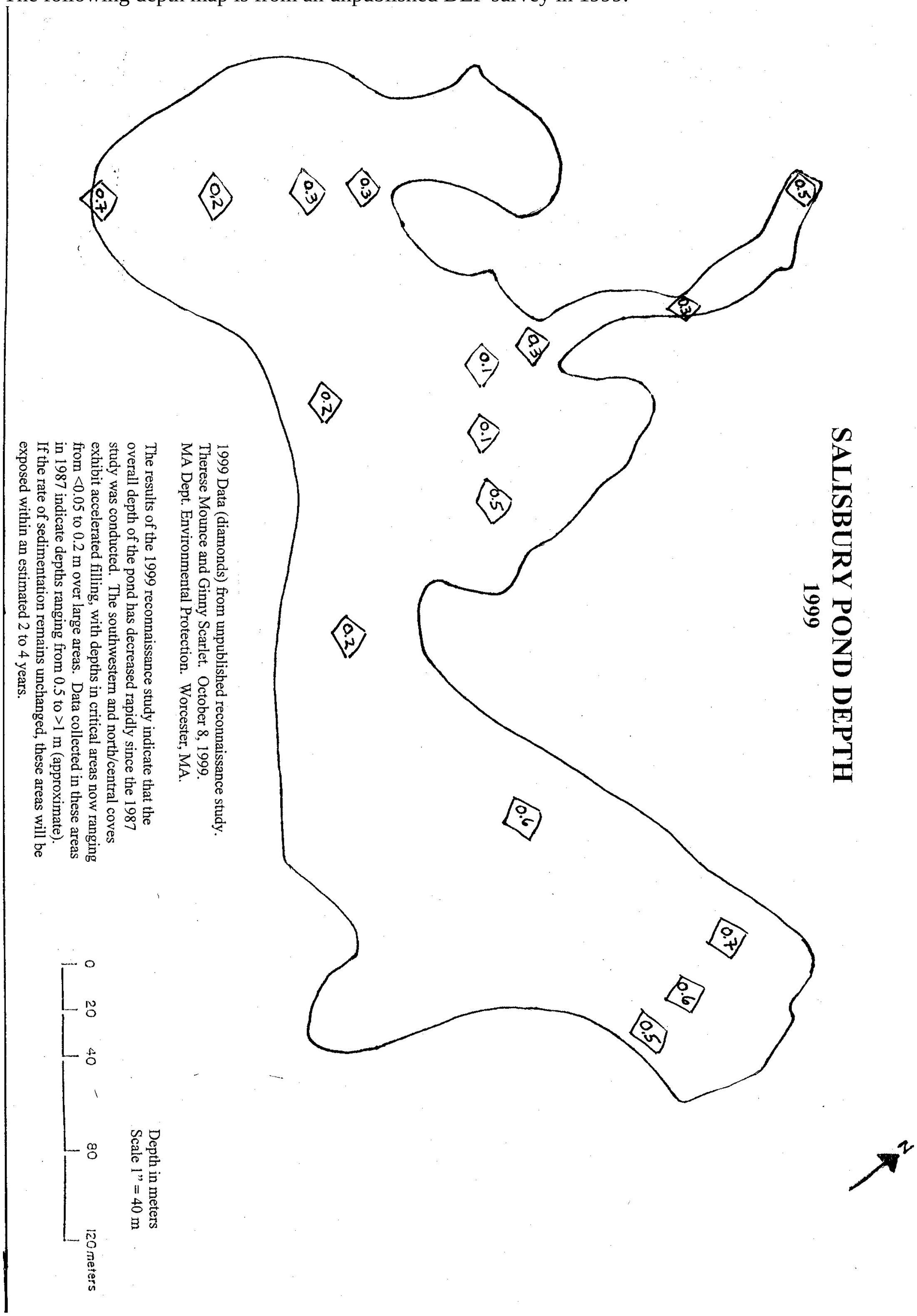
SCALE: 1" = 700'

CAMP DRESSER & McKEE INC. in association with IEP, INC.

DATE:

Appendix II Salisbury Pond Water Depths, 1990.

The following depth map is from an unpublished DEP survey in 1999.



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) 767 2742	Therese.Beaudoin@state.ma.us
5	Richard Chase	MADEP/DWM		Richard.Chase@massmail.state.ma.us
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